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LEARNING FROM FUKUSHIMA: INSTITUTIONAL ISOMORPHISM AS CONTRIBUTING AND CONSTRAINING NUCLEAR SAFETY

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Abstract

The objective of the paper is to get understanding of the institutional isomorphism and mechanisms that have affected learning from the Fukushima. Theoretical framework draws on institutional isomorphism and theories of learning. The data consists of the safety requirements and reports of the international organisations, such as the International Atomic Energy Agency (IAEA), the Western European Nuclear Regulators' Association (WENRA) OECD Nuclear Energy Agency (NEA). The method is content analysis. The paper is explorative by nature. The main findings are that learning from the Fukushima can be characterised as single-and double-loop learning, affected by the institutional isomorphic mechanisms, such as tight exchange of knowledge and co-operation between the international organisations. This has promoted efficient, similar understanding of relevant tools to improve safety. At the same, institutional isomorphic mechanisms, such as professionalization of the nuclear sector has maintained the distinction between the technical and social aspects of safety thus blocking partly the triple-loop learning, questioning attitudes towards existing and dominant tools to deal with safety. Without triple-loop learning new safety paradigm that sees safety as an outcome of several structures, processes and activities cannot fully develop.

1. INTRODUCTION

Accidents in the high risk industries tend to trigger major learning processes at international, national and organisational levels. In the resilience thinking, quick learning is seen as an indication of resilience, i.e. an ability of a system (organisation) to maintain its core functions and integrity under conditions of expected or unexpected disturbing events (source) or recover quickly and to normalise its action capacity [1]. Resilient organisations are learning organisations, where continuous learning together with monitoring, responding and anticipation goes hand in hand [1]. However, the nature of learning and mechanisms of learning would require more attention especially in the context of globalisation, development of new technologies, interconnectedness of social and technical aspects and the subsequent complexity and uncertainties.

If one follows new safety paradigm based on sociotechnical thinking of safety, i.e. safety as an emergent phenomenon and outcome of several structures, processes and activities, then one also needs to reflect upon the learning [2]. As learning usually follows the existing paths, and exploits traditional methods of analysis, as well as clear distinction between the technical aspects and social aspects of safety, sociotechnical thinking is often neglected. Possibly learning from the sociotechnical perspective has remained inadequate, despite several endeavours to pay attention to socio-technical aspects. Perhaps new ideas can be got from the practices in other high-risk industries.

The objective of the paper is to look at the learning after the Fukushima accident at the international level and to get insights into institutional factors and mechanisms that may contribute or hamper learning. Institutional isomorphism, resilience thinking and organisation learning form a theoretical framework for looking at learning. [3,4].

The paper is explorative and it exploits findings from earlier studies on learning from Fukushima based on stress tests outlines and reports, and revisions safety standards of the IAEA and the WENRA reference levels. Content analysis is deployed as the method of analysis. [5].

Research questions are the following: What has been learned from the Fukushima at the international level? How are sociotechnical aspects addressed? What kinds of isomorphic mechanisms have contributed or constrained learning at international level?

The paper is organised as follows: Starting out the description of conceptual framework I provide theoretical understanding of learning and institutional isomorphism. Then I proceed to presenting the data and the method and after that I will examine some relevant mechanisms that have contributed to learning from Fukushima at international level. Then I will examine actual learning from Fukushima and constraints on learning. I also bring into discussion the difference between the new and old safety paradigm and reflect upon the potentials for moving towards more encompassing understanding of safety and the way institutional context and ways of learning can hamper or contribute to profound learning.

2. THE CONCEPTUAL FRAMEWORK: LEARNING AND INSTITUTIONAL ISOMORPHISM

Learning can be defined various ways and approached from several theoretical perspectives. From the resilience perspective learning is identified with knowing. Learning from accidents, for instance, includes knowing what has happened. In addition, learning is closely linked to responding that refers to knowing what to do, and monitoring that means knowing what to look for and finally anticipating that includes finding out and knowing what to expect [1]. Hence learning is closely linked to knowing, the term that can be further problematized. As value judgements, and institutional norms affect knowing (learning) in terms of what is regarded to be relevant things to know and to look for, hence knowing and learning themselves are circumscribed by values and institutional context [cf.6].

Learning can occur at individual and organisational level. Even at the organisational level individuals are seen carriers of knowledge, and it depends on the organisation whether learning at collective level is supported adequately or not

[7]. Learning at organisational level is often slow due to the existing norms and structures, which may delay learning. Learning may be more incremental, step by step type of learning, or more profound which entails adaptation of new goals, norms and values that makes learning a slow process [3]. In addition, preconditions for learning may vary in different societal contexts, thus making learning far from self-evident; it becomes dependent on societal, cultural and institutional factors. I will return to institutional factors after looking at the different ways of learning at the organisational level.

Single-loop, double-loop and even triple-loop learning have been commonly used in the organisational learning discussions [7, 8, 9, 4]. Single-loop and double-loop learning would refer to normal learning from mistakes and errors, whilst triple-loop learning would mean questioning the existing practices and thus providing wider prerequisite for learning. Triple loop learning is more profound in a sense that it may include adoption of new goals and value. However, all types of learning are required, hence one cannot just compensate single-loop learning by triple-loop learning [4].

As learning is circumscribed by institutions, I will introduce institutional isomorphism as a conceptual framework that can be deployed in the examination of learning and that may also provide insights into learning.

The notion of isomorphism refers to the phenomenon by which organisations tend to become structurally or strategically more similar [10]. There are several societal, economic and cultural pressures that make organisations to adopt structures and practices from each other. For instance hard competition and economic pressures make organisations to imitate those organisations that are regarded as successful. DiMaggio and Powell [10] have identified three mechanisms – coercive, mimetic and normative – through which the organisations become more homogeneous. We could interpret these mechanisms as something that both contributes to learning and at the same time enforce learning to the similar directions.

One can look at isomorphic features both at the international and national levels. One can talk about isomorphism a) inside the nuclear sector, b) between the nuclear sector and other regulatory regimes in the country and c) between the national nuclear sector and the international nuclear regulatory regimes. This study focuses on international and national learning.

Coercive isomorphism refers to e.g. national institutional contours, or the structure of the national economy or national patterns of interest organisations that can make national regulatory regimes more homogeneous and less similar to international regulatory regimes in the same sector. The opposite may as well occur, namely, that in a particular sector the national regulatory regime is more affected by international (rather than national) patterns, to which national governments have subscribed. *Mimetic* isomorphism may derive from an uncertain environment that creates pressures to imitate other organisations, which are considered successful. *Normative* isomorphism refers to professionalization, i.e. the need to create cognitive basis through formal education and training courses and networks. Normative isomorphism creates similar orientations to learning and similar understanding of safety among certain professions and experts.

All three pressures to isomorphism may play a role in the nuclear sector. We will look at some mechanisms of institutional isomorphism in chapter four. Isomorphism is important to the extent that it may strengthen and spread effective understandings of, and approaches to, safety, but it may also engender an inability to detect specific needs and requirements deriving from other discourses and fields. It may also lead to contrasting understanding and approaches among bodies involved in nuclear safety that are exposed to different isomorphic pressures. Hence, isomorphism may have pros and cons as regards efficient learning from accidents.

One can derive three hypotheses as regards isomorphism in terms of learning and safety. The first hypothesis is that isomorphism leads to consensus concerning relevant understandings of, and means to deal with, learning and safety. This may enhance awareness and strengthen safety.

The second hypotheses is that isomorphism and related consensus may also lead to blindness about relevant safety aspects, or approaches to safety and learning.

The third hypothesis is that the presence of contrasting isomorphic pressures leads to clashes between different principles and approaches to safety.

The basic hypotheses are that isomorphic tendencies are affected by, and thus express, international and national safety understandings; that these tendencies may affect (either positively or negatively) nuclear safety; and that of particular relevance, if the task is to improve safety, it is to detect those aspects of 'blindness' and 'clash' that can hamper the effectiveness of safety approaches.

The following questions stem from these hypotheses and theories of learning:

(a) What has been learned from the Fukushima?
(b) How have institutional isomorphic factors contributed to, or hampered, learning from the Fukushima accident? What patterns of 'awareness, or 'blindness' stemming from institutional isomorphism can be detected?
(c) What kind of role the single-loop, double-loop and triple-loop models have played in learning from Fukushima?

3. THE DATA AND METHOD

This paper exploits the same data as my previous study on Fukushima and lessons learnt [5]. However, in this paper focus is on learning and therefore the data and findings are examined from different perspective and that means that the paper entails different aspects.

The data consist of the IAEA and WENRA documents. The IAEA documents include safety fundamentals SF-1; General safety requirements: GSR Part 1 and its revision DS462[1]; GS-R-3 and its revision DS456[2]; GSR Part 4 and its revision DS462; GS-R-2 and its revision DS457[3]; and specific safety requirements SSR-2/1, SSR-2/2 [11-19]. The WENRA documents embrace revisions of reference levels: RHWG reports March 2013 and November 2013; Stress tests specifications proposal, April 2011; and WENRA conclusions arising from the Consideration of the Lessons from the TEPCO Fukushima Dai-ichi Nuclear Accident, March 2012 [20-23]. The data consist also of OECD NEA document regarding lessons learnt from Fukushima [24].

Documents are approached as sources of information through content analysis. Here, content analysis refers to a theory-sensitised interpretation and rearticulation of given texts in new analytical terms [25]. Analysis focuses on document content, such as meanings, patterns and relatively strong and consensual understanding of safety in the documents as well as consequences for safety.

Regarding the isomorphic features, the relationships between the main nuclear safety organisations were analysed on the basis of the mentioned documents. The focus is on how the organisations work in cooperation, and how their safety improvements are in line with each other. In identification of institutional isomorphic features, the available documents can only provide a tentative picture. However, as such, they provide clues about inter-organisational learning by showing how the organisations refer to each other in their revisions of safety standards or reference levels. More detailed analysis would also require interviews with the key actors. Therefore, the analysis is by nature explorative.

4. MECHANISMS OF INSTITUTIONAL ISOMORPHISM AT THE INTERNATIONAL LEVEL

In my previous study I have identified mechanisms which contribute to isomorphic features at the international level [26]. Tight co-operation and knowledge exchange characterises interactions between core nuclear safety organisations, such as the IAEA, WENRA, and the European Nuclear Regulators Group (ENSREG). For instance, the intense co-operation between the above

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[1] *Editor's note: Since the paper was submitted, GSR Part 1 was replaced by GSR Part 1 (Rev.1), see INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), IAEA, Vienna (2016).*

[2] *Editor's note: Since the paper was submitted, GS-R-3 was replaced by GSR Part 2, see INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2, IAEA, Vienna (2016).*

[3] *Editor's note: Since the paper was submitted, GSR Part 4 was replaced by GSR Part 4 (Rev. 1), see INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), IAEA, Vienna (2016).*

mentioned organisations emerges in the stress tests initiated by ENSREG together with the European Commission after the Fukushima accident. The idea of stress tests was to reassess the robustness of the European nuclear reactors on the basis of specifications developed by WENRA [27]. Moreover, WENRA has taken the IAEA's safety standards as a starting point for the reference levels, through which nuclear reactor safety is promoted. Therefore, WENRA specifications for reactor safety, as well as stress tests, were influenced by the IAEA safety principles and standards.

Similarly, WENRA aims to enhance safety by contributing to the revision of the IAEA standards when needed. For instance, WENRA countries participated in the work of the IAEA committees, which enhanced convergence between safety orientations [27]. Hence, the interaction moves in both directions, from IAEA to WENRA and ENSREG and vice versa. In addition, WENRA has also taken into consideration suggestions and improvements presented by ENSREG. This exchange of knowledge between organisations represents a normative isomorphic mechanism through which similar orientations and approaches to safety are strengthened. Often, the same people from an organisation, such as a national regulatory body, participate in different international nuclear safety organisations' activities. This arguably reinforces consistency in the understanding of safety principles across institutions and countries. Normative isomorphism is obviously the most common mechanism within the field of nuclear safety to enhance similar understanding of safety. Coercive tendencies within the nuclear safety field come out in the form of Nuclear Safety Conventions, which create common obligations and mechanisms for ensuring safety. Moreover, comparisons between countries, for instance, in their adoption and performance of nuclear reactor safety procedures (e.g. by WENRA) may act both as normative and coercive mechanisms, which create similar approaches to safety among the member countries. Similarly the IAEA Safety standards oblige its member states to act accordingly. Hence, standards can be interpreted as creating both coercive and normative pressures.

These mechanisms – tight exchange of knowledge and co-operation between the organisations, evaluations made by the IAEA whether power plants and regulatory bodies in each country have reached the goals set after lessons learned, and comparisons between the countries as regards reactor safety by WENRA – refer to single loop learning in the sense that it is learning from errors and learning is constrained by the IAEA and WENRA that are outstanding organisations in the nuclear field. At the same it refers to double-loop learning in the sense that learning is based on several experts' evaluation of the Fukushima accident, and also stress tests made in several nuclear power countries provided input information as regards robustness of the facilities in front of the natural hazards. On the basis of that information recommendations for nuclear power plants have been made. Hence it is a question of knowledge sharing between several actors that has paved a way to learning. Moreover, at least for instance OECD Nuclear Energy Agency, has supported questioning attitudes as regards existing methods related to probabilistic risk analysis. [24]. Questioning earlier methods refers to triple-loop learning.

5. LEARNING FROM FUKUSHIMA

Learning requires that one is aware of what has happened. However, what to look for depends on the assumptions and adopted frameworks.

Learning from Fukushima has built on conventional safety paradigm's distinction between the technical and social aspects of safety. For instance, technical scope comes out from the stress tests. Natural hazards, such as earthquake, flooding or heavy rain were taken as initial events, and their consequences such as loss of electric power, loss of ultimate heat sink, or station black-out were assessed. In addition, the design basis of the nuclear power plants was detected in terms of what is severity of earthquake or the level of flooding that the design basis can withstand. Also evaluations of margins, such as what is the strength of wind that doors can withstand were made. Furthermore, specification of cliff-edges, weak points, such as which buildings would be affected in the site were considered. Methods, such as seismic probability safety assessment were exploited in evaluations. [22].

Lessons learnt triggered new requirements for new nuclear power plants. These included a need to consider multiple failure situations and core melt accidents already in the design of new nuclear power plants. In addition, requirements stressed that the independence between different levels of "Defence-in-Depth" safety should be strengthened [22]. For the existing reactors design extension was required as regards independent and diverse means for heat removal and improving spent fuel storage safety.

These show that technical aspects of safety dominated the lessons learnt. Stress tests were built on the natural hazards and technical solutions to them, instead the human and organisational factors were excluded from the stress tests. However social and regulatory aspects were reflected upon separately, social and regulatory aspects after Fukushima emphasised leadership and management, strengthening the safety culture and improving emergency preparedness [27, 22].

Lessons learnt after Fukushima shows that understanding of safety was built on conventional safety paradigm with the distinction between the technical and social aspects of safety rather than on the new safety paradigm with the sociotechnical thinking that combines both the human and organisational as well as technical aspects of safety. Even though socio-technical thinking is acknowledged in the IAEA safety standards, there is a strong division to technical aspects and social or cultural aspects or human and organisational aspects of safety. That distinction undermines the ability to learn from Fukushima as a socio-technical accident. Obviously the strong division to technical aspects and social or cultural aspects of safety derives from the expert structure in the nuclear community. Technically oriented experts tend to focus on their own specialty, and the same applies to safety culture oriented scholars. Obviously separate thinking is also needed because separate technical areas as well as human and organisation aspect requires also separate in-depth examination. Yet, in order to learn efficiently, in a current complex, sociotechnical world there is an urgent need to bring various stakeholders and experts together and to deal with both the technical and social or organisational aspects at the same time.

6. CONSTRAINTS ON LEARNING

Learning at the individual level is circumscribed by what one already knows. Same applies to organisations: learning builds on existing knowledge. Appreciation of new knowledge is dependent on meanings, interpretations as well as institutional context. Hence, when considering the efficient learning, or quick learning that has been seen as a sign of resilience, one needs to understand the process and aspects of meaning giving. This means that understanding of learning requires human sciences' insights into the learning, meaning giving and institutional context within which the learning takes place.

Institutional isomorphism with specific pressures and mechanisms provides institutional context for learning. Institutionalised forms of knowledge and knowledge making are worth of considering, as existing knowledge may block or delay learning. Studies on learning have acknowledged the need to unlearn some things in order to learn new [28].

Based on the examination of learning from Fukushima I argue that institutional isomorphic tendencies are also strong in the nuclear sector. (Harmonisation attempts of reactor safety by WENRA, Stress tests, and lessons learnt (WENRA, IAEA, OECD-NEA). By isomorphic tendencies I refer to vivid exchange of knowledge between organisations that contributes to similar strong understanding of safety. When learning occurs in a planned and coordinated way, it often follows the existing norms and relatively stable structures that promote single-loop and double-loop learning. Instead adoption of questioning attitudes towards existing knowledge and practices as well as adoption of new goals i.e. triple-loop learning seem to be difficult in the current context. However, this does not mean that endeavours to support triple-loop learning would not exist. [e.g. 24].

In the nuclear sector as well as in other high-risk industries learning has occurred for decades and learning has built on existing knowledge. It is necessary to build learning on existing knowledge but there are also needs to question some earlier thinking. Conventional understanding of safety based on idea that safety is something that can be managed and distinction between technical and human and organisational aspects has been challenged by the new safety paradigm [2]. According to new safety paradigm, safety is an emergent phenomenon and by-product of several structures, processes and activities. Hence safety becomes difficult to govern. Only focusing on tools and methods for improving technical or human and organisational aspects of safety would not be adequate approach. In addition to those one should be able to see the overall safety that could be interpreted as all-embracing thing, such as organisations' capacity to act.

New safety paradigm has implications also on safety culture. With regard to safety culture, after Fukushima accident the significance of safety culture has been emphasised. There are pros and cons in the systematisation of safety culture. There are obviously needs to make safety culture concrete thing that can easily be understood by all stakeholders. Concretising and systematising safety culture is also relevant for the business purposes. That way safety culture can become an efficient tool for organisations to achieve their goals successfully. And when defined and concretised safety culture can be treated as something that can be developed further. There are benefits in this kind of instrumentalisation of safety culture in the sense that it becomes more familiar to many people, and many aspects of safety culture can be reflected upon in a systematic and concise way. One could say that there is a need for this kind of engineers' way of thinking of safety culture. It may create new ideas by forcing to make safety culture more concrete thing.

Yet, this kind of instrumentalised understanding of safety culture tends to make it relatively narrow thing that may obscure the idea that safety culture itself is a complex, emergent phenomenon, an outcome of various structures, processes and activities, and that it is not easily reducible phenomenon. If safety (and safety culture as well) are seen as emergent phenomenon, then too strict definition and systematisation of safety culture as measurable tool make it more mechanistic thing and this leads easily attention away from other things that are relevant in safety culture.

7. CONCLUSIONS

Learning from the Fukushima is characterised by both single-loop and double-loop learning. The accident was evaluated by the group of experts and learning from Fukushima in the form of stress tests focused on natural hazards and technical solutions to them. Hence learning was dominated by technical understanding of safety. Learning from errors is typical of single-loop learning. However, learning was also based on double-loop learning in the sense that several experts participated in the evaluations of the accident and the stress tests reports from different nuclear power plants across the Europe provided relevant input information on the basis of which, the revisions were made to the IAEA safety requirements and the WENRA reference levels to reactor safety. Stress tests made the nuclear industry and regulatory bodies to reflect upon the robustness of the power plants in the face of natural hazards. In that sense it took the form of double-loop learning. Similarly, the IAEA and WENRA confronted with the results of the stress test and the need to reflect upon the new requirements. This is also an indication of double-loop learning. With regard to human and organisational aspects, they were detected but in isolation from technical aspects.

Learning from Fukushima follows the conventional safety paradigm's distinction between the technical and social aspects of safety. If the learning would have taken into consideration a combination of human and organisational aspects of safety and technical aspects of safety, then it would have followed the new safety paradigm. Obviously moving from double-loop learning to triple-loop learning would require questioning the conventional methods and approaches to safety. However, institutional isomorphic mechanisms such as tight exchange of knowledge and co-operation between the international organisations, as well as professionalization of the nuclear sector have a tendency to circumscribe learning. Institutional isomorphic mechanisms maintain and promote the existing methods and approaches to safety and the distinction between the technical and social aspects of safety. At the same institutional isomorphism contributes to similar, efficient understanding of safety.

However, institutional isomorphic tendencies with similar understanding of safety may also create blind spots as regards learning and safety. It may block and delay triple-loop learning and appreciation of new safety paradigm. Without triple-loop learning new safety paradigm that sees safety as an outcome of several structures, processes and activities cannot fully develop. This has consequences also to safety culture considerations. Even though more all-encompassing understanding of safety is needed, this does not mean that the existing methods and approaches should be disregarded. They are relevant and co-existence of conventional and new paradigm would be beneficial.

There relevant question is how to develop further reflections and activities that would contribute to development of new safety paradigm.

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REFERENCES

[1] HOLLNAGEL, E. PARIÈS, J, WOODS. D.D. AND WREATHALL, J. Resilience Engineering in Practice. A guidebook. Ashgate, Surrey (2011).

[2] HOLLNAGEL, E. Safety-I and Safety-II. The past and future safety management. Ashgate, Farnham. (2014).

[3] ARGYRIS, C. Reasoning, Learning and Action: Individual and Organizational. San Francisco, Jossey-Bass. (1982).

[4] WANG, C. L., and AHMED.K.P. "Organisational learning: a critical review." The learning organization 10.1 (2003) 8-17.

[5] YLÖNEN, M. and LITMANEN T. Signaled and Silenced Aspects of Nuclear Safety – A Critical Evaluation of International Nuclear Safety Thinking. Journal of Risks, Hazards and Crisis in Public Policy **6** 1 (2015) 22-43.

[6] ELLIOTT, K. C., and MCKAUGHAN.D.J. "Nonepistemic values and the multiple goals of science." Philosophy of Science 81**.**1 (2014) 1-21.

[7] ARGYRIS, C. Single-loop and double-loop models in research on decision making. Administrative Science Quarterly, **21** 3 (1976), 363-375.

[8] ARGYRIS, C. Double-loop learning, teaching and research. Academy of Management Learning and Education **1** 2 (2002) 206-218.

[9] BATESON, G. Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution and Epistemology. London, Intertext. (1972).

[10] DIMAGGIO P. J. and POWELL W.W. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. American Sociological Review, **48** 2 (1983) 147-160.

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, GS-R-2 (revision DS457). (2002). http://www-ns.iaea.org/standards/documents/pubdoc-list.asp?s=11&l=83, pub1133_scr.pdf (Revision DS457: http://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86, dpp457.pdf).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Fundamentals SF-1. (2006). http://www-ns.iaea.org/standards/documents/pubdoc-list.asp?s=11&l=83, pub1273_web.pdf

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, GS-R-3 (revision DS456). (2006). http://www-ns.iaea.org/standards/documents/pubdoc-list.asp?s=11&l=83, pub1252_web.pdf (Revision DS456: http://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86, dpp456.pdf)

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, General Safety Requirements: GSR Part 4 (revision DS462). (2009). http://www-ns.iaea.org/standards/documents/pubdoc-list.asp?s=11&l=83, pub1375_web.pdf (Revision DS462: http://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86, dpp462.pdf).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, General Safety Requirements: GSR Part 1 (Revised: DS462). (2010). http://www-ns.iaea.org/standards/documents/pubdoc-list.asp?s=11&l=83, pub1465_web.pdf (Revision DS462: http://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86, dpp.462.pdf).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Specific Safety Requirements SSR-2/2. (2011). http://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86, dpp.462.pdf

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Specific Safety Requirements SSR-2/1. (2012). http://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86, dpp.462.pdf
[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Fundamentals: Objective and Essential Elements of a State's Nuclear Security Regime. IAEA Nuclear Security Serie No 20. (2013). http://www-ns.iaea.org/security/nss-publications.asp,pub1590_web.pdf
[19] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Standards. (2014). http://www-ns.iaea.org/standards/documents/pubdoc-list.asp?s=11&l=83
[20] WENRA. WENRA RHWG Report, Updating WENRA Reference Levels for existing reactors in the light of TEPCO Fukushima Dai-ichi accident lessons learnt. (2013). http://www.wenra.org/media/filer_public/2013/11/21/rhwg_report_on_updated_rls_for_existing_npp_-_november_2013.pdf
[21] WENRA, WENRA conclusions arising from the Consideration of the Lessons from the TEPCO Fukushima Dai-cihi Nuclear Accident. Statement. 2012.
[22] OECD NEA. The Fukushima Daiichi Nuclear Power Plant Accident. OECD/NEA. Nuclear Safety Response and Lessons Learnt. NEA No. 7161. (2013).
[23] WENRA. Updating WENRA reference levels for existing reactors in the light of Tepco Fukushima Dai-ichi accident lessons learned. (2013) http://www.wenra.org/media/filer_public/2013/11/21/rhwg_report_on_updated_rls_for_existing_npp_-_november_2013.pdf
[24] KRIPPENDORFF, K. H., Content Analysis: An Introduction to Its Methodology, Sage Publications (2003).
[25] YLÖNEN, M. Signalled and Silenced Aspects of Nuclear Safety. (In preparation).
[26] WENRA. Stress tests specifications proposal by the WENRA Task Force, 21 April 2011. (2011). https://www.oecd-nea.org/nsd/fukushima/documents/WENRA20110421StressTestsSpecifications2011-04-21.pdf

DESIGNING FOR AN EFFECTIVE MANAGEMENT OF SAFETY: WHY ANALYSIS OF OPERATING PRACTICES MATERS

Example of an event concerning criticality risks in a French Fuel Cycle Facility

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Abstract

The criticality risk is an unwanted neutron chain reaction that could lead, if not under control, to a criticality accident resulting in an intense emission of neutron and gamma radiation. Thus, in addition to design measures, the management of criticality risk in Fuel Cycle Facilities (FCFs) relies mainly on a set of prescriptions and requirements established by the licensees for achieving safety objectives. This paper intends to show that, beyond prescriptions and requirements, a socio-technical approach is essential to define a relevant set of criticality safety rules favouring efficient and safe human activities. Indeed, a thorough knowledge of staff operating practices, beyond to contribute significantly to the definition of appropriate technical and organisational provisions, enhances safety management combining "rule-based safety" and "managed safety". Rule-based safety (top down definition of the rules) can be achieved by anticipating undesirable situations and defining provisions to avoid and manage them in daily practices. On the other hand, managed safety (integration of local characteristics) develops the socio-technical system capacity to anticipate, to recognize and to formulate appropriate responses to unexpected scenarios that were not foreseen by the organization, or to rules that are not applicable to the operational realities. Thus, an effective safety management relies on human expertise, on the skills of individuals, on the quality of initiatives, and on the way teams and organizations perform the operations on a daily basis, interact and coordinate to integrate and regulate both ruled-based safety and managed safety. In the FCFs, risk analyses and criticality safety frameworks need to be considered in the light of diversity of working situations and complexity of their organisational interfaces. Introducing and maintaining efficient and safe practices in the long term relies on appropriate staff risk awareness. Local management and support of criticality safety experts to operational staff are essential for making operating practices safer. Indeed, situations often arise that are unforeseen or not (yet) analysed (hazards, evolutions following process modifications,

degraded situations …). The way the system responds to these situations will depend on organizational lines of defense which allows local resources (teams and management) to be available for dealing with the situation. Safe production occurs only because each operator manages many sources of variation while performing their tasks, with expertise acquired through experience. As a consequence, global performance of a system in terms of production quality and safety is dependent upon interaction between social and technical components in workplaces. Finally, an organization contributes efficiently to safety when it facilitates an interaction between the formal rules, which provide general expertise, and the knowledge of specific operating situations and practices, which is held by the operators and managers on the field. The paper is illustrated by an event that occurred in a French fuel fabrication, event involving non-compliance with rules and procedures to prevent criticality risks relative to conditioning, storage and internal transfer of containers which hold manufacturing scrap containing fissile material.

1. INTRODUCTION

Criticality accidents constitute sudden release of radiations without any previous warning signs. This is the reason why the corner stone of criticality risk management in nuclear facilities is the prevention of criticality accidents. Following the defence in depth principle, prevention of criticality accidents relies on technical and organisational lines of defence defined in the criticality safety framework.

In the light of the contribution of the socio-technical approach, the IRSN considers that criticality risk management and more generally nuclear risk management should rely on lines of defence which take into account work activities and technical and management support to those activities.

In this paper, IRSN intends to show that, beyond prescriptions and requirements, a socio-technical approach is essential to verify the relevancy of the criticality safety rules and procedures, and to favour efficient and safe human activities. Indeed, a thorough knowledge of work situations and staff operating practices contributes significantly to the definition of appropriate technical and organizational lines of defense in order to ensure that operating situations are always compliant with situations authorized by the criticality safety framework.

The issue addressed by IRSN is illustrated by an example from an event that occurred in 2012 in a French fuel fabrication facility, FBFC[4].

2. DESCRIPTION OF THE EVENT

In September 2012, the company FBFC reported to the French Nuclear Safety Authority (ASN) an event involving non-compliance with rules and procedures to prevent criticality risks relative to conditioning, storage and internal transfer of containers known as "drums" which hold manufacturing scrap containing

[4] FBFC (AREVA group) is a fuel-fabrication facility located in southeast of France.

fissile material. This event is described in the IRSN report reviewing incidents from 2011 and 2012 in Fuel cycle facilities [1].

FBFC produces fuel for pressurized water reactors (PWRs). The main step of the fabrication process is the production of uranium oxide pellets from uranium oxide powder. Manufacturing scraps produced in the pellet fabrication workshop are calcinated before being re-injected in the fabrication process in powder form. A part of these calcinated scraps needs to be chemically purified in the recycling workshop located in another building.

FIG. 1. Specific label for a 10-liters drum with wet fissile material.

Normally, only dry fissile material was transferred between the two buildings. However, since the shutdown of the calcination furnace in the pellet fabrication workshop at the end of 2011, wet fissile material produced during grinding wheel cleaning cannot be dried in this workshop anymore, which is an important change for operating practices and organisation. Parts of this wet material are thus transferred in 10-liters drums between the two buildings.

To prevent criticality risk, operating rules define the conditions for using the drums. Depending on the type of fissile material in a drum (powder or pellet, dry or wet product), these rules set the maximum uranium oxide mass per drum as well as the conditions for identifying (dry or wet products), transporting and storing the drums. Since the criticality risk increases in the presence of moderator, the rules are stricter for wet products (i.e. specific identification, manual handling, individual transfer).

The day when the event has been detected, an operator discovered, when opening a drum in the recycling workshop after its transfer from the pellet fabrication workshop, that it was containing wet fissile material[5], while it was placed

[5] Drums with wet fissile material contain mainly sludge (instead of powder) and sometimes supernatant comprising water.

in a tubular carriage dedicated to carry only dry fissile material between the two above mentioned buildings (and thus unauthorized to receive drums with wet material).

FIG. 2. Tubular carriage for the transfer of drums.

As soon as the event was reported, all transfers of fissile material within the workshops were suspended to proceed to an exhaustive verification of all the drums placed in tubular carriages. This verification process ended up with a total of six drums containing wet material not compliant with the criticality safety framework regarding the rules of identification, storage and internal transfer.

For the IRSN, this event revealed shortcomings in the criticality risk management in this Fuel Cycle Facility (FCF), reflected in weaknesses of existing lines of defense defined in the criticality safety framework of the facility, especially those concerning the treatment of wet material in compliance with this framework.

3. MAIN LESSONS LEARNT FROM THE ANALYSIS OF THE EVENT

3.1. Failure to apply rules

At the time of the event, the identification of drums with wet fissile material is done with a red “centralized cleaning” label whereas there is no specific label for drums with dry material. The “centralized cleaning” label is the fourth label stuck on the drum (after the labels for enrichment, type of product, origin of the product and before the weight ticket). Therefore, as all the drums look identical, the red label is the unique provision to distinguish drums containing wet fissile material from other drums in order to apply the rules defined for storing and transferring drums with wet material, which state that wet material drums should be individually and manually transferred in the facility (between the two above-mentioned buildings).

For three out of the six non-compliant drums, the rules defined for storing and transferring drums with wet material were not applied because operators omit to stick on the red “centralized cleaning label” on the drums with wet material. These drums were erroneously placed on a tubular carriage later on.

The three other non-compliant drums containing wet material were misplaced in tubular carriage while they were correctly labelled. To understand the reason why operators did not apply the rules for storing and transferring those three drums, it is essential to tackle the issue of the consequences of the modification of material flow on their own activity.

3.2. A systemic approach for understanding the event

Whereas human error is often invoked by licensees as a major factor that caused or contributed to an incident/accident, some technical and organizational configurations are more likely than others to generate inappropriate operators’ actions and to prevent from their recovery.

If corrective actions focus only on human error, it will lead to individual actions such as reminding operators to comply with procedures, modification of procedures or training. But it will not consider the whole situation in which people perform their activities and some aspects of that working situation, if not improved, may lead to new events in the future.

A systemic and integrated approach, such as described in Figure 3, addresses the whole system by considering the dynamic interactions within and among all relevant factors of the system — individual factors (e.g. skills and knowledge, decisions, actions), technical factors (e.g. technology, tools, human-system interfaces, equipment) and organizational factors (e.g. management system, organizational structure, governance, resources).

In that whole system, activities are performed by people at work within a “working situation” which is determined by categories of factors concerning individual, technology and organisation, and interactions among them. When performing their activities at work, operators deal with a great variability of working situations, because there are always things happening differently than expected (equipment failed, tool not available, resources not adequate, composition of team different from usual, etc.). Work activity at a given moment is a response of operators to a large number of determining factors for achieving the goals of the task. When performing the activities over time, operators develop practices for dealing with different situations, and these practices may sometimes be different from the rules. If management in the licensee is not aware of such practices or does not analyse why such practices occur and what may be the impact on safety, there will be cases where adjustments of the rule made by operators, or even failure in adherence to the rules, may lead to events safety-related.

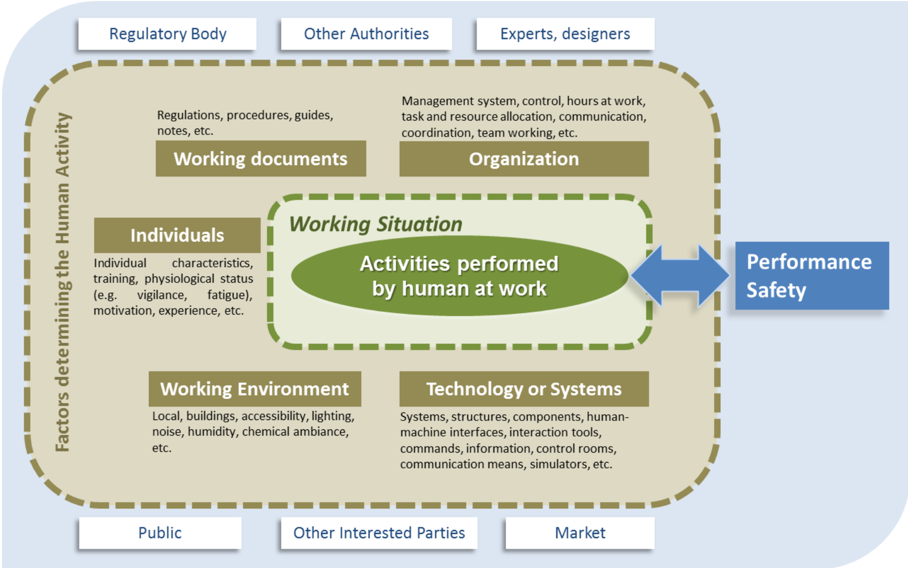

FIG. 3. A systemic approach addressing the whole system.

The approach mainly relies on methods used for understanding and analysing how people really do for performing activities in different situations and context, and not only on what they are supposed to do. In that approach, data are collected by observing activities performed by operators in different kinds of situations, completed by interviews, meetings, etc. This allows identifying and analysing operating practices and their influence on the human performance. When analysing an event, this approach allows identifying root causes in the determining factors that influence the working situations, and then to define more appropriate actions for improving safety in a durable way.

3.3. Why failures happened in applying rules

For the first three non-compliant drums where operators omit to stick on the red “centralized cleaning label” on the drums with wet material, the analysis of working situations showed that no provision was foreseen to prevent or recover from an error of labelling. Such provision could have been, for instance, distinct labels (in forms and colors) for both wet and dry material drums, coded pins on the drums containing wet fissile material, physical lock against the introduction of wet material drums on the tubular carriage, separated circulation flow for dry and wet material drums, separated temporary storage areas before transfer for wet material drums from areas for dry material drums and traceability of wet material drums in the nuclear material database.

Moreover, it appears that no provision for controlling the activity of labelling wet material drums, such as crosschecks, was carried out in the facility documentary framework.

As a consequence, two major lines of defense, work situation design and documentary framework, did not play their full role: an inadequate work situation design combined with shortcomings in the documentary framework relative to activity control lead to a situation unauthorized by the criticality safety framework (drums with wet material not individually transferred) following one single inappropriate operator's action (label not stuck on the wet material drum).

Concerning the three other non-compliant drums, containing wet material misplaced in tubular carriage while they were correctly labelled, the fabrication process had been changed. Following shutdown of one of the old calcination furnace in the pellet fabrication workshop and its replacement by the furnace in the recycling workshop, the flows of fissile material within the facility were modified. Thus, operators had to perform the additional task to individually transfer drums containing wet material from the pellet fabrication workshop to the recycling workshop. The criticality safety framework of the workshop was then updated to take into account this rule.

Why did operators not apply the rule in that fabrication workshop for storing and transferring the drums? In the working document, the rule is clearly stated: the operators must transfer individually, one by one, the drums containing wet fissile material. What do they really were doing in daily operations in the field? Each transfer requires about nine minutes of delivery time per drum. Up to four drums may be transferred per shift work, representing a total period of forty minutes. Thus, in order to reduce the constraint of transferring the drums individually, the operators bundled several wet drums and transfer them in a grouped manner. This operating practice, yet non-compliant with the criticality safety framework but without being really aware of the potential consequences, presents clear advantages to reduce time and number of transfers to the detriment of criticality safety rules. It turned out that operators deliberately circumvent the rules in order to optimize time allocated to transfer of fissile material, without being necessarily aware of the consequences of their actions.

The rule stating that wet material drums should be transferred individually in the facility was not supported by a criticality safety risk analysis addressing the compatibility of that way of transfer with operators' practices and activity constraints. Moreover, the extension of the rule for the individual and manual transfer of wet material drums to the recycling workshop should have been shared with operators in charge to ensure that the rule is well understood and that the link with criticality risk management makes sense to them.

As a consequence, failures of at least three lines of defense, risk analysis, documentary framework sharing and appropriation, and activity preparation, led to the same situation unauthorized by the criticality safety framework as for the three drums incorrectly labelled (drums with wet material not transferred individually), but this situation was caused by inappropriate operators' actions made intentionally.

This event also allows to question the deeper organizational lines of defense which emerge under the inappropriate actions of operators, in particular those associated to the role of first-line managers and criticality safety support entities as well as perception of risks in complex work situations.

3.4. Criticality risk awareness

The analysis made by the licensee showed that the non-compliance with the rule concerning the drums transfer was not only unauthorized by the criticality safety framework but also not covered by a specific criticality study. Consequently, operators are not aware to have breached the criticality margins and to be in an uncontrolled situation. The analysis emphasizes a work situation in which the switchover from an authorized situation to an uncontrolled one, in which the remaining margins are unknown, happens because of one single inappropriate operator's action without any technical and organizational provisions to recover from it. This situation is particularly problematic in the case of criticality risk management for which no forewarning is detectable before the accident is triggered[6].

This leads to the question of how to explain this very particular risk to staff exposed to the risk of criticality, in such a way it is clearly understood and it make sense for the operators. One response could be the training program of staff; it must be designed in order to promote a more proactive role for the operators ahead of the operation in particular through the appropriation of the risk analysis. The involvement of criticality experts at this stage is crucial, to explain the importance of the rules compliance and its link to criticality risk management, to promote the criticality risk analysis and its implementation in connection with the working practices of the operators. Local appropriation by the operators is the key to success for a correct understanding and thus application of the prescriptions and rules, as long as they are adapted to the operational practices.

3.5. Role of first-line managers and criticality safety support entities

This event shows that it is necessary to strengthen the link between operators, line managers (in particular shift supervisor) and criticality safety support entities (operational safety engineer, criticality engineer), in order to reinforce the support provided to the operators in the field. This is also an opportunity to give sense to the working activities by improving the criticality risk awareness individually and collectively, and a better understanding of criticality risk prevention.

On the other hand, it could give the managers and safety experts a better view of the complexity of work situations that the operators have to deal with. In the present case, managers and experts have insufficient detailed knowledge of the

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[6] The decision 2014-DC-0462 from the French Nuclear Safety Authority of the 7th October 2014 relative to the criticality risk control in nuclear facilities specifies that a criticality accident must not in any case arisen from a single fault.

actual activity on workstations and therefore have an erroneous perception of the tasks performed by operators.

As a first example, the binary identification dry/wet of the drums as prescribed did not cover the actual work of operators. Indeed, operators had actually to manage nine types of different products in removal from grinding machine for which the criticality safety framework did not list those authorized in the tubular carriages. The procedure did not indicate the wet or dry nature of those products.

As a second example, loading of the carriage and regulation set up is not performed by one operator. It is the result of a collective work between three operators: the operator in charge of the oxidation furnace, the one performing the grinding of the pellets and the one sorting out the pellets. A detailed knowledge of the work activity performed allows a better understanding of the constraints of each other. It gives a better chance to mutual appropriate information sharing and to avoid or detect inappropriate human action. It also provides the opportunity to anticipate co-ordinations or safety matters.

4. MANAGEMENT OF SAFETY IN A SOCIOTECHNICAL SYSTEM

This event illustrates the importance of observing and analysing operating practices for understanding failures in application of procedures by operators.

Operating documents and procedures are regularly considered as one of the causes contributing to criticality-related events at FCFs facilities, and even of accidents, in which human or organisational error played a significant part ([1], [2]). Same observations can be made for other facilities such as NPPs. As first example, during an event occurred in 2013 at the Cruas NPP, two air-operated valves controlling the turbine generator's steam supply and a compressor in the reactor's compressed air production system malfunctioned, jamming in the open position [3]. The analysis performed by EDF showed that the proper operating procedure for replacing the alumina in the dryer was not followed during the operations for preventive maintenance.

In a second example, EDF detected in October 2013 that a valve in the Emergency Feedwater System of reactor 1 at the Chinon B NPP failed to respond to a 'Close' command [3]. An error had been made on the valve during an operation carried out as part of the basic preventive maintenance schedule, on 24 July 2013. The analysis showed that the subcontractor's personnel did not refer to the existing operating procedure because, in the past, they had committed errors when using other operating documentation.

This raises a more general question of the balance to find, for managing safety of nuclear installations, between compliance with rules and initiative-taking behaviour for achieving the task.

What does "adherence to procedures" mean practically for people at work? Indeed, operators are faced with a great variability of working situations which, in the field, are never exactly the same. For instance, they have to satisfy different, and sometimes contradictory, objectives, in changing context, with resources that can be different from one time to another or an equipment is unavailable or some location usually reachable is uneasy to reach for specific reasons, etc.

4.1. Ruled safety and managed safety

In daily work, “there will always be situations that are either not covered by the rules or in which the rules are locally inapplicable” [4]. Safety relies on the ability of workers to assess the applicability of procedures and adaptations to carry them out [5]. Dekker distinguishes between two models of rule application. The first is based on a normative view: rules are the safest way to perform a job, and operators must comply with them. The second is based on an adaptive view: rules are resources for operators, but they are not sufficient to cover all work situations. Safety then relies on the ability of operators (and managers) to judge when and how they should adapt procedures to local circumstances. The same distinction is made by Morel et al. [6] between “regulated safety”, founded on procedures and scientific knowledge that anticipate undesirable situations, and “managed safety”, that refers to real-time relevant responses made by operators for adapting procedures to the circumstances of the situation.

Amalberti [7] has established the gap between ruled safety, based on procedures and scientific knowledge, and managed safety, which refers to local practices, that is adjustment of procedures taking into account the specific situations. The author points out that over-proceduralisation is counterproductive: by controlling all foreseen situations by rules, the organization is not able anymore to answer to unforeseen situations because of a lack of knowledge to manage them. This can lead to a failure, in terms of performance (expected results) and health, the non-consideration of the efforts made by the operators to face the situations can cause damages on their health [8], or at least on their commitment to work. It is thus essential to pursue a certain degree of flexibility, based on the individuals and the organization leeway, which is essential to strengthen the capability to respond to incidents and crisis [7]. It is the acquisition of this organizational flexibility that Weick [9] admits, particularly in critical situations, as being a source of resilience.

Hollnagell and al. [10] consider that the failure, of the individuals or of the system, assets the temporary inability of the sociotechnical system to face efficiently the complexity. The success belongs to organisations, groups and individuals who are resilient, in the sense that they identify and manage the variations, disruptions and interferences that are outside of the scope that the system is supposed to cope with.

The experience shows that procedures are sometimes not known, not true, or not applied nor applicable because they present too strong inconsistencies with work situations. Often inappropriate human actions are the consequence of the characteristics of the situation, which have not allowed operators (individual or team) to use their expertise in a relevant way, for reasons usually linked to failed lines of defense such as poor design of the systems, bad human-machine interface, lacking or inadequate prescriptions, ineffective organization, inappropriate training.

4.2. Designing for an effective management of safety

Thus, the design of socio-technical systems plays a central role in effective performance of operators as it either facilitates or hinders their decisions and actions. The characteristics of the situations in which a human being is placed make certain types of behavior more likely. These characteristics can be local (design of a workstation, tools, procedures) or much broader in scope (company policy, management system, training programs).

An effective safety management [8] should include two complementary components; one component, called “Rule-based safety”, is based on as complete as possible identification of possible failures in order to define provisions to prevent these failures and limit their consequences; a second component, called “managed safety”, aims to manage unforeseen situations in a safe way.

- “Rule-based safety” seeks to avoid all foreseeable failures through formal procedures, rules, automated safety mechanisms, the use of protective measures and equipment, training in “safe behavior” with management ensuring that rules are respected. This component makes it possible to predefine appropriate provisions (technical, human and organizational) to foreseeable situations. However, the approach to deal with safety in complex systems still tend to focus on the behavior of operators, on human error and on compliance with procedures derived from exhaustive risk analyses. Indeed, licensees still too often regard risk analyses and operators’ compliance with rules as a guarantee of safe facility operation. Operators are often considered as the weak link in the system. Their positive contribution to safety is usually neglected. Event analyses from nuclear licensees particularly reflect very often this erroneous view of safety, as the analyses are limited to the search for apparent causes, leaving aside less apparent essential causes.
- “Managed safety”, the second component of safety management, develops the socio-technical system capacity to anticipate, to recognize and to formulate appropriate responses to unexpected scenarios that were not foreseen by the organisation because it is not possible to identify all the scenarios even for simple activities. It relies on provisions which foster competences and real-time presence of human expertise, the quality of initiatives, the way groups and organisations operate, and on management that is attentive to the situations and encourages coordination between the different type of knowledge that are useful for managing safety.

In other words, procedures and rules prepare the system for configurations that have been anticipated and play a major role in the ability to manage these situations. But situations also arise that are unforeseen or not (yet) analysed (hazards, evolutions following process modifications, degraded situations …). It can lead to situations where compliance to the rules is difficult or impossible to achieve in the case of an unexpected event ([5], [11]). The way the system responds to these will depend on organizational lines of defense which allows the local resources of the teams and the management to be available in real time.

Formalizing the rules necessary to manage foreseeable work situations is essential especially when criticality risk is involved. Nevertheless, formalizing the response to foreseeable situations does not guarantee the relevance of the response to unforeseen situations. Worse still, organizations that base their entire safety policy on prescriptive formal procedures can find their robustness brought into question when a new or unforeseen situation arises.

Besides, Dekker [5] reminds that the gap between the procedure and the practice doesn't necessary lead to an incident or accident, and that safe results can be preceded by as much procedure deviations that incident or accident are.

To sum up, an organization contributes efficiently to safety when it facilitates an interaction between the formal rules, which provide general expertise, and the knowledge of specific operating situations and practices, which is held by the operators and managers on the field.

To reach this objective, an organization should be able to:

— Regularly reassess the assumptions and processes on which safety is based, in particular in case of evolution of safety hypotheses, of processes, of organization, etc.
— Collect operational experience feedback, analyse the data collected, and capitalize the lessons learned and share them among the different entities of the organization.
— Set up a collective functioning relying on effective activity co-ordinations and close coordination of entities involved.
— Carry out operations by detecting and locally managing variability linked to specific operating conditions.
— Involve operators in the design and the improvement of rules and procedures for taking into account the characteristics of work situations, but also to encourage their adoption by operators (in particular, improving their understanding and sense-making of rules, and reinforcing their knowledge and skills). When a participative approach is encouraged/promoted and implemented, it contributes to reinforcing rigorous rule application. The same applies to the presence of management in the field, seen as participative leadership practices, which take the form of both support to the working activities and control.

— Establish a positive safety dialogue while encouraging certain improvements when applicable. In this way, operators, safety experts and managers participate in the coordination of “regulated safety” (top-down definition of the rules) and “managed safety” (integration of local characteristics).

5. CONCLUSION

To meet production and safety objectives, operators’ work activity is not limited to the simple execution of procedures. Operators seek to achieve goals in specific working conditions. Safe production only occurs because each person manages many sources of variation while executing their tasks, with expertise acquired through experience. Hence, work activity is a response to a number of determining factors which present some variability: production and safety objectives, tasks to be performed, equipment available, working conditions, time constraints, abilities and knowledge of the operators, expertise acquired through experience, available collective resources, etc. As a consequence, global performance of a system in terms of production quality and safety is dependent upon interaction between social and technical components in workplaces.

The system into which operators evolve is complex. The actions of one and other interact very often, but not always explicitly. That’s why being able to deal with the criticality risk often requires to finely analyze the activities performed by the operators individually and collectively, in order to define means of performance that make sense to their work and are compliant with the authorized safety framework. It is then crucial that operators clearly understand the relationship between criticality risk in the facility and the criticality safety prescriptions, as well as requirements governing their daily activities in order to be willing to comply with these rules every day. For the same reason, working practices and activity constraints in a given work environment should be taken into account when defining or modifying existing prescriptions or requirements.

Lessons learnt through the analysis of the FBFC event point towards three levers of action. Operators should participate to the definition of new criticality procedures and instructions and to any evolution of existing ones as experts of their own activity. They should also be encouraged to express any concerns about prescriptions they have to apply and possible limits their working environment. It goes without saying that any modification brought to the whole criticality safety framework should lead to check the overall consistency and relevance and the acceptability of the amount of the applicable documents so that those documents would be easily shared and used when required and needed.

The presence in the field of local management and criticality experts seen as a participative leadership practice is crucial to allow managers and criticality experts to fulfil their support function for activity besides their control function. Their role is twofold. They should ensure that any modification brought to the criticality safety rules is well understood by operators in the light of the criticality risk to manage. They also should be able to detect any unwanted evolution in the criticality safety practices and understand the reasons of its emergence, which could cover any evolution of production, quality or safety objectives but also any evolution of the work environment of the concerned operators.

Designing and operating social-technical systems, such as nuclear facilities, so that the ultimate goal of safe production is achieved, requires the contribution of specific skills on human and organizational factors. These skills are essential for taking into account all the components of the variability of work situations (overall objectives, available competence and resources, procedures, technical devices, working conditions, etc.). They are also essential for designing appropriate and efficient technical and organizational lines of defense and for ensuring they remain robust throughout facilities lifecycle.

REFERENCES

[1] IRSN, Safety at basic nuclear installations other than nuclear power plants: Lessons learned from significant events reported in 2011 and 2012, IRSN Report N° DG/2013-00006-EN (2013). http://www.irsn.fr/EN/publications/technical-publications/Documents/IRSN-DG-2013-00006-EN.pdf

[2] MCLAUGHLIN, T., MONAHAN, S., PRUVOST N., FROLOV, V, RYAZANOV, B., SVIRIDOV, V., A Review of Criticality Accidents, 2000 Revision, Los Alamos, LA-13638 (2000).

[3] IRSN, IRSN’s Position on Safety and Radiation Protection at Nuclear Power Plants in France in 2013, http://www.irsn.fr/EN/publications/technical-publications/Documents/IRSN-Report_Safety-Radiation-Protection-NPP-France-2013.pdf

[4] REASON, J., PARKER, D., LAWTON, R., Organizational controls and safety: the varieties of rule-related behaviour, Journal of Occupational and Organizational Psychology 71 4 (1998) 289-304.

[5] DEKKER, S., Ten Questions About Human Error. A New View on Human Factors and System Safety, CRC Press (2005).

[6] MOREL, G., AMALBERTI, R., CHAUVIN, C., Articulating the differences between safety and resilience: the decision-making process of professional sea-fishing skippers, Human Factors 50 1 (2008) 1-16.

[7] AMALBERTI, R., La conduite de systèmes à risques. Coll. Le travail Humain, Presses universitaires de France, Paris (2004).

[8] DANIELLOU, F., SIMARD, M., BOISSIÈRES, I., Human and Organizational Factors of Safety: a State of the Art. Number 2011-01 of the Cahiers de la Sécurité Industrielle. Institute for an Industrial Safety Culture, Toulouse, France (2011).

[9] WEICK, K., SUTCLIFFE, K., Managing the Unexpected: Resilient Performance in an Age of Uncertainty, Jossey-Bass, Second edition (2007).

[10] HOLLNAGEL, E., WOODS, D., LEVESON, N., Resilience engineering: Concepts and precepts, Ashgate Publishing Limited (2006).
[11] AMALBERTI, R., AUROY, Y., ASLANIDES, M., Understanding Violations and Boundaries. The Canadian Healthcare Safety Symposium, Edmonton (October 2004).

AFTER THE FUKUSHIMA DAIICHI ACCIDENT, EXTENDING THE HUMAN AND ORGANIZATIONAL FACTORS (HOF) FRAMEWORK TO SAFETY REGULATION

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Abstract

The Fukushima Dai-ichi accident, has been considered as a "man-made disaster". According to this statement, the Japanese diet reports pointed out many weaknesses of the Japanese regulatory bodies in urging Tepco to tackle in a more extensive and effective way seismic and tsunami flood risks. Another conclusion that may be drawn from the accident occurring in the Fukushima Dai-ichi NPP is that focusing exclusively on what the NPP operator is doing (or not) to improve the nuclear safety of its facilities may not be sufficient to prevent such events. Indeed, one must also pay a particular attention to the functioning of the whole regulatory system. It includes various regulatory processes and instruments, ranging from the very first stages of their design to a more extensive examination of their implementation by the various actors concerned. These views led the French institute for radiological protection and nuclear safety (IRSN) to develop a research program dedicated to the study of the French nuclear regulatory system. To carry on the analysis of this particularly complex object we chose to mobilize a socio-historical framework. This framework and the major challenges encountered in drawing a picture of such a complex object. In a second and the third part, we will present and illustrate the main conceptual and methodological assumptions of the socio-historical framework. Our illustration will be based on the preliminary results of a research aiming to reconstruct the genealogy and the design process of the guidelines developed in France to address flood risks for nuclear facilities. To conclude we will discuss the strategies of the various actors of the nuclear safety regulatory system that can have significant consequences on the effectiveness of the guidance analyzed and will more particularly focus on the construction of legitimacy. This will led us to bring up some of the issues regarding the use of the results of our research program.

1. INTRODUCTION

In the aftermath of the Fukushima Dai-ichi accident, the Japanese Diet asserted that this accident was a “man-made disaster”. According to this statement, the Japanese diet reports pointed out many weaknesses of the Japanese regulatory bodies in urging Tepco to tackle in a more extensive and effective way seismic and tsunami flood risks (see also Delamotte, 2013). In other words, the accident of the Fukushima Dai-ichi Nuclear Power Plant (NPP) may be regarded as a product of multiple failures of the nuclear risks regulatory system in Japan (authorities, regulators, technical support organisations and operators). Moreover, it appears that the Japanese regulatory system failed to make appropriate use of new bodies of knowledge concerning seism and flooding and to adopt more stringent regulations addressing these risks. A further conclusion that could be drawn from the accident occurring in the Fukushima Dai-ichi NPP is that focusing exclusively on what the NPP operator is doing (or not) to improve the nuclear safety of its facilities may not be sufficient to prevent such events. Indeed, one must also pay a particular attention to the functioning of the whole regulatory system. In order to perform this kind of analysis, we have to include in our scope a wider range of actors and a broader view of safety. It includes various regulatory processes and instruments, ranging from the very first stages of their design to a more extensive examination of their implementation by the various actors concerned. These views led the French institute for radiological protection and nuclear safety (IRSN) to develop a research program dedicated to the study of the French nuclear regulatory system. To carry on the analysis of this particularly complex object we chose to mobilize a socio-historical framework. In the next pages we will present this framework and some of the more distinctive features of our new research program. The use of a socio-historical framework is intended to overcome or deal with three of the challenges generally encountered in drawing a picture of such a complex object. We will describe these challenges and the most important one, from our point of view: the temporality of the processes analysed. This statement will bring us, in a second part, to present the main conceptual and methodological assumptions of the socio-historical framework. In a third part, we will illustrate these assumptions with the preliminary results of a research aiming to reconstruct the genealogy and the design process of the guidelines developed in France to address flood risks for nuclear facilities. The strategies of the various actors of the nuclear safety regulatory system that can have significant consequences on the effectiveness of those guidelines will be discussed: the influence of the various actors over a common strategic agenda and the construction of legitimacy. The latter will led us to bring up some of the issues regarding the use of the results of our research program.

2. WHAT DO WE MEAN BY NUCLEAR RISK REGULATORY SYSTEM?

One of the key concepts in our perspective is the concept of risk regulatory regime developed by Hood, Rothstein and Baldwin (2001). The authors set out two key dimensions for analyzing risk regulatory regimes. The first dimension relates to the three components of a risk regulatory regime that are common to any control system—i.e. ways of gathering information about the system to regulate, ways of setting standards, goals or targets and ways of changing behavior and enforcement to meet the standards or targets. The second dimension relates both to the context of risk regulatory regimes—i.e. the character of the risks being tackled, public attitudes towards risks and the configuration of related organized interests— and the content of regimes—i.e. their size, structure, and "style" (Hood et al., 2001). This framework has been applied by the authors to many regulatory systems including the British nuclear safety regulatory system. The regulatory regime framework and the concepts associated proved to be useful to draw stimulating statements regarding regulatory failures, successes and transformations. Our research program regarding the French nuclear safety regulatory system will be largely based upon this framework as will be seen in the illustration presented below (see part 5).

3. SOME SPECIFIC CHALLENGES FOR THE ANALYSIS

The most challenging dimension of the study of such a system is probably the temporal dimension. Some of the processes analysed are developed through decades but also, and sometime in a relatively independent manner, in very short periods of time. This is what we may call the "temporality challenge". Another important challenge is the one following from the specific, sometimes local and sometimes global, dynamics and transformations of the various processes analysed. Some disturbing but apparently unimportant micro-events result from organizational or institutional changes and can have many concrete but difficult to take into account consequences, in the form of, for example, disruptions or discontinuities. The third challenge is the stratification and inter-organizational one. Several regulatory processes develop through different strata of the same organization, for example through the more central levels and simultaneously through the more local levels, but also and in a parallel manner, through different organizations or institutions (the regulator, its technical support organisations, the operators).

To sum up, the ways the actors make sense of a situation and their very logic in this situation are shaped by historical and organizational factors, which are exerting their influence over various situations and during several periods of time. More importantly, a specific context can have profound effects on the framing of the problem at stake, that is to say on the manner the actors interpret available data and represent the problem to solve, but also on the definition of the solution to adopt, the relative legitimacy of the intervening actors, the knowledge and the instruments to gather, etc. To be able to grasp such elements, we have to build up a picture as accurate as possible of the events and to disentangle the intertwined factors (instruments, knowledge, actors, etc.). Methodological approach: Socio-Historical Analysis

How to define socio-historical analysis? It constitutes an essentially qualitative and multidisciplinary approach using concepts and methods developed by different social sciences: History, Sociology and Ethnography. It rests on a major and apparently quite trivial assumption: social interactions and relationships developed and are situated in time. The main objective of this approach is to reconstruct the genesis of observed social phenomena in an effort to reveal the various key-elements (and more particularly: decisions, beliefs, representations) contributing to their production or forming its context. It's not a matter of linear historical descriptions, but instead an effort to investigate past and present events from the actors' point of view by an accumulation of multiples and heterogeneous materials, criss-crossing small traces or indices, but also hard-facts, textual and verbal materials (reports, notes, emails, discourses, etc.), etc.

Another important stance of the socio-historical analysis is about neutrality, particularly when confronted to the difficult task to interpret and to take into account the values put forward by the actors to justify their behaviours or choices. Representations and discourses of each actor must be analysed, as far as achievable given the quality of the available data, in a similar and symmetrical fashion without distortion or prejudice. Related to this point, is the fact that the analyst must be careful to avoid normative, mechanical or retrospective views of the processes or phenomena to analyse. Indeed, the starting point of many historical analyses is a present or a recent event to explain. A tempting bias for the analyst is then to judge or assess past events from a "now-and-here" or from an "ought-to-do" perspective. The danger of such retrospective or normative biases is thus to introduce false or foreign representations in the supposed line of reasoning of the actor, to attribute him falsely specific intentions or to imbue him with qualities he didn't have. At last, the temptation of the analyst to reconstruct a process in a counter-factual (i.e. the idea that if an action would have been done or not, the world would have been totally different) and in a mechanical fashion can have detrimental effects on the validity of his analysis. In particular, it may lead to overestimate the control of the actor over the situation or, inversely, to underestimate the constraints or uncertainties he encountered. Individuals (but also teams, social groups, organizations) are subjected to multiple influences: influences of forces and structures (for example, arising from an institutional or cultural framework into which their activities fit) over which they have little or no control. However, they have room for maneuvers and can influence their own fate during multiple interactions. Thus, they will manage, with more or less success, to redefine to their advantage (but sometimes not) the meanings attributed to the situations they encounter and to influence the decisions that will be taken. The sense-making process (Weick, 1995) triggered in some situations can have profound and unpredictable effects. It must be taken into account by means of a fine-grained and meticulous analysis which is helpful to build a precise representation of the context in which decisions have been elaborated, taken and implemented. This is made possible by a socio-historical analysis.

The socio-historical analysis framework has been successfully applied in the analysis of: policies, policy-making and policy instruments, but also in the development of institutions, including techno-scientific institutions, in the analysis of the emergence of new ideas or news ways to assess and manage risks, etc. (see Halpern, Lascoumes, Le Galès, 2014; but also Buton & Mariot, 2009). The analysis carried out by Diane Vaughan concerning the decision launch of the Challenger space shuttle may be considered as a suitable illustration of this type of analysis applied to "a man-made disaster" (Vaughan, 1997). More recently, Gisquet & Older (2015), concerning the post-accident crisis management of the Fukushima Dai-ichi NPP, developed a fine-grained description and analysis illustrating a social-historical analysis framework and supporting the assumptions developed above.

4. ILLUSTRATION: A SOCIO-HISTORICAL ANALYSIS OF THE FLOOD RISKS REGULATION

We have chosen to focus one part of our research program concerning the French nuclear safety regulatory system on one of the three components described above: the process by which standards are set. As it will be shown in this part of our paper, the major aim of these instruments (regulatory instruments) and of the knowledge (regulatory knowledge) is to guide nuclear facilities operators during two main stages of their efforts to tackle specific hazards: its identification and characterization stage and the design of protections against these hazards. These guidelines have profound and multiple effects. They affect not only the design of nuclear facilities, or the criteria used and the way the safety of nuclear facilities will be demonstrated, but also the ways in which actions defined by the operator will be assessed and their implementation controlled by the regulator. The descriptions provided below concerning the design and the implementation of a regulatory instrument provide us with an opportunity to illustrate further what is a socio-historical analysis and the challenges associated. This research began with an important work aiming to reconstruct the genealogy of the guide developed in France to assess flood risks for facilities over the period between 2005 and 2013. Indeed, this guide replaced another standard published in 1984.

This work highlights important evolutions in the way flooding risks have been conceived, as well as the important role played by Le Blayais's NPP flood event, in December 1999. This work also highlights the importance of the institutional developments related to the progressive independence of the safety authority and institutional expert and the promulgation of the law on transparency and nuclear safety (TSN law, 2006), with, in particular, the creation of the nuclear safety authority (ASN) in France (2006).

In this example, both stories are superimposed over the same period:

- A story of the dynamics of the risk regulatory system;
- A story of the genesis and the dynamics of the guide used to analyse flood risks.

We make the assumption that these two dimensions are intertwined but that organizational, regulatory and political environments have a major influence on the framing, design and implementation of the regulatory instruments.

We start from the idea that studying a regulatory instrument (The floods risks guide) provides information about the evolution of the regulatory system (Lascoumes & Simard, 2011), the latter also being influenced by an institutional and policy framework. The major part of the work presented in this paper is based on historical archives and interviews. The data allowed us to unfold and draw up the genesis and dynamics of the rulemaking process regarding the risk of external flooding, within the French regulatory system of nuclear safety.

4.1. Genesis of a regulatory instrument in the context of the years 70-80

The design of the first guide on external flooding is marked by many technical, political and institutional challenges:

- The development of a large nuclear program called “Messmer’s plan[7]” (1974), led to the construction of many PWR between the mid-70s and mid-80s.
- The birth of the official expert of nuclear safety, the IPSN (Protection and nuclear safety Institute) in 1976 and a regulator, the SCSIN (Service Central of safety of nuclear facilities), in 1973 led to a 'tripod' safety system: Regulator / official expert / operators.
- The birth of the SCSIN generates the design of regulatory instruments called “Fundamental Safety Rule” (FSR) that will take an important place.

These FSR, designed at the end of the 1970s, were based on the models of the USNRC Regulatory Guide and "Safety Guides" of the IAEA. At that time, France had no law to regulate nuclear facilities, unlike USA or Germany. The French regulation was therefore based on a few texts without proper legal status. The design process of the FSR on flood risks can be characterized by many technical exchanges between IPSN (IRSN ancestor) and the specialists of the NPP operator EDF in Hydrology. Through two meetings, in 1982 and in 1984, the Permanent Group of Experts (PGE) formulated a formal advice concerning the FSR. The

7 Messmer’s plan, named by Prime Minister Pierre Messmer, is a vast power program of building 13 900 MW PWR.

existence of the PGE, a rather unstructured group during the late 60s, was institutionalized by a ministry decree in 1972. The PGE included several stakeholders directly concerned by safety of NPP including Operators, ministries, IPSN and SCSIN representatives deliberating on important issues for safety.

The FSR was based on EDF's work including a deterministic framework resting on various concepts like scenarios and safety margins. A retroactivity principle, proposed that the EDF NPP already built are also concerned by this FSR. Indeed the FSR has been elaborated while the major part of EDF NPP was already under construction. To overcome this difficulty, additional procedures or substantive provisions (as dikes) have been built in some sites. This was especially true for Le Blayais NPP where a dyke had been built in 1983-1984. Nevertheless, EDF anticipated the adoption of the FSR. This was possible because EDF was the most important contributor to the design of the FSR. This matter of fact raises one interesting issue regarding the design of safety regulatory instruments: their temporality. The production of the first French regulatory instrument regarding flooding could be described as non-linear, that is to say as following the design of the French NPP and as paralleling their construction.

Here, some contextual elements can explain peculiarities of FSR design and implementation. The choice of the types of implementations (procedures, provisions…) depends on temporality of construction of each NPP. There is also an anticipation of the implementation even before the publication of FSR. An important conclusion that can be drawn from this analysis is that stages of implementation of flood risk provisions and design of the RFS are intertwined.

4.2. The flooding of "Le Blayais" NPP and organizational changes of nuclear safety in the early 2000s

Between the mid-1980s and the late 2000s, flood risks appeared to be a rather minor issue. Indeed, during this period, no event is questioning the approach set in 1984. Following the TMI and Chernobyl accidents, new issues were highlighted in nuclear safety: human factors, safety culture, crisis management… Moreover, the lack of major events or other significant operating experiences concerning flooding during the period "1984-1999" explained that the nuclear safety experts did not challenge this issue.

In contrast, the 1990's marked a willingness to change the organization of nuclear safety regulation by fostering transparency and independence. In 1998, a report[8] commissioned by the Prime Minister recommended the separation of the IPSN from the CEA (Atomic Energy Agency), the creation of an independent safety authority and the implementation of a new legislation in the field of nuclear safety. This report marked the beginning of major and profound changes in the organization

8 J-Y Le Déaut, « Le Système français de radioprotection, de contrôle et de sécurité nucléaire », 1998

and regulation of nuclear safety in France in a particular national political context[9]. It was also at the end of the 1990's that occurs, one of the largest and most publicized events in the history of French nuclear safety, at "Le Blayais" NPP. After the Martin's storm, in December 27, 1999, the flood of "Le Blayais" led to the loss of external power sources and of two essential safeguards systems[10]. However, the situation was quickly stabilized and the accident avoided.

Lessons learned from this event pointed out inadequacies of the ways the French NPP operator took into account flood risk[11] during the previous decades, both in terms of the characterization of flooding hazards and in terms of protection means. As a further evidence of the importance of "Le Blayais" event, a report of the French parliamentary office about scientific and technological assessment and choice (OPECST)[12] tried to figure out and to describe the sequence of events. This incident also raises questions about the regulatory system. The history of "Le Blayais dike" gives us keys to understand the evolution of the relationship between regulator, TSO and operators. Since 1997, the raising of the dike of "Le Blayais" NPP was considered by EDF. Finally, the operator decided to wait until the early 2000s, and the "ten-yearly in service inspection" of the NPP, to engage and achieve the improvements planned, despite insistent and repeated requests of the regulator. This episode is significant of the lack of coercive power of the regulator during the period preceding the event, and the inability of the regulator to enforce its decisions, partly due to insufficient regulatory instruments. After 2000 and "Le Blayais" event, the safety authority was able to take more coercive measures (in the form of final notices for example, to issue a summons for non-compliance, as this was the case for the classical industry[13]). Despite this fact, it should be noted that even if EDF had conformed itself to the FSR and had raised the dike in time, it would probably not had been enough to prevent the flood of December 1999.

This process emphasizes a change in the relationship between the regulator and operators. If technical dialogue remains the preferred method by the various stakeholders, the regulator hardened its regulation policy with new instruments that are published on the ASN internet website. This shift can be viewed as a break with past practices. According to our analysis, the publication appears to be a new way to

[9] It was Dominique Voynet, Green Party leader and Minister of Spatial Planning and the Environment (1997 to 2001), who wrote the first draft of the TSN Act in 1999, when Greens and socialists were in government.

[10] Injection system and containment spray system.

[11] The FSR does not take into account additional phenomena such as wind intensity.

[12] C. Birraux : « Rapport sur le contrôle de la sûreté et de la sécurité des installations nucléaires ». Première partie : analyse des incidents survenus à la centrale nucléaire du Blayais lors de la tempête du 27 décembre 1999: enseignements sur le risque d'inondation des installations nucléaires.

[13] Moreover, following EDF delays in studies on the stability of the new Blayais dyke, the regulator delivered his first formal notice in June 2000 and made it public.

exert a media pressure on the operator and a way to avoid the use of administrative or financial penalties.

To return to the flood risk, then two paths seemed opened after the return on experience drawn up from the events occurring in “Le Blayais” NPP:

— A Deterministic approach named "Rex-Blayais" to assess flooding risk designed and presented by EDF;
— A Probabilistic Safety Analysis (PSA) on the external flooding risk called for by the IRSN experts.

For technical feasibility reasons and a willingness of continuity on the part of EDF, a deterministic approach, called "Rex Blayais” has been developed by EDF to analyse the flooding hazard and protection of its NPP sites. In parallel, several modifications and expertise works to improve the protection of the NPP against floods were launched, at the same time as the design of a new approach. The Rex-Blayais approach multiplies flood’s scenarios and offers additional measures protection based on the defence in depth principle. This approach was validated by the safety authority in 2001.

At the same time, institutional and organizational changes occurred with the separation between CEA and IPSN and the creation of a new public institution called IRSN. Thus, expertise gained a reinforced independence and autonomy. The creation of an independent regulatory authority (ASN) and the Transparency and Nuclear Safety Act (TSN law) in 2006, marked another remarkable shift in the institutional functioning of nuclear safety. Moreover, the new regulatory authority decided to begin an in depth reshuffle of its regulation. At the top of this hierarchy, we find the Environmental Code and the TSN Act, and at the bottom the “safety decisions” of the ASN and its technical guides. These guides will replace gradually the old FSR designed in the 70’s-80’s. The design of the new guidelines must be put back in the context of a movement towards Europeanization of nuclear safety regulations and practices, especially promoted by the WENRA and its “safety reference levels”. This movement explained the adoption by the ASN of an explicit probabilistic objective of 10^{-4} per year occurrence of a feared event for each flooding scenarios defined in the “floods guide”.

Indeed, guided by EDF's Rex-Blayais approach and by other flooding events, the ASN decided to launch the design of a "Floods Guide" intended to replace the FSR I.2.e. Dedicated to this task, two groups have been formed: a group named "Phenomena", led by IRSN, and a group named "Safety objectives", led by ASN. In addition to the classical nuclear stakeholders (authority, Expert and operators) the “phenomena” group involved laboratories and French institutes specialized in water management and climatic hazards. Flooding risks became an increasingly important issue for the IRSN whose skills on this theme have been renewed and strengthened with the addition of new scientists and the development of new knowledge.

Another important innovation inaugurated by this design process has been the implication of the public which was invited to question, criticize or comment a draft version of the guide. As in 1984, the design process ended with the validation of the guide by the PGE (2012), followed by the validation and publication by the nuclear safety authority.

To sum up, we emphasized the multiple effects of “Le Blayais” incident. The most important one is probably the adoption by the regulator of a more coercive and stringent set of instruments in the early 2000s which were devoted to a better enforcement of its decisions. We made the assumption that these new instruments were a response to the "crisis" initiated by the flooding of “Le Blayais” NPP and of the immediately preceding events.

We can also connect the launch of the floods guide to a new organizational context. The creation of the ASN in 2006 implies a regulatory clarification and an important update of its regulatory powers and renewed legitimacy. The “floods guide” appears to be one of the first guide of the ASN and appears to inaugurate new ways in designing regulations. Moreover, because of the agenda setting of its design, this guide appears to be a rather consistent and effective answer to the flooding of “Le Blayais” NPP. The floods regulation had already been subjected to an important test in the form of the Rex-Blayais approach and assessment.

4.3. The flood risk after Fukushima Daiichi accident

The design process that begun in 2006 and ended with the publication of the guide in 2013 was marked by the Fukushima accident which challenges the management of flood risk and the choice of protection measures. The guide was not actually amended by Rex of the accident because at the same time, ASN conducted “SCA” (Safety Complementary Assessment), following the European directorate asking to implement “stress tests” on nuclear facilities. The stakeholders seemed to be reluctant to engage in another long, effortful and quite risky process aiming at revising the design of the near-finished “floods guide”. SCA then allowed the creation or updating of some safety concepts (Creation of “Hard Safety Core”, consideration of “Extreme hazards” and of “cliff-edge effects”). Once again, the time was accelerating for several months and, between 2011 and 2015, one can observe several ASN decisions related to the flooding risk. At the same time, the GPE validates the flooding guide (2012) and ended up of its design process.

After the publication of the guide, in 2013, there was a complicated situation with different instruments addressing the same risk. While the implementation of the Rex Blayais process was still in progress, the SCA process was entering a first phase of implementation. In the same time, IRSN experts and the ASN pushed for rapid implementation of flood guide. Furthermore, in 2012, a new decree (the INB decree of 2012) clarified fundamental principles in regulatory legislation including the concept of "proportionate approach” introduced in the “Floods guide”. The introduction of this concept allows some flexibility aiming at differential provision implementations of the new regulation, depending on the safety issues of facilities.

The end of SCA implementation (2017-2018) will finally match with the beginning of the implementation of the floods guide. SCA influences the implementation of the guide: indeed, SCA provide answers to many of the recommendations of the guide for NPP. In the other hand, SCA regarding flood on specific plants take the recommendations of the guide. Finally, after Fukushima, the idea of launching the implementation of PSA regarding external flooding, abandoned after “Le Blayais” incident, seems restarted at IRSN.

Since 2011, there is a real acceleration of temporality on the topic of flooding, as was the case after “Le Blayais” incident. These periods contrast with quieter periods, like between 1984 and 1999. The analysis of lessons-learned on the subject seems to encourage the design or revision of instruments. On the other hand, it is also the lack of lessons-learned, which sometimes leads to put a subject in the background, which was dangerous in the case of “Le Blayais”. This is an important limitation of an approach based solely on experience feedback emphasized by our socio-historical analysis. It appears difficult to change procedures without incident or accident.

From the point of view of the design of the instruments, we note an enlargement to experts and scientists communities that were rarely involved in such design processes and that stood outside of the “nuclear safety world”.

4.4. First issues

The question of the temporality appears as essential. It allows highlighting the difficult coupling of a regulatory model in the long running time and the related emergency issues constituted by major accidents or incidents. These phenomena make the process nonlinear and may also destabilize institutions.

Following this idea the various actors of the nuclear safety regulatory system develop strategies to gain or preserve their influence over a common strategic agenda. In this case, agenda setting of new instruments is particularly interesting to analyse (Kingdon & Thurber, 1984). It can be a medium to long term strategy (Floods Guide) but also create windows of opportunities, open after accidents and incidents (Rex-Blayais approach, ECS post-Fukushima and PSA external flooding). Finally, socio-historical analysis also enables us to understand how the international context and political events influence organizational and regulatory system changes. All these events can inflect regulator towards more flexibility versus more coercion. Finally, this type of analysis is also a way to promote a longstanding culture of nuclear safety and to step back on current safety practices.

One of the fundamental issues raised by the above presentation is the question of the effectiveness of the regulatory instruments which genealogy has just been presented. The analysis of temporality allows us to identify some specifics:

— The duration of the design of the instruments asked us about the potential delay of the instruments, (in terms of knowledge and methods) at the time of their implementation in facilities. This effect is sometimes thwarting thanks to the anticipation of the implementation by operators but does not respond to the question of the validity of an instrument over several decades (like FSR).
— Incidents and accidents can also disrupt or accelerate the design process. Next the impact of these events, stakeholders can choose to integrate lessons learned into the instrument current design or create new instruments (as is the case with the post-Fukushima ECS).
— Effects of the instrument can be observed from design stage because operators often anticipate the implementation.
— We can observe the existence of "turning point" which explains, in micro scale, the change from an instrument to another but also, to the more macro scale, more profound changes of the regulatory system. In this sense, the late 90s and early 2000s corresponds to a point turning, whose Le Blayais incident is one of the engines.

5. PERSPECTIVES AND CONCLUDING REMARKS

One of the fundamental issues raised by the above presentation is the question of the changes produced by the regulatory instruments and, more importantly, the ways it can do so. We would like to conclude about the influence of such instruments and about an important condition of this influence: legitimacy.

An important assumption concerning legitimacy is that the actors of a regulatory system strive to construct, gain and preserve legitimacy. Legitimacy is an important social resource for individuals but also for organisations and institutions. It is a matter of (individual) representations and perceptions. In other words there is no legitimacy *per se*. This is neither an objective, nor a simple or quantifiable property. On the contrary, it is the product of a plurality of utterances, specific to an institutional framework, a slow and a patient discursive construction of interconnected, credible and supportive utterances. However, crisis, uncertainties, controversies and disputes can undermine the legitimacy of a particular institution but also the legitimacy of the whole institutional framework at stake (Boltanski, 2009). In such circumstances, institutions should reinforce specific perceptions in the mind of the stakeholders (including the public) to counterbalance the undermining effects of the various representations of the targeted institutions threatened by the ongoing crisis. Starting from this point, we would like to focus on two particular modes of legitimation that have been emphasized by the description of the design process of the guidelines concerning flood risks. The first one is the knowledge-based legitimacy. An utterance is accepted because it has been subjected to a strict, careful and contradictory examination by the actors. This type of legitimacy is firmly linked to an important form of authority in our civilization: the authority of Science. The second form of legitimacy is the procedure-based legitimacy. This type of legitimacy rest on legitimating principles described in various documents (in France, see for example Hermitte, 1997, and Joly, 1999) and borrowed, once again, from Sciences, but also from a second important form of authority in our civilization: the authority derived from our democratic institutions. For example, an expertise must conform to different rules: it must be collective, contradictory, it must also mention the objections and advices of the minority, secure independence and preserve transparency. One must emphasize that these modes of legitimation are not mutually exclusive. On the contrary, they appear to be quite complementary in the various strategies adopted by the actors participating to the nuclear safety regulatory system. In the long term, a regulatory system have many opportunities to build conventional agreements, procedures or arenas (for example: permanent expert groups, administrative procedures), or to adapt inherited ones from its regulatory systems ancestors (in France those derived from the regulation of the classified plants). Concerning specifically nuclear safety regulatory system, as can be seen in the preceding part, one central, recurrent and probably inescapable legitimizing instrument, is the permanent expert group. It is a semi-permanent arena where contradictory points of views can be expressed freely, fed with the knowledge and the analyses carried out by the IRSN and by the NPP operator. The experts most frequently gathered in this arena represent the stakeholders directly involved in nuclear regulation and, less frequently, people coming from other parts of the society, involved or concerned but less directly connected to the nuclear regulatory system. The recommendations and other utterances expressed and accepted in this arena, no matter their origin and who is uttering, can be seen as institutionally validated and legitimized as a suitable utterance. As can be seen in the previous part, each important regulation is subjected to this examination. This was the case for the various recent regulatory instruments addressing flood risks. A major gain was anticipated by the actors implied in its design and has probably been obtained in the form of institutional and organisational influence.

One important aim of a HOF analysis is to define useful recommendations to improve the performance and the effectiveness of the activity at stake. A quite straightforward question of the actors involved in the conception of a regulatory instrument or decision, and this was the case for the guidelines concerning flooding risks, is: How can we ascertain that a regulatory instrument or decision will be implemented? What are the important features of a regulatory instrument or decision that can contribute to this result? We hypothesized that legitimacy is one of these important features and we described briefly how it can be gained or threatened, in general. However, the production of more specific recommendations requires fine-grained analysis. These analysis are necessary to improve our knowledge about the strategies of the actors involved and about the institutional framework in which the conception of a regulatory instrument (or of a decision) takes place. We also need to improve our knowledge about the genealogy of past regulatory instruments (or decisions) and about the specific context and events influencing there conception, about the procedures adapted or specifically developed, etc. This is the aim of an extended HOF framework based on socio-historical analysis and this is the aim of the research described above. We are reasonably optimistic concerning the fact that this important work will be fruitful to improve the French nuclear safety regulatory system.

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BIBLIOGRAPHY

BOLTANSKI, L., De la critique: Précis de sociologie de l'émancipation. Éditions Gallimard, Paris (2009).

BUTON, F. et MARIOT, N., Pratiques et méthodes de la socio-histoire. Presses universitaires de France, Paris (2009).

DELAMOTTE, G., Fukushima, crise d'un modèle de gouvernance. Critique internationale, (2), 107-117 (2013).

GISQUET, E. & OLDER, M., A Human and Organizational Factors Perspective on the Fukushima Nuclear Accident-March 11-March 15, 2011 (2015).

HALPERN, C., LASCOUMES, P., & Le GALES, P., L'instrumentation de l'action publique: controverses, résistances, effets. Presses de Sciences Po, Paris (2014).

HERMITTE, M. A., L'expertise scientifique à finalité politique. Réflexions sur l'organisation et la responsabilité des experts. Justices, 8, 79-103 (1997).

HOOD, C., ROTHSTEIN, H., & BALDWIN, R., The government of risk: Understanding risk regulation regimes. Oxford University Press, USA (2001).

[14] Amélioration de la gouvernance des organisations et des réseaux d'acteurs pour la sûreté nucléaire.

JOLY, P. B., Besoin d'expertise et quête d'une légitimité nouvelle: quelles procédures pour réguler l'expertise scientifique? Revue française des affaires sociales, 53, 45-52 (1999).

KINGDON, J.W. & THURBER, J.A., Agendas, alternatives, and public policies. Boston : Little, Brown (1984).

LASCOUMES, P., & SIMARD, L., L'action publique au prisme de ses instruments (Vol. 61, No. 1, pp. 5-22). Presses de Sciences Po (2011).

VAUGHAN, D., The Challenger launch decision: Risky technology, culture, and deviance at NASA. University of Chicago Press, Chicago (1997).

WEICK, Karl E., Sensemaking in organizations. Sage (1995).

HTO APPROACH APPLICATIONS IN ROSATOM CICET

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Abstract

The paper shows ROSATOM Central Institute for Continuing Education&Training experience in HTO approach application in in safety culture issues and the institute activity starting from methodological aspect of safety culture concept to special training course development and application.

1. INTRODUCTION

ROSATOM's Central Institute for Continuing Education & Training (hereinafter - CICET) implements activities in the areas of nuclear facilities personnel training and relevant research.

CICET has a strategic goal to get the safety culture competence center for ROSATOM organizations. It will do more effective their activity in continue safety culture improvement in accordance with [1].

Safety culture ensures for nuclear organization to achieve both the business goals and high safety level. Safety is a state of ergatic system when influence of internal and external factors impact does not lead to its operation deterioration or stoppage. Let's consider an interface between "Safety" and "safety culture" concepts (Figure 1).

Following the definition of safety one can see that there are many factors external to the organization: national culture, political situation, economic situation in the state, relations with regulatory body, stockholders, contractors, suppliers, climate in family and so on. Internal factors are distributed in "Human-Technology-Organization" (hereinafter - HTO) model components. On an individual level we have three factors: attitudes, knowledge and skills. This set is defined by motivation-attitude regulation of activity theory [2]. Organizational factors block (based on [3]) consists of those following components: goals and strategies, management processes, operational processes, organizational climate and knowledge, communication, resource allocation, co-ordination of work, procedure determination and inculcation, organizational learning and so on. Technology factors block include: man-machine interface, work environment, work sets, technological processes, details, protection and others. HTO factors effects are reflected on all levels of the organizational culture model [4]. It allows developing a model of safety culture which is a part of the organizational one. The safety culture model is a composition of ideal image of reliable personnel with right attitude to safety, corresponding professional behavior, effective work implementation and image of ideal organizational behavior to provide safety and form reliable personnel. The images could be expressed in terms of expected indicators. Of course, the model will be different for operating, R&D or regulatory organizations because there are distinguishes in technology and organization factors.

Dramatic history of world nuclear energetics shows that HTO constitute the main assembly of factors influencing safety. Individual work performance and organizational factors (or organizational behavior) display are visible, "artefact" part of the organization culture. Approaches and tools to enhance human and organization behavior are under CICET activity focus.

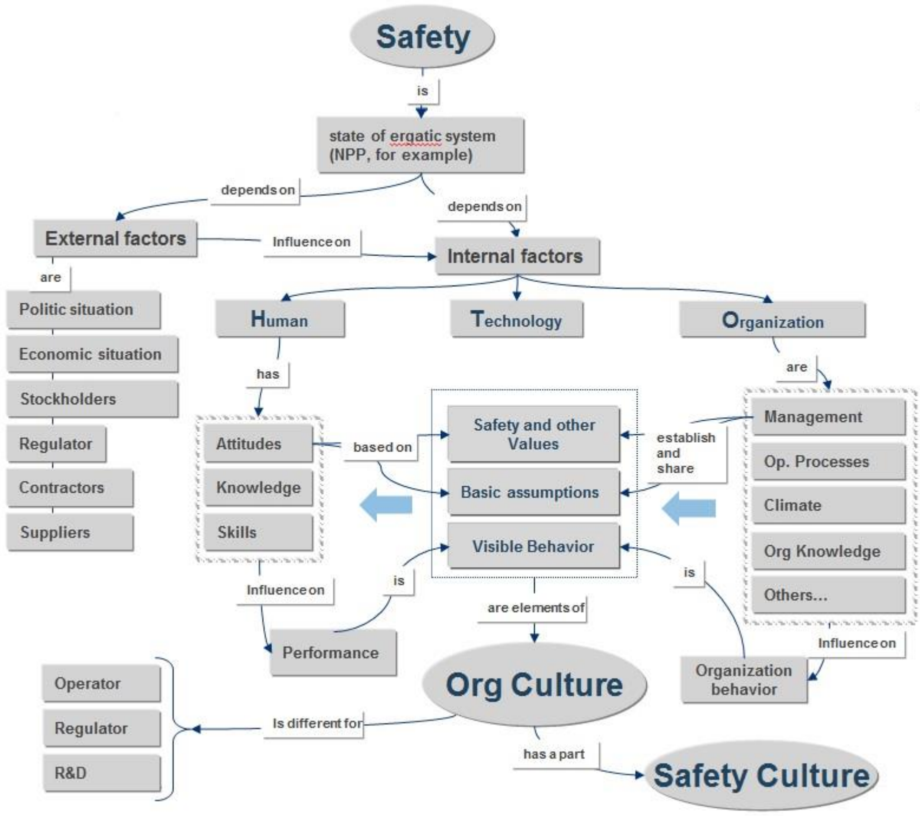

FIG. 1. "Safety – Safety Culture" interface.

So, we can see two main sources of "culture waves" within the organization – individual and organizational factors. In order to provide strong safety culture we need to foster in personnel right attitude for safety and adjust organization factors in order to create an environment to educate, to train of "cultured", safety committed worker.

2. EDUCATION AND TRAINING

Education, training means translation of meaning. There are three main ways how implement the process: meaning genesis during practical activity, meaning rearrangement during joint activity and meaning appropriation during pointed meaning translation (training, mass media and so on).

Each of the way realization needs competences and tools to translate safety related meanings of professional domain. To satisfy the needs CICET has developed and apply training course.

The training process is based on the programme describing the concept of safety culture, methodology of safety culture management in nuclear facilities, the principles of strong safety culture, processes and tools to improve safety culture for all stages of the nuclear facility life circle, best international and Russian practice in the domain.

The course is useful for those categories of trainees: managerial personnel of nuclear facilities, regulatory bodies, human performance and human factor specialists, specialists of nuclear power industry.

The length of the course is 80 hours, including final examination. The set of training courses implementation allows to form understanding: What safety culture is? What is the safety culture model (attributes, indicators) for the organization? How organize safety culture enhancement system? Who (roles, resources) must implement the activity? What methods and tools should be used?

The course consists of the following training modules:

Module 1: "Safety Culture in nuclear facilities concept". The module contains three main topics: history and modern description of safety culture concept; requirements to safety culture on government, senior management, line managers and individual levels; safety culture characteristics in complex social technical systems.

Terminal training objective of the module:

- to describe the safety culture concept and the main approaches of its management.

Enabling training objectives:

- to explain modern view on safety culture, safety culture applications in nuclear facilities, safety culture characteristics;

- to describe safety culture influence on a personnel reliability and an organization effectiveness, factors influencing on human reliability, human performance instruments, organizational and psychological factors of safety culture;
- to explain the ways of safety culture enhancement in a nuclear facility;
- to explain leadership for safety.

Module 2: "Safety culture enhancement in high risk facilities". The module contains the following topics: safety culture enhancement organization; safety culture enhancement implementation and the activity assessment and further improvement.

Terminal training objective:

- to describe the methodological knowledge about safety culture management process, to train in the safety culture management process introduction, in the tools to manage safety culture.

Enabling training objectives:

- to explain the management for safety;
- to explain systemic safety and managing for the unexpected;
- to explain the key principles of safety culture continuous improvement;
- to describe the main components of safety culture management system;
- to explain safety culture management process description, development of regulations and guides, roles, responsibilities, tools and performance indicators for safety culture management implementation;
- to list the basic methodological documents for safety culture;
- to explain safety culture management integration into the management system;
- to explain practical methods of safety culture commitment formation;
- to describe the organizational (corporate) safety culture model;
- to describe safety culture assessment methodology;
- to explain safety culture assessment, self-assessment tools;
- to describe leadership for safety.

Module 3: "safety culture enhancement: human performance improvement". The module contains two main topics: personnel reliability concept and system to support personnel reliability in nuclear facilities.

Terminal training objective:

- to describe theoretical and methodological knowledge on human performance, personnel reliability and their Contribution in safety culture, to train in human performance improvement tools application.

Enabling training objectives:

- to explain the human performance;
- to explain personnel reliability in nuclear industry;
- to describe the link between safety culture and human performance;
- to explain engineer and psychological approach in human performance management;
- to explain organizational activity on human performance management;
- to describe human errors;
- to describe factors influencing human performance;
- to describe international experience in human performance management;
- to explain personnel reliability support activity in nuclear facility;
- to describe the tools to improve human performance;
- to explain the human performance improvement tools use;
- to explain the human errors analysis procedure.

Module 4: "Safety culture enhancement: process approach". The module contains those main topics: the process description, development and integration to the organization management system; safety culture enhancement regulations and guides development; safety culture enhancement process introduction.

Terminal training objective:

- to describe methodology of safety culture enhancement process development and implementation, to train in safety culture model (set of indicators) development.

Enabling training objectives:

- to explain the main components of safety culture enhancement process;
- to explain how describe it in process approach;
- to describe safety culture model development procedure;
- to describe the process regulations development, to explain roles of the process;
- to explain how integrate the process into the organization management system;
- to describe the process implementation plan development.

Moreover, CICET starting from 2012 holds safety culture International Summer School on regular base. The mission of the school - promotion and development of the methodology and safety culture practice in organizations that use dangerous technology to provide high reliability and effectiveness their operations.

The school highlights many practical applications inside those following topics:

- modern view on safety culture;
- safety culture influence on a personnel reliability and an organization effectiveness;
- safety culture continuous improvement system;
- safety culture assessment approaches and tools;
- practical method on safety culture commitment formation;
- leadership for safety;
- management for safety;
- nuclear knowledge management in safety culture context;
- systemic safety and managing for the unexpected.

Leading experts from different IAEA member states participate in the school work as lectors.

Most training courses developed base of on system approach, field researches and methodological applications. For example, CICET has developed Ontology of factors (based on HTO approach) influencing on human performance (Figure 2).

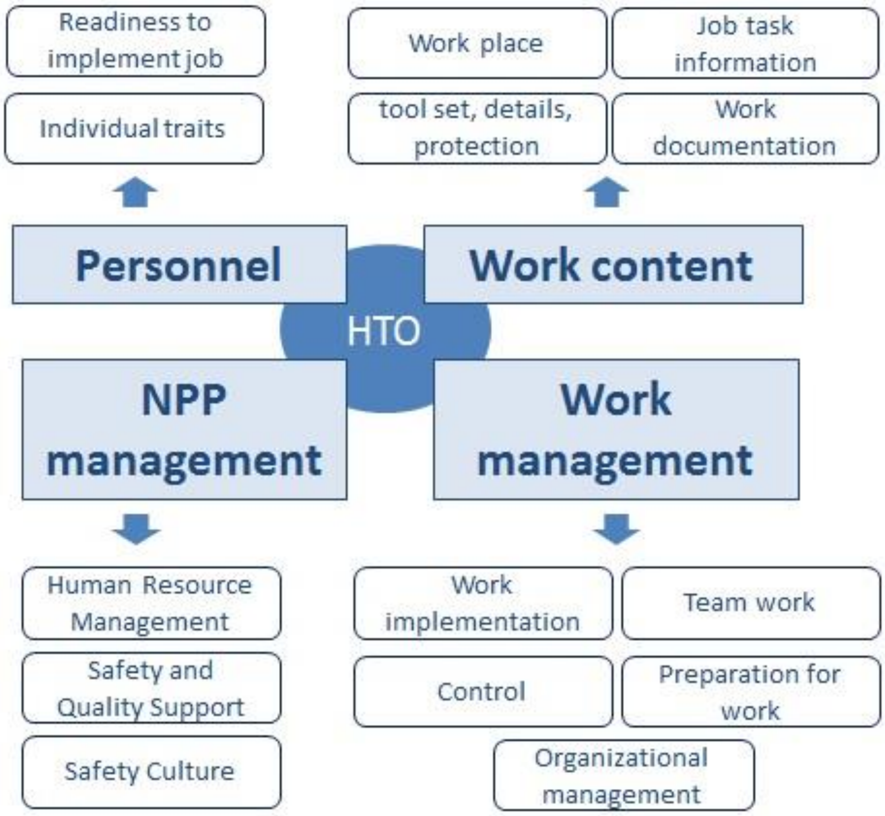

FIG. 2. Ontology of factors influencing on human performance (group level of classification).

One can see on the Figure only group level of those factors classification. Total amount of factors distributed in the groups is around 50.

The model is applied now to implement inspection activity and could be used in training materials development, root cause analysis, risk management and safety culture models building.

REFERENCES

[1] STATE POLICY BASICS TO SUPPORT NUCLEAR AND RADIATION SAFETY UP TO 2025, Approved by the President of Russian Federation in 2012.

[2] ABRAMOVA, V., Organizational psychology, organizational culture and safety culture in nuclear industry, Obninsk, SRC “Prognoz”, Volumes 1 (2009), 2 (2011).

[3] OECD NUCLEAR ENERGY AGENCY, Longitude Verification of the Organizational Factor's Influence on Nuclear Power Plant's Reliability, in Identification and Assessment of Organizational Factors Related to the Safety of NPPs, Nuclear Safety NEA/CSNI/R(98)17 Feb 1999, Expanded Task Force on Human Factors Principal Working Group No. 1, Volume 2.
[4] SCHEIN E., Organizational Culture and Leadership, Josey-Bass Business & Management Series (2010).

THE REGULATORY BODY'S PERSPECTIVES ON SAFETY CULTURE

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Abstract

Safety Culture has traditionally been treated as an issue primarily related to the operators of nuclear (and other) installations. As the Fukushima accident clearly highlighted, though, it is not enough to focus merely on licensees. There is a need to adopt a broader view on the entire overall system of stakeholders and on how the participants in this system mutually influence each other. Among the stakeholders who play an important role in the overall system and interact with the licensees are the regulators. They are concerned with the safety culture of the organisations they oversee and develop approaches and tools for oversight in the domain of safety culture. However, this is only one perspective. The regulators also deeply impact the licensees' safety culture with their own safety culture. Therefore, the regulatory body needs to take different perspectives on the issue of safety culture: (1) Safety culture as an oversight issue, with the need and challenge to develop suitable approaches and tools for oversight on the licensees' safety culture, and (2) safety culture as an issue of self-reflection, in order to understand how the own (regulatory) safety culture influences the licensees' safety culture and to develop and apply appropriate regulatory approaches capable of positively influencing the licensees' safety culture. The paper illustrates how ENSI has embraced these two perspectives on safety culture. ENSI's approach and practices on oversight of safety culture is presented, as well as ENSI's project which has been conducted over three years after the Fukushima accident in order to initialise and institutionalize a self-reflection process on its own safety culture.

1. INTRODUCTION

Since the concept was coined after the Chernobyl accident in the beginning of the 1990s, safety culture has traditionally been treated as an issue primarily related to the operators of nuclear installations and other facilities bearing risks for people and the environment. Although there is still a lack of consensus on many theoretical as well as methodological and practical aspects of the concept, there is meanwhile a large agreement among scholars and practitioners on the importance of a good safety culture in relation to nuclear installations.

As the Fukushima accident clearly highlighted, though, it is not enough to focus merely on licensees. The responsibility for the accident cannot entirely be attributed to the operator of the Fukushima Daiichi Nuclear Power Plant, the Tokyo Electric Power Company (TEPCO). Rather, it is shared by a large number of organizations and groups which, together, developed over the decades the preconditions eventually allowing the accident to happen [1]. In fact, these organizations and groups collectively developed and reinforced a deep and strong belief in the robustness of the nuclear installations against accidents caused by natural disasters and in the factual impossibility of natural disasters with the magnitude of the earthquake and tsunami that struck the Fukushima Daiichi site on the 11th of March 2011 and, hence, found them technically and organizationally insufficiently prepared [2].

There is therefore the need to adopt a broader, more systemic view. Each organization is always embedded in a greater context which comprises other stakeholders with similar or different functions (such as operators, manufacturers, contractors, regulatory authorities, international organizations, research organizations, as well as political institutions, the media and the public etc.) that are interrelated and mutually influence each other. Each participant in this overall system is characterized by its own (safety) culture, but at the same time it is part of the overall culture based on general societal norms and values which in turn it contributes to further develop over time by acting in its role and interacting with the other stakeholders (cf. Fig. 1).

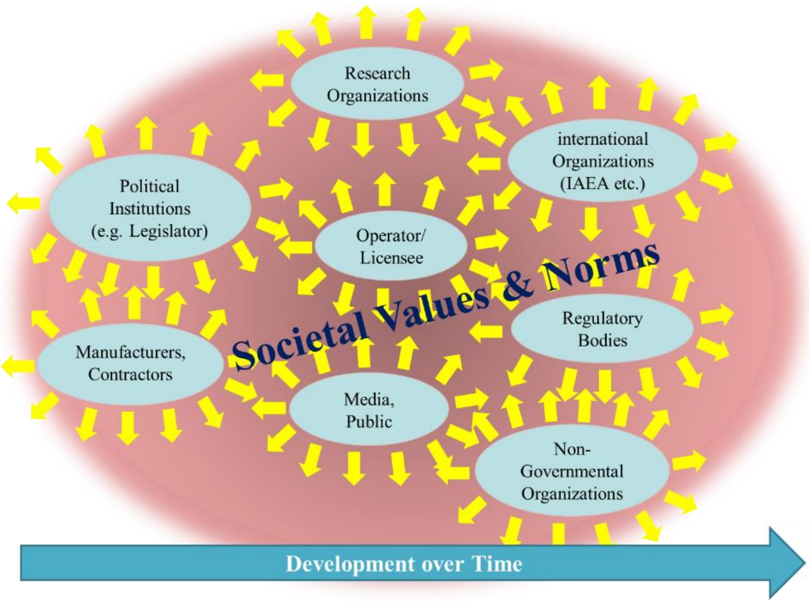

FIG. 1. Overall System of Stakeholders.

As a consequence, when thinking about an organization's (safety) culture, one needs to consider that it cannot be regarded and understood in isolation. Rather, it has to be considered in the context of the overall culture, being at the same time an outcome as well as a determinant of this overall culture.

Among the stakeholders who play an important role in the overall system and interact with the licensees – as well as with many other stakeholders – are the regulatory bodies. Their role within the broader system, particularly in the domain of nuclear energy, is seen as crucial in assuring protection of people and the environment from harmful effects of ionizing radiation to the point that they have been assigned a legal mandate by society to regulate and oversee the operators of (nuclear) installations. Within this mandate, the regulatory bodies are concerned with the safety culture of the organizations they regulate and oversee and to this end they develop and apply approaches and tools for oversight. However, this is only one of the perspectives the regulatory body must take concerning safety culture.

The regulatory body also deeply impacts the licensee's safety culture. The underlying values and norms concerning safety shared by the regulatory body's staff which manifest themselves in their regulatory approaches and activities, in the nature of relationships they cultivate with the licensees, in the issues they do or do not address in oversight etc. influence the licensees' safety culture, either positively or, in the worst case, even negatively. In other words, the regulatory body's own safety culture has an important effect on the licensee's safety culture. Conversely, the licensee's (safety) culture which manifests itself in the licensee's behavior, in its way to manage safety issues and to respond to regulatory requirements, in the condition of technical equipment, in the quality and use of documentation and procedures, in the importance attributed to competence of the staff etc., influences the regulatory body's own behavior, products, values and beliefs. Moreover, the regulatory body's own (safety) culture is influenced by the other stakeholders of the overall system, by the legal and institutional framework, by the general values and norms that are predominant in the broad society, etc. and can therefore not be considered singularly, without considering the relativity of its acting and role against the background of the overall system of values and norms. For this reason, besides considering safety culture as an issue for oversight and regulation, the regulatory body also needs to consider safety culture as an issue of self-reflection: It must understand its role and impact within the overall system of stakeholders, how it interrelates with the other participants of this system and how it is itself influenced by them and by the overall culture.

This entails that the regulatory body develops and cultivates a questioning attitude on its own work and that it constantly scrutinizes its own culture, how it changes over time and especially how it influences the safety culture of the organizations it oversees. It also implies that it reflects on how it should interpret and implement its role and legal mandate in its regulatory approach and practice. As IAEA states in connection with Principle 1 of the Safety Fundamentals[15] "…regulatory bodies … have an important responsibility in establishing standards and establishing the regulatory framework for protecting people and the

[15] Principle 1, Responsibility for safety, says: "The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks" [3].

environment against radiation risks. However, the prime responsibility for safety rests with the licensee" [3]. Several questions, though, arise from this statement:

— If the prime responsibility for safety must rest with the licensee, what exactly is the regulatory body's responsibility related to the fundamental safety objective "to protect people and the environment" [3]?
— In what way does the regulatory body impact (either positively or negatively) the licensee's ability and willingness to take on its legally assigned responsibility?
— (How) can and should the regulatory body (actively) foster the licensee's sense of and actual assumption of responsibility for safety?

The regulatory body should, therefore, find answers to these questions and translate them into its regulatory approaches and practical work in fulfillment of its "statutory obligation for the regulatory control of facilities and activities" [4]. Beyond establishing regulations and assuring compliance with them, it should strive to actively and positively influence the licensee's safety culture, as the Nuclear Energy Agency of the OECD stated several years back: "In addition to enforcing safety regulations, the regulator should make sure he/she has a positive effect on the operator's safety culture" [5]. This implies that the regulatory body should choose regulatory approaches and apply oversight practices that are suitable to positively influence the licensees' safety culture and to strengthen their ability and willingness to assume responsibility. It is argued that this entails for the regulatory body the continuous effort to understand and recognize how it impacts the licensee's safety culture and the need not to leave the effect of its regulatory work to chance but to consciously and actively attempt to shape its effect towards a positive impact on safety culture and of strengthening the licensee's responsibility.

ENSI specified its understanding of its mandate and role in its new Mission Statement in 2014. It put the Mission Statement under the motto „We strengthen safety", implying that the regulatory body has a role that goes beyond the mere establishment of regulations and assurance of compliance with them by the licensees. As a concretion of this motto, ENSI states as a guiding principle: „We strengthen nuclear safety through our supervisory work" as well as „Through our supervision, we strengthen the safety culture of the supervised parties, and we encourage them to take responsibility for their own actions" [6], envisaging an active role in the promotion of nuclear safety culture and fostering the sense of responsibility by the licensees.

The present paper discusses the two perspectives on safety culture described above and shows how ENSI has embraced them. ENSI's approach and practices on oversight of safety culture are presented, as well as a three-year project that ENSI has conducted in order to initialize and institutionalize a self-reflection process on its own safety culture.

2. SAFETY CULTURE AS AN ISSUE FOR OVERSIGHT

Since the concept of Safety Culture was brought up in the beginning of the 1990s regulatory bodies all over the world struggle with the question whether and how the safety culture of the organizations they oversee can and should be regulated and if it can and should be the object of oversight activities. During one of the earlier International Conferences organized by the IAEA on the topic of safety culture in 2002, the former president of the French regulatory body ASN described the regulatory bodies' struggle with the concept of safety culture as follows: „The word ‚safety culture' sometimes leads nuclear regulators into very awkward reactions, jumping up to say that yes, they are very interested in the subject... But becoming quickly unable to explain what they actually mean by it. The difficulties increase when they are asked in what way their actions actually allow them to monitor safety culture or contribute to its development" [7]. A joint workshop organized by the Working Group on Human and Organisational Factors (WGHOF) of the OECD Nuclear Energy Agency and the IAEA in 2008 concluded that regulatory bodies should have methods and processes in place for oversight of safety culture [8]. Many attempts were made by regulators and other organizations to define what an appropriate safety culture would be for organizations operating in the nuclear industry and corresponding methods and instruments were developed with the aim to assess those organizations' safety culture. In recent years, however, skepticism has been expressed on whether regulatory bodies should address the concept of safety culture within their regulatory approach at all (e.g. [9]). For instance, the argument has been brought forward that "inclusion of safety culture into regulatory requirements may have detrimental effects on the factual safety of high-risk organizations because by trying to understand and use the concept attention is pulled away from addressing more manifest safety issues" [9]. The conclusion drawn from this argument is that instead "the strengths and weaknesses in the organization's operational safety management should be the main focus. Consequently, regulatory agencies should concentrate their activities on prescribing, monitoring and enforcing operational safety management and abandon any attempt to include safety culture into regulations" [9].

In ENSI's view, the answer to the question whether safety culture can and should be regulated and overseen by the regulatory body cannot be either YES or NO. Rather, the question needs a more differentiated answer which also depends on the understanding of the notion of oversight. In order to allow a more sophisticated oversight approach to safety culture which avoids the above mentioned problems commented by critics, ENSI distinguishes between „oversight in the stricter sense" and „oversight in the broader sense" [10]. Whereas oversight in the stricter sense refers to monitoring whether a licensee meets its obligations as defined by the regulatory framework (laws, ordinances, guidelines etc.), oversight in the broader sense also includes activities which aim at prompting self-reflection by the organization of the licensee and addresses the more immaterial aspects of safety culture, such as values and deeply rooted basic assumptions which are even (partially) unconscious to their holders and that cannot be directly observed and assessed by the regulatory body.

2.1. ENSI's approach to oversight of safety culture

In any case, whether one concludes that the regulatory body should or should not include the concept of safety culture in its oversight and regulatory approach, it is clear that safety culture cannot be treated in its entirety in the same way as „traditional" oversight issues, but rather needs a differentiated approach. The reasons for this are manifold and are linked to the complex nature of the concept of culture that includes immaterial elements such as values and basic world views, stemming from methodological difficulties in assessing cultural expressions, over normative reasons such as the impossibility to define an objective and comprehensive set of characteristics of a „good safety culture", i.e. setting standards, to the impossibility to prescribe a specific culture to an organization [10].

Due to these reasons, ENSI refrains from prescriptively regulating safety culture within its regulatory framework. In its regulatory guideline on the Organization of Nuclear Installations [11] rather general requirements concerning safety culture are formulated[16]. ENSI's description of characteristics of a good safety culture [10] is not part of the formal regulatory framework. It does not have the character of requirements nor is it used by ENSI as a catalogue of criteria to assess the licensees' safety culture as a whole. Rather, it aims at encouraging the licensees to reflect about their safety culture and as a basis for an ongoing dialogue between ENSI and the licensees on issues related to safety culture.

ENSI described the approach it has been practicing for more than ten years with the help of a model for oversight of safety culture which is based on E. Schein's multi-level concept of organizational culture [12] and distinguishes different approaches in its oversight work, depending on the accessibility of different elements of the safety culture for the regulatory body (cf. Fig. 2).

[16] „Measures for the purpose of observing, assessing and fostering a good safety culture must be incorporated in the management system. It is necessary to promote a working atmosphere that encourages trust, cooperation and open communication, and one which attaches value to the communication of problems. Consideration must be given to cultural aspects in connection with the organisation's own staff and third-party personnel, and efforts shall be made to encourage the positive development of the culture in the nuclear installation" [11].

Accessibility	Approach by the regulatory body	Content
Easy	Observation Queries Document analysis	**Human-made physical environment** (e.g. technical equipment, documents used)
		Behavior (e.g. working methods, verbal statements)
Moderate	Queries Document analysis	**Conscious values** (goals and evaluation criteria) **Conscious world views** (descriptions of reality and explanatory models)
Difficult	Restricted queries	**Non-conscious values** (goals and evaluation criteria) **Non-conscious world views** (descriptions of reality and explanatory models)

FIG. 2. ENSI's model for oversight of safety culture in nuclear installations [10].

As the model shows, ENSI's practice of oversight of safety culture addresses all levels of safety culture according to E. Schein's understanding, from the artifacts level (physical environment, e.g. technical equipment, documents; behavior, e.g. working methods, verbal statements) to the less visible and accessible levels of espoused values as well as basic underlying assumptions (conscious values and world views; non-conscious values and world views). Due to their different accessibility and assessability, though, different scopes and goals are aimed at and different methodologies are applied in oversight practice.

The easily accessible elements of safety culture (such as technical equipment, documents used, e.g. procedures, process descriptions, safety reports etc., as well as the daily behavior of the organization's staff at all hierarchical levels) and for which clear standards (e.g. requirements within the regulatory framework) exist, are the object of the major part of ENSI's oversight activities (such as inspections, event analysis, issuance of permits etc.) and incorporated into ENSI's yearly systematic safety assessment[17]. Conventional oversight activities (e.g. inspections) are performed by ENSI in this area concerning for instance the management system of the licensee, staffing and training issues, the technical condition of the installations etc. based on guidelines that formulate specific target conditions that can be assessed by ENSI.

Nevertheless, for a considerable number of aspects of safety culture, although in fact they can be directly observed or at least made indirectly accessible through queries, no specific requirements exist and therefore they cannot be assessed singularly and systematically. This is the case, for example, of activities the licensees undertake on their own initiative to foster their safety culture, such as self-assessments or third party assessments. Moreover, no specific requirements can be formulated concerning immaterial aspects such as values and world views. As far as the individuals who hold these values and world views are aware of them and willing to reveal them to the regulatory body, they can be accessed through questioning. Nevertheless, due to the absence of a basis for their evaluation, they cannot be assessed nor can they be incorporated into the systematic safety assessment. Although it is not possible for these elements to be assessed singularly, considered as a whole they can show patterns or contain other relevant information related to the safety of the nuclear installation and the safety culture of its organization. In this sense these singular, not directly assessable observations, though not immediately relevant and not needing immediate intervention by the regulatory body, are important pieces of the overall safety picture that the regulatory body aims at acquiring through the entirety of its oversight activities. In order to be better able to benefit from this vast fund of available but not directly usable information and observations, ENSI has recently developed a data base with which it aims at collecting observations and „low level" findings with respect to human and organizational factors and safety culture over a longer period of time. This data base which is currently applied in a pilot phase serves the purpose of sharpening the big picture by adding the missing small pieces between the big pieces of the „puzzle" and to – hopefully – better highlight the connections between these big pieces as well as developments and trends over a longer period of time. Identified patterns and trends may eventually lead to findings which can be assessed within the framework of the systematic safety assessment.

Finally, the question arises how the regulatory body can deal with elements of safety culture which are non-conscious and as such are not observable and difficult to elicit and hence cannot be subject to oversight in the stricter sense, i.e. they cannot be monitored and assessed within the mandate of the regulatory body as defined by the regulatory framework. Since the implicit, taken for granted and thus often non-conscious values and world views, represent the core of a culture (cf. e.g. [12]) and are determinant for the behavior of the members of an organization and ultimately for the safety of the nuclear installations, ENSI holds the view that the

[17] For a description of ENSI's systematic safety assessment cf. ENSI [13].

regulatory body should also try to address them in its oversight activities, although with a different approach. Since these deepest layers of culture are very difficult to access and cannot just be asked for, there is no way to systematically elicit them and even less to assess them. Hence, ENSI does not pursue the objective of making (conscious as well as non-conscious) values and world views assessable and amenable to „oversight in the stricter sense“. Rather it aims at fostering the licensee's self-reflection about its own (safety) culture, its own values and world views as well as enable common reflection between ENSI and the licensees by means of an open and constructive dialogue on issues related to safety culture addressing values and world views („oversight in a broader sense“). For this purpose, ENSI introduced in 2005 a special activity which it calls „specialist discussions promoting a dialogue on safety culture“ [10]. The discussions, which are conducted bilaterally with the licensees once in three years, comprise two parts of approximately three hours each. During the first round, a topic related to safety culture, previously announced to the licensee by ENSI with a list of questions, is discussed. After this first part, ENSI processes the results of the discussion and draws a number of hypotheses which are presented to the licensee during the second part some weeks later, allowing for further reflection and consolidation of the discussed issues.

In contrast to classical oversight activities, these specialist discussions do not lead to concrete results, such as a judgement by the regulatory body on whether the requirements of the regulatory framework are met or in concrete demands towards the licensee. Rather, the dialogue intends to prompt individual and collective reflection processes, making previously non-conscious or implicit values and world views (at least partially) conscious and explicit. Such discussions invariably lead to a constructive dialogue not only between the participants of the licensee organization on one side and the participants of the regulatory body on the other side, but also among the members of the licensee organization themselves. The individual understanding of concepts, personal values and assumptions are made explicit and shared among the participants in the dialogue, differences and commonalities are identified, mutual understanding and trust are fostered and a common understanding of implications of values and world views is developed and deepened. Beside the self-reflection of the licensee organization, the specialists discussions also serve ENSI's own self-reflection: for instance the effect of ENSI's oversight work on licensees' safety culture as perceived by the licensees is discussed during the specialist discussions.

This activity is seen by ENSI as one concretion of its guiding principle on strengthening of nuclear safety and in particular of the safety culture of the licensees and of their sense of responsibility as formulated in its Mission Statement. It has meanwhile become a well-established element of its oversight approach and is well accepted and appreciated by the licensees.

3. SAFETY CULTURE AS AN ISSUE FOR SELF-REFLECTION

As described in the introduction to the present paper, the regulatory body's regulatory and oversight work by nature has – intentionally as well as unintentionally – a crucial impact on the licensees' safety culture. For this reason it is important that regulatory bodies do not only consider safety culture as an issue for oversight of licensees, but also critically question and monitor their own safety culture – referred to as "oversight culture" within ENSI – and how it influences the licensees' safety and safety culture.

3.1. ENSI's project on oversight culture

Right after the Fukushima accident, in summer 2011 ENSI set up a comprehensive three-year project on its oversight culture. The goals of the project were on one hand to initialize and institutionalize a self-reflection process on its own oversight culture and particularly on its impact on the licensees, and on the other hand to develop a vision of the oversight culture that ENSI should strive for as well as to develop activities in order to realize this vision.

Not much research and practical work has been done yet in the (international) community on the topic of safety culture related to the regulatory body. It is not until recently, particularly after the Fukushima accident, that regulatory bodies and international organizations along with research institutes have started to deepen the debate about the nature and relevance of the regulatory body's own safety culture. Therefore, no well-founded and generally recognized "theory of a good oversight culture" or a comprehensive set of criteria for a "good regulatory safety culture" were (and still are) available as a conceptual basis for the project. Thus, an explorative – i.e. a descriptive as opposed to a normative – approach was chosen by which the elements of ENSI's oversight culture were explored during the project. Also, a participative approach was applied. On one hand the project was led by an interdisciplinary team composed of staff members from all divisions directly or indirectly involved with oversight activities as well as of all different hierarchical levels. On the other hand, all ENSI staff were repeatedly involved in project activities in order to promote motivation and identification of the staff with the issue and the project. Hence, the realization of the project itself was already the trigger and the start of the self-reflection process that is intended to be institutionalized in ENSI's culture.

The project was conceived in three phases as depicted in Fig. 3.

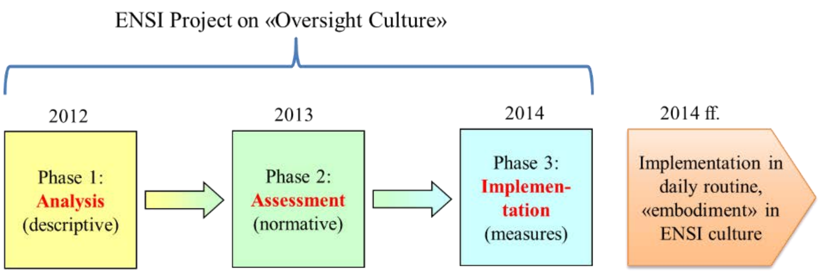

FIG. 3. Phases of the project.

In *phase 1* a descriptive analysis of ENSI's current oversight culture was carried out on the basis of specific examples of oversight and regulatory activities realized by ENSI. Interviews with ENSI staff of different hierarchical levels actively involved in these activities as well as surveys with staff members of those organizational units which were not involved in the chosen activities were carried out. On the basis of the gathered material, a set of hypotheses on ENSI's current oversight culture was extracted by the project team. These hypotheses were then submitted to the entire ENSI staff for validation in the form of a questionnaire during a workshop that was performed with the staff of each division[18]. During these workshops the sections of each division also created a metaphor (i.e. a figurative representation by means of different material such as paper, pencils, Lego bricks, modeling clay, cotton wool etc.) of their own oversight culture. The metaphors were then discussed within the division and similarities and differences were sought. Finally, in order to compare ENSI's self-perception of its own oversight culture with the perception of the organizations who directly experience ENSI's oversight culture, a workshop was carried out with representatives of the licensees during which their views on ENSI's oversight culture and its effect on their own safety culture were reflected.

Three main topics were identified in phase 1 on the basis of the analysis carried out as essential elements of ENSI's oversight culture:

(a) Oversight philosophy and practice (What is good oversight?);
(b) Cooperation and communication within ENSI (How do we interact within/between the sections, divisions, hierarchical levels?);
(c) Oversight role versus public role (How do the oversight role and the public role impact each other?).

In *phase 2* the question was examined what kind of oversight culture ENSI should strive for and the need for action was assessed. Based on the descriptive results of phase 1, the project team drafted a proposal of a "target" oversight culture.

[18] ENSI's organizational structure is basically composed of six divisions, each of which comprises between 3 and 5 sections.

This draft was again presented to the entire ENSI staff who discussed it, developed it further during a series of workshops and identified need for action. This iterative process lead to a set of "target" sentences on the desired oversight culture part of which were used as an input for the newly developed ENSI Mission Statement, published in 2014 [6].

In *phase 3* measures were developed to implement the defined "target" oversight culture and the new Mission Statement. A package comprising 15 activities was decided on the following issues:

— Fostering self-reflection and improvement of oversight;
— Strengthening of competence and professionalism of ENSI's staff;
— Improvement of cooperation as well as mutual knowledge and understanding;
— Clarification of basic discussions on the regulatory framework (e.g. guidelines);
— Monitoring of the implementation of the present package of measures.

The measures are currently being implemented. After the official termination of the project at the end of 2014, the monitoring and controlling of the implementation of the measures was transferred from the (temporary) project team to the normal organizational structures of ENSI in order to ensure that the processes and activities that were initiated with the project are carried on in future and that the sensitivity of the staff to issues related to the oversight culture is kept alive and integrated into ENSI's culture on the long term.

4. CONCLUSIONS

Although the concept of safety culture has been debated for almost 30 years, there is still no consensus on its significance and use in practice. There is still a need to discuss whether and how the concept can be fruitfully integrated in oversight approaches and practices. What became meanwhile evident, especially after the Fukushima accident, at least, is that a more systemic view is necessary as a basis for this debate. It is not enough to only focus on licensees. Rather, the overall system of stakeholders needs to be addressed, and in particular the regulatory body's own safety culture and its impact on the licensees' safety culture. This is what was realized by ENSI after the Fukushima accident. A self-reflection process on its own oversight culture and on its impact on the licensees' safety culture was triggered with the help of a comprehensive project involving the staff of the entire organization. Out of the project, a series of specific measures was defined in order to further improve ENSI's oversight approach and practice. It has to be emphasized, though, that the collective reflection process which took place within the entire organization during the project, was at least as valuable as the concrete output of the project itself. For that reason alone, the project was worth the (considerable) efforts made during the three years of its duration. Nevertheless, the sensitivity of the staff for issues of oversight culture and the self-reflection process started during the project now need to be kept alive within the organization. It is ENSI's opinion that an analogous project could be as well helpful for other regulatory bodies who wish to engage in a reflection process on their own safety culture and its impact on the organizations they oversee.

Yet, the last few years have brought about significant progress in this respect, with regulators as well as international organizations starting various activities and projects related to the regulatory bodies' safety culture. This seems to be a promising development which needs to be kept going on. Especially the international organizations, namely the IAEA and the NEA of the OECD have an important role in promoting the exchange between member states and encouraging them to adopt a more systemic view through their activities but also through the further development of international safety standards.

REFERENCES

[1] SWISS FEDERAL NUCLEAR SAFETY INSPECTORATE ENSI, In-depth Analysis of the Accident at Fukushima on 11 March 2011 – With Special Consideration of Human and Organisational Factors, ENSI, Brugg/Switzerland (2011).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident. IAEA, Vienna (2015).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, Safety Fundamentals No. SF-1, IAEA, Vienna (2006).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, General Safety Requirements Part 1 No. GSR Part 1, IAEA, Vienna (2010).

[5] NUCLEAR ENERGY AGENCY/OECD, The Role of the Nuclear Regulator in Promoting and Evaluating Safety Culture, OECD, Paris (1999).

[6] SWISS FEDERAL NUCLEAR SAFETY INSPECTORATE ENSI, ENSI Mission Statement, ENSI, Brugg/Switzerland (2014).

[7] LACOSTE, A.-C., "Role of the Regulator in the Development of Safety Culture", International Conference on Safety Culture in Nuclear Installations (Rio de Janeiro, 2002), IAEA (2002).

[8] NUCLEAR ENERGY AGENCY/CSNI/OECD, INTERNATIONAL ATOMIC ENERGY AGENCY, R(2008)10, Proceedings of the CSNI/IAEA Workshop on Maintaining Oversight of Licensee Safety Culture – Methods and Approaches, OECD, Paris (2008).

[9] GROTE, G., WEICHBRODT, J., "Why Regulators Should Stay Away From Safety Culture and Stick to Rules Instead", Trapping Safety Into Rules – How Desirable or Avoidable is Proceduralization?, Ashgate, Farnham (2013).

[10] SWISS FEDERAL NUCLEAR SAFETY INSPECTORATE ENSI, Oversight of Safety Culture in Nuclear Installations, ENSI Report on Oversight Practice, ENSI-AN-8980, ENSI, Brugg/Switzerland (2014).
[11] SWISS FEDERAL NUCLEAR SAFETY INSPECTORATE ENSI, The Organisation of Nuclear Installations, Guideline for Swiss Nuclear Installations ENSI G07, ENSI, Brugg/Switzerland (2013).
[12] SCHEIN, E., Organizational Culture and Leadership (2nd Ed.), Jossey Bass, San Francisco (1992).
[13] SWISS FEDERAL NUCLEAR SAFETY INSPECTORATE ENSI, Integrated Oversight, ENSI report on Oversight Practice, ENSI-AN-8968, ENSI, Brugg/Switzerland (2014).

SAFETY CULTURE IMPLEMENTATION IN INDONESIAN NUCLEAR ENERGY REGULATORY AGENCY (BAPETEN)

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Abstract

Based on Indonesia Nuclear Energy Act No. 10 of 1997, Nuclear Energy Regulatory Agency (BAPETEN) is the Nuclear Regulatory Body has responsibility to control nuclear energy utilization. BAPETEN is responsible and accountable for nuclear system, so it shares a significant attention in fostering safety culture. BAPETEN Chairman in June 2000, has released a Nuclear Safety Policy Statement as the safety culture policy statement and stated the assurance of nuclear safety should be granted as first priority. BAPETEN develops several regulation as the regulatory framework of safety culture implementation for licensees also BAPETEN it self. The safety culture activity in BAPETEN is a part of the BAPETEN Integrated Management System implementation include occupational safety and health (OSH). BAPETEN has safety culture training programs for senior management and staffs to be implemented in accordance with the role and responsibilities and in the regulatory process. To set up a safety culture self assessment, BAPETEN has initiated to organize an IAEA workshop on Safety Culture Self-Assessment for Senior Management in May 2015, and started to prepare its guidance. BAPETEN inspection program does not cover a specific safety culture inspection. During auditing process of quality assurance program, inspectors can put inquiries regarding safety culture implementation based on nuclear safety regulations, and analysis by using data taken from the results of safety inspection; safety culture self assessment from the licensees, and Report of Safety Operation from the facilities, and its evaluation. Based on the analysis result, then compare it with the IAEA safety culture characteristic and attributes to find out the weaknesses of safety culture implementation in each nuclear installation. BAPETEN has been engaged in promoting and conducting dialogues with licensees to enhance the understanding of safety culture aspects, and to seek licensees commitment to perform self and independent peer assessments of safety culture implementation.

1. INTRODUCTION

The Indonesia Nuclear Energy Act no. 10 of 1997 clearly stated that Nuclear Energy Regulatory Agency (BAPETEN) is the Nuclear Regulatory Body. This is the legal basis of BAPETEN to perform regulatory functions on the use of nuclear energy in Indonesia, including regulation, licensing, inspection and law enforcement. The Independent regulatory functions are stipulated in Article 4 and Article 14 of the Nuclear Energy Act no. 10 of 1997 which require the government to establish regulatory body that is reporting directly to the president and has responsibility to control nuclear energy utilization.

BAPETEN has been fully started its function on January 4, 1999. In its roles of BAPETEN as a nuclear regulatory body, the main aspect that continuously develops is fostering nuclear safety culture in Indonesia. BAPETEN has stated in its vision to become a world class nuclear regulatory body and to achieve nuclear safety and security conditions and improvisational competitiveness. Nuclear energy eco system views an opportunity for regulator to achieve the mission of nuclear safety culture within the national nuclear program. Nuclear Regulator is responsible and accountable for nuclear system. BAPETEN shares a significant attention in the development and implementation of safety culture within the regulatory body. BAPETEN as regulatory body should provide a good example for the licensees related to the safety culture implementation.

In order to implement the vision concept in creating nuclear safety and security conditions, BAPETEN defines its mission to realize the national safety and security culture in accordance with the national personality and character. This mission is then elaborated in its objectives e.g. to reduce the nuclear incident rates in Indonesia by implementing nuclear safety and security culture for radiation workers, organizations and relevant stakeholders based on national personality.

2. SAFETY CULTURE POLICY

In order to foster the implementation of a good safety culture among BAPETEN or licensees, BAPETEN has released a Nuclear Safety Policy Statement initiated by BAPETEN Chairman in June 2000. The contents of the safety culture policy statement are the following:

— The purpose is to provide the framework for regulatory authority to manage the regulatory control of nuclear energy with due respect to safety, security, health of radiation workers, environmental protection and peaceful use and to improve the professionalism in nuclear regulatory activities by providing public information on the government basic policies regarding nuclear safety to achieve the ultimate goal of safe use of nuclear energy;
— The assurance of nuclear safety should be granted as first priority in nuclear energy utilization within organization of nuclear installations and radiation facilities as well as individuals engaged in aspects of nuclear energy utilization. They should adhere to safety principles as top priority;

- People in nuclear fields should have more pro-active attitude in ensuring nuclear safety to obtain public trust and confidence for the sustainable development of nuclear energy utilization;
- BAPETEN strives for effective regulations through the development of clear and transparent safety regulatory practices;
- BAPETEN will actively encourage the achievement of expertise of regulatory activities in safety related assessments and reviews; participate in seminar or symposium; and ensure the regulatory independence by minimizing any undue pressure and interference;
- Safety culture cannot be achieved in a day, but rather it is secured through consistent regulatory practices, through clear and transparent rules and procedures, and uncompromised law enforcement activities;
- The ultimate responsibility for safety of nuclear energy utilization rests solely on the licensees;
- In performing regulatory functions, BAPETEN should try to overcome public distrust and fear of nuclear activities

BAPETEN doing assessment for new safety culture policy statement to be implemented by BAPETEN and licensees in accordance to IAEA documents; IAEA Safety Guide GS-G-3.1 on "Application of the Management System for Facilities and Activities" 2006 and IAEA GS-G-3.5 on "Management Systems for Nuclear Installations " 2009. The concept of safety culture policy statement integrates IAEA safety culture characteristic and attributes to be applied in the safety culture oversight programs and safety culture self-assessment in the BAPETEN and licensees.

3. REGULATORY FRAMEWORK

The basic framework for safety culture implementation is clearly stated in Nuclear Energy Act no. 10 of 1997. One of the objectives of regulatory functions is to increase legal awareness of nuclear energy utilization to develop safety culture (article 15, point d), while in the elucidation of article 15 it is stipulated that safety culture is a reflection of characteristics and attitudes in organizations and individuals that emphasize the importance of safety.

In 2006 BAPETEN has also published Technical Document on Guidance of Safety Culture Implementation. This document was prepared by using IAEA safety culture references, starting from the basic document INSAG-4 to the IAEA TECDOC 1329 on Safety Culture Implementation for Nuclear Installation.

Article 5 of Government Regulation No. 33/2007 on the Safety of Ionizing Radiation and the Security of Radioactive Sources, states that Safety Culture is one part of the management requirements that must be realized in any nuclear energy utilization. Safety Culture is performed at least by:

(1) Creating a standard operating procedures and policies that put a high priority on safety protection;
(2) Identifying and correcting the factors affecting the level of safety protection for any potential hazards;
(3) Identifying clearly the responsibilities of each person on the protection and safety;
(4) Establishing clear authority personnel in any implementation of protection and safety;
(5) Establishing qualifications and adequate training for the personnel; and
(6) Building a network of good communication at all levels of the organization, to produce a flowing current of appropriate information on protection and safety.

IAEA GS-R-3 on Safety Requirements on "The Management System for Facilities and Activities", provides requirements to foster and support a strong safety culture through the development and reinforcement of good safety attitudes and behaviours in individuals and teams. These will enable them to carry out their tasks safely and provide the means by which the organization can continuously strive to develop and improve its safety culture. BAPETEN has adopted the GSR-3 by publishing BAPETEN Chairman Regulation (BCR) No. 4 year 2010 on Management System for Nuclear Energy Facilities and Activities. The regulation mandates the licensees to conduct an independent assessment for the improvement of safety culture. Apart from that, management system should be implemented by the licensees to foster and support strong safety culture by :

(a) Ensuring a common understanding of the key aspects of safety culture;
(b) Providing a convenience to organizations and individuals to support the team in performing its task by considering the interaction between individuals, technology, and organization;
(c) Cultivating attitudes of asking questions and learning at all levels of the organization; and
(d) Providing a convenience to the organization to continuously develop and improve the safety culture

To apply this regulation, BAPETEN also adopts by translating and enforcing IAEA document; IAEA Safety Guide GS-G-3.1 on Application of the Management System for Facilities and Activities year 2006 and IAEA GS-G-3.5 on Management Systems for Nuclear Installations year 2009.

4. SAFETY CULTURE IMPLEMENTATION

4.1. Safety culture in the processes under the IMS

In order to provide protection to the public, workers and the environment, BAPETEN has implemented good governance through BAPETEN Integrated Management System. The scope of the BAPETEN Integrated Management System covers establishment and implementation of overall management requirements to be integrated in the regulatory process for nuclear energy utilization. It is applied through compliance with integrated of safety, health, environment, security, quality and economy. BAPETEN IMS manual combines the requirements of the IAEA GS-R-3 on Safety Requirements on The Management System for Facilities and Activities, ISO 9001: 2008 and ISO 9004: 2009.

Safety Culture activity in BAPETEN is a part of the BAPETEN Integrated Management System implementation. It states that BAPETEN is fostering and supporting a strong safety and security culture, through the following measures:

(a) Ensuring a common understanding of the main aspects of the safety and security culture in BAPETEN;
(b) Supporting individuals and teams within the organization to complete their tasks safely and successfully taking into account the interaction between individuals, technology and organization in BAPETEN;
(c) Strengthening the learning and questioning attitudes at all levels in BAPETEN;
(d) Developing and improving the safety and security culture continuously.

The strategies to support and assess the safety and security culture will be described in detail in the BAPETEN Guidelines on Development of Safety and Security Culture. The Preparation of Guidelines for Safety Culture in BAPETEN will adopt some part of related IAEA management system documents which can be applied in BAPETEN. The references to be used are the IAEA Safety Guide GS-G-3.1 on "Application of the Management System for Facilities and Activities" year 2006 and IAEA GS-G-3.5 on "Management Systems for Nuclear Installations" year 2009.

In relation with the integrated management system concept in safety culture, BAPETEN also implemented the Occupational Safety and Health (OSH). The goals of occupational safety and health programs include to foster a safe and healthy work environment, also protect co-workers, family members, employers, customers, and many others who might be affected by the workplace environment. The OSH activity in BAPETEN are develop OSH Policy Statement of BAPETEN Chairman, Audit OSH for workplace environment in BAPETEN Building, Community of Practices to share and communicate safety culture and OSH activity, preparing Guidance of OSH Management, OSH Training for staff and team, prepare safety induction for staff and guest, Safety dialog & Communication, socialization concept of 5R (Reduce, Reuse, Recycle, Replace, Replant) for better housekeeping of the office.

4.2. Training senior management and staff

BAPETEN has training programs for senior management and staffs in their respective roles and responsibilities in its implementation to incorporate safety culture in the regulatory process. The training activities cover:

- Nuclear Safety Culture lecture on Basic Professional Training Course on Nuclear Safety, for all new BAPETEN staff (4 hours);
- Training workshop on Safety Culture Implementation for nuclear installation for BAPETEN staff (5 days);
- Safety Culture Implementation for nuclear safety inspectors(3 hour);
- Leadership and Management for Safety and Safety Culture for Managers (3 days);
- Workshop on Safety Culture Self Assessment for Managers (4 days);
- Coaching for Trainers of Safety Culture Implementation (10 X 2 hours);
- Coaching on Safety Culture Implementation using 5 Characteristic for drafting guidance of safety culture oversight core team (5 X 2 hours)

4.3. Self-assessment

Self-assessment of safety culture in BAPETEN is a part of integrated management system implementation program. To set up a safety culture self assessment, BAPETEN has initiated to organize an IAEA workshop on Safety Culture Self-Assessment for Senior Management in May 2015, and started to prepared the guidance for safety culture self assessment. The preparation activities for safety culture self assessment are as follows:

- Coaching on Safety Culture Implementation for core team that will draft the Guidance on self-assessment of safety culture;
- Drafting Guidance on BAPETEN Safety Culture Self Assessment;
- Testing the implementation of self assessment based on guidance prepared;
- Reviewing the Guidance on BAPETEN safety culture self-assessment by IAEA expert;
- Finalizing the guidance on BAPETEN Safety Culture Self-Assessment;
- Conducting a Workshop on Safety Culture Self-Assessment;
- Performing safety culture self-assessment of BAPETEN

4.4. Safety culture oversight

BAPETEN has important role to foster nuclear safety culture in nuclear energy implementation in Indonesia. To ensure the implementation of the safety culture of licensees, BAPETEN needs to perform safety culture oversight. BAPETEN inspection program does not cover a particular safety culture inspection. During auditing process of quality assurance program, inspectors can put inquiries regarding safety culture implementation based on nuclear safety regulations as described in the regulatory framework.

Based on the recommendations of the IAEA IRRS Mission, BAPETEN is advised to conduct safety culture oversight activities to the operator organizations both for nuclear installations and radiation facilities. The scope of nuclear safety inspections are safety of operation, maintenance programs, radiation protection and environmental radiation safety, nuclear emergency preparedness programs and quality assurance programs.

During the period of quality assurance inspection program, inspectors also conduct an audit of the safety culture implementation to the licensees as required in the safety regulations.

BAPETEN performs an analysis of safety culture implementation of the licensees by using data taken from:

- the results of safety inspection,
- safety culture self assessment from the licensees, and
- report of safety operation from the facilities, and its evaluation.

Based on the analysis result as mentioned above, BAPETEN will compare it with the IAEA safety culture characteristic to find out the weaknesses of safety culture implementation in each nuclear installation. Despite the fact that there is no specified inspection for safety culture, the results of inspection and evaluation reports have been compared with the safety culture characteristics.

Due to the recommendation of the IRRS mission to implement specific safety culture oversight, BAPETEN has initiated drafting the Guidance on Safety Culture Oversight. The preparations for implementation of safety culture oversight are as follows:

- Coaching on Safety Culture Implementation for core team that will draft the guidance on safety culture oversight;
- Drafting the Guidance on Safety Culture Oversight;
- Creating Safety culture oversight for Multipurpose Research Reactor as the model project;
- Inviting IAEA Expert to review the guidance and model implementation of safety culture oversight;
- Finalizing the guidance on safety culture oversight;

- Organizing workshop on Safety Culture Oversight;
- Performing Safety Culture Oversight

4.5. Promoting safety culture to the licensees

BAPETEN has commenced to develop a safety culture since 2000 after publishing BAPETEN Nuclear Safety Policy Statement. BAPETEN has been engaged in promoting and conducting dialogues with licensees to enhance the understanding of safety culture aspects, and to seek licensees' commitment to perform self and independent peer assessments of safety culture implementation. Activities carried out by BAPETEN include:

(a) Providing socialization of Safety Culture Implementation TECDOC published by BAPETEN in 2006;
(b) Providing dissemination of the safety culture aspects contained in the regulation of nuclear safety regulations, both in the form of Government Regulations and BAPETEN Chairman Regulations;
(c) Promoting self assessment and performing independent assessment of safety culture implementation for nuclear installation;
(d) Performing trainings on Nuclear Safety Culture for Nuclear Installation;
(e) Performing trainings on Safety Culture to the Radiation Protection Officer for Radiation Facilities and disseminations of safety culture aspect to the licensees and public;
(f) Publishing a Book on "Improving Our Safety Culture" for public;
(g) Performing workshop seminar on the Safety Culture Implementation of Nuclear Installation. The objective is for sharing the results of self-assessment of licensee’s safety culture and implementation;
(h) Sharing knowledge related to various aspects of safety culture including:
    - Safety Leadership
    - Effective Safety Communication
    - Safety Culture Improvement
    - Safety Culture Self Assessment
    - Behaviour Based Safety

5. CLOSING

BAPETEN has been fully started its function on January 4, 1999. In its roles of BAPETEN as a nuclear regulatory body, the main aspect that continuously develops is fostering nuclear safety culture in Indonesia. BAPETEN defines one of its mission to realize the national safety and security culture in accordance with the national personality and character. This mission is then elaborated in its objectives e.g. to reduce the nuclear incident rates in Indonesia by implementing nuclear safety and security culture for radiation workers, organizations and relevant stakeholders based on national personality.

The Nuclear Safety Policy Statement of BAPETEN Chairman as the safety culture policy implementation provide the framework for regulatory authority to manage the regulatory control of nuclear energy with due respect to safety, security, health of radiation workers, environmental protection and peaceful use and to improve the professionalism in nuclear regulatory activities by providing public information on the government basic policies regarding nuclear safety to achieve the ultimate goal of safe use of nuclear energy and safety as prime priority. BAPETEN develop several regulation as the regulatory framework of safety culture implementation for licensees also BAPETEN it self. The safety culture activity in BAPETEN is a part of the BAPETEN Integrated Management System implementation but several safety culture guidance for self assessment should be develop. BAPETEN has safety culture training programs for senior management and staffs to be implemented in accordance with the role and responsibilities and in the regulatory process. The safety culture self assessment and safety culture oversight is the priority program. BAPETEN has initiated drafting the guidance and training for safety culture oversight and safety culture self assessment. BAPETEN has been engaged in promoting and conducting dialogues with licensees to enhance the understanding and implementing of safety culture.

BIBLIOGRAPHY

NUCLEAR ENERGY CONTROL BOARD OF INDONESIA, Act Number No.10 on Nuclear Energy, Indonesia (1997).

BAPETEN Chairman Nuclear Safety Policy Statement, Indonesia (2000).

BAPETEN Chairman's Regulation No. 4, The Nuclear Energy Facility and Utilization Activity Management System, Indonesia (2010)

BAPETEN Chairman's Regulation No 10, BAPETEN Management System, Indonesia (2011)

BAPETEN Technical document No.DT-0601, Safety Culture Implementation Guidance, Indonesia (2006)

INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Requirements on The Management System for Facilities and Activities, IAEA Safety Requirement No. GS-R-3, IAEA, Vienna (2006)

INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Guide No. GS-G-3.1, IAEA, Vienna (2006)

INTERNATIONAL ATOMIC ENERGY AGENCY, Management Systems for Nuclear Installations, IAEA Safety Guide No. GS-G-3.5, IAEA, Vienna (2009)

NUCLEAR ENERGY CONTROL BOARD OF INDONESIA, The Government Regulation No. 33, The Safety Ionizing Radiation and the Security of Radioactive Sources, Indonesia (2007).

KNOWLEDGE MANAGEMENT METHODOLOGIES FOR IMPROVING SAFETY CULTURE

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Abstract

According to complexity theory, culture is an emerging property of organizations and it is the result of continuous interaction between individual and group viewpoints and of continuous competition between current and new tools to understand a variable context. Knowledge Management (KM) and Education and Training (E&T) methodologies play a fundamental role in Safety Culture improvement and they should be integrated, in an interactive and dynamic way, in order to reflect complexity of organization, exploiting innovative architectures and models where safety is a primary goal and a strong *fil rouge* which connects different disciplines at all levels and represents a leading driver for the process of knowledge creation and awareness development. Therefore, the final goal and the expected outcome of an integrated and well-designed KM-E&T system is to develop systemic vision and improve Safety Culture within the organization through continuous and dynamic interaction of Education and Training actions, Knowledge Management and people's active involvement at all levels of the organization. In the paper, main characteristics and specific features of integrated KM-E&T systems are presented.

1. INTRODUCTION

Epistemic uncertainties could affect operator's capability to prevent rare but potentially catastrophic accident sequences. Safety analysis methodologies are powerful but fragile tools if basic assumptions are not sound and exhaustive.

In particular, expert judgments and technical data could be invalidated by organizational context change (e.g. maintenance planning, supply systems etc.) or by unexpected events.

In 1986 accidents like Chernobyl, the explosion of Shuttle Challenger and - two years before- the toxic release at Bhopal chemical plant represented the point of no return with respect to the previous vision of safety and highlighted the not delayable need to change paradigm and face safety issues in complex systems not only from a technical point of view but adopting a systemic vision able to include and integrate human and organizational aspects.

In a well-known article about his experience in the Presidential Commission on the Space Shuttle Challenger Accident [1] Feynman stated: "So my theory is that the loss of common interest - between the engineers and scientists on the one hand and management on the other - is the cause of the deterioration in cooperation, which, as you've seen, produced a calamity".

Taking the cue from Feynman's observation, we could say that one fundamental condition to set a common interest and then establish a systemic vision is the creation of a common code and a shared and widespread knowledge within the organization.

This effort is still going on but there are some areas where it collides with current trends in organizations operating on edge technologies and high level risks (nuclear, chemical, aerospace etc.). In fact, the over-specialization required for decision-making in such fields could represent a barrier with respect to a global vision of potential criticalities affecting safety of systems and plants. This trend could lead to a state of "knowledge fragmentation" where it could be very difficult to find the common interest.

According to metaphor approach, we could say that there is the risk to have stuck "pools" of knowledge rather than a "stream" of knowledge which all areas of organization can draw from.

The activation of this stream requires a process of connecting different disciplines and expertise in order to create a common background and an information network. Several software applications make possible to deliver information in a widespread way within the organization, anyway this availability does not result automatically in knowledge creation.

2. CULTURE, KNOWLEDGE AND COMPLEXITY

According to complexity theory, culture is an emerging property of organizations and it is the result of continuous interaction between individual and group viewpoints and of continuous competition between current and new tools to understand a variable context. Properties of complex systems cannot be controlled in a deterministic way and it is necessary to adopt suitable methods to act on the system in order to influence its behaviour. In particular, dealing with culture requires capability of "handling" entities as interpretation, meaning, underlying assumptions and unconscious drivers, which lead organizational values and individual behaviours, through effective methods described in [2]. Besides, understanding the gap between expected characteristics of a strong Safety Culture which are well defined by the International Atomic Energy Agency (clear accountability and leadership, safety recognition and integration into all activities and learning-driven safety) and actual values which we could find looking in depth of organization requires a multi-disciplinary approach in order to identify existing configurations yielded by interactions among individual, technological and organizational factors which are usually modelled by feedback loops representing mutual influences at different levels of the organization. Disregarding these dynamics could neutralise decisions or actions aimed at improving Safety Culture or expose the system to risks deriving from unanticipated evolution of not assessed forces.

Knowledge can be considered as organization of information within the system in order to locally reduce the internal entropy and improve adaptive capability of the system with respect to external context. Knowledge emerges from a complex architecture where system's properties and abstract elements (observations, basic concepts etc.) are linked. Increase in system's dimension could affect this process of information exchange and organization, since volume grows following a cubic trend while surface expands following a square trend. For this reason, complex systems are usually characterized by fractal architectures because these structures, which exhibit a repeating pattern at decreasing scale, maximize the ratio between exchange "surfaces" and system's volume. Fractal geometries are, in turn, strictly related to recursive functions and this relation gives interesting cue about potential ways for system's control.

Another fundamental feature of complex systems is represented by feedback loops which subsist at any level of the system and assure capability of maintaining set-points (negative feedback) and reach new states (positive feedback).

Cultural change requires destruction and creation of feedback loops in order to establish new configurations and explore new ways of interaction. Therefore, Safety Culture improvement programmes should, at first, recognize internal dynamics and existing feedback loops at all levels.

In order to analyze the relation among knowledge, culture and safety within complex systems like organizations, we could start from representing safety as the objective function (S) in a three-dimensions diagram where technological (T) and organizational (O) complexity are the group variables which influence safety S=S(T,O) according to this functional representation. Of course, T and O envelop a large number of inter-depending parameters, linked by not-linear relations, including feed-backs and threshold effects. In this functional representation, we expect to meet another fundamental characteristic of complex systems, i.e. the transition from a complex (and resilient) state to a chaotic state where safety curve begins to undergo continuous bifurcations and it is very difficult, if not impossible, to assess safety (meant as risk control) level of plants, facilities, networks etc. managed by the organization. From a cultural point of view, this transition zone corresponds to the crisis of the existing management system and involves the need of a paradigm shift [3].

Such crisis is strictly related to increase in technological and organizational complexity if the evolution of the socio-technological system is not matched by a cultural change where new dynamics are settled. A main issue is therefore represented by methods and tools needed to face this challenge.

At first, we should consider that, as earlier described, variables and parameters which influence the complex safety function are, in turn, complex entities and could undergo same effects of the main function. It entails that, before studying their interactions, we should evaluate their trends when internal context changes. A typical example of these phenomena is given by situations where the external context (market, laws, industrial state of art etc.) seems to be static but the organization evolves toward a fragility state caused by internal forces as bureaucratization, lack of leadership, over-proceduring in place of focus groups and brainstorming etc. These managerial features are dangerous as well as technical forces as ageing, bad maintenance etc. because they contribute to generate a false sensation of “safety” while the actual level of risk control by managers and operators is decreasing. Understanding the reasons and the effects of these phenomena is therefore the first step to understand the impact of the mutual interactions of all these factors on the global safety level of high risk facilities. External context’s changes should induce internal changes in order to keep system functional and stable (not static!). This means that safety can be assured only by a dynamic equilibrium between internal and external forces and requires a continuous effort of anticipating changes and activating psychic and physical resources to exploit feedback loops and maintain adequate margins with respect to loss of functionality and system’s failure.

Anticipating context changes means to face intrinsic uncertainty affecting data (aleatory uncertainty) and, mainly, uncertainty on models (epistemic uncertainty). Dealing with aleatory uncertainty requires well-known techniques while epistemic uncertainty could hide unknown dynamics and interdependence in parameters with potential unexpected effects.

Probabilistic Safety Assessment (PSA) is a powerful and validated tool that allows engineers and project managers to evaluate response of systems to initiating events, through reliability and availability estimation of safety barriers. However, it is very difficult to anticipate with sufficient precision human response to unexpected events. Furthermore, we know that, while failure probability of safety systems is described by widely used mathematical distributions, probability of most initiating events is inherently affected by epistemic uncertainty due to knowledge gaps about physical models. Thus, we should be very cautious in assuming the probability of initiating events as a known factor based on their expected frequency. As these simple considerations illustrate, we must keep in mind, from the design stage on, that people may have to deal with the unexpected [4].

In particular, when context changes move complex system toward transition zone, basic assumptions adopted by safety analysts during design stage could be invalidated and outcomes of PSA could be unreliable. Considerable studies have been carried out during last decades in order to overcome conceptual limits of PSA [5] and integrate human failures probability within the framework of safety analysis [6] [7], but it is very difficult to encompass feedback loops and hidden interactions in classical assessment methodologies.

In fact, PSA analyses impact of design choices on global safety level but only a deep knowledge of interactions among individual, organizational and technological factors can give people (operators, managers, engineers, analysts etc.) the chance to acquire a systemic vision and make the best choices in order to face challenges deriving from context changes. According to this approach, Safety Culture improvement methodologies are complementary and found Safety Assessment methodologies because make PSA basic hypotheses consistent.

Bhopal accident is an example of gap between engineers' basic assumptions and actual evolution of the plant state toward transition zone where safety systems' configuration was modified while external context was dramatically changing (market crisis) and internal context was getting critical both at human and organizational level and at technological level. If engineers assume that plant and field managers and workers will guarantee the operability of designed and installed safety systems but they do not do so, we are in a typical situation described by the ancient roman motto *"ex falso, quod libet"* (if the premises are false, anything can be said).

Resilience means capability of a system to adapt to internal and external context changes in order to maintain functionality and face challenges represented by unexpected events. According to an operative approach, safety can be seen in terms of risk control, i.e. capability to act in a variable context facing hazards and adopting best strategies to prevent damages. Therefore, these two concepts appear strictly related and represent intrinsic goals of any complex system. Moving from technological to organizational point of view, a Safety Culture improvement programme should aim at developing system's resilience through a process of knowledge creation and awareness development. Of course, technological systems as plants and facilities are not able to adapt to context changes while organizations can be considered complex adaptive systems. Therefore, main goal of Safety Culture improvement methodologies is to give people the chance to act at all levels of the organization, including the technical level, in order to recognize criticalities and adopt best solutions.

3. DESIGNING KNOWLEDGE

Knowledge-based Safety Culture improvement methodologies represent a particular way to acquire a systemic vision. The design of a Knowledge Management System (KMS) should aim at reducing barriers and building bridges toward external information sources and creating fractal shared spaces within the system contributing to organizational culture improvement.

In any organization involved in hi-tech systems management, there are different technical areas with specific skills and know-.how. In a deductive conceptual framework, know-how can be seen as operating aspect of knowledge and it can be improved, for example, by sharing experience at professional level. This consideration prompts us to take the reverse track, i.e. an inductive approach, looking for the goal of knowledge creation. Is this way easily walkable?

Actually, know-how could advance along a third dimension, generating the knowledge meta-level within the organization but this process needs the infrastructure where individual expertise, curiosity and searching attitudes could become drivers of dynamic interactions.

Classical training actions aim at enhancing and updating specific know-how in order to improve performance at the technical level. Reaching the meta-level where knowledge emerges requires creation of connections among different disciplines through educational actions. According to this approach, Safety Culture training courses should operate as connectors among the different specific disciplines and allow knowledge meta-level to arise from know-how improvement programmes. In order to achieve this goal, it is necessary to give participants the chance to recognize socio-technological feedback loops within the organization and to learn methods and tools to become players of culture change, moving along information flows of the knowledge meta-level.

The first step to improve people's capability to identify local criticalities and contribute to global change is to establish a shared code exploiting symbols and metaphor approach.

An interesting example of metaphor approach is represented by use of travel metaphor [8]. If you are going to take a trip with some friends and you will be driving, you should face a situation where road is curved and narrow, with unexpected obstacles and tunnels. Of course you may be a very skilled driver and have a very good car with up-to-date safety systems. It is important but it isn't enough. Before leaving, you should have a briefing with your travelmates (communication and knowledge sharing), check the map and the navigator (knowledge management), check safety and control systems (brakes, wheel, lights etc.). You should also clean the windshield and turn on the lights. Safety Culture means clear vision. Expanding this metaphor, we could say that training methodologies should give people the chance to explore complexity without losing the way.

Therefore, a well-designed Knowledge Management System should give people the chance to find methods and tools to organize information and data in a coherent framework where they can be connected in order to yield basic and complex concepts recognized and shared within the organization.

When this process starts, people become aware of their role in the knowledge network and are stimulated to search, share and apply best practices.

4. EDUCATION AND TRAINING

Education and Training (E&T) actions can be very powerful and effective drivers of these processes, because they represent a tool for changing individual and group visions and spreading best practices and updated concepts.

Anyway, E&T actions could be not so effective if they don't aim at shaping the stream of knowledge within the organization. In order to reach this goal, it is necessary to adopt an inductive approach that allows each student to access and share individual experience and knowledge using the "keywords" provided during the course. The trainer leads the process of "knowledge finding" through safety-related case studies, role-playing and simulation based on the technique of brainstorming where specialists and experts of different disciplines work together with people coming from all areas of the organization.

In this way, workgroups are "organizations in micro-scale" where different know-how and expertise combine in order to yield best solutions through collaborative and competitive strategies, according to complex systems dynamics and logics which start knowledge improvement process. In particular, during training courses and workshops, concepts are analyzed by participants according to their own background and linked to each other with the aim to find further implications and connections [9].

Combined use of concepts as cognitive heuristics and feedback are exploited to help people to better understand how certain beliefs are generated within a group, and to become aware of such influences on their own perception of reality. A typical example of belief genesis is represented by "urban myths", where a combination of "availability heuristic" (i.e. easiness of imagining a situation) and positive feedback (the more people repeat something, the "truer" it becomes) could generate a common belief, although science or statistics tell a different story. This can become very dangerous if it modifies the correct perception of risks.

Another interesting topic of E&T sessions is represented by the study of paradoxes and self-fulfilling prophecies in terms of negative and positive feedback respectively.

The first ones can be explained using metaphors, for example moving in a viscous medium, highlighting the need to find a balance between driving forces and environmental resistance or, when it is possible, to "process" the context (e.g. with information sharing and brainstorming) before starting change actions.

The second ones are a typical example of positive feedback where an initial situation of worry is amplified by its own effects until it becomes real as in the case of industrial plants degradation due to carelessness of managers and workers in a blaming context.

A particular focus in E&T methodologies is dedicated to serendipity, originally meant as chance of discovering things you were not searching. This very interesting concept can be translated into capability of finding unexpected solutions to not established problems and linked, in this way, to the capability to manage the unknown. Often, unexpected events and criticalities derive from complex dynamics and hidden interactions. In some cases, available models and established know-how could be not enough to recognize and face these challenges.

Developing a serendipic attitude means acquiring capability to walk through unexplored ways every time we have the chance to establish new and not obvious connections among system's elements.

This attitude could become fundamental in anticipating dangerous outcomes of system's evolution due to internal or external context change.

Training people to develop this attitude requires innovative methodologies based on knowledge creation, because connecting heterogeneous elements as observations, information, surveys, reports etc. needs a conceptual framework which can be found only at knowledge meta-level where it is possible to activate cognitive functions in a recursive way. This process can be described through the metaphor of puzzle solving games where the final image could be unknown and its recognition is based on linking existing elements and updating temporary configurations.

Therefore, a relevant output of class experiences is represented by the role awareness that participants to E&T sessions learn in so far as they acquire a higher view of organizational model and dynamics and recognize their potential contribute to Safety Culture improvement. This upgrade requires the realization of a meta-knowledge within the organization which is possible through the implementation of a Knowledge Management System based on interactive processes of Education and Training.

5. CONCLUSIONS

The fundamental goal of the training methodologies is to give participants the chance to move on knowledge meta-level with the awareness of the effects of individual choices on global safety. Fractal architectures allow information flows to go in depth and activate all levels of the organization, then Safety Culture E&T programmes should be designed with a particular attention to create multi-scale shared spaces, tuning topics and classes, mixing competencies and know-how and involving people from different hierarchical levels of the organization. Besides, in Safety Culture training courses teacher is part of the class and becomes the hub of interactions within the class. Selecting case-studies which encompass several technical and organizational issues and can be analyzed up to root causes gives participants the chance to make experience of simulations and brainstorming, "feeling" the role of context and group suggestions on individual perception.

These E&T methodologies require a strong interaction with KMS in order to exploit all available and suitable tools and methods to carry out workgroups and deal with complex case-studies.

At the same time, a dynamic KMS should be continuously updated exploiting outcomes of all E&T sessions (courses, seminars, workshops etc.) which, in turn, should address researches and extend KMS outreach toward issues and themes which influence safety.

It is easy to observe that these considerations lead to knowledge creation feedback loops and to an integrated Knowledge Management-Education and Training (KM-E&T) system within the organization.

Anyway, a well-designed KM-E&T system could be only an empty architecture if people wander through the hallways without an actual involvement and interaction. For this reason, adopting an inductive approach aims at exploiting individual good attitudes as a lever to make people build and walk through bridges. Besides, good attitudes represent internal drivers of the process and the system should be realized in order to promote their activation, involving psychological, relational and social skills, starting, first of all, from a strong engagement of trainers and managers to develop a sound leadership on safety culture improvement.

Finally, an effective KM-E&T system should reflect complexity of organization, exploiting innovative architectures and models as fractal and interactive physical and virtual shared spaces. In this context, safety is the primary goal and the strong *fil rouge* which connects different disciplines at all levels and represents a leading driver for the process of knowledge creation and awareness development. In this perspective, KM software tools should be designed with the aim to facilitate an actual interaction among individual, organizational and technological agents of the system. It means that a software tool should never take the place of a real interaction but it should be used to give people a common platform where information could be updated, shared and made available for further discussion, analysis etc. In this way, virtual connections can be very useful for moving along flow lines of knowledge meta-level in preliminary and following stages of real interaction sessions as brainstorming, focus groups, courses etc.

In the light of these considerations, the final goal and the expected outcome of an integrated and well-designed KM-E&T System is to develop systemic vision and improve Safety Culture within the organization through continuous and dynamic interaction of Education and Training actions, Knowledge Management and people's active involvement at all levels of the organization.

REFERENCES

[1] FEYNMAN, R.P., "Mr. Feynman Goes to Washington". Engineering and Science, 51 (1). (1987) 6-22.

[2] HAAGE, M., "The IAEA Safety Culture Continuous Improvement Process (SCCIP). Making safety culture tangible", presented at Technical Meeting on Developing Improvement Programmes for Safety Culture, IAEA, Vienna, 2015.

[3] KUHN, T., The Structure of Scientific Revolutions 3rd ed., University of Chicago Press, Chicago (1996).

[4] RUSCONI, C., "Training labs: a way for improving Safety Culture", Transactions of the American Nuclear Society, Vol. 109, Washington, D.C., (2013) 2155-2157.

[5] MC CORMICK, N.J., Reliability and Risk Analysis, Academic Press Inc. (1981).

[6] RASMUSSEN, J., Information Processing and Human-Machine Interaction: an Approach to Cognitive Engineering, North-Holland, Elsevier (1986).

[7] HOLLNAGEL, E., Cognitive Reliability and Error Analysis Method – CREAM, Elsevier Science, Oxford (1998).

[8] RUSCONI, C., "Interactive training: a methodology for improving Safety Culture", presented at International Experts' Meeting on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna, 2013.

[9] RUSCONI, C., "Complexity and safety. Training methodologies for developing a systemic vision", presented at Technical Meeting on Developing Improvement Programmes for Safety Culture, IAEA, Vienna, 2015.

BIBLIOGRAPHY

STAMALEATOS, M., DEZFULI, H., "Probabilistic Risk Assessment Procedures Guide for NASA Managers and Practitioners", NASA/SP-2011-3421, National Aeronautics and Space Administration, Washington (2011).

KLETZ, T., Learning from accidents 3rd ed., Gulf Professional Publishing, Oxford (2001).

LEVESON N., "A New Accident Model for Engineering Safer Systems", Safety Science, Vol. 42, No. 4, (2004), 237-270.

HAAGE, M., "A Systemic Analysis of Human and Organizational Factors at the Fukushima Daiichi Accident", presentation presented at Technical Meeting on Developing Improvement Programmes for Safety Culture, IAEA Vienna, 2015.

A. KOLACZKOWSKI, A., FORESTER, J., LOIS, E., COOPER, S., Good Practices for Implementing Human Reliability Analysis (HRA), NUREG 1792, U.S. Nuclear Regulatory Commission (2005).

FORESTER, J., KOLACZKOWSKI, A., LOIS, E., KELLY, D., Evaluation of Human Reliability Analysis Methods Against Good Practices, NUREG 1842, U.S. Nuclear Regulatory Commission (2006).

CHANDLER, F.T., CHANG, Y.H.J., MOSLEH, A., MARBLE, J.L., BORING, R.L., GERTMAN, D.I., Human Reliability Analysis Methods. Selection Guidance for NASA, NASA/OSMA Technical Report, National Aeronautics and Space Administration, Washington (2006).

INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Safety Culture, Safety Series No. 75-INSAG-4, International Atomic Energy Agency, Vienna (1991).

INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Key Practical Issues in Strengthening Safety Culture, INSAG-15, International Atomic Energy Agency, Vienna (2002).

INTERNATIONAL ATOMIV ENERGY AGENCY, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants, Safety Standards Series No. SSG-3, International Atomic Energy Agency, Vienna (2010).

INTERNATIONAL ATOMIV ENERGY AGENCY, Safety Culture in the Maintenance of Nuclear Power Plants, Safety Reports Series No. 42, International Atomic Energy Agency, Vienna (2005).

INTERNATIONAL ATOMIV ENERGY AGENCY, Safety Culture in Pre-operational Phases of Nuclear Power Plant Projects, Safety Reports Series No. 74, International Atomic Energy Agency, Vienna (2012).

DEVELOPMENT OF THE KINS SAFETY CULTURE MATURITY MODEL FOR SELF AND INDEPENDENT ASSESSMENT
Comparison Study

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Abstract

Safety culture of an organization is cultivated and affected not only by societal and regulatory environments of the organization, but by its philosophies, policies, events and activities experienced in the process of accomplishing of its mission. The safety culture would be continuously changed by the interactions between its circumstanced factors along with time as an organic entity. Based on the notion, Korea Institute of Nuclear Safety (KINS) has developed a safety culture maturity model for self and independent assessment. In the course of the development research, three prerequisite factors of safety culture assessment model (SCAM) were derived from a literature study. From a comparison study, a number of limitations in the IAEA's three-staged model and Kolb's change model have been identified. Hudson's five-staged safety culture maturity model and Prochaska & DiClemente's change model were introduced to overcome the limitations. Hudson's five-staged model was modified into four stages by reflecting the characteristics of Korean nuclear power plant (NPP) operating organizations. Prochaska & DiClemente's change model was extended to amalgamate with the four-staged model. A number of approximately 200 evaluation criteria reflecting four organizational hierarchies were developed to identify safety culture in the development stages. The effectiveness of the KINS SCAM was confirmed by an application of KINS safety culture assessment to a Korean NPP operating organization.

1. INTRODUCTION

There have been considerable efforts for assessment of safety culture since the INSAG (International Nuclear Safety Advisory Group) initially introduced the concept of safety culture into the nuclear industry in 1986 [1]. The concept of safety culture proposed by INSAG has been expanded and the definition of safety culture varied from diverse studies and researches. Recent research, however, agrees that the fundamental constituents of safety culture are values, beliefs and behaviours of organizational personnel. Therefore, if the status of the safety culture is to be assessed, efforts should be made to evaluate personnel's values, beliefs, and behaviours. Considering that, safety culture and its constituents are intangible, and a safety culture assessment team usually consists of numerous experts with diverse expertise, a well-developed safety culture assessment model (SCAM) is indispensable to attain meaningful results which ensure a certain degree of consistency.

As safety culture consists of values, beliefs, and behaviours, a SCAM should be developed to address and evaluate the safety culture constituents while reflecting their attributes. In this paper, we performed a literature study to identify the prerequisite characteristics of SCAM in order to assess the safety culture and its constituents properly. The defined characteristics of SCAM were used as guidelines for model development. A model comparison study was conducted on the IAEA's SCAM [2] and Hudson's safety culture maturity model [8]. Used to illustrate the change process of safety culture in the IAEA's model, Kolb's change model [4] was reviewed along with Prochaska & DiClemente's change model [11]. A number of approximately 200 evaluation criteria for safety culture development stages were developed to represent organizational hierarchies and define safety culture components.

In order to verify the effectiveness of the KINS SCAM, the model was applied to assess a NPP operating organization's safety culture. In the application process, interview strategies and scenarios were developed and applied to the safety culture examination. The application results were integrated into a table in order to assess the organizational safety culture in a holistic manner. The application indicates the KINS SCAM is a useful model for not only assessing safety culture, but developing corrective action plans, strategies and guidelines for evolving safety culture.

2. DEVELOPMENT OF NUCLEAR SAFETY CULTURE ASSESSMENT MODEL USING SAFETY CULTURE MATURITY MODEL

2.1. Defining prerequisite characteristics of safety culture assessment model (SCAM)

A literature study was performed to review the safety culture assessment methodologies developed not only from nuclear industries, but from non-nuclear industries including the gas & oil industry, and the aviation industry. Three indispensable factors of SCAM which should be attained, were derived from the literature study and previously experience from performing safety culture assessments, these factors were applied as criteria for a comparative study.

First of all, safety culture components reflecting industrial characteristics should be clearly defined in SCAM. The characteristics of the nuclear industry are similar to the characteristics of other high-risk industries like the oil & gas industry and the aviation industry in terms of incurrence of tremendous human and environmental damages in accidental circumstances. The nuclear industry, however, has a higher negative acceptance from the public than other high-risk industries in terms of the irreversible harmful effects from radioactive materials. Therefore, SCAM for the nuclear industry should be designed to distinctively define indicators of the nuclear industry's characteristics.

The second factor of SCAM is that SCAM should provide distinguishable standards for evaluators to perform a consistent assessment. As safety culture is intrinsically intangible and, its constituents are interrelated and have universal characteristics, the evaluation of such constituents could be diversified from different assessors' views. In aspects of safety culture, delineation of organic interrelationships between the constituents and the establishment of distinguishable assessment criteria for deficiencies should be one of the indispensable factors.

The last factor for the assessment model included in SCAM should be the availability for developing corrective plans, establishing stepwise goals and strategic guidelines for defined deficiencies of a safety culture from evaluation results. The nuclear industry comprises operating organizations diversified spectra in terms of safety levels. Affiliate organizations attain different safety culture, even they are governed by identical management systems. It is practical that the levels of deficiencies between organizations are different from each other. If assessment results would demand or derive the implementation of high-level corrective actions regardless of organizational level differences, an organization which has a lower level of safety culture would not perform the corrective actions appropriately and not attain an enhanced safety culture. In this context, it is practically effective that establishment of corrective action plans should be developed from an identified level of safety culture, not the highest postulated level based on the notion that the safety culture of an organization does not change before cultural constituents (values, beliefs and behaviours) of the organizational members are changed.

From the literature study, two safety culture assessment methodologies were selected as the research models; one was the IAEA's safety culture assessment methodology for the nuclear industry and the other was the CAA-NL (Civil Aviation Authority in the Netherland) independent assessment model of safety culture for the aviation industry.

2.2. SCAM comparison study of the nuclear industry and the aviation industry

2.2.1. Review of IAEA's SCAM

It is the INSAG (International Nuclear Safety Advisory Group) that initially introduced the concept of safety culture into the industry and extended the concept in the INSAG-4 by suggesting safety culture indicators in the INSAG-1 report [1][2]. In order to assist the evaluation of safety culture indicators in INSAG-4, the IAEA published a set of practical guidelines; ASCOT (Assessment of Safety Culture in Organization Team) Guidelines, key questions developed to identify states of indicators representing an organization's safety culture [3]. From reviewing the guidelines and the experiences attained from the application of the guidelines to the safety culture assessment of Korean NPPs, we found that the IAEA's model was available for identifying the structural effectiveness of NPPs operating organizations. However, it was not clearly identified how the evaluation results could represent the organizational safety culture. In addition, the absence of detailed evaluation criteria was found as another limitation to the model. All the answers to the questions should be inevitably evaluated with certain individual measures postulated by expert participants. The individual measures depended considerably on the differentiated expertise of the evaluators affecting the consistency of the assessment.

The efforts to resolve the limitations of the IAEA's model were subsequently found in the IAEA's Safety Reports Series No. 11, Developing Safety Culture in Nuclear Activities Practical Suggestions to Assist Progress [2]. The report extended the definition of safety culture from the organizational framework and individual attitudes to an amalgamation of values, standards, morals and norms of acceptable behaviour. On the basis of the extended concept of safety culture, the report introduced a three-staged development of safety culture for assessing the level of safety culture. In addition, Kolb's organizational learning model [4] was introduced as the development mechanism of safety culture in the report. The representative characteristics of each stage are denoted briefly as followed [2];

— "Stage I: Safety Based Solely on Rules and Regulation
  - Problems are not anticipated; the organization reacts to each one as it occurs.
  - The decisions taken by departments and functions concentrate upon little more than the need to comply with rules.
  - People who make mistakes are simply blamed for their failure to comply with the rules.

— Stage II: Good Safety Performance Becomes an Organizational Goal
  - The organization concentrates primarily on day to day matters. There is little in the way of strategy.
  - Decisions are often centred on cost and functions. Safety, cost and productivity are seen as detracting from one another. Safety is thought to imply higher cost and reduced production.
  - Management's response to mistakes is to put more control in place via procedures and retaining. There is a little less blaming

— Stage III: Safety Performance Can Always Be Improved
  - The organization begins to act strategically with a focus on the longer term as well as awareness of the present. It anticipates problems and deals with their causes before they happen.
  - Decisions are made in the full knowledge of their safety impact on work or business processes as well as on departments and functions."[2]

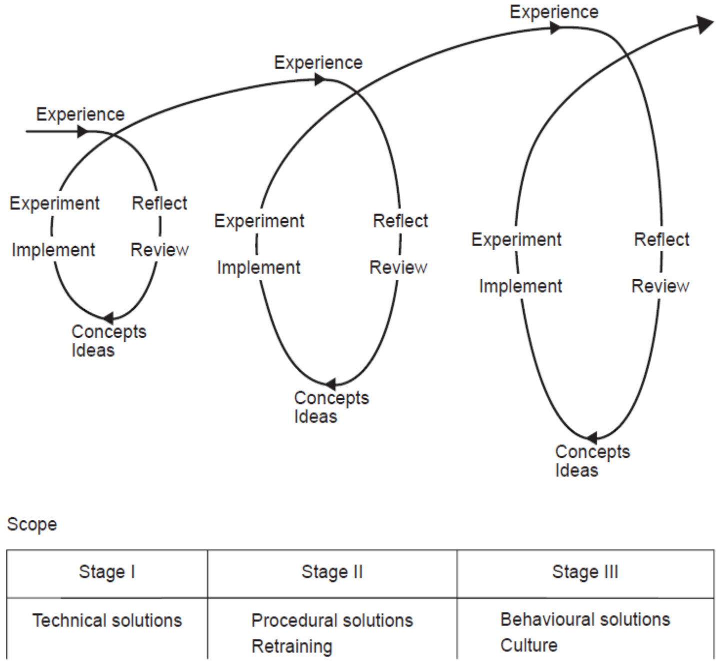


FIG. 1. The IAEA's three-staged model and Kolb's organizational learning model [2].

The No. 11 report should be highly evaluated in the aspects of the SCAM development process as the fundamental transition was made from a restorative approach explained the INSAG-4 to an evolutionary approach. The INSAG-4's approach is attempted to classify the hierarchy of an organization, define and evaluate the constitutional characteristics in each level of the organizational structure, and restore the evaluation results into the holistic safety culture of the organization. In the process of evaluation based on the INSAG-4's approach, fundamental constituents of safety culture such as values, beliefs, and behaviours are not appropriately addressed. On the other hand, the approach described in the No. 11 report attempts to assess the fundamental constituents by defining representative characteristics of three development stages based on the idea that any change in safety culture should be evolutionary rather than revolutionary [2]. The concepts of the No. 11 report were developed and extended in the subsequent IAEA publications including IAEA-TECDOC-1329 [5][7].

Although the approach of the No. 11 report proposed an advanced approach to safety culture assessment, a certain degree of limitations were observed in the application of the approach to assess Korean NPPs' safety culture. The limitations experienced in the application of the three-staged IAEA's model are substantially divided into two different areas; one area was found in the defined representative characteristics of the development stages. The three-staged development model is based on linearly continuous development rather than an abrupt advance of safety culture as depicted in Fig. 1. However, a sudden discontinuous increase of development was observed between Stage II and III. The logically unexpected advances of safety culture development were found on the way of performing tasks. The representative characteristics of Stage II in performing its tasks are defined as short term, daily basis without any strategy. On the other hand, those of Stage III are defined as long term basis with a clearly established strategy by recognition of current status and previous events. The missing stage in terms of a continuous development is a process of introduction and internalization of a relevant system for collecting, refining, analyzing data not only to recognize current status, but also to establish a practically available strategy for anticipating problems. Realistically the system needs considerable time to be as effective as the level defined in Stage III by undergoing the process of conceptualizing, implementing, applying, modifying and internalizing activities. Similar discontinuous developments from Stage II to Stage III were found in other characteristics including decision making, conflict resolution, and communication. Therefore, a stage to link Stage II with Stage III is necessary to practically apply the model.

The other limitation experienced in the application was the absence of modelling and addressing safety culture reversion phenomena. Adopted as the development mechanism in the No. 11 report, Kolb's organizational learning model postulates a continuous development process shown in Fig. 1. According to the learning model, once an organization attains Stage II, it neither fails to progress to Stage III nor recedes to Stage I as long as the six learning steps; Experience, Reflect, Review, Concepts Ideas, Implement, and Experiment, are carried out. The reversion of safety culture, however, occurs frequently and consistently occurring at NPPs as one of the dominant obstacles in the process of safety culture development. The reversion process of safety culture occasionally tends to be intensely activated while in the process of safety culture change, but is difficult to be identified in the early stage. Because of intangible attributes of the reversion process including over-confidence and complacency, SCAM should provide a model for anticipating and addressing them through a more reasonable process in the change mechanism to appropriately apply to NPPs.[19]

2.2.2. Review of the aviation industry's SCAM

The CAA (Civil Aviation Authority) in the Netherlands developed a regulatory independent SCAM based on Professor Patrick Hudson's work in 2005,

[19] Editorial note: Since the paper was submitted, the IAEA has published two publications providing the current IAEA methodology for safety culture assessment, see INTERNATIONAL ATOMIC ENERGY AGENCY, Performing Safety Culture Self Assessments, IAEA Safety Report Series No. 83 IAEA, Vienna (2016) and [3] INTERNATIONAL ATOMIC ENERGY AGENCY, OSART Independent Safety Culture Assessment (ISCA), IAEA Safety Series No. 32, IAEA, Vienna (2016).

and performed safety culture assessments for aviation maintenance companies from 2006 to 2008 [6]. The safety culture maturity model was originated by Professor R. Westrum, who classified the types of organizational culture into three dominant characteristics; Pathological, Bureaucratic, and Generative organization from low level to high [9]. Hudson has extended the three-staged classifications into five stages; Pathological, Reactive, Calculative, Proactive, and Generative, after defining two additional prerequisite stages for Bureaucratic stages of Westrum's classification; Reactive and Proactive [8][10]. In order to explain the change process of safety culture from low level to high, Hudson introduced Prochaska & DiClemente's change model into the maturity model[8]. The change model which was originally developed for getting people off dependencies such as drugs, smoking, and is consisted of five steps; Pre-contemplative, Contemplative, Preparation, Action, and Maintenance[11].

We performed a comparison study on Westrum's, Hudson's and IAEA's model in order to examine whether the models properly address the fundamental constituents of safety culture; values, beliefs and behaviours, and how the models suggest a practical solution to the limitations of the IAEA's model. The results of the comparison study are succinctly shown in Table 1.

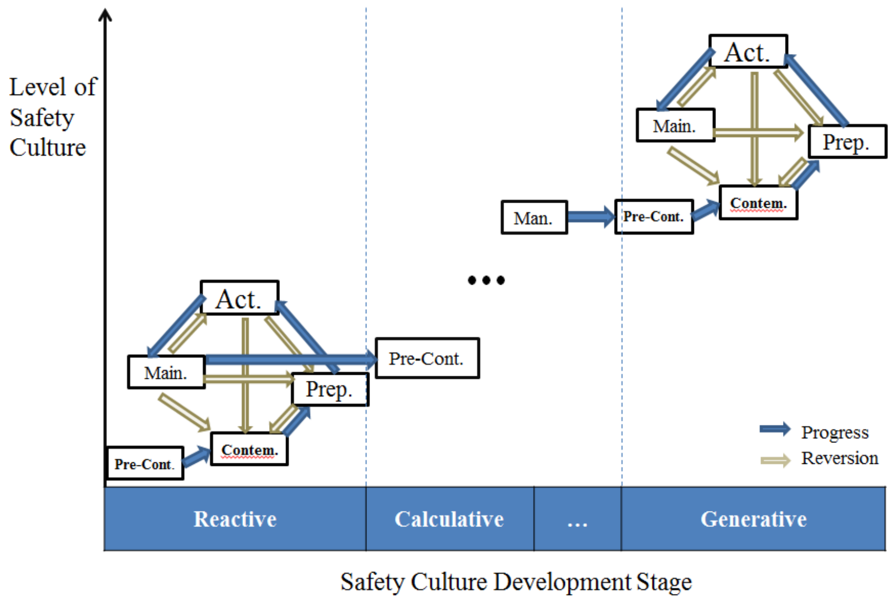
TABLE 1. RESULTS OF SCAM COMPARISON STUDY

Model	Development Level of Safety Culture				
Westrum's Model	Pathological	Bureaucratic			Generative
Hudson's Model	Pathological	Reactive	Calculative	Proactive	Generative
IAEA's Model	Stage I	Stage II		Stage III	

In the aspect of the representative characteristics of each level, we found that the Bureaucratic definitions in Westrum's model were as much extensively defined that most of organization would be identified into the Bureaucratic. On the other hand, Hudson's model defined the dominant traits of each level in terms of safety culture constituents; values, beliefs, and behaviours. One especially notable issue experienced in safety culture assessments of Korean NPPs was how to identify the effectiveness of safety management systems (SMSs). Some NPPs assumed that the SMSs were properly working once they were introduced and used through the procedures regardless of change in the values and beliefs of personnel. Hudson's model addresses the SMS effectiveness with the representative traits at the Calculative stage. He determined that SMSs need to undergo an internalizing process to be effective by changing individual values and beliefs, and the process would take place at the Calculative stage, which begins to introduce various systems [8]. We confirmed that the limitation in the IAEA's model on the discontinuous development between Stage II and III could be resolved by introducing the calculative stage.

The other purpose of the comparison study was to review the availability of Prochaska & DiClemente's change model in addressing the safety culture reversion phenomena identified in the limitations of Kolb's organizational learning model. The change model reflects safety culture reversion in the development process shown in Fig. 2. In the change model, as the first two processes (Pre-contemplative and Contemplative steps) are related with the transition of individual values, it is performed internally without any actual actions. Observable activities begin from the Contemplative to the Preparation step, and the reversion possibilities. For instance, the Maintenance step, which has three different reversion processes, is exposed to higher reversion possibilities than the Preparation step, which has only one reversion process [8][11]. It is reasonable that an organization in the higher level should experience more diverse and complex failures than one in the lower.

3. DEVELOPMENT OF THE KINS SCAM



Pre-Cont.:	Pre-Contemplate	Contem.:	Contemplate
Prep.:	Preparation	Act.:	Action
Man.:	Maintenance		

FIG. 2. Safety culture change model in KINS safety culture maturity model.

The KINS SCAM was developed based on Hudson's safety culture maturity model and Prochaska & DiClemente's change model. Hudson's five-staged maturity model was modified into a four-staged model in the process of reflecting the unique characteristics of the Korean nuclear industry. Korean NPPs are operated by a single utility company, Korea Hydro and Nuclear Power (KHNP) Corporation, which was formerly a state-run organization before it was privatized in 2001. From KINS safety culture examination experiences, it was confirmed that KHNP's organizational culture had a certain degree of bureaucratic characteristics among the senior staff, and the headquarter office had exercised strong governance over the four branch offices located at the NPP sites. The KINS SCAM merged the Pathological and the Reactive stage into the Reactive stage after analyses of periodic inspection data and safety culture assessment results, reflecting selective characteristics of the Pathological stage. Prochaska & DiClemente's change model was extended for four safety culture development stages depicted in Fig. 2 with defining the Maintenance step of the development stage as the Pre-contemplative step of the next stage. There are two reasons for the modification of the change model; one is based on the notion that at the end of the Maintenance step the organizations tend to fall into a state of complacency due to receiving usual praises and rewards for achieving accomplishments. As the state of complacency has the similar representable characteristics of the Pre-contemplative step, the Maintenance step of the previous stage is linked to the Pre-contemplative step of the next stage. The other reason is on the evolutional development concept of the maturity model. The maturity model is fundamentally based on continuous development of safety culture, not jumping over any development stage.

In order to apply the modified maturity model and change model to the safety culture assessment, the representative characteristics of each stage were developed. As representative traits of the development stages are used as the evaluation criteria in safety culture assessment, the degree of details and systemic constituents directly affect the quality of evaluation results. In addition, as properly defined evaluation criteria restrict the evaluator's subjectivity and arguments arising from the difference in expertise to a reasonable degree. Considerable efforts including literature study, data collection and selection, and expert meetings were made to develop such evaluation criteria.

A development strategy for evaluation criteria was established in three ways; First, we extracted representative features of the Generative or the Proactive stage from regulatory inspection data and key references selected from the literature study including IAEA GS-G-3.1[12], US NRC IP95003.02[13]. In this process, we determined that the extracted traits should belong to the four organizational hierarchies: Top Managers (TMs), Team Leaders (TLs), Department Managers (DMs), and Field Staff (FS). The representative attributes for each hierarchy were defined as the following; Philosophies and Principles for TMs, Policies and Guidelines for TLs, Procedures and Programs for DMs, and Practices and Implementations for FS. In the next place, the draft features of the Generative or the

Proactive stage were extended to the other stages in aspects of values, beliefs and behaviours through expert meetings.

TABLE 2. SAFETY CULTURE DEVELOPMENT EVALUATION CRITERIA FOR TMs AND TLs

Org. / *SC Stages*	*Philosophy and Principle (Top Managers, TMs)*
Generative	• TMs established detailed organizational commitments to nuclear safety in order to clearly and practically apply their entire decision making process. • TMs strategically focus on long-term goals, schedules and investment plans for nuclear safety and carry them out themselves. • TMs routinely visit operating installations to find potential problems related to nuclear safety and focus on strengthening long-term nuclear safety.
Proactive	• TMs establish and demonstrate their commitments to nuclear safety especially when resolving apparent conflicts between nuclear safety and production. • TMs ensure plant priorities are aligned to reflect nuclear safety as the overriding priority. • TMs periodically visit operating installations to assess at first hand the effectiveness of management.
Calculative	• TMs establish their commitments to nuclear safety, but they tend to prioritize production over nuclear safety when conflicts occur. • TMs establish and focus on goals, schedules and cost-saving plans for production, but their activities show nuclear safety is given lower priority. • TMs occasionally visit operating installations but they usually depend on managers' reporting.
Reactive	• TMs do not establish their commitments to nuclear safety and even if they did, they act differently with the commitments under the circumstances and conditions. • TMs only establish goals, schedules and plan on production, whereas safety does not get interested before something happened. • TMs do not visit operating installations, and they only depend on managers' reporting.
Org.* / *SC Stages	***Policies & Guidelines (Team Leaders, TLs)***
Generative	• TLs communicate with the staff under the recognition that strengthening nuclear safety will increase production. • TLs perform supervision, coaching and mentoring in the field to set higher standards for identifying potential risks.
Proactive	• TLs communicate production factors with staff in a manner of strengthening nuclear safety factors. • TLs perform supervision, coaching and mentoring in the field to exercise their leaderships, and encourage positive practices for nuclear safety.
Calculative	• TLs only communicate nuclear safety factors that are closely related to production with the staff. Otherwise, they frequently ignore the nuclear safety factors. • TLs supervise the field only based on data and procedures. It is hard to witness their display of leadership and encouragement of positive practices.
Reactive	• TLs communicate with the staff on only production factors in order to resolve decreased efficiency caused by frequent occurrence of events. • TLs supervise only focusing on meeting regulations. They do not display leadership in making improvements.

TABLE 3. SAFETY CULTURE DEVELOPMENT EVALUATION CRITERIA FOR DMs AND FS

Org. / *SC Stages*	*Procedures & Programs (Department Managers, DMs)*
Generative	• DMs display leadership by preparing all relevant resources and managing potential risk to attain higher level of safety. • DMs display leadership by not only witnessing the implementation of the identified work process based on potential risk insights but through observation, coaching and mentoring to encourage positive practices. • DMs display leadership in a vigilant way by taking appropriate measures against adverse effects on work and staff communication.
Proactive	• DMs display leadership by preparing all relevant resources including equipment, procedures, and time to maintain adequacy in work quality. • DMs display leadership by witnessing significant work process and through observation, coaching and mentoring to encourage positive practices. • DMs display leadership in a vigilant way by taking appropriate measures against adverse effects on safety related work.
Calculative	• DMs prepare relevant resources according to the procedures, but it is occasionally hard to work properly due to unqualified equipment, as well as insufficient work knowledge, and working skills. • DMs attend significant work process but they just observe it routinely. Rarely do they display leadership by communicating with the field staff. • DMs focus on productivity so they immediately display leadership by taking appropriate measures against adverse effects on only effectiveness.
Reactive	• DMs work in an ad hoc manner with inadequate task resources in order to immediately carry out work. • DMs do not attend work process. They just confirm work results from field reports. • DMs come to know of adverse effects on work after something has happened. Sometimes they do not take any measures against adverse effects even after the occurrence of events.
Org. / *SC Stages*	*Practices & Implementation (Field Staff, FS)*
Generative	• Not only do FS fully understand and follow TMs' safety commitments, goal, policies for every safety-significant activities, but they also communicate with colleagues and senior managers to find potential issues. • FS fully display leadership on their task by not only sufficiently knowledgeable and skilled in the fundamentals of nuclear safety, but also having the insight to identify risks in a systematically organized program.
Proactive	• FS rely on TMs' safety commitments and try to follow them during safety-significant activities. • FS fully display leadership on their task because they have enough knowledge and are skilled in the fundamentals of nuclear safety based on a systematically organized program.
Calculative	• FS are acquainted to TMs' safety commitments, but do not follow them during their activities because of lack of credit to the commitments. • FS display limited leadership on their task because they have just basic knowledge and skills on nuclear safety. They did not receive enough training.
Reactive	• FS are not acquainted to TMs' safety commitments, even if they were, they would not follow them for their activities, because they assume the commitments exist only on paper. • FS frequently make mistakes because they did not receive adequate training. If FS make mistakes, they make up for them in an ad hoc manner.

Lastly, the developed sets of evaluation criteria were steadily modified by reflecting newly acquired experiences from safety culture assessments. A number of approximately 200 evaluation criteria for each development stage were developed for 13 safety culture components of the KINS SCAM. Table 2 and table 3 show part of the developed evaluation criteria for the safety culture development.

4. APPLICATION OF THE KINS SCAM TO ASSESS SAFETY CULTURE OF KOREA NUCLEAR POWER PLANT

4.1. KINS safety culture assessment process

KINS performed a safety culture examination with the developed SCAM on a NPP operating organization which has approximately 450 staff and operates two units of power plants. The safety culture examination team consisted of six experts including a team leader, human and organizational experts and nuclear safety experts. The examination methods used were interviews, document reviews, and questionnaires.

The interviews were conducted on a focus group identified from established selection criteria which include a more than 10 years consecutive working career at the NPP. The focus group consisted of 31 staff representing each organizational structure and hierarchy including three top managers; a plant manager and two division managers. As the interviews and the questionnaires were performed separately from the document reviews, the interviewees were excluded from any interaction with the document review team. In order to prevent any organizational interventions, the list of staff selected for the focus group was not notified to the corporation and the interviewees were contacted individually. Interview strategies and interview scenarios were developed and applied to overcome interviewees' defensive attitudes, naturally formed from the unique Korean culture, corporate bureaucratic characteristics, and psychological tensions deriving from the notion of being subject to the regulatory examination. The interview questions were primarily developed as open questions to elicit individual apprehension and sensitivity based on their own experiences regarding safety concepts and tasks, as well as strategically arranged through the scenarios. The interviewer made preparation to create an open atmosphere for the interviews, such as arranging parallel tables and seats, and securing a place preventing any interruption from other people. The interviewer tried to maintain an open and friendly attitudes towards the interviewees by carefully listening with minimal interventions during the interviews. The interview data was recorded after the interviewees exited the interview room. The interview data acquired from the interviews was analyzed in two ways; a statement based analysis and a contextual based one. The former was performed by confirming reliability by checking the interviewees' statement and the related data, while the latter focuses on understanding and extracting contextual meanings from the statements by reviewing word choices, linkages between sentences, and nuance changes, etc.

The questionnaires were developed as a supplementary measure for interviews and focused on only one area of safety culture, safety conscious work environment (SCWE) as some issues on SCWE were identified from previous assessments. The questionnaires were filled out by the selected focus group before commencing the interviews.

The document review was conducted to review SMS documents, plant performance data, organizational management data including operating procedures, administrative procedures, events reports, etc. The document review was focused on identifying technically and administratively adequacy in nuclear safety related activities.

The results of the safety culture assessment were derived from integrating the results of separately conducted interviews and questionnaires, and the document reviews. The results from the interviews and the questionnaires were crosschecked with the results of the document reviews to acquire insights on safety culture through deviation analysis and in-depth review area of safety culture. The integrated results shown in Table 4 were arranged into a table format which was developed to depict SCAM results from a holistic view of safety culture.

4.2. Analysis of the KINS SCAM application results

The KINS SCAM application results in Table 4 indicate that all interview results were evaluated to be one stage lower than the document review results except for the employee protection (EP) component in the safety conscious work environment (SCWE) area. After re-evaluating EP results while comparing the interview data and the questionnaire data, we found that the interview results were biased due to the interviewees' misunderstanding of EP. They seemed to have recognized EP as a reporting process which guarantees anonymity rather than a system to protect employees when mistakes, near misses, etc. are reported. Other biased results were found in the Just Culture (JC) component of the SCWE area. From the document review, it was confirmed that requisite systems for EP and JC were not appropriately introduced to the organization. Therefore, the evaluation results for EP and JC were corrected from the Calculative stage to the Reactive stage by re-evaluating interviews (I), questionnaires (Q), and document reviews (D) altogether.

From the integration of SCAM results, the weaknesses of the organization's safety culture lay on the SCWE and leadership & organizational control (LOC) areas. The deficiencies of the two components, EP and JC in SCWE were anticipated before conducting the safety culture assessment based on a case of concealing a Station Black Out (SBO) event at a nuclear power plant in 2012. The model revealed that the extent of the concealment case affected the related safety culture components clearly. Weaknesses on organizational competence (OC) and change management (CM) components in the LOC area were identified through an in-depth review for the components. It was also confirmed that the staff relocation system had recently been strengthened negatively affecting the components evaluation. According to the model review, the strengthened staff relocation system resulted in the increased rate of inexperienced staff and decrease in maintenance work performance. The model gave a credible clue on the negative influence of the OC and CM evaluation in the LOC area to the work management (WM) component in the Human Performance (HP) area.

TABLE 4. THE KINS SCAM APPLICATION RESULTS FOR A KOREAN NPP

SC Area	SC Comp.	Reactive	Calculative	Proactive	Generative
Human Performance (HP)	DM		I, D	D	
	WM	I	D		
	WP			I, D	
	RM		I, D		
Mgmt. for Improvement (MI)	OEF		I, D	D	
	PIR		I, D	D	
	DI		D		
Safety Conscious Work Environment (SCWE)	EP	D	I, Q		
	IS			I, D	
	JC	I, D	I, Q		
Leadership & Org. Control (LOC)	LS			D	
	OC	I	D		
	CM	I, D	D		

DM (Decision Making)	WM (Work Management)	WP (Work Practices)
RM (Resource Management)	OEF (Operating Experience Feedback)	DI(Diagnosis & Improvement)
EP (Employee Protection)	JC (Just Culture)	IS (Information Sharing)
LS (Leadership for Safety)	OC (Org. Competencies),	CM (Change Management)
I (Interview)	Q (Questionnaire)	D (Document review)

The model also identified strong sub-cultures were formed within the organization. It was also confirmed from the interview results that conflictions between two different sub-cultures also negatively affected the WM component. The model revealed that the sub-cultures in maintenance departments and non-maintenance departments were mutually adversary about reward systems and work co-operation systems. On the other hand, maintenance departments are highly co-operative and have an understanding attitudes towards one another. As the diagnosis and improvement (DI) component in the management for improvement (MI) area is primarily related with technical issues, interview for DI was not performed.

A number of corrective action plans and guidelines were derived from the identified deficiencies from the SCAM results and delivered to the KHNP. In addition, strategies for follow-up examinations and routine monitoring activities were developed based on the KINS SCAM. As the model is based on continuous development of safety culture, the goal for safety culture development should be to progress to the next stage, not jump to the highest, Generative stage. Based on the principle of safety culture development, the organization should establish corrective action plans to attain the representative characteristics of the next steps. In the case of LOC, the organization should focus on evolving personnel's values, beliefs and behaviours for EP and JC components by developing and performing training, procedures, and campaigning, rather than setting up matured systems for evaluating practices and behaviours.

From a comprehensive review of the KINS SCAM application results, we confirmed that the model meets to a considerable degree the two indispensable factors for SCAM derived from the literature study. The KINS SCAM can provide distinguishable criteria to identify the level of safety culture with classified definitions through not only organizational hierarchies, but also safety culture stages. In addition, the assessment results from the application were useful in establishing stepwise goals, strategies and guidelines for developing effective corrective action plans. The model defines not only the representative characteristics that should be attained to move to the next stage, but delineate anticipated reversion factors against safety culture development in the change model. The last factor for SCAM's characteristics, a clear definition of safety culture components reflecting the nuclear industry, derived from the literature study was evaluated in another research conducted to develop the KINS safety culture components. Finally, we confirmed that the KINS SCAM is a useful model for assessing the nuclear safety culture of an organization in the aspect of providing a holistic view of safety culture.

5. CONCLUSIONS

The KINS developed a SCAM for self and independent assessment of safety culture in NPPs. In the process of SCAM development, three prerequisite characteristics for SCAM were derived from the literature study. In addition, a number of limitations on the IAEA's safety culture assessment model were confirmed from the model's comparison study. Hudson's safety culture maturity model and Prochaska & DiClemente's change model were introduced and modified to overcome the limitations and reflect the characteristics of the Korean NPP operating organization and safety culture assessment experiences. Approximately 200 evaluation criteria for safety culture development stages were developed to represent organizational hierarchies and define safety culture components. The KINS SCAM was applied to assess a NPP operating organization's safety culture. In the process of the application, we confirmed that the model is useful in integrating all evaluation results into one table to assess the safety culture in a holistic manner.

In addition, the model's availability was confirmed by evaluating safety cultural impacts of a recent organizational event and the management change by deriving the deficiencies on from SCWE, LOC and HP areas. In addition, the model delineated the adverse sub-cultures between maintenance departments and non-maintenance departments.

Since the International Nuclear Safety Group (INSAG) initially introduced the concept of safety culture into the nuclear industry, the IAEA and its member countries have made a great deal of effort into developing effective assessment models for nuclear safety culture. According to the IAEA's report on the Fukushima Daiichi accident [14], the need to implement a systematic approach to safety culture synthesizing the interaction between humans, technology and organization has been emerged. The KINS SCAM and research experiences would be one of the reference models for the development of a systematic approach to self and independent assessment of safety culture.

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REFERENCES

[1] INTERNATIONAL NUCLER SAFETY ADVISORY GROUP, Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident, Safety Series No. 75-INSAG-1, IAEA, Vienna (1986).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Developing Safety Culture in Nuclear Activities Practical Suggestions to Assist Progress, Safety Reports Series No. 11, IAEA, Vienna (1998).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, ASCOT Guidelines, Guidelines for organizational self-assessment of safety culture and for reviews by the Assessment of Safety Culture in Organizations Team, IAEA-TECDOC-860, IAEA, Vienna (1996).

[4] KOLB, D., "Experiential Learning", Prentice-Hall, Englewood Cliffs, NJ (1984).

[5] INTERNATIONAL NUCLER SAFETY ADVISORY GROUP, Safety Culture, Safety Series No. 75-INSAG-4, IAEA, Vienna (1991).

[6] GOEI, H., HUDSON, P., "Moving Beyond Compliance to Performance-based Regulator Oversight", Flight Safety Foundation International Seminar, Beijing (2009)
[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety culture in nuclear installations, Guidance for use in the enhancement of safety culture, IAEA-TECDOC-1329, IAEA, Vienna (2002).
[8] HUSON, P., "Safety Culture – Theory and Practice", The Human Factor in System Reliability – Is Human Performance Predictable?, RTO HFM Workshop, RTO MP-032, Siena, Italy (1999).
[9] WESTRUM, R., "Cultures with Requisite Imagination", Verification and Validation in Complex Man-Machine Systems, Springer, New York (1991).
[10] REASON, J., HOBBS, A., "Safety Culture", Managing Maintenance Error, A Practical Guide, Ashgate, VT USA (2003).
[11] PROCHASKA, D., DICLEMENTE, C., "In Search of How People Change: Applications to Addictive Behaviours", 47, p. 1102-1114, The American Psychologist (1995).
[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, Safety Guide No. GS-G-3.1, IAEA, Vienna (2014).
[13] US NUCLEAR REGULATORY COMMITTEE, Guidance for Conducting an Independent NRC Safety Culture Assessment, Inspection Procedure 95003.02, USNRC, Washington (2009).
[14] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Nuclear Power Plant, IAEA, Vienna (2014).

CRITICAL CONVERSATIONS AND THE ROLE OF DIALOGUE IN DELIVERING MEANINGFUL IMPROVEMENTS IN SAFETY AND SECURITY CULTURE

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Abstract

Significant scholarship has been devoted to safety culture assessment methodologies focusing on the development, delivery and interpretations of safety culture surveys and other assessment techniques to provide insights into the safety culture of an organization. The aim of the paper is to discuss the value of establishing mechanisms, immediately after an assessment and regularly between assessments, to facilitate a structured dialogue among leaders around insights derived from an assessment, to enable ongoing improvements in safety and security culture. The leader's role includes both understanding the current state of culture, the "what is", and creating regular, open and informed dialogue around their role in shaping the culture to achieve "what should be". Meaningful improvements arise when leaders proactively nurture a healthy safety and security culture. The concept of 'critical conversations' is central to the engagement of leaders and provides a basis for leaders to use their own knowledge of the organization to make informed decisions on those activities that can best influence the culture. In addition to the process used to enable reflection, key enablers of a successful process will be discussed in the paper; the experience of Bruce Power will provide practical considerations for implementation. The aspects support the implementation of an integrated management system and include the adoption of a framework against which to establish a dialogue, regular engagement in reflexive 'critical conversations', leveraging existing oversight mechanisms, emphasis on limited, high visibility improvements, and exploring new approaches to understanding culture. To successfully navigate towards an ever-improving safety and security culture, leadership must create mechanisms to regularly discuss safety and security related cultural topics; be attuned to faint signals of cultural change and take appropriate action; and create the shared space and collegial atmosphere in which to engage in critical conversations about the state of safety and security culture.

1. INTRODUCTION

Significant scholarship has been devoted to research into safety culture assessment methodologies. These focus on the development, delivery and interpretations of safety culture surveys and other assessment techniques to assure reliable outcomes that provide insights into the safety culture of an organization across multiple dimensions. It is a common practice among nuclear utilities to undertake periodic safety culture assessments and the lessons from the collective experience and scholarship can also be applied to the emerging area of security culture assessments as the nuclear industry broadens its focus on this topic.

Periodic assessments can provide an important snapshot of the state of health of safety culture at a point in time, and offer insights into the actions necessary by leadership to reinforce areas of strength and address opportunities for improvement. Based on the experience of Bruce Power, a Canadian nuclear generating company operating 8 CANDU reactors (6300MW), there is also value in establishing mechanisms, immediately after an assessment and regularly between assessments, to facilitate on-going reflection by leaders about the state of safety culture.

2. SAFETY CULTURE REFLECTION: THE ROLE OF THE LEADER

The leader's role includes both understanding the current state of culture, the "what is," and creating regular, open and informed dialogue around their role in shaping the culture to achieve "what should be." The establishment of a structured dialogue among leaders around insights derived from an assessment contributes to the creation of a baseline understanding of safety culture within an organization. Leaders can then engage in reflection upon the implications of events between safety culture assessments, to consider their role as contributors to shaping that culture, while becoming better attuned to discern subtle changes that may require intervention.

Meaningful improvements arise when leaders proactively nurture a healthy safety and security culture. The concept of 'critical conversations', based on that described in US-based Nuclear Energy Institute's document, Fostering a Healthy Nuclear Safety Culture [1], provides a basis for leaders to use their own knowledge of the organization to make informed decisions on those activities and approaches that can best influence the culture and support practical improvements.

Establishing a regular leadership forum to address safety culture reinforces the day-to-day role of the leader in assuring that safety remains the overriding consideration guiding decisions and actions by creating a shared experience in which a series of events, issues and activities are reviewed collectively. The aim of such a forum is not to reinterpret the facts as identified within a corrective action process, but rather to holistically reflect upon the cultural attributes and patterns that evidenced from this reflection. Experience at Bruce Power suggests that over time, the process becomes reflexive, that is, those engaged in the process move beyond using the forum to simply understand the state of safety culture and instead undertake self-reflection to better understand how their individual and collective role contributes to its current state.

As the process matures, the quality of critical conversations improves because of the deepened understanding of participants, the insights arising from the process shift from more superficial attributes and behaviours to deeper reflections on values, motivation, and human factors, and the nature of actions arising undergoes a subtle shift to include a greater emphasis on individualised leadership actions and commitments, undertaken in an aligned manner.

3. IMPLEMENTING A PROCESS TO MONITOR SAFETY CULTURE

Bruce Power began its Nuclear Safety Culture Monitoring Process in 2012. The decision to implement this approach, based on industry leading thinking arising from the United States nuclear industry, was made at the most senior levels of the corporation. In particular, sponsorship by the Chief Nuclear Officer was instrumental in assuring the sustainability of the process. The leader's role includes both understanding the current state of culture, the "what is," and creating regular, open and informed dialogue around their role in shaping the culture to achieve "what should be." Meaningful improvements arise when leaders proactively nurture a healthy safety and security culture. However, the nuclear industry is heavily technical and rational in its decision making; the establishment of a forum in which to have critical conversations about cultural attributes, motivations, and patterns of behaviour is a significant departure from metric and fact based decision forums typical of a nuclear utility. There was initially scepticism by participants; this was overcome through executive sponsorship, facilitation, education, and the building of trust within a shared space over time.

The Nuclear Safety Culture Monitoring Process at Bruce Power consists of a series of leadership meetings that include the nuclear safety culture monitoring panel, the station senior leadership reflection session, and the executive leadership reflection session. Each of these is described below. The process is documented in Bruce Power's governance.

3.1. Nuclear safety culture monitoring panel

At Bruce Power, mid-level nuclear power station leadership and corporate leaders from a variety of disciplines meet 3-4 times per year to reflect on the health of Bruce Power's safety culture, and to deepen their understanding of the role of the leader in shaping culture. The forum is called the nuclear safety culture monitoring panel.

3.1.1. Review of case study

Each meeting begins with the review of a safety culture case study, typically but not always from outside the nuclear industry, followed by a dialogue about the cultural factors contributing to the event and their applicability to our organization. In addition to deepening participant knowledge of safety culture, these case studies set the stage for the work to come and serve to outline the human, environmental or other consequences of the event. In the nuclear industry, we can never become complacent and must guard against the idea of "it can't happen here" but we have the kind of safety record where significant events are rare. Reviewing a case study reinforces the fallibility of humans and the systems we create, and sets the tone for engaging in critical conversations about maintaining a healthy safety culture within Bruce Power.

3.1.2. Review of process inputs

The Nuclear Safety Culture Monitoring Panel considers a series of inputs from which may include issues, events, successes, lessons learned, etc. since the last meeting. Critical to the success of the meeting is the selection of inputs for consideration. The advance preparatory work by the meeting chairperson/facilitator in selecting representative issues from inputs as varied as the corrective action process, industry operating experience, and employee concerns has a material impact on the quality of conversations and the success of the meeting, as does the selection of a subject matter expert who can present the issue in sufficient detail for all participants to grasp, regardless of their level of specialist knowledge.

At these panel meetings, consideration is given to including inputs that reflect Bruce Power's four pillars of nuclear safety, which include reactor safety, radiological safety, environmental safety, and conventional safety, as well as security. However, there is an emphasis on adequate review of those aspects most related to the IAEA's fundamental safety principle that people and the environment are protected from the harm of ionizing radiation. Typically no more than 6 to 8 issues are considered in a meeting, with each one taking up to thirty minutes to fully address.

Once the subject matter expert has presented the topic, participants identify the trait and attribute most significant to the topic being discussed using the World Association of Nuclear Operators (WANO) Traits of a Healthy Nuclear Safety Culture as a framework [2]. Participants use multi-voting technology to enable immediate display of results for broader discussion. Each input is reviewed in a similar manner.

The number of events for review is a matter of much discussion among utilities who have implemented a similar process, with some utilities regularly reviewing dozens, or even hundreds of events as part of their process. Bruce Power's experience is that fewer inputs progresses the participant's reflection by calling upon their judgement and experience in the workplace and offers more time to enable critical reflexive conversations about the nature of culture in contributing to the topic at hand.

3.1.3. Review of cultural patterns

Following the discussion of the individual inputs, monitoring panel members complete a short 'survey' of twelve cultural pattern questions on a 7-point Likert scale. These same questions are used in Bruce Power's periodic safety culture assessments. Although the data set from the monitoring panel's responses over time may not be statistically significant, they prepare the participants to consider underlying cultural patterns arising from the inputs upon which they have reflected to assist them in identifying insights arising from the meeting.

3.1.4. Development of insights

Monitoring panel members are separated into groups and given time for individual discussion and development of insights, which are then raised to the senior leadership of the nuclear power stations for further reflection in the next stage of the process. The small groups present their findings to the panel and after more dialogue, the monitoring panel members crystalize 3 to 5 key insights for consideration.

As the process has matured, the monitoring panel members have gained deeper knowledge of safety culture concepts and have build the level of trust necessary to have conversations that move beyond hard facts and metrics and delve into perceptions, experiences, and the organizational drivers around culture. This has enhanced the quality of insights being developed for senior leader consideration and has made each participant more attuned to their own role in influencing culture within their sphere.

3.2. Station senior leadership reflection session

The chairperson of the monitoring panel, typically one of the performance improvement leaders at Bruce Power, prepares a summary report for consideration by the senior leadership of each of Bruce Power's four-unit stations, Bruce A and Bruce B. The senior leaders of each station (site senior vice president, plant manager, and direct reports) each meet twice per year to undertake a station senior leadership reflection session.

3.2.1. Individual rating of safety culture

Prior to the meeting, the summary report from the nuclear safety culture monitoring panel is circulated for review. It includes the inputs considered by the panel, the results of the assessment of the WANO Traits of a Healthy Nuclear Safety Culture and an aggregate view of those Traits that were most often identified by the panel as contributing to the inputs considered, and the insights from the panel for consideration.

Each participant of the senior leadership reflection session is expected to individually rate the health of each of the 10 Traits of a Healthy Nuclear Safety Culture prior to the meeting as part of their preparatory activities.

3.2.2. Critical conversation

Each meeting begins with a review of the nuclear safety culture monitoring panel report, including key lessons from the case study, discussion of inputs and the contributing Traits and attributes, and a presentation of the insights.

The station plant manager and senior vice president play an instrumental role in setting the tone for the meeting, often bringing forward issues beyond those considered by the panel that are of importance to the health of safety culture at the station. They also create the sense of shared space that allows reflection and deeper, thoughtful conversations to flourish.

This is a fairly unstructured meeting compared to other station leadership meetings; it is not meant to replace oversight or accountability meetings where important safety issues are dealt with on an on-going basis. Rather, this forum allows senior station leaders to take a step back and adopt a more holistic and strategic perspective. This can help to identify subtle changes in culture that may be difficult to discern during the day-to-day activities of a nuclear power station.

3.2.3. Collective rating of safety culture traits and commitment to action

The members of the station senior leadership reflection session conclude the meeting by sharing their ratings of the Traits of a Healthy Nuclear Safety Culture and agreeing a collective rating based on the discussion during the meeting. Where the team feels that an area deserves increased leadership focus, actions may be identified to address the issue. These actions do not need to be grand corporate or station wide initiatives, although Bruce Power has successfully implemented improvements in areas such as field presence and risk recognition using a risk matrix as part of pre-job briefing as a direct result of lessons from safety culture assessment and monitoring processes. Some actions may be more subtle, such as reassessing how we communicate about safety to ensure that what is said, as well as how it is said, reinforces a fervent commitment to Bruce Power's 'Safety First' value. When the meetings become reflexive, the participants are affected by new learning and insights, which can contribute to personal development and result in small but meaningful shifts in words, decisions and actions that better reinforce the traits of a healthy nuclear safety culture within the context of Bruce Power's environment.

3.3. Executive leadership reflection session

Although Bruce Power operates all 8 of its reactors on a single site, it was recognized that the role of corporate functions were not be represented in the station senior leadership reflection sessions. Once per year, Bruce Power has recently begun an executive leadership reflection session, which considers reports documenting the station senior leadership reflection sessions, as well as broader corporate inputs on safety culture related topics. This meeting allows all the officers of the company to deepen their understanding of cultural drivers and proceeds in a manner similar to the station senior leadership reflection session.

The output from this process is shared with Bruce Power's nuclear safety review board, a subcommittee of the Board of Directors and is used as input to the periodic effectiveness review of Bruce Power's management system.

4. ENABLERS OF AN EFFECTIVE MONITORING PROCESS

There are five enablers that have contributed to the sustainability and perceived value of the process to date; these provide some practical considerations for those considering implementation of a similar process. The aspects are aligned to a Plan-Do-Check-Act cycle and support the implementation of an integrated management system.

4.1. Adopt a consistent framework

Determine the framework against which to establish a dialogue. Bruce Power's experience has been with the WANO Traits of a Healthy Nuclear Safety Culture, but other frameworks such as the IAEA Safety Characteristics can be used with equal success. Although Bruce Power considers security inputs as part of the process, the company has not yet adopted a broader framework to address those cultural aspects that may be unique to establishing a strong security culture, although this is currently being explored.

The key lesson is to establish a common language among participants of the process against which to have a dialogue and develop a shared understanding. The use of a consistent and well understood framework and shared understanding better enables critical conversations to flourish, although a shared framework is not sufficient in and of itself.

4.2. Build momentum with regularly reflection sessions

Through the nuclear safety culture monitoring process, Bruce Power created opportunities for leaders to engage regularly in Critical Conversations, and to share experiences of the culture with one another. The regularity of the nuclear safety culture monitoring panel, coupled with consistent attendance by key leaders has created a level of comfort with a forum that is dissimilar to most other meetings in its structure and approach. Over time, panel members have deepened their understanding of safety culture concepts and application, have gained new perspectives from reviewing case studies of significant events within and out side the nuclear industry and have become comfortable with having a dialogue among peers about perceptions and experiences of culture. The frequency of the panels, coupled with the structure of the process and strong facilitation has led to richer, deeper insights emerging from the panel. Strong executive sponsorship in the process is essential to assuring continued momentum, especially in the early phases of implementation when the value is not immediately evident to all participants.

4.3. Leverage existing oversight mechanisms

Bruce Power leverages existing oversight mechanisms to advance safety culture improvement and sustained engagement around cultural findings from assessments. The corrective action process is a key source of data for the nuclear safety culture monitoring panel, rich with examples from which to draw inputs for consideration. The role of the chairperson/facilitator in distilling those inputs that can generate deeper learning is critical, in particular when only a limited number of inputs are being considered at any one meeting. Reviewing inputs from the existing oversight mechanisms, without revisiting the conclusions of any causal evaluation, has enabled deeper organizational insights into the nature of events and associated human, technology and organizational aspects

Selecting the most significant events may not always yield the most insights. Bruce Power also includes a review of an issue where the result met or exceeded expectations, in addition to considering issues where deficiencies were identified. Having a dialogue about what went right can lead to a critical conversation about the barriers that may prevent this from being consistently achieved; these conversations also yield valuable insights for senior leadership on which to reflect.

4.4. Focus on meaningful actions

Bruce Power has adopted a successful approach of focusing on a limited number of highly visible initiatives, consistently applied across the organization. At its last safety culture assessment, Bruce Power identified 3 key initiatives and made them multi-year corporate focus areas. In addition to assuring leadership alignment on those things that would most impact safety culture, it helped the employees realize the company's commitment to addressing the results of the safety culture assessment. This approach has been carried through to the nuclear safety culture monitoring process. The process has not resulted in a flurry of detailed action plans. Instead, the insights from the process have led to new understanding of the safety culture implications of changes, have improved the communication about safety, risk and operational issues within the stations, and have introduced a limited number of actions to support the effectiveness of the first line supervisor.

4.5. Innovate

Safety culture is an area where there are opportunities to build on effective, well-researched assessment practices and processes. Engagement in safety culture is essential for all leaders and key to the on-going viability of the nuclear industry. There are opportunities to innovate, whether in learning from those outside our industry, in broadening the reach of safety culture monitoring and assessment to consider security culture, or to extend beyond the actions within our respective organizations and delve into those of major vendors who may partner with a utility on refurbishments, new builds, decommissioning, or other major projects. Innovate: try new approaches to deepen understanding of culture. Culture within and between individuals and organizations is a topic of rich exploratory potential that lends itself to active engagement. At Bruce Power, we have adjusted our approach to the implementation of the nuclear safety culture monitoring process, to enrich the leadership's ability to understand and shape the culture and have the framework and language to undertake critical conversations, rather than trying to establish a precise measure of culture. The mechanics of the process are, in this instance, of lesser importance that the outcome of engaging in collegial dialogue about the culture.

5. CONCLUSION

Scholarship on techniques used to assess culture is valuable to ensure an accurate understanding of the state of safety and security culture within an organization. However, deepening understanding of "what is" is only the first part of the journey to "what should be." To successfully navigate towards an ever-improving safety, and security, culture, leadership must create mechanisms to regularly discuss safety and security related cultural topics; be attuned to faint signals of cultural change and take appropriate action; and create the shared space and collegial atmosphere in which to engage in critical conversations about this vital topic.

REFERENCES

[1] NUCLEAR ENERGY INSTITUTE, Fostering a Healthy Nuclear Safety Culture, No. NEI 09-07 Rev. 1, NEI, Washington, DC (2014).

[2] WORLD ASSOCIATION OF NUCLEAR OPERATORS, Traits of a Healthy Nuclear Safety Culture, PL-2013-1, WANO, London (2014).