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Safety culture and organisational resilience in the nuclear industry throughout the different lifecycle phases

Pia Oedewald | Nadezhda Gotcheva |
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Preface

Nuclear safety depends on the ability of the organisations involved to anticipate, monitor, respond to and to learn from the risks inherent in nuclear power production. It also depends on the organisations' ability and willingness to deal with these risks in their daily activities in a fruitful way. These abilities and this willingness are the essence of a good safety culture.

Although commercial nuclear power production has decades of experience of quality, risk and safety management, the experiences from the Fukushima Daiichi accident point to the importance of a culture, where vigilance towards the unexpected can be maintained even though significant effort is already put into controlling risks. Researchers have argued that the management strategies in the nuclear domain sometimes overemphasise plans, rules and procedures in guaranteeing the safety of plants. Nuclear industry culture has been described as a "culture of control", where organisations do not always appreciate the inherent uncertainties. The Fukushima accident reminded everyone of the importance of continuously questioning the prevailing way of managing activities in the industry, but it also underlined the tendency to become blind to the vulnerabilities of one's own culture – national or organisational.

The Fukushima accident also pinpointed the importance of understanding the roles of various actors in nuclear safety. It is not only the operating organisation that creates safety; the design companies, expert organisations, headquarters, subcontractor companies and regulatory bodies are part of the system, and their impact on safety needs to be better understood. This is also a lesson learned from some of the new build projects and major modernisation activities, which have faced challenges in establishing a shared view of the safety or quality requirements and practices needed to fulfil them. The various actors in the big projects may have partially con-

flicting goals and different levels of knowledge on nuclear domain which manifests in their decision and actions. The actors also bring along to the project their own national and company culture assumptions, beliefs, norms and values, which pose special challenges for the development of a shared safety culture.

The safety science community has developed various means for analysing and developing a safety culture and organisational activities for proactive purposes, but it may be that these methods are not optimally integrated into the management practices of the nuclear industry. There is a need for research in the interface of the safety culture theories and the practical management approaches. It may also be that safety culture approaches and safety management practices need to be further developed in order to support a transformation from too strong a focus on "culture of control" towards resilient organisations. Furthermore, the safety culture challenges at the various lifecycle stages, which involve multiple subcontractors, should be better understood, in order to be able to improve the practices for managing safety in those activities.

This publication is a final report of the research project "Managing safety culture throughout the lifecycle of nuclear plants" (MANSCU). The generic objective of the MANSCU project (2011–2014) was to create knowledge that can be used in developing safety management approaches in such a way that they better take into account recent developments in safety science. The MANSCU project focuses on three topics that are relevant for practitioners in the Nordic nuclear industry. In particular, safety management approaches should:

1) Support the development of sufficient *understanding and knowledge of nuclear safety* and risks as well as nuclear industry-specific working practice demands.

2) Take into account the needs of *contexts other than the operating units*. Especially we focus on creating knowledge on how safety culture should be understood in a) design activities, and b) complex networks of subcontractors. The networks and supply chains may be multicultural and interdisciplinary.

3) Support *organisational alertness (mindfulness)* to new risks or other unexpected conditions which are based on either technical or social phenomena. It also means avoiding complacency and a constant effort of continual improvement.

The MANSCU project carried out both theoretical work and case studies in Finland and Sweden. The case studies were designed based on interests of the power companies and regulators and thus they were not directly structured according to the MANSCU project generic goals. During 2011 and 2014 the case studies focused on:

- Understanding *design* activities from a safety culture point of view. For further information concerning this task, see (Macchi et al. 2012b, 2013b, 2014, Gotcheva et al., 2014, Gotcheva et al. 2015, Gotcheva & Oedewald 2015)
- Understanding how unexpected daily situations are handled and could be supported in maintenance activities. Various concepts stemming from a *resilience engineering* paradigm were applied, and their applicability in the nuclear domain was illustrated. For further information concerning this task, see (Oedewald et al. 2012, Oedewald & Macchi 2012, Macchi et al. 2012a, Macchi et al. 2013a).
- Understanding the expected and experienced benefits of *Human Performance Programmes*, which has become a popular safety management approach also in the Nordic countries over the last decade. For further information concerning this task, see (Oedewald et al. 2014, 2015).

In addition to the case studies, the MANSCU project studied how the concept of safety culture could be utilised in networked activities typical in the pre-operational and post-operational stages of a nuclear power plant lifecycle (Gotcheva et al. 2012 Oedewald et al. 2011, Oedewald 2012, Oedewald & Gotcheva 2015).

This publication is aimed at practitioners in the power companies, regulatory bodies, technical support organisations and supplier companies. The aim is to support their understanding of the concept of safety culture, the practical tools to develop it and the challenges of achieving a good safety culture in different circumstances. The authors believe that this report will be helpful to practitioners, for example in carrying out the oversight of safety culture and safety management of the licensees, planning of safety initiatives in operating organisations, training and supporting the contractors and subcontractors, and auditing design activities. It is the authors' hope that this publication facilitates reflection on the current safety management philosophies in the nuclear domain and encourages the actors in the field to pay even greater attention to the organisational and cultural factors of safety.

The publication unfolds as follows: Chapter 1 states that organisations tend to be blind to some of their cultural assumptions, which sometimes allows them to drift into unsafe practices. Therefore, safety culture assessments are an important practice for the nuclear industry. The chapter summarises the safety culture assessment framework DISC, which has been developed in Finland in the earlier nuclear safety research programme, with the aim of encouraging the practitioners to engage in

thorough safety culture (self) assessment endeavour. The theoretical basis of the DISC framework is followed throughout the other chapters. Chapter 2 moves from safety culture assessment to its improvement, and discusses the prevailing practical tools and approaches for safety culture development. Chapter 3 summarises the lessons learned from a study, which focused on the benefits of Human Performance tools from a safety culture development point of view. Chapter 4 pays attention to a specific non-operational activity, namely the design of modernisations; it highlights how the regulatory activities may strongly influence the culture of design. Chapter 5 discusses how the safety culture challenges may differ across the lifecycle phases of nuclear plants. The focus of attention and practices used for safety culture development may need to be somewhat different in the various lifecycle phases. Finally, Chapter 6 introduces the concept of network safety culture by emphasizing that, when multiple subcontractors are involved in the activities, the entire network should be understood as a unit of analysis. It is not sufficient to develop safety culture of individual organisations; rather, the interactions between them become an important focus area. Adopting the idea of a network safety culture may require changes in the prevailing management mindset, since a multicultural network of subcontractors is heterogeneous, self-adaptive and thus necessitates approaches beyond the "culture of control".

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1. Safety culture: meaning and assessment

Pia Oedewald

Abstract

The culture of an organisation affects what the organisation considers worth paying attention to, and what is ignored. In safety critical industries often only a serious incident wakes up an organization to realize the aspects it had ignored. This makes external safety culture assessments an important proactive learning mechanism in the nuclear organizations: it enables the organisation to perceive its taken-for-granted thought patterns and to understand the reasons for certain organisational behaviour issues. Better understanding of the safety culture of one's own organisation also enables an anticipation of reactions to changes and development initiatives. A safety culture development programme should, therefore, always be based on a solid understanding of the current culture of the organisation. This chapter describes a safety culture assessment methodology called DISC (Design for Integrated Safety Culture) which has been developed by VTT. We will clarify what kind of cultural characteristics are needed in order for an organisation to have a good potential for safety. Furthermore, we will provide practical insights into the safety culture assessment process.

1.1 Introduction

The concept of safety culture has been used in emphasising that safety of high-hazard systems cannot be reduced to technical reliability, but rather, safety is a

property of the whole sociotechnical system. The organisations that design, manufacture, operate and oversee high-hazard technologies create safety as they take decisions and carry out everyday activities. Similarly, organisations have a tendency to develop a variety of social and psychological phenomena that may make them more vulnerable to risks. Organisations may start to drift towards risky strategies because small deviations, which used to serve as warning signals, gradually become normalised, or because different organisational units optimise their local goals and working practices without fully considering the overall activities (see Dekker 2011, Snook 2000, Reiman & Oedewald 2009). Failure to share lessons learned, suboptimal information flow, misinterpretation of technical phenomena and cutting corners when executing operational tasks have been common findings in various accident investigations.

Safety culture is a concept which can be used to analyse and explain the underlying logic of organisational behaviour, especially how the organisation works with respect to safety.[1] This kind of view on safety culture has its roots in organisational culture theories which share an interest in the meanings and beliefs in organisations (Czarniawska-Joerges 1992, Weick 1987, 1995, Alvesson 2002, Reiman & Oedewald, 2007). Schein (1985, 1990) has defined that organisational culture is what a group has learned as it solves problems related to internal integration and adaptation to its environment. When these learned patterns work well enough, they are considered to be a valid way to think, feel and act in relation to those problems (Schein 1990). These cultural patterns then guide the development of organisational structures, working practices, socialisation of newcomers and daily decision-making. In essence, the culture of an organisation choreographs all activities undertaken in the organisation.

From a safety management point of view, it is important to notice that the impact of culture is in many ways not perceived by the organisation itself, since the members of the organization consider all things that fit the cultural norms or assumptions to be “business as usual”. Members of an organisation seldom explicitly reflect on the rationale of their feelings and thoughts. When an occurrence in the

[1] There are other types of conceptualisations of the concept of safety culture as well. Some conceptualisations perceive culture as only one of the subfactors of organisational behaviour, and approach it typically from a worker behaviour perspective. Many scholars have categorised different types of safety culture approaches (for an overview of how safety culture has been conceptualised, see e.g. Edwards et al. 2013, Reiman & Rollenhagen 2013, Silbey 2009, Guldenmund 2000, 2010).

organisation is surprising enough and requires a mutual explanation, a collective sense-making process begins (Weick 1995). However, sense-making processes are just as bound by the organisational culture as any other organisational activities, and thus the group usually comes up with explanations that fit their existing thoughts and assumptions. Culture affects what is worth paying attention to, and what is ignored. Weick (1998) emphasizes that organizations are, in fact, defined more by what they ignore than by what they attend to. Unfortunately, in safety-critical industries often only an accident wakes up an organization to realize the aspects it had ignored. This makes external safety culture assessments an important proactive learning mechanism in safety-critical organizations: it enables the organisation to perceive its taken-for-granted thought patterns – some of which may be problematic for safety – and to understand the reasons for certain organisational behaviour issues. Better understanding of the safety culture of one's own organisation also enables an anticipation of reactions e.g. towards changes and development initiatives. A safety culture development programme should, therefore, always be based on a solid understanding of the current culture of the organisation.

This chapter describes a safety culture assessment methodology called DISC (Design for Integrated Safety Culture), which has been developed by VTT (Reiman & Oedewald 2009, Oedewald et al. 2011, Reiman et al. 2012, Gotcheva et al. 2013). We aim to clarify what kind of cultural characteristics are needed in order for an organisation to have a good potential for safety. These "criteria for good safety culture" underlie our thinking in all the chapters in this publication when we discuss safety culture development and challenges in different contexts. Furthermore, in this chapter we will summarise how we conduct the judgement concerning safety culture in practice. This may serve as a guideline for practitioners who are interested in conducting self-assessments of safety culture in their organisations.

1.2 The DISC framework

The starting point of the DISC safety culture framework is that safety is an emerging property of an organisation. This statement follows the logics of e.g. resilience engineering discourse which aims to emphasise that safety management and assessment approaches should better take into account the fact that system safe-

ty is not a stable outcome; rather it is a dynamic phenomenon which is continuously created as a by-product as the organisation carries out its activities (Woods 2006, Hollnagel 2014, see also LeCoze 2012). Hollnagel (2014) sees *safety* as an "epiphenomenon", which means that *safety* is an incidental product of some process that has no effects of its own. For organisational safety evaluations, this is a challenging starting point, since it suggests that it impossible to decompose safety into a measurable, predetermined set of factors. It is impossible to conclude too much about e.g. the safety of an organization. Therefore, safety culture is a usable construct: the safety culture of an organization can be understood as the organization's *potential* for safety (Reiman & Oedewald 2009, Oedewald et al. 2011). This is what we aim at grasping by safety culture assessments: to evaluate how good a potential there is for safe activities and what the strengths and weaknesses of the culture are from a safety point of view. In other words, we see the connection between safety culture and safe performance so that in specific situations, the preconditions created by the safety culture actualize in ways which depend on situation-specific variables.

We have argued that the essence of safety culture is the ability and willingness of the organization to understand safety, hazards and the means of preventing them, as well as the ability and willingness to act safely, prevent hazards from actualizing and promote safety (Reiman et al. 2008). More precisely, *the DISC framework proposes that an organisation has a good potential for safety when the following criteria are met in organisational activity* (Reiman & Oedewald 2009, Oedewald et al. 2011):

1. ***Safety is a genuine value in the organisation and that is reflected in decision-making and daily activities.***
    - This means that safety manifests itself in the organisation's practices, documents and discussions, and in the individuals' self-reported opinions as a matter that is a necessity and meaningful in a positive sense. Safety is meaningful and important because it is genuinely considered to be right, well and good. Improved safety motivates. Compared with all other important organisational goals, safety gets a high priority.
2. ***Safety is understood to be a complex and systemic phenomenon.***
    - This means that the prevailing safety conception in the organisation encompasses the following aspects:

i. Safety is a dynamic property of activity that requires constant effort; it does not equal a lack of accidents, and it cannot be decomposed into simplified factors.
ii. Safety effects are not linear; small inputs can cause major effects therefore, the organisation constantly monitors its performance, and considers dealing with even minor issues.
iii. Safety is socio-technical and influenced by the interaction of multiple stakeholders (individuals, groups, management, support functions, society). Each person and task has a potential to influence safety. Therefore, each person can describe the effect of his/her work on safety. The interfaces are important; thus the organisation promotes a good overview of work processes.
iv. There are multiple types of safety in addition to operational safety (e.g. occupational safety, information security, security, environmental safety). Their special requirements (e.g. the different laws, different safeguarding measures) are taken into account.

3. Hazards and core task requirements are thoroughly understood.

- This means that the organisation has a good knowledge of phenomena that need to be managed in order to carry out the core task successfully. Especially a good understanding of hazards exists in all the organisation's functions and at all the personnel levels. Each actor knows the possible risks embedded in his/her work in relation to all types of safety.

4. The organisation is mindful in its practices.

- This means that the organisation is capable of maintaining a mindset that views the knowledge and practices as being imperfect, even though they are developed continually. The tolerance for expressing uncertainties is good, and organisational practices encourage questioning habits when these relate to identifying possible hazards. Risks are constantly monitored with the help of a variety of competencies and methods, because the organisation is aware of the possibility of new hazard mechanisms.

5. ***Responsibility is taken for the safe functioning of the whole system.***
    - This means that the organisation possesses an idea that every member has an opportunity and a responsibility to act for the safety of the whole system. Even though the official task descriptions are clear, there are practices and mindsets that encourage juridical accountabilities to be exceeded when safety may be affected for better or for worse. Dealing with safety issues is prompt: when a need for development is identified, no dodging or procrastination occurs.
6. ***Activities are organised in a manageable way****.*
    - This means that there are sufficient resources for carrying out the work tasks with good quality. Staffing level, competencies, working conditions and work process knowledge are sufficient. Even exceptional work situations can be managed without chaos.

If an organisation works as described above, it has a good potential for succeeding under varying everyday conditions and learning to adjust its activities so as to cope with challenges in the future. *A safety culture assessment carried out according to the DISC framework is about judging to what degree the organisation fulfils each of the above mentioned six criteria.* When an organisation fulfils all the criteria at least fairly well, its safety culture is on a good level. If even one of the criteria is fulfilled poorly, the potential for safety is significantly impaired. If the organisation has cultural features that clearly work against some of the criteria, the safety culture is judged as unacceptable. This means that such an organisation should not operate high hazard systems.

It is difficult for an organisation to directly improve the fulfilment of the six safety culture criteria (for example, to directly change employee values or their level of understanding), but they can be influenced through consistent and shared ways of executing various organisational functions. In order to assist the practical execution of safety culture assessment and to help the organisations to identify the means for improving safety culture, we have defined organisational functions which are necessary for the development of a good safety culture. These organisational functions are summarised in the DISC model (Figure 1) along with the criteria for good safety culture.

Figure 1. The DISC model summarises the criteria for good safety culture (in the inner circle) and the organisational functions that support the development of a good safety culture (outer circle) (Oedewald et al. 2011).

The functions depict the activities and measures that an organization with good safety culture needs to carry out, in one way or another. These functions are described as follows:

- *Work conditions management*: management of the physical conditions (e.g. workspace, lighting), the structural means necessary for carrying out the work (e.g. tools, instructions) as well as human resources.

- *Work process management:* how cooperation and communication as well as information flow are managed in the organization.
- *Safety management and leadership:* How safety considerations are included in management decision making. This function involves gathering feedback and information, making expectations clear, communicating on safety issues and ensuring that management is up to date in the way work is conducted in the field.
- *Supervisory support for safety:* supervisors organizing the work in the immediate work environment in such a manner that it can be safely accomplished, providing positive feedback on the safety-conscious behaviour of the personnel, treating subordinates fairly, and monitoring the subordinates' coping skills, stress, fatigue levels and skills.
- *Proactive safety development:* means continuous development of practices, monitoring of the current level of safety and maintaining a constant vigilance for weak signals. The function includes organizational arrangements for learning from experience, auditing and benchmarking the organizational safety culture.
- *Hazard control:* how known hazards are prevented from causing harm. This function deals with the provision and implementation of barriers (e.g. quality assurance, back-up systems, checklists and physical barriers) in order to prevent unwanted human and technical variance.
- *Competence management:* how the competence needs are identified and how the skills and knowledge of the personnel are developed and maintained. This function also includes the training and socialization of newcomers and transfer of knowledge from the experienced personnel to newcomers.
- *Change management:* handling of changes in organizational structures, practices and technology; planning, implementation, as well as follow up on changes already implemented.
- *Management of third parties:* how contractors and leased employees are selected and trained in safety-related issues, and how their know-how in the field of interest is ensured. This function also con-

cerns the practices to facilitate organizational learning from contractors as well as contractors' own learning.

- *Strategic management:* Refers to how the organization addresses long-term preconditions for work (workforce availability, environment, investments), sets long-term goals for development and guarantees the financial viability.

1.3 DISC safety culture assessments in practice

Two basic preconditions need to be met in any safety culture assessments. Firstly, the assessment team needs to be able to *identify and characterise organisational cultures*. They need to have sufficient knowledge of culture as a phenomenon to be able to identify which of the findings represent cultural features (i.e. are guided by shared norms, conceptions, assumptions, beliefs and meanings) and which are individual opinions, behaviours or isolated events. Secondly, the assessment team has to have a good understanding of the assessment criteria. In other words, they need to be able *to take a stance on whether the identified cultural features are good or poor from a safety point of view*. Maybe surprisingly, this is often a weak link in safety culture studies (cf. Guldenmund 2010). The reasoning why specific findings are considered to be "poor safety culture" often remains elusive. The DISC framework provides the criteria for the assessment by specifying what kind of culture is desirable from a safety point of view. However, the DISC criteria are not – and cannot be – very detailed. A safety culture assessment always requires interpretation and a good knowledge of the case organisation's unique context in order to judge whether a certain identified organisational feature should be treated as evidence for a good or poor safety culture.

It is important to highlight that the six criteria that the DISC framework utilises are *organisational level* criteria. The aim is not to evaluate the individual worker's values, mindfulness or understanding as such, but to understand whether these features prevail in the organisation, whether they are part of the culture of that organisation. Aggregating the information gained from isolated observations or individual workers' opinions into cultural factors often receives too little considerations among safety culture experts, and is done in a questionable manner (cf. Guldenmund 2000). There should be evidence that those features permeate

through different elements of the organisation (Oedewald et al. 2011). They should manifest at the psychological level (such as feelings and conceptions of individual workers), and they should be evident in the social interaction of groups (e.g. group norms, power relations or communication climate). They should also manifest in the way the organisational structures and systems are built (e.g. in management systems, resourcing, design of work processes).

1.3.1 Safety culture assessment data

In order to grasp such a complex and intangible phenomenon as culture, the organisation needs to be approached from several viewpoints. As mentioned earlier, the assessment team should explore psychological aspects, social processes and concrete structures and systems of the organisation, and for that a rich set of data is needed. Therefore, the final generic rule of a safety culture assessment is that it should always utilise multiple data collection methods, such as interviews, document analysis, observations, personnel surveys and group work.

Interviews are an essential data source for safety culture assessments. To gain rich and reliable data, we use loosely structured interview schemes and only seldom ask directly normative “safety culture questions”. Rather, the interviews cover themes related to the everyday work tasks of the interviewee, perceptions of organisational practices and future development needs in the organisation, and conceptions of safety and risks in their domain. Some of the interviewees are good at reflecting the culture of their organisation; some talk mainly from the perspective of their own work and as such can be approached as representatives of the culture. Some interviewees can best be utilised as informants of concrete work processes or events, as they prefer not to reveal too much about their own or their organisation’s conceptions, norms and beliefs.

Document analysis is another important stage. Depending on the goals, scope and depth of the safety culture assessment, we review and analyse selected parts of the organisation’s management system documentation and often event investigation and organisational assessment reports as well as documentations describing the consequent development initiatives. The analysis pays attention firstly to the objective aspects of the organisation: how are activities structured and resourced, and are there such functions that are considered relevant for supporting safe activities? Secondly, the analysis focuses on basic assumptions on how

organisation should work, what is safety and what are the risks? These can be concluded, for example, by studying how an ideal organisational performance and safety are depicted in the documents or by investigating the responses to incidents or organisational assessments.

VTT has developed a safety culture questionnaire, TUKU (see e.g. Reiman et al. 2013), which can be utilised as one of the data collection methods, especially if the organisation is large and the aim is to identify subcultures or to monitor changes in climate before and after reorganisations or development initiatives. The TUKU survey is based on the DISC model, but it does not measure personnel opinions on the fulfilment of criteria directly, because they would have been too abstract to be evaluated validly by a self-reporting survey. The TUKU survey measures personnel experiences concerning their own work (safety motivation, mindfulness, sense of responsibility and sense of control) which are thematically connected to some of the DISC criteria (1, 4, 5, and 6, respectively). The DISC criteria 2 and 3, which focus on *understanding* of safety and knowledge of hazards, are not covered in the survey, due to the nature of those criteria. It is challenging to come up with a scale that could reliably indicate individual understanding concerning such complex issues. The TUKU survey also measures personnel opinions of the functioning of the organisational functions (see Figure 1, the outer layer factors). This is an important piece of data especially for drafting adequate recommendations.

Interpersonal relations, group dynamics, social norms and power issues can be best understood if the data collection covers observations of meetings, field work or seminars. The observed situations can be natural work situations, or the safety culture assessment team can arrange e.g. focus groups or safety culture seminars where the case organisation personnel interact.

1.3.2 The assessment process and guidelines

A typical safety culture assessment process which utilises the DISC framework consists of the following steps:

1. Establishment of a steering group which clarifies the goals, scope and policy of the assessment. The group consists of the (external) safety culture experts and representatives from the case organization

2. Collecting different types of data, for example, interviews, documents, observations, safety culture surveys
3. Structuring and analysing the different data sets
4. *Describing* the cultural characteristics (descriptive analysis)
5. Making the final *evaluation* of the level and quality of the safety culture according to the six DISC criteria (normative analysis)
6. Establishing recommendations and prioritizing them with the steering group
7. Establishing a strategy for follow up.

During step four we characterise the organisation's culture, which means that we describe aspects such as values, coherence, prominent beliefs, norms and assumptions that we have identified. The core of the assessment process is step 5 where the aim is to evaluate to what degree the organisation's culture fulfils each of the six criteria. We often use a four-point scale (the criterion is fulfilled poorly, fairly poorly, fairly well, very well) to illustrate how well the organisation is doing with respect to each of the criteria. The assessment is always an expert judgement and, thus, no detailed, overarching instructions can be specified (for an example of judgement guidelines, see Oedewald et al. 2011 pp. 40–42). In order to come up with a valid judgement, it may be beneficial for the assessment team members to first conduct the evaluation independently and only then to cross check and discuss the arguments pro and against fulfilment of the criteria. When conducting the assessment, the evaluation team should be able to answer the following questions:

- Is the criterion fulfilled?
    - Does the empirical evidence support the fulfilment of the criterion? What is the evidence? How do you argue that it is good evidence for the fulfilment of this criterion?
    - Does the data provide evidence against the criterion? What is the evidence?
    - If there is evidence for and against the fulfilment of the criterion, and which is stronger? On what grounds? (the next questions may be helpful in answering this)

- Are the empirical observations (positive or negative) generalizable to the organization (are the cultural characteristics shared) or are they unique to certain personnel groups or subunits?
    - Do individuals and subunits provide similar or contradictory evidence?
    - If there are different subcultures or fragmented cultural patterns, are they significant enough to affect the fulfilment of some of the criteria? Or is the fragmentation natural considering e.g. the roles of the subunits or the maturity of the organization?
- Have the characteristics clearly taken root in the organization's culture? Are the findings inconsistent or contradictory?
    - Is the evidence similar / in the same direction, or does the organization look totally different according to the data source e.g.:
        - Workers' opinions and beliefs expressed in interviews
        - Management's opinions and beliefs expressed in interviews and public presentations
        - Official organizational structures, processes and practices evident from documentation and the management system
        - Social processes, climate and norms that manifest in e.g. informal discussions, observations of daily work
    - If the organization seems to express inconsistent characteristics:
        - Is that natural due to e.g. recent major changes in the organization or the early development stage of the company?
        - Is the organisation unaware that there are gaps e.g. between formal and informal processes and thus is unable to establish sufficiently clear responses or to manage those issues?
        - Does the organization aim at giving a misleading picture of its activities while it knows that it is not the whole picture?

The assessment results then consist of a judgement of the fulfilment of each of the criteria and associated argumentation. It is typical that an organization does better with respect to some criteria and has some specific weaknesses (Figure 2).

CRITERION	Very good	Fairly good	Fairly poor	Very poor/ Unacceptable
1) Safety as a value		√		
2) Systemic safety view			√	
3) Understanding of hazards and core task		√		
4) Mindfulness			√	
5) Responsibility	√			
6) Manageability		√		

Figure 2. An example of an organization's safety culture profile. In this hypothetical example, the organization's safety culture is at an acceptable level, since none of the criteria are considered unacceptable. A special strength here is that responsibility for safety is taken. However, this organization's conception of safety is somehow not systemic, and the organizational mindfulness requires special attention as well.

It is useful to inspect this profile and discuss it carefully with the organization before the final recommendations on safety culture development are made.

1.4 Discussion and conclusions

Development of safety culture has to take into account the existing profile and level of safety culture in the organization. The challenges faced by development initiatives are different in a high level safety culture than in immature culture (cf. Amalberti et al. 2005). For example, in a high level safety culture the improve-

ments may be harder to perceive since the drastic safety flaws have already been dealt with. The complexity of the safety management system itself can hide certain risks and create a false sense of security or complacency. In a low level safety culture the main challenges often overcome the excessive production focus and unsystematic nature of organizational practices (Amalberti et al. ibid). Sometimes, if the organisation utilises innovative technologies or has outsourced most of the activities to external companies, the low level safety culture can be a consequence of insufficient knowledge and experience in the domain. If the above-mentioned characteristics are very prominent, the organisation does not fulfil the DISC criteria and significant changes are needed in order for the organisation to perform in a manner that it is trustworthy. More often, the safety culture is, generally speaking, acceptable, but there are unique challenges which need attention and some strengths to build on.

The basic premises of the DISC approach can be utilised for giving guidance on integrated safety culture development. The following aspects should be taken into account:

- The deepest levels of culture are hard to change, but understanding them is the basis of the safety culture development work.
    - The focus of development should be equally on organizational structures, work practices, employees' understanding and collective mindset (attitudes, values, norms). Seeking a development of only one component (e.g., attitudes) can lead to an imbalance in the organization between the new elements and the old structures and elements. This will is turn likely lead to the organization reverting back to the old ways, and learning only a negative attitude to future improvement efforts.
    - The focus on development should be on the organization itself, not on the abstract notion of safety as such. Safety should be integrated into the daily operations of the organization. This does not mean that there is no need for safety specialists or a strong safety department.

Assessing safety culture is about understanding the underlying logic that guides the organisation's activities, especially in relation to safety. Being able to understand the culture of an organisation is important for the operating company itself and for the regulator, because it allows an opportunity to change course before the

organisation drifts into failure. It also allows efficient development activities. An in-depth assessment of safety culture often requires external experts, due to the fact that the members of an organisation tend to be at least partially blind to their cultural norms and assumptions. However, the development and continuous improvement of safety culture cannot be completely outsourced. It needs to be integrated in the development of the organisational processes and everyday management actions.

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2. Developing safety culture in nuclear power plants

Kaupo Viitanen

Abstract

Licensees in the nuclear industry are expected to develop and maintain a good safety culture in their organisations. A good safety culture is required and monitored by a multitude of authorities such as governments, regulators, peers and umbrella organisations. Various organisations and experts provide the tools and guidelines for safety culture development. In this chapter, the key parties involved in setting the requirements and providing know-how for safety culture development and their possible effect on safety culture programs are discussed.

The common safety culture development methods include interventions such as the development of working practices, safety culture training sessions or changing the behaviour of personnel. This chapter compiles commonly used safety culture development interventions and provides insights into topics such as mechanisms of action, efficiency and unwanted side-effects. In addition, the special characteristics of occupational safety and nuclear safety aspects of safety culture are discussed as are the effects of various management styles. Furthermore, as the organisational structures and various working arrangements transform from traditional organisations into networked systems, the effect of subcultures or cultures other than organisational culture gains relevance and is therefore discussed. Finally, tentative recommendations are provided to address the aforementioned topics.

2.1 Introduction

Good safety culture is widely accepted as an important ingredient in ensuring safety in the nuclear industry. As the concept has gained popularity, the expectation of good safety culture has been integrated into various formal bodies such as the Safety Standards fundamentals provided by the International Atomic Energy Agency (IAEA), regulatory requirements, and in some countries also into legislation. This means that there is a strong external pressure on licensees to monitor and develop the safety culture of their organisation.

Since the launch of the concept of safety culture, a multitude of theories and practical methods have been introduced that are claimed to be beneficial for the development of safety culture. Various schools of thought emphasize different aspects of safety culture and recommend different practical development solutions which may appear contradictory or confusing. The practitioners at nuclear power plants therefore face the dilemma of having to satisfy the requirements regarding the monitoring and development of safety culture, and at the same time having to aggregate the knowledge from various sources to find suitable tools for performing this task. In order to approach this dilemma, it is important to include all the parties involved in safety culture development and approach this as a larger system that influences the way in which licensees implement their safety culture programmes. The following general themes are discussed:

- Who are the parties that set the requirements and provide the know-how for safety culture development?
- How do the activities of these parties influence safety culture programs of the licensee?
- Are the safety culture development methods required or provided by the above-mentioned parties valid?

2.2 Key parties involved in developing safety culture in the nuclear industry

In addition to practitioners at nuclear organisations who develop safety culture at their respective organisations, there are a diverse variety of other key parties that influence safety culture development. These parties may set safety culture re-

quirements or provide the knowledge and practical solutions for safety culture development. It is relevant to discuss who these key parties are, because they may affect how the success of a safety culture programme is defined and measured, and who is considered the authoritative source of advice and information. In addition, the nature of the motivation behind safety culture programmes and the interaction between the key parties (including practitioners) may have an effect on how safety culture is developed and what the outcome of safety culture development will be.

Among the most active promoters of the concept of safety culture in the nuclear industry is the IAEA which has also created the concept (IAEA, 1991). The IAEA both sets general requirements for safety culture (IAEA, 2006) and also provides various theoretical and practical guidelines for developing safety culture at nuclear facilities in its Member States. Alongside the IAEA there are other nuclear industry specific expert organisations providing safety culture-related knowledge such the Institute of Nuclear Power Operations (INPO), the Nuclear Energy Agency (NEA) and the World Association of Nuclear Operations (WANO). These associations contribute to safety culture management by creating frameworks, guidelines and development programs for practitioners, and also by facilitating communication and information sharing between operators. Some examples of the services provided by these associations are peer reviews, evaluations, training sessions, human performance programmes and global operating experience databases.

In some countries, the requirement for developing and monitoring safety culture is regulated by national legislation. One of the first countries to regulate safety culture in the nuclear industry was Finland, where “good safety culture” is required by law in nuclear installations (Government Decree on the Safety of Nuclear Power Plants, 717/2013, 28 §) and disposal sites (Government Decree on the Safety of Disposal of Nuclear Waste 736/2008, 19 §). In Finnish legislation, however, the definition and content of safety culture is rather vague and open to interpretation, and thus in practice other parties are responsible for interpreting this legislation and creating practical solutions to address it. When a general requirement of safety culture is in national legislation, the regulator provides more specific interpretations in their binding regulatory guides on nuclear safety (YVL-guides). In the regulatory guide YVL A.4, issued by STUK, it is stated that a good safety culture is characterised by “a full commitment by the management and personnel to compliance with the management system and continuous improvement of performance

throughout the life cycle of the nuclear facility". Furthermore, the regulatory guide YVL A.3 provides general guidelines for a good safety culture, such as "in a good safety culture, safety is of primary importance, actions are prioritised based on their significance, the senior management and the entire personnel are committed to a high level of safety, the atmosphere is open and fosters a questioning attitudes, safety is considered systematically, and safety is continuously improved". In addition, there are requirements regarding the concretisation of the concept of safety culture and having sufficient safety culture expertise. Providing these binding guides and working in continuous interaction with the power plants means that national regulators (in this case, the Finnish authority) may have an effect on how the safety culture is going to be developed by the licensees. This sets expectations both for the regulators' competence regarding safety culture-related know-how, and also for the regulators' own safety culture. Furthermore, the relationship (e.g. quality of communication) between the licensee and the regulator may have an effect on how the licensee perceives the regulator's requirements.

In addition to nuclear industry-specific associations such as the IAEA, WANO and INPO, nuclear facilities and regulators often use the services of other expert organisations for such tasks as safety leadership and training programmes, safety development interventions, safety climate surveys and independent assessments of safety culture. External expert companies often provide either standardised solutions or solutions for specific problems. Examples of such services could be carrying out independent safety culture assessments or training sessions, or implementing a development program in the organisation. The expertise provided by expert companies does not replace the organisation's own functioning safety culture programme, but rather, it provides expert advice or solutions for a particular issue that the organisation has recognized but is unable to address by itself. Therefore, the services provided by external experts need to be integrated into the organisation's way of functioning, which is where the role of the in-house safety culture expert is crucial. External expertise is useful in guiding or supporting the work of existing professionals by providing new insights, specific knowledge or abilities that the organisation does not already have but it does not replace the in-house safety culture expert.

The scientific community plays an essential role in developing safety culture in the nuclear industry. Scientific knowledge can be used to develop new ways to approach safety culture development and also to provide efficient and valid as-

sessment and intervention methods. Scientific research provides the building blocks that other key parties will use in their activities. One of the key challenges for the successful use of scientific information is in ensuring the knowledge transfer between the scientific community and the practitioners. Close collaboration between the scientific community and field workers is required both in order to provide scholars with usable data in order to verify and elaborate their theories, but also to provide information regarding what issues practitioners actually struggle with. Also, promoting applied research in addition to basic research is required for developing scientifically-based tools that are applicable in field work. If the interests of scientific community and practitioners differ too much, this can lead to scientific theories that are useful only to other scholars and inefficient field practices that are not based on rigorous research. An active dialogue and participation from both sides is needed and should be encouraged so as to ensure that practitioners and scholars have enough common ground to benefit from each other's work.

2.3 Practical methods of managing safety culture in NPP's

Safety culture programmes are often assumed to follow a simple model of organisational change which contains the phases of defining desirable future state, assessing the gap between current state and future state, and then applying intervention to reduce this gap (IAEA, 2002). In practice, this involves monitoring the current state of safety culture using various assessment methods and then using the information gained from them as a basis for safety culture interventions. Common practical methods used to develop safety culture in nuclear industry are summarized in Table 1.

Table 1. Commonly used safety culture development methods.

Tool	Function/scope	Target group
Assessment		
Document analysis	Analyse tangible records of the organisation	Organisation
Field observations	Practical manifestation	Usually shop-floor workers
Interviews	Acquire detailed information	Specific workers, typically management or supervisors
Surveys and questionnaires	Operationalize and quantify safety culture	Whole organisation, limited by response rate
Workshops[a]	Collaborative assessment	Limited groups
Intervention		
Behavioural-based safety programs	Behaviour modification	Shop-floor workers
Employee recognition	Behaviour modification	Usually single individuals
Human performance programs	Reduce human errors and manage controls[b]	Usually shop-floor workers, potentially also management[c]
Human resource management processes	Ensure continuity of culture, select suitable and competent workers	Whole organisation
Operating experience	Share knowledge with peers	Organisations
Safety culture training sessions, seminars	Create awareness of safety culture	Whole organisation
Safety leadership development	Develop safety leadership skills and implement tools	Management

a) may also function as an intervention method

b) see DoE (2009a)

c) human performance programme guidelines include tools to support work at all levels of hierarchy; however, management development is rarely considered under human performance programmes

Safety culture assessments are carried out by various actors, perhaps most typically in the form of a self-assessment initiated by the organisation itself, or by an independent organisation, such as a consultant or technical support organisation. In the nuclear industry, the licensee is expected to carry out self-assessments of their safety culture. However, an independent organisation can often be beneficial in providing a fresh insight or providing such information that the organisation finds difficult or impossible to acquire.

Questionnaires and surveys are one of the most commonly used and studied methods of assessing safety culture. Questionnaires have the benefit of being cheap and straightforward; they have a potential to reach a large crowd, they are anonymous and easily enable comparative studies to be made. Another often used, but much more resource-demanding, assessment method is interviewing, which enables an in-depth analysis of such subject matters that cannot be approached in questionnaires. Workshops and other group-based methods provide a middle ground between surveys and interviews, and in addition enable a collaborative approach to safety culture assessment. Field observations are often related to behavioural-based programmes, but can also be done with different approaches such as ethnography. Field observations provide information regarding how workers actually behave or act on the field which may be useful to gain such insight that will not come up in self-administered questionnaires or discussions during interviews or workshops. Document reviews are used to analyse an organisation's written material such as public records, organisation structure charts, etc.

Once the future desirable state of safety culture is defined and some assessments to provide a state-of-the-art are completed, a typical approach is to initiate a set of corrective actions to improve safety culture. A multitude of intervention methods exist that are thought to be useful for safety culture development. Some of these are introduced internally by the organisation itself, while others are implemented by external organisations. The interventions can be seen as either directly or indirectly affecting safety culture. Interventions that affect safety culture directly (e.g. safety culture training sessions, workshops and lecture courses) focus explicitly on safety culture, while in the case of indirect interventions, the focus is elsewhere (e.g. behaviour modification), but safety culture is considered either as a backdrop for the programme or it gets changed as a by-product. Due to the complex nature of culture, any action or change in the organisation may have an effect on the culture. This means that sometimes it may be difficult to predict

exactly which actions have an effect on safety culture and which do not. For example, making an overt safety culture assessment may itself initiate changes in safety culture.

One of the most popular safety culture interventions are various types of trainings. The ultimate goal of safety culture training sessions is to change cultural factors such as group attitudes, value and norms, and to create awareness of safety culture within the organisation. Safety culture training sessions and workshops are provided by consultancy companies (e.g. DuPont and ProAct Safety), the IAEA and many other expert organisations. The effect of safety culture training sessions is, however, rarely extensively evaluated, and the mechanisms of action are also largely unclear. Harvey et al. (2001) studied the effectiveness of safety training programmes in the nuclear environment and observed that the context has a strong influence on how well a training programme is received and how useful it will turn out to be. They observed that the same safety training was effective in changing the attitudes in the management group but not among the shop floor workers (Harvey et al. 2001). This suggests that safety training sessions might not affect all groups of staff within the organisation the same way, and thus in order to be effective they need to be adjusted for a specific audience.

Behaviour-based safety programmes such as DuPont's STOP (DuPont, 2014) or ProAct Safety's Lean Behaviour Based Safety (ProAct Safety, 2014) are also associated with safety culture development. Both of these programmes claim culture-sensitive implementation approach that takes the existing culture into consideration, and safety culture improvements, for example through increased safety awareness. Behaviour-based safety as a general approach to safety management is quite well-established and has a long history in safety-critical organisations. It directs attention to shop-floor worker behaviour, identifying unwanted behaviour and attempting to modify it. Behaviour-based safety is very concentrated on specific behaviours and specific people. Therefore, it is considered a "bottom-up" approach to safety management, which does not address systemic issues in the organisation. Behaviour-based safety programmes are usually seen as processes that require continuous reinforcement in order to have an effect on individual behaviour – return to initial behaviour is expected if the programme is terminated. Some scholars have, however, argued that there can also be some longer-lasting effects on the individuals (see DeJoy, 2005), which may further suggest that behaviour-based safety programmes could initiate cultural changes within the target

organisation. DeJoy (2005) contrasts the individual level bottom-up approach (i.e. behaviour-based safety) to group or management level top-down approach (i.e. culture change) and argues that these approaches are essentially complementary and that when developing safety both approaches would be needed.

Other intervention methods that are sometimes discussed in the context of safety culture management are the various forms of employee recognition. Similarly to behaviour-based programmes, in these programmes desirable behaviour is reinforced and motivated by means of operant conditioning methods such as rewards, negative reinforcement, punishment and extinction. In practice, employee recognition manifests itself as safety incentive programs that reward workers for safe behaviour. For example, attendance at safety training sessions may be rewarded with gifts, or trophies may be given to those who have demonstrated good safety performance. Usually, these programmes are directed at occupational safety. Incentive programmes are frequently criticized for their negative effect on reporting: contrary to what is desirable in a good safety culture, rewarding the staff based on safety outcomes may hinder the development of a blame-free culture and promote the formation of a culture where accidents are concealed in order to receive the reward.

In addition, other programmes such as Human Performance Programmes (HPPs; for further discussion, see Chapter 3), Voluntary Protection Programmes (OSHA, 2014), or Six Sigma quality development programmes (Ateekh-ur-Rehman, 2012) are sometimes used in nuclear organisations to improve safety culture. HPPs involve the implementation of various good working practices that are thought to reduce latent conditions and active errors. HPPs are targeted at nuclear safety, but in practice they are also seen to be useful in occupational safety. The Voluntary Protection Programme (VPP) is a voluntary partnership between the organisation and OSHA. The VPP initiative sets criteria for a safety and health system and assesses the organisations against these criteria, then recognizing excellence. These areas of interest include management cooperation and employee involvement, work site analysis, hazard prevention and safety and health training. Six Sigma is a quality improvement programme consisting of various methods for developing safety. These methods range from simple tools such as safety rules and compliance programmes to more elaborate ones such as introducing a continuous improvement team.

Although traditionally not considered a safety culture intervention method, human resource management processes are also related to safety culture development. The way in which human resources are managed in an organisation is relevant to both the quality of safety culture in the organisation and whether a shared, good safety culture is created in the first place. At least two distinct mechanisms of effect can be identified. First, safety culture can be affected through the way in which employees are hired or grouped together. Employee selection practices have an effect on what kinds of individuals enter the organisation – if the selection of certain type of employees is facilitated (e.g. through psychological testing or safety competence evaluation), the safety culture of the organisation could be changed through the introduction of these individuals. Competence and suitability evaluation would need to include both shop-floor workers and management, but also safety professionals. Selection of personnel can also be used so as to influence groups by introducing influential individuals. Secondly, it has been argued that, in an organisation with diverse working arrangements and high turnover rates, shared conceptions might not emerge among the workers (Clarke, 2003). This suggests that some ways of organising work can make it more difficult to form a shared conception of good safety culture. For example, in organisations that consist of a network of loosely related subcontractors, there are few long-term interactions and common denominators between groups of workers. This inhibits the formation of a shared culture at organisation level and the existence of a number of subcultures may be inevitable. Conversely, high turnover may cause subcultures to break down due to the changes in group members. This has implications for safety culture management: work arrangements in safety-critical settings need to be such that an appropriate safety culture can be ensured.

Safety culture interventions in the nuclear industry are typically focused on changing the mindset or working practices of shop-floor staff. Interventions targeted at management or the organisation are often scarce, which is problematic because the culture is not only limited to the shop-floor but rather permeates through the whole organisation and manifests itself in all activities at all levels of the organisation. There are, however, tools to support a safety culture at management level. Several consultancy and training organisations (e.g. DuPont, Pro-Act Safety) provide leadership development programmes such as safety leadership training sessions. These training sessions may, for example, attempt to create safety culture awareness, educate the management, and develop coaching

and communication skills. The IAEA has also organised safety culture workshops for senior management for education and experience-sharing purposes. In addition, Human Performance Programmes include guidelines for some management-oriented practices that can be useful in management of safety culture (DoE, 2009b). These include benchmarking, operating experience, self-assessments, performance indicators, event investigations and change management.

2.4 Discussion

2.4.1 Integration of knowledge

Understanding the relationship between the key parties who provide safety culture know-how and the practitioners at nuclear power plants is essential in order to gain a comprehensive oversight of how safety culture is managed. The IAEA is one of the main proponents of safety culture know-how, and it provides literature and services mainly intended for managers and other practitioners at NPP's. The IAEA and many other nuclear industry associations provide pragmatic guidelines for practitioners at nuclear facilities. Avoiding overly theoretical and complicated discussions and focusing on practice may help the organisations implement safety culture development programmes. This may not be the case if the guidelines require extensive experience in organisational culture development to interpret and implement them. On the other hand, the approach still remains rather general, avoiding straightforward and specific instructions to develop a safety culture. There appears to be a confrontation of general and specific support for safety culture development from the international nuclear organisations. If too general a support is given, the management at the nuclear organisation faces challenges regarding their expertise in interpreting, operationalising and implementing the general information. This may lead to misunderstandings, improper safety culture programmes or abandoning the concept altogether. On the other hand, if too specific a support is given, safety culture programmes may become too superficial, unsuitable for the purpose or for the target organisation. Preferring the general (rather than highly specific) approach suggests that, while IAEA and other associations in the nuclear industry do provide support for the development of safety culture, the licensees are expected to tailor these recommendations to their own requirements.

In practice, this means that the literature provided by the IAEA and others more often than not is expected to function merely as a starting point for the organisation's own safety culture programmes, developed in-house by the safety culture staff. Considering the uniqueness of each organisation, it is natural that local development is preferred to a global and highly specific safety culture programme. It can be concluded that the knowledge learned from the IAEA, other nuclear associations and from the scientific community, and the specific expertise and know-how of consultancy companies needs to be integrated and tailored locally for the target organisation. Furthermore, the resistant and usually slowly-changing nature of the organisational culture needs to be considered. Although interventions can be used to steer the culture, the results cannot be expected to take place in short timeframes and, therefore, a long-term strategy is required to meaningfully develop culture. These requirements suggest that a competent local expert with an understanding of the needs of that particular organisation and a long-term vision regarding how to develop the organisation is needed to implement a successful safety culture programme. Training and recruitment of experienced safety culture specialists, combined with scientifically sound guidelines from consulting associations is, therefore, essential to advanced safety culture development. This sets requirements for both top management commitment to safety culture development, and to human resource strategies.

2.4.2 Systemic interactions

A common problem with many safety culture interventions and practices is that their actual mechanism of action and effect in relation to safety culture is unclear. This is related to the problem that the concept of safety culture and the causal paths between changes and outcomes are often unclear and ill-defined (Guldenmund, 2000). A general issue that stems from this is that any intervention or change in the sociotechnical system can have an effect on organisational culture. This includes both organisational and technical changes. It does not, however, mean that any intervention can be considered to be effective for a specific culture development, or that the effect is predictable for the initiator of the change. Many of the interventions that are considered to be useful for safety culture development have some effect on behaviour, and some improve safety by various other means,

but the effect on safety culture has not really been explicitly described and the possibility of unwanted side-effects is not extensively considered.

Side-effects may manifest themselves as unexpected reactions to change that can be negative, positive, or non-existent. For example, if the shop-floor workers had a sloppy attitude to performing some safety-related activities and a heavily sanctioned intervention was introduced to rectify it, this could have a positive effect on the attitudes towards safety activities, but it could also be ignored completely, or it could have a highly negative effect (e.g. distrust of management, polarization within the organisation, reluctance to communicate and report, an increased tendency towards non-compliance). If the intervention fails, the post-intervention safety culture might not increase the overall safety at all compared to pre-intervention, but could rather decrease it. Therefore, various unexpected side-effects need to be considered and anticipated before and during the implementation of interventions. The side-effects also reveal an inherent tension within the organisation: What does the organisation tend to do naturally, and what does the organisation need to do in order to develop? Sometimes, an intervention that is initially considered to be negative and unwanted is actually necessary in order for the target group to improve its activities. In order to avoid unwanted side-effects and to ensure a successful intervention, a more systemic approach to safety culture development is required – merely concentrating on fixing perceived or obvious weaknesses is not sufficient, nor is naively implementing interventions that have been found to be useful in another organisation.

A more systemic approach to safety culture development could attempt to achieve the following goals:

- Identify the underlying cultural characteristics and their interactions with behaviour and other tangible artefacts (e.g. What cultural characteristics are related to what behaviours?; How can these characteristics be affected?; How do organisational structures and other environmental factors affect the underlying characteristics?)
- Identify how cultural characteristics are related to each other (e.g. Does one characteristic depend on another one, or cause change in others?)
- Identify possible paths to side-effects

- Facilitate change by involving the target group in intervention so as to avoid resistance to change (e.g. giving ownership, communicating the justifiability and usefulness of change)

2.4.3 The role of managers and leaders

Safety culture development in the nuclear industry is typically approached from a “top down” perspective. Safety culture is seen as something that the management (or “leader”) plans, initiates, and is expected to manage and control. It is argued that the management and leaders have a key role in defining what type of culture the organisation learns. More specifically, the leaders define how the current state of the organisation is seen, where the organisation wants to be, and how it will get there (Persson 2012). This leader-centric approach is further reflected in integrating the safety culture and the management system in the nuclear industry. The leader-centric approach to safety culture may have some inherent flaws. First, it leads to the assumption that organisational culture can be prescriptively changed by the management, even though this may not be the case. In fact, it may be impossible to “manage” culture in the traditional sense of the word. Rather, culture manages and maintains itself, involves as diverse a variety of interpretations and sense-making processes, and may thus remain very resistant and unpredictable to pre-planned attempts at intervention (Alvesson & Sveningsson 2008).

The complexity approach to organisational development suggests that culture could be influenced by creating conditions that affect its self-organising processes (e.g. Seel 2000, Shaw 1997). For example, conditions such as organisational structures, means of communication, even physical environment, affect self-organisation. By monitoring and understanding the effect of these conditions, culture could be steered in a desirable direction. In such an approach, the role of the management would change from prescriptively planning the change and then enforcing it, to enabling and facilitating those conditions that lead to a more desirable culture. Secondly, the leader-centric approach emphasizes the role of top management and other managers over other influential agents. The contribution of (alleged) non-leaders to the development of safety culture might be ignored. For example, experienced old-timers in the organisation may be very influential as mentors and examples, even though their position in the line organisation is low.

Lastly, leader-centric approach may dismiss the effect of organisational and national cultures by assuming that similar safety culture development principles are applicable globally. A leader-centric approach may not apply if the leader is not in such a role in the organisation that would enable him/her to control the organisation in an authoritative manner. For example, in the Nordic countries that are characterised by equality and low power distance (i.e. managers and subordinates have a collaborative rather than a hierarchical relationship; Hofstede, 1980) top-down methods of intervention will probably have a different outcome than in high power distance cultures. It is to be noted that, whether the culture is of low or high power distance, prescriptive cultural change is nevertheless very difficult, if not impossible.

2.4.4 Nuclear and occupational safety

Although the concept of safety culture was initially developed to respond to issues in nuclear safety, it has increasingly also been related to occupational safety. This is reflected in the number of safety culture assessment and intervention methods that concentrate on occupational aspects of safety rather than nuclear, environmental or process safety. For example, the programmes that develop work site safety awareness or motivate the use of protective equipment are specifically directed at occupational safety. It is, however, unclear whether there is an overlap between occupational safety and nuclear safety when they are examined on a cultural level. Are there, for example, similar cultural mechanisms or the same underlying factors behind the performance in both types of safety? It could be argued that a culture in which occupational (i.e. individual level) safety is valued, nuclear (i.e. core task level) safety would also be valued. This might not always be the case. Although there is some overlap, the risks to nuclear processes and individuals often emerge from different types of mechanisms. Risks to occupational safety such as the lack of protective gear, carelessness when working near hot places, at heights, or when working with moving machinery usually only have negative consequences to shop-floor staff and do not have any significant effect on the process. For the shop-floor worker, such risks are easy to observe and avoid through being alert and having “common sense”. Risks to nuclear safety, on the other hand, relate more to systemic failures. These may be difficult for the

shop-floor worker to avoid, because he/she might not be aware of whether a mistake has been made.

Due to the sociotechnical complexity of the matter, nuclear safety risks are difficult for a shop-floor worker to comprehend, and are perhaps better understood at a higher level of examination (e.g. by senior workers, experts or designers). Therefore, to really concretize the meaning of nuclear safety culture and communicating the boundaries of safety, the understanding of safe activities at higher-level examination needs to be translated into what it means in practice for a shop-floor level worker. Traditionally, this has been done through bureaucratic means such as rule-based control and formalisation of work: the nuclear safety risks have been identified by experts and then written into instructions, rules or regulations that the shop-floor staff are expected to follow. These means, however, are often slow to renew and may be ineffective in some conditions (e.g. unexpected or inconceivable situations), which means that this approach has limitations. It has been argued that, in addition to the rule-based approach, a certain amount of local adjustments are needed in order to succeed in the work task (Gotcheva et al. 2013, Grote 2006, Grote et al. 2009, Oedewald et al. 2012). This leads to a problem of balancing between the two approaches: neither strict rule-based approach nor local adjustments alone are sufficient for the successful execution of work tasks. Being able to balance between these approaches would then be essential for ensuring nuclear safety. In conclusion, it could be argued that occupational and process safety are at least partially distinct processes from a safety culture point of view – occupational safety appears to emphasize local awareness while process safety focuses on systemic processes and understanding one's role in these processes. This suggests that safety culture development would need to take these two types of safety into consideration when implementing assessment and intervention strategies.

2.4.5 Networks and subcultures

Due to different national or cultural backgrounds, occupational groups, working conditions, etc., it is inevitable that subcultures form within an organisation. Especially in networked and project-based organisations where employee turnover is high and a shared culture will not be able to form easily, understanding subcultures is especially relevant. Representatives of different subcultures may have

different views on safety, or they may approach safety from a different level of examination. Different subcultures may also have different goals or goal conflicts, which affect their behaviours. Subcultures can be characterised by a specific type of jargon or language, demographics, responsibilities, level of authority or hierarchy. These characteristics place subcultures in a certain position in relation to each other: for example, some subcultures may be subordinate to others; some subcultures may communicate more effectively with certain subcultures; some may have more in common in terms of working conditions than others. When developing safety culture management strategy, it is useful to recognize the existence of subcultures and the influence of their characteristics and interaction on safe activities. Current approaches to safety culture largely ignore subcultures and emphasize a single shared culture, even though some scholars do suggest that cultures may vary considerably in various subgroups (Chute et al. 1995, Haukelid 2008). Although it may be desirable to create some cultural processes that are shared by everyone, in practice this may not be achievable due to the inherent heterogeneity of a complex organisation. This is an issue especially in networked organisations with a large number of subcontractors. In such cases, relying on means of common ground other than the licensee organisation may be needed. For example, developing a strong domain culture (e.g. nuclear industry) may help to create a common safety culture for subcontractor companies that are otherwise only loosely connected. More generally, ensuring safety in an organisation with cultural multiplicity would assume that the subcultures are compatible and complementary. Compatible subcultures would be able to communicate with each other in an effective manner, and understand the strengths, weaknesses and other characteristics of other subcultures. Some of the threats to organisations with multiple subcultures are that the functionality of the organisation may be lost if the subcultures hinder communication and cooperation, or cause detrimental competition or power conflicts. Complementary subcultures, on the other hand, would create an effective and diverse organisation where subcultures patch up each other's weaknesses.

2.5 Recommendations

In this chapter, various common methods that are used to develop safety culture at nuclear power plants have been discussed. In addition, insights into some of the

most relevant and current topics regarding efficiency and applicability of these methods have been provided. These insights are summarized as a compilation of recommendations, which may help the practitioners at nuclear facilities in developing and improving their safety culture programmes.

- Acknowledge that safety culture is a broad concept that covers all aspects and activities of the organisation – there are no single tools that improve all aspects of safety culture
- Identify the agents that influence safety culture development programmes (e.g. peers, umbrella organisations, governments, regulators, scientific community), and assess the limitations of their knowledge and its applicability to one's own organisation
- Acknowledge that safety culture is a slowly-moving phenomenon and that corrective actions usually do not result in immediate effects
- Ensure that there is a competent and permanent in-house safety culture expert who has a long-term vision regarding safety culture development
- Identify the logic of safety culture interventions: what is the goal of intervention; what are the mechanisms of action; what actually changes, and is this change desirable?
- Ensure that the safety culture development programme actually covers nuclear safety
- Take the existing culture(s) and subcultures into consideration when attempting to change the culture
- Consider how do the organisational structures and workforce arrangements enable or limit the formation of culture
- Ensure workers' participation and ownership in organisational changes
- Consider the effect of informal leaders apart from the formal ones

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3. Human performance programmes as a means to improve safety culture

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Abstract

Human performance programmes (HPPs) involve selecting and implementing a variety of human performance tools – good working practices that are thought to be beneficial for safety and efficiency. Despite their popularity, the suitability of introducing HPPs to achieve these goals is rarely discussed in the scientific literature. The HUMAX subproject provides insights to the expected and experienced benefits and disadvantages of HPPs. In addition, best practices to implement HPPs are discussed. The project involved three case studies at Nordic nuclear power plants and an international survey sent to human performance professionals. The results of the study demonstrate the heterogeneous nature of HPPs: some practices are more directed at error-prevention, while others focus on efficiency, supporting work or attitude development. Anticipating the effect of HPPs on safety culture is difficult, however, the study suggests that HPPs pay greater attention to rigorous work and help newcomers to integrate to existing working practices. Possible negative effects may be trust and confrontation issues between management and shop-floor workers. A good implementation process was seen as a critical success factor when introducing a human performance programme.

3.1 Introduction

One of the popular means of developing organisations in the nuclear industry is human performance programmes (HPPs). HPPs can be seen as a practical manifestation of a human performance improvement approach (HPI) as presented by the DoE (2009a). The HPI approach is a systemic approach to human performance in which various elements such as organisational factors, job-site conditions and individual behaviour are thought to interact and produce outcomes (DoE, 2009a). According to the HPI approach, human error is not merely seen as a cause of failure but rather a symptom of the whole system (DoE, 2009a). Therefore, the approach suggests that all the interacting elements need to be taken into account when addressing human performance-related issues. In practical terms, DoE (2009a) propose two main strategies for human performance improvement: *reducing error* and *managing controls*. Error reduction focuses on work execution and includes such means as preparation of the work task, improving performance during task execution, and reporting feedback after task completion. Management of controls, on the other hand, focuses on making sure that there are sufficient safeguards and that hazard or opportunities for error are eliminated. There are various approaches on how to develop, implement and conduct HPPs (e.g. IAEA 2001, 2005; Pershing 2006), but typically HPPs consist of choosing and implementing a particular set of human performance tools (HPTs). HPTs are simple aids or working practices to be used at all levels of the line organisation, although shop-floor maintenance and control room workers are most often in focus. The HPTs include, for example, peer checking, three-way-communication, pre-job-briefing and post-job review.

3.2 Human performance tools

The most common human performance tools include the following (DoE, 2009b):

a. pre-job briefing,
b. post-job review,
c. independent verification,
d. peer checking
e. techniques for clear communication.

Pre-job briefing is a formal meeting held before executing a work task. During this meeting, the task is prepared for, workers are briefed and risk analysis is carried out. The main functions of the pre-job briefing are to make sure everyone involved in the task knows his/her job, to ensure coordination and safety, and the smooth progress of the execution.

Post-job review is a meeting held after the task during at which successes and problems are considered and discussed. This is an opportunity to learn.

Independent verification involves an independent entity checking the result of the work task after it has been completed. This tool is especially common in safety critical tasks that are not real-time critical (i.e. no immediate danger after errors) and is useful to catch errors before the work task target is put back into operation.

Peer checking is a pair work technique that involves one of the workers performing the job and another verifying that the work is done correctly. This is a resource-intensive tool that is especially useful in those safety critical tasks where danger is immediate after an error (e.g. high-voltage work, heavy lifts, etc.)

The most popular clear communication techniques are the phonetic alphabet and three-way communication. The phonetic alphabet tool involves replacing letters with words during communications in order to avoid mishearing syllables, which is useful during the communication of arbitrary letter-combinations. Three-way communication involves repeating the message and acknowledging the repetition before applying the communicated information. This tool ensures the quality of information transfer between the parties, and is useful when communicating critical information or during adverse conditions (e.g. noisy rooms). In addition to the aforementioned tools, there are a variety of other HPTs to be used by individual shop-floor workers, workgroups and management (DoE, 2009b).

3.3 HUMAX study methods

HPPs in the nuclear industry have mainly been developed by practitioners and disseminated through informal networks and international bodies such as INPO and WANO. However, despite the prominence of human performance programmes, there is little scientific literature on the basic premises behind the human performance tools or information regarding what the concrete beneficial effects are. The purpose of the HUMAX project was to study the implementation, practical use and usefulness of HPTs at nuclear power plants (Oedewald et al.,

2014; Oedewald et al. 2015). Specifically, the following research questions were put forth:

1. What are the expected benefits of human performance tools applied in nuclear power plant maintenance?
2. What have the measurable benefits of human performance tools been so far in the plants)?
3. How do maintenance personnel perceive the application and effects of human performance tools?
4. What characterizes successful human performance tools and implementation processes?
5. What aspects of maintenance work are most effectively met by the use of human performance tools, and what could be solved by other socio-technical means?

HUMAX consists of case studies at three nuclear plants in Sweden and Finland, and an international survey (for further details, see Oedewald et al., 2014). Two of the case study plants had implemented HPPs, and the third one had not yet implemented an HPP, although they had implemented strategies similar to HPTs over the years. The three case studies were narrowed to maintenance activities. A total of 47 interviews were carried out, including supervisors, managers, technicians, control room operators and electricians. In the plants where HPP was already implemented, a personnel survey was carried out in order to gather personnel opinions on their HPP. The international survey was a self-administered web questionnaire targeted at nuclear industry human performance professionals around the world. The purpose of the survey was to provide complementary data to the Nordic case studies. The survey focused on enquiring the expected benefits, purpose and disadvantages of human performance programmes. In addition, the survey contained other questions, including what HPTs are used by respondent organisations, what were the motives behind the implementation, and what are the success factors of HPP implementation?

3.4 Results

Results from both the case studies and the international survey (Oedewald et al., 2014; Oedewald et al. 2015) suggested that one of the most prominent ex-

pected benefits of HPPs is to improve safety. The mechanism of action seem to be that HPTs help to prevent human error, which leads to reduced number of events, and this in turn would mean improved safety. The Nordic case studies brought up the fact that maintenance work includes different types of human error, each with different error mechanisms. This observation follows Reason's (1997) idea of skill-, rule- and knowledge-based errors. This would mean that a specific HPT would be needed in a particular situation in order to be effective in error-reduction. This is supported by the idea that the effect of HPTs on error appears to have a temporal dimension: some of the tools (e.g. pre-job briefing, self-checking) are executed prior to task execution, which allows the identification of risks and prevention of errors. Other tools that are executed after the task (e.g. independent verification) would catch the error after it has already been made or would develop skills or knowledge for future use (e.g. post-job review). Furthermore, some tools (e.g. self-checking, questioning attitude) provide the means of preparing for unexpected events. Some managers believed that HPTs contribute to safety by increasing the likelihood that operational tasks would be carried out according to procedures and rules. This suggests that HPTs may be expected to provide control over the way shop-floor workers execute their tasks.

HPTs were also perceived to have a range of other purposes that are not directly plant safety-related. These include minimized rework, fewer accumulated doses, fewer issues with the regulator due to procedure compliance problems, improved equipment performance, sharing knowledge and insights among workers, and improved business performance. Occupational safety was also often mentioned in addition to plant safety. In the plant where formal HPP had not yet been implemented, the finding that HPTs may be used for purposes other than safety was even more pronounced. However, it can be argued that both safety and effectiveness are in fact related to the same basic mechanism that the HPTs influence: if the task is executed correctly, then safety is ensured; if it is executed correctly the first time, then both safety and efficiency will be ensured. Respectively, if the task is executed incorrectly, both safety and efficiency are compromised.

The measurable benefits of HPTs were only rarely assessed at nuclear power plants. Some respondents to the international survey did mention that they believe the introduction of HPP could manifest itself in various indicators such as rework, human error rate, or work observations. In the two Nordic case organisations where HPPs were already introduced, it was easy to obtain descriptive examples

of how HPTs had contributed to preventing accidents or had improved efficiency. However, overall measured benefits seemed rarely to be calculated. Instead, it appeared that the positive effects of HPTs were considered self-evident and taken for granted.

A variety of opinions from personnel regarding HPPs was observed. The overall tone was positive; however, there were some concerns and also some very critical comments. HPTs were generally seen as useful and well-integrated: many of the tools were already in use in the organisations in some form before the formal introduction of HPP. A generation effect was observed: newcomers saw the HPTs more positively than old-timers. Newcomers perceived HPTs as something that help them develop their professional identity and, therefore, function as training tools. Experienced workers, on the other hand, were concerned of the potential threat of excessive managerial control and restriction over their established ways of working and individual judgement.

In addition, there were reserved and critical comments regarding the implementation of the HPTs. Especially the case studies showed that it is important to take into consideration the context in which HPTs are to be used. The tools should not be used excessively (e.g. in work tasks where they are not useful or are even detrimental), and they need to be scalable to fit the task in hand (i.e. in less critical tasks a HPT could be used in a lighter form). The general observation was that HPTs are accepted in the organisation if they make sense to the workers. This requires that the workers understand the goals and principles in introducing HPTs, and agree with them. Another important requirement for their introduction is that there must be opportunities to learn and use the tools. It was observed that, especially in the initial stages, the use of HPTs may be time-consuming. Case study organisations and international survey responses agreed that, in order to learn and use the HPTs, enough resources need to be allocated for the workers.

Various group climate-related factors also emerged. Especially trust between the shop-floor workers and between shop-floor and management was seen to be important. For example, the use of HPTs such as peer checking was perceived as a potential lack of trust if done incorrectly. There were also concerns regarding blame: HPTs should not be used as a basis for blaming personnel in case something goes wrong. The national culture effect was also observed in the implementation of HPTs. Anglo-American organisations appeared to use HPTs in a very disciplined manner, which may not be suitable for Nordic organisations. In the

Nordic case study organisations, autonomy and supervisors' ability to tailor tools to fit the context was usually emphasized.

3.5 Relevance to safety culture

When aggregating the results from the HUMAX study, several connections to safety culture emerge: the results suggest that the introduction of an HPP in the organisation may have an effect on safety culture and the introduction of an HPP or the use of HPTs may be affected by culture (see Figure 1).

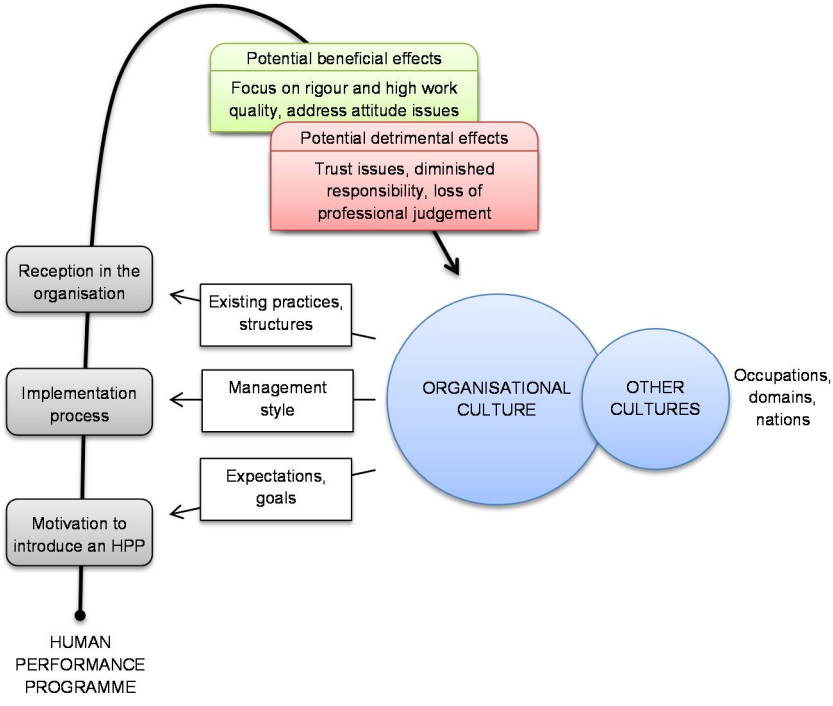

Figure 1. The relation of Human Performance Programmes to organisational culture in various phases of introduction

The effect of HPPs on safety culture was explicitly mentioned as a goal by many managers and human performance experts. HPPs were seen as something that would, for example, affect the culture by improving awareness of human fac-

tors in a safety-critical organisation. HPPs were also expected to develop safety-related attitudes, such as attention to rigour and high quality of work. In addition, there are also HPTs that attempt to specifically address attitudes, questioning attitude and procedure use and adherence, which in the international survey were found to be some of the more popular ones to be implemented.

Attitude development was perhaps most explicitly mentioned in the context of training newcomers. Many newcomers found that HPPs provide them with valuable information regarding expectations and ways of working in that particular organisation. HPPs were seen as a means to develop a positive professional identity. In such scenario, an HPP would collect and formalize the existing working practices and culture into something tangible and explicit, which can then be transferred to newcomers via training and policies. Therefore, the effect of HPPs for safety culture improvement is easy to see in the case of newcomers. However, the experienced workers were often critical of HPPs, because they were concerned that they may restrict their established ways of working and judgement of what is important in a particular situation. This difference in attitudes may suggest that safety culture effect is related to the target group of the programme. For the newcomers, the HPP may provide an effective way to “learn the ropes” of the organisation, especially if it actually reflects the culture of that particular organisation and is not merely a generic training programme. In the case of experienced workers, it would be important to involve them in the development of the programme to make sure the HPP actually reflects the positive characteristics of the culture of that particular organisation, and is applicable in practice. The actual culture change effect of an HPP as regards experienced personnel can probably be expected to be slow and less obvious because they already have established their working practices. On the other hand, if the HPP provides tools that are obviously better than the existing ones, then there is a chance they will be accepted by the experienced crowd too, which results in a culture change. Some indicative evidence of this kind of change was seen in the Nordic case studies. For example, a formal pre-job briefing was initially seen by many to be a burden – many considered it a waste of time having the personnel sit in a meeting room. However, after the pre-job briefing was established and the practical benefits were experienced, there appeared to be a clear consensus that proper pre-job briefings were a good thing, especially in safety-critical or complex tasks. Some interviewees mentioned that, even though a task could have been executed without a formal pre-job briefing

(e.g. by directly going to the work-site and then discuss the situation and coordinate activities as the task proceeds), the formalised pre-job briefing made the execution of a task much more controlled and effective. This can be seen as a concrete example of how the working practices have changed from a more improvised approach to a more pre-planned and meticulous approach.

Second, the introduction of an HPP or the use of HPTs is affected by various types of culture. This can be seen in two ways. The motivation to introduce a HPP and the way it is implemented can be affected by the culture. This can be reflected in what kinds of expectations and goals the organisation sets for the HPP. The culture may also affect how the HPP will be received once it is implemented. Results from the international survey showed that there were a variety of expectations mentioned regarding HPPs. These included safety improvement, improved efficiency, increased financial viability, controlling the work of personnel, training, developing culture and attitudes, and communication of expectations. Some responses suggested that HPP was expected to bring discipline to the organisation, or the workers felt that this was the purpose of the programme. According to international survey, the main motivation behind the implementation of HPPs was most often the external pressure from such organisations as INPO and WANO, or an internal development initiative. Several possible attitudes towards HPPs can be recognized: some organisations may see HPPs as an opportunity to genuinely support the personnel and their work, others may use them to impose more control over the personnel or attempt to reduce human variability, and yet others might merely implement an HPP in order to satisfy external peer pressure.

The insights gained from the HUMAX study argue that some of these approaches are problematic. Attempting to dampen human variability with tools such as HPTs might not result in desirable outcomes, because human variability is also a necessity in successful tasks. Disciplinary control or other behavioural issues should be addressed with other, more effective measures (e.g. poor work conditions or lack of training should not be compensated for with the introduction of HPTs). Finally, introducing HPPs only to meet external requirements, without proper requirement analysis and implementation process, may result in a degradation of work quality and various social issues within the organisation if the tools fail to integrate. Some of the examples of such threats that emerged from the responses were shop-floor personnel focusing on executing HPTs instead of the work task itself, working in a robotic manner and thus eliminating the usefulness of

one's own professional expertise, and the possible confrontation of management and shop-floor personnel. The organisation's culture will probably have an effect on which approach is preferred (e.g. a predominantly top-down organisation might find it appealing to impose more control over the workers, while an externally-driven organisation where meeting external requirements is highly valued might implement an HPP just because of the external pressure). It is, therefore, important to recognize the current culture of the target organisation when implementing HPPs and to ensure that the organisation would take the most desirable approach even though it might not be initially preferred by that organisation.

Each organisation is unique with a unique set of weaknesses and strengths. In order to effectively develop the organisation and its culture, it is reasonable that any development intervention *needs to be tailored* to that specific organisation. Failing to integrate an HPP to existing working practices and taking the culture of the target organisation into consideration may lead to a lack of acceptance of the HPP by target personnel groups. Many respondents (especially in the Nordic case studies) expressed their wish to tailor HPTs to their organisation and for specific work task contexts. In the international survey, several human performance experts emphasized the importance of integration to existing practices as a success factor for HPPs. HPPs are somewhat problematic in terms of tailoring, since they often appear as rigid entities that are implemented as such. Even though in some HPP literature (e.g. DoE materials; see DoE, 2009a), the relevance of integration is implied; in practice it appears that HPPs are often not necessarily tailored as much as needed. For example, in the international survey it was observed that the content of an HPP (i.e. which HPTs were to chosen to be implemented) was very similar between different organisations. This may suggest that HPPs are used as templates to introduce a predefined set of most popular HPTs. In many cases, the most popular tools are also the most important ones; however, due to the universality of HPTs, it is probable that these HPTs are already implemented in the target organisation in some form, and the re-introduction of the same work practices under HPPs may not be fruitful. It is, therefore, important that any organisation that is about to implement an HPP (or has already implemented one) be aware of the strengths and weaknesses of its own culture and working practices, and consider the benefits and disadvantages of introducing a formal development programme, even though the external pressure or other driving factors would only demand generic introduction of HPP. One of the major specific concerns brought up in the

responses regarding the use of HPTs was the availability of resources and possibility of actually using the tools. It was often seen as paradoxical that the use of HPTs was required, yet there were not enough extra resources to use or learn the tools. Such an implementation of an HPP may firstly suggest that there are non-systemic views of safety in the organisation: HPTs are expected to be useful for safety, even though the conditions for their proper use are not provided. Secondly, by sending conflicting messages the management may cause confusion and frustration among the operative staff. The latter issue was especially clear in the interviews of shop-floor supervisors in the HUMAX study.

In addition to organisation culture, there are also other cultures that may have an effect on the implementation of HPPs or the use of HPTs. Examples of such cultures could be domain culture (e.g. nuclear industry), national culture, and occupational culture. One of the HUMAX study research questions was to elaborate on the national culture effects on the implementation and use of HPTs. In the Nordic countries, corporations are typically characterised as democratic (Hofstede, 1980): there is little hierarchy, employees are independent and participate in decision-making, and there is a collaborative interaction between subordinates and managers that aims for consensus. This may mean that some of the tools introduced in HPPs or certain implementation processes may not be directly applicable in the Nordic countries, or at least not in the same way as on other types of national cultures. In HUMAX Nordic case studies personnel attitudes were observed that relate to this illustration of Nordic culture. It was observed that many consider such tools that require formal communication (e.g. phonetic alphabets and three-way communication) to be alien, and that more informal and conversational communication was preferred. This preference was also related to work task characteristics: unless it was possible to clearly demonstrate that formal communication was required (e.g. tasks that involve the communication of a large number of co-ordinates etc.), the staff would prefer informal communication. In addition, the Nordic case studies showed that HPTs such as peer check and task observations were often considered uncomfortable by the personnel, because they were interpreted as something that questions their expertise or ability to perform the work correctly. In many Nordic case study interviews, it was emphasized that one of the means to ensure high quality of work and to avoid errors was the professionalism and professional pride of the personnel. This may reflect national (and perhaps also occupational) culture, in which a certain level of autonomy and personal re-

sponsibility is expected of the personnel and by the personnel. In summary, some HPTs may contradict with the existing cultural traits, which may result in undesirable social issues, and this needs to be taken into consideration when choosing which tools to use and how to use them.

Finally, national culture differences may also affect whether the implementation process will be successful or what factors need to be taken into consideration during implementation. There were some indicative differences between different national groups in the international survey. For example, in Anglo-American (the USA and UK) countries it was often seen that the correct application of the HPTs would result in positive outcomes, while in other European countries there were more concerns of personnel losing their focus on the task and starting to emphasize the execution of the tools too much. Another observation was that the Anglo-American countries apply HPTs in a more disciplined manner, while Europeans, especially the Nordic countries prefer adjustments and local adaptation of the tools. In addition, Anglo-American countries (especially the USA) have applied HPPs much longer than other European countries. These observations may support the idea that the Anglo-American countries tolerate the authoritative implementation process and lack of local adjustments better than other cultures such as Nordic. This suggests that, in some national cultures, one can more easily use a non-collaborative approach and still come up with a functional implementation of a HPP, while in other cultures this may be met with opposition from the personnel.

3.6 Conclusions

Human performance programmes are a heterogeneous compilation of a variety of techniques (human performance tools) that support human performance at nuclear power organisations. Some of the tools are more clearly directed at error prevention, while others focus on learning or supporting efficiency; some are even directed at attitude development. Due to this heterogeneity, the specific effect of HPPs on safety culture can be difficult to anticipate. There are, however, some general beneficial characteristics that may be promoted by an HPP. For example, an HPP may focus the attention on the importance of rigorous work and human factors, and it may help to transfer an existing culture to newcomers or to gather lessons learned from other organisations or domains. Possible negative cultural effects suggested by the HUMAX study are related to creating a confrontation

between management and shop-floor staff and imposing overly controlled ways of executing work tasks. The former issue can result in trust issues, and a lack of collaboration and communication between the management and shop-floor – all of which are problematic from a safety culture point of view. The latter issue may on the other hand result in a culture of diminished responsibility (e.g. focusing on the execution of tools instead of the actual task) or rigid and “robotic” ways of working that eliminate the beneficial effects of professional workers’ input. Throughout the HUMAX study the implementation process of an HPP was seen as critical success factor. In order to be accepted by the organisation and its workers, the HPP needs to take existing practices and structures (including culture) into consideration during implementation, as failing to do so may result in detrimental effects on the organisation and its culture.

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4. More requirements, more safety? Cultural tensions in NPP design activities

Mikael Wahlström

Abstract

This chapter explores some cultural tensions in the Finnish NPP design, and focuses especially on regulator–power company interactions as one of the sources of certain cultural features. Two design cases were studied from organisational and cultural challenges perspective. According to the findings, during the design process the documentation is precise and the regulatory oversight is thorough. These can be interpreted as cultural features aiming at ensuring safety. However, these features may come with some trade-offs: formal and document based connections with the regulator coupled with the expanding set of requirements inevitably produces challenges for NPP design process. Based on the challenges, we delineate possible risks, which have the potential to generate problematic designs from a safety perspective. Possible means for enhancing the current design practices are discussed.

4.1 Introduction

This chapter focuses on design activities by studying what kinds of organisational and cultural characteristics are prominent in actual design cases at Finnish

nuclear power plants. By *design* we mean activities such as idea conception, planning, problem solving, and decision making, as well as the overall management of these activities (e.g. Lawrence, 1988; Aspelund, 2006). Design is a coordinated effort by many individuals and organizations (Curtis et al., 1988). These activities take place when some existing systems in an NPP have to be modified or new solutions have to be generated for an operating unit, or in a new build. Studying organisational and cultural challenges is important because it helps to shed light on the ways in which safety of the end-products are ensured.

Weaknesses in design have played a part in major accidents in the NPP domain (Rollenhagen, 2010). The way in which design is conducted relates to the safety culture of the designing organizations (Macchi et al., 2012). Therefore, we consider that it is important to have an improved understanding on the cultural challenges and threats related to the safety culture and working practices. We delineate potential risks by drawing on our analysis of the current design practices in the nuclear domain in Finland. In view of our findings, it seems that drafting clear documents and carefully considering the various requirements are crucially time consuming and important design activities. Design thus involves comprehensive research as an expanding set of requirements has to be considered; this increase in requirements has accelerated due to the Fukushima incident. The documents are not only applied for the internal use of power companies alone but are crucially important in communicating with the regulator. Our findings indicate that the nuclear regulator in Finland emphasizes clarity and precision of the documents. All these features are highly positive in reflecting thoroughness and transparency; in this sense, they seem to represent well developed and prudent safety culture.

Document-based connections with the regulator together with the expanding set of requirements are a combination which, however, may produce challenges for design. First, there can be extensions to the timetables due to having to wait for the authority's decision. Second, preparing the documents is a considerable effort in itself as they have to be clear, comprehensive and consider numerous requirements. Third, as the documents are fairly comprehensive, including implementation as well as testing of the new design or modification solutions, it seems that the design process is based on the assumption that it is possible to acquire perfect or at least almost perfect foreknowledge of the design solution and the way in which

it will work in reality. All details have to be covered comprehensively, as well as accepted by the regulator before the implementation begins.

This “assumption of perfect foreknowledge”, in turn, brings other logically plausible challenges and threats to actualizing safe design. First, it is assumed that the design process is fairly fixed: there is little flexibility to change the plans after the initial plans are laid out, as much of the design activity focuses on evaluating the plans and in time-consuming requirement management. In other words, a change of plans could delay the process significantly. Iteration and changing the plans might be necessary; however, if it happens that not all the particularities remain as they were pre-imagined when the plans are being actualized or evaluated by the regulator. This might be the case if several modification projects are being actualized at the same time, for example, one modification case might influence the way in which another modification should be actualized. The relatively “fixed” design process with an emphasis on document drafting and requirement study might also imply that there is only little space for iteration in the design work. This would suggest that there is little space for rethinking the design idea as a whole once the process has gone so far that tedious document drafting is on the way. This might not be a problem at the very beginning of design, i.e., in the concept design phase (Macchi et al., 2012). However, given that the interviewees emphasized the document drafting phase and it seemed to be the most time consuming phase, this issue could be considered by those involved in design in the NPP domain.

There is another possible risk related to the tedious process of document drafting. This threat could be called as “losing the big picture”. Could it be so that, while being especially focused on specific requirements, the designers in NPP domain, who may be focused specialists, might overlook some essential elements in the overall design? Indeed, based on interviews, Macchi et al. (2014) have found that understanding the overall power plant can be difficult for individual specialist designers; this seems to be a significant challenge in the NPP domain. So, the leadership overseeing the design process should take care that the big picture is maintained on the level of the overall design project. Given that this can be challenging, another problem should be considered. The ultimate responsibility for the design should lie within the power companies (IAEA 2003). However, as the power companies know that the design plans are being checked out stringently by the regulator, there might be a risk that the licensee assumes that, if the regulator gives the green light, it means the plans are fine. In other words, part of the challenging task

of checking that all the details have been considered in view of the overall power plant is given to the regulator. This might imply that there is, in a sense, a "misplaced focus" in the design process, that is, "designing for the regulator" is taking place instead of considering the overall design as such. The regulator might be "exploited" as a design authority, i.e., as the one with the actual responsibility of the safety of the end-product. We do not have empirical evidence of these issues and they might not exist in current work practices, but this is something to be considered as a potential risk by the power companies.

It is perhaps not a surprise that a combination of strict and prudent governmental regulation with expanding requirements can create a demanding setting for design, especially in a technologically complex and safety-critical industrial domain. As will be discussed, such a setting may entail elements that are problematic for safety. At the end of this chapter, we will also discuss some practical ideas to be considered in NPP design. These relate to:

- more incremental commitment to design plans – for more iterative and flexible design process, with more focus on considering different design alternatives;
- the means of communicating with the regulator – this process could be more efficient with alternative modes of communication allowed by modern digital platforms;
- the requirement management tools – it was claimed by the interviewees that the means for studying the requirements are not the best possible; and
- the overall understanding of good safety culture in NPP design – thoroughness and transparency (i.e. clear documentation) are not sufficient and clear leadership, systemic thinking, flexibility to consider various options and efficiency are needed as well.

Overall, the most important findings and possible challenges are presented in Figure 1. The flow of the picture describes the line of argumentation made in this chapter. The risks are not likely to concern every design project, and they are debatable. In other words, the cultural threats described in this chapter are to be understood as subjects for critical discussion for the purpose of avoiding them or handling them, rather than as descriptions of the state of the art of the NPP design in Finland. Based on the feedback we have gathered on a draft-version of this part

of the report, some practitioners of the field may consider them practically non-existent in Finland. However, human and organizational activity is not always perfect – stress and rush, for instance, may weaken performance – and sometimes designs do fail. Therefore, one should consider potential reasons, or in this case – cultural challenges – as to why some design projects might fail.

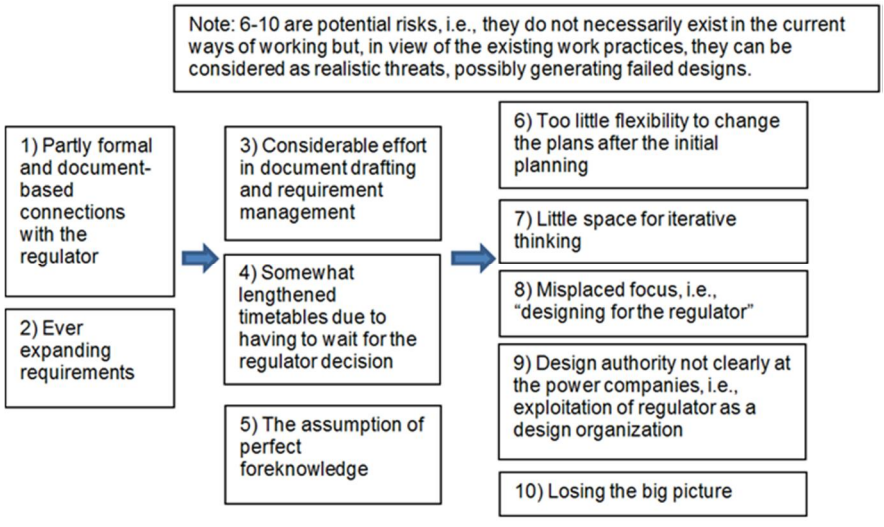

Figure 1. The most basic findings of the study implied (boxes 1–2), and more specific findings (boxes 3–5) and related risks (boxes 6–10).

It is worth mentioning that this chapter provides only a limited overview to the challenges that the current safety culture in Finland implies for NPP design activities. This particular study focuses especially on regulator–power company-relationships, because this issue was addressed in the data and considering it might be a means of enhancing the process. It is evident, however, that there are other issues to be considered as well; these are elaborated in Chapter 5 and in other publications related to the MANSCU project (Macchi et al. 2012, 2013 and 2014, Gotcheva et al. 2014).

4.2 Method

Our study draws from two different NPP design cases at two Finnish nuclear power plants. The first design task was considered fairly small and simple – a minor modification to a pump functionality which did not require designing new components, but changes to circuit diagrams. In contrast, the second design case is a major long-term project, which is continuing – the overall design for management of a specific type of waste, and its associated infrastructure. The way in which the design cases were studied was by interviewing those involved in the design work, which included eight energy company workers and a governmental regulator representative. The method of analysis was pinpointing and inferring possible problems and trade-offs from the accounts of the interviewees. In other words, the method of analysis focused on areas and issues, which might benefit from development, rather than on existing strengths. Otherwise, we viewed the data open-mindedly rather than with a specific theoretical model, i.e., data driven analysis was applied. In doing the analysis, however, the focus was on design activities on the level of broad social practices.

The design cases were suggested by the power companies. Two researchers were present in each interview. The interviews were semi-structured: they aimed at understanding the overall design project and also included questions for validating previous studies (Macchi et al., 2013) made in the project. The specific interview schemes and the results related to validating questions have been reported by Macchi et al. (2014). In this chapter, we apply the general descriptions of the design projects as the analysis data.

In the following, we will first describe the two design cases and then consider the challenges mentioned in greater depth.

4.2.1 Design cases

Design case 1: Slowing down the shut-down speed in the main circulation pumps

As it happens, one of the senior automation engineers at a Finnish NPP realised that, in the existing steam lines of a Finnish NPP, the closing down of some insulation valves happened too quickly. This meant that a peak in steam circulation might occur – shutting down one steam line could momentarily increase the steam flow in the open steam lines. This, in turn, might induce load on the pipes and trigger a shut-down of the main circulation pumps. Some modifications were made already a year before but, based on data on a disruption in which an isolation valve was closed unnecessarily, it was concluded that a modification was necessary. Overall, to improve safety and, also, to reduce the load on the pipes, the speed of closing down would have to be reduced by some milliseconds. No new components were required in this modification as it was sufficient to make new connections in the circuit diagrams in the cabinet controlling the valves. It was considered that the modification was a safety class 3 job, which is the second highest in automation modification, meaning that a large amount of paper work was required.

Despite being technically a fairly easy project, the project took 17 months of research and communication before the actual work could be initiated. After two months of internal decision-making within the power company, a comprehensive 21 page plan, called “preliminary plan” took 10 months to draft. In practice, this included a major effort in studying the requirements involved in the modification work. The drafting took a considerable amount of work time from one engineer and also included the circulation of in-house documents as experts from different fields commented on the plan. The plan was then sent to the safety authorities who gave their first response in three months. The representative of the governmental regulator concluded that the plan is not sufficiently comprehensive, as it did not include enough details on testing the new design in order to verify its functionality. This issue was addressed and the project was finalized successfully.

Design case 2: A waste management system

The second case NPP was built so that it contains fairly large containers for certain kinds of radioactive waste that are generated as a side-product by the plant. Eventually, however, this waste would have to be stored in a final repository. A waste management system would thus have to be planned. The design project involved the storage, the waste management plant and the infrastructure, e.g., the way in which the waste would be transported to the plant and to the final repository. The design work started in the 1980s, but was put on hold for about ten years. More recently, around the millennium, a decision was made that planning would be initiated again; this involved the old plans having to be reviewed. A decade later, at the initial stages of testing of the plant, however, a safety incident took place. The issue was later classified as an INES1 incident. There was a problem in the design and a small part of the system would thus have to be planned again.

Overall, then, the design project was and still is complicated, involving experts from various disciplines. The complexity involves the enormous time span (the repository having to be safe for thousands of years in the future) the complex chemical, radioactive and physical qualities as well as several hundreds, if not thousands, of guidelines and requirements. The project has been conducted mostly in-house by the power company and the project entails a nominated contact person on the regulator's side.

4.3 Findings

4.3.1 Formal connections with the regulator and expanding requirements

As seen in case study 1, the relation between the power company and the regulator can be described as formal. The decisive communication takes place with detailed documents. They communicate in other ways as well, that is, by telephone, by more casual emails and sometimes face-to-face even, but the final decisions are based on the precise documents. It seems that this has not always been the case in the history of the exchange between power companies and the regulator in Finland, as can be seen in the description of one of the interviewees:

"*We also have experienced people here, quite a few of them, and they're used to calling the authorities and simply telling them that we've thought about implementing this kind of a system, sounds good, doesn't it? And the authorities say splendid, and they implement it. I mean this is how it was done 10 years ago. But it doesn't work like that anymore, so what happens is, these, how should I put it, old dogs, they'd like to keep doing things the old way, like they used to, without sending this and that and the other thing there. But we do have to do it now." (Energy company employee, Case 1)*

The importance of formal and precise documents is clear throughout the interviews and is linked to many of the arguments presented in this part of the report. Another phenomenon, which is very descriptive of the design processes in the nuclear domain, is the vast number of requirements that have to be taken into account as the documents are drafted. This too is a changing phenomenon, as the number of requirements has been on the rise. It was especially mentioned that, after the Fukushima Daiichi disaster in 2011, more and more safety requirements were introduced.

Overall, neither of these two distinctive phenomena – formal and document-based connections with the authorities and requirement based-design – are new for the NPP domain, but their importance has increased; it seems that the number of requirements is increasing hand-in-hand with the rigor of the regulator. Though both of the phenomena are positive in ensuring that the design solutions are safe, they might entail some counterproductive elements. The negative issues include evident challenges for the design process in terms of burden and extensions to timetables, but may also generate some other challenges as will be discussed in the following.

4.3.2 Document drafting and requirement management effort

The most direct and clear consequence of the issues above – the need for precise and comprehensive documents and the ever increasing requirements – is the time consumed in any, even small, modification at power plants. This is how an interviewee describes Case 1:

"Let me put it this way, if we were producing dairy products here and not nuclear power, the design would have been pretty much there already, but we have to write a mountain of documents in addition to this." (Energy company employee, Case 1)

The writing of this "mountain of documents" requires hard work by highly trained specialists. Here design turns into a research endeavour, as different requirements and other issues are considered in different ways. It is not a straightforward and simple process, but something that involves different kinds of activities, including discussions between experts of different fields and document study; the requirements may be identified by studying existing plans with similar projects.

"It involves searching for information, digging up documentation. And, in particular, there's a significantly larger number of documents that we need to go through here. We need to go through all of them and check what the effects are elsewhere. So that no (electronic) problems emerge, or installation issues, an error can occur that may cause the new device to... We have always to consider how these can be identified. […] So, as you said, it's easier to remember things if you discuss or go over them with someone rather than just searching for information from folders." (Energy company employee, Case 1)

In addition to research, the writing of the documents is a time consuming task itself. The regulator emphasizes comprehensiveness and clarity, as can be seen in the accounts of a regulator representative (Case 1):

"In this case, it emerged that the testing plan wasn't accurate enough. […] Well, truth be told, this was one of the smallest projects I've worked on. But in relation to the question that comes later about what went well or not so well, these projects always have their challenges because our job is to ensure that the requirements of the NPP guides are met. And, if a document we receive doesn't clearly indicate this, it's a bit, it requires a closer look and further discussion to understand what the meaning is exactly. Clear documents are clear." (Regulator representative, Case 1)

It was also mentioned that writing good documents for the regulator requires learning, that is, it is an effort in itself to learn how to write the plans in a manner such that the sufficient level of unambiguity is achieved. This was a collective effort at the power company.

"If you want a challenge, what's challenging is communicating with the authorities, in writing, on paper you know, since what we do is we may discuss an issue with the authorities over the phone and both parties are aware of the fact that writing unambiguously, it's incredibly difficult. […] And also, in addition to the extra, in addition to the usual circulation, we had three or four internal review cycles at the office, checking everything from spelling to comprehension, so I'd say all of this has made the document clearer, easy to understand." (Energy company employee, Case 1)

It is worth to emphasize, however, that the power company workers interviewed did not complain that writing comprehensive and clear documents took effort and required learning. Instead, they considered document drafting to be a valuable and needed skill. What they did complain about, however, was that the tools for requirement monitoring and requirement management were not the best possible. It was mentioned that, while working with the staff only from the power company, the tracking of the requirements is easy, but with external parties involved it can be somewhat problematic at times. It was said that monitoring the way in which requirements are transferred from one document to another could be improved.

4.3.3 Timetable extensions due to having to wait for the authority's decision

Document drafting and requirement management are time-consuming in themselves; it took 10 months to do these tasks in a plant modification that was described as simple and easy. However, in addition to this, time is consumed as the power companies have to wait for a response from the regulator. In other words, the workload at the regulator translates into inconvenience and need for anticipating extensions to the timetables at the power plants. In Case 1, it took three months to receive the first response from the regulator after the first documents were sent to them – overall this amounts to 13 months and, as there was some

exchange after the first response and internal discussions as well, the modification work could begin 18 months after the need for modification was identified.

On the more complex Case 2, however, the connections with the regulator were described as good and efficient. This is because there was a nominated contact person for the project at the regulator agency.

Researcher: *"You're communicating directly with STUK [the regulator agency]. "*

Interviewee: "*Well, yes, quite directly anyway. And it wasn't that efficient previously, but it's very efficient now, in my opinion." (Energy company employee, Case 2)*

4.3.4 The assumption of perfect foreknowledge

The issue that perfect and comprehensive plans are needed prior to implementation implies that perfect, or at least near perfect, foreknowledge on the affairs at the plant are needed. Given that drafting of these plans takes several months, this, in a sense, implies that the designers would have to "see" months or years into the future. They have to have all the details beforehand. Could this then be a problem? Could the plans somehow become outdated during the writing of them and during the wait for the feedback from the regulator? Naturally, the plans can be somewhat modified during the writing, when necessary if, say, new requirements are introduced. Nevertheless, it seems that the plans are quite fixed to the original plan, that is, the design idea cannot be conveniently changed once the document drafting and requirement study has been initiated.

The design model applied in NPP design resembles the so-called V-model (Figure 2) in the sense that it contains the assumption that the foreknowledge is perfect – "we can define complete, consistent, testable, and buildable requirements; decompose perfect requirements to perfect specifications; accurately estimate effort, cost, and schedule for the specifications; schedule work according to this information early in the programme; and measure progress using earned-value management or similar techniques", as Turner (2007, p. 12) describes it. As also discussed by Turner, the V-model has been criticised due to its lack of flexibility. This same criticism could be applied to the NPP design processes.

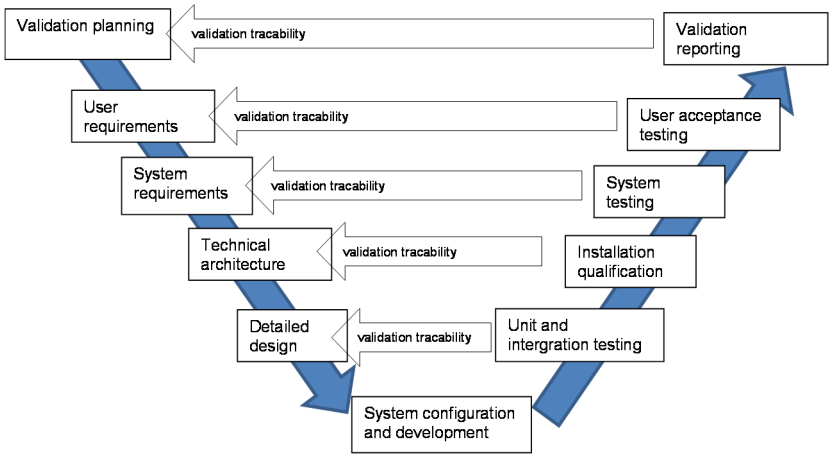

Figure 2. V-Model of a Conventional, Large-System Development Process (adapted from Turner, 2007).

4.3.5 Lack of flexibility and little space for iteration

The argument thus goes that, once an agreement on the design solution has been made, a long process of requirement management and document drafting takes place – and during this requirement study and drafting phase the plans can be changed only slightly, i.e., it is a somewhat rigid process. This description of the design processes at the NPP domain might not apply to all cases, but if it is a predominant or common mode of work, it could be necessary to consider whether this lack of flexibility might be a problem or not. To do this, in turn, one should consider the issues, relevant to a NPP design solution that might vary over time. These unpredictable issues could include, at least: requirement changes, changes in design or implementation work force, advances in technology, and supplier situation. If the situation changes, while the plans have been laid down already, considerable delays might emerge. Additionally, parallel design projects might have an impact as well, that is, one may imagine that, if several design projects with interlinked causal elements take place at the same time and if all of these projects progress especially slowly, managing the overall repertoire of projects might be particularly challenging.

Another issue, which is closely related to the issue of lack of flexibility, is that only little space for iterative thinking remains for the designers. Different iterations

and versions of the design solution might be created in the concept design part of the design process but, as much of the focus is on requirement management, it is questionable whether there is enough time and workforce to consider the different options. The burdensomeness of the document drafting process could play a role here: the requirement study might indicate that a certain design idea is better than another, but it is questionable whether the employees are willing to reconsider the idea, if this reconsideration implies writing a “new mountain of documents”. We do not have direct data of behaviour of this kind, but it is a possible problem to be considered and discussed by the power companies. Being focused on the requirement management and with little space for iteration, the actual use of the design solutions can be left with too little attention. Human-factors issues can be difficult to foresee and, if the technical features of the solution are especially fixed, it can be difficult to implement solutions, which are safe in view of usage.

4.3.6 The threats of “designing for the regulator” and sharing the design authority

If the focus of the work is on the requirement management and document creation, another tension seems plausible: the actual use and functioning of the system should be in the main focus, while, in terms of design activity, addressing the requirements is the most burdensome effort – it seems plausible that these will not always be the same. With a tremendous amount of document creation plus tasks related to project administration, there is a danger that the design team distances itself from the actual aim, that is, the creation of a good solution, which is also usable for the end-users. In other words, too much value would be given to the non-essential elements in the process of design.

The threat that the power companies rely on the authorities in checking that designs are good means that the power companies share “design authority” and responsibility with the regulator. Arguably, in a high reliability organization someone has to have the final word and the responsibility to ensure that the solution actually works. According to an IAEA report (2003), and the regulations, the operating organizations (i.e., power companies) have the responsibility to maintain design authority, that is, to they have to formally approve all the design changes and have to maintain the knowledge needed for this. At the same time, the regulator agency has responsibilities that can be seen as overlapping – it also accepts

the plans. All this might imply a loss of authority in the minds and actual working practices of power company workers; this could depend on the design case and situation. It is noteworthy that the regulator does not only accept the plans, but also restricts and controls the design process itself – this, again, implies a reduction in clear design authority.

"The authorities give us our marching orders for these things, we have to work according to that and also, [power plant name] has established their own guidelines accordingly and, how the design work, what kind of documentation is required, so I'm not sure whether there's anything, they work well or don't, but we'll have to do them anyway. We cannot take any short cuts; we must follow the specified procedures. We cannot establish our own design methods in that sense." (Energy company employee, Case 2)

4.3.7 Losing the big picture?

Closely related to the possible threat of shared design authority, is the possible risk of "losing the big picture". Firstly, shared responsibility can sometimes mean that nobody takes the final responsibility of maintaining an overall understanding of the design process. Understanding the overall NPP context has been found to be a significant challenge in NPP design (Macchi, et al. 2014). Secondly, as it takes time to write clear documents and to consider the vast repertoire of requirements, it might be that these activities become the essence of design work, and the actual solution and systemic thinking on its functioning remain secondary. This can be seen as a leadership issue – a good leader would maintain responsibility and overall understanding of the actual solution rather than concentrate merely on project and requirement management. This is visible in the following account in which a question on good cooperation is being addressed, but which seems to go beyond that issue in discussing leadership.

Researcher: "*Can you think about any practical way of making sure that there is no break [in cooperation]?"*

Interviewee: "*Yeah. It's what we have now. [Project leader name], he's in charge of the project. During the implementation of the project, there was no such*

person. So somebody has to have an interest in what's being done. So that's the basic element that, there's one person who feels that this is mine, on the operator side, who feels that now I'm responsible; my team will operate this plant. Then, the approach is completely different. If nobody's nominated, then who should care what's being done. Nobody. Would we have been, or would we have had such a person during the project, it would have been a bigger success." (Energy company employee, Case 2)

It is understandable that in big complicated projects the leader cannot maintain a specific understanding of all the relevant technical issues. Design and modification tasks, which are sufficiently challenging and important (in terms of safety implications and/or economic indicators) are typically organized as projects. The project would have to be viewed from a sufficiently broad level of abstraction and the project leader would have to maintain an overview of who understands the issues relating to the more specific subdomains of the project. The leader should also ensure that these individuals communicate with each other and with the leader sufficiently for maintaining the big picture.

4.3.8 Conclusions and interpretations from the findings: Increasing requirements and precise documents – always beneficial for safety?

Overall, although one might immediately assume that the increasing number of requirements and the prerequisite of precise documents would *only* imply increased safety; the issues discussed here suggest that these phenomena *may* also impair safety on some occasions if they translate into the risks suggested here.

Firstly, the time consumed in making the "mountain of documents" and in for waiting for the regulator feedback may cause delays to necessary safety improvements. Quite simply, if things do not get done in a reasonable time, there will be delays in creating the necessary enhancements to safety.

Secondly, lack of flexibility and little space for iteration may induce some challenges with safety implications. Arguably, if human factors issues and the actual use of the system are difficult to foresee and cover with the requirements, the designers should be able to make changes to the plans more flexibly. If this flexibility does exist not in practice, as the requirement management is so demanding

and has to clearly predate the implementation, the safety benefits from better usability might remain unfulfilled.

Thirdly, if addressing the requirements is not sufficient for achieving the best possible safety, the possible phenomenon of “designing for the regulator” would be problematic. Additionally, shared design authority implies the possibility that a certain safety related aspect in the overall design remains unconsidered. “Losing the big picture” may be detrimental. Lack of true design authority by the power companies would be a safety risk.

The main message of this chapter of the report is to provide an insight into the possible challenges and risks caused by the existing trend towards increasing bureaucracy involved in NPP design. It should be noted that these challenges and risks are not necessarily present in the existing work practices. Rather, they should be seen as potential problem causes, which should be avoided in the future projects. Human activity always entails the potential for mistakes and therefore the potential risks should be elaborated. In high risk domains, the design process is arguably largely a governmentally regulated process for reducing human mistakes. Regulation is, of course, necessary, but challenges and threats can be identified as well, and regulation does not ensure success. New requirements can be necessary, but at the same time one should consider that, in principle, somewhere there must be a limit beyond which the number of requirements produces negative effects. Evidently, this study cannot identify the correct amount of governmental regulation, as that is something to be discussed by the NPP community as a whole. In the following, however, we will discuss some possible solutions to be considered for alleviating the challenges identified.

4.4 Suggestions for enhancing the working practices and safety culture in NPP design

We will now discuss some possible means for enhancing the existing design activities. It is noteworthy, however, that some of these suggestions come with trade-offs; they might imply a need for adopting new practices, and may imply challenges for maintaining the thoroughness of the regulation. Additionally, these suggestions should be properly considered in future studies. Thus, the main aim here is to stimulate discussion and show alternatives rather than to provide simple clear-cut guidelines.

4.4.1 Alternative design models

As discussed earlier, the current design model resembles the V-model (Turner, 2007) in the sense that it is based on comprehensive plans of the end-product; however, this might not be suitable for all cases, since good design often draws from iteration and consideration of various options (Pew & Mavor, 2007). Could the focus in Finnish NPP design be somehow shifted from the document drafting to the consideration of different alternatives?

One possibility would be that the regulator presence would be shifted from the approval of the final documents to considering different design alternatives and to providing insight on these alternatives, i.e. the regulator would henceforward work as a requirement specialist in the concept design phase. It is unclear to what extent this takes place currently. The regulator's role is currently partly well-defined and partly vague: the regulator inspects the plans formally, but also engages in informal discussions. Perhaps the regulator's participation in design could be defined somewhat more specifically; some kind of defined role in the concept design phase could bring clarity to the way in which authorities take part in design. More studies and consideration would be needed, however, before defining the regulator participation. This is because a specialist role in the concept phase of design might also compromise the regulator's independence as a reviewer; the regulator should be able to check the entire design with an outsider's point of view, and design authority should clearly remain within the operating organizations. Nonetheless, some inspiration could be drawn from the so-called "incremental commitment model", which has been proposed as an alternative to the V-model (Pew & Mavor, 2007). The main idea in the incremental commitment model is that different stakeholders evaluate different versions of the plans in different phases, including initial scoping and concept definition. In other words, stakeholder opinion can be used in defining the initial plans and the overall concept in the very beginning of the design process.

More work would be needed in considering how incremental commitment to plans could suit to the NPP domain – if it is feasible at all; a more iterative and flexible design process, with more focus on considering different design alternatives could be beneficial, however.

4.4.2 Enhancing document-based communication – new digital alternatives

If creating a “mountain of documents” is perhaps the most time-consuming task in NPP design, one might consider how to facilitate this process. Currently things are done in a traditional manner: documents are transferred in paper format and are written with the most common word processing software. However, new more flexible options for transferring and exchanging knowledge exist, and one could consider these when imagining how the enhance regulator–power company-exchange.

Firstly, to the best of our knowledge, the documents do not entail specifically predefined formats, i.e. the regulator has to search and read through the documents as any written book in order to find the needed information. Perhaps the documents could be written by filling in forms with predefined headers. The completed form could then be submitted to the regulator digitally, as we often see in today’s web-based systems. Careful consideration would be needed in designing these forms, as badly designed forms might do more harm than help: the format would have to entail sufficient flexibility, as it would have to be suited to various kinds of design cases. Most likely it would be best if the headers were given, but they would not be fixed, that is, they could be changed by the document drafters when necessary.

Secondly, more varied modes of communication can be imagined thanks to the new digital possibilities. Paper documents only entail text and pictures. If the documents are transferred digitally to the regulator via a digital platform, video clips or sound could be added to the overall document. This could be helpful on some occasions – perhaps certain issues could be explicated more easily by speaking and by showing with video. Assumedly, these video clips would only be small additions in the overall predominantly text-based document, as reviewing videos is burdensome in contrast to text.

Thirdly, more flexible commenting and co-writing is possible with new digital platforms. Changes to the document texts could be done collaboratively. Cloud-based services such as Google Docs, allow collaborative editing of documents. This kind of activity might speed up the feedback process, as the regulator could quite easily indicate problems on the documents, and the power company workers could respond promptly by editing the documents. Additionally, internet forum-

inspired commenting could be applied in discussing the design project and the documents.

Overall, the design documents could resemble the existing Wikipedia pages, with some predefined headers. Wikipedia pages may entail sound and videos in addition to pictures and text, they are written collaboratively, and discussing the pages is possible as well. It is noteworthy that, if a digital platform of this kind is designed, data security would have to be ensured. Additionally, comprehensive ethnographic studies on the current design, document drafting and evaluation processes would be needed prior to designing the new digital platform: the system would have to feasible in view of the existing needs and working practices.

4.4.3 Improved tools for requirements management

One issue that the interviewees mentioned was that the existing tools for requirement management were not the best possible. The appropriate requirements were sought for in various ways, including face-to-face discussions with the colleagues and by reviewing existing, perhaps similar, design documents from other projects. It seems that the power companies lacked good quality research tools with appropriate keyword-system and efficient search engines for requirement management. Most preferably, such tools would include high level of usability in helping the workers find what they are searching for. Good tools in this task would translate into more efficient working, thus speeding up the process. According to our knowledge, the power companies are acquiring or have recently acquired new requirement management software.

4.4.4 Concluding suggestions: An expanded view of good safety culture in NPP design

In view of the design cases, the following characteristics in design seem to be well actualized in Finland:

1. Comprehensive and up-to-date set of appropriate requirements
2. Meticulous requirement management
3. Clear documents for transparency
4. Formal design authority of the operating organization
5. Thorough regulatory oversight

Actualizing the issues above (1–5) could be seen as the core of the current Finnish safety culture in NPP design: things are done by the international standards and with prudent oversight. It is assumed that this precise of adherence to rules and regulation is also the way in which a good safety culture in NPP design is understood in Finland. However, we argue that they are not sufficient. The following also seem to be necessary when good safety culture in design is considered:

The culture of design authority within the operating organizations, including:

a. design authority as a responsibility and as a genuine value permeates the operating organizations, that is, the real-life safety and functioning of the end-products and modifications are considered to be the primary aims, which clearly surpass secondary aims involved in design activity (i.e., requirement management and achieving regulator acceptance),
b. undivided design authority, i.e., the focus of design activity is not in gaining regulator acceptance, and regulator acceptance is not considered as the aim of the design, but always clearly secondary to safety as a design goal in itself.

System thinking in design:

c. leadership assumes that its main task is in overseeing comprehensively the main elements influencing the overall safety and functioning of the end-product or modification, other responsibilities – e.g., project and requirement management – remain as auxiliary tasks serving the main task,
d. resources for iteration, that is, for rethinking the overall design solutions and consideration of various design alternatives.

Efficient practices:

e. state of the art library and search tools for requirement management,
f. prompt feedback from the regulator.

We are *not* claiming that these elements are not sufficiently actualized in Finland. Nonetheless, the issues listed above are inspired by the challenges that we

identified from the descriptions expressed by the interviewees in discussing the design projects. In some design cases, they could be more prevalent and in better condition than in others, and therefore they should be noted by the energy companies. It is noteworthy that these notions are in line with the DISC model of safety culture (Reiman & Oedewald 2009, Oedewald et al. 2011), which has been explained in Chapter 1 of this document: responsibility for the entire system, seeing safety as complex phenomena, mindfulness, and management of good work conditions co-align with the notions of design authority as a value and responsibility, system thinking and efficient practices, mentioned here.

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5. Safety culture challenges in different lifecycle phases of nuclear power plants

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Abstract

Different lifecycle stages bring out distinct Human-Technology-Organization challenges to the stakeholders, which have not been extensively discussed in the nuclear industry research. Organizational processes and practices, beliefs, assumptions and understanding about safety developed in one phase might not be fully relevant for the next phase. This chapter aims at illustrating the generic cultural challenges that arise in the design, construction, commissioning, operation and decommissioning of a nuclear power plant project, and suggests strategies for safety culture development. It is emphasized that safety management approaches should take into account the different cultural features of the lifecycle phases and how they affect safety. Certain aspects deserve special attention, such as the extent of tangibility of the nuclear safety concept, the magnitude of technical and organizational complexity of a nuclear project, the extent of outsourcing and external personnel involvement, organizing of the project activities, or the priority given to nuclear-specific knowledge and understanding. The chapter concludes by suggesting that the means to support a good safety culture might need to be adapted according to the specific cultural challenges in each phase.

5.1 Introduction

Although after the Fukushima accident in 2011 the expectations and regulations regarding the human and organizational performance and safety culture have been revised and strengthened, the ongoing large-scale new nuclear build projects bring out unique Human-Technology-Organization challenges, which have not been widely discussed. A new nuclear power plant lifecycle consists of five general phases: pre-project, project decision-making, construction, operation and decommissioning (IAEA, 2007). Apparently, activities in one phase influence the activities and challenges in the next phases; for example, management decisions taken during the conceptual design phase could have a significant impact on maintenance, waste handling and even final decommissioning costs (IAEA, 2002). It is reasonable to assume that understanding human and organizational issues in the pre-operational phases, such as design, construction and commissioning, creates technical and organizational preconditions for safety in operation and decommissioning phases. Also, the transition from one phase to another represents a change in the roles and responsibilities and the overall context and power balance in the project, which has potential effects on safety. For instance, the short-time involvement of multiple subcontractors from different nationalities during the construction phase requires extensive safety communication, the allocation of resources for management of a large number of workforce, and specific services such as foreign language translation and interpretation. Therefore, in this report we take the nuclear power lifecycle as a unit of analysis and focus on identification and handling of general safety culture challenges that arise in design, construction, commissioning, operation and decommissioning phases.

Nuclear power plants in western countries have been in operation for a long time. They have developed practices, procedures, management systems, and tools to assess, monitor and improve safety culture. However, traditional safety management practices and safety culture models have been developed from a single organization perspective, usually an operating unit. In the design, construction, commissioning or decommissioning phases, as well as in large modernizations projects, many activities are carried out by a network of actors, such as subcontractor companies, which may set particular challenges for establishing a good safety culture. For example, the multitude and diversity of the network actors might bring fresh perspectives but also various tensions, power and accountability is-

sues, since actors might not share the overall goals of the network, and the responsibility for safety might be unclear.

Recent experiences indicate that achieving a good safety culture in the pre-operational phases, such as design, construction and commissioning, might be challenging. In various safety-critical domains, including railway, offshore oil drilling, chemical, petrochemical, aviation and nuclear, design has been found to be a contributing factor to events by accident investigations. In the nuclear industry in particular, it was estimated that 46 percent of accidents can be attributed at least partially to design errors, e.g. design features, which "makes it unable to perform according to its specification" (Taylor, 2007: 62). Some notable examples of design-related accidents are the Challenger space shuttle explosion in 1986, the Piper Alpha oil rig explosion in 1988, the capsize of the MS Estonia ferry in 1994, or the Wenzhou high speed train collision in 2011 (Macchi et al., 2014). Design issues emerged in the analysis of the Fukushima nuclear disaster in 2011 as well, for instance, the height of the tsunami protection wall and the location of the emergency diesel generators (The National Diet of Japan, 2012). Difficulties in ensuring safe design have also been experienced in the Nordic nuclear power plants. In Sweden for example, a design flaw on four valves had caused an abrupt stop of steam to the condenser leading to a short and relatively high pressure spike in the Oskarshamn 3 reactor (www.archive-se.com, 2010). In Finland, in a newly built waste processing plant, low-activity rinsing water had entered the auxiliary building ventilation system during a test run (Kainulainen, 2011). Some recent experiences of megaprojects revealed a range of challenges related to organization and implementation of the commissioning phase too. As an illustration, the issues experienced during the London Heathrow Terminal 5 and Boeing Dreamliner 787 commissioning projects were related to the tricky processes of managing complex megaprojects with a globalized supply chain and keeping a holistic understanding of the changing context while training the personnel and testing innovative technology (e.g. Krigsman, 2008; House of Commons, 2008; Tang and Zimmerman, 2009; Kotha and Srikanth, 2013).

In safety critical organizations in general, balancing between partially conflicting demands is one of the main challenges that needs to be handled continuously, and is thus a core issue in defining their culture (Oedewald and Reiman, 2003; Grote 2004, 2009; Hollnagel, 2009). The ultimate goal in the nuclear industry is to produce electricity safely and efficiently. Still, a general issue in safety culture

development is the need to reach a balance (trade-off) between ensuring economic profit and maintaining operational safety (Perrow, 1984; Kirwan et al. 2002; Woods and Branlat, 2011; Reiman and Rollenhagen, 2012). Furthermore, in terms of trade-offs, there are specific challenges caused by the transition from one lifecycle phase to another, as the underlying goals and requirements that steer the choice for approaches to reach a balance differ between the phases. Each of the lifecycle phases has a specific core task, associated hazards, ways of organizing and competence requirements. The nature of the activities and objectives of each of the lifecycle phases is associated with certain cultural characteristics and challenges, related to structures and practices, values, attitudes, knowledge and understanding. These core challenges "absorb" extended or higher complexity due to the specifics and dynamics of the external context: for example, since the activities are performed in large project networks, different human and organisational factors issues interrelate with national and professional cultures.

5.2 Summary of generic safety culture challenges in different lifecycle phases of nuclear power plants

Tables 1–5 summarize the main cultural challenges that arise in the different lifecycle phases, and provide implications for safety culture development, i.e. how the challenges could be taken into account in certain safety management approaches (for a more detailed report on the safety culture challenges see Gotcheva and Oedewald 2015).

Table 1. Design phase: Safety culture challenges and implications for development.

Safety culture challenges in design	Implications for safety culture development
Understanding and managing safety requirements It is difficult to standardize the conceptual stage of design with detailed instructions and requirements. There is a large number of requirements and their interpretations among designers might differ (Menon and Kelly, 2010). Design involves tedious paper work and formal communication with the regulator: this bureaucratic process might hinder designers' grasp of the big picture.	Support designers in understanding the large amount of requirements and interpreting them in a coherent manner; Licensees and the regulator should be actively involved early in the design process when the work is outsourced. Support designers in concentrating on developing a safe and functional final artefact; beware of possible shift in the focus to mechanical paper work.
Safety impact of involving diverse and multiple actors Design is a collective process and coordinated effort between multiple stakeholders, which might have different safety philosophies and conceptions about the scope of their responsibility. Distributing roles and responsibilities between different stakeholders in design is challenging, especially in the early stages of a project when relationships and organisational structures may not be well-established (Menon and Kelly, 2010; Macchi et al., 2013).	Improve the coordination and shared understanding between different stakeholders in the design process through adequate communication, especially if they are in different geographical locations; Improve the visibility of the design network in the project, especially when design organizations are geographically dispersed.

Managing tensions and developing a systemic view Both technical and non-technical understanding is required (e.g. materials behaviour, end user's needs and future operational context). Both short-term and long-term perspectives on the functionality and safety of the final outcome. Nuclear safety is intangible in design phase, which may contribute to a limited sense of responsibility for the end-product and overall plant safety. A slow and lengthy design process challenges the systemic view on safety, knowledge transfer and continuity.	Support designers in understanding the operators' needs and operational context of the final artefact. Preserve continuity and support knowledge sharing in major design modernizations and new build projects. Make safety a more tangible concept for designers to improve their sense of responsibility for the final artefact.

Table 2. Construction phase: Safety culture challenges and implications for development.

Safety culture challenges in construction	Implications for safety culture development
Ensuring safety understanding in a large and dynamic complex network with temporary employees A large number of actors is involved in various activities, when nuclear hazards are not yet present. It is challenging to understand in practice what is safe and what is unsafe when the knowledge of nuclear specific hazards is insufficient. Preoccupation with occupational safety rather than system safety during construction. In a multilingual project environment, language barriers could complicate understanding of the need to follow procedures and nuclear specific requirements, which could compromise safety. Focus on efficiency: economic constraints might have effects on safety. The challenge of dealing with a dynamic network and workforce: due to the constant flux of personnel, training results are relatively short-lived and insufficiently shared. The construction industry utilizes hierarchical management model, which emphasises bilateral interactions and information flow.	Subcontractors should take an active role and engage in direct and frequent interactions with the vendor in order to improve their understanding of functionality and safety significance of their work, because this influences their attitudes to safety and perception of deviations. For effective safety communication, tools for overcoming language barriers should be developed and utilized. The impact of national cultural differences on safety should be taken into account. Sufficient attention should be paid to developing shared cultural characteristics and practices among the network actors from the beginning of the construction phase. The licensee should develop awareness of the complexity and size of the network of international subcontractors to improve the manageability.

Table 3. Commissioning phase: Safety culture challenges and implications for development.

Safety culture challenges in commissioning	Implications for safety culture development
Organizing nuclear specific activities, clarifying roles and responsibilities During commissioning, possible deficiencies from the previous phases, and especially before the nuclear fuel is loaded, should be fixed. The knowledge base is different from the construction phase, as the work requires experience and deep understanding of the nuclear specific quality requirements. Due to a shortage of experienced staff, newcomers should be trained to contribute to the activities.	To notice and handle the deficiencies and to test the components, systems and structures the vendor, responsible for commissioning, should organize the activities in a manageable way in close cooperation with the licensee, who is responsible for safety. Measures should be taken to clarify and transfer the roles and responsibilities between different stages in commissioning with a special focus on nuclear fuel activities;
Understanding and managing higher safety risks under time pressure and dealing with the unexpected Higher safety risks in the commissioning compared to the construction phase: the hazards of nuclear fuel. The need for a systemic view intensifies due to the complex organizational and technical interfaces. Time pressure: accumulated delays from previous phases might bring pressure and emphasis on pre-defined test programmes issues, with less focus on vague problems. Possible lack of conservative decision-making, i.e. prompt and prudent consideration of the safety impacts of solutions.	The higher safety risks should be clearly communicated and made tangible to all the parties involved; All actors in the project network should be prepared for dealing with the unexpected and with possible emergencies with regard to the nuclear fuel loading stage. Support decision-making on systems safety.

Table 4. Operational phase: Safety culture challenges and implications for development.

Core safety culture challenges in operation	Implications for safety culture development
Maintaining and developing a safety culture: mindset, understanding and organizational structures and systems Maintaining mindfulness is a specific challenge in operational phase, especially if there are no major incidents or changes in the organization during the long lifetime, there is a natural tendency to become complacent and to underestimate the management for the unexpected. In addition, delays and deficiencies from the previous lifecycle phases might actualize during operation & maintenance. Most activities are carried out by in-house personnel and performed by experienced operators; however, outages and modernization projects are often carried out by external companies.	Safety culture should not be taken for granted in this phase: continuous improvement and learning from operating experience is critical for safe operation. Maintain capability to deal with aging phenomena, also related to knowledge continuity as experienced staff retire; Maintenance of staff competence and continuity, especially due to the demographic dynamics (generation change) during the lifespan of the operation phase; Ensuring proper coordination and communication during normal activities, and also when subcontractors are involved for a short period of time.

Table 5. Decommissioning phase: Safety culture challenges and implications for development.

Core safety culture challenges in decommissioning	Implications for safety culture development
Management of change and human resources Staff might experience feelings of uncertainty and insecurity as they might not see any future in the organization. Motivation of the personnel is affected and they experience psychological stress. Preservation of staff competence and understanding of safety and the changing faces of risks: the physical layout of the plant, radiation hazards and contamination risks are changing.	Clear management communication is important on the current arrangements and future prospects so as to reduce insecurity. Preservation and management of the plant "memory" and lessons learned. Human resources planning and management before and after shutting down. Safety effects of deteriorated motivation, psychological stress and feelings of uncertainty should be understood. Measures should be taken for nuclear safety knowledge to adapt to these changes.

5.3 Discussion and conclusions

The lifecycle phases of a nuclear power plant have unique characteristics, relevant to the nature of the activities. Still, there are common features, which span the entire lifetime of a nuclear plant, such as expectations of conservative decision-making and managing conflicting goals, e.g. prioritizing safety under a pressing time schedule and tight economic constraints. The reasons for an organization's tendency to prioritize other-than-safety goals may vary in different phases.

Therefore, the means to support a good safety culture need to be adapted according to the specific cultural challenges in each phase.

Safety culture during the design phase could be promoted by creating awareness of its practical meaning and importance from the very beginning. Active involvement of the licensee and the regulator early in the design process is critical in order to eliminate or minimize the risk for subsequent adaptations or costly changes later in the design phase or in the subsequent phases. However, if legal constraints prevent such an active involvement, other means should be developed to communicate and monitor the development of the design artefact. Designers should be supported in understanding the large number and diversity of regulatory requirements. Organizational infrastructure should be in place to support the coordination and shared understanding between different stakeholders in the design process. The licensee should support designers in making sense of the end user's needs and the operational context of the final artefact. This could be beneficial in making safety a more tangible concept for designers, and thus improving their sense of responsibility for the final artefact and overall plant safety.

During the construction phase, the safety culture development approaches should take into account the challenge of prioritizing quality and safety in a context of hundreds or even thousands of international temporary workers, who have little understanding of the nuclear-specific hazards. The long subcontractor supply chains are not a danger to safety as such, but the pressure for efficiency and the difficulties of communicating safety relevant information throughout the supply chain is a danger to safety. It might be difficult for workers to follow the quality requirements when their role for nuclear safety is not fully comprehended. In this phase, language issues should be tackled actively since shared cultural understanding is constructed through language (Searle, 1997), which in turn directs daily working practices (Lounsbury and Crumley, 2007). Safety culture initiatives should be designed in a way that strengthens the effects of training sessions, despite the tendency for high personnel turnover in this phase.

A good safety culture during the commissioning phase could be supported by paying attention to the fact that the end of the project is approaching, which brings the challenges of prioritizing safety under conditions of time pressure. The critical role of safety culture should be clearly communicated and made tangible to all the parties involved. "Tunnel vision" could hinder the ability for conservative decision-making in this phase: the predominant focus is on pre-defined issues with certain

acceptance criteria rather than vague ones. The higher safety risks related to the nuclear fuel loading stage bring pressure for dealing with the unexpected and even with potential emergencies, just as in operational plants. The increased social and technical complexity in this phase requires well-organized activities and clear roles and responsibilities. One of the organisational complexities stems from the need of the future operators to be actively involved in the commissioning while there are potentially suppliers and subcontractors responsible for the testing and final modifications of the plant. This kind of transition in the responsibilities necessitates an open climate and continual checking that the accountabilities between the parties are similarly understood.

A good safety culture during the operational phase could be sustained by maintaining mindfulness and avoiding the natural propensity for complacency, especially if there have been no major incidents during the long lifetime of the plant. Management for the unexpected should not be underestimated either. During the operational phase, activities are mostly carried out by in-house personnel and performed by experienced operators. However, a thorough understanding of the nuclear hazards and safety consequences of one's work should not be taken for granted in this phase. The licensee needs to engage in a continuous improvement of safety culture by regular internal and independent evaluation by different means (e.g. surveys and questionnaires, interviews, field observations, document analysis, workshops).

Safety culture during the decommissioning phase could be supported by understanding the specific challenges related to human resources management and the changing context in the plant. From a human resources management perspective, safety should be prioritized in a situation where staff is reduced, strong feelings of uncertainty and insecurity are shared, and motivation is affected. The dismantling stage poses challenges for safety insofar as the physical layout of the plant is changing, along with the radiation hazards and contamination risks. The regulator should adapt their organizational oversight practices accordingly.

Identification of these safety culture challenges supports the organizational mindfulness to new risks, associated with social, organizational and cultural phenomena. Although the challenges differ, the normative ideal model of a good safety culture could be the same in all lifecycle phases. Still, since the work processes and people's knowledge base differ, the means to support a good safety culture might vary as well. Understanding the nuclear industry hazards and safety conse-

quences of the work is a critical dimension in safety culture (Oedewald et al., 2011). Still, the prevailing safety culture discussions do not usually pay much attention to how safety is understood. This might be related to the predominantly technical and mechanistic view of how safety is created and ensured in the nuclear industry. In addition, the need for systemic safety perspective should be incorporated into the safety culture models in order to avoid a fragmented approach to the development of safety.

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6. Safety culture in a network of companies

Pia Oedewald and Nadezhda Gotcheva

Abstract

Many activities in safety critical industries are currently carried out by subcontractor networks. This chapter analyses practical challenges in applying the concept of safety culture in a complex dynamic network of subcontractors. First challenge is the unit of analysis issue; what is the organisation that we aim to understand and monitor when talking about networked activities? Further challenges are the temporary nature of the network and the discontinuation and insecurity that the project environment brings, national culture differences and heterogeneous nuclear knowledge of the actors. The chapter proposes that safety culture assessment and development activities should take the entire network activity as the unit of analysis, instead of focusing solely on the culture of the individual subcontractor companies' or their workers' safety behaviour. The interactions between parties, and therefore the network management strategies and practices, are important factors for the network safety culture. Ideas from complex adaptive systems studies can be beneficial for developing safety culture in networks. A good safety culture in complex systems should find *a balance* between a prescriptive strategy, where compliance and control is endorsed, and more flexible strategy where knowledge and capabilities are developed to allow actors more autonomy to take decisions in a safe manner. How this latter strategy could be practically endorsed in the nuclear industry subcontractor networks will require further research.

6.1 Introduction

In the nuclear industry, the operating companies are expected to establish a systematic way of managing the safety of their activities. However, in practice many activities are not carried out by the operating company but by a network of actors i.e. subcontractor companies. In the nuclear power industry subcontractor networks are used, for example, in maintenance activities, modernizations projects or in design and construction of new nuclear plants. By *networks* we mean a dynamic set of actors (organizations and people) who collaborate to achieve shared goals and to jointly generate value (Camarinha-Matos et al. 2009).

Typically, the network in major nuclear plant modernisations or new build projects is multinational and can involve several, even thousands of parties, some of whom might have little experience in the national regulatory requirements or nuclear industry practices in general. Since many of the project participants are also working in other industries and simultaneously involved in other projects, it cannot be expected that they necessary share the values, knowledge and working methods that support the overall safety goal of the project. There have been challenges with both schedule and quality in many recent major projects in the nuclear industry (e.g. STUK 2011, Ruuska et al. 2011). Suboptimal project management and insufficient nuclear safety culture of the network formed by the supplier and its subcontractors has been suspected as being contributing factors to the problems (The Royal Academy of Engineering, 2011). In the nuclear industry, projects are subject to detailed safety rules and regulations, which represent an additional dimension to the effective management of these projects.

The activities performed by subcontractor networks may involve both occupational risks and overall system safety effects. Scientific research on subcontractors and safety has largely focused on occupational safety (see e.g. Mayhew et al. 1997, Jaselskis et al. 2008, with few exceptions (e.g. Quinlan et al. 2013, Nesheim & Gressgård 2014, Dahl 2013). However, the critical role of contractors have been analysed in major accident investigations, e.g. Challenger space shuttle explosion (Vaughan 1996) and Deepwater Horizon oil rig accident (Bea 2011). Safety research has so far paid little attention to management of projects because project delays and quality issues have been perceived mainly as economic problems and not safety concerns as such. However, if a systemic view on safety is applied, safety cannot be separated from other performance issues. Challenges in sched-

ule and quality may reflect issues in knowledge, competence, information flow, roles and responsibilities and attitudes among the project participants. Furthermore, delays may cause pressures to cut corners, create tensions between partners, deteriorate open communication climate, accelerate turnover of key persons, and thus, increase the risk of latent technical problems or non-conservative decision making.

Some international nuclear institutions have recently paid attention to safety culture in networks and project management in the nuclear industry (e.g., INPO 2010, The Royal Academy of Engineering 2011, IAEA 2012). Recent studies on the governance of Olkiluoto 3 nuclear power plant project indicated that there is a need to better understand the links between management and coordination of the activities in a subcontractor network and the overall system safety (Ruuska et al. 2011, Hellström et al. 2013). Another safety-critical complex project that involved a multicultural network of subcontractors and ended up with quality issues was the Boeing's Dreamliner 787 case. Boeing used extensive outsourcing – about 70 per cent of the work was outsourced to tier-1 global suppliers, some of which outsourced to additional tiers (Gates 2013, Tang and Zimmerman 2009). However, reportedly managing the global supply chain proved to be challenging since there were safety issues related to the battery systems, and the Dreamliner 787 project was over budget and schedule (Kotha and Srikanth 2013). Albrechtsen and Hovden (2014) analysed major accident risks in non-nuclear construction projects and concluded that the problems related to quality assurance, coordination and communication in early phases cascaded and manifested in the construction phase of the project. The authors discussed that the emerging accident risks were largely attributed to deficiencies from other organisational units: different units were blaming each other, top management and the builder.

For practitioners the challenge is that many concepts and models used for improving system safety embed an implicit assumption that the activity is carried out by a single organization, or that the organization which is carrying out the activity corresponds to one company or legal entity. This is reflected in safety management system literature, where management system is seen as a company specific system. A single organization focus is relevant also for the concept of safety culture. The frequently appearing notions in safety culture literature, for example, "top management commitment", "open communication", "organizational learning" and "levels of organization" (Cooper 2000, Guldenmund 2000, Sorensen 2002) imply

that safety culture models have been developed to grasp a culture of a coherent unit. Safety culture assessment and development models seldom pay attention to power issues, conflicting group interests, or inequality of the actors (Silbey 2009, Antonsen 2009). Because current safety culture and safety management practices are largely focused on single organisations it is far from clear how to apply them in the dynamically changing subcontractor networks.

The objective of this chapter is to describe and analyse practical challenges in applying the concept of safety culture in a complex, dynamic network of subcontractors. This is of relevance for example to nuclear new build projects, which are vast and complex undertakings in terms of number of companies, disciplines and nationalities involved.

6.2 Practitioner's challenges when developing safety culture in a network of actors

6.2.1 What is the unit of analysis?

The first practical question when thinking about safety culture and networked activity is: Whose culture should be analysed/monitored/improved? In the nuclear industry, the responsibility for nuclear safety usually lies within the licensee, and the regulator's requirements and oversight activities primarily focus on the licensee organization. In Finland the Government decree on Safety of Nuclear Power Plants (issued 2008), section 28 states: "*When designing, constructing, operating and decommissioning a nuclear power plant, a good safety culture shall be maintained. The decisions and activities of the management of all organisations participating in the above mentioned activities shall reflect its commitment to safety-promoting operating methods and solutions".* This statement indicates that all organisations, not only the licensee, are expected to engage in processes and behaviours that are believed to exemplify good safety culture.

In practice it is impossible to approach safety culture in a complex networked project by assessing, monitoring or developing culture of each of the companies case by case. It may also be insufficient since the entire network shapes the performance of the individual actors; new cultural features will emerge when the actors work together. Therefore Oedewald et al. (2011) proposed a shift towards network thinking to advance practices and research on safety culture in large

projects. The network as a whole and its dynamic should be understood. This means that the network can be understood as an organisation and its culture should be the focus. Also IAEA (2012) point towards that direction when they emphasise that “nuclear power plant projects involve a dynamic network of interactions and relationships that can benefit from the application of systems thinking.”

The question whether the temporary network of subcontractors establishes a shared culture is a relevant one. However, we state that the actors are engaged in shared activities, which require interaction and compliance with shared rules and expectations. Therefore, it is evident that to some degree shared conceptions, norms and routines need to be established by the actors to support coordination, reduce uncertainty and avoid chaos (Weick 1987, Grote & Künzler 2000). Thus, the complexity of the network necessitates formation of some shared cultural features.

Since many of the members of the organisation develop multiple cultural identifications, e.g. those related to their professional group, company and ethnic group, the culture which emerges in complex networks is not necessarily uniform and strong. However, it could still be characterized as a good safety culture, as far as the competing interests, diverse competencies and various viewpoints are opportunities to continually reflect on the process of creating safety (cf. Silbey 2009). Structure and quality of the processes where the various solutions are developed and decisions taken are of key importance when aiming at understanding and developing safety culture of the network.

For the practitioners at the licensee organizations or regulatory agencies overcoming the organizational boundaries and gaining access to the subcontractor companies to inquire and demand something related to their values, beliefs, assumptions may be a challenge. The contracting phase is an important opportunity to communicate the expectations and to audit the management approach of the potential partners (Kjellen 2012). However, the practices to evaluate the safety culture during these processes have only begun to develop. Furthermore, the knowledge gained during the contracting process may not be sufficiently deep and accurate for gaining understanding of cultural aspects if the parties have no prior collaboration experience. Consequently, the majority of the practical activities related to safety culture in subcontracted activities seem to focus on subcontractor worker safety performance rather than to the culture of the subcontractor companies.

6.2.2 The challenge of temporary network with temporary employees

Project networks have temporary nature, which sets specific challenges for safety culture due to the short time span of activities and internal dynamics of the system. The nature of a project network encompasses features of insecurity due to the short-term contracts, possible competition between contractors and contract-based trust. Although safety culture literature emphasizes the importance of open communication, questioning attitude and reporting of concerns, it may be more challenging to achieve these in temporary project organization than in an organization where stability is higher and relationships last longer. If one admits safety or quality deviations there may be a (experienced) threat of being replaced or excluded from future work opportunities.

Creating a common understanding and facilitating shared cultural norms through personnel training may also be challenging. Training results are short-lived as there is a constant flux; companies and workers join the network and others leave. The temporary nature of the project may also reduce motivation of different parties to invest in joint development of activities and culture. In such a fast-changing networked context, the shared time with various partners is short and fragmented which sets constraints also for accumulation of lessons learned through informal interactions.

The role of managers and leaders is emphasized in safety culture literature as one of the main factors contributing to good or poor safety culture. One of the IAEA's (1991) characteristic of a good safety culture states that "leadership for safety is clear". In reality in complex networks leadership is distributed and most likely incoherent and unclear to some degree. Networks are characterized by multitude of managers and leaders, with varying perspectives and emphasis. Therefore, it may be difficult to establish a clear vision of safety culture and the necessary practical actions for its development.

Although parts of the organization change constantly, the cultural characteristics begin to be more distinct as they become embedded in the concrete work processes and practices of the network. Therefore, the practical development of safety culture in networks is not only about behaviours of individuals at the sharp-end, even though that might appear as the most tempting scope for the safety

practitioners since the complex and adaptive structures and processes may seem impossible to grasp. Safety culture development is largely framed by the overall management approach, including the formal allocation of responsibilities and power between actors, and therefore, safety culture experts should be involved in those processes.

6.2.3 National culture differences

Difficulties in achieving a shared view on sufficiently good quality, acceptability of a technical solution, open communication or distribution of responsibilities have sometimes been attributed to national culture differences among the network actors. However, although the assumption that national culture clashes may become an obstacle for safe performance sounds commonsensical, it seems to be difficult to make sense as to how to approach and take into account the national cultural differences in safety culture.

One of the profound questions is can there be a global model of a good safety culture (e.g. the IAEA model or the DISC model) or are the current models biased by Western culture. For example, Moray (2000) claims that the results of ergonomics research are not universally applicable. Is that the case with the theoretical conceptualisations of safety culture as well? Certain safety culture characteristics, for instance willingness for reporting safety concerns, may be more difficult to achieve in e.g. East Asian countries (cf. Ruy & Meshkati 2014). Does that mean that in those countries it is unrealistic to expect similar safety culture propensities as in e.g. Nordic countries? We have taken a stance that normative models of good safety culture such as the IAEA model or the DISC model should be understood as universal ideal models, i.e. they should be globally applicable. However, how the characteristics of good safety culture manifest in practice and how to promote those characteristics will likely differ across different nations. For the practitioners this means that the same safety measures will not likely be equally effective across different groups.

Research on national culture differences and safety performance/culture has relied mainly on Hofstede's (1991) work with the aim to identify if certain national cultural value dimensions (individualism-collectivism, uncertainty avoidance, power distance, masculinity-femininity) explain workers' risk-taking behaviour (Mearns & Yule 2009), behaviours and attitudes toward safety (Mohamed et al. 2009, Mer-

rit and Helmreich 1996) or safety orientation (Håvold 2007). Although some of the Hofstede's cultural value dimensions have been associated with safety behaviours or attitudes, e.g. high power distance may correlate with adhering to standard operating procedures and extremely high collectivism may create groupthink issues, the organisational culture characteristic may be more powerful determinants of behaviour than the national culture dimensions (Mearns and Yule 2009). Deetz (2014) also claims that national culture has greater impact in some societies than in others. He refers to Taras et al. (2011) who suggest that in "culturally tight" societies, such as Japan or Pakistan, the relationship between national culture and workplace outcomes is stronger than in "culturally loose" societies, such as U.S.

The Fukushima Daiichi accident pointed out that national culture may also play a role in the formation of societal structures and systems which contribute to safety of nuclear power production, such as the regulatory regime and communication processes between different actors (The National Diet of Japan 2012, Kinsella 2013). Although the international collaboration within the industry may create shared cultural features in the nuclear domain (Ylönen 2015), the national differences embedded e.g. in the regulations may surface as culture clashes in the multinational projects (see e.g. STUK 2011).

In subcontractor networks the activities and actors are heterogeneous, and their cultures cannot be homogenized by any safety culture initiative – although shared safety culture features can be promoted. The possible effects of national culture on work activities, management styles and decision making structures will likely be fairly persistent in temporary subcontractor networks. For the practitioners knowledge on the national value dimensions or management styles in different societies may be beneficial, since it allows anticipation of misunderstandings or identification of areas requiring mutual agreements on working practices. It may also help in developing an effective strategy for safety culture training sessions and other interventions. However, being aware of one's own national or domain specific culture is the first crucial step in successful collaboration in multicultural activities.

6.2.4 The challenge of domain specific knowledge and understanding

Subcontractor companies might have little prior experience on nuclear power industry and the national requirements. This is especially true in countries where there is no large nuclear fleet and thus no established nuclear specific business network. Expectations on nuclear specific working practices may not easily be understood in the subcontractor companies even when communicated via project specifications or formal contracts. Consequently, the subcontractors may fail to follow procedures or to detect and communicate minor deficiencies. This may actualise if an unexpected occurrence necessitates a local decision by the subcontractor supervisor. Following practices which are common for the conventional industrial domain, rather than what are expected in the nuclear domain, have been witnessed in subcontractors' activities (cf. STUK 2006). These challenges are not necessarily attitudinal issues as such, but rather, lack of basic information which is needed in order to create adequate attentiveness. To internalise and commit to the technical quality requirements and behavioural expectations, the actors need to possess basic knowledge on nuclear power production processes, basic accident scenarios and safety principles. Furthermore, they need information on the functionalities of the systems or components they were working on, and their role in nuclear safety: how it is supposed to work during normal operations or if it has specific requirements in severe accident condition (Oedewald et al. 2011, IAEA 2012).

A challenge is that the hazards may be difficult to understand. Complex systems pose countless opportunities for things to go wrong. Some of the mechanisms involved are easy to perceive, some involve rare phenomena that only few experts master. When subcontractors are increasingly used, it is important for the overall safety that they know and understand in practice what is safe and what is unsafe, and what are the safety consequences of their decisions and actions. Although accident investigations have emphasized that insufficient understanding of specific hazards is one of the underlying causes to accidents, few safety culture models or development methods include knowledge or understanding of risks in the agenda. Safety culture practitioners need to find strategies to convey this knowledge to the subcontractors in a manageable and understandable way. Safety culture development should not focus solely on endorsing motivation for safety

compliance, it should also provide sufficient knowledge for doing that (cf. Dahl 2013).

6.3 Toward a model of safety culture in networks

Nuclear industry is often associated with a tradition of mechanistic management models, technical focus, strict quality requirements and regulatory oversight. A well-functioning organisation in nuclear domain emphasises clear requirements, control and supervision. The management models utilized in the nuclear industry can be characterised as a "culture of control" (Perin 2004) and top-down hierarchy: the regulators set the overall requirements, which the licensee needs to comply with. The licensee requires the vendor to take the requirements into account, who in turn translates these into applicable requirements for the contractors and subcontractors. Although the aim is, presumably, to establish clear structures of responsibility and decompose the tasks into manageable parts, the model does not correspond with the reality of the features of the complex system it aims to manage. The need for horizontal interactions between the subcontractor companies and their workers – to locally coordinate, solve problems and learn – seems to be underestimated. The hierarchical management model may also hamper the subcontractors' commitment to the network activities, since the information the downstream subcontractors gain may be narrow and delayed. They may lack information on the big picture and generic lessons learned and become passive in terms of delivering information concerning safety and progress of activities.

Gotcheva et al. (2012) have emphasised that more attention should be paid to the *interactions* between the network parties, in addition to the culture of each of the companies. The concept of *heedful interrelating* was originally defined as a team-level phenomenon, related to the deliberate efforts of all team members to interact and to reconsider the effects of their actions in terms of the goals and actions of others and to the broader context (Weick and Roberts 1993). Gotcheva et al. (2012) suggested that the term heedful interrelating could be applied to understand network interactions as well. If the network members are interrelating heedfully, it is unlikely they will narrowly follow protocols or rely on over-learned responses (Wears and Sutcliffe 2003). Instead, the network actors would develop a mindset that they are part of a network, and that they need to care about the others' work activities. This requires development of contracting practices and

well-functioning communication strategies in the network level. In that sense, the actors who interact heedfully communicate in order to facilitate the pooling of information, knowledge and experience in the network and facilitate the development of shared mindset, understanding and work systems and structures (Figure 1).

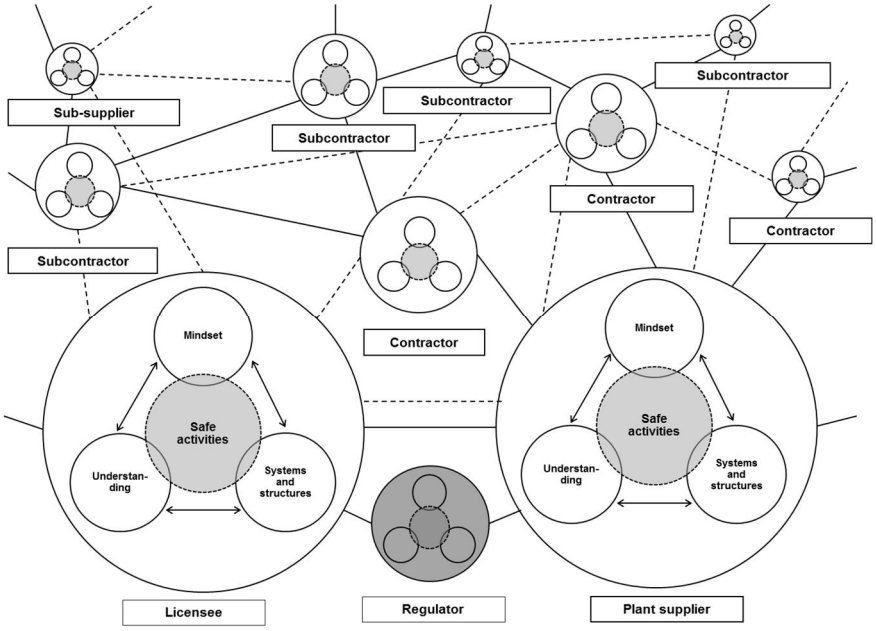

Figure 1. The structure, style and quality of the interactions within the network are an important factor for safety culture. It affects the degree to which the individual parties' cultural features will become aligned. The interaction process should not be seen only as top-down control. (Adopted from Gotcheva et al. 2012.)

The Figure 1 illustrates that the network is complex and the relationships are not merely hierarchical. It also points out that all parties have their own culture (which is characterised by mindset, understanding and systems and structures). Gotcheva et al. (2012) emphasised that the capability for the network for safety emerges from *both* individual actors' performance *and* the interactions between the parties. Therefore the safety culture practitioners who work with complex sub-

contractor networks should pay special attention to the climate, power, and communication between the parties.

Similarly the network management studies by Ruuska et al. (2009) and Choi et al. (2001) imply that to improve the success of complex projects the networks should be managed *both* as a single entity *and* as a collection of partially autonomous partners. Complex adaptive systems studies talk about *polycentric governance* (Woods & Branlat 2011). Polycentric control or governance means that each actor of a network has sufficient autonomy and power to make own decisions and take action within its specific domain of competence, while at the same time is partially responsible for achieving a shared goal. Applying polycentric governance would overcome two issues in safety culture development in networks. First, it does not see downstream subcontractors as passive actors but as active partners in developing a shared culture. Second, it perceives horizontal interactions between the other partners as important, in contrast to the bilateral information flow style in a hierarchy, as they allow the parties to share knowledge and to get to know each other, which facilities shared cultural features also in terms of safety.

A management strategy which allows more autonomy may seem impossible in the nuclear industry which relies on supervision and control as the means to ensure safety. Grote (2009, 2004), has tackled this issue in her work. She indicated that the difficulty in finding a safety management approach is in essence a problem of finding a way to handle uncertainty. Many organizations in safety critical domains tend to apply a strategy of "minimizing uncertainty" even when effective action would require "coping with uncertainties", which means more degrees of freedom and autonomy. Grote (2009) claims that in safety critical domains both (intuitively exclusive) strategies are needed at the same time. She suggests that *the ability of the organization to balance between these two strategies could be viewed as one characteristic of a good safety culture.* In other words the organisation should be able to create cultural norms concerning where strict and prescribed working practices need to be followed and enforced and where flexibility and local adjustment is allowed. However, Grote (2004) pointed out an important precondition for applying the coping with uncertainty strategy: the actors need to be well informed about the boundaries of safe actions. In a heterogeneous subcontractor network this precondition is not easy to fulfil: often many subcontractors have no experience in nuclear industry and know little on their work scope and its safety significance. Therefore, in order to cope with uncertainties and to increase

adaptability, the knowledge level of the actors in a network needs to be improved through selection, training or some specific and relevant involvement of the sub-contractors in the nuclear domain.

Also Reiman et al. (2015) came up with a conclusion that when dealing with complex and self-adaptive systems effective safety management is about balancing tensions. They summarised trade-offs that management of complex adaptive systems face but which can never be "resolved" (Figure 2). Each management strategy (in both ends of the continuum) carries different set of values.

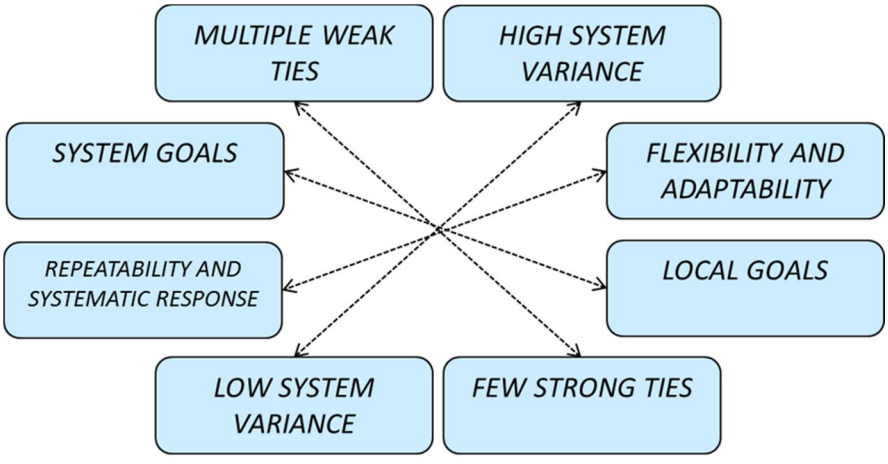

Figure 2. The model of trade-offs when managing complex adaptive safety critical systems. Adopted from Reiman et al. (2015)

The model by Reiman et al. (2015) suggests that trade-offs are made with respect to:

- responding to contingencies (cf. with Grote 2004): whether they aim at building flexibility and adaptability, or repeatable and systematic responses
- role of variance in the systems: whether variance is perceived as requisite variability, or whether it is controlled and reduced (cf. cultural diversity in network)
- role of strong and weak ties: whether organisation facilitate multiple but weak contacts which are less intense emotionally but which facilitate in-

formation flow, or if there are fewer, clear connections but which allow strong local subgroup cohesion (cf. hierarchical management vs. network governance).

- locus of goals: whether organisation emphasises shared goals such as safety and profitability, or local goals of achieving immediate interests such as getting the work done in a subunit and saving time.

The lesson learned from the complex systems studies to network safety culture is that the culture in a network should fall in between the two extremes, or rather it should be able to utilise both strategies flexibly. It means that the practical safety culture initiatives with the subcontractor companies and their workers need to go beyond talking about straightforward safety compliance.

6.4 Conclusions

Even though it may be challenging to apply the concept of safety culture in a large, heterogeneous, dynamic, and geographically disperse network of subcontractors it is precisely because of those conditions why it should be done. Social and cultural phenomena that arise from the interactions of the network of actors cannot be effectively controlled by formal management approaches. The power of culture is that some of the safety relevant conceptions, knowledge, values and norms become internalized among the members of the organization, which creates intrinsic motivation, serve as coordination mechanisms and reduce uncertainties (Weick 1987).

In network organizations it is challenging to assess and to develop safety culture due to the practical difficulties in crossing organizational boundaries when inquiring and aiming to change deeply ingrained cultural norms, values and assumptions. Achieving trust, vision and continuity in temporary project settings is also a challenge which the practitioners need to overcome. Therefore safety culture need to be considered already during the contracting phase and the management at the different levels and locations of the network need to be involved in the definition of the common expectations.

The tension relating to the scope of safety culture development: whether safety culture should aim at fostering compliance (minimising uncertainties) or to create capabilities to deal with various challenges (coping with uncertainties) needs more

nuanced discussion among practitioners. The solution provided by the scientists is that the organisation should find a balance between the two options, but the practitioners challenge is to determine how they can facilitate two seemingly contradictory strategies at the same time, without vitiating each of them.

A parallel challenge is the cultural heterogeneity of the actors. It underlines the question whether the culture in the network can be fragmented and loose, but still a good safety culture. Again, the answer seems to be paradoxical: the diversity should be allowed but shared cultural features facilitated. Shared vision of safety as an important aim and sufficient knowledge on the actual hazards and safety features of each activity needs to permeate throughout the network. Similarly, working practice expectations needs to be mutually understood but the specific behavioural manifestations of safe work and challenges in living up to the safety expectations will likely take different forms in the various groups. Therefore, finding a balance between executing systematic approaches vs. developing local solutions is also a challenge that the safety culture practitioner needs to consider in his/her own work.

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VTT Technology 222

Title	**Safety culture and organisational resilience in the nuclear industry throughout the different lifecycle phases**
Author(s)	Pia Oedewald, Nadezhda Gotcheva, Kaupo Viitanen & Mikael Wahlström
Abstract	The aim of this publication is to advance the safety culture knowledge and practice based on the experience gained in the Nordic nuclear sector. A further aim is to encourage the nuclear industry to reflect on its prevalent safety management approaches. The publication provides a view of safety culture which follows the premises of resilience engineering. A good safety culture can be seen as a potential for an organisation to succeed in varying conditions. The publication describes a method for assessing safety culture. Furthermore, the report summarizes commonly used safety culture development interventions and analyses human performance programmes as a means of improving safety culture. Since the operational phase has traditionally been the main focus of the nuclear industry, some of the practical challenges in the domain stem from the need for developing a sound safety culture also in the other lifecycle phases, such as the design and construction of new builds, or major modernisations in the operating plants. Such projects are often carried out by a network of subcontractors rather than by the licensee organisation. The report elaborates on the cultural tensions in nuclear power design activities. In order to improve the quality and management of safety in design activities, safety culture approaches should take better account of the networked nature of the work processes and the specifics of the local context, the need for requirements management and the importance of designers' responsibilities for safety. The practical and theoretical challenges for applying the concept of safety culture in a large, complex dynamic network of subcontractors were analysed, and the main aspects of developing safety culture in a network of organisations were initially conceptualized. It should be highlighted that the core tasks and typical challenges in lifecycle phases of a nuclear power plant differ, which may require different safety management and safety culture development approaches.
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Julkaisun sarja ja numero

VTT Technology 222

Nimeke	**Turvallisuuskulttuuri ja resilienssi ydinvoima-alalla laitosten elinkaaren eri vaiheissa**
Tekijä(t)	Pia Oedewald, Nadezhda Gotcheva, Kaupo Viitanen & Mikael Wahlström
Tiivistelmä	Tässä julkaisussa kiteytetään oppeja Pohjoismaissa ydinvoima-alalla toteutetuista turvallisuuskulttuuria koskevista tutkimuksista. Tavoitteena on edistää turvallisuuskulttuurin käytännöllistä kehittämistä sekä rohkaista ydinvoima-alaa tarkastelemaan vallitsevia turvallisuuden johtamisen lähestymistapojaan. Turvallisuuskulttuuria tarkastellaan "resilience engineering" -lähestymistavan periaatteita mukaillen. Hyvä turvallisuuskulttuuri voidaan nähdä organisaatiossa vallitsevana potentiaalina selvitä tehtävistä turvallisesti vaihtelevissa olosuhteissa. Julkaisussa esitellään menetelmä turvallisuuskulttuurin arvioimiseksi. Lisäksi analysoidaan tavanomaisten turvallisuuskulttuurin kehittämiskeinojen hyötyjä ja haasteita, esimerkiksi niin sanottujen Human Performance -ohjelmien roolia turvallisuuskulttuurin kehittämisessä. Yleensä turvallisuuskulttuuri-käsitettä on käytetty käyvien ydinvoimalaitosten organisaatioiden toimintaa kuvattaessa, mutta tässä julkaisussa tarkastellaan hyvän turvallisuuskulttuurin luomisen ja ylläpitämisen haasteita myös ydinvoiman tuotannon elinkaaren eri vaiheissa, kuten suunnittelutoiminnassa ja uusien laitosten rakentamisessa. Monissa ydinvoimalaitosten elinkaaren vaiheissa työt toteuttaa monimutkainen ja muuttuva alihankkijoiden verkosto. Tämä asettaa turvallisuuskulttuurin kehittämiselle erityisiä haasteita, joita tässä julkaisussa myös tarkastellaan.Tutkimustulosten perustella nähdään, että ydinvoimalaitosten elinkaaren eri vaiheissa organisaatioilla on erilaisia perustehtäviä ja niistä seuraa erilaisia turvallisuuskulttuurihaasteita, joista toimijoiden on hyvä olla tietoisia turvallisuuden johtamisen käytäntöjä suunnitellessaan.
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Safety culture and organisational resilience in the nuclear industry throughout the different lifecycle phases

This publication is aimed at practitioners in the nuclear power companies, regulatory bodies, technical support organisations and supplier companies. The aim is to support their understanding of the concept of safety culture, the practical tools to develop it and the challenges of achieving a good safety culture in different circumstances.

The publication describes a method for assessing safety culture and summarizes commonly used safety culture development interventions. Although the operational phase has traditionally been the main focus of the nuclear safety culture activities, there is a practical need for developing a sound safety culture also in the other lifecycle phases, such as the design and construction of new builds, or major modernisations in the operating plants.
Such activities are often carried out by a network of subcontractors rather than by the licensee organisation. The practical and theoretical challenges for applying the concept of safety culture in a large, complex dynamic network of subcontractors is discussed.

The publication provides a view of safety culture which follows the premises of resilience engineering: a good safety culture can be seen as a potential for an organisation to succeed in varying conditions.

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