Human and Organizational Aspects of Assuring Nuclear Safety — Exploring 30 Years of Safety Culture

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HUMAN AND ORGANIZATIONAL ASPECTS OF ASSURING NUCLEAR SAFETY — EXPLORING 30 YEARS OF SAFETY CULTURE

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FOREWORD

The International Conference on Human and Organizational Aspects of Assuring Nuclear Safety — Exploring 30 Years of Safety Culture was organized by the IAEA and held in Vienna from 22 to 26 February 2016. Altogether, the conference attracted 350 registered participants from 56 IAEA Member States and 7 organizations.

The overall purpose of the conference was to provide an opportunity for the nuclear community to reflect on the pivotal role that human and organizational aspects play in ensuring nuclear safety. The objectives of the conference were threefold: (a) to review the experience gained with regard to human and organizational factors, safety culture and leadership for safety; (b) to share and gather experiences related to current developments, approaches, methods and research in the areas of human and organizational factors, safety culture and leadership for safety; and (c) to identify the future needs for building organizational resilience capabilities in order to further strengthen defence in depth for nuclear facilities and activities. The special focus of the conference was on safety culture and the past 30 years of developments in this area.

This publication contains the conference opening and closing addresses, summaries of all conference sessions as well as the papers produced for the conference plenary sessions. The papers presented at the parallel sessions and dialogue sessions of the conference are included in their original form in the CD-ROM accompanying this publication.

The IAEA gratefully acknowledges the cooperation and support of the organizations and individuals involved in this conference. The IAEA officer responsible for this publication was B. Skarbø of the Division of Nuclear Installation Safety.

EDITORIAL NOTE

CONTENTS

EXPLORING 30 YEARS OF SAFETY CULTURE

SUMMARIES OF PARALLEL SESSIONS

SUMMARIES OF TOPICAL SESSIONS

CLOSING SESSION

EXECUTIVE SUMMARY

This conference — Human and Organizational Aspects of Assuring Nuclear Safety: Exploring 30 Years of Safety Culture — was intended as an update of developments in the area of safety culture 30 years after the 1986 Chernobyl accident first placed this aspect of safety on the nuclear agenda. The accident in 2011 at the Fukushima Daiichi nuclear power plant was a further reminder of the importance of this critical area for the nuclear sector, the public and for governments worldwide. The term 'nuclear sector', as used at the conference, included: nuclear power generation; radiation sources in medicine, industry and research; the transport of radioactive material; radioactive waste management; and all other nuclear and radiological applications.

Three main topics emerged at the conference:

(1) Leadership and culture for safety;
(2) Learning;
(3) Systemic approach to safety through collaborative action.

These topics were discussed throughout the conference, demonstrating their natural interdependence. This summary of the conference papers and discussions highlights this interdependency, and also presents the key nuclear safety challenges for the future.

1. LEADERSHIP AND CULTURE FOR SAFETY

The contributions to the conference highlighted a number of questions that were thought to require further study. The first was: does the nuclear sector really understand what culture is in the context of organizations and safety? The simple answer to this question could easily be, no. However, the complexity and scope of the issues led the conference participants to suggest that the solution to the safety culture challenge was not to be found in a single answer. Rather, it was to be found through an ongoing dialogue on the social responsibilities of nuclear science and technology in a given cultural context.

The second question followed closely from the first: is the concept of safety culture defined clearly, adequately operationalized and appropriately utilized in relation to nuclear safety? Again, the wide range of practices illustrated the complexities in this area. Several contributions expressed scepticism about this question and, again, the answer at the collective level must be, no.

The third question — Are the core safety culture concepts developed and used in one Member State and in one part of the nuclear sector able to be translated and used in another Member State and/or different nuclear sector? — posed a challenge to the wider applicability around the world of the safety culture concept and approach, noting that the development of this concept has been conducted largely in English speaking countries. The conference participants questioned whether the concept of safety culture and the approaches to it developed in this way translate easily into other languages and other political and socioeconomic contexts.

The discussions indicated that there is no one way to achieve a strong safety culture that leads to outcomes that maintain safe performance. It was argued that at the very least, safety culture issues should not be taken for granted. No matter what the answers are to these three questions, considering them should prevent any complacency that may have developed in this area.

The relationship between safety culture and the wider organizational culture lies at the centre of the first two questions mentioned above. Several participants argued that for many in the nuclear sector, safety culture is something discrete and separate from organizational culture. This view not only influences how people think about safety culture, but also their approach to managing it. The participants argued that other models of this relationship are possible and may be more in line with current thinking outside the nuclear sector on safety, and with data collected within the nuclear sector. With regard to the latter, participants stated that while superficial culture change programmes may appear to have some effect on safety performance in the short term, they often have less effect, or may even have unexpected adverse effects, on the culture they are designed to change. This implies that the chain of effect is not as simple as intervention to change the culture leading to sustained improvement of performance, and makes the case for first understanding how the organizational culture works before attempting to alter the behaviour of people. Several contributions described how the effective use of independent self-assessments of safety culture can help in developing such an understanding, both for regulators and license holders.

The conference made three recommendations:

(1) Safety culture should no longer be seen as a discrete entity separate from organizational culture. While this relationship can be cast in a number of ways, a popular model presented at the conference viewed safety culture as one property of organizational culture; to borrow from Schein, “the way we do safety around here”.[1]

[1] SCHEIN, E., “Why nuclear safety culture requires humble leadership”, Opening Keynote Address, these Proceedings, p. 31.

(2) Organizations should move from thinking narrowly and superficially about safety culture to thinking in terms of (organizational) culture for safety.
(3) The manner in which safety culture is changed should be carefully considered. Several contributors pointed to an over-reliance on quantitative data to both design and drive culture change. There were two issues identified. First, in light of the various questions raised in the conference about the adequacy of the definition and operationalization of safety culture, can the sector be sure that it is looking at the right things when trying to understand and, even more important, change it? It is widely acknowledged that in all sectors there is a tendency to ascribe importance to certain issues and manage them as if they can be measured, rather than managing issues that are actually important. This tendency ignores the fact that the most important aspects of human cooperation, such as trust and communication, cannot be reduced to numerically descriptive indicators. Following this, it was pointed out how the over-reliance on quantitative data appears to be at the cost, in many assessment endeavours, of knowing, understanding and involving the workforce in decisions about safety and in change programmes. Expressed differently, the absence of disagreement does not mean the presence of agreement. It was cautioned that fear of retribution or culturally accepted deference to age or authority may discourage the open, respectful communication that forms the basis of a strong culture for safety.

In some contributions, the point was made that leaders need to know their people, understand them, work with them and value their knowledge and experience. This was made very clear in Schein's presentation on humble leadership, which is an approach based on respect, engagement and collaboration, and honest enquiry rather than top-down command. Schein suggested that appropriate leadership that is based upon trust and openness constitutes the key to developing organizational cultures that ensure that safety comes first.

It was made clear in the discussions (dialogue) that leadership and management are not the same thing and, to ensure nuclear safety, both good leadership and good management are required. Furthermore, it is important to recognize that leadership occurs at all levels within organizations. However, a dominant view at the conference was that to change the way things are done in the nuclear sector, the visible commitment of leaders at the top of the organization is needed. In particular, it was argued that they must be seen to be personally accountable for safety as part of that commitment.

The emphasis on leadership should not be understood to imply an underestimation of the knowledge and role played by others who work in the nuclear sector at various organizational levels. The point was made in several different ways during the conference that the workforce has valuable expertise in its own work and collectively represents not only much of the agency for change but also the final common pathway for achieving sustainable change. The non-management workforce often has valuable insights into what is actually happening within the organization and understands how best it might be changed. As was highlighted at the conference, these workers are a resource to be harnessed rather than a problem that needs to be fixed. The final observation made was that while management means getting work done through others, leadership defines the work in its longer term context and motivates people. The saying, popular in some business quarters, that management has the right to manage should not be taken as carte blanche for management by diktat rather than collaboration.

2. LEARNING

Many of the contributions focusing on 'learning for safety' in the nuclear sector focused on descriptions of particular examples of learning initiatives and experiences and methodologies. Several interesting questions emerged during this part of the conference: does the nuclear sector actually learn from its experiences, does the sector know how to learn and what does the sector learn and to what effect?

These questions lie at the heart of the wider topic of organizational learning and understanding, and answering them is a prerequisite for moving this area forward. In addressing complex problems such as the ones encountered in the nuclear sector, it is often tempting to think of learning as solving a particular problem. However, some contributors remarked that developing competence in learning is quite different than solving a given problem. Reassuringly, the conference saw several cross-industry projects completed on organizational learning for safety. From these, it was argued that learning within an organization requires several key aspects to be in place. These include: values and rewards that promote learning and knowledge; processes that support learning; reflection upon the utility of the knowledge gained; and structures that help organize and share knowledge. Facilitating learning is a key aspect of good leadership.

Several contributors asked what was being learned by the nuclear sector from its past experiences. Most learning appears to be retrospective: learning from past mistakes to avoid repeating them. The suggestion was made that the sector has become relatively skilled at preventing past accidents from occurring, but not so good at preventing future ones. Within this strategy, the focus is on the mistakes made, rather than on what was done right. In other words, the emphasis has been on human, technical and organizational weaknesses and not on strengths. There appeared to be recognition that learning should be proactive, but also some unease about being able to predict unknowable events. This unease is understandable and justifiable. Furthermore, it was suggested by some speakers that a complete shift away from retrospective to prospective learning would be ill advised. Abramova[2] made clear that both are required for a comprehensive learning strategy. Her logic was that retrospective learning is necessary to avoid repetition of past unsafe events, while prospective learning is an attempt to prevent future events that are new. At the same time both contribute not only to the prevention of unsafe events, but also the response to them.

The point was also made that learning in organizations is a natural phenomenon. However, it was noted that such learning may not be useful, as learning alone may not contribute to a coherent strategy of awareness and improvement. Among other things, it was argued that for learning to be useful, it needs to be focused and needs to contribute to the organization's collective sense-making. Organizationally useful learning was seen to be a function of leadership and collaborative management. An emerging aspect of learning that was discussed was the difference in learning and communication styles of the different generations of nuclear personnel. Within each of these focus areas it was clear that learning and knowledge needed to be shared and discussed. It was implied in all of the relevant contributions that learning, at all stages, is dependent on communication and dialogue.

There was an overarching question that emerged from many of the relevant discussions: with whom should the nuclear sector discuss and share safety knowledge and experiences? There were three answers to this question that were suggested within the various contributions.

The first and perhaps most obvious answer was: with those working in the nuclear sector at all levels. It was made clear at the conference that the nuclear sector includes not only those involved in nuclear power generation but also those involved in the use of radiation sources in medicine, industry and research, the transport of radioactive material, radioactive waste management, and all other users of nuclear and radiological applications. Nevertheless — perhaps due to the genealogies of the concepts in use within the area — the contributions to the conference tended to be focused more on activities taking place at nuclear installations rather than on other uses of radiation sources. This highlighted a need for the knowledge and experience gained in this field to be more widely shared and utilized throughout the entire nuclear sector. In this regard, the conference participants noted that a graded approach was needed in order to account for the varying magnitudes and ranges of risks in the different types of organizations and activities in the nuclear sector.

[2] ABRAMOVA, V.N., "What needs to be changed based on lessons learned from Chernobyl", these Proceedings, p. 81.

In addition, it was reiterated several times that suppliers, regulators, international bodies and governments belong to the sector. They also need to be understood as interdependent contributors that mutually influence each other and the license holders they are working with. Similarly, it was noted that even within a singular organization there are different subcultures (such as operations or maintenance), and that the unique aspects of these subcultures need to be understood, respected and engaged. Within the nuclear sector, such dialogue between subcultures was highlighted as one function of leadership and a characteristic of a strong culture for safety.

The second answer to the question, with whom should the nuclear sector discuss and share safety knowledge and experiences, was: with other organizations in other sectors and particularly those characterized as high reliability organizations. This was discussed in several of the contributions in the parallel sessions on other high reliability organizations and possible learning points for the nuclear sector were explored. It was argued that such interaction and cooperation had the potential to offer much more to the nuclear sector than it currently does. It was noted that while the nuclear sector has been an exemplar of the high reliability organizations concept, other sectors embracing the concept may be creating new distinctions and perceptions which could invigorate and refresh traditional nuclear sector thinking.

The third answer to the question, with whom should the nuclear sector discuss and share safety knowledge and experiences, was: the public and, by implication, relevant public bodies. One view expressed repeatedly at the conference was that the nuclear sector is not safe until the public believes that it is. Given the current economic and political pressures on the nuclear sector, this point was highlighted as being of particular importance. It was argued that, in several countries, nuclear power generation has been cut back or halted because of public opinion.

3. A SYSTEMIC APPROACH TO SAFETY THROUGH COLLABORATIVE ACTION

The need to take a more systemic approach to strengthening nuclear safety was recognized by the conference. In many ways, the discussions on this issue developed the conversations around organizational learning and knowledge sharing and also around leadership. In particular, several examples were given of projects and methods built upon collaboration; many of these brought to light the principles of good leadership and management, and knowledge sharing that were recommended elsewhere in the conference.

Together, the contributions in this area implied a recognition of the complexity of the nuclear sector; the plethora of different stakeholders, scientific disciplines, areas of expertise and generations all spread across different countries with their own languages and cultures, economic status, political development and type of government.

The necessity for dialogue, both formal and informal, was emphasized, as was the need for effective management and channels of communication. Collaboration cannot occur without communication and dialogue, but it also cannot be effective without trust and openness.

The conference highlighted a significant barrier to collaboration, namely the failure to understand and respect one’s collaborators and their backgrounds, objectives and limitations. Multidisciplinary collaboration often fails because the members of one discipline do not understand or respect members of other disciplines. There can be fundamental gaps between disciplines and even within one language in terms of the use of language to describe issues, problems and solutions. Language means more than simply terminology; it includes, among other things, the narratives and concepts used to describe events. For example, at the conference, some talked about human beings as ‘people’, others as ‘operators’ or ‘the workforce’, and some simply as ‘humans’. This might simply illustrate a difference in language and translation, or it might illustrate more basic differences in the various perspectives that need to be considered.

In a similar sense, the perspectives presented during the conference illustrate that when it comes to ensuring that the systemic interactions between humans, technology and organizations result in a high level of nuclear safety, a unique sensitivity to different viewpoints is needed. This requires an intellectual rigour grounded in acceptance of the legitimacy of multiple perspectives in order to create and maintain a constructive environment for questioning and problem solving.

The discussions around public involvement in strengthening nuclear safety were particularly highlighted, both in terms of defining what is accepted by the public as safe and what is not, and also with regard to how the public might be invited to become more involved in discussing various issues around how to assure nuclear safety in the future.

4. EMERGENT ACTION PLAN

The conference validated the view that nuclear safety remains a ‘living issue’ and, looking back over many years, that real progress has been made and is expected to continue. There was little complacency obvious in relation to the current position and perceived importance of the organizational and human aspects discussed at this conference. It was, however, recognized that there is still much that can and should be done. Furthermore, although focused on three apparently different sets of organizational and human aspects of nuclear safety, the discussions that emerged overlapped in a useful manner. This fact served as a powerful demonstration of the interdependency of those issues and a testament to the nature, structure and success of the conference.

The key conclusions of the conference are as follows:

— There needs to be a better understanding of the nature and utility of the concept of culture in relation to safety and its meaning across languages, cultures and circumstances. The nuclear sector needs to develop this aspect in its thinking about safety.
— There needs to be an acknowledgement that culture and leadership in relation to safety are about people: knowing, understanding, caring and involving. Good practices with regard to leadership and culture for safety require trust, openness and dialogue.
— People working in the nuclear sector are not a problem to be fixed. Rather, it is their collective knowledge, experience and unique ethic of responsibility that exemplify nuclear safety for the future. It is not only the technological aspects, but also the work related knowledge and expertise of people that should be respected, harnessed and used.
— A strong and effective culture for safety requires organizational learning and the establishment of a structured knowledge base holding useful and usable information. Developing the right conditions for learning in organizations is a function of good leadership.
— Knowledge and expertise relevant to ensuring nuclear safety has to be built up across all stakeholders in the sector and, as appropriate, shared among them. It is important to take into account that the nuclear sector involves not only those involved in power generation but also those involved in the use of radiation sources in medicine, industry and research, the transport of radioactive material, radioactive waste management, and all other users of nuclear and radiological applications. Of particular note within the nuclear sector are the cross-cutting interrelations within and among licensees, regulators, suppliers, local and central governments, the public and international bodies, all mutually influencing each other’s actions.
— More attention should be paid to high reliability organizations from other sectors as these deal with challenges that are conceptually similar to those of the nuclear sector, and which may offer novel and effective input to challenging areas such as learning and continuous improvement.
— All of the issues mentioned above need to be better understood in relation to the nature of the complex and interacting systems that together make

up the nuclear sector. This includes addressing the multiplicity of contexts within which the nuclear sector exists and operates. The perception and understanding of the interdependencies of the larger sociotechnical systems within the nuclear sector is the next competency needed to enable the continued development of a strong and common culture for safety.

OPENING SESSION

Chairperson

M. WEIGHTMAN
United Kingdom

OPENING REMARKS

INTERNATIONAL CONFERENCE ON HUMAN AND ORGANIZATIONAL ASPECTS OF ASSURING NUCLEAR SAFETY

Y. Amano
Director General,
International Atomic Energy Agency,
Vienna

Good afternoon, Ladies and Gentlemen.

I am pleased to welcome you to this IAEA International Conference on Human and Organizational Aspects of Assuring Nuclear Safety: Exploring 30 Years of Safety Culture.

The term ‘safety culture’ became established in the nuclear world after the Chernobyl accident in 1986.

A 1991 report by the International Nuclear Safety Advisory Group, entitled Safety Culture, stressed the importance of good practices for nuclear safety.

The report added that it was also essential for “all duties important to safety to be carried out correctly, with alertness, due thought and full knowledge, sound judgement and a proper sense of accountability.”

In other words, safety culture is about the human factor. It addresses the human tendency towards complacency and taking things for granted. This approach is essential in undertaking nuclear activities.

Nuclear safety is primarily the responsibility of licensees in individual States. But accidents can transcend borders, so effective international cooperation on nuclear safety is vital. The IAEA plays the leading role in bringing States together to shape a safer nuclear future throughout the world.

Our publications, including the Fundamental Safety Principles and IAEA safety standards, have established a strong global framework for safety.

In the early years after Chernobyl, the focus was, understandably, on safety at nuclear power plants.

But now the concept of safety culture is being used to enhance safety at all types of nuclear facilities, and for activities in which radiation and radioactive sources are used. These include industrial and research applications, medical diagnosis and treatment, and the transport of radioactive material.

Ladies and Gentlemen,

Last year, my report on the Fukushima Daiichi accident was published. The report found that a major factor that contributed to the accident was a widespread assumption in Japan that its nuclear power plants were so safe that an accident of this magnitude was simply unthinkable. Japan was not sufficiently prepared in March 2011 for a severe nuclear accident.

In the five years since then, Japan — and all countries with nuclear power programmes — have taken vigorous steps to reassess and, where necessary, improve safety in all its aspects.

These ranged from additional measures to protect nuclear power plants against extreme natural events such as major earthquakes and tsunamis, to organizational changes and reform of regulatory systems. Increased efforts have been made to better understand the human aspects of assuring nuclear safety.

The report on the Fukushima Daiichi accident emphasized the importance of a systemic approach to safety culture. It concluded that a strong safety culture is vital not just for the licensee, but also for the regulatory body, relevant government bodies, technical support organizations and other stakeholders.

I have just returned from the United Arab Emirates, where I had a chance to visit the Barakah site, where four nuclear power reactors are under construction. All staff and visitors to the site must attend a presentation on nuclear safety before entering. I was impressed by this commitment to instilling a safety culture long before the start of operations.

For an organization to achieve a high level of nuclear safety, it must establish a culture in which people are encouraged to continuously look for improvement, and feel able to challenge assumptions and question received wisdom. In short, a culture that puts safety first.

Technology is a human endeavour. No technology is ever 100 per cent safe. Nuclear is no exception. But I believe that important lessons for safety have been identified from Fukushima Daiichi, both in Japan and internationally.

Ladies and Gentlemen,

This conference will provide an opportunity for this expert audience to reflect upon the lessons that have been learned for safety culture over the past 30 years, and to consider what lessons may still need to be learned.

I am sure we will agree that continuous questioning, and openness to learning from experience, are key.

I wish you every success for the coming days and look forward to learning about the outcome of this important event.

Thank you.

OPENING ADDRESS

INTERNATIONAL CONFERENCE ON HUMAN AND ORGANIZATIONAL ASPECTS OF ASSURING NUCLEAR SAFETY

M. Weightman
Independent Nuclear Consultant,
United Kingdom

Ladies and Gentlemen, Director General, welcome. It is my great honour and pleasure to be your chair for this most timely, most important and, I anticipate, most exciting conference, on the impact of human and organizational factors on nuclear safety.

Most timely, as it comes some 30 years after the first coining of the term ‘safety culture’, and provides an opportunity to reflect and gather together the many advances on this topic as a foundation for the future.

Most timely, as it comes soon after the authoritative and comprehensive report by the IAEA Director General on the circumstances and lessons from the TEPCO Fukushima Daiichi nuclear accident, highlighting several lessons for this conference to build on.

But perhaps, most of all timely because we are at the cusp of challenge, opportunity and hopefully great change — a Darwinian time.

We hear that the world needs nuclear power if it is to provide all its citizens with the basic requirements of purposeful human life while preserving the natural beauty and environment of our planet. And yet, the continued use and growth of nuclear power has been challenged in some cases by a failure to deliver its promises of building new plants to time and cost, challenged by its rising financing costs and need for expert human resources, challenged by a severe nuclear accident in a highly developed and prosperous nation, and challenged, quite rightly, by a more sophisticated, questioning society. Let me emphasize the point about human resources.

After 60 years we nuclear experts who have grown up with the nuclear sector are dying out and now we must ensure we pass on our hard won lessons of what has worked well, and most importantly, where we have failed and perhaps only now are slowly realizing what is needed. New generations of nuclear experts are here today and you have the opportunity to take these lessons and deliver a better future through changing the way safe nuclear energy is assessed, delivered and assured. As the Director General has indicated, we must change the way we look at nuclear safety — take a holistic system approach involving technological, human and organizational elements This conference can act as the catalyst for that change. Indeed, we are at the cusp in time of great challenge and opportunity to change.

I said also that this conference is most important. You can gain a sense of why I believe this from what I say about its timing. If we are to deliver the change that is needed, and we must, then this conference has to succeed in laying the foundation stones of a brighter future. One of the most important lessons for universal high levels of nuclear safety, that we are slowly realizing, is that while high levels of technical standards are necessary, they are not on their own sufficient. You can only ensure their implementation through organizations and people, and people's attributes, behaviours and decisions determine what level of nuclear safety is achieved. It is this systemic approach that we must push forward with and rebalance with greater attention to the human side.

But to do so we must win the hearts and minds of those involved in the system. This crucially involves those engineers and scientists who have worked tirelessly to develop the high technical standards that we have today, based on sound science and understanding. Consequently, we must ensure that they recognize that the human and organizational input to nuclear safety is similarly solidly based on sound science and understanding, not merely common sense.

That is why this conference is so important.

And that is why for me this conference is so exciting.

We have the opportunity over the next few days to review the state of the art research and ideas on human and organizational aspects of safety; to challenge, learn and develop the scientific understanding behind it, and thereby establish the foundation stone for a new dawn of nuclear safety. Doing so can provide an essential basis for the peoples of this world to universally benefit from the peaceful use of nuclear energy for the betterment of the human race and this fragile planet of ours.

That is why for me, this conference is so timely, so important and so exciting.

And why now with great pleasure and anticipation I declare this conference open.

Thank you.

OPENING KEYNOTE ADDRESS

SAFETY CULTURE AND BELIEFS IN THE NUCLEAR INDUSTRY — LOOKING FORWARD: LOOKING BACK

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Abstract

Over the last three decades, the nuclear industry has come to accept both the concept of safety culture and the possible role that it might play in the aetiology of accidents and incidents and in safety management. This development is to be welcomed in general terms but is not without its shortcomings in practice. These largely concern the definition and subsequent operationalization of the concept and the way in which it has then been put to use. While many would agree that safety culture is an emergent property of a complex organizational system and is multifaceted, in the nuclear industry, its measurement and management have often been focused on self-reported beliefs, perceptions and behaviours. Interventions often target changes in these psychological (individual) outcomes at the expense of the other aspects of safety culture. Furthermore, many of the models that underpin this approach have assumed universality: one size fits all. While such models are useful in population level research, they can be seriously inadequate and even misleading in more particular situations. They are not sufficiently context specific at the plant level or in functions within plants. Unsurprisingly, therefore, improvements in safety culture, so modelled and measured, do not always strongly relate to improvements in safety management and safety performance. The paper explores the changes that might be necessary for a fair test of the utility of safety culture in determining the quality of safety management and actual safety performance. The final point raised in the paper is fundamental but missed by some. However cast, measured and managed, the concept of safety culture was never promoted as the sole determinant of safety management or the sole reason for safety failure. Therefore, judging the utility of the concept in relation to the quality of safety management in the nuclear industry can only be done logically in the context of the other factors involved.

1. INTRODUCTION

Over the last three decades, the nuclear industry has come to accept both the concept of safety culture and the possible role that it might play in the management of safety and in the avoidance of safety failures. Furthermore, it has played an important part in both the development of this concept and in its real world application. This is to be welcomed in general terms, but is not without its shortcomings in practice. These largely concern the definition and operationalization of the concept and the way it is used both in measurement and the management of safety.

This international conference, Human and Organizational Aspects of Assuring Nuclear Safety has been convened by the IAEA to facilitate the sharing of the experiences of the nuclear community in the application of the safety culture concept and as an encouragement for its future development.

In order to better understand the utility of the safety culture concept to the nuclear industry, this paper will first look back and consider briefly the learning points that might be drawn from its recent history. It will then look forward and discuss how the concept of safety might be further developed and how it might be better applied to ensure nuclear safety. This approach will be scaffolded by three particular aims. The first is to consider the current utility of the concept to the nuclear industry, the second is to provide a constructive challenge to current beliefs about safety culture and the third is to consider what the future could hold for the way in which this concept is thought about, operationalized and used in a time of marked change.

2. CONCEPTS, DEFINITIONS AND MEASUREMENT

The concept of safety culture was first given prominence as a result of the International Atomic Energy Agency's [1] initial report following the Chernobyl nuclear accident. It was reported there that the lack of a safety culture impacted on operator behaviour to the extent that the defence in depth barriers were breached. Safety culture was subsequently highlighted in several other major accident enquiries including, in the UK, the Piper Alpha Oil platform explosion in the North Sea and the Ladbroke Grove Rail Disaster in London. In both of these cases, the public enquiry reports argued that the existence of a poor safety culture was an important determinant of those accidents [2, 3]. The challenge to define, model and operationalize the concept then began.

Some in the scientific community questioned whether there was a need to develop this concept. A number of critics, such as Hale [4], even challenged the very existence of safety culture as something tangible. There was, and still is, the fundamental question of whether it is an entity in its own right, which if present and nurtured is good, or whether it is an emergent property of complex sociotechnical systems that exists only in terms of those aspects of the systems that it derives from [5, 6]. In general, most conceptualizations of safety culture in use appear to be derived from the more general notion of organizational culture as used in management science and given prominence in the early 1980s by organizational theorists such as Rohner [7] and Schein [8].

Although there is no universally accepted definition of safety culture, in the nuclear community, one of the most comprehensive and widely used definitions is that proposed by the Human Factors Working Group of the Advisory Committee on Safety in Nuclear Installations. Adopting a social–psychological perspective, the advisory committee proposed that, in the context of the nuclear sector, “the safety culture of an organization is the product of individual and group values, attitudes, perception, competencies, and the patterns of behaviours that determine the commitment to and the style and proficiency of, an organization’s health and safety management” [9].

A plethora of derivative models and definitions have followed and there is an extensive supporting literature spread across many countries. As above, these models have mainly represented safety culture either as a separate psychological or social entity or as an emergent property of the sociotechnical system albeit with an emphasis on its human and organizational elements. The literature has identified some of its dimensions (as a psychological and social entity) or its systems elements (as an emergent property) as, among other things, the individual’s beliefs, assumptions, behaviour and practices, shared understanding and meaning within teams, the organizational norms of behaviour and collective experience and knowledge. In addition, it appears that good safety cultures are characterized by the importance that is given to safety by all employees, and particularly by organizational leaders, in relation to other organizational goals [10].

The challenge of operationalizing a concept and developing reliable and valid measures of it is essentially that of taking an idea and grounding it in a useful way. The question is always about the context dependency of the idea and the universality of the associated measures and subsequent interventions. In terms of measurement, there are two questions: what is being measured and how? Sometimes these questions are confused. The answer to the question of what is being measured is dependent on the way in which safety culture is conceived and defined: psychological and social entity or emergent property of nuclear organizations. The answer to the question how is it measured, in turn, depends on the use of measures that are fit for purpose in relation to what is being measured. Experiences to date strongly suggest that safety culture is context dependent [11] and that the assumption of the universality of measurement is sometimes unhelpful while that of interventions is more so.

Much of the research on safety culture has tended to focus on three measurement methods, case studies, comparative studies and psychometric surveys, sometimes regardless what is being measured. As is sensible, research has often combined different methods in the study of major hazard scenarios [12, 13].

3. ACTORS, ROLES AND APPROACHES

There are a number of different actors involved in the continuing development of the notion and use of safety culture within the nuclear sector. Among these, mention of four particular groups is warranted. Together they form the platform for the collaboration that, in some part, marks out the approach of the nuclear sector to the management of safety. They are the nuclear operators, international nuclear agencies, regulators and the scientific community.

Here, the notion of nuclear operators includes their responsibility for and involvement in the design of the plant, its management and that of suppliers and also of the psychological, social and organizational aspects of the work that frames and makes possible plant operation. The international nuclear agencies include, most notably, the IAEA, World Association of Nuclear Operators and Institute of Nuclear Power Operations. These bodies provide important guidance and monitoring (see, for example, Refs [14, 15]). The IAEA [14], by way of guidance, has highlighted five key characteristics of a good safety culture. They are that safety is a clearly recognized value, that leadership for safety is clear, that accountability for safety is also clear, that safety is integrated into all activities, and that learning for safety is seen as essential. Regulators have a dual role to play in relation to safety culture; first in setting an example within their own organizations and, second, in evaluation. The Nuclear Energy Agency of the Organisation for Economic Co-operation and Development suggested that the regulator can promote safety culture in operators' organizations just through the mere fact of placing it on the agenda at the highest levels [16].

Arguably, the contributions of the nuclear operators, international agencies and regulators are clear to most. However, the contribution of the scientific community is sometimes misunderstood and underestimated. Its role is essentially one of questioning and one focused on advancing understanding, measurement and evaluated intervention. It begins with challenging the very nature of safety culture as presently conceived and its role in the aetiology of accidents and incidents. It progresses through concept operationalization to the development of reliable, valid and adequately sensitive measures. It is then expressed through the development of appropriate and feasible interventions and their evaluation with an emphasis on links to safety performance data [10].

4. CURRENT UTILITY OF THE CONCEPT IN THE NUCLEAR SECTOR

Often, the question of the utility of a concept has been answered in relatively local terms of its measurement and use in driving interventions. However, the true utility of the concept of safety culture, in the nuclear context, rests as much in its strategic added value at the management, organizational and sector levels.

The current utility of the construct of safety is vested in four different but interconnected areas.

First, it has added significantly to the pool of factors that are considered in relation to safety policies and management in pursuit of safety excellence. It has given human factors a voice and also made related issues accessible to all in nuclear organizations and not just human factors experts.

Second, and in particular, it has focused attention on human and organizational factors and provided both a framework and an argument for the measurement and management of those factors in relation to safety management. A number of useful things have resulted from this. It has encouraged even more collaboration among operators, international agencies and scientific researchers. It has ensured that discussions of these factors at all levels in the sector are more data driven. It has also opened the door to a new genre of safety interventions focused on the different dimensions or elements of safety culture and it has added to the ways in which such interventions might be evaluated. Among such interventions, one might include behavioural safety programmes [17, 18], leadership development [19] and the facilitation of organizational learning [20].

Third, It has provided a basis for bench marking and comparison within and across high hazard sectors [13, 21].

Finally, it has enhanced the reporting of safety performance and provided an additional focus of communication to stakeholders including international agencies, national governments and the public. It has offered another way of providing an assurance of quality not only in relation to safety but also more widely.

5. LOOKING BACK

It is widely recognized that the nuclear sector has played a leading role in the conceptual development, operationalization and use of the notion of safety culture. This role has been largely shaped by the major accidents and incidents that occurred over the last 30 years. As a result, the application of the concept of safety culture has been largely about what not to do and less about what we do well. This rather defensive posture has detracted from thinking about safety culture more broadly and positively. The nuclear sector has also challenged itself to rethink and optimize organizational learning as a tool to developing a good safety culture and good safety performance [20]. This shared learning has mainly focused on learning from accidents and incidents from within and across nuclear operators. The consequence has been to support the organization in becoming able to prevent past incidents from recurring while still struggling to predict, prevent and respond to future safety events.

A number of beliefs and associated behaviours have emerged over the years that are not helpful overall.

The first is reliance on the belief that a strong safety culture exists and on the power of indicative measures. This represents an unhelpful shift of responsibility for safety from individual employees, managers and executives to (the hypothetical construct of) safety culture and with this comes the risk of complacency. In extremis, this may also lead to the insidious accumulation of latent conditions that lead to accidents or incidents in complex and otherwise well defended sociotechnical systems [22]. An example may be obvious in the IAEA's preliminary report on the accident at Tokaimura [23], where failures in management oversight and scrutiny occurred and managers became unaware of plant conditions at the local level. The reliance on the belief that a strong safety culture exists has sometimes provided an excuse for not addressing more fundamental safety problems in plant design and operation [24].

The second and third unhelpful beliefs are linked cognitively by a need to simplify things and avoid the mental load of complexity. There is a widespread hope if not belief that safety culture is not context dependent — that one size fits all — and similarly that there is one universal, easy to apply intervention to strengthen or otherwise improve safety culture — the silver bullet. The scientific community both challenges these beliefs but, inadvertently, also strengthens them. Both experience and the available data strongly suggest that safety cultures are context dependent and can differ in both their nature and strength. For example, a key component of safety culture, employee attitudes to safety, can vary both within and between sectors, organizations and suborganizational structures [25, 26]. It is clear that organizational cultures evolve differently but naturally over time and in response to local and national conditions, past events and the characters of both leaders and the wider workforce [27].

Within the framework of safety culture, the nuclear community has identified the importance not only of management but also of leadership and, in doing so, has made clear the distinction between the two. There are four particular points of note.

First, poor leadership and management behaviours have been shown to be of paramount importance in the causation of and failure to prevent and respond adequately to major accidents and incidents [9]. In March 1996, Millstone nuclear power station made the cover of Time magazine because of allegations of bullying, harassment and the intimidation of employees who had tried to bring safety concerns to the attention of senior management and who eventually blew the whistle to the US Nuclear Regulatory Commission. This was the final signal that led the Nuclear Regulatory Commission to close all three Millstone plants [28].

Second, there is a need to manage both individual and team behaviours in strengthening safety culture, including those of functional jobholders. Studies have shown that groups of workers that are normally rule compliant and risk averse can take actions collectively at a level of higher risk after discussions within the group [29]. Similarly, design engineers, for example, may be tasked to design plant and equipment with little or no contact with operational teams. Beliefs in the existence of a strong safety culture can lead to more latitude in plant design and operation.

Third, there is a need to recognize and build trust as a critical factor in the success or otherwise of safety culture interventions as, for example, in behavioural safety interventions [17, 18].

Fourth, there is a need to manage cultural diversity and change. In relation to the latter, increasingly the operation of nuclear power plants and supply chains involves multicultural teams from a variety of different national backgrounds. This point was brought out clearly in the LearnSafe project and has been highlighted in studies of culture in other major hazard industries [27].

LearnSafe was a European based and funded project designed to create methodologies and associated tools to facilitate the processes involved in organizational learning in nuclear power plants. Data were collected from over 1000 participants in nuclear power plants across Europe [30].

Of relevance was that safety culture and change were among the major challenges to nuclear power plant operators as reported by participants. The project also considered the barriers to organizational learning and a number of issues were identified. These included limited organizational resources, conflicting priorities, difficulties with formal systems and procedures, lack of openness, of trust and of reward systems, and the inadequacy of available means and methods.

The continuing challenges to the sector are well known and much discussed. They should not be underestimated and they are not (see below). However, despite this, there is widely held belief within the sector that it is too good to fail.

6. LOOKING FORWARD

Looking forward, it is obvious that there are major challenges facing the nuclear sector globally. These include not only those of new build and decommissioning, terrorist acts and natural disasters, but also the economic pressures from changes in the energy markets. These have led to increased scrutiny of cost-bases and cutbacks and, in some cases, plant closures. At the same time, global partnerships with both multiple and international contractors have become involved in nuclear projects and activities worldwide. These changes need to be factored in to the ongoing maintenance and development of safety culture. Among other things, managers need to develop the necessary skills to accommodate such multicultural operations. For example, the Finnish power consortium Fennovoima has engaged the Russian building contractor Titan-2 on the preparatory work for its new nuclear power plant at Pyhajoki. Guidance on optimizing the safety culture across these two differing national cultures is clearly essential.

The nuclear sector has also developed a reliance on project structures and multi-tasking teams supported by its supply chain networks during its decommissioning activities. This needs to be critically examined including thinking through the integration of the different subcultures involved and the overall impact of this reliance on safety culture. At the same time, the successful development of a decommissioning mindset together with the management of mindset issues in the decommissioning process are important factors in cultural change. Better educational and support systems are needed to ensure that this style of working is understood and adopted as new technological solutions emerge.

The world of work continues to change and these changes affect working people, the work that they do and how they do it and their employing organizations. Traditional patterns of career and skill development and employment in engineering have changed dramatically over the last three decades and will continue to change. The nuclear sector has not been immune to the effects of such changes. Several of these changes affect the demographic nature of the available workforce that is both ageing and becoming more culturally diverse. The inherent challenges to management and leadership have already been noted. The workforce has become more mobile in terms of both career and skill development, longevity of employment and geography. The latter obviously adding to the cultural mix in any particular country or region [27]. Most jobs require such mobility and also the pattern of demand that they embody is also changing particularly in relation to knowledge load, and continual development, the use of information and communication technology and the requirement for multitasking. There is also an increasing demand for fairness at work that now appears to be central to much of employer–employee relations [31, 32].

These changes and others have led to two things in particular. The first is the need to cultivate nuclear professionalism across the sector in a way that encompasses and takes account of national and international requirements and sensitivities (for example, the National Skills Academy for Nuclear (United Kingdom)). The second is that greater collaboration is required among all key stakeholders and, in particular, the four constituencies already discussed. Effective collaboration requires communication both with and across organizations. The nature, methods and technology associated with such communications need to be reconsidered.

As part of the drive for professionalization, two issues must be considered and addressed. They are related. The first is creating a just culture in which, for example, the reporting of incidents can be done with reasonable immunity. Systems that can handle such reporting are well established in the aviation and rail sectors and are available in many nuclear power plants. Second, a just culture, like many other things, depends on trust among those involved and building trust is necessary although not sufficient for a just culture [33]. Building trust, in turn, can depend on perceived fairness at work. Both have been shown to be related to leadership styles and to the existence or otherwise of a just culture [34].

While much of what has been written here naturally concerns management, attention has to be paid to leadership and to leadership with both a small ‘l’ (at all levels) and leadership with a large ‘L’ (at senior levels). To be effective, most types of leadership have to be empowered and empowering and this issue must be addressed in relation to safety culture and management in the nuclear sector as it has elsewhere.

Whatever changes are needed, looking forward, they must be subject to adequate scrutiny and properly evaluated. In respect of safety culture and performance, the desired outcome of all interventions is an improvement in safety performance in all respects and not just the continued avoidance of major incidents. To properly judge whether any particular intervention is achieving this broader objective, it has to be looked at through the lens of real time data directly relating to safety performance.

Finally, there is and has been for some time fundamental questions about the nature of safety culture and its relationship to more general organizational culture. The answers to these two questions have changed over time with more and better research and greater professional experience and it should continue to change as we have more data to work with. The two questions can be expanded.

First, is safety culture a real entity or is it an emergent property of a complex system and, as such, a hypothetical construct? Possibly, we are asking whether you can see, touch and feel it — is it tangible — or whether it is an idea that brings together and summarizes a number of different facets across the various levels of an organization because they have something in common — is it an intangible? Whatever the answer, the concept remains a powerful one in our intellectual armoury for managing nuclear safety, but it does mean that we have to deal with it in a certain way. We have to accommodate the other elements of the system including the nuclear technologies [24].

Second, the question is whether safety culture is a part of the overall organizational culture and reflects that culture in a particular area or whether it is more independent and may or may not reflect the general organizational culture (see, for example Ref. [6]). Possibly, we are asking here whether the general culture, being good or not so good, weak or strong, is directly reflected in the safety culture or whether the two can be different in these respects. If safety culture does stand differently from the general organizational culture, then there is a clear need to reconcile the two and to ensure the importance of safety throughout the organization. Again, whatever the answer, safety culture remains an important tool for understanding and managing nuclear safety but how we use it, again, depends on the answer given to these questions.

7. CONCLUSIONS

The conclusions that could be listed here would all reflect the issues raised above and the points made in doing so. However, to the author, four things stand out as important.

First, we need to rethink and evaluate the notion of safety culture as it applied to the nuclear sector as part of a process of continuous improvement. Answering this challenge is not simply a research task, although there is a clear and important role for data driven research, it also requires collaboration between all the key stakeholders.

Second, however we look at safety culture, in terms of the questions raised above, we will continue to agree that it is about people in their work and organizational contexts. It is about the behaviour of employees, of their managers and leaders and of their organizations in a way that describes ‘how we do things around here’ [35].

Third, whatever our answer to the question of what is safety culture and how can we best use it to ensure nuclear safety, it will be a complex one. By its very nature, safety culture is a complex, multifaceted being and one that is going to be context dependent. And the manner in which any organizational safety culture can be affected, changed and developed is difficult to predict. As such there will be no one size fits all intervention to deal with the challenge and no easy to administer silver bullet.

Fourth, one of the important lessons that can be taken from the review of the accident at the Fukushima Daiichi nuclear plant [36] is that there is a need for the nuclear community to take into account the complexity of the sociotechnical systems that are part of the nuclear operational infrastructure. These bring into focus not only the human and organizational factors, but also the technical ones that are important in relation to safety culture [37]. However, this focus should not be on these different factors individually but on the interactions among them.

Together, these four things could appear as a plea for the industry to go back to basics on safety culture. However, it is not a plea in terms of winding the clock back, but rather a plea not to forget the basic issues and questions. In answering these, more and better data will be required. Future attempts to address the overall challenge of safety culture and its utility must be data driven.

Interestingly, several of the points made here in 2016 were made over a decade earlier by the author [5] and still remain to be considered and dealt with; such is the enduring challenge of safety culture.

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OPENING KEYNOTE ADDRESS

WHY NUCLEAR SAFETY CULTURE REQUIRES HUMBLE LEADERSHIP

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Abstract

The concept of safety culture is widely accepted but not very well understood. In the paper the argument is made that the attributes of safety culture all hinge on whether the executives in the nuclear plant actually create the climate of trust and openness that the other attributes hinge on. The right kind of executive behaviour is especially important in nuclear plants and sites because of the unique characteristics of nuclear technology. In order to create the climate of trust and openness that is required the concept of humble leadership is explained as the essential characteristic needed in nuclear plant executives.

1. INTRODUCTION

Safety culture has almost become a household word in both the chemical and nuclear industries. It is promulgated as essential and is presented as if we really understood what it means. The International Atomic Energy Agency (IAEA) launched this concept in the mid-1980s [1] and has elaborated it very effectively since then as a set of attributes, all of which must be present, for a nuclear plant to be safe [2]. When I worked with the US Institute of Nuclear Power Operations (INPO), I found that this organization was also using a very similar set of attributes to describe a safe situation and something to be aspired to in all plants. Since then I have seen the concept adopted in various ways by the Nuclear Regulatory Commission (NRC) and other organizations dealing with safety [3] such as the oil industry following the British Petroleum disaster in the Gulf of Mexico.

In this paper, I will briefly review how the IAEA conceptualized this concept and then argue that for such a culture to be actually created requires a particular kind of executive structure and a full acknowledgement of the uniqueness of nuclear technology. I will argue that this executive structure must have particular characteristics and be willing and able to practice humble inquiry [4] and humble consulting [5], which together make up the concept of humble leadership.

2. WHAT IS UNIQUE ABOUT NUCLEAR TECHNOLOGY?

Before reviewing the concept of safety culture, the point needs to be made that the basic list of attributes that make up safety culture and will be reviewed below can be applied to any effective organization. It could be an automobile factory, a hospital, or a construction company. If we are to use a concept like safety culture in the nuclear industry, we must identify the unique problems and risks of the nuclear industry and consider what the implications are of those unique factors for safety.

In considering what these unique factors are, I am mindful of the useful distinctions that Rene Amalberti [6] makes about the degrees of maturity of different kinds of industrial technologies. Is nuclear technology an industry like ocean fishing that is very dependent on unpredictable natural conditions, or more like certain parts of medicine that are well understood and controlled, but depend on multiple interdependent operators doing things correctly and in a tightly coordinated manner. Nuclear technology is clearly more like the latter, which creates some of the unique factors I want to mention. These unique factors will not strike anyone as particularly new, but I think it is easy to forget them and not to think through what kind of management system one needs for such a technology.

2.1. Nuclear technology is both very complex and very dangerous

Nuclear technology is so complex and so dangerous that total familiarity with it is essential in all employees connected with it. That also implies that all engineering design must take the technology and its risks fully into account by designing multiple fail-safe routines, backup systems, barriers, and user-friendly operations. On the operations side, the high degree of complexity and interdependence of components makes it essential that every employee understands his or her role in that system. Pockets of indifference and neglect can be tolerated in most industries but not in nuclear technology. It is therefore a unique challenge to executive management to get literally everyone on board, fully trained and fully accountable for his or her part of the operation.

2.2. Nuclear technology is very difficult to run and to manage reliably

Because of its complexity, running a nuclear plant is difficult and requires special expertise. The parts are all interconnected in complex ways, which means there are many possible malfunctions, each of which could cause a major accident. Maintaining a level of technical know-how and commitment to perpetual monitoring becomes especially difficult when the work is often routine and monotonous. It is very difficult to define individual accountabilities in a technology that is complex, highly interconnected, and dangerous. Responsibility and accountability are often spread over groups and teams, which then requires effective teamwork and collaboration.

2.3. Nuclear technology is dangerous to the public and to the operators, hence uniquely frightening

Because of its potential dangers nuclear technology is uniquely frightening to the public and to the employees. Not only are accidents potentially lethal and destructive to the environment, but the risks of radiation exposure also provide constant danger even if no accidents occur. Radiation is uniquely dangerous because it is invisible and its consequences do not show up immediately. It is mysterious and hard to understand. The challenge to executive management is to create a climate in which the employees will not only feel personally safe, but will convey their own confidence in the safe operations to their friends, relatives and the public at large.

2.4. Nuclear technology accidents create toxic conditions for a very long time in very large areas

The public has learned from past accidents that a large area around each accident is lethal and remains so for a very long time. The fear of an accident is therefore compounded by the fear of long run loss of health and territory. The combination of immediate loss of life, threat to health, and long run damage to the environment make nuclear energy more threatening even if the probability of an accident is very low.

2.5. Nuclear technology is very costly

Not only is it very expensive to design and build nuclear plants, but the safety concerns require shutting down and starting up nuclear plants, processes that are themselves very costly leading to very complex formal and informal rules for who can make shut down decisions and under what circumstances they should be made.

2.6. Nuclear technology is potentially very powerful and useful

There seems to be wide agreement that nuclear technology is one of the cleanest and most desirable ways to create energy, if cost factors and public fear can be overcome [7]. This creates complex decision problems for different countries in how much to invest in new plants, whether or not to replace ageing plants, how much to invest in alternate technologies and how much to invest in alleviating public fears.

In summary, given all of these unique factors and their interaction, the one common element seems to be that safety must be maximized because the consequences of accidents are potentially so severe. The concept of safety culture is an effort in this direction in focusing on all the things that must work together to maximize safety. The question then is what kind of management system will facilitate a safety culture?

3. SAFETY CULTURE AND ITS ATTRIBUTES

I will begin with some selected quotes from the IAEA [2], which originated the concept and defined some of the key attributes in great detail [8]. In my selection of attributes I will focus on those that I have found to pertain particularly to the concept of culture and that have been widely quoted in other descriptions of safety culture.

"[S]afety culture. The assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance." [1]

IAEA Safety Standards Series No. GS-G-3.1, Application of the Management System for Facilities and Activities, [2] lists attributes for a strong safety culture.

"Safety is integrated into all activities:

- Trust permeates the organization.
- Consideration of all types of safety, including industrial safety and environmental safety, and of security is evident.
- The quality of documentation and procedures is good.
- The quality of processes, from planning to implementation and review, is good.
- Individuals have the necessary knowledge and understanding of the work processes.

[1] The full normative safety culture framework of the IAEA, listing five main characteristics of safety culture and 37 corresponding attributes, is found in Ref. [2].

- Factors affecting work motivation and job satisfaction are considered. Good working conditions exist with regard to time pressures, workload and stress.
- There is cross-functional and interdisciplinary cooperation and teamwork.
- Housekeeping and material conditions reflect commitment to excellence." [2]

These attributes not only cover all aspects of operations but also reflect values and behaviours at all levels of the organization. In fact, taken together, they are practically identical to what any management theorist might list as attributes of any effective organization in any industry. If I were a hospital executive or ran a restaurant chain I would want all of these attributes to be present not just for patient and customer safety but also for overall excellent performance. What is needed for safety is not fundamentally different from what is needed for effectiveness, especially as concerns accountability, trust and openness throughout the organization.

The attributes are a mixture of some foundation elements, the DNA of the culture, and some derivative elements that can only be present if the foundational elements are present. I consider accountability, trust and openness as those foundational elements on which we should focus at the outset. It is significant that this IAEA list [2] begins with "trust permeates the organization" because none of the other attributes are achievable if there is no trust up and down the hierarchy and across functions. Trust hinges on openness of communication, which, in turn, is necessary for employees and managers to feel accountable to make all the other things happen that are on the list.

Therefore, trust, openness of communication and accountability make up a cultural DNA cluster that must be present in the organization if it is to be safe and effective.

How does an organization create and evolve trust, openness and accountability? It is this question that is too often ignored in descriptions of safety culture and in proposals to create or enhance several of the other attributes such as collaboration, housekeeping and good documentation. If there is insufficient trust, openness and accountability, programmes around the other attributes will fail. What then does it take to produce this DNA in the culture of a nuclear plant? To answer this question, we first have to examine the social dynamics of trust and openness, and show their connection to accountability.

4. CREATING TRUST, OPENNESS AND ACCOUNTABILITY — THE ROLE OF THE EXECUTIVE FUNCTION

Trust, openness and accountability are created and supported by the executive function of the organization. If the board and the Chief Executive Officer (CEO) selected by the board do not value these three attributes, working on the other attributes will be a waste of time. If they do not understand that it is their own values, attitudes and daily behaviour that create the trust and openness on which safety and effectiveness depend, then the organization will not be optimally safe and effective. If they do not personally hold their own subordinates accountable for safety and effectiveness, accountability further down in the organization will atrophy. The central elements of that executive behaviour will be to display trust, to be open and to hold their immediate subordinates accountable for creating trust and openness in their own organizations. These values have to be more than espoused and announced, they have to be displayed in the daily behaviour of the board with the CEO and the CEO with his or her immediate subordinates.

The IAEA explanation of safety culture partially acknowledges the role of executive management, as follows:

> "The management system shall be used to promote and support a strong safety culture by:
>
> - Ensuring a common understanding of the key aspects of safety culture within the organization;
> - Providing the means by which the organization supports individuals and teams in carrying out their tasks safely and successfully, taking into account the interaction between individuals, technology and the organization;
> - Reinforcing a learning and questioning attitude at all levels of the organization;
> - Providing the means by which the organization continually seeks to develop and improve its safety culture" [9].

The main argument of this paper is that promoting and supporting is not enough. The board and the CEO must actively create the conditions for trust and openness to be developed throughout the organization. The reason for this is that the normal processes of hierarchy and the cultural assumptions of our current management theories actually work against trust and openness, as is argued in Humble Inquiry [4]. If the CEO does not start and maintain the process in the manner described, it will not permeate the organization. The middle management and the employees will not give priority to safety and effectiveness if they do not see it at every level of management starting at the very top. And, worse, they will not be aware that they are making trade-offs against costs, productivity, schedules and just the normal need to get things done. Even if they do become aware of these trade-offs, they will not have any incentive to tell their supervisors that they are making them.

This upward communication failure produces great blind spots within the management structure. I have seen manager after manager saying explicitly or implicitly to supervisors and employees: ‘Safety is number one, but we must stay on schedule and we have important productivity and cost control programmes that also matter.’ I heard another executive tell his staff: ‘Bring me a good safety programme but make sure it is cost effective’, without any recognition of how that simple ‘but’ destroys the DNA of safety culture.

Why is it not enough just to announce that ‘safety is always number one?’ Most boards and CEOs in high hazard industries would certainly claim that effectiveness and safety are their central values, so why is there a problem of implementing a safety culture? Because, as Amalberti [6] has so effectively reminded us, these are not the only values that drive top management. Products and services can never be absolutely perfect and safety cannot be absolute because executives inevitably have to consider the survival of their organizations, costs, risks, and the human desires to get things done, to satisfice rather than to maximize. Other values and motives coexist with our concern for safety.

For example, when I drive I do not drive perfectly or absolutely safely. I consider how much time I have, the costs of arriving late, my level of fatigue, the weather, how congested the road is, and who else is in the car whose safety I am responsible for. My actual behaviour is a product of constant calculation of all these factors even though I claim to be a good and safe driver. Let us now scale this up to a complex organization; let’s say a driving school, in which there are executives, middle managers, driving instructors and mechanics who keep our cars in good condition. As the CEO of this organization I could assume that everyone down to the lowest employees would agree that safety is number one because of the nature of the business we are in. I would regularly make speeches to this effect and have posters all over the organization touting safety. But will that be enough to ensure that all my managers and drivers and maintenance people will be accountable, will trust each other, will tell their managers about unsafe driving instructors or cars that are not well enough maintained? Clearly not.

In my own experience with organizations, I find that the very nature of hierarchy and the inevitable trade-off between safety and the other values of efficiency, productivity, schedules, and the need to get work done will undermine accountability, upward communication and trust across hierarchical and functional boundaries.

The most common version of this problem that I have encountered in most organizations is that subordinates will not tell their bosses what is wrong down in the organization. The reasons are multiple: the boss doesn't want to hear bad news; the boss says, don't bring me a problem unless you bring me a solution; the boss listens politely and never does anything about what I have told him or her; the boss is more concerned about schedule and productivity and makes that clear to me [10]. What is missing is the immediate boss creating an environment in which upward flowing information of any sort is welcome, bad news is rewarded so that things can be fixed, and upward communicators are heroes instead of nuisances, whistle-blowers, or wimps always seeing problems. Middle managers will not create such a safe and supportive environment for upward communication unless their own bosses create such a climate for them. And so on up the line.

In other words, to implement safety at the level of the various other attributes requires first accurate information about what is actually going on and then a reward system that actually encourages such openness, which in turn creates the trust that we say must permeate the organization. Once openness and trust have been created it becomes possible and necessary to hold people accountable for safe and effective behaviour. Accountability is created by the explicit behaviour of the top level executives demonstrating trust and openness. It cannot just be assumed, promoted, called for or encouraged. It must first be explicitly created.

5. INTERACTION OF ACCOUNTABILITY, OPENNESS AND TRUST

How does one hold one's immediate subordinates accountable? Let's start with an example that I encountered a few years ago in a meeting at which the Safety Committee of this Urban Power Co., which included the CEO and all the key divisional VPs, was finally able to agree on a set of cardinal rules for employee safety behaviour. If any of these rules, such as not wearing safety equipment or not stopping jobs that were deemed unsafe, were broken, this would lead to instant dismissal, no exceptions. Members of the union were present at the meeting and had, in meetings of their own, agreed to these rules. During this meeting a few words were exchanged here and there in the list of rules, but the group was clearly headed towards agreement.

Towards the end of the meeting the CEO asked for a vote on the list and the group unanimously accepted it. There was a huge sigh of relief. 'We have done it, let's get the list published and distributed, great work everyone! Now let's get on with our other business. Let's look at how we are doing against last month's numbers on slips, trips and falls…'

While the group was congratulating itself and preparing to look at their numbers, I felt a sense of unease. Something did not feel right. What was missing? I found myself asking ‘Now that you have this list and will publish it, will you do anything different with your immediate subordinates tomorrow? Will you ask them how the existence of these new rules will impact their operations? Will you ask them to review the disciplinary procedures in their organizations to decide what to do if there are extenuating circumstances? Will you ensure that your subordinates will sit down with their middle manager subordinates to be certain that they understand the new rules and how the disciplinary procedures will work? For example, should an electrical worker be fired for not wearing his protective glasses which he took off because they fogged up in the manhole in which he was working and he could not complete his job with them on? Should the company be developing along with the list of cardinal rules some inquiry processes that would identify working conditions under which the rules could not or should not be implemented? Should the CEO create and mandate some review processes after important actions have been taken to determine how the implementation of the rules impacted safety, productivity, and schedules? Should the CEO demonstrate through his or her own behaviour a commitment to collective learning and frequent reviews of how things are working?

All this seemed crucial to me as necessary implementation, yet I felt that the executives in the room had somehow reached the conclusion that publishing a list of the new rules was enough. They had misunderstood what accountability means in a complex hierarchy. As I feared, the CEO was taking it for granted that the subordinates and middle managers would get the message and sort out all the details. He told me, ‘They are professionals and will be able to figure out all the complexities of implementation’. He did not consider that they live in a different world in which daily productivity, staying on schedule, doing things in a cost effective way all compete with figuring out how to change the discipline system to reinforce the cardinal rules list. Middle managers and supervisors and employees might very well see this as the ‘safety project of the month’ and just pay lip service to it, or, even worse, see it as one more chore to be administered and one more difficult problem to be dealt with once rule violations occurred.

I realized that one of the assumptions of traditional management theory is that when people take on a set of responsibilities they will hold themselves accountable. This assumption is derivative from the belief that delegation is a good thing; it makes the subordinate more responsible. Delegation avoids micromanaging, which most subordinates hate. We then build very general rewards into the system and measure managers on productivity, efficiency, and safety statistics but, paradoxically, do not measure them on frequency of upward communication or on the degree to which they foster psychological safety for their own subordinates. What that means is that if middle management or supervisors do not take seriously the implementation of the programme, top management will not hear about it. They will not learn that things are not being implemented if they have to be traded off against other important goals. This is why openness is such a critical value. If top management does not hear about how things are going down in the trenches, they will assume that things are done in a way that supports their intentions.

The following example illustrates how the intention to create safety can be undermined unwittingly. A power company had instituted a very important safety programme that trained employees to use a timeout card to stop a job if anyone felt it was unsafe. The job could only be resumed after a safety inspector had cleared it. The programme became a key part of the whole safety effort because it was working so well in reducing injuries and accidents. The operating system in this organization was old and in need of constant maintenance. It was not always clear where maintenance was needed most urgently, but it was discovered that the timeout programme might provide critical information that would enable the organization to decide better where the big risks were that needed immediate attention. The company therefore instituted a records keeping programme that required each supervisor to write a brief report of every timeout. Middle managers would collect these reports, analyse them and send information up to maintenance where attention was most needed.

At this stage, the next and higher level of area managers (who were measured largely on productivity and efficiency) noticed that work groups with the same jobs had different levels of timeouts. They called in the supervisors of groups with the larger numbers and inquired, ‘Why does your group have so many timeouts?’ Those supervisors found out for the first time that they had more timeouts than other groups. They did not like the implications for their own advancement and promptly told their group not to be such wimps and not to call so many timeouts. The number of timeouts subsequently went down. This defeated the very purpose of the timeout programme because groups began to take more risks in their work. Worst of all, senior management did not know this was happening. I found out about this in focus groups that I led as an outside consultant.

The middle managers in this organization did not take it as a central value to create a climate of openness and to reward their subordinates for bringing in timeout information. They did not feel that it was an important part of their job to make subordinates feel psychologically safe to bring in negative information. Their own superiors did not evaluate them on the degree to which they created such a climate of openness. Furthermore, the formal reward systems did not in any way measure or evaluate such managerial behaviour. Why not? Because senior executives did not evaluate themselves or their own immediate subordinates on the degree to which they encouraged upward openness. Their blind spot was failing to see that if they did not explicitly encourage and reward such behaviour, the trade-offs further down the organization would favour productivity, efficiency and schedules over safety. Senior management did not know what was going on because there was no incentive for lower levels to report upwards what they were willing to tell me as the outside consultant in focus groups. Employees and their immediate supervisors had learned not to trust upper management because they felt that they were actually punished for having too many timeouts instead of rewarded for being more safety conscious. Many employees said in the focus groups that, 'They don't really care about safety up there, it is just window dressing' and this occurred on the same day that I had heard the CEO say, 'Safety has to be our number one priority'. Had I told him then and there what the employees were saying, he would have discounted it as just a few malcontents.

Confusion about accountability enters the equation when top management is surprised and shocked to find out how lower level managers and employees are subverting the timeout programme by either not seeing or not reporting what is happening. Senior managers would say to me that one of the problems of the organization was lack of accountability. If I asked them for examples, they would tell me that lower level managers and employees could not be trusted to do things safely. They could not see that the problem was lack of upward openness that prevented them from finding out why those managers and employees were not more responsible. They could not see that the only way to fix that was not by more rules and announcements and programmes, but by holding their own immediate subordinates accountable for upward communication. That, in turn, requires a different kind of behaviour from those top executives — what I call humble leadership and describe below.

For subordinates to begin to tell their superiors what is really going on requires that they feel psychologically safe [11]. Such safety is necessary because the nature of what they need to tell their superiors is, by definition, very sensitive in that it might imply that the boss is not doing something correctly or must change some things that he or she has mandated. The most common version of this difficulty is to tell the boss when a target that the boss sets for some aspect of the work is unrealistic from the subordinate's point of view. In the United States Marine Corps, it is accepted that a good leader is one who earns the respect and trust of the troops, is the one who knows that the troops are used to walking 25 miles a day but asks them occasionally to walk 26 miles because he knows that they can do it. The troops would lose respect for him if he asked them to walk 30 miles because higher command had demanded it knowing deep down that they probably could not do it. Yet that is precisely what a lot of managers and leaders do. They set unrealistic goals and make it difficult for the subordinates to speak up to say they cannot do it. Or, even worse, if they try to speak up, the superior says, ‘Well we have to do it, so just work a little harder’.

The most dangerous aspect of developing such blind spots is that CEOs unwittingly create a climate where achieving goals becomes so non-negotiable that it forces subordinates to cut corners, falsify data and actually lie about what is going on in the organization. We saw this occurring in recent years in the United States Veteran’s Administration when unrealistic targets were created for how many patients were to be seen by a certain time without sufficient conversation to determine whether or not such goals were realistic given the increase in patient load due to combat results from current wars.

Top management in Washington insisted on meeting the numbers, which led many local offices to be forced to falsify records and claim that patients were being seen. When this was discovered and a public scandal ensued, the first reaction was that it was a few bad apples in the barrel, a ‘few irresponsible middle managers and employees’ was offered as the explanation. It took some careful soul searching and further data gathering within the organization to get past this knee jerk reaction to the recognition that setting unrealistic goals and not listening to subordinates who were saying ‘We can’t do it’ was the real cause of the problem.

Part of the problem is traditional management theory, which encourages competition as a motivator. Whenever an organization has several units doing similar things there is the strong temptation to have them compete and reward the ones who meet the targets best. We have all witnessed how comparing units on safety statistics does not necessarily reduce accidents but does reduce the reporting of accidents because units are encouraged to compete to see who can be the safest. Again, the real pathology in the system is that managers do not feel safe in reporting to their bosses that they are ‘gaming the system’.

Holding subordinates accountable requires a great deal of direct conversation about goals, about how they will be accomplished, about difficulties that might be encountered, and about how accountability will be created in the next level down. The CEO not only has to have these conversations with the immediate subordinates but must also inquire how those subordinates will have conversations with their subordinates to ensure consistency of implementation of the new rules. What I have seen all too often is CEOs being so concerned with upward and external communications that they forget to make their subordinates accountable and do not enquire about what may be going on in middle management and below.

6. ACCOUNTABILITY THROUGH OPENNESS AND INQUIRY

So what should CEOs do to ensure that their subordinates and the whole organization becomes more open, more trusting, and, thereby, more accountable? What should my power company executives do after agreeing on the list of cardinal safety rules? What should the top Veteran's Administration executives have done when the high level performance goals were mandated by the political system? The head of the Veteran's Administration should have sat down with each of his geographic unit heads and asked: 'Can you meet these performance targets?' 'If not, what additional resources do you need to meet them?', 'What might prevent you from achieving the goals and what should we do about those conditions'. Had the Veteran's Administration heads done this in a psychologically safe climate, the regional heads might have revealed sudden increases in caseloads that made the goals unrealistic even with additional resources. Of course, the higher levels do not want to hear this because that requires them to go to their politician superiors and say, 'Sorry, we just cannot do this'. The information then either does not surface or is ignored and scandals result from the inevitable falsification of what is actually going on.

Unfortunately, our traditional management theory would say that senior managers should go to their subordinates, restate the targets, explain in detail how the top level goals were set and why they were so necessary, and in a perfunctory way, say, 'Any questions?' Having been told all the reasons and how important the goals were, would a subordinate be able to say, 'I don't think we can meet those targets'? The courageous subordinate might say, 'I think we will need additional resources to do this', only to be told, 'You know we have used up our discretionary parts of the budget for this year, so just do the best you can, there won't be any more coming'. Very likely the boss's explanation will function as a stone wall that cannot be breached.

To overcome some of the cultural assumptions of traditional management theory, especially norms about competition as a good motivator, assumptions about bosses as motivators and controllers, and norms about the importance of maintaining 'professional distance' across rank boundaries and between functions, requires a different concept of the role of the manager, especially the CEO as the most senior manager in the organization. This new role becomes critical as the complexity of problems that organizations face increases, which makes the manager the lone hero with all the answers no longer viable, especially in nuclear plants.

7. HUMBLE LEADERSHIP — THE NEW CEO ATTITUDE AND BEHAVIOUR

I have argued that upward communication and the necessary openness, trust and accountability needed for an effective safety programme will require new attitudes and behaviour on the part of the CEO. CEOs and others below them will have to recognize that their own performance ultimately hinges on the performance of their subordinates and the whole organization. The more complex the technology that underlies the production process, the more the requisite knowledge and skill will be distributed among the lower levels. No matter how much authority and raw power the CEO has, he or she will be, to varying degrees, dependent on the subordinates and those below them. Hence this new form of leadership hinges on the capacity of the CEO to be humble [4, 5]. Humble leadership can best be explained by looking at several components that are directly in conflict with traditional management theory.

7.1. Here and now humility

I think of this as ‘here-and-now’ humility that has to be present when CEOs are in conversation with subordinates upon whom they are dependent. With such here-and-now humility goes the ability to make oneself vulnerable. CEOs who always tell are effectively insulating themselves from information that their decisions or actions might be dysfunctional or not implementable. To create a climate in which subordinates can tell the CEO how things are not working or might not be implementable leaves CEOs vulnerable to learning things that they might not like and that challenges their decisions and plans. They might even have to go back to their boards or higher level CEOs to undo some things that had already been put into motion.

A significant example of such humility was the admission by senior military officers carrying out operations in Afghanistan that command and control no longer worked when the troops were dispersed, were in different kinds of local environments, had different on the ground challenges, and, therefore, had to be given the autonomy to make their own decisions. The Generals have to ask, ‘What is going on out there and what do you think you should do’ instead of telling, ‘Here are your orders’.

7.2. A new superior–subordinate ‘level two’ relationship

In my new book Humble Consulting [5], I point out that the broader cultural norms by which we all live and get along make a distinction between level one transactional and professional relationships, and more personal level two relationships which are characterized by varying degrees of friendship but also includes people whom we know as individuals and whom we trust not to cheat or lie to us. Beyond this there is also level three, which we can think of as more intimate relationships.

When problems are simple the transactional relationship works. We call the repairman, doctor, and lawyer and accept their professional expertise. The superior trains the subordinate, explains what is to be done, and then just measures results. However, when problems become complex and messy, when it is not clear how to fix things, when everything is connected to everything else, when problems are systemic, then level one transactions and expert help no longer work. The superior as expert cannot know enough of the subordinate's world to give precise directions.

With messy complex systemic problems, subordinates should tell their superiors that something is wrong, but do not necessarily have the insight (or the courage) to report precisely what is wrong or how to fix it if they are in a level one relationship. In that kind of situation, they together have to get to a more personal level two relationship in which it becomes safe for them to be more open, to reveal what is really worrying them, to admit that they do not see an immediate answer, that they do not know what to do, but can work together to try to figure out some adaptive move to deal with the immediate worry.

In these situations, level one relationships prevent good adaptive problem solving because the norms of professional distance undermine openness and shared problem solving. The doctor who walks into the patient's room, looks at the chart, addresses his resident and the accompanying interns instead of the patient, will not find out that the patient has asked a couple of friends about the prescription she was given, was told not to take it because 'it makes you feel awful' but has neither the inclination nor the courage to tell the doctor that. On the other hand, the oncologist who developed a level two more personal relationship with my wife during her first bout of breast cancer learned from her that the course of chemotherapy would interfere with an important trip to California that we had planned. He discussed all the options with both of us and decided to arrange to have part of the chemo done in California so that both the treatment plan and our personal lifestyle could be maximized. As a result she learned to trust this doctor completely, which was crucial when later difficult decisions had to be made.

An interesting example of the importance of such openness is reported in Perin's Shouldering Risks [12] when an unexplained hot spot was found in a transformer outside the nuclear plant. The question arose of who should make the decision to shut the plant down in order to find out what was going on in the transformer. The complex trade-offs between risk and the cost of shutting down the plant had to be shared by several levels of the hierarchy in order to make a sensible adaptive move. The operator who found the hot spot, the shift supervisor, and the plant manager all had to be involved and had to be completely open with each other in order for an effective move to be made.

When such inter-level openness is not there, we get the situation in New York where a transformer was hit by lightning, spilling polychlorinated biphenyls (PCBs) into the area. The engineer in charge did not have an open enough relationship with his boss to report the PCBs because he did not believe the data. He had monitored this transformer and 'knew' there could not be any PCBs, asked the lab to check the data, and learned a week later that the PCBs were there and had, therefore, exposed firefighters and others to the harm. A lawsuit and many recriminations resulted and it was only six months later that it was discovered that the PCBs were in some sealed sound deadening rods that had been installed at a time when PCBs had not even been named as harmful. The point of the story is that the engineer did not have the kind of open level two relationship with his boss that would have enabled him to say, 'I found PCBs, I don't believe it can be accurate because I have checked this transformer over the years, what should we do?' Together they could have decided to immediately pass this information on to the fire department and other authorities and saved themselves and the public from a lot of messy recriminations.

7.3. Personalization, the key to level two relationships

Our cultural learning makes clear the difference between staying at the polite level of conversation with strangers or in transactions with sales people, and what it means to get more personal as when we 'want to get to know someone better'. Level two implies that we now know the other as a person, not as a stranger in a certain role. We get to know the person's name, something about their background and, most importantly, develop some motivation to get to know them better to enlarge the relationship to some degree beyond the formal transaction. When we are motivated to enlarge or deepen the relationship we do this in conversation by 'personalizing'.

The essence of personalization is either to ask something more personal or to reveal something more personal. It might be his superior saying to the engineer, 'Weren't you really scared and upset when you found out about those high PCBs?' instead of 'OK, here is what I want you to do', or 'So what will you do next, what is your plan?'

There is no formula for personalization. The cultural rules about what is personal, what is intimate, what is politically correct, and so on will vary with the culture and with the times. Personalization is more of an attitude built on the motive to build a relationship in which boss and subordinate can be more open with each other and trust each other. It is an attitude that is built on the value of listening to each other and building empathy for each other's job and role.

There is, however, an important guideline. We all learn within our cultural upbringing what can be called situational propriety.

7.4. Situational propriety — task related personalization

Part of our socialization into a culture is to know what is appropriate in different kinds of situations, what is often called etiquette, tact, or good manners, or knowing what is politically correct. Hierarchical relationships are bound by cultural norms of proper deference by the subordinate and proper demeanour by the boss. Personalization in this relationship does not mean we abandon those norms, but we evolve new norms that elicit more openness around task related information. As one of my German students told his more laissez-faire American peers, 'When I go in to see my boss I click my heels, shake his hand, stand very deferentially, and then tell him the truth'.

The personalization should be oriented to the task and the shared goals of what the boss and the subordinates are trying to do in the context of the mission of the organization. The goal is not to become intimate or even to become friends. The goal is to achieve the openness and trust needed to get the job done effectively and safely. To talk at a personal level about how scary it was to find a hot spot in the transformer or the PCBs after the lightning strike is not the same kind of personalization that two neighbours might engage in to become friends or that two people on a date might do to test their level of mutual attraction. Personalization has to be situation appropriate. The founder of Digital Equipment Corporation would wander around the engineering department and suddenly sit down with an engineer and ask out of genuine curiosity what that engineer was working on. This led to open level two relationships. When he lost his temper and became very personal with a subordinate and criticized him in front of others, that was viewed by everyone as very inappropriate. It led to great distance between him and the subordinate.

8. PROCESS FOCUS

There is a second guideline for personalization — the boss can say to the subordinate, 'Here are the goals. How are you going about meeting them?' The doctor can say, 'Here is the treatment programme. How will you implement it?' An extreme example was provided by Douglas McGregor in his story of how he helped a CEO create an executive development programme. The company CEO wanted him to create and implement such a programme. Instead, McGregor asked a question about the reward processes in this company: ‘Do you have a bonus programme for your subordinates?’ When he learned that such a programme existed, he wondered out loud, ‘What would happen if you told your subordinates that from now on, half their bonus would depend on how well they developed their own subordinates, and that you (the CEO) would ask them to report monthly and in person on what they were doing and how it was working out.’ The CEO tried this out and within half a year had an excellent programme that they had collectively worked out and instituted. The CEO did not care about or mandate the details of the development programme but created open discussions with the subordinates on what each of them was doing.

Another version of using process focus for personalization is to ask process questions about the conversation itself. A manager and a subordinate having a conversation about work related issues could at any point ask, ‘Is this helpful, or, is this want you wanted to hear, or, should we be approaching this differently?’ In other words, the process of the conversation itself can often be usefully discussed. Perhaps the best example is the process decisions we make about giving and receiving feedback around performance or development. Just sitting the subordinate down and telling him or her what we think, what our judgements are, what others have said is a level one relationship process that is usually ineffective because the recipient either does not hear the message or does not know how to interpret it.

An effective manager should personalize this process and bring it towards level two by first asking how the subordinate feels about his or her own performance, what the goals and aspirations were, and, therefore, in what specific areas the subordinate particularly wants and needs feedback. Asking questions like, what were you trying to do, what were your goals, how do you think you performed against them, in what areas do you need help, what kind of feedback can I usefully give you personalizes the relationship and opens the communication channel to enable the subordinate to tell what is really on his or her mind. That mutual openness must be the goal for a long run trusting relationship to be achieved.

9. JOINT PROBLEM SOLVING AND ADAPTIVE MOVES

With messy complex problems, the best problem solving process is what has been appropriately called ‘joint sense making’ [13]. Once a level two relationship of trust and openness is operating, the manager and the subordinate should work together on whatever brought them into the conversation. If the subordinate brought up a safety problem, they should now talk together on what the options are for the next adaptive move. They each bring something to the conversation, which will result in a better move than if either of them felt that they had to make the next move on their own.

If the problem is simple, they rely on whoever has the most expertise and experience to decide what to do. If the problem is complex, messy and involves systemic interdependencies, then they pool their knowledge and insights. What they decide to do should be thought of as adaptive, i.e. deal with the problem as they jointly see it, and should be a move not a whole big intervention or massive program. Adaptive moves are often needed in order to elicit more information and to test how different parts of the system may react. They are often small changes rather than massive interventions.

10. JOINT LEARNING, TEAMING

The joint problem solving that is enabled by level two relationships often involves not just the boss and the subordinate but a wider group representing different parts of the system. Edmondson, in the book Teaming [11], made a crucial point that for an interdependent group to work together effectively, they must actually learn together. The point is that just getting to know each other and becoming a team is not enough. It is only through confronting complex messy problems together that they get to know each other at the necessary deeper level and evolve joint coping mechanisms for future action. This kind of learning together is especially relevant where different subcultures are involved across functional or hierarchical boundaries.

In the example of the PCBs released from the transformer accident, the engineers, the public relations managers, and senior management together had to face the criminal charges launched by the people exposed to the dangers. They had to learn together how to think about problems like this if they occurred again, leading to both a different set of rules about reporting dangers and a whole different approach to educating the environmental agencies on how the company was evolving its safety programmes. This learning process resulted in a whole new adaptive move inviting representatives of the environmental groups to attend safety programmes in the company so that they could see what the company was doing. Building Level Two relationships with the outside evaluators enabled the company to display all of its constructive efforts so that if another accident happened, the outsiders would at least know that it was not company negligence.

11. TRUST, OPENNESS AND ACCOUNTABILITY REVISITED

Trust and openness are tightly intertwined. If I think that you are withholding information or telling me lies, this defines low trust. If I want to build trust, I must not only be more open with you, but I must be willing to hear what you have to tell me. I must reward you for bringing up problems, for challenging unrealistic goals, for keeping me posted on how things are going. It is not enough to say, 'I have an open door'. The CEO must actively seek information by walking around, scheduling regular meetings with subordinates, and telling stories that illustrate the importance of upward communication.

Trust can be thought of as the ability to predict what you will do in relation to the things we both care about and have agreed to in our working relationship. I trust you if I know that you will: tell me the truth (not withhold information relative to what we are doing or care about), be willing to make commitments and hold to those commitments, and understand what I am trying to tell you with an air of acceptance. Trust is built up over a series of interactions where the commitments are tested. As I feel you are open with me and keep your commitment and promises, I build up trust, which takes time. If you withhold, lie, or fail to keep promises, I lose trust very fast. Our feelings towards each other get tested in conversations such as the ones I suggested above for the CEO to hold with each subordinate around goals and accountability.

A corollary to the argument that the CEO must do this with his or her subordinates is the further argument that unless the CEO does this with immediate subordinates, there is no guarantee that those subordinates will have such inquiry conversations with their subordinates. They may know that the CEO cares about quality and safety and even observe the CEO pronouncing it to the outside world but they will revert almost always to focusing on what they get measured on, which most likely will be schedules, and productivity.

In summary, communication and team building programmes for middle managers and employees will have little effect if top management has not launched the organization with safety and effectiveness values and embedded them through role modelling them in their own behaviour. Trust will not be fostered if top managers do not trust their subordinates and, even more importantly, if subordinates do not trust their bosses to listen for and act on information that they bring that pertains to quality and safety.

12. SO WHAT MANAGEMENT STRUCTURE DO NUCLEAR PLANTS NEED?

Creating the cultural DNA that will enable all of the other components of the safety culture begins with the board and the selection of the CEO. The board and/or the corporate or site management must select a CEO who has two critical attributes: (1) nuclear knowledge and/or experience that provides empathy for the unique risks, dangers, and advantages of the nuclear technology; and (2) the attitude and skills of humble leadership.

If such a person is selected, he or she will immediately create the conditions for a safety culture by his or her behaviour with the immediate subordinates, seeking a level two relationship with them that will convey immediately the necessity for complete task related openness. That level two openness will begin to build trust and psychological safety for the immediate subordinates.

The CEO then has to create as a central part of the reward system for the immediate subordinates that he or she is holding them accountable for creating level two relationships with their subordinates and that they will perpetuate this reward system below them. They will then make the immediate subordinates and all the managers below them accountable not only for task performance, but also for creating and maintaining openness as a condition for building trust.

In conclusion, I am arguing that if the CEO does this, all the other attributes that are considered necessary will become possible. If the CEO does not have these attitudes and skills, or does not display these behaviours, the other attributes will not be achievable.

13. SUMMARY AND CONCLUSIONS

It is my conclusion that given all of the complexities that cut across hierarchies and functional units, safe and effective operations in a nuclear plant cannot be sustained without a CEO who totally understands the technology and, working with the Chief Nuclear Officer, creates the conditions for trust and openness by seeking and supporting level two relationships, in my model of humble leadership, throughout the plant.

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SUMMARY OF PLENARY SESSIONS

This summary of the conference's plenary sessions is divided into four sections, each providing different perspectives on the impact of human and organizational aspects on nuclear safety. The first section, Setting the Scene, summarizes the keynote papers from the opening plenary session. This is followed by a retrospective review of the past 30 years, a check-in on the current status, and finally perspectives on the future of nuclear energy and state of the art approaches on improving nuclear safety.

1. OPENING PLENARY SESSION: SETTING THE SCENE

The keynote opening presentations on day one of the conference served to set the scene for the entire conference. Four keynote speakers provided their professional, personal and challenging views on culture and on leadership for safety.

N. Stavropoulos, President, Gas, PG&E, shared how a personal experience inspired him to follow an approach to leadership and safety culture change that puts workforce involvement and cross-hierarchical collaboration at the forefront. Taking on the job as president after PG&E experienced the San Bruno accident — a major accident that killed 8 people, injured 35 and destroyed 75 homes — Stavropoulos turned to the workers on the shop floor to learn directly from them. He first met with the electrical workers union at their union hall, listened to their frustrations, their concerns and the issues that they felt needed to be worked on. During the four hours spent at this first meeting, Stavropoulos learned more than from any of the accident reports. Looking back, about 80% of the improvements that have been implemented during the last four and a half years have come about as a result of this first meeting with the employees. The management team still goes back every four months to continue the conversation, finding out what is working well and what needs improvement.

Stavropoulos argued that building personal relationships and paying more attention to the people who actually do the work has made a difference to the safety culture within the organization. Looking at the cause of the San Bruno accident, and realizing that the 'unqualified' component in the pipeline that ruptured was installed in 1956, Stavropoulos asked himself how PG&E could create a culture where people would not allow an unqualified component to be installed; one in which people could be trusted to do the right thing when no one is looking so as to ensure that phrases like 'safety is paramount' are not just words but something people live for and care about. Stavropoulos confessed that at the organization, there used to be a culture of not wanting to hear about problems.

Since the accident, the organization has worked hard to make the expression 'we cannot fix what we don't know about' commonplace throughout their operations. Stavropoulos further explained that a part of the strategy is to celebrate the gaps, encouraging reporting and openness. Learning from the nuclear industry, a corrective action programme was introduced and in 2015, employees submitted 12 000 CAP entries, of which only 3% were anonymous. Stavropoulos explained that the greatest source of pride in terms of the change in culture was the change in attitudes. As the organization was restructured to split the gas and electrical operations shortly after Stavropoulos arrived, 75% of the leadership team had to be recruited from the outside. During this process, Stavropoulos observed that there were two types of leaders: the 'minimum compliance' leaders and the 'do the right thing' leaders. People in the first group are excellent at doing their job, always know what to do and can clearly explain what the rules are and what needs to be done as a minimum to comply with the rules. Those in the second group understand that the minimum is not enough, and that the responsibility of leaders is to understand where the organization needs to go beyond minimum compliance. Stavropoulos argued that the second type of leader is needed for high risk industries, leaders who go out and meet with the workforce, try to learn and carefully listen. He concluded by reminding everyone that the 'do–say ratio' of a manager needs to equal one as leaders are judged not by words alone but by their actions.

S. Cox, Dean Emeritus, Lancaster University and Professor of Safety and Risk Management, provided a candid and comprehensive presentation entitled Safety culture and beliefs in the nuclear industry: Looking forward, looking back. Cox critically reviewed the introduction and use of safety culture as a concept by the nuclear industry, asking whether safety culture has given the sector an appropriate tool to measure and monitor behaviour, and if it has really done anything to improve the safety of nuclear installations.

Cox argued that the introduction of safety culture has taken the nuclear community to a level beyond a mechanistic view of people. It has encouraged collaboration across stakeholders and given a framework that led the industry to focus more on people's attitudes and behaviours (i.e. how people think and feel). Safety culture has reminded managers not only of the need to listen to feedback from employees, but also of the need to take on the perspective of these employees to try to understand their realities, as it is the realities of the employees that they need to manage. It has helped public acceptance and understanding, as safety culture as a concept is better understood than the complexity of technical issues. Attitude surveys and other methods have been developed to 'measure' safety culture focussed on the nuclear industry. However, Cox noted that these need to be employed with caution. At the very least, when measuring attitudes, one needs to remember that attitudes are not always a good predictor of behaviour.

In practice, what gets measured gets noticed, and trying to find the processes of appropriate measures for culture may help in drawing management attention towards the improvement of culture in general. As the concept of safety culture was born out of an accident, Cox explained that there is a tendency to focus on what not to do, rather than reinforcing what we do well. One has to ask then if the nuclear industry has become brilliant at preventing the last accident, but poor at preventing the next. Cox cautioned against using safety culture as a warm blanket that prevents organizations from addressing more fundamental safety problems, and reminded the conference of cases where the declaration of a perfect safety culture was followed by severe events.

Cox believes that the sector has also been challenged in attempting to optimize organizational learning from accidents and incidents, and argued that people often underestimate learning, thinking it is merely about gathering facts that can be inserted into any context. In reality, the dissemination of such information can only help people learn if the information is presented in a way that is readily assimilated and understood, and where feedback from the recipient is acknowledged. Trust is critical to learning. Finally, Cox asserted that safety culture is context dependent, that there are no one size fits all approaches available. What works in one context might fail in the next. Leadership and management need to be grounded in modelling behaviour, but also need to be cautious in deploying the right amount of power.

Cox also argued that while there is a good basic framework for safety culture, there was the issue of how it could be improved for the future. For instance, when addressing challenges such as the constant cycle of change in decommissioning, the meaning of safety culture may need to be rethought, moving away from seeing safety culture as risk aversion requiring passive protection, as safety culture in a decommissioning context requires active safety protection because the designed ‘passive’ safety protection will be removed or bypassed during the act of decommmisssioning (breaking into shielded places).

Research shows that in the future there will be an increased need for visible and just treatment, and that increased complexity will demand more and better teamwork, organizational learning and project management. The relationship between organizational culture and various safety cultures needs to be examined and real time data need to be collected. Cox challenged the nuclear community, arguing that there has been an overriding belief in ‘too good to fail’. The audience was encouraged to ask itself whether we really have understood system interaction, or if the pendulum has swung too far and we have become so obsessed with ‘soft issues’ that the fundamental interaction with technology is no longer questioned. Has there been a drift away from the fundamentals that we know about the system and the ‘person–machine’ interactions, rather than advancement?

M. Alvesson, Professor of Business Administration, Lund University, and a student of 'functional stupidity in organizations', gave an address entitled The risk of hyperculture: How to avoid it and work with real organizational culture. Alvesson applied Geertz's definition of culture, describing the concept as the creation of meaning through which people interpret their experiences and guide their actions. He reminded participants that culture does a lot of positive things for organizations; it helps during decision making, supports identity building, facilitates commitment, communication and coordination, and generally guides direction. However, at the same time, culture is a source of inertia, leading to a lack of imagination and low receptivity to new ideas. Because of this, Alvesson warned that it is probably not possible to create a perfect, 'good culture' producing all the normative outcomes we wish. Although culture can be regarded as a 'social glue' that supports social order and acts as a compass that guides direction, it always has some elements of a 'psychic prison', leading to tunnel vision and mental and emotional traps that prevent effective learning from taking place.

Alvesson explained that cultural change initiatives often fail because they are not focused on the real organizational culture, but are instead developed around well formulated, vague and idealistic words and slogans. Alvesson has termed the result 'hyperculture'. Hyperculture evolves as the product of cultural change and improvement programmes in organizations where a few standardized, attractive, but abstract, values are picked out by management or by a consultancy firm and presented as a package that employees are expected to take on board. The values will sound positive but are often difficult to live up to when the organizational setting is not compatible. Examples of these values include, 'free speech is encouraged' and 'always be respectful and never insult anyone'. Often the concepts and explanations used to support the introduction of corporate cultural values are characterized by what Alvesson calls 'symbolic world anorexia'. They are so abstract, vague and broad that they do not resonate with their audience and the real word and experience. For that to happen, one needs to apply real life stories that connect to the specific problems experienced.

Following this, Alvesson underlined that to work effectively with culture means trying to better understand the culture. This requires talking to people and finding out more about the organizational patterns and interpretive logic applied in daily work life, rather than looking at what has been written in pamphlets and messaged through management speeches. To succeed with organizational change the cultural change cannot be just about making others change. The managers, HR experts and other cultural change agents also have to change themselves. Alvesson warned against 'multistep thinking', where steps of the change process are predicted and delegated down the hierarchy like a relay race. This is not how culture change works; it should rather be treated as a football game, where all players need to take part to win the game. Culture change needs to remain on the agenda, in the sense that people in the organization ask themselves how their day to day tasks relate to the cultural challenges identified. By choosing specific, well represented examples close to practices, and asking critical questions challenging business as usual, the trap of hyperculture may be avoided. Real organizational culture change is time consuming, and will not succeed without setbacks and unintended consequences, but if the organization is not ready or able to invest this time, then Alvesson recommended not to try changing culture at all.

E. Schein, Professor Emeritus, MIT Sloan School of Management, and the founder of modern work on organizational culture, presented a challenging talk on the unique problems of the nuclear industry and the need for humble inquiry. Schein argued that the concept of culture is widely accepted, but still not very well understood. Since safety culture hinges fundamentally upon whether the executives of the nuclear plants and sites manage to create a climate of trust and openness, all other safety culture attributes follow from these, and therefore Schein radically recommended revising the safety culture normative framework to only focus on trust and openness. If trust is present, it means that employees openly communicate safety issues and concerns upward in the organization, ensuring that the information needed to safeguard safety is received. Schein remarked that in most organizations, upward communication is inadequate, for several reasons. First, as peer group norms at plant, union and operator levels are very strong, it is often not socially accepted to forward information that may reflect negatively on peers. Second, people are prevented from reporting issues upward because they often want to believe they are in a place working well, preferring to keep the faith that somehow top management knows about what they saw and will probably fix it. Third, and most significant according to Schein, managers often fail at soliciting and being respectful and helpful when receiving negative upward communication. If managers leave the impression that information provided on a safety issue will not be acted upon, he or she sends a message saying safety matters do not concern the worker, and that management will deal with this. And even more dramatic, if the manager makes the messenger responsible for dealing with the issue brought up, saying ‘don’t bring a problem unless you have a solution’, employees will give up reporting, or maybe even resort to whistle-blower practices.

Schein argued that in the end, whether people trust each other and are open to share depends on the CEO. Organizational culture — with its basic assumptions, values and norms — originates from the CEO; he or she imposes and specifies the rules and processes that end up defining the assumptions that are then operated on. As a consequence, subcultures develop since every department has to deal with its own specific challenges, which in turn means that each of the issues dealt with by the organization end up being controlled by a different sub-culture that has grown up in parallel with the original founding culture. Schein held that the only person in a position to see and understand the system of interactions between all the departments and their subcultures is the CEO. So, in order for engineering to produce the best process for the plant, and for operators to feel accountable and responsible, CEOs need to understand that their own behaviour will ultimately determine how the sociotechnical system beneath them functions. Schein argued that a capability to understand the systemic, sociotechnical nature of the operations to be managed needs to be made an upfront criterion when selecting CEOs and senior managers for the nuclear industry.

According to Schein, CEOs send the most important signals through the specific interaction with their immediate team. To succeed in creating openness and trust, the CEO has to start by being open, trusting and creating personal relations with his or her immediate subordinates through asking humble inquiry questions, rewarding upward communication and honesty, and making them feel safe to report any issue. The CEO also needs to hold senior management clearly accountable for displaying upward and downward openness and trusting themselves. They also need to ensure that their own subordinates feel psychologically safe to be open and trusting as well. Schein asserted that sooner or later, productivity and schedules will overwhelm safety. That is why it has to be the CEO's burden and no one else's to put safety first and ensure that managers are held accountable not only for productivity but also for safety.

Schein concluded that the responsibility of creating a strong safety culture based on trust and openness needs to rest upon the CEO, not a culture manager or a consultant. If this is not the case, the CEO has misunderstood culture all together.

Schein was challenged by the audience who questioned whether it was possible to find candidates with the ability to live up to Schein's high expectations of CEOs. Schein admitted this was a challenge, but argued that in the nuclear industry, if safety is really treated as important, a new standard for CEOs needs to be set, selecting individuals who are able to manage the systemic, sociotechnical nature of their organizations by putting openness and trust first.

Concluding the opening plenary session, the keynote speakers provided unified messages on leadership and culture. Leaders must take accountability for safety and safety culture, realizing they make the difference. They must pay attention to the people who actually do the work, learn from them and act upon what is learned. They need to demonstrate to employees and to the wider public that they care for their safety. This can only be done through real actions with a 'do the right thing' attitude, rather than excelling at minimum compliance. In safety significant domains such as the nuclear sector, there must be a standard for CEO selection and performance that treats the understanding of the systemic nature, or the sociotechnical system, as a fundamental skill and knowledge set; without this ability, all other qualifications become irrelevant.

For safety culture improvement initiatives to work, they must emerge from employee perceptions of needs, not merely top-down imposition based on vague and idealistic words that fail to reflect the realities of employees. In its simplest form, safety culture in safety significant sectors is about trust and open communication. We cannot fix what we don't know about — and in order to transmit the needed safety information to the top, trust and openness needs to permeate the organization. There is a danger in using safety culture characteristics as a checklist; rather, they must be used as a framework for understanding. The key is not about ticking the boxes of the characteristics; it is about producing what the world needs, and then doing it safely.

2. PLENARY SESSION: RETROSPECTIVE LESSONS

The plenary session started with a dialogue designed to share the personal experiences of key experts from past major accidents, discuss the nature of the lessons learned, and evaluate the impact on their life and career. The focus was on a fundamental question: how does the industry deal with human factors in comparison with technological factors during incident investigation and in its subsequent preventive actions. The session was moderated by M. Haage (IAEA).

V.N. Abramova, Head of Science Research Centre 'Prognoz'; B. Stoliarchuck, State Nuclear Regulatory Inspectorate Ukraine; and **A. Kawano, Tokyo Electric Power Company (TEPCO),** shared personal experiences from the Chernobyl and Fukushima Daiichi nuclear accidents, pointing out a number of common features in terms of the human side of the accidents. The shift personnel proved to be extremely courageous when responding to the accidents, and did not abandon the plant despite the dangerous conditions they were forced to deal with, including elevated levels of radiation, lack of supplies, missing or unreliable communication channels and insufficient information about their relatives. Difficult conditions continued beyond the initial accident, with fear of further explosions in the Chernobyl Unit 4 reactor and with 463 aftershocks occurring in the region of the Fukushima Daiichi plant in the first week after the accident.

The different roles of each witness to the accidents provided different personal stories. Stoliarchuck, who was lead engineer of reactor control at Chernobyl Unit 4, recalled thinking that it was not possible, when the control panel in the control room of Unit 4 showed that reactor 4 stopped existing. Abramova investigated the feelings and behaviour of the personnel and attempted to understand what they were experiencing during the accident in order to indicate both the causes of the Chernobyl accident and to study how society treated those people who sacrificed themselves for the sake of our welfare.

Kawano described the earthquake that triggered the tsunami which damaged the Fukushima Daiichi plant as a “very, very long horizontal movement when all employees were trying to hide under the tables”. Reiterating the alarming working conditions under which 700 employees were forced to work for several days, Kawano mentioned also very simple but unexpected human issues that needed to be dealt with such as the sanitary conditions; they only had two temporary bathrooms for several hundred people.

The discussion concluded by addressing Haage’s final question: if there is one thing you can do better in terms of the human side of safety, what would it be? It was argued that despite the fact that management devotes 90–95% of its time to work with people and only 5–10% to work with equipment, educational institutions devote very little time on teaching how to perform this management task. The panellists agreed that lessons learned from disciplines such as ergonomics and psychology need to be reinforced in those institutions educating future engineers. Furthermore, experts asked for more efforts to be put into creating a working environment that would facilitate collaboration between people, both between corporate headquarters and the site, and between managers and workers. At the same time, safety awareness also needs to be enhanced, for example through workshops and seminars, as stressed by Kawano, who described TEPCO’s newly established Nuclear Safety Oversight Office, which has organized such training for senior management.

V.N. Abramova, Head of Science Research Centre ‘Prognoz’ questioned whether we have learned the lessons from the Chernobyl accident and identified what still needs to change. Abramova emphasized the fact that each aspect of safety culture has a psychological component and that this needs to be taken into consideration by everyone involved in the nuclear industry.

A precursor for actually addressing and learning from lessons is to ensure proper understanding of what a lesson really means. The most important is to acknowledge that the event happened, along with all the relevant circumstances. It is necessary to look both at the individuals directly involved, and at society as a whole, in order to understand how the event is both perceived and reacted to. Moreover, if a lesson is to be considered as learned, it is necessary to establish a psychological barrier that prevents people from repeating the mistake. It was stressed that only when a taboo is created can a lesson be regarded as properly learned.

Abramova referred to a summary developed by Stoliarchuck describing the Chernobyl accident from the psychological point of view. The conclusion, based on the Minnesota Multiphasic Personality Inventory test, was that the personnel who could have been the direct cause of some of the erroneous actions that led to the accident were not different from the personnel of any other nuclear power plant. This implies that whoever is involved in decision making at any level of responsibility has to be fully appraised of the potential consequences of their errors: at the end of the day, it is still about people depending on each other and on their colleagues. That is why there is a need to develop relations with workers and to acquire and develop two types of human capital: professional personality formation and human resource management.

Concluding the talk, Abramova argued that the future approach to safety has to be systemic and carried out in two areas: first from a retrospective perspective; looking at human factors and concentrating on finding what is needed to be done differently in order to avoid repeat events; second, from a prospective perspective by looking at the science of designing people's behaviour and attitudes. In the latter, more attention needs to be paid to operator behaviour, to the ergonomics and design of the workplace, and to operator reliability and the quality of their attitudes towards nuclear safety and safety culture concepts.

A. Kawano, General Manager of the Nuclear Safety Management Department at TEPCO, presented a paper by T. Anegawa, Chief Nuclear Officer (CNO) of TEPCO. Kawano explained the story of Unit 1 of the Fukushima Daiichi nuclear power plant after a 15 m tsunami triggered by a 9.0 magnitude earthquake washed over the plant. Kawano focused on the operation of the isolation condenser (IC), which caused several misunderstandings. These prevented the personnel from performing the necessary actions in responding to the accident.

Kawano explained that after the earthquake, the IC was working well, but mainly due to poor communication, the shift supervisor understood from the senior supervisor that the IC was not in operation. This assumption was based on the status (i.e. presumed loss) of AC/DC power. An IC is in operation if steam is coming out from its 'pig's nose' pipe so the shift supervisor asked the Emergency Response Centre (ERC) to observe if there was any steam coming out. The ERC reported back that there was a very small amount of steam. The shift supervisor, along with the ERC team, understood that the IC would be in operation only if there was a lot of steam, so he took the information received as confirming that the IC was not operational. In hindsight, the ERC team was not competent and knowledgeable enough to assess the state of the IC properly. The situation was made even worse by the absence of clarification between the shift supervisor and the deputy team leader of the ERC in the main control room about their understanding of the ERC.

Kawano explained that the lack of operational knowledge, miscommunication and a gap in understanding (and other human factors) not only caused the alarming situation of the plant to deteriorate, but also prevented operational measures which otherwise would have been taken to respond to the accident. TEPCO has kept these human factors in mind when addressing the lessons to be learned. It has introduced several improvements, including an ICS (Incident Command System) designed to limit the number of subordinates and managers to 3–7 people for decision making during accident response. The strategic and planning group has been separated from the implementation group and communication tools have also been improved, introducing satellite phones or radio communication tools to enhance the quality of communication between control rooms and the ERC. A more comprehensive overview on progress made since 11 March 2011 was offered in a second presentation by Kawano (see Summary of Plenary Session in these Proceedings, “Future Perspectives”).

3. PLENARY SESSION: THE CURRENT STATUS

The plenary session started with a dialogue designed to share experiences of key experts regarding the current situation and highlight the challenges facing safety culture. Participants included **R.H. Taylor, former non-executive Director of the UK Health and Safety Executive; M. Griffon, former board member of the United States Chemical Safety and Hazard Investigation Board; G. Grote, Professor of Work and Organizational Psychology at ETH Zürich; and M. Nishizawa, risk communication consultant and Director, Litera Japan Co.** The experts were all asked to reflect upon the question: are we concentrating on the right issues? H. Rycraft (IAEA) moderated the session.

The experts largely agreed that the nuclear industry focuses on several important organizational factors and areas of work when it comes to safety culture. However, they highlighted the challenges that need to be faced for further improvement. Grote spoke on the difficulty of developing stringent procedures while at the same time trying to equip people with the skills and means to cope with unexpected situations, which may in turn require them to deviate from procedures. Taylor mentioned the difficulty for leaders to deal with increasingly strong business pressures during unprecedented times of change, while at the same time adopting a conservative position regarding safety. Griffon noticed a time lag between safety culture theoreticians and practitioners in the field, for whom safety culture appears to be just a sophisticated way of blaming the worker. Nishizawa expressed the need for the nuclear industry to focus more on improving communication skills, both for communicating technical knowledge in the field and for enabling a wider public debate.

Rycraft asked the panellists if the safety culture improvement programmes currently in place were useful for tackling the right challenges, and actually improving culture for safety. Taylor felt that sometimes these programmes are too focused on questionnaires and surveys, leading managers to have a limited view of what is happening in the field. Grote explained that both operating organizations and regulators have been too focused on talking about what safety culture is as a concept, and that this in turn has distracted them from performing concrete actions to actually improve culture. He believed that people need to spend less time discussing the concept of safety culture and more on actually building characteristics such as trust, openness and transparency.

Panellists underlined different ways of achieving this. They focused on strong personal involvement of leaders: presence in the field, hearing from everyone, and acquiring knowledge of what is actually happening within the organization by talking to the people doing the hands-on work. The panellists also underlined the challenge of keeping knowledge of past events in the minds of workers as a way to avoid complacency and to enhance vigilance. Taylor insisted that vigilance should lead to a feeling of chronic unease, i.e. the awareness that things can always go wrong. However, Grote remarked how challenging this feeling can be for leaders who need to be self-assured without being complacent as they take decisions. Panellists also highlighted the effectiveness of sharing personal stories to convey important messages in the organization.

Finally, the panellists insisted on the necessity for leaders to create a no-blame environment for workers, be involved on the ground and make sure their actions align with words to build trust and open a dialogue within organizations to enhance safety culture. Upon concluding the session, Griffon reminded the conference audience that, “Workers are a resource to be harnessed, not fixed”; this comment was picked up and repeated throughout the course of the conference.

G. Grote, Professor of Work and Organizational Psychology, ETH Zürich, Switzerland, presented a paper explaining the need for social science to be applied within safety management, showing what role it fulfils and how it can facilitate a dialogue between different professional cultures fostering different perspectives and cross-learning.

The role of social science within major hazard environments has been evolving over the past decades as those in the industry have started to realize its importance and potential. It is not only about making people fit the technology, but recognizing the broader role individuals and their social systems can contribute when designing advanced technical systems. The human factors era replaced the technological era in the 1970s. However, it was the introduction of more contemporary management systems in the 1990s that initiated the push for a systemic approach to the complex interaction between social and technological processes. In order to achieve this, openness to different world views and a readiness to challenge basic assumptions of different professional (sub) cultures are required. In this regard, the core issue that a comprehensive management system deals with — how to manage risks rationally — seems to be challenging given differing human and technological perspectives. Grote explained how a decision deemed rational by a psychologist is not necessarily seen as rational by an engineer, as the rationality guiding each of the professions is driven by different content. How can this be dealt with?

The answer, as well as the main message from Grote, is to develop a culture of interdisciplinary (or transdisciplinary) appreciation, which would permit a more systemic, integrated approach to safety. As an example, Grote referred to the work of the Swiss Federal Nuclear Safety Inspectorate in the area of safety culture, explaining how forums for dialogue are arranged where people from the regulator and operator meet for an open conversation on emergent issues. The conversation is noted, and the notes are distributed to the parties to ensure that everyone is on the same page. Another example was drawn from Grote's work with hospitals. It relates to cross-hierarchical groups in the sector, some of whom (for example, senior and resident physicians) have direct power over the colleagues of other colleagues. Grote was able to facilitate cross-learning and provide the appropriate tools and techniques for building trust. It was also deemed important for the ensuing discussions to debrief and learn from some events which do not go well.

The follow-up discussion with the audience triggered a remark on coping with the issue of transparency versus confidentiality between a regulator and an operator. Grote explained that the need for transparency often comes as a demand from the public, based on mistrust, and a demand to be able to see everything in order to be able to determine that things are all right. Therefore, in some cases, the public needs to understand that being too transparent might be counterproductive to safety, as some organizational issues are better dealt with without sharing everything in the open.

L.K. Clewett, Executive Vice President and Chief Nuclear Officer of Bruce Power, presented the leadership actions taken to improve safety culture at Bruce Power and discussed their safety culture assessment approach, which was reviewed in 2012, focusing especially on the identification and prioritization of actions based on the results obtained.

Safety culture activities are structured around a single process: a thorough self-assessment conducted periodically and completed by regular safety culture monitoring panels, monthly and weekly leadership communication on safety culture, and refreshed leadership training around safety culture for first-line managers. The central objective of these activities is to collect feedback from first-line managers and generally engage employees by meeting them in the field.

Regular safety culture monitoring panels are small groups formed by people from performance improvement or corporate safety assessment teams. The teams not only meet with leaders but also review recent events at Bruce Power to obtain inputs from people on the floor as to what actions were taken and what they mean to the people who are actually doing the work. Clewett described this feedback as insightful and stated that it is used to trend progress between safety culture assessments.

The self-assessment methodology is based on a survey, interviews, focus groups and insights from the monitoring panels over the previous year. In 2013, this process included an independent industry expert in safety culture, as well as three teams of 34 employees conducting interviews. The purpose of the assessment is to obtain input on how employees perceive safety. Safety cannot be rated in absolute terms, therefore the assessment process is designed to include people's concerns, behaviour patterns and other insights surfacing in the assessment to identify actions to improve nuclear safety.

An oversight committee chaired by the Chief Nuclear Officer with a cross-department team reviews the results. The most commonly raised concerns in the previous survey were: the long term health of the plant, equipment condition, communication gaps between the purpose, value and performance of the corrective action programmes, and a lack of field presence of managers. They were perceived to be too focused on data and not enough on talking with people and understanding what is not working and why.

Following this, three main focus areas were identified: improving equipment health, improving first-line managers' communication through visual management boards, and improving the organization's corrective action programmes and learning ability. Actions have been led by cross-functional teams involving top performers across the organization, with sponsorship from senior leaders. According to Clewett, results have been very positive: the error rate was reduced by 50% (a record for power generation in 2015), safety awareness was improved and better communication was observed involving all staff.

Finally, Clewett identified several different key lessons and success factors, including, having site-wide actions, establishing sponsorships from key leaders, and focussing actions and communication on the top three issues. These factors contributed to the success of acting upon the safety culture assessment results, which led to improved safety and commercial performance.

M.A. Habib, Chief Executive of Pakistan Nuclear Regulatory Authority (PNRA), presented PNRA's activities to assess and improve safety culture. Habib focused especially on their safety culture self-assessment and the subsequent improvement activities implemented with the support of the IAEA.

Habib described the importance of safety culture for PNRA in fulfilling its vision and mission: to create a relationship of trust and transparency in the regulation of nuclear safety in order to protect people and the environment from the harmful effects of ionizing radiation in a manner that gains the confidence of all stakeholders. PNRA regards safety culture as a model for communication at the national level for licensees and other stakeholders, and at the international level for other regulatory bodies. In order to improve safety culture within PNRA, but also in the industry, PNRA identified a need for dialogue sessions to develop a common understanding of safety culture between stakeholders, and a need for safety culture self-assessments, not only by the licensees but also by the regulatory body.

PNRA developed its safety culture self-assessment programme with the support of the IAEA Technical Cooperation programme. Following an IAEA led safety culture workshop for senior management, a multidisciplinary safety culture self-assessment team was selected to receive training on the IAEA safety culture self-assessment methodology as well as on the regulatory oversight of safety culture. In order to avoid 'group think' and ensure a diversity of perspectives, the team consisted of representatives from all parts of the organization. Prior to launching the assessment, PNRA implemented an awareness campaign and related communication activities to facilitate involvement, participation and feedback from all staff throughout the assessment.

The first step of the assessment involved the collection of data through a variety of methods (observations, interviews, document analysis, surveys and focus groups) and led to the identification of 1900 items related to culture. PNRA performed a descriptive analysis of these items using a systemic approach based on tools such as bubble diagrams. From this, cultural themes were identified, and the basic assumptions driving behaviour and norms were explored. Cultural themes highlighted through the analysis were grouped together to form overarching themes. Additionally, some of the cultural themes that were not as prominent, but had high safety significance, were also considered as overarching themes.

The second step of the assessment was to perform a normative analysis by reviewing these higher order themes against characteristics and attributes of safety culture specified in international standards such as IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations.[1] These characteristics and attributes were used as a framework to evaluate the strengths (e.g. organizational progression, friendly working environment) and weaknesses (e.g. fear of reporting) in PNRA.

The assessment triggered improvement activities and related communications to raise awareness of the organization's strengths and weaknesses. The structure of core regulatory processes was reviewed to improve their effectiveness by incorporating the concept of safety culture. Moreover, dialogue sessions carried out during the implementation of safety culture

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, IAEA, Vienna (2009).

self-assessment tools helped promote a shared understanding of safety culture within PNRA.

Habib concluded that the safety culture self-assessment started a learning journey within PNRA. It helped in understanding the linkage between beliefs, basic assumptions about actions and attitudes, and improved safety culture.

Y. Hah, Head of the Division of Human Aspects of Nuclear Safety of OECD Nuclear Energy Agency (OECD/NEA), presented the OECD/NEA's approach to the human aspects of nuclear safety, especially the missions and areas of work of the organization.

The Fukushima Daiichi accident sparked a great deal of discussion between the OECD/NEA and its member countries that led to equipment changes, operational improvements and other activities to check and confirm that nuclear installations were safe to continue operation. Moreover, this accident also highlighted significant human, organizational and cultural challenges that had received less attention, but that were deemed essential to understanding the lessons from previous accidents. In order to support its member countries in their efforts to address these challenges, the OECD/NEA created the Division of Human Aspects of Nuclear Safety, which has five identified work areas: human and organizational factors, safety culture, public communication, stakeholder involvement and training. This division supports the different committees of the OECD/NEA that cover these areas of work.

Since 2014, this division has highlighted the importance of proper safety cultures for regulatory bodies in reports of the Committee of Nuclear Regulatory Activities because these cultures also influence licensees and operators. Hah underlined the importance of refraining from setting safety culture in opposition to national culture, and of using the strengths of each national culture as a positive influence to improve safety.

This new division leads activities on human and organizational factors; for example, issues such as human performance in extreme conditions, human reliability assessment, and integrated system performance for nuclear power plant main control rooms. Its aim is to support the safety performance of nuclear installations and to improve the effectiveness of regulatory practices. The division is also working on issues of stakeholder confidence and involvement.

Lessons from the past show that improving technical systems is not enough. Improving safety culture and human and organizational factors, as well as enhancing openness, transparency and stakeholder involvement is vital for improving nuclear safety.

G. Rzentkowski, Director of the Division of Nuclear Installation Safety of the IAEA, presented the IAEA's approach to leadership, management and safety culture. Rzentkowski recalled that the concept of safety culture developed after the Chernobyl accident was focused initially on operating organizations and nuclear plant safety issues. The revised definition in the 2007 IAEA Safety Glossary[2] expanded its scope to cover all organizations dealing with, ‘protection and safety issues’, including regulatory bodies. The extension of safety culture to apply directly to regulatory bodies was described as relatively new, forming an important part of the current IAEA actions supporting leadership, management and safety culture in its Member States. The IAEA safety standards provide thorough guidance on the implementation of the cultural characteristics and attributes that establish nuclear safety as an overriding priority. The current approach treats safety culture, or culture for safety, as a subset of the culture of the whole organization, comprising the mix of shared values, attitudes and patterns of behaviour.

The IAEA reports issued after the Fukushima Daiichi accident led to several important lessons being implemented in this area. Rzentkowski argued that as the technology itself has been shown to be sound, the main gains in safety are to be achieved in addressing human and organizational factors by applying a systemic approach that considers the dynamic interactions between human, organization and technical factors through the entire life cycle of nuclear installations.

Strong leadership and management are essential for developing a culture where safety comes first. However, the process has to involve the whole organization: safety has to be viewed by all actors as a continual process of improvement where everyone can contribute. This idea of safety is also challenging for regulatory bodies as it goes beyond national requirements and defines safety as the overarching priority for all stakeholders.

The IAEA has been revising and developing new documentation (requirements, associated guidance, safety reports and technical documents) on leadership and management for safety to take these challenges into account. The main achievement is the publication of IAEA Safety Standards Series No. GSR Part 2,[3] which provides revised and strengthened requirements on leadership and management. Publications on independent assessment and self-assessment of safety culture were published in 2016; further guidance is under development.

Rzentkowski presented findings related to leadership, management and safety culture from the IAEA peer review services for regulatory bodies (Integrated Regulatory Review Service) and operating organizations (Operational Safety Review Team). Recently, the leadership, management and human, organization and technical aspects of the Operational Safety Review Team review

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection, 2018 Edition, IAEA, Vienna (in preparation).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2, IAEA, Vienna (2016).

process were enhanced through the introduction of two new review modules covering these areas. These reviews have facilitated the identification of good practices and challenges, such as the need to promote, rather than enforce, safety culture or the necessity of regulatory bodies to act as role models for licensees when it comes to their own safety culture. Rzentkowski stressed that regulatory bodies are still generally lagging behind licensees in terms of safety culture, but mentioned several IAEA initiatives in this regard, such as guidance on safety culture self-assessment and oversight.

Finally, highlights from the IAEA's specific safety culture services were presented, including the Safety Culture Continuous Improvement Process — developing improvement capacity within both operating organizations and regulatory bodies; the Independent Safety Culture Assessments; the development of safety culture perception questionnaires for licensees and regulatory bodies as well as a range of tailored missions and workshops arranged upon direct Member State request.

C.A. Hart, Chairman of the US National Transportation Safety Board, presented the 'system think' approach. This builds on an awareness of the impacts throughout a system through changes in any of its subsystems. Many potentially hazardous industries consist of interdependent subsystems, and in these industries there is a need for subsystems to work together effectively for the entire system to perform well. Hart explained that the more interactions occurring within a system, the more issues are created. These interactions leads to an ever increasing number of human errors, unanticipated situations and situations in which the predetermined, 'by the book' response may not be optimal.

Hart stated that making mistakes is part of being human; that is why we have to accept mistakes and deal with them. A common way of doing so is to punish and retrain workers who made the mistake despite their training. A second option, proposed by Hart, acknowledges that people are prone to making mistakes, but instead of punishing them it attempts to find out why the system allowed a mistake or failed to accommodate it. The objective is working to improve the system so it will be less error prone and more error tolerant.

According to Hart, collaboration is the answer to implementing the system think approach in practice. Hart explained how the US commercial aviation industry has implemented system think by developing the volunteer programme Commercial Aviation Safety Team (CAST). This programme involves gathering representatives from all parts of their complex system, pilots, air traffic controllers, regulators, airlines, manufacturers and others to develop approaches to identify, prioritize, solve and evaluate potential safety concerns. By gathering the stakeholders around the same table, it has been possible to find solutions that better address the entire system. This accomplishes the desired results while avoiding unintended consequences. Hart underlined that to be able to understand

and improve a complex system, the influx of information needs to come from the employees dealing within the system. They are the ones best equipped to address the gaps between what is happening and what is supposed to happen; in other words, those who are involved in the problem need to be engaged in its solution. Although the aviation industry was already considered very safe in 1997, the implementation of the CAST programme has been a success, diminishing the fatal accident rate by more than 80% in the first five years.

Acknowledging that a shift of paradigm and approach always comes with some challenges, Hart argued that the ‘I am ok, you’re not’ approach must be replaced with a willingness to do things differently if it is shown to contribute to the improvement of the entire system. Moreover, values and beliefs within an organization must be common for all personnel and whatever happens, it must be considered as everybody’s accident instead of anybody’s accident. In order to successfully take on this approach, trust across and within organizations is essential.

Hart concluded that implementing a safety programme that also improves the bottom line is more likely to be sustainable, and that the collaborative approach applied in US commercial aviation has been shown to do just that. This collaborative approach is improving both safety and productivity and further reduces the likelihood of unintended consequences.

4. PLENARY SESSION: FUTURE PERSPECTIVES

The plenary session on future perspectives started with a dialogue on future challenges and possible new ways of thinking about safety within the nuclear industry and other high hazard industries. **A.N. Afghan, MBA Programme Director, IBA; A. Kawano, General Manager (TEPCO); J. Ward, Manager, Continuous Improvement Section, Australian Radiation and Nuclear Safety Agency (ARPANSA); J. Pariès, President, Dedale;** and **E. Fischer, COO Nuclear Operations and Technology, E.ON,** addressed the question: what will safety culture look like in the year 2046? Their task was to envisage the changes that will have to be carried out in terms of safe operations both with regard to technology and to the people involved in the industry, as some parts of the world witness the commissioning of new nuclear sites, while other regions largely face shutdown and decommissioning.

Asking what safety culture will look like in 30 years led the participants to question whether people will still be talking about safety culture in 2046, or maybe have moved on to another concept by then. It was suggested that the term safety culture may shift towards something more limited such as ‘safety awareness’, and there was also a hope that safety culture would no longer be needed as a concept, as safety behaviour and attitudes would have become an integral part of working life. What the potential new concept would cover would depend significantly on the people involved in the nuclear industry in the 2040s. It was predicted that the nuclear industry will be dealing with an ever more complex reality that will require systemic solutions. As this is also the case for society in general, people may also develop greater skills in handling complexity. When it came to leadership for safety in 30 years, it was predicted that the qualities required from a leader would become more universal, in comparison to the current situation when the expectations of a good leader differ from one cultural context to another. It was agreed that a good leader needs the capability to motivate and support employees throughout the organization through personal relationships. In line with this, the participants contended that the new modes of communications, which make remote work possible, can not replace the need for direct relationships and contact in the workplace.

It was argued that, based on past experience and data, there is a possibility of another nuclear disaster occurring within 15–20 years. In order to change this trend and better cope with extraordinary and unexpected situations in the future, upgrades and advances in design are not enough. There is a need to ensure that personnel assume personal responsibility in fulfilling the advanced requirements of the design, and that this needs to happen on a voluntary basis. The panel contended that the first step in transforming the mindset of employees is to establish values such as mutual respect and appreciation throughout the organization, as this will help define ways of working together that can ensure committed behaviour of personnel.

It was finally cautioned that there may be further challenges to deal with when looking into the future. In 30 years, there will be a number of nuclear power plants that are either operating on extended life times or will be under decommissioning, creating further economic challenges for the nuclear industry. At the same time, the threat of terrorism is increasing. All of this may even lead to challenges in recruitment. This bleak outlook was contested. It was pointed out that the situation of the nuclear industry differs considerably across the world and that one should consider the global situation as a whole when looking at the future. Finally, it was noted that nuclear safety goes beyond conventional nuclear power operation and this should be taken into account in the future when considering safety culture and human and organizational aspects.

A. Kawano, General Manager of the Nuclear Safety Management Department at TEPCO, presented the progress accomplished through TEPCO's nuclear safety reform. Kawano reflected back to the 2000s, in particular to TEPCO's cover-up scandal in 2002. Several cracks and other indications were found in the core internals and recirculation system piping, but the findings were not reported to regulators mainly due to a fear of possible long term shutdown and consequent financial impact. At that time, TEPCO responded to the scandal by introducing a variety of countermeasures, particularly in terms of quality, such as a quality management system and corrective actions programme. However, few activities were successfully implemented and many of them were put on hold since promised sponsorships and commitment by top management were not apparent.

Kawano also explained how TEPCO was involved in several discussions and calculations about the height of potential tsunamis prior to the Fukushima Daiichi accident. In 2002, a new methodology for calculating tsunami height was introduced by the Japan Society of Civil Engineering (JSCE). The existing methodology did not assume that the potential source of a tsunami could be a trench in Fukushima Prefecture and therefore the calculated height of a tsunami resulted in relatively low estimates. Kawano explained that TEPCO was relatively comfortable with the commonly used methodology, since no additional actions were needed. Using the JSCE methodology, the expected height of tsunamis increased from 3.1 m to 5.7 m and was finally set at 6.1 m. However, on 11 March 2011, the tsunami inundation height reached a level of 15.5 m at the Fukushima Daiichi site. Another study introduced by the Headquarters for Earthquake Research Promotion showed different numbers. The possible height of a potential tsunami was calculated to be about 13–16 m, taking into account Fukushima Prefecture. TEPCO was not convinced by the study since the numbers were regarded as too high and asked the relevant authority (JSCE) to assess them. JSCE assessed the calculations as highly hypothetical, resulting in a situation where TEPCO relied too much on the outside authority and lost chances to protect related systems from flooding.

In 2013, TEPCO issued the Nuclear Safety Reform Plan divided into six pillars to overcome negative spiral issues, such as insufficient safety awareness, overdependence on capacity factors (engineering and technical ability) and lack of communication abilities. The most important pillar was the reform of top management. Opportunities for nuclear leaders to share experience among themselves were created, and leaders were sent on benchmarking trips. A robust management model was created. Nuclear leaders are now required to do walkdowns and talk to people at the site more frequently. They are also expected to demonstrate good nuclear safety culture behaviour through reinforced communication with all employees. Another goal was to enhance defence in depth. TEPCO has held safety enhancement contests where young professionals had a chance to propose ideas for improvements which, if relevant, were supported by management and consequently implemented. After the Fukushima Daiichi accident, TEPCO worked to strengthen its emergency response capabilities beyond earthquakes and tsunamis, developing measures against any hazard that a plant might be exposed to such as a terrorist attack, tornadoes or a volcanic eruption. Public risk communication has also been improved as a social communication office was established in order to bridge the gap between TEPCO's approaches and social standards. Kawano concluded the presentation by showing a film documenting the progress made at the Fukushima Daiichi site since 2011.

M. Nishizawa, **risk communication consultant and Director, Litera Japan Co.,** made a presentation on risk communication, which is key for fostering a more resilient safety culture. Nishizawa noted that the acceptable risk is not decided by utility companies or regulators; it is decided by the public. Challenging the current practices of the nuclear community, it was argued that the way the safety of nuclear technology is conveyed to the public requires improvement to better meet the needs of the public. The expert–layperson gap needs to be acknowledged, as very often risk communication assumes a higher level of expertise among the public than is the case. This can lead to information failing to be received as intended. Nishizawa's talk supported this argument by presenting the results of two empirical studies conducted from 2011 to 2015 after the Fukushima Daiichi accident.

The first study examined the risk communication practices designed for the evacuees of Iitate Village in Fukushima Prefecture. It sought to answer why communication between professionals and laypersons often ends up creating mistrust rather than building trust. The study discovered that the failure was largely caused by the way the information was delivered. Scientists sought to convey the information through numbers and scientific logic, while the public were better equipped to understand information through the use of images and emotions. The attendees also wanted more practical information than the scientists had been prepared to offer. They wanted to know how to deal with the situation on a day to day basis, what they could eat, including a straightforward comparison between radiation levels in regular food staples and food staples affected by the Fukushima Daiichi accident. The study also highlighted how people had different aims. The elderly were more concerned about whether they could return to their homes, while young mothers wanted more details on safe nutrition.

The second study, conducted in 2015, looked at a citizen panel organizing stakeholder dialogues on the safety of the Hamaoka nuclear power plant. According to Nishizawa, the dialogues helped both experts and laymen to understand the need to share responsibilities in creating safe neighbourhoods and secure energy supplies. For risk communication to be successful, it needs to start in a non-crisis situation. This was clearly shown by the Fukushima Daiichi accident. There was no effective communications programme in place, causing a great deal of confusion from which it was difficult to recover. By creating public forums, such as the Hamaoka nuclear power plant citizen panel, experts and laymen can meet to discuss issues openly and build the trust needed.

T. Melnitckaia, Professor at the Psychology Department, Obninsk Institute for Nuclear Power Engineering, presented a paper explaining the ‘theory of generations’ and specifically how safety culture is influenced when leaders try to implement values and norms in their organizations, without taking into account generational gaps among their employees.

The theory of generations, as elaborated by Howe and Strauss[4], defines ‘a generation’ as an “aggregate of people who were born over a particular span, who were influenced by similar events, parenting traits and values respected”. Melnitckaia pointed out that the theory is normally not applicable to the entire population of a country but to its middle class. Economic opportunities usually define a country’s middle class. For example, in the Russian Federation, people in the middle class have an annual income of US $20 000–30 000 per family and a university degree.

Melnitckaia noted that the three age diverse generations, Baby Boomers (born 1944–1963), Generation X (born 1963–1983) and Generation Y (born 1984–2003) are particularly relevant for the operation of nuclear power plants today. Melnitckaia focused on the fact that these generations are actively working together in organizations. The age diversity of personnel must be taken into account when improving and maintaining safety in an organization through training processes, progressive norms, or implementation of the latest technologies.

When it comes to intergenerational interactions in an organization, there is a need to be aware of the problems that might arise in day to day communication between employees. For instance, when people assess the behaviour of other people, they do so from the standpoint of their own values and beliefs. At the same time, when people give advice to colleagues, they usually suggest what they consider is good for themselves. Different interpretations of the same words between two age diverse employees can also occur and might lead to significant misunderstandings or information gaps.

Melnitckaia concluded the presentation with some suggestions on how to foster organizational values and norms when taking an age diverse workforce into consideration. To minimize the problems of intergenerational interactions, leaders need to better understand how to communicate with different age groups through knowledge of their specific values and beliefs. Moreover, when fostering safety culture by introducing more progressive norms and values among the

[4] HOWE, N., STRAUSS, W., Generations: The History of America’s Future, 1584 to 2069, William Morrow & Company, New York (1991).

people involved, it is essential to look at how these correlate with the real world beliefs and values of different generations.

J. Pariès, Dedale S.A.S., explained what the nuclear sector could learn from resilience engineering. The concept of resilience engineering describes the ability of a system to prepare to be unprepared, that is, the capability of a system to stretch near and beyond its boundaries without breaking down. The concept requires the awareness of a system's margins of manoeuvres, in other words, how far it is from the limits of its capacity. Pariès also underlined the need to be knowledgeable about what we know as well as about what we tend to ignore. To prepare for the unpredicted, we have to be able to respond to more general, rather than specific threats, and create vital actions. These are actions that can be applied in a variety of scenarios and which are independent from already known scenarios.

Having mentioned the defence in depth concept as one of the frameworks behind a resilience strategy, Pariès warned against the core of this safety approach as it relies upon the "deterministic and probabilistic anticipation of all potential situations and predetermination of all the expected (safe) responses". An over-reliance on the ability to predetermine how a system will function leads safety to be ensured only through the real world's correspondence with the predicted world. It constrains the adaptability of the system in dealing with anything unexpected. Pariès explained that the currently popular command and control approach does not fully acknowledge the limits of predictability inherent in a complex adaptive and self-generated system. As a result, the importance of adapting to unknown situations is underestimated. Following this, Pariès quoted Sutcliffe[5] in suggesting the need for a shift from "reducing uncertainty about the future to managing uncertainty as events unfold".

Referring to a comprehensive global study by BST & ORC Mercer, Pariès explained that contrary to common industry belief — expected declines in low level events leading to a proportionate decrease in severe events (i.e. the Heinrich/Bird pyramid) — there is evidence showing that decreasing the number of low level events actually correlates with increases in the number of severe events. Pariès explained this by referring back to the "vicious circle of predetermination". As there is a perceived vulnerability to the unexpected, people attempt to increase predictability through anticipation, predetermination and simplification of the system. This continuous attempt to prepare for the expected erodes the capacity to cope with the unexpected and surprises become even more surprising.

Pariès further discussed the ratio between autonomy and control of subordinates and its influence on their ability to handle difficult situations.

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[5] WEICK, K.E., SUTCLIFFE, K.M., Managing the Unexpected: Assuring High Performance in an Age of Complexity, Jossey-Bass, San Francisco, CA (2001).

According to Pariès, giving way to more autonomous environments with less surveillance and procedures will lead to more adaptability, and thus to an increased capacity to handle abnormal situations (beyond the limits of predictability). On the contrary, if control and surveillance are reinforced, adaptability is curbed but the capacity to handle normal situations is improved. The key question becomes: what are the consequences of losing control in normal versus abnormal situations?

The presentation concluded with the notion that the current safety strategy — seeking anticipation of all potential threats — makes the system more efficient and more reliable within its envelope of design, but more and more vulnerable when dealing with outside situations. It was argued that the safety strategy needs to recognize the real world's complexity (with a certain degree of unpredictability) by developing resilience features within systems. Pariès provided the audience with a range of initiatives as to how management, training, procedural adherence, learning and design can be treated differently to fulfil this objective.

M.-S. Yim, Professor and Head, Department of Nuclear and Quantum Engineering at KAIST, presented a paper reviewing safety culture and the future of nuclear energy.

The nuclear industry has experienced three major accidents (Three Mile Island, Chernobyl and Fukushima Daiichi) which have significantly affected the evolution of nuclear safety. Taking into account the frequency of these major nuclear accidents and looking at the number of cumulative reactor-years (16 000) of commercial nuclear power plants operating in 33 countries, Yim explained that a nuclear accident is predicted to occur within the next 12 years. Yim considered how this trend could be averted by looking to the example of the aviation industry where a dramatic improvement in the level of safety has been achieved. The number of annual fatal accidents per 1 million departures has gone from more than 30 in 1959 to around 3 in 2013. Although factors such as technological improvements and reinforced regulatory oversight have been of relevance, the change in safety thinking was the real foundation of this evolution.

Yim explained how each of the above mentioned accidents transformed the different phases of safety thinking in the nuclear industry. Before the Three Mile Island accident, safety thinking was in the technical phase, where technology was regarded as the main source of problems. TMI changed this by revealing a new source of problems — individuals — leading safety thinking into the 'human error phase'. This view was again altered by the Chernobyl accident, as the source of the problem went beyond the individual level, introducing the sociotechnical phase. In this phase, the interaction of subsystems was recognized as a primary cause of the accident. The Fukushima Daiichi accident highlighted further complexity, making it clear that pointing to individuals and technology is not enough. The dysfunctional relationship between organizations was added as one of the main causes of problems, leading safety thinking to the ‘interorganizational relationship’ phase.

When it comes to the future of nuclear power, Yim pointed out that demand for nuclear power did not change significantly after the Fukushima Daiichi accident and the phase-out decisions in Germany and Switzerland that followed. Nuclear power can be regarded, along with renewables, as one of the few options that enable the current global consensus on greenhouse gas reduction. For this to be realized, rapid expansion of nuclear power is called for. In order to build the public trust and acceptance needed for this to take place, Yim argued that a new level of nuclear safety is required.

There are many challenges to address in order to enhance the level of nuclear safety. Many nuclear power plants are currently approaching the initial operating license limits and at the same time the infrastructure to support safe operation of a nuclear power plant may be weakening in many countries. The nuclear workforce is ageing while the number of graduates in nuclear technologies is decreasing. Moreover, research and development funding has generally decreased.

Another challenge involves the increasing number of newcomer countries without experience in the operation of nuclear power plants. Yim stressed that many such aspiring countries lack domestic good governance characteristics that will enable proper nuclear operation, management and regulation. In addition to this, these countries rely on foreign workforces because of a shortage of adequately experienced domestic workers. This might lead to multicultural challenges.

Yim concluded the presentation by labelling the final phase of safety culture as ‘socially-trusted nuclear safety’, referring to the basic need and desire of people to feel secure and free from fear and anxiety. Even if the nuclear industry is able to reach the best level of safety with the best available technology, if the people still experience fear and anxiety, it is not safe.

PAPERS SUBMITTED FOR PLENARY SESSIONS

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WHAT NEEDS TO BE CHANGED BASED ON LESSONS LEARNED FROM CHERNOBYL

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Abstract

The direct and root causes of the Chernobyl catastrophe form a system of negative conditions related to technological, organizational, social and psychological safety. The human factor is present in all these conditions. An in-depth, exhaustive analysis revealed different errors in human activities within all stages of the nuclear power plant (NPP) life cycle. The Chernobyl catastrophe reconfirmed existing and emerging lessons that have already opened and are still opening up local and specific national problems as well as global cultural problems. At present the world has changed and it keeps changing. Within this context, NPP safety requirements have become more rigorous due to increasing risks of military, political and economic nature. In the unstable social and political situation currently at hand, it is vitally important to ensure physical and psychological protection of all NPP personnel as well as of society as a whole. The need to implement large scale international projects and programmes of joint complex activities to ensure global NPP safety has become pressing.

1. INTRODUCTION

History poses questions: whether the lessons from Chernobyl are not wasted, and whether our contemporaries and future generations are ready to guarantee NPP safety. At the same time, terrorist attacks and military actions in nuclear countries have aggravated NPP safety challenges globally [1–5].

Negative event perception logic points to the need to draw lessons from experience to correct governmental activities, the industry, regulatory bodies, scientific organizations, NPPs, individuals, etc. Based on the obtained experience, corrective actions are developed and aimed at better safety operation of people and equipment.

The concept of a 'lesson' is a phenomenon occurring when people acknowledge the experience of an actual negative event by creating individual and/or publicly recognized representations of this event. People learn a lesson when finding and acknowledging the causes of such an event. The act of learning a lesson manifests in correcting attitudes and behaviours on the basis of the causes found, and is targeted at preventing similar incidents and accidents in the future.

In the last 20–30 years there came an understanding of the importance of shifts in attitudes when performing measures to strengthen human factors in all areas of NPP design and operation. This is discussed in Refs [4, 5]. Furthermore, trends in staff management such as:

- Enhancement of organizational factors related to the safety of NPPs [6–10];
- Adequate personnel motivation and focus on the paramount importance of safety [6, 11–14];
- Personnel success and reliability management [6, 12, 14, 15];
- Human factor risk management [3, 7–9, 15];
- Analysis of personnel errors, appeared and evolved intensively [6, 15, 16].

The need to improve activities in areas such as social safety monitoring, human resource management, human capital formation and analysis of psychological climate in teams has further been shaped.

Many years of worldwide NPP operation shows the need to improve the system of staff training adequately in line with nuclear science and technology development. At the same time not only professional knowledge, but also personal characteristics of people whose efforts can impact NPP safety need to be formed. Thus, it is important in the current conditions of professional training including the trend of ageing staff, to prolong personnel professional longevity, to secure professional knowledge and upgrade the quality of staff training. With regard to methods, professional competence programmes must include and ensure professionally important personal identities (responsibility, trustworthiness) and psychophysiological characteristics (self-control, self-regulation of functional state) of all NPP personnel and executives.

It is necessary to correct educational and professional standards, to study factors leading to management, specialist and operational errors. Technology and equipment specialists should be provided with knowledge on human factors, solving specific issues of technology design, technological processes and, foremost, of human activities at the NPP design level.

The limited number of human factor specialists within the nuclear power industry combined with the large scope of work and invaluable experience accumulated in every country, requires a consolidation of efforts by such specialists throughout the world. This is discussed in Refs [2, 6–8, 14, 15].

2. THE HUMAN FACTOR IN THE CHERNOBYL ACCIDENT

The official version of the Chernobyl accident causes, given in the USSR Governmental commission in the INSAG-1 report, says that the initial cause of the accident was an extremely improbable combination of operational mode errors made by the power unit staff. However, at a later stage, more exact data were delivered (p. 38) [12] through the publications of engineers and the scientific society. The following research of the work done by the former USSR Minenergo Trade research laboratory 'Prognoz' experts was published:

> "…Personality and socio-psychological characteristics of the Chernobyl NPP staff before and after the accident were analyzed. The results demonstrated that there was no difference between the Chernobyl NPP and other NPPs operational staff personal characteristics that could be a direct cause of the accident. And in general the Chernobyl NPP 1986 staff is described as quite ordinary, mature, well-formed, consisting of qualified specialists at the level recognized in the country as satisfactory. The staff was no better, yet no worse than other NPPs teams. These conclusions indicate that damages and errors were made by the staff not because the fact that the Chernobyl NPP personnel had some "outstanding" characteristics (p. 39) [12]."

Further analyses of the accident causes and circumstances were based on increasingly more accurate and objective initial data. The accident causes were discussed on both national and international levels as a set of incorrect political (in the field of nuclear power development) decisions in managing the industries of the country, deficiencies in the reactor design allowed by its designers, and erroneous staff actions.

Under the IAEA initiative, starting from 1986 and based on the Chernobyl accident causes, the concept of safety culture has evolved. In INSAG-4, it is emphasized that "Safety Culture is attitudinal as well as structural, relates both to organizations and individuals, and concerns the requirement to match all safety issues with appropriate perceptions and action" [12]. It is assumed by several practitioners that safety culture is the main idea of organizational culture in the nuclear industry [6, 7, 14] (and all INSAG reports). The Chernobyl accident in 1986 resulted from the overlap of many circumstances, from politics and decision making at the governmental level to reactor design drawbacks and incorrect actions of the staff due to gaps in professional training programmes [4–6, 12]. In the light of the human factor the most important aspect is human attitudes to nuclear safety issues. The cornerstone of safety culture is the attitude towards safety issues and their priority in the system of values.

Each of these circumstances proceeds from human work experience gained at non-nuclear power facilities. Attitudes to technology and safety issues at heat and other types of power plants general was generally transferred into the attitude to technology within NPPs. Each of the Chernobyl accident conditions were separately not viewed as a risk factor at that time, due to the fact that these did not attract proper attention by the personnel within the given circumstances. Therefore, currently within the scope of the safety culture concept, attention is paid not only to the evidently safety related aspects of running a NPP, but also to what may be seen at first sight as safety insignificant or possibly as only a slight abnormality, whether it is within the industry policies, in human activities, in procedures, or in technical solutions.

This idea is confirmed by the accident at the Fukushima Daiichi nuclear power plant, as these were also resulting from a great number of factors. Not only by natural force majeure circumstances, but also by inaccuracies in risk estimations regarding earthquake and tsunami intensity at the specific location of the NPP in Japan; by deficiencies in the plant design, and by some gaps in staff training to work under high risk conditions [11].

At present, based on theoretical physiological–structural activity analysis and empirical material from the industry (mainly NPPs, see Refs [6, 15]), the concept of 'operating activities success' is formulated. It provides ways to enhance organizational culture and the industry safety culture within the entire system of human activities and responsibilities, at all levels.

At organizational departmental level and at the level of a single personnel, carrying out activities in every position of an organization, success is ensured through the staff management system starting from professional recruitment of new personnel to social benefits for veterans.

The need to perform staff recruitment and training not only according to the knowledge, skills and techniques required for the job, but also according to the criteria of the proper attitude to the job and motivation to its perfect implementation is evident. Timely updates of personnel job requirements and identification of objective indicators in labour competences for every position under contemporary rapid, technical and social changes are required with due regard to the industry development outlooks for many years ahead.

3. CHERNOBYL ACCIDENT LESSONS

The INSAG-7 report and the recollections of veterans who worked in the immediate proximity of the Chernobyl NPP [4, 5, 12] provide the most complete and precise information on the causes of, and situation after, the Chernobyl accident. Thirty years after the Chernobyl catastrophe, scientists and engineers from different fields continue to analyse its specifics and clarify its direct and basic causes. There was a lot of evidence that the accident occurred due to a systemic combination of objective technological, organizational, social and individual psychological human factors present at all life cycle stages. Basically, all countries intensified their NPP accident analysis immediately after the Chernobyl accident. There were many advancements increasing power unit safety, enhancing reactor types of that time beginning with the Chernobyl NPP itself.

After 30 years, the lessons from the accident are of a different kind. They are not only from the accident, but also post-accident experience in mitigating the accident's impact.

3.1. Lessons at the state and global level

In the first years after the Chernobyl accident the nuclear power industry experienced a global crisis. Many countries rejected the plans of building new NPPs, and many plants under construction were converted to other energy sources [9, 12].

Striving to enhance nuclear safety, the IAEA worked to improve the regulatory and methodological base (theory, methods, programmes, techniques), and also enhanced collection and sharing of information on analysing safety significant events in the course of nuclear plants operation. Established in 1982, the IAEA programme Operational Safety Analysis Review Team (OSART) was enhanced. Several other IAEA voluntary review services were initiated, such as Analysis and Screening of Safety Events Teams (ASSET) and Assessment of Safety Culture in Organizations Teams[1] [17]. The IAEA is managing the Incident Reporting System (IRS), a database jointly operated with the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), aiming to improve nuclear safety through the collection and sharing of reports on unusual events. Insignificant events are also to be considered within the working site where they occurred.

While obtaining positive experience and good results on decreasing the number of significant events, the focus shifts to the search and analysis of their precursors — direct and root causes of damages, and further towards correction of conditions provoking damages, including incorrect actions of the personnel.

Thus, in a foreword to INSAG-23, R.A. Meserve, the Chairman, underlined that "serious accidents are nearly always preceded by less serious precursor events. If the lessons can be learned from precursor events, the probability of

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[1] The latter review service has been replaced with the Independent Safety Culture Assessment, see Ref. [17].

a serious accident could be significantly reduced" [2]. Yet, to implement such an approach, the efficiency and potential of both national, and especially international systems for operating experience feedback (OEF) should be significantly enhanced.

3.2. Lessons at the individual level

At all personnel management levels in the nuclear industry, acceptance of safety culture occurs in the psychology of every individual separately, although under the influence of external conditions.

A person learns lessons as a result of events in the production facility if the experience of the event is acquired, and the person behaves in a new, more correct manner, on the basis of this obtained experience [2–5].

Accident lessons have the following stages [6]:

- Getting information on the accident or event;
- Assessment of importance, the role of the accident or event in production activities;
- Assessment of personality regarding the accident or event in further activities;
- Drawing up a psychological prohibition (taboo) to avoid repeating conditions or actions resulting in accidents of this or another type;
- Memorizing and applying rules to prevent repetition of conditions or actions resulting in accidents of similar or other type;
- Only actions elaborated on the basis of the acquired lesson are allowed.

Obtaining new information regarding what, how and why things happened in the course of accident involves the following actions [6, 15]:

- Analysing and obtaining adequate, correct and maximally precise information regarding what happened in the accident;
- Analysing and obtaining adequate, correct and maximally precise information regarding how the events were happening in the accident;
- Analysis of direct causes: obtaining adequate conclusions regarding why the accident occurred (technology drawbacks, procedures deficiencies, wrong personnel actions);
- Analysis of root causes: answering the question: why conditions or factors preceding manifestation of direct causes that led to the accident, took place;
- Analysis of accompanying conditions that made possible and\or strengthened the influence of events and factors which served as root or direct causes of the accident.

4. 30 YEARS LATER: WHAT SHOULD BE CHANGED

4.1. Accepting strategies on organizational structure enhancement

Activities supporting NPP safety are split into two major strategic areas: prospective and retrospective [8]. In particular, prospective and retrospective directions are identified also in activities on development and enhancement of both safety culture and organizational culture in the nuclear power industry.

Project developments, calculations of power unit technical parameters, and economic numbers on the basis of electrical generation are done in the prospective area, human resources characteristics are identified and activity planning and regulation is carried out. In this area the main instrument is safety probability assessment in all directions of nuclear plant and human functioning.

In the retrospective area, operational experience of the whole industry, a particular nuclear plant, NPP facilities and, in particular, people are analysed. Positive achievements and negative experiences in plant operation are studied. The main instrument in this activity is analysis of near misses and events, to identify the precursors and factors of these [2, 6]. Direct and root causes for events, corrective actions to prevent their reoccurrence and to prevent them further on are identified.

In each prospective area it is important to organize and to implement proper development projects for the whole industry, and every company implementing projects on both the technical and human behaviour levels. In other words, to organize production it is necessary to create optimum models of successfully operating technology and people, and rules on following those models with due regard to the accumulated experience in strategic and short term (tactical) industry development plans.

Human behaviour at all levels of responsibility represents the biggest modelling (or designing) difficulty. The methodological basis for designing human behaviour is based on the following: psychology, sociology, ergonomics, economics and, of course, technical sciences. These sciences define the contents and the essence of personnel activities, through their role as a participant in the technological process.

In each retrospective area it is important to study positive and negative experience obtained in the real production conditions. Positive experience serves as a supporting structure of industry development. Negative experience encourages learning lessons, to improve production processes, and to search for better forms of production organization. Negative experience manifests in disorders of an NPP operation due to technology, procedures or human factors deficiencies.

However, any disorders in technology or deficiencies of procedures are the result of errors made either by NPP personnel directly, or people maintaining technology procedures at the previous stages. The human factor is a part of all disorders.

The more significant the errors are and the higher they are in number (at the operation stage or at previous stages), the more significant are disruptions in work or damage to the technology. Safety insignificant problems result, as a rule, from minor deviations from norms in human behaviour. Yet, as mentioned above, serious accidents are preceded by less serious safety events [2]; in combination with each other these 'precursors' therefore represent a threat of a serious accident.

The scale of problems depends on the time of occurrence or on alignment of a logical chain of objective conditions and facts regarding incorrect actions, or manifestations of human error consequences (wrong decisions or actions) at previous stages.

In terms of organizational culture and safety culture, the human factor role is determined and maintained at every stage of the life cycle and in the creation or implementation of the development policy and industry functions. The following stages can be singled out:

— Providing for scientific studies and feasibility studies of economic and technical development in the industry;
— Analysis of human resource needs of the industry;
— Setting forth staff development strategies, including training;
— Decision making regarding the industry's development, identifying tactical steps in its policy and strategy, adoption of programmes to further the industry's development;
— Identifying geographical locations for new industry facilities, taking into account seismic, geological and demographic conditions;
— Construction of the industry facilities;
— Scientific theory development, equipment calculations and design to ensure safe and high performance operation of the industry facilities;
— Equipment installation, adjustment and start-up, commissioning;
— Operation, repairs and upgrade of facilities;
— Extension of operating lifetime, decommissioning of facilities.

People working at every stage are endowed with duties, authorities and responsibility for the quality of fulfilling their duties. The quality of human work at preceding stages to a large extent ensures the appropriate level of quality and reliability of human activities at further stages.

4.2. Global projects

The Chernobyl accident disrupted the lives of people not only from 39 regions of Ukraine, Belarus and the former USSR, but also in Central Europe. An area of 150 000 km^2 was contaminated with radionuclides for many years. A radiation contaminated 'belt' consisting of radiation 'spots' appeared on the planet. People were faced with such a problem for the first time. Referring to the accident 25 years later, V.P. Malyshev (Ministry for Emergency situations of Russia) wrote:

> "One of the Chernobyl NPP accident lessons was the fact that the scale of problems solved during post-accident liquidation helped to develop new approaches to ensuring technogenic safety based on the theory of risk analysis and management. Currently it is necessary to concentrate efforts by the specialists working in this area on creating technologies to forecast large scale emergency situations and on development of rational ways to improve stability of basic industries in the economy, including strategically and critically important facilities" [5].

In the context of human factor involvement in the accident and also in post-accident activities under the current conditions of social and political instability in the world, development of a project providing effective organizational structure and safety culture in the nuclear industry worldwide is relevant.

Such a project should include the following:

— Concept elaboration and creation of a scientific–methodological complex to manage human factor risks in the nuclear power industry.
— Development of educational programmes to form professional competences in the human factor area, staff activities reliability, safety culture and organizational culture for higher education institutions training nuclear industry staff and/or providing continued advanced training.
— Setting up a system of knowledge regarding personnel psychology to be applied in professional activities of equipment designers, specialists in technology operation and staff management at all stages of the life cycle in nuclear organizations; organizing educational training programmes to form psychological readiness of every graduate in universities that are training staff of nuclear power organizations. Training should cover professionally important qualities such as responsible work attitude, stress resistance, self-control, functional state self-regulation, and other psychological

professionally important personality traits and psychophysiological specifics.
- Outfitting educational organizations and training centres with high performance equipment, including usage of non-contact methods to obtain biological data aimed at providing training for state self-regulation and self-control under stressful circumstances.

Correction of professional and educational standards is required to train specialists and engineers at NPPs aimed at achieving adequate ratio between these standards and staff training, with due account of technical progress and safety culture:

- Enhancement of professional training quality regarding future technical personnel within the academic period at universities/institutes to ensure a high level of safety culture within the organizational culture of the nuclear power organizations;
- Enhancement of human resources management quality in the nuclear industry by means of improving professional training quality in higher education institutions;
- Setting up a scientific methodology base for advanced training departments in the system of postgraduate training, in training divisions of organizations and companies, and in other organizations applying potentially hazardous technologies.
- The programme should contain a methodology aimed at maintaining human factor reliability in the nuclear power industry, including the basis of international legislative and regulative human capital management systems within the global nuclear power industry. Objectives of the programme could be international cooperation and synergy in reliability enhancement and human activities success at all stages of the NPP life cycle within the legislation of every country backed by global programmes.

4.3. NPP staff success management

The concept of human activity success [6], unlike the concept of reliability, contains a psychological aspect. Reliability is a technical characteristic of a person functioning in a human–machine environment system (MMES), and his or her ability and capabilities to act timely and precisely within the given quality level. Success characterizes the human input in MMES, functioning not only as an element of this system, but also as a subject of work, as humans have attitudes, motivations, and a sense of work satisfaction.

Success of professional activities includes characteristics of personnel reliability, performance, efficiency and timely results of personnel performance. Successful NPP personnel are committed to both safety culture and the corporate culture of organizations [14].

Self-assessment of every person's success — participants in the MMES — influences his or her quality of work and, indirectly quality, safety and performance of the entire MMES.

Success management processes are targeted at NPP operational safety and efficiency through minimization of risks regarding deteriorating conditions of the environment, external to a person, related to individual and social–psychological factors of staff activities. The risk concept is related to identifying subjective perception characteristics which to a great extent predetermines the understanding of safety culture.

The success of every person's professional activities is, according to the activity approach and visions on the functional structure of activities, determined by the state of the three basic functional blocks: the motivational–personal substructure (motivation-sets regulation); the cognitive area; and executive mechanisms, as well as by the specifics of their mutual influence in professional activities.

Personnel success management is performed indirectly — by creating external conditions that are developing optimum personnel qualities for successful work; and also directly — through every individual's psychological preparation for work in a staff training system starting from school pupil to student to personnel to executive.

Psychological training of NPP staff is performed within a system of professional activity success management in four basic (prospective) areas:

— Enhancement of efficiency of staff motivational regulation and its adequacy towards reaching organization objectives;
— Enhancement of professional training quality and improvement of professional knowledge needed for confident personnel behaviour under normal operation and under high risk conditions, for successful work in the organization;
— Development of professional behaviour, labour skills and know-how to apply professional knowledge in production;
— Ensuring personnel's personal growth, improvement of professionally important personal qualities and professionally significant individual traits as personnel professional competences.

The psychological assessment of personnel success defines the compliance between every personnel's individual data and job requirements, and contains indicators (or their criteria) for evaluating both the professional and personal qualities of the staff.

Objectives of staff psychological assessment and training are:

— To create conditions for objective assessment and personnel incentive measures (material and non-material incentives) versus criteria for their successful work.
— To motivate personnel in personal development, including mobilization under their own initiative to more productive and reliable work, finally ensuring their successful development.
— To create objective conditions to reduce the number of incorrect staff actions through incentives, also regarding safety attitudes that correspond to safety culture principles.
— To implement the opportunities to create and control enhancement of safety culture at the level of a particular plant's personnel, as everybody is striving personally to take an active part in safety enhancement.
— To incorporate into a single complex and to align organizational factors in activity success management. To incorporate psychological, ergonomic, social–psychological, sociological, psychological–pedagogical, psychophysiological and medical areas to enhance professional success of the staff.

Retrospective success management should include activities that correct the revealed causes of incorrect actions by the staff. Concrete measures to maintain technical conditions and social safety conditions, i.e. their technical and economic validity, are required.

4.4. Strengthening social safety

In a situation of social–political instability, activities aimed at ensuring social safety have special importance (Fig. 1). Social safety is determined by the state of safety and the living standards of nuclear plant personnel. Social safety of nuclear power industry personnel is an essential condition in the nuclear plant organizational culture [4]:

— Ensure the level of social safety and available social benefits are viewed by personnel as fair and adequate to the labour inputs.
— Minimum risk to life and the physical and mental health of people is guaranteed.

Socioeconomic, sociopolitical upheavals, crises, the threat of unemployment, recession, lowering the standard of living and quality of life

↓

Whipping up the situation in communities of staff, the formation of protest motivations, aspirations to defend their rights

↓

Deterioration of the sociopsychological climate, decrease of psycho-emotional state, psychosomatic disorders among employees

↓

Increase in the number of diseases, decreased performance and working capacity, abnormalities in attention, memory, thinking, coordination of movements

↓

Errors in the work of the staff

↓

Breach of order in the work stations

FIG. 1. Why are social safety and NPP staff welfare important issues?

— Human rights and constitutional order are guaranteed and set forth and observed at the level of the government, nuclear plant local community and labour teams.

The level of social safety is identified by activities of the industry's organizations, social conditions representing and characterizing the organizational culture, and establishing corporate responsibility to ensure social safety of the industry.

Labour and living conditions are linked directly to social conditions. These include programmes to construct accommodation, high quality roads, regular public transportation, outfitting and design of work premises, timely equipment upgrades, recreational facilities, and health care. The system of successful material and psychological labour motivation should be in place in organizations, and paid vacations must be provided.

The logical chain of 'conditions–reaction to conditions' smoothly 'working' in relatively stable conditions is even more relevant and efficient in long term crisis situations.

Potential opportunities to lower social condition characteristics down to the level of life and health risks determines the need for labour safety rules, safety culture and social safety.

Activities aimed at providing social safety rest on an organizational structure and extensive regulatory basis.

Under normal social–economic conditions, labour functions and duties, personnel and executive responsibilities are predetermined by known and predictable technological production conditions. Social–economic complications from life activities create a set of negative factors for which both personnel and executives need to compensate, which requires additional resources.

The nuclear industry as a corporate system of organizations generating electrical power through the use of nuclear fuel bears its portion of responsibility for insuring population safety. However, the nuclear power industry itself needs both social safety and technical safety on an equal scale.

To balance the negative impact of external world instability and to create predictable conditions for personnel, every country has to take social–economic measures and ensure that the industry has a specific and scientifically based social safety policy for personnel.

The fundamental aspects of such policies are identification and legitimization of job requirements and setting up more definite norms which specify professional job standards at NPPs. In other words, there is objective interest (as opposed to instability of social situation) in the identification and standardization of labour conditions and organizations in production facilities related to technological and social–economic risks.

Standardization in turn calls for such a social safety system in the nuclear power industry, which is on the one hand a systematic part of complex safety, and on the other hand, meets corporate social standard requirements.

4.5. Modifications in educational standards as regards NPP staff training

Traditionally, the competences of industrial personnel are formed in higher education institutions, mainly in the area of professional knowledge, expertise and skills. Professionally important personal qualities are given very little attention, though these qualities, motives and attitudes in no less degree predetermine the success and failures of a specialist.

The psychological training of a person to apply professional knowledge in high risk conditions is especially important. Methods of psychological training contain approaches, scientific methods and techniques of function structural activity analysis, psychology of building professionally important qualities, including professional motivation and psychological sets for high safety culture and organizational culture.

The success of human activity is the result of labour contribution efficiency, labour satisfaction, personal fulfillment at work and public acknowledgement of achievements. It depends on aspirations, ambitions, motivation (in particular to avoid failure), communication skills, and other motives and professionally important personal qualities. Educational standards must be adequate for professional personnel standards at particular departments and positions of the nuclear power companies and must contain educational materials covering the following areas:

— Psychological aspects of safety in future NPP personnel systems of values (creation of safety culture);
— Professional knowledge regarding psychology and psychophysiology, capacity of a working person in designing human–machine systems in future professional activity of a student;
— Professional psychological knowledge of a person as a member of a working team (in terms of management, leadership, group consolidation, group interaction, personnel success management, psychological climate and other issues);
— Ergonomic knowledge at the level of work stations, level of equipment and technologies, and technical documentation (instructions, labour regulations, orders, etc.).

Within the educational disciplines relating to the human factor and organizational culture development, safety culture should be included, as well as basic psycho–emotional state self-regulation training, self-control and self-assessment for students.

4.6. Human factor risk management in the nuclear power industry

Human factor risks are mainly determined by the probability of doing wrong actions in the course of human activity. In NPP operation, the biggest emphasis is on normal professional perception of radiation risk by a person knowledgeable of nuclear safety [5, 6, 13].

The SRC Prognoz has been implementing monitoring of the interruptions in NPP work connected with incorrect actions of personnel in all Russian NPPs for more than 20 years. The direct and root causes of incorrect actions are described and analysed [6].

According to research [6, 15, 16], incorrect actions by NPP staff (Figs 2 and 3) are classified based on their causes as:

— Motivational errors — intention — conscious infringement of NPP operation, intentional (deliberate) wrong actions (when personnel have

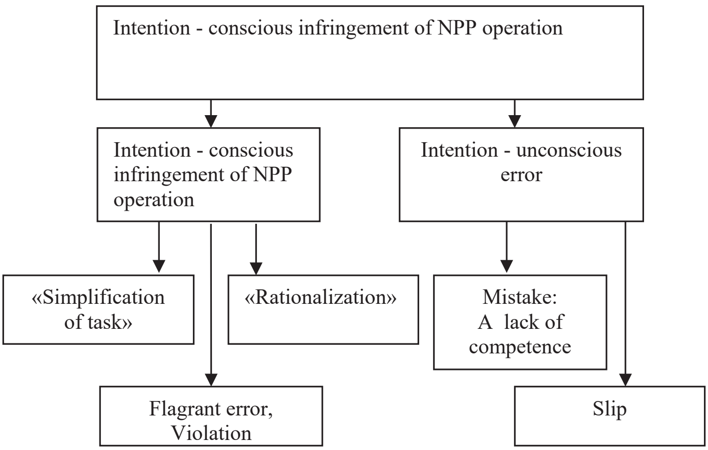

FIG. 2. Determination of error type in the level of psychological assessment in causal analysis of operational events.

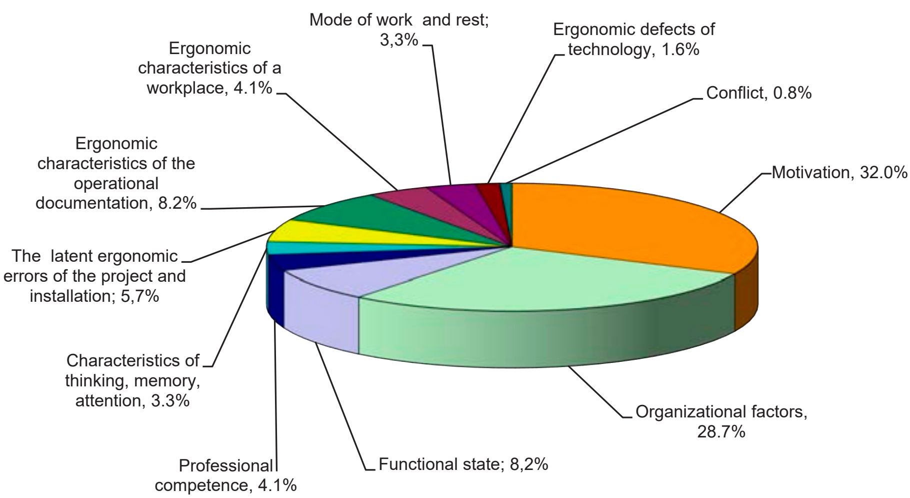

FIG. 3. An example of incorrect personnel action analysis results as causes of work events at the NPP (based on Ref. [6]).

professional knowledge regarding the rules of work, but deliberately 'simplify' or consider themselves entitled to change the rules — (rationalizing), or deliberately acts against the rules harmfully for somebody (violation));

- Knowledge errors, mistakes — unconscious wrong actions (due to deficiencies of the personnel professional training system, or drawbacks in their personal qualities — relating to memory, attention distribution, thinking);
- Lapse, slip — occasional wrong actions (due to ergonomic deficiencies of work station, technology, technical documentation, or inadequate personnel psycho-physiological functional state, or drawbacks in training).

According to the opinion of this author and several other specialists [6, 14, 15], it is now necessary:

- To elaborate scientific–methodological support of psychological services in the system of staff management in the nuclear power industry.
- To create a system of psychological staff training at schools, institutes and staff training services at nuclear power facilities.
- To create a psychological and ergonomic knowledge training system to develop professional competences in education of technical experts and executives.
- To perform ergonomic design in new NPP projects, to analyse human adjustment capabilities to operate power units.
- To monitor human resources, to identify population potential regarding training through information available through educational institutions and staff recruitment at NPPs under construction (planned ones).

4.7. Applying results of accumulated experience in new NPP design

At the same time the main objectives for scientific–method support of psychological services (SRC Prognoz, NPP and other SC Rosatom company psycho-physiological laboratories) are:

- Psychological staff support under extreme conditions;
- Regulatory and method coordination;
- Coordination of services ensuring NPP operational safety, labour protection, other services and organizations responsible for staff safety enhancement;
- Social–psychological support of staff activities;
- Psychological and sociological analysis of staff problems, labour motivation analysis, monitoring NPP social–psychological climate, forecasting

problems in NPP social trends and preparing executive recommendations on conflict settlement;
- Rehabilitation activities with NPP staff;
- Ergonomic studies of labour conditions and job analysis at NPPs;
- Consulting and provision of psychological–pedagogical services;
- Managing an industry database of psychological and psychophysiological test results;
- Managing an industry database of faulty staff actions and their causes (including psychological and psychophysiological, ergonomic, social–psychological, economic and social–political factors) that resulted in damages in NPP operation and impacted staff professional reliability;
- Scientific maintenance of NPP design organizations in terms of the human factor (ergonomic design, HF engineering to NPP build).

5. CONCLUSIONS

The activities analysing the circumstances and causes of the Chernobyl accident, as well as the lessons to be learned, remain important 30 years after the accident. In addition, history's first experience of post-accident liquidation was acquired over the last 30 years. Comparison of new, clarifying data regarding the causes of the catastrophe, and data on the mitigation measures that were taken for the first time during these 30 years, serve as the basis of determining the contemporary Chernobyl accident lessons.

The main lesson of the accident is the understanding and the acceptance of the safety culture concept and the fact that safety culture is a basic, mandatory, part of organizational culture in the nuclear industry.

In terms of determining the role of the human factor, which was clarified in the course of analysis and identification of the lessons from the accident, it seems important to create prospective and retrospective directions in accounting for the Chernobyl accident's lessons. Within each prospective area it is important to design personnel professional behaviour and conditions that prevent malfunctions either in technology operation, or in personnel activities. A transition from the local measures concept applied after the accident to the concept of managing human success at all stages of the NPP life cycle, including all people employed within the nuclear industry organizations, is under way.

At present it is important to join efforts in learning the lessons of the Chernobyl accident at a global level. These efforts are important due to the large scope of work at all stages of the NPP life cycle, including type of damages (single, non-repeating damages, especially with regard to human error) and the currently limited number of human factor specialists in the nuclear industry.

In the situation of social, political and even military instability in the world, it is necessary to take into account the Chernobyl accident experience where decisions on different power unit operation issues were taken not by the specialists but by the government and party authorities who were quite often incompetent in nuclear plant safety questions. NPP personnel social safety programmes at the global and national levels are required.

Special attention should be paid to staff training in nuclear industry organizations. In order to implement global measures to correct and achieve a common understanding of the objectives of the different countries involved, methods providing professional training systems for staff and industry executives are needed. Engineering students need professional training in human factor reliability and successful staff performance. It is necessary to harmonize higher educational nuclear institution standards in different countries with NPP professional standards.

It is essential to organize activities, including psychological, ergonomic and social–psychological aspects into the design of both new and already operational NPPs. Taking into account the influence of the human factor on the operation of technical systems will improve reliability, safety and attractiveness of the nuclear power industry in the future.

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SOCIAL SCIENCE FOR SAFETY
Steps towards establishing a culture of interdisciplinary appreciation

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Abstract

Three eras in safety science can be distinguished based on the predominant focus of safety measures taken. A technical focus was followed by attention devoted to human factors, which has now broadened to an organizational, or sociotechnical focus. Along with this changed focus the knowledge from the social sciences that is relevant for promoting safety has expanded considerably. Not only is the psychological knowledge concerning individuals' abilities and attitudes as they relate to operating technical systems important, but also a broad range of theories and empirical findings from disciplines such as work and organizational psychology, social psychology, and the sociology of work and organizations. Even political science is relevant in view of the power relations found in organizations and in regulatory regimes. Embracing the wealth of knowledge in the social sciences and applying it in the service of improved safety is a complex interdisciplinary endeavour. Most fundamentally, it requires openness to divergent world views and the readiness to challenge long held basic assumptions. Conceptions of risk control tend to vary across professional (sub) cultures within organizations. While engineers and executives believe in uncertainty reduction through design and planning, operative personnel are acutely aware of the need for resilience in the face of only partially controllable uncertainties. Social scientists finally argue for promoting learning and innovation, thereby adding uncertainty. In the paper, examples of the wide range of relevant social science knowledge and its implications for safety management are described and methods discussed to stimulate the dialogue between different professions in ways that foster perspective taking and cross-learning. There is no turning back from the realization that effective safety management has to build on evidence from technical and social sciences. The task ahead is to establish a culture of interdisciplinary appreciation that permits a truly integrated approach to safety.

1. INTRODUCTION

There is general agreement that the history of safety management in organizations can be described in terms of three eras, known as the technical era, the human factors era and the organizational, or sociotechnical, era [1].

While in the technical era the focus was on improving safety by better technical design, with a corresponding emphasis on technical causes in risk and accident analyses, the human factors and organizational eras were characterized by an increasing awareness of the important role of humans as operators of systems and of the wider organizational and social context within which safety has to be achieved. Originally, social science knowledge was only considered relevant in order to fit human operators to the requirements of technical systems by means of selection and training. Later, after the accident at Three Mile Island [2] that is generally considered as a milestone, increasing attention was given to the design of technical systems with respect to their psychological requirements. The aims were to improve user interface based on knowledge of human information processing and decision making to balance workload through adequate function allocation between operators and technical systems, and to guide their behaviour through technical support and rules. Risk analyses and accident investigations were complemented by considerations of human reliability and its prerequisites.

Eventually, with another nuclear accident being an important milestone, namely the accident at Chernobyl [3], safety considerations were broadened beyond the fit between humans and technical systems to include social and organizational factors and to develop integral management systems within a systemic approach to safety. As a consequence, the range of relevant social science knowledge broadened to include research on team dynamics, leadership, sociotechnical design of work systems, organizational learning and organizational culture. Moreover, managing external relationships, foremost with the general public, requires knowledge on strategies and instruments for risk communication. As not only safety management within organizations changed, but also the relationship between regulators and operating organizations, moving towards more self-regulation in many countries, institutional sociology and political science have become relevant as well [4]. Finally, any changes in organizations aimed at improving safety are always a matter of organizational dynamics that need to be considered and managed for change to be successful [5].

Anyone working in the field of safety management can probably attest to the difficulties in integrating the many sources of relevant knowledge into a shared understanding of problems and of the actions required to solve them. In the following sections, these difficulties are approached from the perspective of different world-views related to risk control. The impact of these world-views on decision making in safety management is described and some examples are provided for instruments that can support perspective taking and cross-learning needed to implement a truly systemic approach to safety.

2. APPROACHES TO RISK CONTROL AS EXPRESSIONS OF DIFFERENT WORLD-VIEWS

The relevance of world-views has been discussed in the safety literature [6, 7], especially with respect to organizational concepts such as organizational culture and organizational learning, Often, reductionist causal logics attributed to engineering disciplines are juxtaposed with holistic phenomenological approaches advocated in parts of the social sciences to illustrate the difficulties inherent in systemic approaches to safety management. This reaches also into fundamental beliefs about human rationality, which determine what is considered ‘good’ decision making and what should be discounted as ‘irrational’.

A simple task, used extensively in psychological experiments, provides a demonstration of controversial assumptions about rationality. Participants read a short text about a woman called Linda that describes her as having leftist political attitudes. They have to indicate whether they consider it more probable for her to be a bank teller or a bank teller and a feminist. The usual answer is the latter. This implies, in mathematical terms, a completely irrational decision that two events combined are more likely than one of them alone. Even two of the most prominent decision researchers interpret this result very differently. While Kahneman [8] argues that this finding reflects the workings of heuristics based intuition and as a consequence faulty decision making, Gigerenzer [9] postulates that it is perfectly rational to decide for the formally less likely but, based on the contextual information, more plausible option. Given how pervasive probability based reasoning is in safety management, one can easily imagine the clashes produced when different stakeholders use different logics of rationality, as for instance evidenced in examples of unsuccessful public risk dialogues [10].

Concerning risk control, Grote [11] has summarized existing world-views into three broad categories based on differences in handling uncertainty (see Table 1). Reducing uncertainty to a level of acceptable risk, the main thrust in classic risk mitigation, is built on the belief that safety can only be achieved in stable systems with a maximum of central control. This belief favours safety measures such as standardization and automation in order to streamline work processes. Absorbing uncertainty follows from acknowledging the limits to reducing uncertainty in complex systems and the corresponding belief that safety stems from a system’s resilience, which is its capacity to recover from perturbations. Within this belief system, control is to be decentralized, based for example on empowerment of local actors and fast feedback loops. The importance of creating uncertainty, finally, is inherent in a world-view that stresses self-organization and innovation as drivers for safety. Local agents are assumed to be controllable only through shaping contexts for their adaptive behaviour, for instance through setting incentives and constraints for experimentation.

TABLE 1. APPROACHES TO RISK CONTROL *(adapted from Ref. [11])*

	Reducing uncertainty	Absorbing uncertainty	Creating uncertainty
Objective	Stability	Flexibility	Innovation
Conceptual approach	Classic risk mitigation	Resilience	Self-organization
Control paradigm	Central control	Control by local actors	Shaping contexts for local actors
Examples of safety measures	Standardization; automation	Empowerment; Fast feedback loops	Setting constraints for experimentation

Carroll [7] has pointed out that the different conceptions of risk control tend to be prevalent in different professional (sub) cultures within organizations. While engineers and executives believe in uncertainty reduction through design and planning, operational personnel are very aware of the need for resilience in the face of only partially controllable uncertainties. Social scientists, for example, in their role as consultants or human factor specialists, will argue for openness to learning and innovation thereby creating uncertainty.

Building a shared understanding across professional boundaries of the legitimacy of reducing, absorbing and creating uncertainty is paramount to developing a more comprehensive approach to safety. This also entails a better integration of social science knowledge into safety management. In order to achieve this, perspective taking and cross-learning among the different professions involved in safety is needed. The diverse belief systems which exist have to be reflected on and sufficiently reconciled to create shared views on problems and ways to solve them. Three examples of methods that can help build such a culture of interdisciplinary appreciation are presented in the next section.

3. METHODS TO SUPPORT CROSS-DISCIPLINARY DIALOGUE

The following three methods concern crucial components of safety management. They were chosen because they illustrate core components of cross-disciplinary dialogue in different settings and tasks. These core components are the creation of an open communication climate based on psychological safety, explicit and systematic perspective taking, and building a shared understanding on which to base action, while acknowledging the legitimacy of different world-views.

3.1. KOMPASS

Sociotechnical system design is a core requirement of safety management [12]. Systems are to be built and run in ways that ensure adequate distribution of tasks across operators and between operators and components of the technical system. KOMPASS is a method that is designed to support multidisciplinary teams in achieving just that [13]. It presents a set of criteria to guide the analysis of existing systems and the design of new systems and a detailed process to be followed for the establishment of system requirements. This process contains three phases described below.

Phase 1: Analysis of existing work systems. Existing work systems, which can be considered a baseline from which to start the design process, are analysed with respect to criteria on three levels. At the level of the human–machine system, the controllability of the technical system by the operator is captured by four criteria: process transparency, dynamic coupling, decision authority, and flexibility. Concerning the level of the operator's task, the concept of motivation through task orientation is operationalized in terms of eight criteria: task completeness, planning and decision making requirements, communication requirements, opportunities for learning and personal development, variety, transparency of work flow, influence over working conditions, and temporal flexibility. At the level of the work system, local regulation of system variances and disturbances is measured by six criteria: means of task completeness, independence of work systems, fit between regulation requirements and regulation opportunities, polyvalence of work system members, autonomy of work groups, and boundary regulation by superiors. The initial discussions about the relevance of these criteria and their scientific and normative underpinnings set the stage for a more in-depth reflection of the design philosophy and strategy to be followed.

Phase 2: Discussion of design philosophy. This phase fosters a common learning process, which enables the team to apply the concept of sociotechnical system design to their current design problem. It also allows the team to reflect upon their own implicit assumptions and theories about the roles of people, technology and organization in work systems. To achieve this, a facilitator leads the design team through a discussion of the following questions: What differentiates successful work systems from less successful ones? What do humans, technology and organization contribute to the success of a work system? What do people need to make their contribution to the success of a work system? This discussion helps to show how the outcomes of a work system always depend on the interplay of people, technology and organization, allowing a shared perspective to emerge that the system in question has to be designed as a sociotechnical and not just a technical system. Moreover, different expectations of the team members regarding the components of a successful system can be made explicit and integrated into a common evaluation concept. This also serves as a basis for discussion and comparison of different design scenarios. Finally, the focus on working conditions required for operators to make their specific contributions promotes a debate about possibly deep-rooted assumptions about the nature of motivation and about safety and risk enhancing properties of peoples' attitudes and behaviour. In the last step, the KOMPASS design criteria and the results from the system analysis, conducted in Phase 1, are discussed and agreement reached on which criteria are to be used in the subsequent phase. This is focused on defining the system requirements. The result is usually a modified list of criteria which reconciles different world-views among the members of the design team.

Phase 3: Derivation of design requirements. In this phase the design team is free to use whatever method it choses for requirements engineering. The design criteria agreed upon in Phase 2 are then used to evaluate different design scenarios and serve as a basis for deciding on the scenario to be developed further.

KOMPASS has been applied in a variety of settings, which sometimes have also necessitated adaptations to the process described above [14, 15]. Overall, it has proved to be a powerful tool for fostering cross-disciplinary dialogue. Interestingly, divergent views were never found to be restricted to camps of engineers and social scientists, respectively, but also included different professional roles and subdisciplines as well. The discussions often led to discoveries of unsuspected similarities and differences of basic assumptions and beliefs across all participants, which is exactly what an open dialogue should be about.

3.2. After-event reviews: The example of TeamGAINS

After-event reviews have been defined as "a learning procedure that gives learners an opportunity to systematically analyse their behaviour and to be able to evaluate the contribution of its various components to performance outcomes" (Ref. [16], p. 857). They are an important component of safety management as they foster learning and continuous improvement [12]. They typically involve three elements: self-explanation, data verification, and feedback. Self-explanation refers to a systematic analysis of behaviour, which helps individuals to see how their behaviour contributed to team performance. In the data verification process, individuals are asked to contrast these behaviours with alternative possibilities. Lastly, the feedback component allows for understanding the specific links between individual actions and outcomes. After-event reviews enable teams to review past interaction episodes in terms of the causes and consequences of particular event sequences during the accomplishment of their goals. Through this review process, team learning from both successes and failures is fostered.

TeamGAINS is an after-event review method designed for structured debriefings in simulation based team training [17]. The principles applied in TeamGAINS can also be used in other types of after-event reviews, though, for instance for debriefings following safety critical, non-routine events. Techniques employed in TeamGAINS are guided team self-correction, open-ended inquiry, and encouragement for perspective taking. Table 2 provides an example of how these techniques have been used in the debriefing after a simulation based training aimed at promoting ‘speaking up’ in medical teams.

One crucial prerequisite for constructive after-event reviews is a high level of psychological safety in the team, defined as team members’ belief that they can take interpersonal risks without having to fear punishment, rejection, or embarrassment [18]. Psychological safety needs to be created by carefully tailored, non-threatening interventions by the moderator and by firmly establishing rules such as ‘Whatever happens in Vegas stays in Vegas’. Only if everyone is assured that the open dialogue about their own and others’ strengths and weaknesses will have no adverse consequences, full disclosure and sustained learning is possible. Clearly, the greater the power differential and more generally the greater the diversity between participants the more difficult it is to establish psychological safety in a team. However, this is exactly when psychological safety is needed most, and so great care should be taken by those conducting the after-event reviews to prepare the ground well for an open exchange.

3.3. ENSI dialogues on safety culture

Much has been written about the difficulties of and possibly even contra-indications against making safety culture a key indicator of safety [12]. However, in many industries and countries not only are the operating organizations required to establish a safety culture, but regulators are obligated to assess the safety culture of these organizations.

Switzerland is one example where the nuclear regulator has to provide safety culture assessments. The Swiss Federal Nuclear Safety Inspectorate (ENSI) therefore developed a method which they call Dialogue on Safety Culture [19]. This method aims to do justice to both the legal and the methodological requirements for judging the safety culture of nuclear installations. There are four steps. An open discussion with members of the nuclear installation on any currently relevant safety issues which is conducted by ENSI members; this discussion is analysed by the ENSI members in view

TABLE 2. DEBRIEFING TECHNIQUES USED DURING AN AFTER-EVENT REVIEW FOLLOWING A SIMULATOR TRAINING FOR MEDICAL TEAMS *(adapted from Ref. [17])*

Step in debriefing	Instructor's methods (examples)	Example of instructor's communication
First reactions of team members	Narrative question	How did you feel?
Debriefing of the clinical part of the scenario	Advocacy–inquiry	I saw you attempting to intubate using the laryngoscope three times in a row, each time it turned out unsuccessful. I think you could have intubated faster by using another device (...). So, I am wondering what was on your mind at that moment?
Discussion of crew resource management (CRM) principles and their relationship to clinical outcomes	Guided team self-correction: elicit reflection about positive behaviour	'Speaking up' when in doubt can be life-saving in anaesthesia. Describe an instance when you have spoken up in the past.
	Advocacy–inquiry (using simulation video)	My impression is that you were not OK with what he was doing. I was concerned that you would not let him know this and that he would proceed with his inadequate behaviour. What was on your mind?
	Observer perspective, circular question (to trainees who have observed the scenario)	What do you think she might have needed from him to speak up in that situation?
Summary of learning experience and closing debriefing	Circular question	If inexperienced anaesthesia residents and nurses had watched you during the scenario, what could they have learned from you?

of indicators for an (in)adequate safety culture. The results are fed back to the installation and an opportunity is provided for refuting ENSI interpretation. Finally, a report on the installation's safety culture is then written on the basis of the validated ENSI analysis.

The ENSI Dialogues on Safety Culture contain both appreciative inquiry and the discussion of interpretations as important elements that establish reciprocal respect and encourage perspective taking. Instead of claiming the superior validity of expert judgements. The method aims for the integration of different perspectives which are all considered to be valid. Thereby the assessments provided by ENSI provide the basis for a continued dialogue aimed at improving the cultural underpinnings of safety in the nuclear installations.

4. CONCLUSION

There is no turning back; safety needs social science. Social science knowledge is required to select and train people, to understand human motivation and decision making for creating appropriate work environments, to support effective teamwork and leadership, to foster learning and change in organizations, to manage the requirements of internal and external oversight, and to shape the dialogue with the public. An appropriate consideration of safety science knowledge requires a culture of interdisciplinary appreciation, which helps to bridge different world-views and to build a shared understanding of problems and solutions on the way towards a systemic approach to safety management. The examples given in this paper of methods that support interdisciplinary dialogue and cross-learning as part of important tasks within safety management, specifically system design, learning from incidents, and safety culture assessment, are hoped to encourage practitioners to embrace cross-disciplinary collaboration.

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PNRA: PRACTICALLY IMPROVING SAFETY CULTURE WITHIN THE REGULATORY BODY

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Abstract

The paper presents the Pakistan Nuclear Regulatory Authority's (PNRA) experience of using the IAEA methodology for safety culture self-assessment (SCSA) in regulatory bodies. It highlights the strategy utilized for disseminating the outcomes of SCSA in the organization at different levels along with associated safety culture improvement activities. Moreover, improvements in regulatory processes, where safety culture is expected to be included, are also addressed in this paper.

1. INTRODUCTION

The role of safety consciousness is pivotal in ensuring the safe functioning of organizations dealing with activities involving high risk. Most of the major accidents that occur in such high reliability organizations, for example the aviation and chemical industries, have been attributed, at least in part, to a lack of safety consciousness.

The nuclear industry is unique because the effects of nuclear accidents may last for many future generations. This fact is evident from major nuclear accidents like Chernobyl and Fukushima Daiichi. With an understanding of the unique nature of the nuclear industry, the concept of safety consciousness becomes even more relevant for all organizations involved in that industry including operating organizations, vendors, regulators, and designers. In the nuclear industry, the consideration of safety consciousness in organizational activities is largely conceptualized in term of safety culture.

With the development of IAEA GS-R-3, which addressed the management system for facilities and activities, the concept of safety culture became an important part of management systems in the nuclear industry [1][1]. Its requirements are equally applicable to all kinds of organization including regulatory bodies. One of the major tasks of such management systems is to strengthen safety culture within their organization ensuring a common understanding of its key aspects.

2. IMPORTANCE OF SAFETY CULTURE FOR THE NUCLEAR REGULATORY AUTHORITY

The importance of safety culture in nuclear organizations, including nuclear regulatory authorities, has remained under discussion for several years and is reflected in the IAEA Safety Standards [1, 2]. After the Fukushima Daiichi accident, the IAEA held an International Expert's Meeting on Regulatory Effectiveness in April 2013 to share lessons learned from the accident in order to improve regulatory processes and practices [3].

One important outcome of the Meeting was the unanimous realization of the importance of safety culture for effective regulatory oversight. In particular, the need to incorporate safety culture into regulatory processes and, within the ongoing dialogue with licensees, to enhance the understanding of safety culture. At the same time, regulators were encouraged to perform self-assessments of safety culture on a regular basis [3].

A further International Expert's Meeting on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant [4] was held in 2013. The meeting report highlighted the importance of safety culture self-assessment of regulatory bodies [4]. It recommended that the IAEA should provide further support to regulatory authorities for performing their own safety culture self-assessments and for implementing safety culture oversight of their licensees.

3. CONSIDERATION OF SAFETY CULTURE ASPECTS OF REGULATORY ACTIVITIES AT PNRA

The PNRA was established as an independent nuclear regulatory authority in 2001 and in the initial phase of its establishment, core values were defined by the PNRA leadership. These core values included integrity, transparency,

[1] IAEA Safety Standards Series No. GS-R-3 was superseded by GSR Part 2, Leadership and Management for Safety, in June 2016. The requirements relating to safety culture in GS-R-3 have been kept, and in some cases strengthened, in this new revision.

independence in decision making, competence and professionalism, mutual respect, and a caring and compassionate attitude. The incorporation of these core values in regulatory business at PNRA supported safety consciousness in the implementation of regulatory processes. As a result, the concept of safety culture indirectly remained an important part of PNRA's regulatory business.

4. PRESENTING PNRA AS A ROLE MODEL AT NATIONAL AND INTERNATIONAL LEVELS

The incorporation of safety culture into regulatory processes shapes the pattern of compliance with regulatory requirements by licensees. This is based on the fact that the safety culture of the regulatory body influences the safety culture at its licensed facilities. PNRA's regulatory framework requires that its licensees establish and maintain a strong safety culture in order to enhance safety consciousness. PNRA presents itself as a role model by assessing its own safety culture in order to encourage its licensees to develop a strong safety culture at their facilities after assessing its current status and strengths and weaknesses.

PNRA is also a pioneer regulatory body at the international level in that it has carried out assessment of its safety culture and has ensured that safety culture is equally important for regulatory bodies as it is for any other organization in the nuclear industry. Moreover, experts from PNRA are also supporting other regulatory bodies worldwide in carrying out assessments of safety culture through IAEA.

5. PNRA'S SAFETY CULTURE SELF-ASSESSMENT (SCSA) PROJECT

PNRA initiated its SCSA project in 2013 after discussions with the IAEA over performing a safety culture self-assessment. The IAEA prepared a training course on the implementation of SCSA in a regulatory body with the help of international experts as this was being done for the first time by a regulatory body. PNRA was also involved in the development and finalization of the training course material.

5.1. Team selection

A SCSA project is different in its nature compared with other regulatory activities. The SCSA team selection was carried out taking into consideration of the characteristics and attributes described in the IAEA guidance documents [5, 6].

The PNRA team for SCSA was composed of 22 members along with a team leader. The team members represented almost all areas of the organization. All selected individuals needed to have adequate understanding of the principles underpinning a strong safety culture, according to the IAEA, and somewhat different perspectives in order to avoid unidirectional thinking [6].

5.2. Training on SCSA methodology

The IAEA conducted two training sessions on the SCSA methodology for the SCSA team members. This training mainly focused on understanding the importance of safety culture for a regulatory authority, the utilization of tools for assessing safety culture, the analysis and interpretation of the data collected. The practical implementation of the safety culture self-assessment methodology was also discussed during the training sessions. The IAEA training also included a module to 'train the trainers' to support oversight of safety culture in order to evaluate the safety culture of licensees. The effectiveness of these training sessions was enhanced by utilizing a 'learning by doing' approach.

5.3. Planning for the implementation of a SCSA

A procedure was prepared for the implementation of a SCSA at PNRA. Responsibilities were assigned and timelines established [7]. In order to oversee progress, team meetings and meetings with senior management were planned periodically. These meetings helped to highlight challenges in term of resources and other difficulties in implementing SCSA tools. These challenges and difficulties were discussed with management to facilitate their effective resolution.

5.3.1. Pre-launch activities and awareness campaign

The success of the SCSA project was always going to be connected with active participation of everyone in the organization when implementing the SCSA tools. In order to achieve success, an awareness campaign was initiated in PNRA to brief about the SCSA activity and role of PNRA employees regarding providing true feedback on the culture of PNRA. This campaign included presentation sessions and posters.

The awareness campaign provided insight among PNRA employees into the importance of the SCSA project for PNRA for its role as an effective nuclear regulator. The campaign resulted in the active participation of everyone in the organization which, in turn, helped bring a significant amount of cultural data to the surface.

5.3.2. Implementation of SCSA tools

The use of SCSA tools started in September 2013 and was completed in September 2014. The implementation of the different tools used was carried out in parallel to each other. All members of the SCSA team participated in the implementation of these tools. A brief description regarding the use of the SCSA tools is provided below.

Observations

The observations of culturally relevant aspects of organizational life were made throughout the SCSA project. These observations were made by the SCSA team during routine work at their desk, at formal and informal gatherings and meetings and other aspects of work.

Interviews

Seventy-seven members of staff were selected for interview from different areas and levels of the PNRA. The objective of this selection was to establish a sample representing all segments of the organization including, for example, technical and non-technical staff, managers and support staff. The interviews were conducted using explorative techniques.

Focus groups

Ten focus groups were run; six groups at PNRA HQs and two groups at each of the two PNRA regional offices. The composition of each focus group was representative sample of the whole organization. Each focus group was composed of eight–ten members of staff. Two or three members of the SCSA team acted as moderators during the group meetings and discussions.

Surveys

A survey questionnaire composed of 77 questions was circulated across the organization designed to capture for feedback from all areas of the PNRA.

Document analysis

Fifty documents of different types (for example, procedures and reports.) were selected for analysis. Different teams were formulated from within the SCSA team to analyse these documents.

5.3.3. Cultural data secure storage/confidentiality

In order to ensure the confidentiality of the data collected using the SCSA tools, anonymity was assured. Moreover, access to the data was restricted for everyone else except the SCSA team members.

5.3.4. Descriptive analysis

Almost 1900 cultural facts were collected during the descriptive analysis phase of the SCSA project. In order to effectively perform a descriptive analysis of this large amount of data, it was decided to group the data by focus for each of the SCSA tools. An IAEA support missions was invited to review the descriptive analysis carried out by the SCSA team.

5.3.5. Refinement in descriptive analysis

The descriptive analysis was revisited in the light of feedback provided by the IAEA support mission. The cultural facts gathered with each of the SCSA data collection tools were reevaluated using bubble charts and a number of cultural themes were identified. The basic assumptions underpinning each of these cultural themes were determined and the factors driving the themes were also highlighted.

From the analysis of the cultural themes, overarching themes were established. Most overarching themes were manifest in the data of more than one SCSA tool. Additionally, some cultural themes regarded as particularly safety significant were selected as overarching themes. While these were not found with more than one SCSA tool, they had strong and obvious safety implications.

5.3.6. Normative analysis

In order to carry out the normative analysis based on the outcomes of the descriptive analysis, a safety culture framework was required. The IAEA safety culture framework, as described in the IAEA Safety Standards [6], was utilized for this purpose after the necessary modifications to make this framework fully applicable for the nuclear regulatory authority [6]. In order to achieve this objective, the five IAEA safety culture characteristics were utilized for the safety culture framework at PNRA, namely;

(1) Safety is a clearly recognized value.
(2) Leadership for safety is clear.
(3) Accountability for safety is clear.

(4) Safety is integrated into all activities.
(5) Safety is learning driven.

The attributes under these safety culture characteristics were selected on the basis of their relevance to regulatory activities. The 36 attributes of the IAEA safety culture framework were found applicable for a regulatory authority, except for one attribute, regarding assigning equal importance to safety and production, which was not considered applicable for PNRA.

The normative analysis was carried out after finalizing the safety culture framework. The overarching cultural themes emerging from the descriptive analysis of the SCSA data were evaluated against the framework, in order to identify both the positive and negative linkages of the cultural themes with the safety culture characteristics and attributes. This exercise resulted in the identification of strong areas of PNRA's safety culture that needed to be maintained and weak areas for which attention was required to make them at par with international standards (Fig. 1).

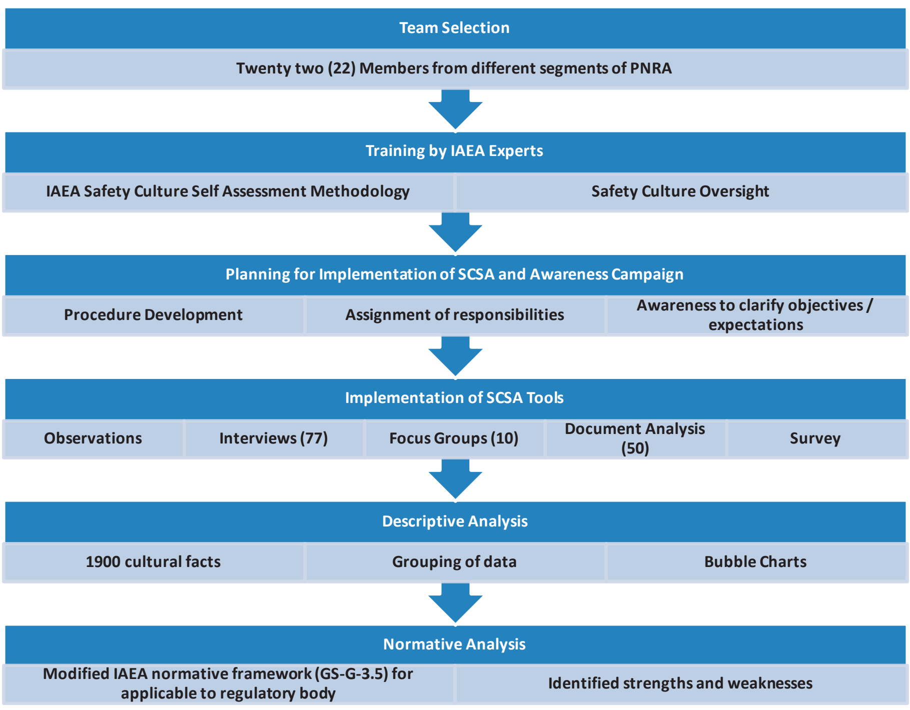

FIG. 1. Process for safety culture self-assessment at PNRA.

6. SAFETY CULTURE IMPROVEMENT ACTIVITIES

Safety culture improvement activities are being designed to improve aspects of PNRA's culture that contribute negatively towards a strong safety culture. The philosophy underpinning these activities for improving safety culture lies in widespread communication within the organization and the awareness among individuals of issues that contribute negatively to a strong safety culture.

7. STRATEGY FOR COMMUNICATING SCSA OUTCOMES IN PNRA

A strategy for communicating the results of the SCSA at different levels within PNRA was developed that took into account that the level of understanding of those not involved in the SCSA project would be different from that of those who were involved. A number of different communication sessions were conducted targeting members of staff from different levels in the organization:

(1) Communication sessions with top management;
(2) Communication sessions with senior management;
(3) Seminars for all PNRA management;
(4) Communication sessions for different working groups.

8. ENVISAGED IMPROVEMENTS

8.1. Shared understanding of safety culture

One of the major improvements that was anticipated as result of assessing safety culture at PNRA was a common understanding of the concept of safety culture, of its importance and of its use within a nuclear regulatory authority. During different steps involved in the SCSA process, dialogue sessions were conducted by involving both vertical and horizontal levels in the organizational hierarchy. These dialogue sessions triggered discussion and thought processes about why safety culture is important to the regulatory business. It is envisaged that these dialogue sessions will lead to a more global understanding within PNRA of the importance of safety culture for regulatory bodies.

8.2. Improvement in regulatory processes by incorporating safety culture

Improvement of the core regulatory processes is one of the major outcomes being envisaged. This would come about by incorporating safety consciousness during the development and subsequent implementation of licensing, review and assessment, inspection and enforcement, and the development of the regulatory framework. The outcomes of PNRA's SCSA project highlighted cultural areas that may impact the effectiveness of core regulatory processes. The improvement in these core regulatory processes might be carried out in following ways:

(a) The structure of core regulatory processes are revisited to eliminate cultural elements that contribute negatively from the perspective of safety culture.
(b) The effective implementation of regulatory processes be managed by individuals having improved safety consciousness. Safety consciousness shapes attitudes, behaviours that lead to the implementation of regulatory processes with a focus on safety culture.

8.3. Improvements in regulatory oversight process for safety culture

The regulatory oversight process for assessing safety culture at nuclear power plants was mainly based upon the material presented in INSAG-4 [8]. The limitation of this methodology was that it restricted the cultural assessment to some selected areas for inspection. Areas that were not selected for inspection might make a significant contribution to safety culture which would be missed during the assessment process. The methodology utilized by PNRA in assessing its own safety culture resulted in drawing a cultural picture of organization which was analysed in comparison with the normative safety culture framework for identification of strengths and cultural areas for further improvement of safety culture. This new methodology utilizes safety culture assessment tools, such as observation, document review, focus groups and interview. The implementation of such safety culture assessment tools requires training. Accordingly, PNRA inspectors received training to implement this new methodology for assessing safety culture at licensed facilities.

9. LEARNING JOURNEY

The learning journey of the SCSA team in PNRA started with IAEA training sessions and continued during the use of SCSA tools in descriptive and normative analyses. It was learning of its own kind that unveiled the basic assumptions and beliefs about safety residing at the bottom of the hearts of those in the organization. This learning journey continues and is also useful for social interactions with society.

10. CONCLUSION

The importance of safety culture is evident for every organization connected with the nuclear industry including operators, regulatory bodies and other stakeholders and interested parties. PNRA, being the national nuclear regulatory authority in Pakistan, considers safety culture as a vital element in its regulatory activities. It has presented itself as a role model by conducting its own SCSA using the IAEA methodology. The SCSA in PNRA highlighted strengths that should be maintained and enhanced and weaknesses that should be considered for remedial action. The activities for maintaining safety culture at PNRA are consistent with international standards. The communication of the results of the SCSA project within PNRA is in progress. Significant lessons regarding the effective implementation of the SCSA have also been learned. These will be drawn on in the future implementation of the SCSA process.

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THE POWER OF COLLABORATION FOR IMPROVING SAFETY IN COMPLEX SYSTEMS[1]

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Abstract

Many industries that are engaged in potentially hazardous endeavours involve systems that consist of a complex array of subsystems that must work together effectively in order for the entire system to perform successfully. To the extent the subsystems are coupled, changes in any one subsystem can affect some or all of the other subsystems. The US commercial aviation industry, in its continuing endeavour to improve safety, is using a collaborative approach to accomplish 'system think' — an awareness of the impacts throughout a system of changes in any of its subsystems. The industry accomplished system think by bringing all of the key parts of the industry together to work in a collaborative manner to identify and address potential safety concerns. The collaborative approach resulted in a reduction of 83% in the US commercial aviation fatal accident rate in only ten years. It also demonstrated that, contrary to conventional wisdom, safety improvements usually undermine productivity, while safety improvements that result from a collaborative approach can simultaneously improve productivity. The purpose of the paper is to help other industries that are engaged in potentially hazardous endeavours determine whether a collaborative approach might help them manage their safety risks more efficiently and effectively.

1. INTRODUCTION

The US National Transportation Safety Board is a federal government agency that was created to investigate accidents, in all modes of transportation, in order to determine what caused the accidents, and make recommendations to prevent recurrences. This paper is about what the agency has seen as investigators regarding the power of collaboration to improve safety in commercial aviation.

The collaboration process appears to be very generic, and the aviation industry experience, as well as that of the nuclear power industry,[2] suggests that in theory it should be transferable to other complex industries that are engaged in potentially hazardous endeavours.

2. THE CONTEXT

In order to explore the transferability of the collaborative process, it is helpful to look at the typical structure of complex industries. Complex industries often involve systems that are made up of several interconnected and coupled subsystems. Because of the coupling, a change in one subsystem will often affect other subsystems. Moreover, the subsystems often include many high tech aspects in which there is continuous and sometimes frequent innovation. The industry is continually learning how best to incorporate and use those innovations. In this context, if a mishap occurs, the cause is usually not that one subsystem was not working properly; more typically the cause is that the interactions between the subsystems were not as anticipated.

The good news regarding such complex systems, especially in industries that are engaged in potentially hazardous endeavours, is that their defences are usually sufficiently robust that more than one thing must go wrong to result in a mishap. The bad news is that the interactions between the subsystems are often so numerous and complicated that, when something does go wrong, preventing it from happening again may require several interventions at several places in the system as opposed to a simple or single intervention.

3. EFFECTS OF INCREASING COMPLEXITY

Many systems are becoming increasingly complex rather than less so, often because of increasing automation to make the operation more productive, reliable, and efficient. Our investigations have shown that increasing complexity may increase the likelihood of human error in at least three ways.

First, the more complex a system becomes, the more difficult it is to design out potential opportunities for human error. As the interactive situations that

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[2] After the nuclear power plant accident at Three Mile Island in 1979, the US nuclear power industry created the Institute of Nuclear Power Operations (INPO), which developed a collaborative process to improve nuclear reactor safety. INPO's collaborative process is not addressed in detail here because it is beyond the scope of the US National Transportation Safety Board's expertise.

might arise, and the potential human responses to those situations, become more complex and diverse, the difficulty of designing the system to avoid possibilities of human error also increases.[3]

Second, increasing complexity increases the likelihood that operators, the "people at the sharp end" as Professor James Reason describes it [1], will encounter situations that were not anticipated, even by the designers of the systems and subsystems. When an unanticipated situation is encountered, the operator is forced to respond in the moment, usually without any training regarding how to handle the event because the situation was unanticipated. Moreover, because automation is generally becoming more reliable, the likelihood increases that the operator will never have seen a given failure before, even in training. Last, but not least, the problem may not be a failure of the automation; it may be that the automation encountered a situation or environment that was not anticipated. A highly competent and well trained operator may be able to salvage the situation successfully. However, if operators of average abilities cannot handle it reliably, for example if they have been lulled into complacency by the reliability of the automation, sooner or later the situation will generate an undesirable outcome.

Third, increasing complexity increases the likelihood that operating 'by the book' may not generate the best response. Competent and well trained operators may routinely ignore 'the book' in those situations because they have learned how to do it better, commonly known as 'workarounds'. If something happens to go wrong during that process, a common response is to punish the operator for not going by the book. If there are frequent differences between how things are done and how the book says they should be done, a more productive response would be to determine the reason for the disconnect and then remedy it. Such disconnects are not conducive to safe and reliable operations.

The result of the increased likelihood of human error due to increasing complexity is that frontline workers who are highly trained, competent, experienced, trying to do the right thing, and proud of doing it well may still commit inadvertent human errors. In that respect, people are both the greatest weakness and the greatest strength of complex systems. They are the greatest weakness because people make mistakes, even on their best day. If it is not their best day, because they are distracted, fatigued, or medically unfit, the operators

[3] This is why equipment manufacturers should bring in operators of the equipment they are designing, during the design phase, to help them get a better understanding of the human–machine interface. Manufacturers of large aircraft generally involve pilots during the design phase, which has greatly improved commercial aviation safety.

are more likely to be a source of error.[4] Attempting to prevent such errors or plan for them is very challenging. People are also the greatest strength because they are the last line of defence if, for whatever reason, the complex system fails to function as designed. The possibility of system failure and other unanticipated events, however slight, is the primary reason that automation will not replace people in the commercial aviation system in the foreseeable future.[5]

4. THE PARADIGM SHIFT

In complex systems, such as commercial aviation in which operators will be essential for safe and reliable operation for the foreseeable future,[6] the challenge is how to make those systems and their operators work more safely and reliably together.

Historically, one of the most common responses when something went wrong in the system was to punish the operator. The theory was that the operator was highly trained, and if the operator had performed as trained, the undesirable result would not have occurred. Many industries are realizing that simply punishing the operator generally does not solve the problem. Instead, safety experts are realizing that to err is human, and most mistakes are not intentional. Rather than focusing solely on why the operator's action produced an undesirable result, they should also explore why the system allowed, or failed to accommodate, the operator's inappropriate action, and then determine how to improve the system.

This does not amount to a 'get out of jail free card' for the operator. To the contrary, the operator is always ultimately accountable. What it means is that instead of focusing solely on the operator, the system issues should also be addressed; those that resulted in a competent, highly trained operator doing something that was inappropriate for the situation.

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[4] The terms 'mistake' and 'error' are not intended to be pejorative because they include situations in which an inappropriate decision was made based upon correct information, as well as situations in which the decision was inappropriate because the available information was inadequate, misleading, incorrect, or otherwise unsuitable as the basis for a decision.

[5] Commercial aviation examples showing the importance of pilots when things go wrong include the crash into the Hudson River in New York City in 2009 that resulted from bird ingestion, and the crash in Sioux City, Iowa, in 1979 that resulted from an uncontained engine failure that irreparably damaged all three of the aircraft's hydraulic systems.

[6] Operators are gradually being designed out of various systems. Most trams within airports do not have human operators, and some cities have begun installing subway systems that have no human operators. Some may remember when elevators had operators.

The initial challenge, therefore, is understanding how complex systems behave. One suggested method is called ‘system think’, i.e. understanding how a change in one subsystem of a complex system may affect other subsystems within that system.

5. SYSTEM THINK

The commercial aviation industry accomplished system think by bringing representatives from all parts of their complex system together, including airlines, manufacturers, pilots, air traffic controllers, the regulator and others. The objective was to work collaboratively to: (a) identify potential safety concerns; (b) prioritize those issues (because they will identify more issues than they have resources to address immediately); (c) develop solutions for the prioritized issues; and (d) evaluate whether the solutions are accomplishing the desired result, and are not creating unintended consequences. This programme, in which participation is completely voluntary, is called the Commercial Aviation Safety Team, or CAST.

Understanding the system, however, is only the beginning of the challenge. Ultimately the challenge is about understanding the interactions between the system and the operators, in order to determine how to make them work more effectively together. The aviation industry is doing that by collecting, analysing, and sharing information about human–system interactions. The information that they are collecting includes automatically generated data, such as from aircraft flight data recorders and air traffic control radar systems, as well as reports from pilots, air traffic controllers, and others, usually about near misses.[7]

The collaborative process has two objectives: to make the systems less likely to generate opportunities for human error, and given that human error cannot be eliminated, to make the system more able to tolerate error without any undesirable consequences.

Another industry that is seeking to address these issues is healthcare. According to a report entitled To Err is Human: Building a Safer Health System, issued by the US Institute of Medicine, Committee on Quality of Health Care in

[7] In the nuclear power industry, INPO uses voluntary peer review to gain a better understanding of how complex systems function. Nuclear power plants can elect to be visited by teams of experts from other nuclear power plants to review how the plant functions and to find out what is working well and what is not. The peer review process is rated very highly as a win-win — it enables the visited plant to learn from the successes and failures in the systems of the visiting team members, and the visiting team members also all learn about how other systems operate so they can take that knowledge back to their respective systems.

America: the focus must shift from blaming individuals for past errors to a focus on preventing future errors by designing safety into the system [2].

The fuel for the system think process is information about what is happening every day on the front lines, including what is working well and what is not. One of the best sources of information about what is happening every day on the front lines is the frontline workers. Not only do they know what is going well and what is not, because they do it every day, they probably also have some good ideas about how to make things work better. In order to obtain information from frontline workers, it is important to encourage them to report on what is happening, and to assure them that, unless there is criminal or intentional wrongdoing, their reports will not be used against them.

When the frontline workers are confident that their reports will not be used against them, large quantities of data will become available. Then the challenge is for safety experts to transform that large quantity of data into useful information that can be used to accomplish the four steps described above: identify potential safety concerns; prioritize them; develop interventions for the prioritized concerns; and evaluate the effectiveness of the interventions.

6. THE AVIATION INDUSTRY SUCCESS STORY

The collaborative process has worked very well in the US commercial aviation industry. Aviation was already considered very safe in 1997. However, the CAST programme reduced the fatal accident rate, that had become stuck on a plateau, by more than 80% in its first ten years. This improvement occurred largely because of system think supported by proactive safety information programmes. The process generated a win-win situation because it also improved productivity, which flew in the face of conventional wisdom that improving safety usually undercuts productivity and vice versa. If that were not enough, one of the major challenges in complex systems is making intended changes without generating unintended consequences. CAST has generated very few unintended consequences. Last but not least, the CAST process accomplished this significant safety improvement without generating a single new regulation. The industry was already highly regulated. The way to improve it further was not thought to be through more regulations, but through a better understanding of how to make all the subsystems and the people in the complex commercial aviation system work together better.

The moral of the story is very simple. Anyone who is involved in the problem should be involved in developing the solution. CAST includes everyone who is involved in the problem.[8]

7. BENEFITS OF COLLABORATION

Getting the industry to participate in CAST was a major paradigm shift. In most regulated industries the regulator identifies a problem and proposes a solution. The industry often responds that the regulator does not understand the operational realities. Thus, the industry gives little credibility to the regulator's identification of the problem, and even less credibility to the regulator's proposed solution because, even if the problem was correctly identified, the proposed solution may not be the best way to resolve it. Hence, the industry does everything it can to fight and otherwise delay the solution, and to the extent it absolutely has to, industry implements the solution minimally and begrudgingly. In other words, the process is adversarial.

In a collaborative system think process, on the other hand, all of the industry participants are involved in identifying problems and developing solutions. The result, instead of being adversarial, is that when the process generates a solution, every participant has 'buy-in' regarding the solution. Why? Because all participants' perspectives were openly discussed and considered, and the participants understand each other's perspectives as they never did before. Consequently, the solutions are promptly and willingly implemented. Equally important, if the solution turns out not to be quite right, as often occurs in complex systems, all of the participants, because of their buy-in, eagerly tweak the solution to make it work. The usual regulatory process has no capability to tweak. The bottom line is that the solution is not only more effective and efficient, but also less likely to generate unintended consequences.

8. WHY IS COLLABORATION NOT MORE WIDESPREAD?

Given how successful this process has been, we must ask why it is not being used at the industry level in more industries than commercial aviation and nuclear power. There are several aspects to this answer: the need for a significant catalyst that stirs the players to action, and the need for incentives that outweigh the factors that make collaboration challenging.

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[8] INPO apparently does not include labour in its collaborative programme to the extent that CAST does.

8.1. The catalyst

The industry did not create CAST simply because it was a good idea. The industry created CAST because, as was noted above, its accident rate, which had been falling rapidly for several decades, began to flatten out on a plateau by the 1990s. Meanwhile, the US Federal Aviation Administration was projecting that the volume of commercial aviation would double within 20 years. The concern was that doubling the volume of flying while maintaining the same accident rate meant that the public would see twice as many fatal accidents. Since anybody's accident is everybody's accident, and since the public cares only about the number of events and not about the rate, that would have been a marketing nightmare for the industry.[9]

8.2. The incentives

The catalyst was important to get the process started, but the incentives that encourage participation are also crucial to keeping it going. First, aviation mishaps, even minor mishaps, command intense media and political interest. Second, as noted above, anybody's accident is everybody's accident, so the entire industry engages in helping everyone prevent accidents. When an airliner crashes, the public does not respond, 'That crash was on Airline X, so I'm not worried because I'm going on Airline Y.' To the contrary, crashes anywhere in the world may discourage people from flying. Third, airlines do not compete in safety, which enables them to exchange information more freely about their safety concerns and how they were addressed. The nuclear power industry shares these three characteristics,[10] but many other industries do not.

8.3. Challenges of collaboration

The catalyst and the incentives must be sufficiently compelling to overcome the considerable challenges of getting industry participants to collaborate. For several reasons, that is not a trivial undertaking. First, there is basic human nature, which is, 'I'm doing it right. This complex system has problems because

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[9] As noted above, the catalyst for the nuclear power industry to create INPO was the accident at Three Mile Island in 1979.

[10] Incidents in the nuclear power industry command significant media interest; anyone's accident is everyone's accident — thus, for example, the Fukushima Daiichi disaster in Japan in 2011 caused several countries to reduce or even terminate their use of nuclear power. And nuclear power plants do not compete regarding safety.

others are not doing it correctly.' Getting people beyond their natural 'I'm OK, you're not' thinking can be challenging.[11]

In addition, the participants generally have differing and sometimes competing interests. For example, getting labour and management to come to the table together is often challenging. Furthermore, many of the participants may be co-defendants in accident litigation, e.g. the manufacturer and the operator, and their focus in litigation is to show that the accident was the other party's fault. Getting them to work together in this process may be challenging.

The regulator is not normally welcome in the process because nobody wants to 'bare their soul', for fear that the information will be used for enforcement purposes. Conversely, the regulator may challenge the process as looking too much like a democracy, where everyone decides what happens by majority vote, in a context in which the regulator, by law, is in charge and is supposed to decide how best to improve safety.

The bottom line is that the collaborative process requires everyone to be willing, in their enlightened self-interest, to participate to improve the overall system, rather than think narrowly about only their own situation. The argument is that if the system improves, everyone wins. The important distinction is between ordinary self-interest, i.e. participating only for oneself; and enlightened self-interest, i.e. participating for the benefit of the system. By analogy, the most successful teams are usually those in which every player is playing for the team, as opposed to trying to distinguish themselves as individuals.

A crucial ingredient to get all of the participants to think about the system is trust. All of the participants must trust that the other participants are working in the interests of the system, and not just to be out for themselves.

9. THE ROLE OF LEADERSHIP AND THE REGULATOR

Given the challenges of developing a collaborative process, what is necessary to make it happen? A crucial ingredient is strong leadership. Within each participating entity, leadership will play a crucial role in making it work and must do several things. First, leadership must demonstrate a commitment to improving safety, but that commitment must also reflect a clear recognition that people make mistakes, as opposed to demanding "No errors on my watch". If leadership demands no errors, errors will still occur but they will be hidden for fear of punishment.

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[11] This trait of human nature often manifests itself on a more personal level as, 'I don't need to go to the marriage counselor. You're the one with the problem, so you need to go to the counselor.'

Second, leadership must avoid falling into the ‘I’m OK, you’re not’ trap by making it clear that improvements must occur not only in the frontline workers, but also at every level in the organization, including at the top. If the leader’s message is that the solution is simply more training for frontline workers, that sends a polarizing message that the leader has everything in order but the workers have not. Instead, leadership should make clear to all that what is called for is improvement at all levels rather than simply stressing more training for the workers.

Third, leadership must ensure that middle management’s performance metrics include safety. If the only performance metric for middle management is production or throughput, middle management will implicitly or explicitly discourage feedback from the frontline workers about potential safety issues, especially if addressing those issues might interfere with production or throughput goals.

Fourth, leadership must include labour from the outset in identifying and addressing the issues as opposed to deciding unilaterally what the issues are and what the solution should be. This is somewhat analogous to the situation described above in which the regulator defines the problem and tells the industry how to solve it. Ultimately, the frontline workers have to implement the solution, and the more they are on board with identifying the problem and developing the solution, the more they will have an ownership interest in making the solution work. If they are merely recipients of a mandate from above on how to do it better, they are much less likely to be receptive to the solution.

Fifth, leadership must ensure that everyone who is involved in the problem is collaboratively involved in developing the solution. That includes manufacturers, operators, regulators, and anyone else who is involved in the problem.

Last, but not least, leadership must do whatever is necessary to generate the fuel for the process which is reports from frontline workers about what is working well and what is not on the front lines. Leadership must encourage and facilitate reporting by frontline workers. It must provide feedback to them so they will know that their reports are not disappearing into a black hole, never to be heard from again. Leadership must also provide adequate resources for every step of the process and make reporting simple and doable on work time. It must follow through with action on those reports to ensure that the workers know that their reports are appreciated. The potential win-win can be enormous: management is better informed about what is happening, and labour feels more appreciated, knowing that management is actually listening to them.

In regulated industries, regulators also play a key role in making the collaborative process work. On an industry wide basis, regulators are effectively the leaders. To enable the collaborative process, regulators should do everything that leaders should do. In addition, on an industry wide basis, regulators have the duty of conducting enforcement against individual operators, but they should also emphasize the importance of system issues. Moreover, regulators must recognize that, while enforcement is an important tool for improving safety, overzealous enforcement can undermine collaboration. They must carefully strike a balance between enforcement regarding egregious wrongdoing and seeking improvement in response to inadvertent errors.

One of a regulator's most important roles is to facilitate collection, analysis, and sharing of information by clarifying that, except for in cases of criminal or intentional wrongdoing, information provided by workers to proactive information programmes will not be used for enforcement purposes. Similarly, regulators should encourage the companies in their industry to avoid punishment of their employees except in relation to criminal or intentional wrongdoing. Unless these steps are taken, frontline workers are unlikely to submit reports.

Ultimately, regulators must recognize that while compliance is very important, their mission is reducing systemic risk in their industry. As CAST has demonstrated, if an industry is already heavily regulated, giving the regulator a 'bigger stick' is probably not the most effective way to continue improving safety.

10. MICRO COLLABORATION

In theory, the collaborative process can be used at any macro or micro level at which there is a problem that needs to be addressed. Thus, in industries in which an industry wide collaborative process is unlikely as a starting point, one suggestion is to use a 'crawl–walk–run' strategy by starting with a much more finite micro approach that addresses a very specific process. If the industry is suffering from a process that has been a 'burr under the saddle' for years, with many failed attempts to fix it, then they might try forming a collaborative process improvement team, as a beta test. If the problem has existed for a long time and resists improvement, chances are that the problem lies in the processes involved rather than in the people who are implementing those processes.

The process improvement team would consist of everyone who is involved in any way because, as CAST demonstrated, everyone who is involved in the problem should be involved in developing the solution. The team would collaboratively determine why the problem is occurring and then collaboratively develop a solution to the problem. Engagement in the process improvement team by the people who implement the process that is being improved would be assured once it is made clear to them that the objective is not to punish or blame anyone, but to figure out how a process that they use every day can be improved to enable them to do their jobs more safely, efficiently and effectively.

If the beta test is successful in addressing the burr under the saddle, the industry will have a concrete success story that can become the basis for other beta tests on other longstanding troublesome processes. Moreover, it will probably also be able to address lesser problems. After that initial crawl, the walk–run is for it to evolve into broader applications, perhaps eventually at an industry wide level.

11. CONCLUSION

Safety programmes that improve the bottom line are more likely to be sustainable, and collaboration can help generate safety programmes that also improve productivity while improving safety. The US commercial aviation industry's collaboration success story is probably transferable, in whole or in part, to other complex industries engaged in potentially hazardous endeavours that are looking to improve their safety and reliability.

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RISK COMMUNICATION AS A KEY DRIVER FOR FOSTERING A MORE RESILIENT SAFETY CULTURE

Two empirical cases from Japan in the post-Fukushima accident period

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Abstract

Risk communication is a tool for conveying the results of the scientific assessment and management of risk, for sharing safety related information, and exchanging views and values among varying stakeholder groups. Its ultimate aim is to build trust through social interaction. However, the nature of effective risk communication is yet to be fully understood and, consequently, gaps in perceptions about risks between experts and non-expert remain significant. In order to address this issue and suggest how risk communication can contribute to the creation of shared awareness of the risks and benefits of nuclear energy, the paper will discuss two empirical studies conducted in Japan in the post-Fukushima accident period between 2011 and 2015. One was conducted in Fukushima and the other in Shizuoka. In both cases, scientists explained nuclear safety and the health effects of radiation to local residents. The paper concludes that the lessons from Fukushima need to be more readily shared and this will contribute to building emergency communication programmes that are both robust and resilient. Accurate safety information needs to be shared in non-crisis situations and, in order to pursue this, the creation of public 'spheres' for science-lay encounters need to be developed.

1. INTRODUCTION

It is widely agreed that the accident at the Fukushima Daiichi nuclear power plant was triggered by natural events combined with technical failures and was a human induced disaster as well [1]. From this unfortunate accident, we have learned that human and organizational factors associated with emergency planning and response and decision making for nuclear safety need to be more carefully reviewed and enhanced. Contributions from the social sciences, especially risk management and risk communication, play key roles.

Risk communication is an established concept within the risk analysis and management framework. It is a vital tool for conveying the meaning of scientific assessments and risk management, for sharing safety related information and exchanging views and values among various stakeholder groups. Its ultimate aim is to build trust through dialogue and social interaction.

However, it would not be an overstatement that the nature of effective risk communication is yet to be fully understood. As a result, risk communication is sometimes only partially integrated into risk management practice or is not considered at all. This marginalization of risk communication is observed in a variety of risk related practices, or, more evidently, in the perception gaps that exist between the lay public and experts about risks.

In order to address this pressing issue and suggest how risk communication can contribute to create shared awareness about the risks and benefits of nuclear energy, this paper will discuss two empirical studies in Japan conducted between 2011 and 2015 in the post-Fukushima accident period. In both cases, scientists explained nuclear safety and the health effects of radiation to local residents. The author was directly involved in both studies in their planning. They also acted as the facilitator.

The first study concerns a series of risk communication practices planned for the evacuees from a disaster affected region, Iitate Village of Fukushima Prefecture, between 2001 and 2012 in the aftermath of the nuclear accident. This exploratory study investigated why communication between professionals and lay persons often fails and, ironically, how it can sometimes lead to a mistrust of science.

The second study concerns a citizen panel providing stakeholder dialogue on the safety of the Hamaoka nuclear plant. This was conducted in Shizuoka in 2015. It was the first time a large scale deliberative practice was employed in Japan after the Fukushima accident.

Before presenting these empirical studies, the following sections of this paper describe the public sentiment in post-disaster Fukushima. This is followed by a literature review on risk communication.

2. THE ACCIDENT IN FUKUSHIMA AND PERSISTENT HEALTH CONCERNS

The earthquake and associated tsunami and the accident at the Fukushima Daiichi nuclear power plant occurred in March 2011. It was the largest disaster in Japan's post-war period (since 1945). The accident forced a large number of local residents to take shelter outside Fukushima Prefecture. As of 2015, four years after the disaster, as many as 100 000 people have yet to return home.

According to the Fukushima Prefectural Government, the number of deaths in the elderly due to associated physical and mental stress during the long term evacuation has amounted to nearly 2000 [2]. While a large number of people still wish to return home, they are reluctant to do so, primarily due to the fear of unnecessary exposure to radiation but also due to the lack of infrastructure such as supermarkets and hospitals that would allow them to live a normal life again.

The average level of radiation in Fukushima has steadily declined to less than one tenth of its peak, for example, levels in Fukushima City have decreased from 2.7 μSv/h in 2011 to 0.2 μSv/h in 2015. However, there is still concern about the adverse health effects of radiation in Fukushima. In some residential areas, the level of radiation remains higher than the average radioactivity of Japan. Some areas are above 4 mSv/year. For reference, the natural radiation exposure in Japan is 2.1 mSv/year [3], and worldwide average radiation level is 2.4 mSv/year [4]. In particular, the child-rearing generation is concerned about the potential long term health effects of radiation to children [5].

The government-led cleanup process for radioactive material is initiated when radiation levels are more than 1 mSv/year above background radiation levels. Yet, many local residents want areas to be remediated to the radiation level before the accident and express concerns about living in areas where the radiation exceeds more than 1 mSv/year.

The value of 1 mSv/year is a long term goal/target to be achieved through intensive cleanup activities announced by the government in 2011, yet, it is perceived as the de facto safety 'standard' to be maintained. This is not surprising. The failure of crisis communication at an early stage seems to have strongly influenced the perceptions of the public regarding safety. Not only the government but also academia in Japan failed to provide swift, consistent, and reliable scientific information to the society on the accident and associated risk. For instance, a large number of affected local residents were not aware of a series of governmental evacuation warnings and remained in the contaminated areas and therefore felt left abandoned [6]. The consequent loss of trust in the government and science has resulted in conflicting and contested opinions being expressed in the conventional as well as the social media and on social network services such as Twitter [7].

Although international bodies, such as the World Health Organization (WHO) and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), concluded that the effects on the health of local residents of Fukushima from the radiation derived from the affected nuclear reactors is likely to be negligible [8, 9], some researchers and citizen groups have raised concerns about the adverse health effects from low dose, long term exposure to radiation. They argue that additional radiation from the troubled reactors in the residential area above 1 mSv per year could cause serious health effects and argue that exposure to elevated radiation for a long period of time, even in low doses, can cause cancer and hereditary disease, especially among children.

3. RISK CONTROVERSY AND DIALOGUES: LITERATURE REVIEW

Studies of risk communication in the past have shown that risk related controversies in which even experts are divided on safety issues, or those that are closely bound with values, ethics, religious beliefs or world views, tend to be intense. This makes forming a consensus more difficult. Worldwide disputes over genetically modified crops provide a symbolic example [10, 11]. The debate over low dose radiation exposure from the reactors at Fukushima is another example. Risk perception remains high in contrast to experts' scientific risk assessment.

It is suggested that dialogue based risk communication and participatory methods are likely to be effective in risk debates that are complicated and for which scientific conclusions about the risks are ambiguous [12]. One example related to a post-nuclear disaster situation is a participatory communication programme that took place in Belarus ten years after the Chernobyl accident occurred in 1986. The ETHOS/CORE project was introduced after one way risk communication had failed. A more discourse based initiative was then employed which enabled local residents to take directly participate in the management of radioactive contamination. This has eased the sense of helplessness and alienation among residents exposed to that radiation. It was reported to be effective in terms of the residents introducing practicable protection measures into their daily life [13].

In recent years, there has been more attention to dialogue based communication in Japan. An example is a health communication practice for the residents during the volcanic eruption in the mountains on Miyakejima Island in 2000. A communication programme about the health effects of volcanic gas was carried out by a team of university researchers [14]. There are also reports on community based, participatory disaster planning in a village in Tottori [15]. Notwithstanding these, typical communication practices in Japan are still designed to be top-down and one way. Hence, truly participatory and dialogue based risk and crisis communication is limited [11, 16].

It was therefore not surprising that the initial emergency communications on the events at Fukushima Daiichi nuclear power plant by the central government were one way. The one way communication was symbolized in a frequently quoted phase, 'no immediate impact' (tadachini eikyoha nai). This was criticized by local residents as well as the media who both felt that the central government and scientists were trying to make the effects of the radiation look less severe

[17–19]. Subsequently, local residents demanded that their local governments provided them with more reliable safety information.

It was in this context that, six months after the accident, the author was appointed to be a risk communication advisor for Iitate Village from September 2011 to March 2012. They were involved in implementing an emergency communication programme for its residents.

4. RISK COMMUNICATION FOR THE RESIDENTS OF IITATE VILLAGE, FUKUSHIMA, 2011–2012

4.1. Initial group interview in September 2011

Iitate is a small village in the northern part of Fukushima that used to be known for its organic farming and for raising cattle. However, after the accident, it became known domestically and internationally as a village badly affected by the nuclear fallout. The village is located 25–45 km from the Fukushima Daiichi nuclear power plant. Initially, it was outside the mandatory evacuation zone that was set after the explosions. Nevertheless, it was later discovered that the radiation level was higher than initially estimated due to nuclear fallout blown by the wind. Of the approximately 6500 people who lived in the area before the accident, virtually all left the village as a precautionary measure when the evacuation zone was widened two month after the disaster. As of April 2013, the level varied from 4.5 μSv/h in a heavily contaminated area to 1.4 μSv/h in a less contaminated area. By January 2016, the value had decreased even more, to less than 1 μSv/h, at the majority of measured areas; according to the official data from Fukushima Prefecture [2].

The Iitate Village municipality asked the Risk Communication Advisory Group to plan and implement an emergency communication programme. The author was its primary architect as its only expert on risk communication. Its role was to help scientific experts explain the science of radiation and the health effects of radioactive material to local residents who had been evacuated from areas contaminated by nuclear fallout from the Fukushima Daiichi nuclear power plant.

In order to deploy a pilot study, the author selected one particular residential complex (Y) in Fukushima City where approximately 250 had taken refuge. Nearly 40% of the refugees were children under the age of 12. Parents and grandparents were particularly concerned about the health effects of radiation on their children. In order to design such a programme, the author visited the sheltering site with a graduate student for initial group interviews in September 2011. Twenty residents, ranging in age from 25 to 80, were interviewed to assess their level of knowledge of radiation and to determine their needs. The interviews lasted for a day.

The interviews revealed that the interviewees had received little information about radiation from the local government or from schools during the six months after the accident. When asked about their sources of information, they said it was primarily television or the Internet. They expressed anger, disappointment and fear and said that they needed safety information that was trustworthy. The information they had received from the media was contradictory and largely frightening and, consequently, they could not fully trust it. Many felt abandoned, frustrated and scared and without any substantial safety information to protect their families.

4.2. Communication programme by the scientist in October 2011

Together with another communication advisor who was an expert in radiation science, the author attempted to deploy a communication roundtable at the sheltering complex. He invited about 20 residents to participate, ranging in ages from 25 to 80 years. All of them volunteered to attend the initiative.

The communication session lasted one and half hours, with a 60 minute lecture about radiation and its health effects, followed by a Q&A session. At the beginning of the session, the author told the audience that the lecture could be interrupted at any time with questions. The attendees, the lecturer and the author (facilitator) sat together on tatami mattresses. This created a friendly atmosphere in which participants could readily ask any questions or express their concerns.

Initially, the session looked to be successful. Feedback by questionnaire demonstrated that the participants had improved their understanding of radiation, and their fears about health effects were lessened. Yet, when the author conducted follow-up telephone interviews with several participants after the initiative, it was revealed that the programme had had little real influence on their thinking. They remembered very little from the lecture with a few exceptions. For example, in the lecture, it was mentioned that bananas naturally contain a radioactive material, potassium-40. However, rather than calm one woman's fears about radiation, she said that she would not give her daughter bananas anymore. Hot springs that naturally contain radon were also mentioned in the talk and people remembered this. Fukushima has several radon hot springs. In other words, although people remembered some things from the programme, these were not the things that would help them make better decisions about living in Fukushima. Accordingly, the communication programme needed to be changed so it better suited the needs of the attendees.

4.3. Follow-up interviews: More active listening necessary

Risk communication needs to be well designed and the cost of poorly designed communication can be high [20]. In order to implement a more adequate an effective programme, the author conducted another group interview in January 2012 with 11 volunteers. Interviewees were separated into two groups; a group of the elderly (average over 60 years old, N = 7) and a group of mothers (average 30–39 years old, N = 4).

The results of the interviews with the former group, the elderly, showed that this generation was more interested in prospects for rebuilding lives than radiation related information. They saw the decision to return to the village as is in the hands of the younger generation. They showed little interest in knowledge about radiation. A frequently used sentence was: ‘We want to know when we can return (home)’; their primary concerns were not about radiation science.

On the other hand, the results of interviews with the mothers illuminated two issues. The first was that they are seriously concerned about the health effects of radiation on their children and, based on this, they had taken actions to protect them by changing the food that the children ate. The second was that a divergence occurred between what they actually wanted to know and what they actually heard from experts. What mothers wanted was hands-on information that they could use to help them protect their children and not the more detailed and scientific information provided by the experts.

The failure of the initial communication programme deployed in October 2011 made us realize that an effective programme can be planned only after active and careful listening to the target audience. The interviews with a group of mothers highlighted that they had a high interest in practical radiation related information, but not in the science of radiation. They found it difficult to understand the science of radiation and its relevance to their situation. They wanted crucial information on how to protect their families and not an academic classroom lecture. In particular, they wanted reliable information on the risks of consumption of radiation contaminated food and on the measures that they could take to limit their radiation exposure. In risk decisions, people feel safer when they have personal control over a risk [21]. The group of mothers expressed its disappointment because they were yet to be given such practical hands-on information by the scientists.

In summary, the attendees of communication exercises in Fukushima felt frustrated because the information provided by the scientists was not what they expected and wanted. It was either too scientific, and thus difficult to grasp, or not relevant to what they needed for their everyday life.

Furthermore, the author realized that the two groups involved, the elderly and mothers, needed to be approached separately. Among other things, the younger generation expressed a reluctance to talk frankly and give honest views in front of the older generation. It is understandable, since Iitate is a small village and its social structure is strong and conservative unlike cities like Tokyo. In particular, the behavioural expectation for females to be silent and obedient prevails in Iitate. Without active listening, such important elements could have been easily overlooked.

4.4. Revised communication programme in February 2012

Based on the results of the group interviews, the author formed a small study group and designed and piloted a communication initiative that involved a study hour on 'foods and radiation'. The programme took place in Iitate in February 2012. Four mothers volunteered to take part. Three mothers had participated in the earlier group interviews and the author was acquainted with them.

The author prepared information material on 'How to deal with radioactive material in foods'. This explained that eating locally grown vegetables and drinking tap water was safe and why. In addition, the author asked a mother who acted as a quasi-leader of the group to bring in foods like milk and banana to make it more participative, hands-on and more visibly clear. The discussion of how to deal with foods was deliberately slow paced and took almost two hours. The author provided them with an email address and promised to answer any questions that they had later.

Before starting the discussion, the author asked participants what they wanted to know regarding the food they eat. Their interests varied. Some wanted to know about the safety of eating local fish and others about the safety of drinking tap water. The author did not begin with a description of the risk of radiation but instead explained that there is no such thing as zero risk in foods. Some natural toxins are found in many vegetables, and non-pasteurized milk and raw eggs have certain risks that can be fatal. Conventional foods contain carcinogenic and neurotoxicants, such as acrylamide in potato fries, coffee, and burnt bread. Hijiki (a sort of seaweed seen as healthy food in Japan) contains inorganic arsenic and is banned from being sold in the UK.

The level of risks can be more readily grasped by being compared to socially accepted risks. The primary chemical of concern from Fukushima was caesium. However, potassium-40 has similar pharmacokinetics [22] and is a naturally occurring radioactive isotope in many foods. So, the author discussed that many foods, such as potato chips, milk and banana, contain natural radioactive potassium-40 and that we consume as much as 100 Bq per a day of such radioactive material. That is, 20 Bq of potassium-40 is consumed from one bag of potato chips, 20 Bq by eating a large sized banana, 50 Bq by drinking

1 L of milk, and 5 Bq by drinking a large can of beer; according to the Ministry of Education, Science and Technology of Japan (MEXT) [23]. In order to make this seem more real to participants, such food was placed on the table in front of everyone.

This discussion was followed by showing the results of sampling of the vegetables that had been conducted by the Ministry of Health, Labour and Welfare of Japan. The current and future regulatory values of radioactive caesium in Japan were then explained. Finally, the author showed the results of monitoring tests conducted by Coop Fukushima that measured the actual amount of radioactivity found in cooked meals at home. The measurements conducted at 51 households in Fukushima Prefecture, demonstrated that the detected radioactivity came predominantly from potassium-40 and only a limited amount of caesium was detected (Fig. 1) [24]. Those households where caesium was found were reported to have used vegetables not on the market or home-grown but rather from edible mushrooms and plants taken from wild sources by the households themselves.

The participants said that the dialogue was more helpful and practical than the conventional explanations they had heard from the scientists visiting Fukushima. They said that they had overestimated the risks from radiation and said they would change the way they choose foods and water. An example was provided by the way they chose drinking water. Originally, they were afraid of giving tap water to their children and usually bought more expensive bottled

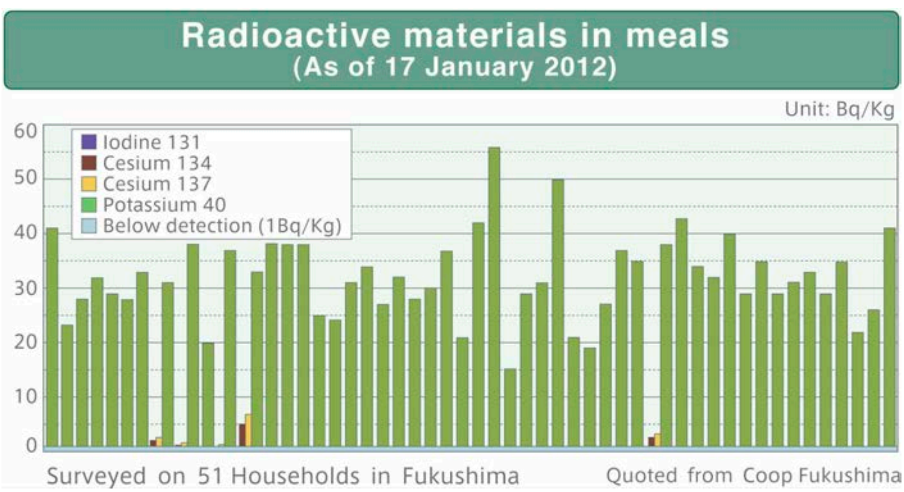

FIG. 1. Radioactive material in cooked foods [24].

water. However, after the discussion they said they would stop purchasing bottled water. The discussion appeared to help households decide what to consume.

4.5. Discussion

Effective risk communication delivers to its audience a clear and convincing view of risk by appealing to its emotions and needs; people interpret information largely using intuitive (emotion based) heuristics. Scientists tend to explain facts using numbers and logic, but this approach is not consistent with intuitive heuristics. In other words, risk communication needs to be designed so that it speaks to System 1 (intuition (emotion)), rather than to System 2 (logic); as psychologists or behavioural economists like Daniel Kahneman discuss [25].

Another key element in risk communication is risk comparison, as noted in a preceding section [17]. There is a tendency that when focused on one risk, people tend to perceive that the level of that risk is higher than it actually is [26]. Therefore, the author tried to explain the strength of the risk from radiation in comparison to other socially accepted risks; particularly radioactive potassium-40 in foods.

There is a persistent misunderstanding that the primary goal of risk communication is to accurately convey scientific facts. In fact, the goal should be to give the information that people need to make appropriate and practical decisions about their lives and community. As was argued in a preceding section, one needs to listen to those involved, so that risk communication can be tailored to their concerns, needs and interests. This is to say that risk communication starts by listening.

Creating an atmosphere where one can ask ‘dumb’ questions about risk is also an important factor and one which is often neglected in practice. It was the reason that we all sat on the tatami floor together, drinking tea. This allowed the conversation to be sometimes derailed by talk about the weather, families, and even fashion. However, it allowed it to flow and provided a platform for questions that were about risk and of importance to the participants. The session was set in the early afternoon before their children came home; this helped mothers attend the session.

In paying attention to the ‘risk-information strategy’, it is also essential to make risk communication programmes more effective. It is known that risk related information is conveyed mainly through two communication channels: the mass media and mouth-to-mouth [27]. In fact, the mothers in the study said that they felt that their most reliable source of information was mothers’ friends. Hence, it was hoped that accurate and useful information about radiation would be passed on among the mothers’ circle; ripple effects in the horizontal connection. They did say that they would pass the information onto their friends who were not able to come to the session.

From the series of largely exploratory studies in Fukushima, we may argue that common failures in providing safety information were identified, not in the scientific information itself, but in the ways that such information was conveyed to lay people. As discussed in the preceding sections, scientists primarily try to explain the science of radiation risk by the use of numbers and logic. However, lay people understand health related safety information by images and emotions in the context of their needs. Experts want to be scientifically correct whereas the public need hands-on, clear and concise explanations of practical use. Scientists' adherence to scientific accuracy is understandable but communicating scientific information requires a different skill set and objective. This lay expert gap needs to be more readily acknowledged, and, as an attempt to narrow the gap, experts need to deliver the safety related information that is asked for tailoring their language to be more readily understood by their lay audience.

Our experience in Fukushima made us realize that more frequent science–lay encounters will help scientists become more aware of the needs of lay people and of how they understand information. We also learned that it is best that the first encounter occurs during a non-crisis situation and not during the crisis itself. This realization led the author to initiate a dialogue based, participatory risk communication programme focused on nuclear and radiation science in a non-crisis context. In 2015, four years after the Fukushima accident, the author initiated a stakeholder dialogue on the future of Hamaoka nuclear site in Shizuoka (SDS, Stakeholder Dialogue in Shizuoka) and acted as the director and facilitator of that discursive process.

5. STAKEHOLDER DIALOGUE IN SHIZUOKA (SDS) IN 2015

The SDS programme on the safety of the Hamaoka Nuclear Power Station was conducted between April and July 2015. Shizuoka Prefecture is located on the Pacific coast of Japan, around 200 km from Tokyo. It is an important industrial region of the eastern part Japan where a large number of manufacturing companies are located. Yamaha and Suzuki, Japanese automobile manufacturers, have their headquarters in the region. It is also an agricultural area famous for its fisheries, green tea and oranges.

The Hamaoka plant is operated by Chubu Electric Company. It has five nuclear reactors, three of which are active and the other two are in the process of decommissioning. The nuclear accident at Fukushima sparked a public debate because the Hamaoka plant is located at place where a mega-sized Tokai type earthquake is predicted to occur in during the next 30 years. This led the central government to stop its operation two months after the Fukushima accident.

The SDS served as the first large scale discursive programme at a nuclear site in Japan after the Fukushima accident. It was designed to share facts and safety information, exchange views about the future of the Hamaoka plant, and exchange the beliefs and values of the different interested parties such as local residents, farmers, academics, journalists, civil servant and the operator of the plant. It was stressed that it was not designed to reach a consensus on the future use of nuclear energy but share facts and views among the varying stakeholder groups.

5.1. A citizen panel process

Like a consensus conference, a citizen panel (also referred to as Plannungszelle) is a form of scientific communication especially suited to dealing with controversial issues of public concern that are often perceived as being too complex or expert-dominated [16, 27]. It is a three to four day conference at which both the technically and socially relevant aspects of science and technology are discussed. It is usually divided into four stages: selection of an overall topic; recruitment and selection of the lay panel members; two preparatory weekends; and then the main conference. The citizen panel then produces the conference report.

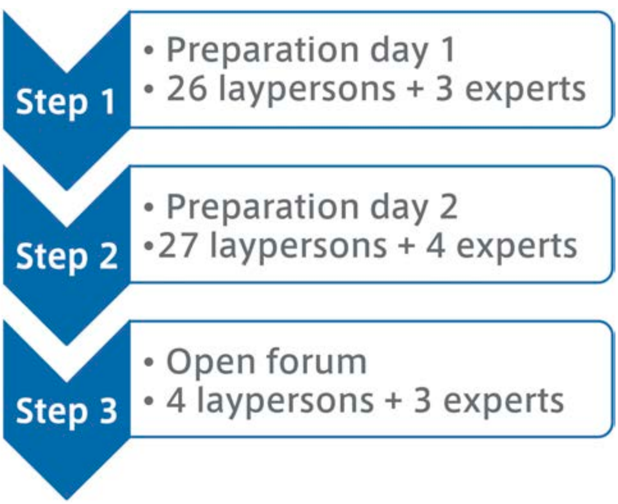

FIG. 2. Structure of the SDS.

The SDS adopted the core part of this original process while some processes were modified (Fig. 2). During two preparation days, held on weekends, 27–28 participants were split into five groups. The participants varied across housewives, researchers, students, shop owners, journalists, and those in farming businesses and veterinarian. The subjects to be discussed were given at the commencement of the session. The first day was designed to discuss the issues surrounding restarting nuclear reactors and on the second day, images and actual risks of the nuclear energy were to be considered.

After listening to talks by experts, group discussions were initiated on both days. Each group presented the results of their discussions afterwards. Invited experts varied from a nuclear scientist to a journalist and a crisis consultant. Each preparation day lasted for half a day (Fig. 3).

The main day was open to journalists and, from the preparation weekends, four representative lay members and three experts discussed the risks of nuclear energy for today and for the future (Fig. 4).

FIG. 3. Day 1 and 2 preparation days.

FIG. 4. SDS on the last day (open forum).

5.2. Results

It is often reported, and the author concurs, that the Japanese are not good at participating in western-style discussion processes [16]. Yet, the SDS programme showed that it was the lack of such a platform that partly prevented the advancement of dialogue based risk communication.

Follow-up questionnaires revealed that the discussions helped both the lay public and experts acknowledge the need for more active and continuing dialogue to improve mutual understanding of nuclear risk and, more importantly, share responsibilities for a safe neighbourhood (Hakaoma) and secured energy supply.

The need for considered and participative decision making was quoted in a comment by a lay participant: “In order to judge what to believe, we have to gather data and also hear a range of expert talks. We can then put the collected information on the table and start to think by ourselves. This process makes us judge whether we can be convinced by the information or not. We have to train ourselves how to think from early ages. Adults can also learn by organizing a seminar like this SDS. We have to foster a culture that we have to think by ourselves what ought to be done, not leaving the burden for safety on somebody else’s shoulder” [28].

We may note that the SDS programme was certainly not a panacea. The lay participants were not entirely convinced by the discussions. Some found the explanations of experts too difficult to follow, and some thought they wanted to hear more ‘honest’ views from the operator. Others thought the scientific explanations by the experts could not eliminate the anxiety of the elderly or child-rearing generation about the safety of nuclear energy. This was reflected in the follow-up questionnaire that, while many answered they could trust what the experts said, some had mixed feelings about whether nuclear energy would be more rigorously sought for the future or not. Nevertheless, it can safely be stated that the SDS programme achieved its aim sharing facts and values about the use of nuclear energy.

6. CONCLUSION

The present paper discussed how to provide information that is both accurate and of practical use for local residents in relation to nuclear risk.

The first case presented was complicated as the local residents felt abandoned and had persistent mistrust towards scientists and authority. As a result, one way risk communication failed. Hence, interactive and a dialogue based communication was used not only to deliver accurate information but also to create mutual understanding and build trust. In the event of an emergency, it is essential to deliver information concisely and within a short period of time. However, when a certain amount of time has elapsed, it becomes more important to consider delivering information tailored to the characteristics, emotions and needs of each population group. As reported in this paper, demands for information about radiation were notably different between the child-rearing generation and the older generation. It was the former group that needed hands-on practical advice about radiation, not the latter. The programme used must to be tailored to the needs of its target audience. Therefore, it is necessary to actively listen to that audience in the design of the programme. It is good to remember that good communication starts from good listening.

The second case presented in this paper illustrates that expert–lay dialogue can be beneficial not only for sharing scientific facts, but also for exchanging opinions and values of stakeholder groups with different backgrounds [28]. This result is consistent with studies about the effectiveness of participatory risk communication in a complicated risk disputes, such as local participation in plant sludge treatment and refuse disposal from Germany [29, 30].

Drawn from these observations, it could be said that a well designed, participatory communication can more readily deliver accurate and useful safety information to local residents than one way non-participatory approaches. The study showed that such a programme enables the residents to develop a feeling of empowerment in actively controlling and protecting their health, while at the same time, feeling a responsibility to create a sustainable future for local community.

The National Diet wrote [6] that before Fukushima, a mindset that “severe nuclear accidents will not occur” prevented responsible actors, such as the government and the operators, from preparing for such accidents. It was this particular culture that also did not allow comprehensive emergency plans nor communication programme to be in place. In their final report, the Japanese Government-led Investigation Committee of the Fukushima Accident concluded:

> "In view of the reality that safety culture was not necessarily established in our country, the Investigation Committee would strongly require rebuilding safety culture of practically every stakeholder in nuclear power generation such as nuclear operators, regulators, relevant institutions, and government advisory bodies." [1]

Yotaro Hatamura, Chairman of the Investigation Committee, wrote that the core of the problem lay in the lack of risk management, and that a safety culture resilient to unexpected accidents and natural disasters needed to be developed in Japan [31].

Science and technology are intimately associated with uncertainty. With the increasing deployment of nuclear technology in developing countries in Asia and elsewhere, the bitter lessons from Fukushima need to be shared on an international basis. This will hopefully contribute to the creation of emergency communication programmes that are robust and resilient. What we learned from Fukushima is that we can communicate more effectively regarding risks during non-crisis situations in a way that cannot be achieved during a crisis. Accurate safety information therefore needs to be shared during non-crisis situations and, in order to pursue this, public 'spheres' (platforms) for science-lay encounters need to be rigorously developed during non-crisis situations. More fundamentally, risk communication needs to be paid more attention in the spheres of science and technology. This can help strengthen capacity building and foster a more resilient culture in nuclear safety.

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THE PSYCHOLOGICAL ASPECT OF SAFETY CULTURE
Application of the theory of generations for the formation of safety culture among personnel

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Abstract

The formation of safety culture requires an attempt to exert constructive influence on the sociopsychological atmosphere of the team and the behaviour of individual employees. By creating a value system for the organization's staff, as part of its general organizational culture, it may be possible to forecast, plan and promote the desired behaviour. However, it is also necessary to take into account the corporate culture of the organization. Leaders often try to establish a safety culture, where progressive values and behavioural norms are declared, but the results obtained are not those expected. This may be because those values and norms come into conflict with the reality and, therefore, are actively rejected by many members of the organization. The theory of generations developed by the US scientists Howe and Strauss helps in the analysis and consideration of the staff values formed under the influence of many different factors. The development of safety culture may depend, among other things, on the age of the employees involved.

1. INTRODUCTION

The organizational and safely cultures of nuclear power plants (NPPs) will change over their lifetime and remain under the influence of the values and beliefs of the managers and personnel involved. The process of changing such cultures is not an easy one. The old values and beliefs have to be discarded and the new ones have to be understood and accepted. This process begins with the top management of the organization and evolves from there, depending on the consideration that it is given, and ends when managers lose interest in it.

Personnel often resist such changes. Furthermore, if one succeeds in making them change their observable behaviour, then such change is not always stable.

According to the IAEA's INSAG-15 [1], three stages can be identified in the development of safety culture, each differing in the degree of awareness required in terms of the influence of social attitudes and behavioural factors, as well as the degree of readiness to accept such influence.

Each stage draws on the most distinctive attributes of a strong safety culture including, for example, attitudes to errors, attitudes to people and the role of managers. It is necessary to assess the current strengths and weaknesses of the existing culture and then foster values and beliefs relevant to a higher stage of safety culture development; first among the managers and then among the workforce.

The first stage is characterized by compliance with operational rules and regulations imposed by external supervisory and regulatory authorities. Safety is seen as the responsibility of management and is largely imposed by others [1]. People are considered as ‘system components’; their characteristics and values are only determined by what they do [2].

At the second stage, the attributes of a stronger safety culture are represented by the situation when all employees are involved in the proactive development of ideas for improvement. They make their contributions not because they were instructed to do so but because they wish to do so [1]. At the same time, top management explains to other managers that the values, positions and behaviour of individual workers are essential factors in achieving high safety performance.

The third stage is characterized by the conscious aspiration and personal commitment of each individual employee to safety enhancement. For the effective management of age diverse personnel, managers should understand how to communicate with any particular employee taking into account his or her generational values and beliefs.

Knowledge of the peculiarities of work reflecting sociopsychological differences across generations is a necessary resource for managers when they are fostering new values among the personnel which are relevant to a higher level of safety culture. Melnitckaia, Chernetskaya and Belykh, specialists at the scientific and methodological centre Psycho-Physiological Support of Personnel Professional Reliability, Federal State Institution, All-Russian Research Institute on Problems of Civil Defense and Emergencies, Ministry of Emergencies of Russia (Federal Center of Science and High Technologies) developed and conducted a course on ‘Safety Culture in Nuclear Power’ at the Smolensk NPP in 2015. The course was designed to build the practical skills that the NPP managers and experts needed for the effective management of age diverse personnel in the development of the safety culture.

2. FUNDAMENTALS OF THE THEORY OF GENERATIONS

Howe and Strauss [3] studied the period of the world history from 1584 to 1991 and made a forecast on developments up to 2069. In the 20th century, they singled out five generations and in the 21st century just one (so far). According to these authors, a generation is defined as the aggregate of people born over a particular span who experienced the influence of the same events and parenting traits, and who have similar values.

The authors formulated the following postulates for their theory of generations:

(1) Belonging to a generation is specified not by the year of birth or age but is based on common values. The indicative years represent tentative boundaries of generations. Within the same year, in the same country, people can be born who will subsequently share widely different values and belong to different generations.
(2) The theory of generations is formulated and applied, not for the entire population of a country, but for its middle class. In the USA and other countries, it is shaped by economic opportunities. In Russia, these are the people with a certain level of annual income (at least US $20 000–30 000 per family) or having a university degree.
(3) The classical theory of generations concerns not the age of people, but the generations being of different perspectives in relation to: developing and creating values, trying to live in accordance with those values, administering and managing with the use of these values, and preserving them.

Three groups of values were identified:

(1) Universal: Common to humanity, little time and culture dependent: well-being of the families, love, peace, freedom, respect, etc.;
(2) Group: Perceptions of groups of people differing in age, nationality, religion, of what is desirable, acceptable, good or bad: cooperativeness, discipline like self-discipline, internationalism, solidarity, equality of starting opportunities, etc.;
(3) Personal: Specific individual’s own values: faithfulness, kindness, patriotism, honesty etc.

Many factors influence the formation of values; cultural, political, economic, social and technological. The parenting style adopted in the family plays a special role in the development of such values. Many values are fostered before the person reaches 12–14 years of age. At that period, an individual takes the family behaviour pattern for granted. He or she does not see them with a critical eye; parents tell their children what is good and what is evil. Thus, their value system is formed; one with which they will live through his or her life.

Evolution has endowed our brain with the ability to imprint in our memory an inconceivable variety of facts and behaviour patterns. The scientists are of the opinion that the key to understanding this ability is the electrical brain activity [4]. Up to the age of 2 years, delta waves (from 0.5 to 4 oscillations per second (hertz)) predominate in the brain activity of children. With the use of them, the ability of a child to imprint in his memory an incredible amount of information is ensured. At the age of 2 to 6 years, electrical brain activity of a higher frequency starts predominating. These are the theta waves. As we get older, we become less susceptible to external programming, and, in our brain activity, the predominance of high frequency alpha waves becomes more and more apparent (812 Hz). Approximately after the age of 12 years, protracted periods of yet higher frequency activity, the so called beta waves (1235 Hz), can be observed. The ability to assimilate information reduces drastically when alpha and beta waves predominate in the brain activity.

In view of these findings, the theory of generations can be further developed to consider that many values fostered before the age of 12–14 years are imprinted in the child's subconscious memory as the absolute 'facts'. Somewhat similar to bits and bytes on a computer's hard drive. The subconscious resembles a jukebox; in full obedience, it reproduces a certain behavioural song, once you press the required button [4]. And even if you do not like something in this song, it is not an easy thing to defeat the subconscious, because it processes about 20 million external stimuli per second. Over the same second, the consciousness is only able to process only 40 stimuli.

These findings point up the major challenges that managers might face when trying to foster the values of a higher level of safety culture among adult personnel. This may be especially true when such progressive values and norms are declared, but the results obtained are not those expected. This may be partly because the norms and values introduced come into conflict with the real world beliefs and values of different generations. For example, the representatives of the older generation find it difficult to understand why it is important to learn to notice good points in a subordinates' work and commend them in public for it rather than just publicly reproaching them for drawbacks and errors. Here, there is a lack of understanding of why control measures do not result in the expected improvement of safety performance [2].

Text cont. on p. 166

3. APPLICATION OF THE THEORY OF GENERATIONS FOR THE FORMATION OF SAFETY CULTURE AMONG PERSONNEL

Currently, three age diverse generations are actively working in organizations: Baby Boomers (born 1944–1963), X (born 1963–1983), and Y (born 1984–2003). For the purpose of training the leaders in the effective management of age diverse personnel in the framework of the course 'Safety culture in nuclear power', the procedures and tools for safety culture formation were worked out. These are presented in Tables 1–3.

TABLE 1. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR THE GENERATION OF BABY BOOMERS

The conditions of the Baby Boomers' generation: baby boom, space exploration, USSR is a world superpower, the Cold War, lines and coupons, common educational standards in schools and medical care security

Values of Baby Boomers generation	Traits of Baby Boomer generation	Procedures and tools for the formation of safety culture among Baby Boomer personnel
Cult of youth	It is essential for this generation to remain at duty as long as possible, to feel themselves young. They do what earlier was not customary at that age: explore computer software, work with up to date technical equipment. There has not yet been anything like that before in the history of mankind: the entire generation does not wish to hear that they are 'elderly', even more so 'old'. At the same time Baby Boomers do not want to be 'juvenile', putting on youthful airs either. They prefer to live in their own age — with the experience gained, and wisdom while staying young at heart and soul.	Propose to share the experience in the area of safety culture, act as mentors for the young adults. In socializing with Baby Boomers, not to use the word 'problem'. Replace it with synonyms, e.g. 'difficulty', 'growth area'. It is 'stylish and up to date' to use these epithets.

TABLE 1. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR THE GENERATION OF BABY BOOMERS (cont.)

The conditions of the Baby Boomers' generation: baby boom, space exploration, USSR is a world superpower, the Cold War, lines and coupons, common educational standards in schools and medical care security

Values of Baby Boomers generation	Traits of Baby Boomer generation	Procedures and tools for the formation of safety culture among Baby Boomer personnel
Responsibility	If in order to reach the goal, there is a need to solve the problems beyond their area of responsibility, they will do it. Baby Boomers view the events not in the short term, they are long term, strategy oriented, because they want to live long and actively.	Emphasize that the work on safety culture assumes a great responsibility. Offer an opportunity to participate in the development of long term strategies.
Commitment to personal growth, striving to lead	They are competitive in everything they are involved in. They work hard, work after hours and actually are the generation that "lives for the sake of working"; therefore, they can sacrifice their weekends and holidays to implement what they have conceived. Baby Boomers value personal growth; strive to build a career with the movement upwards in the hierarchy of the positions and expertise growth.	Send them to continuing education courses, to various events on sharing experiences. Propose promotion in the career for the achievements in safety culture. Attention and support of the management. Propose sharing experience with young professionals. Provide access to the up to date information, latest news on safety culture. They should be told that they have done a good job; it is vital for them that their leader or advisor could confirm it.

TABLE 1. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR THE GENERATION OF BABY BOOMERS (cont.)

The conditions of the Baby Boomers' generation: baby boom, space exploration, USSR is a world superpower, the Cold War, lines and coupons, common educational standards in schools and medical care security

Values of Baby Boomers generation	Traits of Baby Boomer generation	Procedures and tools for the formation of safety culture among Baby Boomer personnel
Personal reward and status	They need a lot of material possessions, which are a tangible acknowledgement of their hard work; they are interested in a big amount of money. Money sets them in motion. It is the reward for their effort and the measure of success. Baby Boomers tend to conspicuous symbols, such as certificates, prizes, plaques.	Stimulate by letters of appreciation, rewards, plaques etc. Pay a cash bonus for the achievements in safety culture. It is important to place emphasis on their authority. Publish articles about their achievements in media sources. Offer proactive positions in safety culture projects that underline their status.
Collectivism, team spirit	For a Baby Boomer the team image is related to that of a sports team. In this team there is a captain whose actions are out of the question and undisputable. The team members have their specializations and areas of responsibility. The key rule of cooperation in such a team is one for all and all for one. The interests of the team are placed ahead of the interests of its individual teammates. They believe that the team is made of those who can be trusted.	Offer teamwork on safety culture. Ensure a positive atmosphere and fair corporate culture. In doing so you will demonstrate an important quality — 'systematicity'. For winning Baby Boomer's confidence it is essential to become understandable as a human being, as a personality. It means you should speak about yourself, your plans, and your values.

TABLE 2. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR GENERATION X

The conditions of X Generation: Continuation of the Cold War, perestroika, the war in Afghanistan, drugs and AIDS

Values of Generation X	Traits of Generation X	Procedures and tools for the formation of safety culture among Generation X personnel
Pragmatism Existence and understanding of the rationale	Values for X — money as the resource for ensuring safety for themselves and their families, travelling — trips combining work and leisure, a possibility to manage their time. The Generation X require the existence of rationale and understanding of this rationale, rationalism — pragmatism, recognition as a personality, i.e. he is not merely a performer who does what he is told to do. The Baby Boomer leaders frequently do not fulfil this item— within their value system the goal requires no clarification, and the instruction must be fulfilled for the simple reason that it was assigned by the leader, and there is no doubt about it. Generation X do an excellent job in a competitive environment.	Elucidate the sense of the target, goal, certain activity and what it implies. Keep them informed about incentives and safety culture achievement awards. Demonstrate prospects for advancement, career development. Clearly outline the set of rules, consequences of violations, achievement awards.

TABLE 2. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR GENERATION X (cont.)

The conditions of X Generation: Continuation of the Cold War, perestroika, the war in Afghanistan, drugs and AIDS		
Values of Generation X	Traits of Generation X	Procedures and tools for the formation of safety culture among Generation X personnel
Individualism (self-reliance)	X focus more on their interests and the interests of a specific individual. If they understand it is easier for them to act. X focus on the solution of problems and achieving goals — where appropriate they will work overtime, they will use their personal resources and time at the weekend. Commitment to the work in a project team of experts The X own set of technologies is aimed at personal effectiveness and reaching the goals due to their efforts or the work of project team of experts (task force).	Clarify why reaching this goal is important for the employee, indicate its benefit. Ask about interests (normally employee does not discuss them). Seek and explain how the fulfillment of the task is associated with these interests. Offer job in a project team of experts assisting in setting up a general results oriented management team. Propose complex tasks. Authority can and should be delegated to them. Provide an opportunity not only to work out solutions, but also implement them in practical work.
Liberty	Provide X with liberty — this is one of the key values of the generation. Any choice, e.g. you may join this or other training programme; you may make these decisions at your discretion.	Make it possible to select time for work at their discretion (or at least select from several assigned options). Get them involved in a few projects at a time, give a chance to choose, where they prefer to participate.

TABLE 2. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR GENERATION X (cont.)

The conditions of X Generation: Continuation of the Cold War, perestroika, the war in Afghanistan, drugs and AIDS		
Values of Generation X	Traits of Generation X	Procedures and tools for the formation of safety culture among Generation X personnel
Readiness for changes (one step ahead)	X feel uncomfortable at the time of stability (they grew up in the time of change, and the set of individual technologies is "customized" to actions under these conditions).	They should be communicated with, with the explanation of the goals of the organization in the conditions of crisis or changes in the organization; they should be involved in making management decisions concerning the future development of the nuclear power station.
Global information awareness Technical and computer competence Life-long learning (one step ahead)	Generation X like the use of new technologies very much: they are unable to work without them. They like learning very much, and are ready for self-studying.	Send them to continuing education courses, various events on sharing experience. Get them involved as mentors. Get them involved as instructors. The management has to allot special time and place to provide information to this group. Focus on self-study of new skills required for safety culture development.

TABLE 3. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR GENERATION Y

The conditions of Generation Y: Breakup of the Soviet Union, acts of terrorism and military conflicts, the crisis of 2008, mobile telephones, Internet, and the era of branding

Values of Generation Y	Traits of Generation Y	Procedures and tools for the formation of safety culture among Generation Y personnel
Individualism Submission	Totally self-reliant, however, need an experienced mentor, just ‘here-and-now’; Y are unable to think long term and work more efficiently, if they are not left to themselves and see short term objectives. The decisions are made based on discussions and expert review, rather than implicitly following the instructions of their bosses. Their communications and rapport are well developed, in particular among the representatives of Generation Y; therefore, they do not often seek help of other generations. They are ready to offer their ideas and speak without disguise about what they like and dislike. They want to do everything promptly — they save time. They like specifics (definite answers to the questions raised).	They need an experienced mentor. An opportunity should be provided to contact the leader, mentor or advisor with any question in the safety culture chat rooms. Monthly meetings with the leader have to be arranged. It is necessary to split up the goals set for the employees. And it is still better, if the leader assigns the tasks for a week and sometimes for a day and keeps track of the employee’s performance together with the employee. Do not make long term plans (maximum — one year). They need feedback and are not afraid to get it. Encourage Y to put forward their SC ideas and provide an opportunity to speak without disguise about what they like and dislike. Allow participation in the discussion concerning decision making on safety culture issues.

TABLE 3. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR GENERATION Y (cont.)

The conditions of Generation Y: Breakup of the Soviet Union, acts of terrorism and military conflicts, the crisis of 2008, mobile telephones, Internet, and the era of branding

Values of Generation Y	Traits of Generation Y	Procedures and tools for the formation of safety culture among Generation Y personnel
Interesting work and comfort	Y need an interesting job, with a potentiality to work in a remote access mode, preferably without a tough work schedule (an interest declines — the employee leaves the organization). They have an informal attitude to everything: from the vacancy description to the interior design. They value psychological comfort at work.	Flexible work schedule (with no fixed hours): the beginning and the end of the working day floating within the range of 1–2 hours. Remote work. Comfortable, nice, convenient offices. Selection of applicants with an increased attention to the interest in the work performed. The leader should take an interest in and be concerned about the arrangement of comfortable conditions at a workplace for the Y taking into account a personal motivation potential for work.
Computer addiction	They actively employ information technologies, cannot live without them.	It is important to hold dialogues with them through social networking websites (SC blogs). It is necessary to create corporate media sources, portals, groups on safety culture in social media (to feel yourself in the society).

TABLE 3. PROCEDURES AND TOOLS FOR THE FORMATION OF SAFETY CULTURE FOR GENERATION Y (cont.)

The conditions of Generation Y: Breakup of the Soviet Union, acts of terrorism and military conflicts, the crisis of 2008, mobile telephones, Internet, and the era of branding		
Values of Generation Y	Traits of Generation Y	Procedures and tools for the formation of safety culture among Generation Y personnel
Immediate reward	They expect immediate reward, because they cannot think longterm.	Promptly and actively use a verbal incentive — acknowledgement. Need in the immediate reward — for specific achievements, for the results in safety culture. Get the ‘cult figures’ of the industry involved — as opinion leaders. Reflect the significance of their involvement in safety culture development activities in the media, especially in the social network.
Training	Very inquisitive. They like game study modes. Y do not like scrutinizing instructions on their own, they prefer live discussion.	Ensure ongoing training while playing. Ensure a high quality of training — they exhibit high exactingness to the instructors and trainers. Training should be conducted in social networking websites, quests.
Competition and perspective	Y like competing and after that discussing their performance in the internal social network. Y set a high value upon a social status of an individual.	Organize a safety culture competition (best poster, best project etc.). It is important to demonstrate to them the prospect of work or training, and propose the real opportunities of advancement, acquisition of knowledge and gaining experience.

The problems of intergenerational interactions can also be related to the facts, that:

(1) The behaviour of other people is accounted for from the standpoint of our own values;
(2) The same words have different meaning and sometimes do not agree with what see and experience;
(3) We often offer to others what we consider good for ourselves.

In the course of the training sessions with the leaders, the trainees were gaining knowledge and building the skills to enhance the efficiency of the process for developing new beliefs. These included: feedback provision for multi-generational employees, and the leader's work techniques when changing from one stage of safety culture development to another, as well as the issues surrounding the organization of training processes to take into account the age of the trainees.

"Leaders exhibit behaviors that set the standard for safety" [5]. Therefore, the key aspect of the change process is the responsibility of the leader for his or her behaviour, which necessarily has to exemplify the implementation of new values, beliefs and norms in that behaviour.

In view of the foregoing considerations, the following conclusions can be drawn:

(1) It is essential to assess the current level of safety culture at the NPP and foster values and beliefs relevant to the subsequent higher stage of safety culture development among the managers and then the personnel. This has to be framed by the realization that the practical development of safety culture principles is a complex process, where one cannot rely on making uniform and universal rules and recommendations.
(2) For the effective management of age diverse personnel, the leaders need to understand how to communicate with a certain employee with regard to their and his or her values and beliefs. This should allow the problems of intergenerational interaction to be minimized.
(3) When fostering more progressive values, beliefs and norms among the personnel, considerations should be given to how they correlate with the real world beliefs and values of different generations.

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PROGRESS IN TEPCO's NUCLEAR SAFETY REFORM

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Abstract

On March 11, 2011, a tsunami exceeding the design basis struck Tokyo Electric Power Company's (TEPCO's) Fukushima Daiichi Nuclear Power Station, which resulted in the Fukushima nuclear accident. Realizing that organizational and cultural factors were intimately related to the reason why the accident could not be prevented, TEPCO implemented the Nuclear Safety Reform Plan in September 2012 as a countermeasure. Its aim was to become an organization that would never allow such an accident to occur again. The paper discusses the organizational and cultural factors behind the accident as analysed by TEPCO's Nuclear Reform Special Task Force, which was launched in September 2012. Those factors, linked with each other are presented in terms of a 'negative chain' that starts from insufficient 'safety awareness', extends to degradation of 'engineering and technical capability', and results in lack of 'communication ability'. The paper also presents TEPCO's current activities related to the Nuclear Reform Plan, based on the results of analyses of the Fukushima nuclear accident with regard to organizational and cultural factors.

1. INTRODUCTION

On March 11, 2011, a tsunami far exceeding the design basis struck Tokyo Electric Power Company's (TEPCO's) Fukushima Daiichi Nuclear Power Station (Fukushima Daiichi NPS) causing a loss of almost all safety systems and resulting in the Fukushima nuclear accident. Realizing that both organizational and cultural issues were closely related to the reasons why we could not prevent this accident, TEPCO developed the Nuclear Safety Reform Plan [1]. This was designed as a countermeasure to ensure that the organization would never allow such an accident to occur again. TEPCO is currently implementing that plan.

This paper describes the organizational and cultural factors behind the accident as analysed in the Nuclear Safety Reform Plan. It also presents the status of current activities as well as the direction of future activities that will serve as measures in addressing these factors.

2. RETROSPECTIVE REVIEW OF ORGANIZATIONAL AND CULTURAL FACTORS PRIOR TO THE FUKUSHIMA NUCLEAR ACCIDENT

2.1. Before the Great East Japan Earthquake

The business environment for Japan's electric power companies has changed significantly over the past decade. TEPCO was significantly affected financially. The capacity factor declined after the announcement of falsified voluntary inspection records for reactor internal structures and other components in 2002 (the TEPCO scandal) and after the Niigata-Chuetsu-Oki Earthquake in 2007.

In these circumstances, the Nuclear Power Division believed that safety had been established after several severe accident countermeasures were implemented. In order to improve TEPCO's financial situation, the TEPCO Nuclear Division recognized improvement in capacity factor as an important business challenge. In a risk map used for determining operational priorities, the avoidance of long term shutdown periods was configured as one axis for making such assessments. For example, the discovery of a crack in the shroud would require a long term shutdown, so, despite the high cost, such issues were focused on, even though they did not contribute much to improving safety. On the other hand, more effective measures for enhancing safety, such as considering how to diversify or arrange power supply facilities as well as sealing important pump and battery rooms against water intrusion, did not to contribute to improve capacity factor and therefore were not taken seriously nor implemented.

In response to the TEPCO scandal, a variety of improvements focused on quality aspects. For example, the introduction of the Quality Management Systems (QMS) was one facet of its response to the 2002 scandal. QMS was employed to establish processes for rigorously managing non-conformance events. However, activities focusing directly on safety, such as engaging in reviews that go back and reconsider the design basis were not performed in any great detail. The actions taken proved to be insufficient to foster the strong safety consciousness necessary for a nuclear operator.

From organizational and cultural perspectives, the fact that the learning attitude within the organization was not sufficient might have caused the Fukushima nuclear accident. From knowledge of the incident in 1999 in which a flood knocked out the power supply at France's Le Blayais Nuclear Power Plant [2] and from that of the inundated seawater pumps at India's Madras Atomic Power Station following the Sumatra Island earthquake, we should have considered the impact on a plant that arises from the total loss of its power supply. If we had learned from the variety of documentation that was available around the world in our daily operations, we would have been able to obtain information about B5b, an anti-terrorism countermeasure adopted in the USA. All of these things are clear now in hindsight. We believe a sort of self-satisfying complacency existed, as part of our organizational culture, which became an underlying factor preventing us from carrying out sufficient safety preparations prior to the Fukushima nuclear accident.

2.2. Nuclear renaissance activities

The nuclear renaissance activities were initiated after the 2002 TEPCO scandal for the purpose of extending measures to prevent such a recurrence and turning TEPCO into a world class nuclear operator. These activities were advanced principally through the Leadership Development Exchange (LDE) and Operation Process Improvement Activities (peer group activities).

LDE was a two week programme designed to alter the way participants think. They were able to gain an understanding of the best practices employed in the USA as they learned communication skills and problem solving techniques. Over six years, nearly 600 managers and team leaders were sent to the USA. Participants gave these training sessions high marks and the programme sufficiently achieved its aim of jolting participants in a positive way and channelling them towards addressing improvements. On the other hand, nuclear top management in place at the time provided insufficient sponsorship for the programme, and the operational reforms that would use the skills gained were not sufficiently instituted.

The purpose behind the peer activities was to analyse and improve maintenance, operations and other processes at our three power stations. It also encouraged sharing practices and raising their quality to world class levels. As a result of such activities, a certain level of success was achieved, such as the revision of processes to prepare for refuelling outages to make these more efficient and systematic. However, against a backdrop of power stations persistently adhering to their own processes, much time and effort were spent on achieving consistency across those organizations. In addition, it was observed that ‘approvals necessary for implementing improvement plans were not readily granted’, that ‘managers who approved plans just left the implementation to review groups’ and that ‘nuclear top management ceased to be committed midway through such projects’. Nuclear senior managers did not sufficiently share the belief that improvements could be promoted throughout the entire organization in a unified, efficient and effective manner by standardizing the processes and tools supporting these processes. Consequently, nuclear senior managers were not engaged in continuous and integrated monitoring and follow-up of these activities and they gradually waned. Middle management, team leaders and senior operators, who were the backbone of these activities, began to question the seriousness of top management.

2.3. Activities to foster nuclear safety culture

A WANO corporate peer review, conducted in September 2008, indicated that there is room for improving comprehension and acceptance of a safety culture throughout the entire organization. TEPCO then established ‘TEPCO’s Basic Principles for Safety Culture (Seven Safety Culture Principles)’, using WANO’s Eight Principles for a Strong Nuclear Safety Culture as a guide. Assessments of safety activities at power stations, in accordance with the Seven Safety Culture Principles, were conducted and the results were reported to the President annually. External safety inspectors also annually conducted ‘assessments of activities for fostering a safety culture’.

TEPCO’s activities to promote greater comprehension and acceptance of safety culture, after the establishment of the Seven Safety Culture Principles, were limited to superficial pursuits such as explaining language, reciting the said principles and attending annual lectures delivered by external instructors. Over that period of time, not only did the previously mentioned TEPCO scandal occur, but a variety of problems arose leading to shutdowns. Facility modifications that are likely to have affected nuclear safety were implemented. Industrial safety events continued to occur and even sabotage was carried out by workers. The frequency of occurrence and reporting of these and other events indicated a deteriorating safety culture. However, self-assessments and safety inspections before the Fukushima nuclear accident produced results showing ‘no signs of degradation of safety culture’. No drastic or thorough actions were therefore carried out to improve the safety culture.

A significant factor in creating such a situation was that the organization, and particularly its leaders lacked a willingness to face the status quo.

2.4. Summary of organizational factors reconsidered

The Nuclear Reform Special Task Force reviewed the organizational factors underlying TEPCO’s emergency response at the time of the Fukushima accident. These are summarized below.

There was a perception that an acceptable level of nuclear safety had already been sufficiently achieved, and that the organization was going to be reorganized by simply training communication skills and problem solving techniques. There was no keen awareness that the TEPCO scandal was a sign of a deteriorating safety culture, making organizational efforts made to improve safety awareness insufficient.

The former nuclear top management should have taken the initiative to enhance safety awareness throughout the organization in a committed manner. However, no specific policies were adopted to change their own awareness or the way in which work was performed. They believed that causes were weaknesses in first-line supervisors and problems in site organization.

Although unclear organizational authority and responsibility were revealed during the emergency, such a lack of clarity regarding authority and responsibility was also observed even during normal operation.

This could all be summarized in terms of a belief that safety had already been established and that capacity and other such indices were perceived to be the important management issues. This resulted in an increased dependence on manufacturers for engineering and contractors for field work. This, in turn, lowered TEPCO's engineering and technical capabilities and led to insufficient preparation for accidents. Moreover, this situation also involved insufficient communication with local stakeholders.

An illustrative structure is presented in Fig. 1 in terms of a 'negative spiral'. Because this negative spiral was firmly rooted in the organization, such problems were very difficult to resolved.

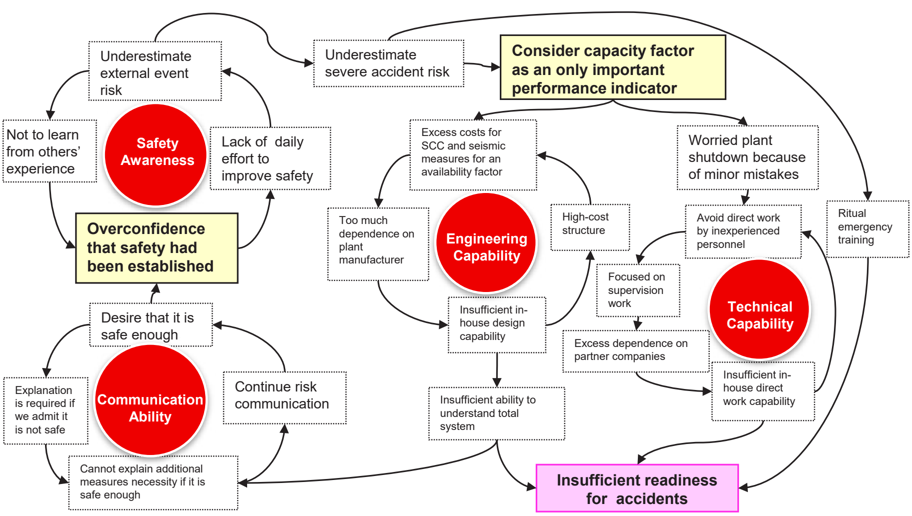

FIG. 1. The negative spiral.

3. NUCLEAR SAFETY REFORM PLAN AND ITS CURRENT IMPLEMENTATION STATUS

In order to prevent a severe accident from occurring again, it was necessary for TEPCO to resolve the negative spiral described above. Taking into account the results of its analyses, the Nuclear Reform Special Task Force formulated six measures to stop this spiral. The measures were compiled in the Nuclear Safety Reform Plan, which TEPCO's Nuclear Power Division has put into action. These measures and their accompanying activities are described below.

3.1. Measure 1: Reform from top management

Measures

(1) To enhance the nuclear safety knowledge that top management needs, and have top management execute nuclear safety reforms themselves so that a safety culture permeates down through the organization;
(2) To have third parties evaluate the organization and its management, including the Nuclear Safety Reform Plan, so as to accelerate improvements that will promote further enhancements.

Current status

Based on WANO documents, TEPCO enacted the '10 Traits of a Healthy Safety Culture'. The TEPCO President, Chief Nuclear Officer and President of the Fukushima Daiichi Decontamination & Decommissioning Engineering Company are leading personnel in engaging in daily retrospective reviews based on the 10 Traits of a Healthy Safety Culture. The reviews are well established with an implementation rate of over 90%.

In addition to sending out messages directly and indirectly to convey their expectations and thoughts, senior managers are engaged in interactive dialogues on safety with their people at the sites. TEPCO has proactively had third party assessments by WANO, IAEA, and JANSI which are leading to a variety of improvements. These include enhancing management observations and analysis of near-miss events.

Various benchmarking activities are being performed including discussions with INPO, Hatch Nuclear Power Station, Palo Verde Nuclear Power Station and other sites to learn the world best practices.

3.2. Measure 2: Enhancement of oversight and support for top management

Measures

(1) To establish the Nuclear Safety Oversight Office (NSOO) which will monitor and offer advice to executives as well as assist the Board of Directors in making decisions. A person from outside TEPCO was appointed to be the Head the Nuclear Safety Oversight Office.
(2) To enhance the roles played by middle management and licensed reactor engineers as a means of bolstering support for management.

Current status

NSOO was reorganized to report directly to the President (1 April 2015), and has been monitoring and providing advice from a position closer to the front line at the sites as well as directly participating in management decisions involving nuclear safety.

The work of NSOO has resulted in recommendations for strengthening training for supervisors in the field, for reassessing work involving excessive exposure on account of scheduling priorities while decommissioning Fukushima Daiichi NPS, and for switching to a management policy based on ALARA principles.

With the aim of strengthening middle management's capabilities and converting their work styles to a more reform oriented approach, senior managers have served as instructors in offering training for middle management that enhances interactive discussions (Fig. 2).

FIG. 2. Management training session (Measure 1) and exchange of opinions between NSOO experts and power station personnel (Measure 2).

3.3. Measure 3: Enhancement of ability to propose defence in depth

Measures

From the standpoint of making continuous improvements to defence in depth, the following measures are being implemented:

(1) So that improving defence in depth is well recognized as a part of their daily operations across the organization, a safety enhancement contest for personnel is held in which outstanding proposals for improvements are commended and their implementation is supported by management;
(2) From the perspective of defence in depth, the identification and utilization of lessons learned from operational experience data accumulated both in Japan and other countries are enhanced and accelerated;
(3) Hazard data are analysed relating to external events which, although rare, could have a significant impact on nuclear safety.

Current status

Contests to enhance the ability of personnel to propose safety improvements have been held twice annually with the number of submissions per contest exceeding 100. The quality of the proposals has improved each time and innovative ideas have emerged, such as proposals for circulation cooling to prevent PCV temperature and pressure rise as a substitute for using filtered vents.

In order to foster an atmosphere in which personnel are able to familiarize themselves with operational experience (OE), easy to understand commentaries have been posted on the intranet, and activities are under way so that all employees can share the lessons gained from OE over short periods of time and on a daily basis.

3.4. Measure 4: Enhancement of risk communication activities

Measures

(1) To establish the Social Communication (SC) Office, which reports directly to the President. The Director of SC Office was appointed from outside the company. The SC Office will propose, to top management and the Nuclear Power Division, policies on the announcement of risks and also explanations of the various measures taken. The aim is to educate personnel

within the company, to collect information about TEPCO's risk data and to share internally cases where improvements have been made.

(2) To assign personnel to serve as risk communicators, who are given the role of communicating risks in accordance with the above policies.

Current status

Improvements in management are being addressed that relate to the handling of information. As part of this effort, the full public disclosure of all data has been made since 20 August 2015 in accordance with the policy of 'disclosing all radiation data' from the Fukushima Daiichi NPS.

Easy to understand information is continually being communicated through the production of videos, invitations extended for site tours as well as the improvement a variety of tools and utilization of opportunities (Fig. 3).

FIG. 3. Exhibition booth at the IAEA General Conference (Measure 4).

3.5. Measure 5: Reorganization of power station and head office emergency response organizations

Measures

To emulate the Incident Command System (ICS), as adopted as the standard for emergency response organizations in the USA, and to reorganize power station and head office nuclear accident emergency response organizations. ICS has the following distinguishing features:

(1) Clarified role assignments (incident commander vested with decision making authority);
(2) Clarified chain of command (following orders of direct-line superiors);
(3) Number of personnel managed by one supervisor is limited to a maximum of seven.

Current status

Training has been conducted with the ICS framework, linking the power stations and head office, and training sessions have been held to reinforce individual functions.

Basically, trainees are not given any information about the training scenarios used (blind training scenarios). Severe malfunctions were incorporated into the training scenarios but not made known to participants. For example, one case assumed that the main anti-earthquake building was unusable at Kashiwazaki-Kariwa NPS so that participants were trained in moving the emergency response headquarters to the Unit 3 reactor building.

3.6. Measure 6: Reassessment of power station organization, enhancement of first-hand skills in the field and development of personnel to improve nuclear safety

Measures

(1) To change power station organization so that oversight and assurance functions for nuclear safety could be enhanced.
(2) To enhance operator abilities and to develop personnel who can manage the work by themselves within the Maintenance Department, and consequently to foster the practical skills enabling those personnel to respond to unexpected situations so that TEPCO employees are able to execute the initial emergency response.

Current status

Power station organization has been reviewed and developed so that nuclear safety can be overseen and assured in a comprehensive manner.

Training has been conducted so that personnel are acquiring the capability to perform the work necessary during an actual emergency, such as disassembling and mounting pumps as well as connecting cables.

In order to learn about good practices for training system engineers, the Director of the Plant Engineering Department, Palo Verde Nuclear Power Station (USA), was invited to Japan and discussions were held with him.

A new training programme is under development based on the definition and assessment of the skills that all personnel within the Nuclear Power Division should possess and also the specific skills necessary to implement each work process.

4. SUMMARY — FOR IMPROVING SAFETY CULTURE

TEPCO is determined to be a ‘nuclear operator that continuously improves safety to unparalleled levels by enhancing the level of safety with the spirit of ‘today more than yesterday, tomorrow more than today’ while always keeping the Fukushima nuclear accident firmly in mind’. We are continuing our efforts to realize this goal by putting the Nuclear Safety Reform Plan into practice [2]. In addition, the following reforms are being implemented to further enhance safety:

(1) Training personnel so that they have the necessary skills and knowledge, and never give up even when confronted with an unexpected event (Fig.4);
(2) Further reinforce an attitude of intensely pursuing nuclear safety;
(3) Streamlining of operations so that personnel are afforded sufficient time to develop ideas about nuclear safety;
(4) Foster a culture in which learning takes place from a variety of opportunities in understanding what is happening worldwide;
(5) Improve technical capabilities through discussion based on original design concept and also through partnerships with suppliers.

Emergency drills

Training in pump disassembly and assembly

FIG. 4. Training sessions at Kashiwazaki-Kariwa NPS (Measures 5 and 6).

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LEADERSHIP ACTIONS TO IMPROVE NUCLEAR SAFETY CULTURE

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Abstract

The challenge many leaders face is how to effectively implement and then utilize the results of safety culture surveys. Bruce Power has recently successfully implemented changes to the safety culture survey process including how corrective actions were identified and implemented. The actions taken in response to the latest survey have proven effective with a step change in performance noted. In the safety culture assessment completed in 2013, Bruce Power conducted an assessment across the entire organization as part of the corporate assessment. The report generated from the analysis of the data provided the character of the nuclear safety culture and trends at the facilities and across the organization. A thorough review of the results was conducted with a cross-departmental team that included individual contributors, supervisors and managers with an executive committee chaired by the Chief Nuclear Officer providing provided oversight. From this process, Bruce Power established a number of corrective actions to address the three main focus areas identified as part of the safety culture assessment: improve equipment health, improve corrective action program, and improve first-line manager communication. A key success factor in addressing these focus areas was the establishment of sponsorship and site-wide initiatives to respond to each of the three focus areas. Another success factor was the decision to focus on the top three issues. Oversight on the progress against these actions was also undertaken at the Corporate Corrective Action Review Board each quarter, whose purpose is to provide senior management review and oversight of significant corporate level events. Such oversight ensured that the causes of these events had been identified and that timely and effective corrective actions had been put in place. This integrated framework, which was developed using the experience of external expertise and international industry standards, provides a valid characterization of the nuclear safety culture and drives continual improvement. In this way, Bruce Power maintains a healthy nuclear safety culture.

1. INTRODUCTION

The challenge that many leaders face is how to effectively implement and then utilize the results of safety culture assessments (SCAs). Bruce Power has recently successfully implemented changes to the safety culture assessment process, including how necessary corrective actions are identified and implemented. The actions taken in response to the latest assessment have proven effective with step changes in performance noted. This paper will address Bruce Power's approach to nuclear SCAs; the effectiveness of the implementation of corrective actions, the lessons learned, and planned changes in the next SCA taking place in 2016.

2. ABOUT BRUCE POWER

Nuclear safety is a core value for Bruce Power. It runs the world's largest operating nuclear generation facility and is the source of roughly 30% of electricity in Canada's most populous province of Ontario. The Bruce Power site, on the shores of Lake Huron, one of North America's five Great Lakes, is home to eight CANDU reactors.

Formed in 2001, Bruce Power is a private, all-Canadian partnership among Borealis Infrastructure Management (a division of the Ontario Municipal Employees Retirement System), TransCanada and the two main unions representing workers on the Bruce Power site. These are the Power Workers' Union and the Society of Energy Professionals. Over 90% of employees also own a part of the company. Bruce Power is the source of about half of Ontario's nuclear generation and is the lowest cost source of nuclear energy in the province; consistently demonstrating that safety and commercial success go hand in hand.

Since being formed, Bruce Power has returned the site to its full operational capacity, with eight units providing 6300 MW of carbon-free electricity to Ontario's grid. This was accomplished through the restart of Units 3 and 4 in 2003/04, the refurbishment of Units 1 and 2 in 2012 and a range of life extension investments on Units 3–8 over the past 14 years. To achieve this, Bruce Power has invested $10 billion private dollars into these publicly owned assets since 2001.

Bruce Power announced, in late 2015, that it had entered into an amended long term agreement with the Independent Electricity System Operator (IESO) to secure 6300 megawatts (MW) of electricity from the Bruce Power site, through a multi-year investment programme.

The amended agreement will enable the company to progress with a series of incremental life extension investments, including refurbishment through major component replacement and asset management (AM) to secure a clean, reliable and affordable source of electricity for Ontario families and businesses for decades.

Securing the future of the site to 2064 has only been possible because of the exemplary safety record of the company. “Safety First” is one of Bruce Power’s core values.

At Bruce Power, nuclear safety is based on the following four pillars: reactor safety, industrial safety, radiological safety and environmental safety. Bruce Power understands the link between a healthy nuclear safety culture and excellence in nuclear safety performance. Processes and practices are in place to achieve a healthy nuclear safety culture within Bruce Power such that nuclear safety is the overriding priority. The approach used is based on industry leading practices and includes monitoring, assessing, and taking actions to drive continual improvements in the nuclear safety culture within Bruce Power.

3. MANAGING EFFECTIVENESS REVIEW IDENTIFIED OPPORTUNITIES IN SAFETY CULTURE ASSESSMENT

An important aspect of determining the status of the nuclear safety culture within Bruce Power is effective leadership oversight which sets standards and behaviour expectations for all staff. Effective leadership draws on a variety of day to day controls to monitor the operations of the facilities as well as reinforcing the behaviours associated with the expectations of a healthy nuclear safety culture.

Evaluation processes identify weaknesses in nuclear safety culture and monitor the effectiveness of the remedial actions taken. A variety of communications and leadership awareness activities have been implemented to enhance leaders’ and employees’ knowledge of the framework.

Historically, Bruce Power’s two stations, Bruce A and Bruce B, had conducted their periodic SCAs independently, using slightly different methodologies. In 2012, as part of the Bruce Power Management Effectiveness Review process, which is based on IAEA Safety Standards Series No. GS-R-3 [1], a review was undertaken of Bruce Power’s SCA approach. This included a review of what was happening internationally in the field of safety culture.

At that time, the environment around safety culture was changing following Fukushima, with renewed interest, collaboration and innovation. In the USA, an Institute of Nuclear Power Operations (INPO) Significant Operating Experience Report (SOER 10-2 Engaged, Thinking Organizations) gave rise to an approach for more effective monitoring of subtle changes in safety culture between periodic SCAs [2]. Internationally, INPO and the World Association of Nuclear Operators (WANO) were collaborating with the IAEA and other stakeholders to revise their eight principles of a strong nuclear safety culture into ten traits of a healthy nuclear safety culture.

Bruce Power decided upon a significant revision to its approach. It introduced regular Nuclear Safety Culture Monitoring Panels, engaging workers in the launch of the 'Traits of a Healthy Nuclear Safety Culture', refreshing its leadership training around safety culture, and planning for an SCA that would not only address the two stations, but also the corporate functions. Three simultaneous assessments were conducted using a common methodology and with central coordination.

4. SAFETY CULTURE ASSESSMENT METHODOLOGY

The purpose of the self-assessment was to understand the employee's perceptions about safety at Bruce Power. This type of assessment cannot rate safety performance in absolute terms, but instead is designed to make clear people's concerns and their behaviour patterns and to offer other insights to help management improve the safety culture.

Bruce Power decided upon a self-assessment approach with a survey, interviews and focus groups, together with the insights obtained from implementing the Nuclear Safety Culture Monitoring process over the previous year. This monitoring process had, for the previous year, brought together mid-level leaders to review key Bruce Power events. It also considered external case studies. Its purpose was to develop insights around the culture that could be provided to senior station leadership for consideration and action.

4.1. Logistics

An assessment project leader was assigned, and the services of an industry expert in safety culture were engaged. The industry expert was to provide a robust methodology, administer and interpret the survey, prepare the self-assessment team with training and tools, lead the focus group sessions and be the author of the reports. To undertake the size of the assessment being considered, 34 individuals, from all levels in the organization, were used to conduct interviews. There were three teams; each was supplemented by industry peers and each was led by a senior manager. The team members were released for 10 days to participate in training, conduct interviews and participate in the follow-up workshop to develop action plans. Two administrative support staff were required for approximately eight weeks to arrange the participation in interviews and focus groups, and support the teams during the assessment.

4.2. Safety culture survey

An electronic survey was delivered to all staff in May 2013. A total of 2932 surveys were returned with 13 092 written comments. The survey had a response rate of 54% and the data were internally consistent (that is the ranking orders of questions and the ratings were stable before the end of the data collection period). The survey was independently administered and was voluntary and anonymous.

The survey consisted of 65 core questions, plus a set of 10 cultural pattern questions. The main question set was developed for Bruce Power drawing on past years' questions and informed by the INPO questions used in their safety culture and organizational effectiveness surveys. It was also mapped against the new INPO/WANO Traits of a Healthy Nuclear Safety Culture. The survey was open to all regular employees, as well as to temporary and supplemental staff. Staff of major contractors were not included in the survey.

Survey participants were required to provide some high level demographic information which included both organizational information and their primary work location. It was hypothesized that primary work location could have a greater impact on culture than organizational alignment. Gender, stratum, years of service, and type of work (in-plant versus office) were also captured.

4.3. Interviews and focus groups

Interviews and focus groups were held with a total of 290 people in the week of 24–28 June 2013.

The interview questions were identical to the safety culture survey questions. They were administered by pairs of interviewers to a cross-section of staff from each location, with about 65% of interviewees being individual contributors. 25% were first-line supervisors. The remainder were more senior staff.

The interviewers were not provided details of the survey results until after the interviews were all completed.

Each interview was scheduled for one hour, and the interview team then had one hour to input their rating for each question. The interviews did not always capture the results from all 65 questions included in the survey. A statistician was on the team to help identify those questions that were not being addressed and a daily team brief highlighted these. By the end of the interview process, all 65 questions provided sufficient data to give confidence in the results.

Focus groups were held with groups of 10–15 employees and led by the safety culture expert.

4.4. Determination of ratings

Upon the completion of the week of interviews, the team members gathered for a full day to review the results of the interviews against the results of the survey and to make a determination about the final rating for each question and for each location (Bruce A, Bruce B, and Corporate Functions). The process was used to share insights and questions and for team members to challenge one another to be self-critical. Ratings were classified as weak, concern, reasonable or healthy.

5. SCA RESULTS

The report generated from the analysis of the data described the character of the nuclear safety culture and trends at the facilities and across the organization. A thorough review of the results was conducted with a cross-departmental team that included individual contributors, supervisors and managers. An executive committee chaired by the Chief Nuclear Officer provided oversight for the entire process.

The assessment results clearly showed that the nuclear safety culture is viewed very similarly across the entire organization. The higher and lower rated areas are almost identical and the issues of concern were also very similar.

The demographic results from the survey showed that the higher levels of management at both of the operating stations had a more positive view of the nuclear safety culture than the other levels in the organization. There was no major difference in the nuclear safety culture reported by regular and non-regular staff, between hands-on workers and office-workers, between people with different years of service, or between men and women.

5.1. Frequently raised issues

The issues highlighted by the SCA did not reflect the full story, but the themes identified in these data were threaded through the process and were used to form the eventual actions:

(a) Nuclear safety focus. The focus placed on nuclear safety in the organization was high. However, the effect of decision making on the long term health of the plant was a central theme raised at the working level in this assessment.
(b) Equipment condition. The predominant view was that the condition of operating plant equipment is degrading. However, some people felt that the situation might have been slowly improving at Bruce B. People had faith

that the plants are operated within the design limits, but there was a level of unease about the accumulated effect of deficiencies.

(c) Corrective Action Program. The level of support for the Corrective Action Programme (CAP) was low in all areas. There was cynicism and frustration with the lack of effective action taken on concerns and with the large numbers of Station Condition Records that were 'Closed to Trend'. The feedback on the CAP programme indicated that, as well as there being process problems, there was a communications gap about the purpose, value, and performance of the process.

(d) Management presence. Many people said that they rarely saw a manager above the first-line level, and that the amount of interpretative communication was low. There were comments that recent management changes were making some improvement in this area, but that these were at senior levels. There were concerns that managers were focused too much on data and not enough on getting out and talking to people to learn more about what was not working and why.

6. SCA ACTIONS

Bruce Power established a number of corrective actions to address the three main focus areas identified as part of the SCA including:

(1) Improve equipment health;
(2) Improve the CAP/learning organization;
(3) Improve first-line manager communication/visual management boards.

These focus areas were seen as integral to improvements across the site. They have been instrumental in contributing to enhanced performance across the measures associated with operational performance and those related to the four pillars of nuclear safety.

7. EQUIPMENT HEALTH INITIATIVE

The equipment health focus area was intended to address weaknesses in "the predominant view that the plant equipment condition was degrading" although some felt that there was a slow improvement at Bruce B.

In launching the focus area, Bruce Power established a vision for equipment health: "We are aligned and relentless in our pursuit of excellence in Equipment Health."

Bruce Power also recognized that success would be achieved only if the team were prepared to address the cultural shift required to achieve that vision. There was strong Senior Vice President sponsorship and endorsement. A cross-functional team was selected, comprising emerging leaders, with a Department Manager released from role to lead the team. The team used an analysis method, Common Cause Analysis, that was already ingrained in the CAP. It involved industry experts and WANO/INPO in validating the proposed action plans. A collaborative effort involving stakeholders from many departments ensured that site intellectual property was developed. Effective oversight was assured through a cross-site Executive Oversight Committee.

In the past three years, a remarkable improvement can be seen in the area of equipment reliability. With the efforts of the equipment health initiative, Bruce Power's Equipment Reliability Index (ERI) continues to reach record highs across both stations. The ERI for Bruce A saw an increase from 58% in 2013 to 79% at the end of 2015. Similarly, the ERI for Bruce B also increased; from 69% in 2013 to 80% at the end of 2015.

Moreover, the 2015 year end forced loss rate (FLR) across both stations was at an all-time low since the return to service of Unit 1 and 2. This is another testimony of the significant improvements accomplished in equipment reliability. The year end 2015 FLR for Bruce A was 2.85% and Bruce B was 1.75%.

Between Q4 2013 and year end 2015, the number of corrective critical (CC) work order backlogs reduced by 163 between both stations, leaving both with approximately 30 CC backlogs in total. This is equivalent to an approximate 84% reduction. Similarly, the deficient critical work order backlogs also saw a reduction of approximately 710; equivalent to a reduction of 31%.

Finally, an overall elevation of system health can be observed as the total number of red systems reduced from 4, at the beginning of Q1 2013, to zero at Bruce A and Bruce B at year end 2015. The number of yellow systems in both stations reduced by more than 15% over the same period. As high level issues are being resolved, a shift is occurring towards identifying and resolving lower level equipment issues.

8. VISUAL MANAGEMENT BOARD INITIATIVE

The Visual Management Board's (VMB) focus area was intended to address the weaknesses in Leadership Safety Values and Actions (LA) INPO Trait and in particular, Field Presence (LA.2). It also created the opportunity to communicate issues associated with CAP fixing the identified problems.

VMBs are a tool borrowed from lean manufacturing methods. They provide a communication anchor for the supervisor so that they may hold short, daily morning briefings with their teams. There is an expectation that more senior leaders rotate their participation around the VMBs of their units. There are currently 330 VMBs actively being used across the Bruce Power site on a daily basis. The VMBs have played a key role in dealing with the weaknesses identified in the 2013 Safety Culture Assessment.

Daily VMB printable content is available on the Bruce Power Intranet Home Page. The VMB content is separated into that for major business units including the two stations, the Outage and Maintenance Services organization, and other corporate divisions.

The content is used by leaders to review with their staff; it includes topics such as:

— Safety;
— Plant status;
— Daily focus areas;
— Station priorities;
— Operating experience (OPEX);
— Outage performance;
— Business performance;
— Other general communications.

Leaders have received training in the use and maintenance of the VMBs during continuing and initial leader training sessions.

The other elements incorporated on the VMBs to support nuclear safety and improve situational awareness include:

— The 2 × 2 risk matrix that is used during pre-job briefing activities. This matrix provides workers with an opportunity to understand the potential risks to the personnel or equipment prior to commencing the work.
— Work crew and departmental performance metrics. These allow leaders to speak to the staff regarding how they contribute to the overall performance of the company. They help engage leaders and staff in discussions on activities and actions to improve work crew performance.

To ensure continued and increased leader field presence, observation and coaching checklists have been developed for use by leaders. These checklists prompt the leaders to review the materials on the VMBs and to provide feedback to subordinate leaders on their performance in leading the daily VMB meetings.

In 2014, the average VMB observation and coaching checklists completed per month was 367. In comparison, in 2015, the average VMB observation and coaching checklists completed per month was 475.

The VMB process has also facilitated an increase in leader field presence, improved communications and increased awareness by all staff, including leaders, of the current state of the station, emergent issues and the performance of the business.

9. LEARNING ORGANIZATION/IMPROVE CAP INITIATIVE

The 'Learning Organization/Improve CAP' focus area was intended to address weaknesses in the Continuous Learning (CL) INPO Trait and in the Problem Identification and Resolution (PI) INPO Trait.

This initiative used a multi-faceted approach. It was integrated with the VMB initiative to ensure that corrective actions and their status would be communicated to staff as part of their VMB daily meetings.

There were four elements supporting this learning organization initiative:

(1) Improve the CAP;
(2) Improve the use of OPEX;
(3) Improve the use of focus area self-assessments;
(4) Strengthen independent oversight.

Part of the focus on effectiveness of corrective actions, was assuring that actions were SMART — specific, measurable, achievable, realistic, and timely. To this end, a computer based training qualification was established. In addition, new reporting mechanisms, to assure that actions were completed on time, together with senior leadership oversight have significantly improved the completion and effectiveness of corrective actions.

It was obvious that OPEX was not always being effectively used between stations and self-evaluation tools, such as focus area self-assessments, could have been more effective at identifying opportunities for improvements.

The learning organization initiative also ensured that the company's Independent Oversight (Audit and Assessment) organization was strengthened, in particular, by releasing some of the company's best staff to participate in rotations of 6–24 months in the Independent Oversight department.

Over the past three years, significant improvements have been accomplished in the areas of nuclear safety, safety culture, human performance, cost, equipment reliability, generation, as well as in outage performance. Strong safety and human performance, record output and record low maintenance backlogs were achieved with a significant three year operating budget savings. These improvements were accomplished through the use of strategic initiatives, improved oversight and effective leadership.

Human performance (HU) has steadily improved with a 2015 metric of less than one station level reset per unit. In comparison to 2013, a notable 40% reduction in station HU clock reset can be observed at the end of 2015.

With the focus on the use of core four tools and the efforts of the learning organization and managing defences initiative over the past few years, work quality has evidently improved while human performance events continue to trend down. The HU station clock resets show an improving trend over the past three years.

10. LESSONS LEARNED AND NEXT STEPS

A key success factor was the establishment of sponsorship and site-wide initiatives to respond to each of the three focus areas. Another success factor was the decision to focus on the top three issues. Oversight on the progress against these actions was also undertaken at the Corporate Corrective Action Review Board (CARB) each quarter, whose purpose is to provide senior management review and oversight of significant corporate level events; ensuring that the causes of these events have been identified and that timely and effective corrective actions have been put in place. The Corporate CARB ensured the proper focus is maintained on public, plant and personnel safety as well as generation, business plan and safety culture.

10.1. 2016 assessment

Bruce Power's next assessment will be in Q3 of 2016. Going forward, Bruce Power plans to include a focus on security culture in this assessment, and conduct additional focus groups on more specialized topics such as contractor oversight, technical conscience and security culture. Bruce Power will also reach out to more industry peers and engage a behavioural science expert to supplement the team.

11. CONCLUSIONS

This integrated framework, which was developed using the experience of external expertise and international industry standards provides a valid characterization of the nuclear safety culture and drives continual improvement such that Bruce Power maintains a healthy nuclear safety culture. The value of these new methodologies has been validated through various measures, metrics and surveys. The SCA, used in conjunction with ongoing monitoring of safety culture, management effectiveness reviews, and a strong focus on oversight and the effective implementation of the corrective action process results in good safety and commercial performance.

Bruce Power continues to look for innovative methods for improving safety culture, moving beyond behavioural observations and coaching to a more holistic approach based around the interaction between humans, technology and organization aspects. The company recognizes that providing consistent and aligned leadership messages which allow staff to internalise the company's expectations around safety, and why this matters, is vital to Bruce Power's ongoing success. As Bruce Power enters into a phase of significant refurbishment, it will be crucial to find new ways to engage contractors and temporary workers in contributing to a healthy safety culture and new ways to assess effectiveness. The role of leaders, through their words, decisions and actions, will set the stage for success. This will only occur if two conditions are met. The first is if vigilance and proactiveness are exercised in fostering an environment where safety continues to be the overriding consideration. The second is if Bruce Power succeeds in assuring that all those involved in the industry have deeply held and shared beliefs about the importance of protecting people and the environment from the risks inherent in the peaceful application of nuclear technology.

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WHAT THE NUCLEAR SECTOR COULD LEARN FROM RESILIENCE ENGINEERING

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Abstract

The adoption of the concept of safety culture by the International Nuclear Safety Advisory Group (INSAG) 30 years ago was an acknowledgement that merely expecting full compliance with (good) procedures and practices was not enough to guarantee safety. Something more was needed at all levels of the organization for a correct accomplishment of 'all duties important to safety'. Since those early days, the concern for safety culture has spread to most industries, and the concept has been the subject of many academic publications, while managers and leaders have been provided with practical methods to assess and improve it. However, the debate around the notion of safety culture, its implications and its applications, has remained at the syntax rather than at the semantics level. Topics felt important for safety were initially defined by consensus within practitioner groups. They included components as diverse as commitment to safety, leadership, communication, risk awareness, transparency, error reporting, compliance to procedures, competence, questioning attitudes or 'just' sanctions. All these issues are undoubtedly important for safety, but their mere aggregation does not really tell us on what strategic basement nuclear safety is built up (e.g. there is no reference to the safety model, no mention of defence in depth (DID), which is the key strategic principle of nuclear safety). In other words, the current notion of safety culture does not refer to a clear and explicit 'safety paradigm'. The industry lacks the observational data to match the assessed attitudes with actual safety results, hence the relationship between safety culture and actual safety performance remains hypothetical. This may be a real obstacle to an efficient learning process. The contention in the paper is that the relationship between safety culture and actual safety would be less speculative if a more explicit connection were established between the 'cultural' expectations and the safety model. The goal of the paper is consequently to discuss this potential connection, that is to discuss the semantics of safety culture. The core of the nuclear industry safety is the DID concept.

Defence in depth (DID) is an ancient military strategy. A reconstruction of the city of Tell Al-Rawda (Syria), dated circa 2500 BC, clearly shows a series of defence lines protecting what was one of the first cities in history (Fig. 1). Applied to nuclear safety, the DID concept initially referred to a series of independent physical barriers containing radioactivity from fission products: fuel matrix, fuel

FIG. 1. Hypothetical reconstitution of the city of Al-Rawda (Syria) (circa 2200 BC) (photo © Mission Archéologique franco-syrienne de Tell Al-Rawda. Y. Ubelmann and C. Castel).

rod cladding, primary circuit boundary, reactor containment building, and so on. It then evolved into a safety strategy, a more generic approach to designing and operating safe nuclear facilities, that includes access controls, the design of physical barriers against fission products, the provision of redundant and diverse key safety functions, and the definition of emergency response measures.

A typical implementation of that extended DID concept includes five layers of safety measures, as shown in Fig 2.

As a matter of fact, this kind of framework to safety management provides the basement of a resilience oriented strategy. 'Resilience' is the intrinsic ability of a system to maintain its structural identity, its (main) features, and at least partially its performance, in the presence of disturbances, including large, unusual, or unexpected ones, going beyond those for which the system had been designed for, or those to which it is adapted. It is easy to see that the above DID framework is a predefined and structured reaction to progressively degrading levels of control on the situation, a hierarchical response to disturbances worsening from known to unknown.

But ironically, while the need to design and organize responses to the unknown — to unanticipated situations — is in principle accounted for and embedded into the DID framework, it is not really incorporated into the safety philosophy. The current nuclear industry safety paradigm fails to draw all the consequences of this acknowledgement. It fails to properly assess the challenge

FIG. 2. The defence in depth concept.

of the unpredictable. Indeed, the current nuclear industry safety paradigm is heavily based on the deterministic and/or probabilistic anticipation of all potential situations, and the predetermination of all the expected (safe) responses, all through the five levels of the DID. Safety is mainly expected from the real world's conformity to this designed-to-be-safe world, a world where nothing goes wrong, or when something goes wrong, it has been properly anticipated. A perfectly controlled world where organizations, processes, hardware, teams, and individuals comply with their rationally designed specifications and predetermined (safe) behaviours, including for extreme events. In this 'command and control' perspective, risk is seen as generated by deviations and variations from rules, procedures, norms, and behavioural expectations. Hence, the goal is to reduce complexity through tighter compliance to specifications and to improve predictions capabilities through a tighter monitoring of weak signals and precursors.

But life is complex, even in normal situations, which means partially unpredictable. The traditional top-down, command and control perspective and the correlated linear thinking fail to properly acknowledge the limits to predictability inherent to a complex adaptive system. In a complex world, precursors are usually obvious after the event, while not identifiable before. And the efforts made to reduce complexity also simultaneously tighten couplings between system's components —hence increase complexity — and reduce the diversity and flexibility needed to respond to it. Most capacities needed to cope with the unexpected are eroded in the continuous attempt to prepare for the expected.

The perceived vulnerability to the unexpected leads to attempts to increase predictability, hence to more anticipation and predetermination, that make surprises even more 'surprising' and destabilizing, increasing the fear of the unexpected. The existence of a proper procedure easily contributes to the post hoc illusion that there was only one 'rational' course of action. The post-event seeks for 'causes' to explain these deviations from the expected course of actions maintains and reinforces the illusion of attainable rationality. For example, a frequent assumption to 'explain' the Fukushima accident is that TEPCO — or the whole Japanese nuclear safety organization — has been negligent in managing the risk associated with tsunamis. An alternative vision is that TEPCO has 'reasonably' used the available scientific knowledge, methodology and expertise to predict the magnitude of potential tsunamis off the cost of Fukushima. What we would then have here is not a poor implementation of an effective paradigm (total anticipation), but a reasonable application of a paradigm of limited efficacy.

There is evidence in favour of the latter interpretation, and not only in the nuclear industry. In other domains, like aviation, or offshore oil operations, several major recent accidents (Air France 447, Qantas 32, Deep Water Horizon,) have also recently illustrated a critical vulnerability to the 'fundamental surprises' triggered by unexpected, unthought-of events, or simply rare events. In most industries, the factually observed safety level does not match with the predicted figures. The observed frequency of uncontained core melting in the western technology world is about twice the initial target one. A comparison, within several high risk domains (e.g. Space Shuttle, Offshore), between the predicted safety level and the actual level of safety empirically demonstrated through real disasters frequency, shows that risk control capabilities are overestimated by a factor of 2 to 150 (Space Shuttle).

The usual response to this kind of vulnerability goes like: 'we have taken the lesson: let's add this scenario to the current threat list, and we won't be trapped next time'. In other words, the usual response is a commitment to do more of what is already done: an exhaustive anticipation of threats and responses, through a permanent seek for extending the domain of predetermination. Most of the adaptation needs to deal with the unexpected is 'black matter' to the current safety paradigm. The current 'safety culture' is overemphasizing predefined responses and underestimating the need for adaptation to the unknown, including within the range of 'normal' operations (Fig. 3).

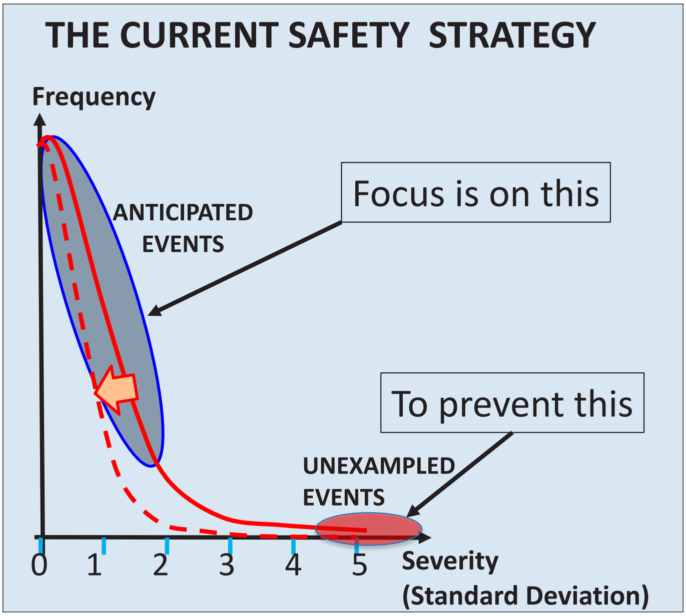

FIG. 3. The current safety strategy.

The core of the safety model is a representation of the frequency-severity distribution as a bell curve. This representation carries two main illusions. The first one concerns the thin tail of the Gaussian distribution: the observed frequency of extreme events in most domains is much higher than predicted by a bell curve. The second one is a linearity illusion. The safety strategy focuses on low criticality/high frequency events (incidents) and postulates that reducing their frequency will proportionately reduce the tail frequency. This latter assumption, illustrated by the famous Bird-Heinrich triangle, is simply wrong. It has been contradicted by several statistical studies conducted on complex systems including in occupational safety, the empirical foundation of Bird's study.

There is a need for a paradigm shift, a need to reconcile and balance predetermination and adaptation, to reasonably shift the core of the safety model from compliance to resilience. In the words of K. Suttclife, "we need a shift from reducing uncertainty about the future to managing uncertainty as events unfold".

This shift first implies recognizing complexity and acknowledging that unexpected events, 'black swans' or 'fundamental surprises' will happen. As S. Sagan nicely put it: "Things that have never happened happen all the time".

This implies the need to better understand how people handle the unexpected. In turn, this makes clear the need to understand (daily) success rather than (rare) failures. We need to better grasp how people and systems stay in control of the situation, how they monitor, respond, anticipate and learn from their experiences, to paraphrase E. Hollnagel's words. When the situation evolves from known to unknown, the degree of potential control inevitably decreases. However, the efficiency of normative top-down 'command and control' strategies decreases even faster and to a greater extent. The amount of adaptive control needed increases. Merely decreasing staff autonomy (seeking higher compliance to predefined responses) will increase the odds that a normal situation stays normal, but will reduce the odds of recovery in the case of unexpected events. The more unexpected is the situation, the more what matters is the ability to make sense of it, to assess the degree of current and future control, and to maintain some room for manoeuvre. This calls for specific forms of individual and collective competence. In particular, it calls for the capacity to maintain a relevant representation of the risks and corresponding vital actions; things never-to-do and things to-do-absolutely in the situation. It requires the capacity to properly adjust one's level of trust and confidence.

These skills must be built. It would be a serious mistake to consider that we must take care of all that can be expected, and trust the creativity and intelligence of people in case things would turn out differently. It may be that people are actually creative. It is likely, however, that stress reduces many of these abilities or that creativity turns out to be dangerous if it is not properly framed. And this is the irony of resilience: we must prepare the organization for not being prepared. This leads to another, possibly complementary, vision of the management of safety that includes the provision or the development of:

(1) Enhanced capabilities to react and adapt, within, as well as beyond, the boundaries of the safe operations envelope;
(2) 'Graceful extensibility' (the capacity to stretch near and beyond those boundaries);
(3) 'Sustained adaptability' (the capacity to manage adaptive capacities);
(4) Simple and understandable design;
(5) Adaptive automation;
(6) Operational flexibility (more than 'one best way');
(7) Slacks, buffers, stocks, oversizing, extra resources, backups, and bunkers;
(8) Redundancies, diversity, vicariance (the ability of a structure dedicated to a function to take over a different function);
(9) A repertoire of generic strategies responding to generic threats (for example, vital actions responding to fundamental states, independent from scenarios);
(10) Capacities to reorganize, shift priorities, redefine goals, reallocate roles and resources, make 'sacrificing decisions' (cutting one's losses);
(11) Capacities to manage room for manoeuvre and dynamic replanning;

(12) Collective sense making capabilities, collective mindfulness, shared goals and values, shared risk perception;
(13) Reactive skills, through the introduction of uncertainty, and fundamental surprises into simulation training.

In summary, the current nuclear safety paradigm puts too much emphasis on anticipation and predetermination. This is understandable considering its history and the societal demand of absolute control. However, it leads to an unacceptable vulnerability to the unexpected. There is a need to shift some control from past to present (from anticipation to monitoring and reactivity), and from the top to the bottom of the organizations (from designers and managers to front line operators).

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SAFETY CULTURE AND THE FUTURE OF NUCLEAR ENERGY

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Abstract

The occurrence of the Three Mile Island (TMI), Chernobyl and Fukushima accidents in the past gives people a false belief that nuclear accidents are destined to happen. In fact, these accidents could have been prevented by the presence of strong safety culture. Based on a review of the history of nuclear power and nuclear safety, the paper examines how safety culture evolved over the years and how it can guide the future of global nuclear power development without repeating the past course of accidents.

1. INTRODUCTION

The history of nuclear power started with a concern over safety. The technology was first developed for military purposes and made manifest in the form of the most potent bomb ever known. When the civilian application of nuclear technology was first proposed, safety was the primary concern. The world's first nuclear reactor built by Enrico Fermi emphasized safety through the implementation of multiple layers of safety controls including the use of a 'safety control rod axe man'.

At its inception, the nuclear power industry addressed safety through instituting 'siting and containment' requirements given real uncertainty over the behaviour of nuclear reactors and potential health effects from nuclear accidents. Under siting and containment, it was suggested that nuclear power plants should be located far away from the centres of large population. However, with the evolution of a nuclear power industry as a commercial entity, it was proposed that reactors should be sited near large metropolitan areas. In fact, the proposed new reactors in the United States of America were all within 25 miles of major metropolitan areas. The focus of discussion on nuclear safety then shifted to engineered safety features. The goal of reactor safety then was to limit radioactive releases by prevention, or, at least, to mitigate accidents through the use of engineered safeguards.

The philosophy of defence in depth was developed. Plant exclusion zones were set up reflecting the allowable radiation exposure limit for humans. Utilities were required to purchase the land within the exclusion zone. To minimize the financial burden of land purchasing, utilities pressured reactor vendors to design engineered safeguards into containment to minimize the extent of exclusion zones. Later on, emphasis shifted to the prevention of core meltdown (with loss of coolant accident (LOCA) as the most probable source). The expectation was that with improved ECC (emergency core cooling), a full-scale core meltdown was not credible. The focus shifted to ECCS design. This shift in focus persisted for a while. Even if the worst accident happened, the engineered safety systems were expected to handle the situation. Thus the belief that 'nuclear reactors are safe' prevailed.

This belief was seriously challenged when the TMI accident took place. At the same time, although the accident was serious enough to cause core meltdown, there was no major release of radioactive materials to the environment. Although the accident reminded the industry of the importance of human error and operator training, many believed that the accident was a vindication of the success of nuclear safety design.

This belief was once again challenged with the Chernobyl accident. This time, the accident resulted in an unprecedented environmental disaster in Europe. However, people noted that the reactor was an old Soviet type without major containment. Many believed that the western designed reactors would never experience such a catastrophe even if a major reactor accident happened.

Then came the Fukushima accident in Japan. The accident shattered the major existing paradigm of nuclear safety. A severe accident did happen at a western designed nuclear reactor. It was a beyond-design basis accident. The result was as devastating as had ever happened. For the first time, the nuclear industry began looking seriously into severe accident issues and the measures necessary to prepare for such accidents.

After witnessing the three major nuclear accidents, some claimed that nuclear accidents are destined to happen again in the future. Based on the observation that these three accidents occurred in over 16 000 cumulative reactor-years of commercial nuclear power operation across 33 countries, it could be argued that a major nuclear accident happens every 5300 reactor-years. With 438 nuclear reactors operating in the world, it could be postulated that another major nuclear accident would happen in the next 12 years. Believing this, many members of the public are concerned about the use of nuclear power. For example, in the Republic of Korea [1] although the majority (~ 83%) of the public agrees that nuclear power is necessary and important, the majority (~ 63%) also believes that nuclear power is not safe. With such a concern among the public, sustaining the use of nuclear power will be challenging.

2. LESSONS FROM THE AVIATION INDUSTRY

Is another major nuclear accident destined to happen in the future? The answer to this question is related not only to what has happened in the past but also to what happens today and in the future. A related example can be found in the commercial aviation industry. In the 1950s and 1960s, the commercial aviation industry was plagued with accidents. The frequency of accidents was at 50 to 60 fatal accidents per year. The projected fatalities with the growth of the industry were too big to sustain the industry. Did the projection continue into the future?

Today, commercial airplanes are accepted by the public with no major safety concern. The rate of fatal accident in the industry has been reduced significantly. Today the rate is approximately three per million departures [2]. What made this change possible?

There has been a concerted effort by the industry and governments to make changes over the last several decades. In response to frequently occurring accidents, airplane builders continuously improved the design and materials used in the technical components designed for safety. Technological innovations continued. Efforts to improve operations and maintenance also continued through changes in regulatory oversight. The selection of capable people and training to ensure their competencies were continuously improved. Maintenance was done frequently to ensure the safe performance of the system. Regulatory oversight provided strong incentives for the industry to invest in these activities, thus constantly improving the safety records. As the industry continued to change, the projection based on the past was no longer valid.

The key in all these developments was safety thinking. There were strong enough social and cultural demands for safety made of the aviation industry. Proven safety record was a prerequisite for the viability of the industry. There were enough economic incentives for the industry to invest heavily in safety. These led to the development of a safety culture in the commercial aviation industry. Today the global aviation industry remains viable and strong while maintaining a steady accident rate of less than five accidents per million departures for the last two decades. Most of the members of the public, when they get on the plane, do not worry about the safety of that plane.

3. EVOLUTION OF SAFETY THINKING AND CULTURE

According to Reason [3], safety thinking evolves through three different phases.

The first phase is the technical phase. In this phase, safety concern is mainly addressed through technology development. New designs and materials are developed and implemented to improve safety. If a problem in safety arises, technology is seen as the culprit, as a source of that problem. During the early period of the nuclear industry, up to 1970s, nuclear safety thinking remained in this phase.

The second phase is the human error phase. In this phase, erroneous human action is recognized as a source of the problem. In other words, people are recognized as a problem. Thus, improving safety requires minimizing human error. Consequently, making investments in people was emphasized through enhancing the competence of operators by way of appropriate selection and training. In the nuclear industry, this phase was clearly made manifest in the post-TMI accident developments. The corrective actions taken after the accident were mainly focused on human engineering issues such as the technological, procedural, training and man–machine interface aspects. The discipline of human factors was introduced into the nuclear industry during this phase.

The third phase is the sociotechnical phase. In this phase, it is recognized that problems in safety arise beyond the individual level. During the 1980s, it was recognized that the complex and often poorly understood interaction of social (human) and technical features can be the root of large scale system failures [3]. Thus, interactions of subsystems within an organization were recognized as a source of problems. The importance of this phase was highlighted after the Chernobyl accident as the accident was found to be the outcome of organizational, cultural, managerial, and institutional failings. The accident also led the development of the concept of ‘safety culture’. The word was coined by the International Nuclear Safety Advisory Group (INSAG) of the IAEA after the accident. INSAG [4] defined safety culture as that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.

Wilpert et al. [5, 6] added an additional phase in addition to the three described above. It is the interorganizational phase. This phase notes that relationship between organizations is important in determining the occurrence and the ultimate outcome of a safety related incident. In this case, incidents are explained by taking into account extraorganizational actors and their inter-relationships including: site personnel, utilities, regulators, contracting firms, consultants, etc. In this phase, dysfunctional relations between organizations are noted as a source of problems. The recent Fukushima accident highlighted the importance of this phase as the consequence of the accident was largely attributed to the inadequacies of the communications between organizations while coping with the situation. Thus, the sphere of safety culture was expanded under this phase.

It is argued here that one additional phase needs to be added to safety thinking and is the final phase. It is called the socially-trusted safety phase. Socially-trusted safety is achieved when the society believes in the safety of the industry; people believe in it. For example, when people ride an airplane, most of them are not concerned about the safety of their trip. Thus, it can be said that the aviation industry has reached this phase.

However, in the case of the nuclear industry, most people are not convinced about the safety of nuclear power. Although there are differences among countries, in general, the public does not have strong trust in the people who run or regulate nuclear power plants. This leaves major challenges to the future of nuclear power worldwide.

4. NUCLEAR SAFETY AND THE FUTURE OF NUCLEAR POWER

Despite the 2011 Fukushima accident in Japan and the phase-out decisions by a few European countries, demand for nuclear power continues in the world. The demand is particularly strong among the existing nuclear power countries in the developing economies such as China and India. Even among the developed countries, there is a sign of recovery or serious renewed interests in nuclear power. Examples of this include the USA, UK and Sweden. On 6 November 2015, in the USA, there was special summit held at the White House where the need for nuclear power was clearly affirmed by President Obama. This development is due to the current global consensus on the need for a reduction in greenhouse gases. Nuclear power used to be considered as just one of many alternative technologies to produce electricity. In fact, nuclear power was one of the technologies people thought could be replaced due to concern over safety and nuclear waste. Nuclear power is being touted as one of the few options that we must use to fight the gravest challenge that the world faces today.

Among the dialogues on future energy strategies, the role of nuclear power is envisioned as something that can coexist and cooperate with renewable energy technologies. This is to realize carbon-free energy generation while minimizing the use of fossil fuel that exacerbates the global warming problem. Use of nuclear power is also suggested through the construction of small and modular reactors for smaller grid applications and through nuclear marine applications. These developments assume the presence of nuclear power plants in close proximity to people and centres of populations. For these developments to be realized, nuclear power must be accepted by the public and local communities. If not, the social cost associated with the construction and operation of nuclear plant will be too large and prohibitive. Thus, the future requires a new level of nuclear safety. This new level of nuclear safety needs to be supported by the final phase of safety thinking, that is socially trusted safety.

Nuclear safety is safety only if nuclear power is seen to serve its purpose, that is providing cost effective electricity with built-in safety, security and stewardship. In a country like Germany, concern over nuclear safety is ending its nuclear power program. Is Germany phasing out their nuclear power programme because the German reactors are particularly unsafe? German reactors are known to be among the more safely designed and run power plants in the world. The reason why Germany chose to phase-out their nuclear power programme was because the public did not believe in the safety of nuclear power.

One key challenge in this is to achieve socially accepted nuclear safety in a cost effective way. There is a good lesson to be reminded of from the history. When the nuclear power industry in the USA went through deregulation in the 1980s, people were predicting that nuclear safety performance would deteriorate due to the industry's emphasis on cost reduction resulting in compromise in nuclear safety. But the result was the opposite. The nuclear industry realized that improving safety also improves economics of nuclear power. Nuclear safety performance continuously improved through the 1990s in the USA.

People have a basic, innate need for safety. Its satisfaction requires security, stability, protection, structure, order, and freedom from fear and anxiety [7]. Even if the nuclear industry achieves the best level of safety with the best available technology, if the people still experience fear and anxiety, it is not safe. If the public does not trust the people who manage and operate the technology, nuclear power is not safe.

Trust is gained through repeated behaviours that demonstrate: (1) A belief that those with whom you interact will take your interest into account; and (2) A sense of confidence that the party trusted is able to empathize with your interests and is competent to act on that knowledge. Trust can be easily eroded or lost. For example, trust can be lost if an organization is unable or unwilling to respect the views of vulnerable parties or unable or unwilling to fulfil promises. If there is mismatch in the distribution of benefits and costs associated with the organization's mission, trust can be also lost. If there is a long time lag between taking an action and discovering its outcome, either as success or failure, it is also difficult to maintain trust. Furthermore, if the organization is not transparent in sharing information, it is difficult to maintain trust.

Many of the nuclear power plants currently operating are approaching their initial operating license limits. As these plants age, equipment deteriorates with time and use. The plants built in the 1960s and 1970s may not have all the safety features and characteristics of the post-TMI designs. At the same time, the infrastructure to support safe operation of nuclear power plants may be decaying [8]. In many countries, the nuclear work force is ageing. The slowdown of nuclear development in the past two decades has also resulted in a reduction in the nuclear workforce. The number of highly qualified experts is on a steady decline in most of the countries. The number of graduates with training in nuclear technology has also declined. In terms of research to support nuclear safety, the amount of research funding has decreased.

As the number of newcomer States increases, countries without experience in the operation of nuclear power increase. Although the IAEA provides technical guidance and support, the level of international cooperation to support safe operation of nuclear power plants is low. Many of the aspiring States do not have domestic good governance characteristics that will encourage proper nuclear operation and management. These characteristics include low levels of corruption, high degrees of political stability, governmental effectiveness, and a strong degree of regulatory competence [9]. Propagation of nuclear power technology to the States with weak ‘good governance’ characteristics certainly does not contribute to global nuclear safety. As some of the newcomer countries do not have the necessary domestic infrastructure, these countries may rely on foreign workforces to operate and maintain their plants. This creates new situations where the task of running a nuclear power plant becomes the responsibility of multicultural workforces. As human error has become one of the leading causes of nuclear reactor accidents, these new international developments are important. The 2011 Fukushima accident also provides clear demonstration that severe nuclear accidents can happen with western designed nuclear reactors with serious environmental impacts. This accident has also provided warning against the terrorism induced nuclear accidents. However, integration of nuclear safety and nuclear security has rarely been exercised in nuclear power plant operation.

These observations call for new levels of investment and higher levels of international cooperation. International leadership for these new efforts is called for. The future also requires new mind sets among nuclear professionals in dealing with the public until we get to achieve socially trusted nuclear safety. This requires change.

How do we get there? We get there through continuous and, consistently good safety performance. The industry’s practice and performance of safety must prove that nuclear power is safe. Consistent safety performance must be continued until public trust is earned. For this to take place, efforts to address nuclear safety should cover not only the component level and systems levels but also the post-accidental level and the social level. Failure of safety critical components and equipment must be effectively avoided through online preventive monitoring. Furthermore, when a component or equipment fails, the systems level safety must be able to cover it, manned by capable operators. Safety systems must be built and installed to prevent the propagation of a failure event into an accident including balanced use of systems between active and passive safety. The system must be designed in such as a way to be tolerant to operator errors or, where necessary, to minimize operator interventions. The system must also be capable of coping with a variety of off-normal accident situations. In this regard, big data trend analysis focused on system safety should be utilized, intelligent automatic safety system need to be designed and implemented, and safety culture of an organization must be constantly monitored, analysed and reinforced. Even if there is a situation with a release of radioactive materials from the reactor to the outside environment, the safety system must be able to minimize the resulting impact on people. In this respect, new technologies and approaches are needed. Currently post-accident nuclear safety is addressed only through emergency management including evacuation and relocation. Attempts to mitigate the dispersion and release of radioactive materials are made through the development of filtered venting technology. However, the technology is still not effective in mitigating public fear. This is where we are today.

Alternative approaches are needed to address public fear and feeling of the unknown. Even if severe accidents do not actually take place, technologies that can provide certainty in mitigating the impacts of accidents need to be available and known about. There needs to be a change in the paradigm of nuclear safety thinking: Nuclear safety not as seen by nuclear experts but by the public.

Change is possible when there is a need. And for this change to take place, a sense of urgency needs to be created. A sense of urgency is created when there is a gap between expectation and reality. Expectation is the continued growth of nuclear power: Reality is that the world has changed. The public is no longer on the side of the industry. Nuclear power operates in a much different world today compared to the early days of nuclear power. The expectation of change for the future can be informed and placed in perspective by knowledge of outside events and a sense of purpose. Complacency, an obsession with the past when things were better, blind pride, and an accompanying lack of openness will prevent such change [10].

The change can be possible when safety culture is essential and core part of the industry. According to the US Nuclear Regulatory Commission [11], the presence of an effective safety culture in the nuclear industry means that risk to people and to the environment is maintained as low as reasonably achievable thereby assuring stakeholder trust. Consistent practice of safety culture will enable the industry to earn the trust by the public. By creating new networks of relationships and through repeated, consistent effort to communicate with people, mutual understanding and trust is developed. This will lead to socially-trusted nuclear safety. Socially-trusted nuclear safety also requires the majority in the political system to believe in the safety and benefits of nuclear power. This is possible when stakeholder groups see nuclear power as their ally and productive coalitions can be built. Current crisis in the global ecosystem demand rapid expansion of nuclear power. But such expansion is only possible through establishing socially-trusted nuclear safety with consistent practice of safety culture.

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EXPLORING 30 YEARS OF SAFETY CULTURE

KEY CONFERENCE CONTRIBUTIONS

INTRODUCTION: CHALLENGES TO CURRENT THINKING ABOUT SAFETY CULTURE IN THE NUCLEAR INDUSTRY

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There is now widespread recognition of the importance of organizational culture not only in assuring the safe operation of nuclear power plants but also in shaping the response to nuclear accidents and related events. The IAEA conference captured this very effectively. In doing so, it laid the foundations for the further development of an approach that is now an integral part of the nuclear industry's overall safety strategy. Recent advances in our thinking about organizational culture and safety were flagged and discussed in several of the conference sessions. Two, in particular, are worthy of further comment with respect to the significant challenges that they throw out to our current thinking in this area.

Haber argued for a shift in thinking from 'safety culture' to a 'culture for safety'. While at first sight this might seem only to be playing with words, such a shift could prove very significant both conceptually and in practice. It implies an important move away from treating 'safety culture' as something separate and discrete from the overall organizational culture, or as a detachable piece of that jigsaw. It offers up an alternative way of understanding the nature of 'safety culture'. It sees an organization's culture as an emergent property of the organizational system. Over many years, E. Schein has explained how this might work with a focus on 'the way we do things around here'. By this, he means how members of an organization see, think about, understand and describe the organization's world, how they share knowledge and what knowledge they share, and how problems are perceived and solved and how challenges are coped with.

These things have obvious relevance to nuclear safety. This view has been widely accepted outside the nuclear industry for some time.

Haber questioned whether the nuclear industry has ever properly understood the concept of ‘safety culture’, mentioning a continuing lack of clarity around its definition and status and around the mechanisms underpinning its influence on safety performance. She noted that, despite this relatively poor basis for operationalization, there has been a continuing development of methods of assessment and the implementation of safety culture programmes. She wondered whether the gains in safety performance associated with such programmes actually reflect a change in safety culture and if they could be sustained without reversion to the previous state. Her paper signals both the possibility of a significant step forward in our thinking towards a concept of ‘cultures for safety’ and, if not, a real need to think more critically about the existing concept of ‘safety culture’.

The conference offered a second significant challenge to our thinking about the current concept of ‘safety culture’ and from a different perspective. It is one that, given the international platform for working with the concept of ‘safety culture’, should be of real concern. In a short paper, A.J. González explored the comparative epistemology of the concept across different languages. What he pointed up was the likelihood that this concept — having been defined in the English language — could have less or different meanings in other languages.

The question is how the English language concept of ‘safety culture’ plays out in different languages and also in the national cultures that provide the context for those languages. Here, we need to think in terms not just of the major language groups, for example English vs Spanish, but also in terms of the regional and subregional variation within those groups, for example English use of English versus American English or Argentinian Spanish versus the use of Spanish in mainland Spain. Of course, this comparative analysis becomes more challenging when considering language groups that use different representations and scripts such as English (Latin) versus Russian (Cyrillic) or Mandarin (Logographic).

These language based differences are important because language both reflects and shapes our thinking and the concepts that we use and therefore our behaviour and, in turn, the behaviour of our organizations. Bringing González’s argument together with that of Haber, it is easy to see that quite naturally those working in different languages will understand the concept of ‘safety culture’ differently and behave differently with respect to it at both the individual and organizational levels. Indeed, this combined argument will also apply even if thinking shifts towards ‘cultures for safety’. In some senses, it therefore represents the greater challenge.

At the very least, these language based differences in understanding ‘safety culture’ could lead to misunderstandings and frustrations but also differences in the way problems are perceived and responded to. Arguably, our accounts of the Chernobyl and Fukushima accidents imply this. At the operational level, a related scenario could exist when an international regulator cannot understand why a safety committed provider continually falls short of the cultural requirements on them while the provider cannot understand why they can never completely satisfy the regulator in this respect. They speak different languages and therefore naturally may think about safety culture differently.

At the same time, the development of the concept of ‘safety culture’ and consideration of its utility might be held back and interesting opportunities missed if the challenge of working across a variety of languages is dismissed or ignored.

The most meaningful answer to this question of language-based differences in understanding is not necessarily to adopt one particular language as the working platform for relevant conversations and discussions. However, it is probably the easiest answer, on a number of different levels, and is more or less what happens. If so, perhaps, there is a need to further research this particular challenge as described in the conference by González.

In many ways, together these two papers, Haber and González, challenge our current thinking about ‘safety culture’ in important and useful ways. Addressing the questions that they raise will allow the nuclear industry to move forward significantly in this area. These papers are presented in this section of the Proceedings.

SAFETY CULTURE — WHAT'S IN TWO WORDS?

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A recurring theme throughout this conference Exploring 30 Years of Safety Culture, was the precise denotation of the concept 'safety culture'. 'Safety culture' is composed by two nouns, the subject culture, (arguably, the manifestations of human intellectual achievement regarded collectively), and the qualifier safety (that is the condition of being protected from or not exposed to danger or risk). In the expression safety culture, safety is not used as an adjective proper, but as a modifier of the noun culture, denoting a culture designed to prevent injury or damage. This use, while common in the English language, is imprecise and definitively objectionable in other languages

Unsurprisingly, the expression 'safety culture' is subject to subtle different interpretations, particularly in languages other than English. Depending on the preposition being assumed to link 'culture' with 'safety', the denotation of safety culture can be very different. Is it a 'culture of safety', an expression denoting association of belonging between culture and safety? Or is it a 'culture for safety', a culture in favour of safety, affecting safety, to the benefit of safety, having as a purpose safety, or having safety as a reason or cause? Or it is a 'culture by safety', indicating that safety just happens with culture? Or is it 'culture through safety', that is a culture from the beginning to the end of safety? Hopefully, it is not a 'culture against safety!', but grammatically it could be. All these ideas appear to be of the same kind in appearance and character, but they are not identical but rather subtly diverse. It is noted that in the Spanish and French translations of safety culture the preposition used was 'of" ('de'). However, in the new revision of the IAEA General Safety Requirements on 'Leadership and Management for Safety', the preposition used is 'for'. Moreover, during the conference, there were even proposals of using the expression cultural safety, in which the noun becomes an adjective and the adjective becomes a noun. This significantly changes the meaning of the concept.

In fact, it was noted, there are many national denotations of the expression safety culture, some of them differing markedly from the international definition in the IAEA nuclear safety glossary. This 'international' definition reads as follows: safety culture is the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance. However, this description is not very helpful for identifying the preposition intended for linking the two nouns. A popular definition of safety culture is described in Wikipedia as: safety culture refers to the ways that safety issues are addressed in a workplace, reflecting the attitudes, beliefs, perceptions and values that employees share in relation to safety; in other words, the way we do safety around here. This definition very much reflects Schein's seminal work.

The lack of a globally agreeable and precise understanding on what safety culture really means has caused significant bewilderment and has challenged its operationalization. Perhaps due to vagueness on the precise denotation of safety culture, it was argued during the conference that the concept should be considered intangible and therefore unfeasible to regulate as a whole and thus unable to be subjected to legally binding obligations. This was always clear in the nuclear area (e.g. safety culture is not a legally binding obligation under the Nuclear Safety Convention). During the session it became apparent that this also seems to be the case in other applications.

FROM SAFETY CULTURE TO CULTURE FOR SAFETY
What is it that we still have not learned?

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Abstract

The Chernobyl accident happened in April 1986. In 1991, the IAEA's International Nuclear Safety Advisory Group published INSAG-4 and the concept of safety culture was defined for the nuclear community because of its relationship to the accident. Work in the nuclear community evolved around the concept of safety culture although a clear understanding of what was actually meant was often missing. Methods to evaluate and assess safety culture were developed. Safety culture became thought of as a process that could be written into a procedure, measured by performance indicators and fixed in a corrective action program. Short term improvements in safety performance and the metrics to measure them were observed and many concluded they had really changed their safety culture. The changes were often not sustainable. The efforts did not include an in-depth understanding of why individuals thought or behaved in the way that they did. In March 2011, the Fukushima Daiichi accident took place. The IAEA conducted an in-depth analysis of the human and organizational factors of that accident and drew a number of conclusions, but none as critical as the finding that while the same natural phenomena might not occur in every nuclear facility around the world, the same human and organizational issues could. What is taken for granted and what is assumed represents culture and will influence behaviours, decisions, and what is attended to. By working within the organizational culture to achieve and maintain safety performance a more realistic and sustainable outcome will result. It is time to shift the thinking in the nuclear community from safety culture to culture for safety. It is the necessary step for each organization to try to move forward to achieve long term sustainable safety performance.

1. INTRODUCTION

The Chernobyl accident happened in April 1986. Several years later, in 1991, the IAEA International Nuclear Safety Advisory Group published INSAG 4 [1] and the concept of safety culture was defined for the nuclear community because of its relationship to the accident. Where the Three Mile Island accident in 1979 had brought human factors issues in procedure development, human performance, and training to light, the Chernobyl accident was discussed in terms of management, supervision, and safety culture. Work in the nuclear community evolved around the concept of safety culture although a clear understanding of what was actually meant was often missing. Methods to evaluate and assess safety culture were developed and efforts to integrate the findings of those evaluations into more traditional nuclear tools, such as probabilistic risk/safety assessment were attempted as well. Safety culture became thought of as a process that could be written into a procedure, measured by performance indicators and fixed in a corrective action program. The changes that organizations saw as a function of their safety culture improvement programmes though were often just changes in some behaviours. Short term improvements in safety performance and the metrics to measure them were observed and many concluded they had really changed their safety culture. The changes were often not sustainable. The efforts did not include an in-depth understanding of why individuals thought or behaved in the way that they did.

In March 2011 the Fukushima Daiichi accident took place. Initially, it was explained as a natural disaster. While the earthquake or the tsunami could not be prevented, there were things that could have been done before, during and immediately after the natural phenomena that would have helped to mitigate the consequences of the accident. The IAEA conducted an in-depth analysis of the human and organizational factors of that accident [2] and drew a number of conclusions but none as critical as the finding that while the same natural phenomena might not occur in every nuclear facility location around the world, the same human and organizational issues could. What is taken for granted and what is assumed represents culture and will influence behaviours, decisions, and what is attended to. There is a need for the nuclear community to move forward now in the way it thinks about safety culture. By thinking about culture as the foundation for the shared beliefs and values in any organization the realization that improvement programmes will not succeed with short term efforts but rather will require time and commitment, will be evident. By working within the organizational culture to achieve and maintain safety performance a more realistic and sustainable outcome will result.

2. THE PAST 30 YEARS

After the accident at Chernobyl many efforts especially across North America and Western Europe were initiated to better understand the influence of organization and management on safety performance. The challenge was in recognizing that this was an area that had not been relevant for the nuclear community up until this point. Experts in fields outside of the traditional areas associated with nuclear technology had not been involved in ensuring nuclear safety.

From the North American perspective, researchers at the University of California at Berkeley were involved in studying ‘high reliability organizations’ [3]. High reliability organizations were those that could not afford to make a mistake because the consequence to public health and safety would be significant. Initially their work focused on naval aircraft carriers and air traffic controllers. Concurrently, the US Nuclear Regulatory Commission (NRC) began research into the influence of organization and management influences on performance reliability in nuclear power plants [4]. In the late 1980s, the two sets of researchers worked together and conducted a study that involved both a fossil and nuclear power plant for the feasibility of a methodology that could evaluate these organization and management factors. For the NRC researchers the goal was to develop a methodology that would allow the quantification of these factors so they could be incorporated into probabilistic risk assessment. For the Berkeley researchers the goal was to continue to delineate the characteristics of high reliability organizations. Both objectives would eventually become critical in the evolution and implementation of the concept of safety culture.

Over the next several years the NRC researchers continued their work and published the results of their efforts [5]. A systematic, more objective and standardized methodology for assessing the influence of organization and management on safety performance was developed and implemented. When the NRC decided to discontinue the work, their own Advisory Committee for Reactor Safeguards published comments that recognized “management science as a real and sophisticated academic field that needs to be tapped if the industry is to continue to make progress in dealing with organizational performance issues.” The comments go on to say that “There appears to be a lack of communication between the management science academic community and most policy-makers out in the ‘real world’ of nuclear power plant regulation and operations. We believe that the Commission should encourage the involvement of the management science community in helping to improve the organizational performance of both the staff and the nuclear utilities” [6]. The NRC discontinued the management science aspects of the project for several reasons and the US commercial nuclear industry took responsibility for ensuring that the management aspects of the nuclear plants’ performance would promote and ensure safety [7]. Efforts were being made in other countries to continue such work and use the methodology developed by the NRC research to promote their own objectives [8]. In addition, a review of the theory and research around the nature of safety culture was published in 2000 [9].

In 2002, the Davis Besse reactor vessel head event in the USA occurred. In spite of issues identified by employees over years and bulletins about the existence of similar problems across the industry, management at the First Energy Corporation allowed the problem to continue. During the 2002 refuelling outage a ‘hole’ in the reactor vessel head created by boron leakage had gotten to within ¼ in of the lining of the vessel. The causal analysis of the event identified ‘safety culture’ as the root cause. It was the first time in the US commercial industry that the term safety culture was used as the basis for a failure in the performance reliability of a nuclear power plant.

Around the same time as the Davis Besse event, the IAEA published a document identifying the characteristics in an organization necessary for a strong safety culture [10]. The IAEA described five characteristics along with multiple attributes for each characteristic. In 2004, two years after Davis Besse, the Institute for Nuclear Power Operations (INPO) in the USA published Principles for a Strong Nuclear Safety Culture [11]. INPO identified eight principles of a strong nuclear safety culture. The NRC published Safety Culture Components and Attributes in 2006. The NRC identified 13 components with multiple attributes associated with each component. In 2014, 28 years after Chernobyl, and 12 years after Davis Besse, the NRC, INPO and other nuclear license holders in the USA agreed on the Traits for a Healthy Safety Culture [12]. Ten traits were identified with multiple attributes for each trait. In 2015 the IAEA initiated an effort to get the IAEA, INPO, NRC, and the World Association of Nuclear Operators (WANO) to agree upon a common language with respect to safety culture; that effort is ongoing.

During the time of the development of these various frameworks for safety culture one thing was clear; most organizations did not really understand the concept, know how to assess it or know what to do about it if change was required. The concept of safety culture became treated as a discrete entity that could be easily measured, managed through performance indicators, and ‘fixed’ with a corrective action. Safety culture improvement programmes often consist of hundreds of corrective actions that organizations believe can be completed individually and independently to obtain the desired results. Experience has shown that what these actions and programmes are really changing is safety performance as represented by expected behaviours and outcomes. Often these changes are only short term because the basis of the behaviour, and consequently the performance, is not understood well enough to ensure the changes are long term and sustainable.

3. EMPHASIS SHIFT — WHY ‘CULTURE FOR SAFETY?’

The term safety culture should implicitly create the necessity to identify and understand the concept of culture as much as the notion of safety. This has been a weakness in the thinking to date. Schein published a model of organizational culture which has become widely accepted and describes three levels that comprise culture: artefacts, espoused values and basic assumptions [13]. The artefacts are the observable outcomes that are representative of culture that can be seen, e.g. behaviours, practices, and policies. The espoused values are the claimed shared values and norms that the organization communicates. The basic assumptions reside in the lowest level of culture and are the most difficult to capture. As Schein defines culture: "The shared basic assumptions that have come to be taken for granted and that determine the member's daily behaviour" [14]. Basic assumptions are often unconscious or subconscious and are reflected in behaviours that are done automatically without reflection or analysis. It is from this level that culture drives organizational behaviour which results in performance and impacts all aspects such as safety, security, production or economics.

The idea of basic assumptions is best explained through an example. Assume that an organization shares a basic assumption that its employees are productive, creative, and motivated. When someone sees an employee sitting at their desk and staring out the window the basic assumption will drive the belief that this individual is thinking about a new idea or trying to resolve a problem. If the same organization, however, shares a basic assumption that its employees are lazy, not creative and non-motivated, then when someone sees an employee sitting at their desk and staring out the window the assumption will drive the belief that this individual is daydreaming, wasting time and being non-productive. Same behaviour, sitting at the desk and staring out the window, very different conclusions. The importance of basic assumptions in understanding behaviour and the reasons that certain actions occur cannot be over stated.

By better understanding the concept of culture it becomes clear that the idea of 'safety culture' and how it has been conceived, assessed and managed to date, is not getting at the lowest level of culture, the basic assumptions. It is the artefacts and some of the espoused values that have been assessed, measured and managed by most organizations. By not getting at what drives the behaviour that is observed, the changes that are made become short lived and often revert back to their original form not long after corrective actions have been implemented. This creates the cyclical nature that is often observed in performance in many organizations. The intention of organizations in trying to implement safety culture improvement programmes is by and large sincere, but without the incorporation of an understanding of the organization's culture and how it drives performance, the results are not likely to be effective over the long term.

The idea of 'culture for safety' more accurately reflects what must be understood and described for an effective and sustainable change in safety performance. Thinking back to some of the original definitions of 'safety culture' [9] we can create a working definition of 'culture for safety'. Culture for safety refers to "the characteristics of the work environment, such as the values, rules and common understandings that influence employees' perceptions and attitudes about the importance that the organization places on safety" [15].

4. METHODOLOGICAL PREMISES

To describe a culture for safety accurately, an organizational cultural assessment must be conducted, whose focus is safety performance. This implies some methodological premises:

— Models of organizational culture identify behaviours as the observables of the values and beliefs underlying them.
— Understanding the behaviours and having reliable and valid tools to assess and describe them is the most effective way to understand and assess organizational culture.
— Too often organizations just look at processes or indicators which are only outcome measures and may be obtained by several different behaviours.
— The complexity of the relationships between individuals, technology and organizations must be considered to fully understand the organizational culture for safety.
— A safe working environment is impossible without an effective organizational culture for safety.
— Organizational culture consists of the context within which behaviours occur and the expectations and values that are perceived to be reinforced by the organization.
— A method that allows objective and systematic measurement of the organizational behaviours that impact safety performance is a necessary tool.

5. EMPHASIS SHIFT — CONSEQUENCES AND PRACTICAL IMPLICATIONS

Five characteristics of a high reliability organization have been described [16]. Since the high reliability model has been well documented in the scientific literature it is being used here as an example of how the change in thinking around basic assumptions can be valuable. In thinking about shifting our emphasis from safety culture to culture for safety it is useful to describe how the basic assumptions of an organization might drive the characteristics of a high reliability organization. The consequence of thinking in this way is that focusing on the potential basic assumptions driving those characteristics will help to promote a more sustainable change towards a high reliability organization. The five characteristics are:

(a) Preoccupation with failure. High reliability organizations are always thinking about the ways in which they can fail or get into trouble. Examples from organizations that have had significant events indicate that they did not have this preoccupation with failure and in fact most probably worked on the basic assumption that we are safe [2]. What if the basic assumption was 'Are we safe?' The consequence of that type of thinking would drive the organization to be more preoccupied with failure.
(b) Reluctance to simplify interpretations. Simplified interpretations of why things happen do not often address the real reasons that certain actions or behaviours occurred. Simplification also does not recognize the complexity of events and it does not promote thinking 'outside of the box'. The basic assumption driving simplification may well be, 'We have the answer'. What if the basic assumption was, 'What have we not considered?'. The consequence of that type of driver will help to prevent complacency and move the organization to continuously examine events without accepting the fastest or simplest explanation.
(c) Sensitivity to operations. In a highly reliable organization individuals are aware of the systems in the organization. They cannot necessarily operate all systems but they are sensitive to how the system should operate and therefore become critical in identifying any unusual occurrences. In many organizations the basic assumption around this characteristic would be 'It's not my job' and individuals would not take responsibility to identify or help resolve a problem. What if the basic assumption in the organization was 'Each person plays close attention to what is and what is not working?' The organization would become more efficient and effective in identifying and resolving its problems before they become bigger issues.
(d) Commitment to resilience. Many organizations during unusual or problematic situations explore resolutions that are within their 'toolbox'. If none of those solutions work there is a reluctance to go beyond what they have anticipated. The basic assumption driving this performance is probably, 'We have no more alternatives'. The high reliability organization, recognizing the value in being resilient, is most likely driven by the basic assumption, 'We are relentless to succeed.' The value to succeed far outweighs the risk of going in an unexplored direction and the organization relies on what it knows it can do successfully to move forward in these situations.

(e) Deference to expertise. The deference to expertise is often lost in many organizations because of hierarchical expectations and the belief by members of the organization that not knowing something is a sign of weakness. The basic assumption driving this behaviour is that people in the organization believe that, 'I already know that' and do not value or listen to others in the organization. In a high reliability organization the members are more likely to be driven by the basic assumption, 'There are people who know more than me in this area'. They will defer to those with more experience and expertise for support and problem resolution.

The practical implications going forward and shifting the emphasis to thinking about a culture for safety are not insignificant. First, there must be the recognition of the importance of understanding and assessing organizational culture. Second, if culture is the driver of performance in an organization, how are leaders selected going forward? How are leaders trained to use the description of culture in their organization to achieve the performance goals and standards that are required? Third, what needs to be measured and how so that performance can be continuously improved? Fourth, how is sustainable change achieved? What does a culture for safety improvement programme look like? Finally, there needs to be a recognition of the complexity of culture and the need for a diversity of expertise to establish, develop, implement, maintain and change a culture for safety. A systemic approach is needed to effect a successful outcome.

6. CONCLUSIONS — CULTURE FOR THE FUTURE

In order for organizations to move forward from thinking about safety culture to culture for safety several important steps must be taken. Organizations must use reliable and validated tools for the assessment and analysis of the underlying basic assumptions of organizational culture and they do exist. Organizations must also recognize the need to learn from successes as well as failures. This will make organizations more resilient to future events. There needs to be a serious effort to comprehend the dynamic interplay between humans, technology and organizations using a systemic approach to looking at safety performance. As the whole system is far too complex for one individual to comprehend, an integrated approach is needed. A diversity of expertise and thinking will be required to effectively understand the cultural drivers of safety performance.

By thinking about culture as the foundation for the shared beliefs and values in any organization the realization that improvement programmes will not succeed with short term efforts but rather will require time and commitment will be evident. By working within the organizational culture to achieve and maintain safety performance a more realistic and sustainable outcome will result. It is time 30 years after the Chernobyl accident to shift the thinking in the nuclear community from safety culture to culture for safety. It is the necessary step for each organization to try to move forward to achieve long term sustainable safety performance.

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SUMMARIES OF PARALLEL SESSIONS

Chairpersons

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South Africa

A.J. GONZÁLEZ
Argentina

N. AHN
Republic of Korea

CHAIRPERSON'S SUMMARY

PARALLEL SESSIONS ON LEADERSHIP, MANAGEMENT AND CULTURE FOR SAFETY

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Leadership, management and culture for safety were topics that were discussed during the conference. The participants in this session included members from utilities, regulatory authorities, vendors and international organizations. The topics were discussed over three parallel sessions that consisted of a total of 12 presentations. The overall theme was: 'The role of leaders and managers in developing, nurturing, maintaining and continuously improving the culture for safety in the organization they led'.

1. SESSION 1

This session focused on opportunities for learning and how organizations put the lessons learned into action.

S. Haber, Human Performance Analysis Corp., USA, made a presentation entitled 'From Safety Culture to Culture for Safety — What Is It That We Still Haven't Learned?' The presentation described the history of safety culture over nearly 30 years, taking into consideration lessons learned from Three Mile Island, Chernobyl, Davis Besse Reactor Vessel Head and the Fukushima Daiichi accident. Haber emphasized that the concept of safety culture had been defined specifically for the nuclear community because of its relationship to such accidents. The Three Mile Island Accident in 1979 had highlighted human factors issues in procedural development, human performance, and training. The Chernobyl accident was discussed in terms of management, supervision, and the prevailing safety culture. The nuclear community has continued to work around the concept of safety culture, although Haber believed that a clear understanding of the definition of safety culture was still missing.

Methods to evaluate and assess safety culture have been developed and efforts to integrate the findings of those evaluations into more traditional nuclear tools, such as probabilistic risk and safety assessment, have been attempted. After the Fukushima Daiichi accident, the IAEA conducted an in-depth analysis of the human and organizational factors associated with the accident. One of the highlights from the report was that while the same natural phenomenon might not occur in every other nuclear facility location around the world, the same people and organizational issues could. Things taken for granted and the underpinning assumptions fostered by the prevailing culture influence behaviours and decisions. Haber urged the nuclear community to consider what was needed to move forward in relation to safety culture.

Haber argued that when thinking about culture as the foundation for the shared beliefs and values in any organization, the realization that improvement programmes will not succeed with short term efforts. Rather, they will require time and commitment. It takes working within the organizational culture to achieve and maintain safety performance. It has been 30 years since the Chernobyl accident. It is now time to shift thinking in the nuclear community from safety culture to culture for safety. This is the necessary step for each organization when trying to try to move forward to achieve long term sustainable safety performance. An integrative approach is more likely to influence positive culture for safety through behavioural change than just more singular performance measures. When using cultural understanding to promote change, there can be more sustainable performance. When the organizations learn from their successes as well as failures then they will be more resilient to future events.

B.M. Tyobeka, National Nuclear Regulator, South Africa, presented on Leadership for Safety in Practice: Perspectives from a Nuclear Regulator. The principal responsibility for a nuclear regulator is to ensure compliance by operators with regulations and safety standards. One of these requirements is the demonstration of, and adherence to, a nuclear safety culture by the operators. At the same time, the regulators themselves are expected to live the talk and practice that they preach. That is, they must demonstrate the highest levels of nuclear safety culture within their organizations. Regulators have a critical role in ensuring the stringent monitoring and implementation of measures to eliminate or minimize human errors during the entire value chain and life cycle of a nuclear facility thereby preventing accidents.

Consequently, it is recognized that leadership is important in the creation of a culture that supports and promotes a strong nuclear safety performance of an organization. The leaders of a regulatory body are vital in inspiring employees to a higher level of safety and productivity, which means that they must apply good leadership attributes on a daily basis. Human error and performance are two sides of the same coin. Human errors could have a major impact (both positive and negative) on: the condition of plant, financial resources, morale of employees, quality of supply to customers' health and safety which might lead to injury or death. Human error must be eliminated in nuclear facilities as the results could have catastrophic consequences. We need to recognize that nuclear safety is an encompassing term and that all parties involved in the value chain could potentially impact nuclear safety.

F. González, Tecnatom, Spain, made a presentation on the Experience of Tecnatom in Developing a Strong Leadership for Safety and Performance. The presentation described Tecnatom's experience and insights in support of internal and external clients to develop a strong leadership for safety. Such support includes:

- Leadership competencies for safety and the ability to inculcate cultural change;
- Development and implementation of a leadership model;
- Design and implementation of a training programme on safety culture for top managers.

One important characteristic of the Tecnatom programme was the detailed evaluation of the underlying organizational culture that underpins safety culture. Measurable improvements have been achieved as a consequence of the training. González describes the development and implementation of the model, which included 17 leadership competencies. The benefit of such a model is that it allows the user to perform a quantitative assessment of leadership effectiveness in the safety domain. The model uses an approach to development which is oriented towards existing strengths, which may be complemented to enhance leadership competencies. Moreover, it also aims to produce significant improvements in performance, since productivity and safety should not be competing goals if the proper leadership model is selected. The programme was also designed to be sensitive to the time availability of top managers. It uses a combination of learning approaches such as: webinars, e-Learning, web meetings that provide higher flexibility for the user. These are complemented by other proven methods such as group dialogue, journaling and mentoring. González was clear on the importance of leadership in enhancing safety culture.

All these experiences suggest that to improve the organizational safety culture needs to enhance leadership for safety and performance.

J. Julius, Curtiss-Wright, USA, discussed the Use of Human Reliability Insights to Improve Decision Making. The presentation described the use of such insights obtained during the development and application of human reliability analysis (HRA) as part of a probabilistic risk assessment (PRA) to support decision making. The challenge included consideration of improvements to operations, training, and safety culture. Such insights have been gained from the development and application of HRA as part of a PRA for nuclear power plants in the USA, Europe and Asia over the last two decades. The model consists of Level 1 and Level 2 PRA models of internal and external events, during full power and shutdown modes of plant operation. These insights include the use of human factors information to improve the qualitative portion of the HRA.

The subsequent quantification in the HRA effectively prioritizes the contribution to the unreliability of operator actions. The process facilitates the identification of the factors that are important to the success of the operator actions. Additionally, the tools and techniques also allow for the evaluation of key assumptions and of sources of uncertainty.

The end result has been used to effectively support decision making for day to day plant operations as well as licensing issues. HRA results have been used to provide feedback and improvements to plant procedures, operator training and other areas contributing the plant safety culture.

2. SESSION 2

During the second session, the speakers and their organizations shared their current activities for monitoring and developing leadership, management and culture for safety.

F. Guarnieri, École Nationale Supérieure des Mines de Paris (MINES ParisTech), France, presented a paper entitled Entering into the Unexpected: Managing Resilience in Extreme Situations. Guarneri explained both the concept of resilience and the concept of resilience in extreme situations. He used the Fukushima Daiichi accident as an example to show that the earthquakes, tsunamis and resulting nuclear accident were unexpected and reminded the participants that it was the same with Chernobyl and Three Mile Island. These accidents were a surprise to everyone. The characteristics of extreme situations include (inter alia) hostility, uncertainty, limited resources and social pressure. The goal now is to both understand and exhibit resilience. Resilience is the capability to bounce back rapidly through survival, adaptability, evolution, and growth in the face of turbulent changes and or brutal and dramatic events. Resilience is a dynamic process, and at the time of resilience activation, one needs to study the moment and ask, is this mechanism:

- A movement;
- A transition;
- A time dimension;
- An exploratory zone;
- A learning phase;
- A new system (temporary)?

These concepts were further elaborated in Guarnieri's paper.

S.A. Adamchik, State Atomic Energy Corporation "ROSATOM", Russian Federation, made a presentation on safety culture in Rosatom. He described Rosatom's current activity in its safety culture enhancement. During the last 30 years, much work has been undertaken with regard to improving safety culture. However, he believed that, even after such a long period of time, there were still questions to answer in this important domain, including:

— How to formulate safety culture.
— How to assess safety culture.
— How to implement safety culture.

Rosatom uses the three concepts of safety culture as provided by the IAEA, Russian safety regulations and the World Association of Nuclear Operators. The approach is the same, priority to safety, but the definitions differ in their focus towards leaders, teams and individuals. Safety culture should be addressed at all levels of management.

Rosatom believes that there are two key elements in safety culture activities: (1) knowledge and competence, and (2) responsibility.

Safety is one of the six organizational values of Rosatom. There is also the belief that safety culture must be cascaded down from the State level (acts, laws, legislation, etc.) to individual nuclear facilities. Finally, the human factors, people, are regarded as the most important factor in ensuring safety. People make mistakes and we need to minimize those mistakes. Adamchik commented that the IAEA plays a big role in bringing the necessary experts together.

B. Zronek, ČEZ, S.A., Czech Republic, addressed Safety Culture Monitoring — How to Measure Safety Culture in Real Time. As safety culture is understood as a vital part of the nuclear industry's daily life, it is crucial to know what the current level is. It is vital to be able to follow current trends and understand what the contemporary issues are. To identify safety culture improvement priorities, the focus should not only be on its weak points, but also on its strengths. It is common practice to perform safety culture surveys or ad hoc assessments. This can create an isolated assessment system. The use of behavioural related outputs of gap solving systems, observation programmes, dedicated surveys and regulatory assessment, for example, allow the creation of real time safety culture monitoring without the need to perform any other activities.

In the Czech Republic, safety culture surveys are conducted once in three years at a corporate level and annually at power plant level. The focus is on both positive and weak points. The assessment inputs are categorized by:

— External assessment (peer reviews);
— Independent assessment (individual);
— Internal assessment (self-assessment).

It is better to use the current assessment methods and not entertain any other new activities unless absolutely necessary. There is a need to speak one language as processes remain the same, but different inputs and methods are used to identify what is wrong. There is a need to evaluate the results of such assessments and then conduct follow-ups.

D.J. Williams, INPO, USA, made a presentation on Leadership and Safety Culture: An INPO Perspective. He argued that safety culture is, at its heart, about people and that leaders build cultures for safety through people. INPO believes that strong leaders and leadership teams are essential for high levels of safety and strong safety cultures. Some of the industry's challenges include worker deficiencies in applying knowledge and skills, supplier and non-nuclear support performance, and resilience in the face of external events.

The characteristics of good performers and what good leadership should look like are demonstrated in people understanding their roles and what they should to do. The organization's visions are important. Some NPPs show declines in performance because their vision is not defined properly. Workers do not know what the vision is. There can be high turnover but low coaching and accountability. Positive coaching and defined accountability can change behaviour in organizations.

Weak leadership has a negative impact on performance. The link between the presence of effective leadership teams and high levels of sustainable performance is supported by numerous examples throughout the industry's history. Unfortunately, at times, site and corporate leaders are either unaware of declines in performance or are slow to react to them.

INPO has determined that weak leadership teams and weak organizational cultures have continued to challenge the industry's performance and are key drivers of plant declines. After reviewing industry strengths and areas for improvement and relevant research, nine leadership attributes and five team attributes have been identified as associated with high performance. INPO has captured these attributes in the document INPO 15–005, Leadership and Team Effectiveness Attributes. The aim is to help the industry more quickly identify weak leadership behaviours and help prevent plant performance declines.

3. SESSION 3

The third session provided a platform for participants to share their thinking about how future challenges to nuclear safety can be approached.

L. Axelsson, Swedish Radiation Safety Authority (SSM), Sweden, presented the work of the NEA/CSNI Working Group on Human and Organizational Factors (WGHOF). The OECD/NEA is a forum for cooperation between the most advanced countries in the world. The Working Group on Human and Organizational Factors (WGHOF) has a mission to improve the understanding and management of such factors (HOF) within the nuclear industry. Its aim is to support the continued safe performance of nuclear installations and improve the effectiveness of regulatory practices in member countries. The WGHOF expert group consists of member countries, regulatory and technical safety organizations, research institutions, the industry, and international organizations such as the IAEA.The WGHOF identifies and prioritizes HOF issues, methodologies, practices and further research needs. Topics covered over recent years include:

- Plant maintenance which is of concern with regard to HOF;
- Management within NPP activities (WGHOF hosted a workshop and developed a technical opinion paper in 2008);
- Plant modifications processes (a number of workshops and a technical opinion paper were developed in 2008);
- New plant technology;
- Oversight.

Recent work includes:

- Integrated system validation (ISV);
- Fukushima Daiichi accident (follow-ups to ensure that lessons learned are properly addressed).

The issue of reliability versus resilience requires us to think about how we can adapt when we face an unexpected challenge. When you are confronted by such a surprise, your perceptions of the world and of reality are incompatible. The big question is how can you train for this situation? How can we conduct training in managing such difficult conditions? Would simulations be ethically correct? Deregulators support only reliability, or do they support resilience as well? These are things to be explored. In relation to assessment of resilience in the organization:

— We need to identify gaps in resilience;
— We need to adopt systematic approaches to safety culture;
— We need to know where we are now and how far we are from our goals.

E. Fischer, E.ON, Germany, presented Leadership and Safety Culture: Leadership for Safety. Since the German 'Energiewende', leadership has become an increasingly important issue. Following the challenge to operate NPPs at a high level of operational excellence, highly skilled and motivated organizations are needed. Leadership becomes a critical success factor. At the same time, a well engineered, safety oriented design for NPPs remains necessary. Beyond their design and build, NPPs constantly require maintenance, ageing management and lifetime modifications.

E.ON tries to keep its nuclear units as close as possible to state of the art science and technology and beyond the requirements of German regulation.

In its opinion, the safe and successful operation of NPPs is due to:

— The highest priority being given to protecting people, the environment and assets;
— Safety positive attitudes and values as part of a living safety culture;
— Effective and sustained leadership for safety;
— Effective leadership and a strong safety culture throughout the overall business; suppliers, utilities, independent examiners and regulatory bodies.

German NPPs are regularly listed in the top ten worldwide in terms of their safety, accessibility and production of electricity. This is because of their safety culture, ways of working, levels of performance, and operational excellence. From their experience, leaders should:

— Take responsibility, strive for excellence, and convince people to see change as an opportunity;
— Promote innovation and lead by example;
— Ensure that nuclear safety culture is a core leadership responsibility;
— Raise the bar whenever possible;
— Use reviews to discuss and evaluate observations in order to be able to identify trends and to avoid any decline in plant improvements;
— Avoid complacency.

D. Engström, Swedish Nuclear Fuel and Waste Management Co., Sweden, presented a paper on the Limitation of Managing Safety by Numbers. The presentation discussed four issues, among other things. These were: the effectiveness of computerized reporting systems, data trending and categorization; why computerized reporting systems and trending have had such a big impact in the nuclear industry; the scientific perspective on knowledge; and the illusion of control.

Engström argued that a categorizing and trending in nuclear safety may lead to managing safety by numbers which may uphold an illusion of rationality and control, but which can lead to box-ticking. They believe that this focus can also lead to the standardization of complex systems through simplistic methods of categorization or trading. As a result of these timings a ‘false’ answer might be given to the question of what is actually wrong with the organization. Engström emphasized the need to understand the limitations of each of the analysis systems involved (trending, categorizing), as well as the need for more detailed investigations and root cause analyses.

L. Hu, Ministry of Environmental Protection, China, presented Cultivating and Development — 30 Years Practice of Safety Culture in China. Safety culture has been cultivated and promoted in China since its very beginning by the IAEA. The first stage (exploration), from 1984 to 2007, was one in which the international concept of safety culture was imported to China and studied. The framework was set by the processes of combination and convergence with the positive elements of Chinese traditional culture. The basic ideas, such as the principles of and guidance for nuclear safety, were established in China.

The second stage (practice and maturation) was from 2006 to 2014, when safety culture was promoted by the Government and by the regulatory body (NNSA). NNSA established its basic supervisory values based on safety culture. The Chinese nuclear industry was encouraged to develop its safety culture.

The third stage (rapid development) was from 2014 to the present day. The Chinese President announced, at the Chinese Nuclear Security Summit in The Hague in March 2014, that a strong safety culture would be fostered in the nuclear industry and nuclear safety would be put at the highest level. The policy declaration was issued and the nuclear safety promotion special action was carried out by NNSA. Safety culture is now widely accepted and acknowledged by the nuclear and by the radioactivity-relevant industry.

4. FINAL REMARKS AND CHAIR’S SUGGESTIONS

The three sessions shared a number of common themes and these are elaborated in the following section alongside a call for action.

4.1. Key messages

Leadership and management for safety have long been recognized as the core ingredient of a strong culture of safety within the nuclear community. Thirteen key messages were identified across the sessions and the papers presented as follows.

The IAEA's Fundamental Safety Principles (Principle 3) and General Safety Requirements (GSR-3) are evidence of such a consensus. The generally accepted approach for developing a strong safety culture is through an effective management system with an emphasis on leadership. However, the best management systems, good compliance processes and procedures are no substitute for a pair of hands that has to fiddle with the systems and its components (pumps, valves, etc.).

Leadership will always count and helps shape the attitudes and behaviour of the workforce. It is at the heart of the culture for safety. Leadership must own up and take responsibility for safety. To deal with scepticism, leaders must provide independent relevant proof, and demonstrate with actions and not just words. They must listen with open minds without filtering. The reality of the manager may be different from that of the workers that he or she leads.

Top management is not always aware of what is going on within its organization. Upward communication and trust are pivotal for the culture of safety and managers must be prepared to solicit negative upward communications. Management must break up psychological and social silos. Furthermore, as organizations age, different departments develop their own cultures. These can distort the overall organizational culture and consequently can interfere with a culture for safety.

Leaders must eradicate the blame culture if a culture for safety is to thrive. Leaders and managers must be properly trained to communicate with workers and vice versa. More emphasis must be placed on qualified and competent leaders.

4.2. A call for action

Based on discussions in the three sessions, an eight point call for action might be described as follows:

- More work has to be done in fostering a culture of interdisciplinary appreciation.
- Tools to objectively measure effective culture for safety with greater validation need to be developed.

— Regulatory bodies need to be taken along the journey to a strong culture for safety; strong leadership for safety is called for within the regulatory system.
— Leadership for safety under extreme situations in relation to resilience needs to be researched further.
— Leadership and management must be cognizant of different generational dynamics when trying to foster values and beliefs relevant to a culture for safety.
— Nuclear leaders can benefit from a closer collaboration with leaders of other high performance industries in strengthening a culture for safety.
— A shift away from managing by numbers and over-relying on trends and categorizations is needed for leaders to take decisions that support a culture for safety.
— Ultimately, a move from safety culture to a culture for safety should be the new norm and imperative.

CHAIRPERSON'S SUMMARY

PARALLEL SESSIONS ON APPROACHES TO SAFETY OF OTHER HIGH RELIABILITY ORGANIZATIONS

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The three parallel sessions dedicated to approaches to safety of other high reliability organizations addressed many issues related to the attitude to safety culture in other organizations presenting high level of trustworthiness and commitment with regard to safety. What follows are the Chairperson's summary views on the presentations and discussions. The nature of the subject necessarily implieds that the issues could not be grouped in a logical order, mainly due to their diversity, and are therefore presented in the order of the presentations. These were important sessions as they provided many opportunities for the nuclear industry to learn from practical experience of developing safety culture in other high reliability organizations (HROs).[1] The human and organizational aspects raised within the broad and varied range of presentations could occur in any organizational setting, including the nuclear industry. Major accidents and incidents in the nuclear sector may have been prevented if the industry had been more receptive to inter-industry learning opportunities presented in these sessions.

[1] HROs have been defined by Rochlin as "organizations that have not just avoided failure through good fortune or the vagaries of probability, but that have actively managed to control and reduce the risks of technical operations whose inherent hazards make them prone to catastrophic failure (ROCHLIN, G.I., "Defining 'high reliability' organizations: A comparative framework", New Challenges to Understanding Organizations (ROBERTS, K.H., Ed.), Macmillan, New York (1993)). HROs include, among others, the aviation, chemical, nuclear, offshore and rail sectors.

1. SESSION 1

R.H. Taylor, University of Bristol, United Kingdom, presented a paper on Managing the Organizational and Cultural Precursors to Major Events — Recognizing and Addressing Complexity. Taylor noted that the occurrence of significant safety events is not unique to nuclear activities. Major events have happened in many organizations in different industries and fields of activity. The key organizational and cultural precursors of such events have been systematically reviewed by Taylor's research team. It discovered that such organizational and cultural precursors were strikingly similar across most major events. These were then grouped under eight generic headings. Organizational learning was one of these headings. Failures to learn were recurrent in many organizations due to various reasons: a blame culture; failure to investigate events; patterns of learning that had not been consolidated.

Questions were asked about the use of research findings to better develop a sustainable safety culture. A number of approaches were proposed, including raising employee awareness; thorough investigation of events; reviewing regulatory requirements; condition monitoring and a more systematic approach, including hierarchical process modelling (HPM) and techniques such as mapping systems dynamics.

HPM has been used in the development of probing question sets. The output from this process can then be used to identify actions for improvement. In order to avoid any unintended consequences, the use of casual loop diagrams as described in Taylor's paper was recommended. System dynamic modelling implies thinking through implementation, looking at performance measures and indicators.

The importance of the client–contractor interface was highlighted. In practice, the process mapping required a large wire table to accommodate the consequences and relationships between the client and the contractor on the map.

In summary, organizational and cultural precursors to events have been investigated across a number of HROs. The complexity of such events has been recognized. It was concluded that:

- The common findings on factors leading to major organizational accidents are very similar across different organizations, regardless of the industry.
- These common findings can be actively used in many ways: reviewing; monitoring; raising awareness; systematic modelling, etc.
- Lack of organization-wide learning was found to be a major precursor of major events. The importance of organizational learning processes was stressed.

— Techniques for a better and more systematic approach to learning have been developed and introduced focused on the client–contractor interface. As with probabilistic safety assessment (PSA), quantification should be used with care when employing systematic techniques such as HPM.
— The findings on common failure patterns should enable operators to implement effective action plans for the improvement of safety culture in their facilities.

S. Elegba, University of Abuja, Nigeria, addressed the Evolution of Radiation Safety Culture in Africa: Impact of the Chernobyl Accident. Probably Elegba’s most relevant point was that radiation safety infrastructure is a necessary, but not necessarily sufficient, component of safety culture. This seemingly obvious, but usually ignored, statement should be emphasized. Safety culture is the ‘fabric’ woven from the different fibres of the radiation safety infrastructure. When such an infrastructure is put together well it can make the safety culture stronger.

It was noted that a better radiation safety infrastructure was very much needed in Africa, especially now that radiation is used in so many different fields. The Chernobyl accident has focused the attention on the importance of radiation safety within African countries. It has also highlighted the importance of learning from such major nuclear events. The session emphasized the importance of the role of the international response to Chernobyl under the aegis of the IAEA. Conventions, standards, missions, technical cooperation programmes and, in particular, the so called Model Project, have been implemented. The Model Project has led to the development of radiation protection in each African Member State, leading to the Forum of Nuclear Regulatory authorities in Africa. This was established in 2008. The Model Project addressed thematic safety areas (TSAs) in order to strengthen the radiation safety infrastructure consistent with international basic safety standards. This process proved very effective, particularly in Nigeria. The Nuclear Safety and Radiation Protection Act was promulgated establishing the Nigerian Nuclear Regulatory Authority (NNRA) in 2001.

It was concluded that it is very difficult to nurture a safety culture without a strong radiation safety infrastructure. Despite the establishment of the NNRA, it was noted that many challenges remain. However, there are many available tools to measure and evaluate radiation safety infrastructure but not for assessing safety culture. Safety culture has dimensions of people, technology and organizations. Any measuring tool should be able to cover all these aspects. The power of the regulatory bodies and the scarcity of resources were identified as a major challenge.

In summary:

— With the growing use of and interest in radiation in Africa, safety culture has been developed through the efforts of numerous stakeholders, but there are still needs for improvement and refinement.
— After the Chernobyl accident, international, regional, and national responses have been implemented which have led to development of radiation safety infrastructure in Africa today.
— There has been continuous IAEA support over the last decades. Opportunities and challenges lie ahead in the future for the nuclear activities of Africa.
— However, the major issue is that safety infrastructure is an a priori condition for safety culture. Safety culture should not be separated from safety infrastructure but embedded within it.
— Efforts to improve both safety infrastructure and safety culture are needed.

D. Minnema, United States Defense Nuclear Facilities Safety Board, USA, addressed the historical foundation for the development of safety cultures vis-à-vis HROs. The 1960s to 1980s were identified as one of the key periods for safety culture and HROs. The 1960s were the foundational decade, when there were a number of significant nuclear accidents although investigations were not then performed thoroughly. The 1970s were the formative decade; in fact the first seminal event took place on March 28, 1979 when a stuck pressure relief valve led to a core meltdown at a unit of the Three Mile Island NPP. This event led to numerous actions being taken. The 1980s were the nurturing decade, when the second seminal event occurred: the Chernobyl accident in Ukraine. Following this event, the IAEA coined the phrase 'safety culture', which also inspired the establishment of World Association of Nuclear Operations (WANO).

During these three decades, many concepts and theories were developed. The traditional, hardware oriented, view was changed and culture was recognized to be one of the most critical parts of safety. It was recognized that it was necessary to balance between operational demands and safety. It was also necessary to reflect on our understanding of risk, safety, and true priorities, and correct the misunderstandings and to watch for the indicators of declining performance. At the same time the importance of leaders was recognized. Leaders can play a big role in improving safety and safety culture. The speaker reminded the audience that organizational accidents can happen at any time. Small contributors in the workplace may prevent such accidents. All accidents are organizational learning opportunities.

During the discussions it was observed that many of the accidents mostly come from failures to learn from past accidents of workers. Current generations forget the lessons of the past. People make the same mistakes over and over again. The necessary safety activities associated in the history cannot be neglected.

Nuclear facilities could learn from other organizations in this respect. For instance, in the process of making submarines, the manufacturers have an annual ‘remembrance programme’. This creates emotion and every worker understands his or her role. This event has been carried out through generations.

In summary:

— The investigation and contemplation on the safety in nuclear field has been performed since the 1960s.
— A review of seminal events for the last decades shows that many concepts and theories have been formulated in this period.
— The understanding between culture and accidents has been continuously developed and we need to understand that neither technical investigation nor culture assessment alone can (or will) provide an adequate explanation of a specific accident.
— Striking the balance between operation and safety lies on the hands of individual workers. However, leaders should take an important role in managing the process and in shaping safety culture.
— We should not forget what has been learned throughout previous generations the history has demonstrated that organizational accidents happen (and will continue to happen). It is the consequences of such accidents that has made them become extraordinary, e.g. Chernobyl.

R. Amalberti, Haute Autorité de Santé (French Medical Accreditation Agengy), France, addressed a very challenging area for safety culture: Patient Safety: Present and Future. Amalberti noted that safety is usually not the main concern in the development of medical parts and equipment, e.g. those used in radiodiagnosis or radiotherapy. While in many industries safety related elements are within the same platform, in the medical area, dangerous activities often mix with safe activities. Comprehensive research is needed to better understand these interactions, particularly in this field.

Learning from other industries, new theories and tools have been developed within the medical area. As a consequence, many local safety problems have been resolved but fundamental problems still exist.

For example, the medical practice seeks to make major health improvements to improve both existing and new lives. To this end, new technologies are being introduced. However, such technologies may not necessarily be safe, as the ambition may be too great and consequently place patients in danger.

Amalberti recommended that a cultural partnership between patients, and the health professionals, adopting a comprehensive and systemic view of safety, should be developed.

Ageing society was recognized as a further big challenge with a lot of consequential problems, as the burden of care is getting bigger and bigger. Consequently, Amalberti argued that it is necessary to rethink patient safety. This would include changing the definition, defining patient safety as ‘the management of risk over time’; work to better understand risk and harm through the patient’s eyes; consider the balance of benefit and harm within an episode of care; use a wider range of safety strategies and interventions; and finally, adopt different safety models dependent on context.

Different safety models and associated intervention strategies to be considered include:

(1) Ultra-adaptive (taking risks is the essence of the profession, e.g. sea fishing, military war time, trading): Safety model emphasizes strong regulators, training to apply procedure even in abnormal situation, priority to prevention strategies).
(2) HRO (risk is not sought out, but it is inherent in the profession, e.g. firefighters, scheduled medicine): Safety model emphasizes power to the group, including perception of changes and adaptation, training to gain knowledge of group capacity, priority to recovery strategies.
(3) Ultra-safe (risk is excluded as far as possible; e.g. aviation, nuclear, medical lab). Safety model emphasizes power to experts, peer-to-peer knowledge transfer, priority to recovery and mitigation strategies).

None of the models were considered to be ideal, nor is there a ‘one size fits all’ solution. There are different approaches highlighting different needs.

In summary:

— Looking at patient risk, there are many variations in the medical practices and each need different approaches to ensure safety.
— Even though the field of radiation protection of patients is growing, it still needs improvement. More attention should be drawn into the new field.
— People always seek healthier and longer lives, especially in the modern ageing society.
— Three classes of safety models: resilient, high reliability, and ultra-safe models all need specific different approaches. Different aspects and different rules apply. No model is ideal so there are numerous general lessons to learn.

- — The challenge is to reduce the severity of accidents and not necessarily their frequency.
- — There is a marked contrast with other activities (e.g. with nuclear). It is difficult, even unfeasible, to shut down a hospital.

2. SESSION 2

Lena Kecklund, MTO Safety, Sweden, made a presentation entitled Safety Culture: A Requirement for New Business Models — Lessons Learned from Other High Risk Industries. She discussed safety culture and safety performance in high risk industries other than nuclear and underlined the impact of new business models and their effects on safety and safety performance.

Changes have been under way for a decade in the aviation, transportation, and railway industries. For instance, deregulation and changes in the legal and regulatory frameworks significantly allow for more competition.

She states that the nuclear industry is facing various challenges. For instance, in relation to public acceptance and market demands for lower prices. These challenges are already faced by other industries and the nuclear industry can learn from these.

New business models are having an impact that will affect nuclear industries. For instance, how to set new goals and targets, change company mission statements and, change company cultures in the short term. A typical example mentioned was Sweden’s switch from regulated to a partially regulated air traffic control market. Staff have to adapt to new work processes and conditions at all levels in response to these new regulations. The European Air Traffic agency has addressed safety culture as part of a new oversight systems.

It was emphasized that communication, participation, trust, and openness are necessary to cope with the rapid rate of change in market conditions. External demands are very important for setting the scene for safety culture. Stakeholder and regulatory and legislative requirements and competitive situation together set the boundaries for what managers are able to do. Managers will communicate priorities, safety commitment and profit commitment and these will be transferred into the organization’s social processes and group norms.

Safety, as a fundamental value and priority, is not always a core value in times of change. Safety can remain a basic value at the operational level but change at the senior management level. This may be more obvious when management does not have operational background.

Even though senior level management may think that they emphasize safety, most staff members perceive senior management as giving priority to economic priorities and to cost reductions over safety. There are differences in the perceptions of efforts put into safety and safety culture.

It was noted that changing group norms may cost more than changing formal rules. It was also noted that certain management styles contradict safety, such as a blame culture and not renewing contracts for staff who make reports. Staff may not feel that they can make reports. This implies that there is no trust. Learning opportunities may be reduced. More emphasis maybe given to reactive learning with a focus on negative events less and attention given to proactive learning.

An important issue addressed by Kecklund was subcontracting. Subcontractors may be reluctant to report occurrences to those hiring them. Outsourcing and subcontracting can be difficult to manage because of opportunities for miscommunication at interfaces and handover points.

It should be understood that changes in process can be stressful and require much effort from the entire organization. Arguably, senior management levels and officials can create the conditions that prevent major accidents. The focus here should be on growth, learning development, and creating a sustainable business organization. The concept of a 'just culture' was discussed in this context. It should be made certain that safety is included in the business model.

In summary:

— External demands are very important for setting the scene for safety culture. Managers' commitment to safety versus their commitment to profits will be transferred into organizations social processes and group norms.
— In times of change, especially organizational change, safety must be held as a core value and priority.
— Safety must be a basic value at the senior management level as well as at the operational level. This is more important when management comes from an operational background.
— Even though senior level management may think they emphasize safety and communication to staff in times of change, most staff members perceive senior management as giving priority to economic issues. and to cost reductions over safety.
— Breaking the group norms should not cost more than changing the formal rules. There should not be a social risk in following safety procedures.
— Arguably senior management levels and officials create conditions to prevent major accidents.

Cora Goicea, National Commission for Nuclear Activities Control (CNCAN), Romania, made a presentation entitled, Current Approaches of Regulating Radiological Safety of Medical and Industrial Practices in Romania.

She emphasized that safety culture is a transferable concept across industries. In Romania, fundamental norms regulate radiological safety. They were set up in accordance with law 111/1996. The basic principles are justification and optimization of practices taking into account economic and social factors, the limitation of dose exposures and dose constraints. The norms cover all situations with medical, occupational, and public exposures, and include potential exposures. Specific regulations have been developed for medical and industrial practices, radiotherapy practice, and diagnostic and interventional radiology practices. In Romania, the main responsibility for the application of these regulations lies with the legally designated person (registrants or licensees).

The commitment to safety culture is expressed in written policy statements known by all management, staff, and other personnel. Safety cultures should encourage active learning attitudes to protection and safety and discourage complacency.

Goicea questioned how existing regulations are supportive of a safety culture in different facilities and locations. It was suggested that training is an important factor. During their training, workers learn what they should be doing but also what can happen when someone is not doing their job or doctors come to the wrong conclusion. This can cost lives in medical circles. Workers should be aware of the consequences of their actions and, should learn from lessons of the past.

Since facilities should implement safety culture programmes and since safety culture has few tangible elements, it was asked whether regulatory authorities should make recommendations or set requirements when something is good enough.

It was suggested that there are different levels of involvement. There are phases in licensing and applications must be made for the design, construction and operation phases and a management system must also be submitted. These trigger conditions in the license and if they are not followed the license can be lost.

In summary:

— A lot of progress has been made in regulating radiological safety in medical and industrial practices in Romania.
— Safety cultures should encourage active learning attitudes on protection and safety and discourage complacency.
— Commitment to safety culture should be expressed in a written policy statement known by all management, staff, and other personnel.
— The main responsibility for regulations lies with registrants or licensees.

Mark Fleming, St Mary's University, Canada, addressed Regulatory Body Safety Culture in Non-nuclear HROs: Lessons for Nuclear Regulators.

The safety culture of the HRO regulator is important to understand, as regulatory oversight failures are a common component of events. Transparency is important, but how transparent is transparent enough? This has been a difficult question to answer in HROs. Leadership was found to be the key construct for creating a positive culture in a regulatory environment. It is a higher order dimension of safety culture; the fundamental dimension that influences all other dimensions.

Other important dimensions were also highlighted by Fleming: transparency through communication, unwavering ethical standards, proactive risk management on informed and flexible approach, and continuous learning and self-improvement. 'Integrating safety into all activities' was found to be a challenge. This characteristic is included in the IAEA framework of safety culture but not in others such as that of the OECD/NEA.

It was found that the safety culture of HRO regulators influences that of license holders. The regulator sits within and is a part of the wider industry safety culture. Under some circumstances, this can make it a challenge to realize risks and effectively manage safety. Similar to the situation in the Fukushima Daichi NPP, if the equivalent of 'nuclear is safe' is a core cultural value for the license holder, then the regulators may also subscribe to that value.

But it was noted that there is a two way relationship between the license holder and regulator culture. License holder culture also indirectly influences regulator culture through their interactions. Key issues are: how license holders approach safety, what they think their roles are, how they may lobby and influence the regulator to put them in a 'psychological prison' around how they think about and carry out their role. Usually, governments also get involved. Government culture exists outside of the industry culture, but is still able to influence it. There is also a strong influence of external stakeholders. All of this sits within the broader national culture.

Thus, a multi-method approach is required in the assessment of regulator culture. License holders should be included in the assessment process. There is a need to develop appropriate assessment tools.

During the discussion, of Fleming's presentation there was disagreement over linking the regulator to the industry. It was pointed out that the regulatory body is authorized by the government and is a government body. It is therefore governmental culture that has to interface with industry culture. It was suggested, however, that this debate is held and, people originally thought along those lines. However, a change is occurring: one of the reasons is that so much of the regulatory staff usually come from within the industry and interact as part of the industry. To an outsider, it is very hard to see that this is different. As regulators they probably need to think about where they are positioned.

There was an agreement on this point. The regulators share some basic assumptions with the organizations they regulate. It is essential to be aware of shared basic assumptions and values that might be sometimes a problem for proper oversight. For instance, the Swiss regulator gives feedback on how they perceive the impact that our regulatory culture has on the industry is safety culture. It is essential for the regulatory body to understand its own impact on its industries and license holder culture.

There were further questions about how to assess or evaluate national safety culture after something changes and about regulatory bodies who regulate two industries, for example, gas pipelines and railways. It was noted that the model presented was conceptual and not empirical. Any regulator should consider what its relationship with the license holder is, and how that license holder influences the regulator.

In summary:

— It is clear that it is impossible to discuss safety culture if there is not previous agreement on its nature. Different interpretations of the concept can render it ineffective.
— Leadership is the key construct for creating a positive culture in a regulatory environment. It is a fundamental dimension that influences all the other dimensions.
— Regulator safety culture influences license holder safety culture because the regulator sits within and is a part of industry. This can make it a challenge to see risk and effectively manage safety.
— There is also a two way relationship between license holder and regulator culture. License holders are influenced by the regulators and the regulators are influenced by the license holders. Governments influence both.

Mark Griffon, Consulting LLC, USA, presented Safety Culture — Lessons Learned from the US Chemical Safety and Hazard Investigations Board (USCSHIB).

The main focus of the USCSHIB is not just to investigate accidents but also to promote prevention. It is not a regulatory body proper and has no enforcement authority. It looks at whether regulations are satisfactory, as opposed to the regulatory body which focuses on compliance with regulations and infractions. It tries not to focus on ‘what widget broke’; the focus is instead on improving safety and not assigning blame. It really targets human and organizational factors that contribute to accidents and takes into consideration the fact that economic impact can influence the safety culture.

A relevant example was presented: the Macondo accident and the massive economic impact it had. On 20 April 2010, during the final phases of drilling the exploratory well at Macondo in the Gulf of Mexico, a geyser of seawater erupted from the marine riser onto the rig into the air. This was soon followed by the eruption of a slushy combination of drilling mud, methane gas, and water. The gas component of the slushy material quickly transitioned into a fully gaseous state and then ignited into a series of explosions and then a firestorm.

There are important differences between the reaction to this type of accident and that to nuclear accidents. For instance, in Macondo, people wanted to go back to work even as oil was continuing to spill into the Gulf. In the oil industry, safe production must be maintained. However, when oil prices drop, there are cost-cutting efforts that can result in a reduction in staffing, training, and maintenance. This has a massive negative impact on safety, such as certifiers having to pay for their own recertification.

Safety should not be the first thing to be cut when there is cost-cutting, if safety is properly integrated into the business model. Equal attention must be paid to process safety as personal safety. This is more than just attention to injuries and illness rates.

The concept of safety culture should not be just a catch all, for example, ‘safety culture contributed to the accident’. The question should be asked, what aspect of safety culture contributed to the accident. There is a tendency to try to fix the workers when it may not be their fault. A lot of unions hear ‘behavioural safety’ for the workers rather than fixing the entire company. Workers have the highest risk and the least authority in fixing the system. It is important to question the belief that you cannot have everyone thinking alike or else you get organization-wide blind spots. The real question is: how to best mesh subcultures rather than change them?

It was underlined that there is not the same response to disaster in the oil and gas industry as there has been in the nuclear industry.

During questions it was emphasized that the idea of risk tolerance is very important. Zero risk tolerance is not viable. From the point of view of the expert, the concept of the public acceptance of risk has deficiency as well. It seems that there is not something in between these concepts. It is important to question who is accepting the risk and who is tolerating the risk. Workers take the risk. The risks at Macondo, taken by the operator, were related to going after different geological formations, and more technologically challenging areas. Regulators rarely refused a drill on safety terms, but just wanted to modify it. This would likely be different if different stakeholders are at the table to evaluate the risk.

In summary:

— It is important to not only look at whether the regulations have been followed or broken, but whether the regulations are effective appropriate and logical.
— The technical causes of a disaster are not necessarily the most important things to look for. Human and organizational factors have also contributed to major accidents in the oil and gas industry.
— There must be equal attention paid to process safety on the job as well as personal safety.
— Safety culture should be open to refinement, because if everyone is thinking in the same way, there might be organization-wide blind spots.

3. SESSION 3

Lucia Suhanyiova, University of Aberdeen, Scotland, presented Product Safety Culture: A New Variant of Safety Culture, namely a safety culture linked to the final product, this being any physical goods or service, including software services.

A relevant question is: 'How far does product safety extend outside of a company?' Safety culture issues, including management commitment to safety, safety systems and communication, have effects on safety outcomes. For example, injuries and days of missed work. Examples are the well known cases of Toyota product failures and the Volkswagen emissions scandal.

It was mentioned that, for people within the company, product safety culture encompasses the core issues of safety culture but also deals with how safety impacts product integrity and ultimately the users' safety. It was noted that much research has been performed on worker and process safety, but no one looks at how organizational values and culture can affect the user. Product safety culture is not just about management commitment to safety, rather than profit, but also about management commitment to the safety of the product. In some respect, it can be considered similar to patient safety culture in healthcare and medicine.

It was noted that safety culture is not just human culture, but has also technical and design aspects; how humans interact with technology. Things advance so quickly that people may not understand what they are doing when they interact with new technology. Originally technology adapted to human behaviour, but now human behaviour has to adapt to technology. Complex technical system may be detrimental to safety if people cannot understand what is going on and people should not need extensive training if things can be simplified.

Product safety looks at the product's entire life cycle from design to end. A business needs to return a profit, but reputation for safety is important for making that profit. If a product is perceived to be unsafe no one will buy it, so product safety is very important.

In the discussion, it was mentioned that there might be confusion between product safety culture and patient safety culture. The product in medicine can be either radiotherapy or radio diagnostics, which are completely different than many industrial products. However, ultimately, the patient and the product user are the recipients of any services received and in this respect they are comparable.

It was also suggested that the expression 'safety culture' may be confusing in many industries because there are many different aspects to company culture. In companies such as motor industries, and health services, what kind of words do they use to describe their cultures? Do they just use 'product safety culture' and 'safety culture' and set consistent terms for what affects safety culture? Do they use more hands-on terms like PPE for personal protective equipment? In reality, they use a lot of jargon individual to each company that are part of their culture. Each company understands what the words mean and puts their own spin on it.

In summary:

— Product safety culture deals with the integrity of the product or service, and focuses on the safety of the end user rather than the worker or organization. It looks at the product's entire life cycle.
— Organizational culture and values can and do impact the user.
— Safety culture is not just focused on people, but also has technical and design aspects, and involves how humans interact with technology.
— Complex technical systems may be detrimental to safety if people cannot understand what is going on.

E. Nystad, Institute for Energy Technology (IFE), OECD Halden Reactor Project, Norway, made a presentation on a challenging topic: Human and Organizational Safety Barriers in the Oil and Gas Industry. The presentation addressed 'aspects of focus' in the oil and gas industry. These included: human performance, human reliability and organizational factors; control room design and evaluation; human–system interfaces; future operational concepts; virtual and augmented reality applications; and the safety of critical software. The importance of creating a common database was emphasized so all data and models can be used across all phases of design, operation and decommissioning.

The Macondo accident (also referred to as the Deepwater Horizon oil spill accident) in the Gulf of Mexico was discussed again (see above). It was recognized that numerous breaches in the safety barriers were fundamental in the buildup to the accident. These included poor cement plug quality, misinterpreted integrity test, undetected gas inflow, a corporate culture of risk taking and cost-cutting.

The use of mindful safety practices in the oil and gas industry was discussed. People act as safety barriers in their own right, as they can detect incident buildup and unwanted events and can react in order to mitigate or avoid negative effects. Mindful safety practices require people to act (for example, warn someone doing something unsafe). But how willing are employees to use these practices? Willingness is more correlated with group level factors than other levels. Therefore, the safety culture of the whole group is for individual engagement with mindful safety practices. Changes in the work environment can change employees' utilization of mindful safety practices.

Finally, the monitoring of organizational safety barriers in the oil and gas industry was discussed. It was concluded that safety barrier performance should continue to be monitored over the lifetime as of the installation they are vulnerable to degradation. Requirements should be defined for competence and response times. Regulators should look at trends over time.

During the discussions, it was noted that the nuclear industry's main approach to safety is the so called defence in depth. The nuclear industry tends to rely more on hardware safety barriers. A lesson from the oil and gas industry is that they often see a breakdown in organizational control and the loss of many safety barriers before an accident takes place. Perhaps there is a need to start thinking about the organization as a whole as a single barrier rather than a collection of barriers.

In summary:

— Safety barriers are not just hardware. People are safety barriers too.
— Mindful safety practices can be used as part of safety culture.
— Willingness to engage in mindful safety practices is dependent on the group culture. Changes in the work environment can change whether or not a given employee will use mindful safety practices.
— Requirements for mindful safety practices should be defined for competence and response time.
— This is an interesting area for the nuclear industry to explore, given its tendency to focus on hardware safety barriers.

Nicolas Dechy, Institut de Radioprotection et de Sûreté Nucléaire, France, presented Learning Lessons from Three Mile Island (TMI) to Fukushima and Other Industrial Accidents: Key for Assessing Safety Management Practices. He reiterated that one key for assessing safety management practices is to learn the lessons from accidents. He further emphasized that while the nuclear industry has learned from accidents like TMI and Chernobyl, there are still root causes of accidents that have not been addressed, for example, organizational complexity, production pressures, interorganizational relationships, regulatory capture and general failure to learn.

Examples are many. Fukushima regulators were resistant to imports of foreign safety concepts. Accidents in many companies have ‘striking similarities’ to past accidents, and their organizational and cultural causes in the companies’ histories.

So called unique accidents can have similar organizational causes. The motto ‘It cannot happen to us, we are different’ is typical, but history has shown that people can and should learn from others’ hard lessons.

Significantly, it was noted that overall risk reduction appears to be approaching an asymptotic curve. The concept of retrospective and hindsight bias was emphasized: after an accident people become wiser. There was disagreement over the idea that only weak signals cannot be understood by people embedded in the system. Several accidents have shown that both weak and strong signals can be missed.

It was questioned how to transfer the lessons from other accidents into the nuclear sector. What are the elements that can be extracted from accidents for transfer? It was suggested that one action is to see recurring patterns in accidents looking at all accidents with failures to learn and attempt to classify those failures. This helps to guide assessments in normal operations as the lessons from accidents can be used as levers of action.

In summary:

— Opportunities to learn from accidents are often not taken, resulting in many accidents repeating themselves.
— Accident and risk reduction have been following an asymptotic curve, and the nuclear industry may need to add to the paradigm of prevention that of mitigation.
— There is a need to ensure better use of lessons and knowledge gained from accidents and disseminate and make effective this knowledge for operational actors.
— Accidents are not cold cases and should be revisited with new insights.

A.N. Afghan, Institute of Business Administration, Pakistan, made a presentation entitled: Understanding of Nuclear Safety Culture: A Systemic Approach.

The Fukushima Daiichi accident was based on assumptions. Nuclear power plant operators, the regulator, and government all believed that Japan’s nuclear power plants were too safe for this kind of accident to happen. Not all accident scenarios were considered, such as multiple reactors going into crisis simultaneously with a complete power loss for an extended time. The accident was rooted in organizational issues and can be considered a human-made failure and disaster.

When the systems are complex, there will always be unpredictability and unknown risks. It is not feasible to know everything about a complex system. Managers have to balance technical/linear problems with systemic non-linear problems. Basic assumptions must first be explored and influenced before actions can be changed. An interplay should be undertaken among basic assumptions, cognitive processes, behaviour, context and environment.

Systemic failure cannot be described by individual component failure. Instead it is characterized by complexity and uncertainty in the system; complex adaptive systems (CASs). Not accounting for complexity and unpredictability results in little room for changing conditions, or creativity. This is problematic for CAS. Systemic thinking helps in considering CAS; individual behaviour cannot be considered in isolation.

CAS include all social systems. Heterogeneous agents within any system exist, and independently, but interdependently produce complex interactions. Unpredictably evolves as a property of the wider system. One single person can make a difference in the overall system performance, like a ‘butterfly effect’. But a system is usually subject to rapid changes and never truly stable. It becomes impossible to understand group culture by looking only at individuals. If the safety culture is re-conceptualized, it is feasible to change behaviour and actions; small changes can have major impacts.

In summary:

— It is important to question whether the basic assumptions on safety are robust. Risk is unpredictable in complex systems and this is an issue that should be understood.
— All social systems are CASs and subject to rapid change and evolution.
— It is not feasible to understand the culture of a group by looking only at individuals.
— With complex systems there will always be unpredictability and unknown risks.
— Small changes can have major impacts, which can drastically improve the safety culture.

4. CHAIRPERSON'S SUGGESTIONS

The two final suggestions from the Chairperson are as follows:

(1) Nuclear related organizations should learn from safety culture practices and experiences in non-nuclear HROs.
(2) There seems to be a need for an international action.

CHAIRPERSON'S SUMMARY

PARALLEL SESSIONS ON SYSTEMIC APPROACH TO SAFETY

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1. INTRODUCTION

Nuclear power plants (NPPs) are designed to operate safely with a very low accident probability. However, despite the safe and reliable design of nuclear power plants, the nuclear sector has experienced three major nuclear accidents during the last 60 years, which were caused by the defects in non-technical issues such as human error, organizational and safety culture issues. Since then, many attempts have been made to minimize human error. In spite of these effort, we again experienced another Chernobyl type accident. The Chernobyl accident was known to have been caused by a weak safety culture. Safety culture became one of the major challenges in the nuclear industry after Chernobyl and major models and methodologies have been developed to resolve this challenge.

The consequences of the recent Fukushima Daiichi accident require us to develop a new, and better, approach with which to face this issue. This in turn requires more research on safety culture. To answer this question, the IAEA Conference on Human and Organizational Aspects of Assuring Nuclear Safety included three plenary sessions on the systemic approach to safety. These sessions were comprised of three themes: retrospective lessons, current status, and future perspectives

2. RETROSPECTIVE LESSONS

In the session on 'retrospective lessons', four speakers made presentations, including a staff member of the IAEA. **N. Meshkati, University of Southern**

California, USA, introduced the human, organization and technology model, which is composed of three links in a chain. All three links need to be intact, have interactions with each other, and be given equal and adequate attention for the chain to be working efficiently. Meshkati emphasized the importance of the operator's role in emergency situations within NPPs. Focusing on the response to the 2011 Tohoku earthquake and tsunami at the Fukushima Daini nuclear power plant, he argued how this event reaffirmed that people are the last line of defence to a severe accident — they are the ones who protect society. At the end of the day, it is the human operators who need to save the situation. He explained that what was done at the Fukushima Daini nuclear power plant was that four reactors that were operational were brought to cold shut down, through impromptu, but prudent decision making, improvisation and flexibility in applying EOPs.

M. Haage, IAEA, and K. Heppell-Masys, Canadian Nuclear Safety Commission, presented the main observations and lessons identified through the systemic analysis of human and organizational factors performed for the IAEA report on the Fukushima Daiichi accident.[1] The analysis concluded that, over time, the stakeholders in the Japanese nuclear industry developed a shared basic assumption that led them to believe that a nuclear accident would not happen. This constrained their ability to anticipate, prevent and mitigate the consequences of the earthquake that triggered the Fukushima Daiichi accident. This led to the main lesson that individuals and organizations need to consciously and continuously question their own basic assumptions and their implications for actions that impact nuclear safety. The analysis further concluded that the stakeholders involved in the accident at the Fukushima Daiichi NPP were aware of the possibility of isolated issues related to the accident in advance. However, they were not able to anticipate, prevent or successfully mitigate the outcome of the complex and dynamic combination of these issues within the overall sociotechnical system. This led to lessons promoting a systemic approach to safety. Haage and Heppell-Masys explained that this approach means working to understand the system of human, technical and organizational factors as a whole. As the system is too complex for one person to grasp; we need to work together and across disciplines, looking at how HTO factors are interacting not only within, but also across nuclear stakeholder organizations, including government bodies, regulatory bodies, licensees, international bodies, universities, and more.

F. Lemos, Nuclear and Energy Research Institute, Brazil, introduced the systems theoretic process analysis (STPA) model, which is based on modelling the system in terms of control and feedback. He reminded participants that when it comes to the more subtle interactions between components of the system, it

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident: Report by the Director General, IAEA, Vienna (2015).

is hard to detect potentially hazardous situations. These may be hidden, but can lead the system to hazardous states. Lemos explained that control processes exist, and for these to work as planned, we need to have feedback on control actions. Potentially unsafe control actions are classified according to the state of the system and analysed using the STPA model. It was emphasized that an NPP is part of a bigger system at a national level, where the whole system works together, and that safety culture goes beyond the organizational system we are working within.

The last speaker of the first day, **N. Gotcheva, VTT Technical Research Centre of Finland Ltd, Finland,** introduced the ongoing initiative MAPS (management principles and safety culture in complex projects). The objective of MAPS is to enhance nuclear safety by supporting high quality execution of complex projects in the nuclear industry. Gotcheva argued that this is challenging, as keeping safety in focus in dynamic project environments is a difficult long term task. MAPS has shown a need for improved theoretical understanding and for practical tools for integrating project governance and management, cultural phenomena, complexity thinking and safety. As current applications of system dynamics modelling were observed to focus mainly on cost overruns and schedule slippages, the next steps of the MAPS include developing a system dynamics simulation model of governance and cultural phenomena interactions in complex nuclear industry projects.

3. CURRENT STATUS

The theme of the second day was current status. There were five presentations in this session. The first speaker was **M. Weightman, HM Chief Inspector of Nuclear Installations (retired), United Kingdom**. Weightman presented the new INSAG concept of ‘institutional strength in depth’ (ISiD). Referring to the lessons from Fukushima, he reminded the audience that the root causes of the accident were institutional and cultural. The accident therefore showed that rigorous and comprehensive safety standards and tools for safety may not be sufficient, and that a robust nuclear safety system (RNSS), ensuring that all relevant institutions apply these standards, is needed. An RNSS is composed of three main independent layers: strong industry, strong regulator, and strong stakeholders, and the interfaces between these layers are considered crucial towards ensuring overall ISiD. Weightman explained that the foundation stone for an RNSS is strong leadership and a robust safety culture. Strong leadership is the key to developing, nurturing, and maintaining nuclear institutions, cultures and values. There is a need for a common basis for nuclear leadership that has universal applicability across societies, cultures and organizations. Six leadership values which nuclear leaders should champion were proposed: humility, inner strength, responsiveness, objectivity, resilience and integrity.

In the second presentation, **A. Edland**, **Swedish Radiation Safety Authority (SSM), Sweden,** described, from the Swedish regulatory perspective, the efforts of the Swedish industry to work proactively on the interactions between man–technology–organization (MTO) systems. The Swedish regulator has an MTO section, consisting of 12 human factors specialists responsible for, among other tasks, safety management and leadership, safety culture (internal to regulator and within licensees), working conditions, competence, fitness for duty, suitability, education and staffing, and knowledge management. The Swedish regulator considers nuclear safety to be based on preventive actions where both technology and human behaviour need to be considered. Consequently, human factors are an expected expertise in almost all activities at the authority, and joint inspection teams with both psychological and technical expertise have been created in order to have a systemic understanding of safety challenges and solutions. Edland concluded by emphasizing that humans, management and organizations should be discussed in terms of their limitations, errors and shortcomings, but also in terms of their strengths in stopping a chain of events, in learning, inventing and improving.

The third speaker, **J. Svenningsson, Sydkraft AB, Sydkraft Nuclear Power AB and Uniper, Sweden,** proposed continued work towards a systemic approach as the modern view of safety. He argued that the modern view complements and does not negate traditional models and approaches. However, modern safety thinking goes beyond compliance behaviour, and includes key attributes such as: seeing human error as a symptom, not a cause; avoiding hindsight bias; and focusing on success rather than failures. Svenningsson explained that the goal is to build a mature and proactive organizational culture, and that in order to achieve this, it is imperative to incorporate a systemic view. His organization is collaborating with the Amsterdam University of Applied Science to develop tools for implementing systemic views, which base themselves upon Reason's five subcultures of just, flexible, reporting, informative and learning culture. Svenningsson concluded by reminding the audience that wanted as well as unwanted events result from continuous interactions among elements under variable conditions and multiple objectives, as humans and organizations acting and thinking are constantly influenced by their context.

F. Meynen, Swiss Federal Nuclear Safety Inspectorate, Switzerland, presented the Swiss regulatory perspective on HOF and their attempt towards taking a systemic approach. Meynen reviewed past accidents in the nuclear as well as other high reliability industries. He emphasized the need to perform adequate systemic analyses of such accidents to ensure that the interactions between human, technical and organizational factors are adequately understood

— this becomes more needed in an increasingly complex industry and environment. ENSI's approach to such accident analyses was shown, as well as their view of safety culture, including their new publication on safety culture oversight. Meynen concluded by posing a range of questions for reflection, asking: While 'experience increases safety', how does one share the experiences? While 'technical systems increase safety (reliability)', how does one handle the increasing complexity? And while 'organizational barriers reduce the likelihood of occurrence', how does one keep attention levels up?

G. Watts, Intelligent Organizational Systems, Canada, and **J. Misak, ÚJV Řež, Czech Republic,** described the practices experienced from the development of the defence in depth (DID) concept. They first described the screening method developed by the IAEA as a tool for the systematic assessment of DID comprehensiveness. The method uses objective trees to screen safety provisions across the five levels of defence and graphically shows the links between safety provisions and challenges to safety objectives at different levels of defence. Watts and Misak maintained that the method also serves to illustrate that the means for protection of the physical barriers against releases of radioactive substances include more than just NPP technological systems and procedures, and an example applying the method to analysing and strengthening HOF was presented. It was concluded that the uncertainties associated with predicting human behaviour, alongside their sensitivity to organizational factors and societal influences, requires special attention to be given to 'soft' logic trees within the DID framework and screening process. According to Watts and Misak, DID can be further strengthened by understanding nuclear power programmes as 'complex' systems, and by taking into account all the components of the system, from operators, through middle level managers, NPP managers, up to corporate, governmental and even international levels when assessing risk. Taking this systemic perspective enhances the application of the DID concept by screening interactions multi-directionally and across many organizational boundaries.

4. FUTURE PERSPECTIVES

The last day's theme was future research required to support a systemic approach to nuclear safety. **T. Brunelis, AREVA, France,** described the operational HOF practices in the AREVA group which were developed to face new challenges. AREVA is focusing on how to transfer the experience of the first generation of NPPs to the newcomers, the third generation. The first generation built fuel cycle facilities that had unique features. These were based on the fact that this generation started the plant which had specific interactions. These provided the generation with an appreciation of the risks involved and which are important to manage safety. Third generation features include interactions with virtual worlds, where nuclear is generally perceived as safe and distanced from the risks between newcomers and the risks itself. A challenge is to ensure that newcomers have adequate safety knowledge and a strong safety culture. In AREVA, the safety excellence programme started in 2012. It focused on a comprehensive inventory of the operational level of managers' skills involved in SHSE (safety–health–security–environment) implementation in the facilities. The aim was to ensure that plants can be operated in a safe way by involving the target population involved: site directors, production directors, duty officers, project managers and SHSE managers of the sites.

C. Packer, Cherrystone Management, Inc., Canada, with experience from the Darlington NPP, introduced story telling theory and practice. He explained that the biggest reason why we struggle with safety is because it does not exist as something tangible that we can feel and touch. We need to change that absence into something tangible. Changing the invisible to visible draws on the depth of human experience. When we talk about safety culture, from a leadership point of view, what do we have to do? And why do we have to do it? Stories help us to see and to feel what needs to be done. There is no meaning to group identity without people bring in personal aspects, to challenge, to ask, and to question. The individual matters within the group. What people need to know is that we know them and their strengths and weakness.

N. Ahn, Korea Energy Technology Evaluation and Planning (KETEP), Republic of Korea, the third speaker, described the current status of the nuclear industry in the Republic of Korea. He contended that the current nuclear issue in his country is caused by management failure. Despite the rapid increase in workload, management, including the Government, has reduced the manpower of the power plants in the name of restructuring the public sector. According to Ahn, this has caused the workload to increase unexpectedly, and has led to cutting corners in checking the procedures for the procurement of components. He argued that the system dynamics approach is very effective in revealing the structure of the safety culture system. However, he also explained that it is very hard to build this model as it does not come naturally to non-experts. Hence, there is a need to cooperate to build this model. Many systems exhibit common behaviour and flaws in the safety culture that can lead to accident archetypes. There is a need to develop and use the safety culture archetypes to understand more effectively the structure of safety culture. Ahn argued that if some safety culture archetypes are developed and added to the IAEA assessment method, it will be a very effective tool with which to understand the structure of the safety culture system of NPPs. It will contribute to the prevention of accidents related to a weak safety culture.

The last speaker, **J. Ward, Australian Radiation Protection and Nuclear Safety Agency,** made a presentation entitled the Application of Systemic Safety for Smaller Nuclear Installations, describing his organization's holistic approach to safety. Its approach fits well with the new IAEA requirements covering HOF, and similar methods are also used by other nuclear operators and regulators. Ward explained how a graded approach is utilized in order to account for the different sizes and ranges of safety risks in the different types of organizations regulated, as these factors impact the regulatory burden justified. The holistic approach emphasizes seven key characteristics of safety to reduce safety vulnerabilities: (1) human aspects — safe organizations take account of weaknesses and strengths in human performance; (2) non-technical skills — safe organizations will possess and utilize effective non-technical skills; (3) DID — safe organizations will apply DID throughout; (4) management systems — safe organizations integrate safety and environmental protection seamlessly; (5) resilience — safe organizations learn, respond, monitor and anticipate effectively; (6) safety culture — a safe organization will at all levels possess shared values and beliefs for safety that produce behavioural norms that provide an appropriate and demonstrable attention to safety; and (7) protective security and nuclear security culture — organizations with a good security culture will at all levels possess shared characteristics, attitudes and behaviours which serve as a means to support and enhance security. Ward explained how the holistic characteristics have been incorporated into ARPANSAS inspection performance objectives and criteria enabling the analysis of inspection findings to be linked to weaknesses associated with common contributing causes.

5. CONCLUSION AND FUTURE CONSIDERATIONS

Summarizing the parallel sessions on systemic approach to safety, all speakers agreed that this approach to safety is the way forward because safety is the outcome of the interactions among humans, technology, and organization. The safety of NPPs is not a problem only of an operating company but is a national problem. The solution for improving safety culture therefore has to be developed by involving the multiple stakeholders in society. That is why we need a systemic approach to answer the safety challenges of NPPs. A number of regulatory agencies have already adopted this approach and are now developing assessment tools. The IAEA is a pioneer in this, taking a systemic approach to accident investigation through the human and organizational factor analysis of the Fukushima Daiichi accident. If sophisticated methods like system thinking complement the IAEA method, its effectiveness could increase dramatically.

SUMMARIES OF TOPICAL SESSIONS

Chairpersons

N. STEINBERG
Ukraine

I. KUBÁŇOVÁ
Czech Republic

F. DERMARKAR
Canada

CHAIRPERSON'S SUMMARY

TOPICAL SESSION ON LEARNING FROM THE PAST, GOING FORWARD

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1. INTRODUCTION

Parallel session TO1 consisted of presentations and dialogues providing perspectives on lessons to be learned from past incidents and accidents, assessment methods for safety culture, as well as experience of facilities in strengthening organizational effectiveness and culture for safety. These perspectives were shared by members of nuclear installations from the Islamic Republic of Iran and Ukraine, of the French technical support organization Institute for Radiological Protection and Nuclear Safety (IRSN) and the Korea Advanced Institute of Science and Technology (KAIST).

2. SESSION CONTENT

Presenting their study of the unfolding of the Fukushima Daiichi accident from a human and organizational perspective, IRSN stressed the ability to cope with the unknown as essential during the accident. This talk discussed how the operators had to make sense and act upon a completely unknown and 'unpredictable' situation, the challenges faced by the emergency management structure, as well as the cooperation across stakeholders throughout the most urgent early stages of the accident. It was argued that organizations need to generally enhance organizational flexibility and work to find methods that prevent routine processes from leading to overconfidence and lack of improvisation in decision making during critical situations.

Based on their study data, IRSN identified four key areas, or questions, that should be considered when preparing for unexpected events and conditions. These are: (1) How does one make sense of the situation? (2) What are the challenges for the emergency organization? (3) What is the critical decision in the crisis? (4) How do the different stakeholders collaborate in addressing the challenges they face adjusting their actions and making decisions accordingly?

It was further argued in this session that developing assessment tools to evaluate safety culture is needed both to perform efficient safety culture oversight for regulators and to develop effective safety culture improvement programmes for licensees. Assessment tools based on the collection of different types of information on safety culture and organizational effectiveness were presented.

These assessment tools used in a systemic manner enable stakeholders to organize collected data, to analyse them in order to identify safety culture deficiencies, and to monitor the impact of corrective actions over time. It was noted that the evaluation of data, whether qualitative or quantitative, may be challenging, requiring expertise to ensure valid and reliable interpretations and conclusions.

Moreover, it was stressed that the different elements and indicators of safety culture are interrelated. While quantitative methods, such as the Social Network Analysis as described by KAIST, are useful to identify the competencies lacking in a team and prioritize areas of work, it appears that these methods are complementary to an assessment process based on a systemic thinking and safety culture expertise.

3. MAIN CONCLUSIONS

Based on learning from the analysis of past experience, preparation for managing unexpected events and conditions should be carefully thought through in order to enable specialists to quickly assess the situation, organize emergency response and make and implement timely decisions.

Using safety culture assessment tools is crucial to identifying error and failures and monitor the effectiveness of corrective actions data have to be collected through different complementary methods (e.g. document review, observation, surveys, interviews and focus groups) to perform an efficient assessment of safety culture. Specific competences and training are necessary to perform efficient data collection and take into account the systemic aspects of safety.

Enhancement of organizational effectiveness and safety culture is enabled by the development of a structured and planned process, including safety culture self-assessments, use of external assessments audits and inspections and safety culture improvement programmes.

4. MAIN SUGGESTIONS

The session resulted in the following suggestions:

— Sharing of good practices and international experience feedback should be continued and encouraged as it contributes very positively to the development of safety culture programmes for facilities.
— As conducting safety culture assessments requires expertise, education and training to this end should be part of safety culture improvement programmes.
— In strengthening safety cultures, attention needs to be paid to the characteristics and competences of both the individuals and the teams involved, and the interactions among them.

CHAIRPERSON'S SUMMARY

TOPICAL SESSION ON SAFETY CULTURE OVERSIGHT

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Parallel session TO2 consisted of seven presentations and discussions providing national perspectives on safety culture in relation to regulatory oversight activities as well as the assessment of own safety culture. National approaches, programmes and assessment methods were described by members of regulatory bodies or technical support organizations from Belgium, Canada, Finland, Germany, the Republic of Korea, Romania and the Russian Federation. Given this national diversity, the different backgrounds and levels of experience regarding safety culture oversight were described for some regulators. It included their wider approaches to oversight of human and organizational factors as a whole.

1. SESSION CONTENT

Several Member States described the development and existence of comprehensive and systematic safety culture oversight programmes and processes. These were based on data collection on safety culture at every level of interaction between the licensees and regulatory bodies. This included both general inspection activities where safety culture aspects are included as an integral part of inspections and specific inspections focused on safety culture or leadership for safety culture. The data were then analysed by safety culture specialists and integrated into periodic and systematic feedback to licensees. In some Member States, safety culture specialists also performed specific and thorough safety culture inspections conducted periodically or on the basis of previous weak signals and collected data, either by the regulator itself or a technical support organization (TSO). Several of the safety culture methodologies presented have now been in place for some time, and are being reevaluated and refined to improve efficiency.

Generally, presenters underlined the importance of systematic data collection on safety culture and categorization of this data against safety culture characteristics and attributes to identify challenges faced by licensees' with regard to strengthening their safety culture. The analysis and investigation of past events was also identified as a means of collecting information on the safety culture of licensees. It was pointed out that this type of data collection may be particularly useful to Member States new to safety culture oversight in order to prioritize areas of work in safety culture oversight.

Some Member States advocated an objective or goal oriented approach for both safety culture and human and organizational factors oversight in general. It was remarked that an approach identifying discrepancies rather than prescribing solutions could facilitate constructive liaison with licensees and also lead to a common understanding of what the concept of safety culture stands for. An educational approach aiming to support the licensees' safety culture improvement through trainings and workshops was also presented as a viable option in supporting providing both an increased awareness of systemic aspects of safety along with the general reinforcement of licensee's safety culture. In addition, some speakers suggested going further with this approach by providing direct assistance in safety culture improvement activities to licensees, especially to those less experienced in building their own safety culture self-assessment and improvement programmes.

Taking a systemic approach to safety, and acknowledging their own influence on safety culture through their acts and positions as regulators, several Member States also reported work to assess and improve their own safety cultures.

Finally, challenges in developing an effective safety culture oversight process were identified. The importance of developing a common understanding of safety culture between the regulatory body and licensees through constructive dialogue was stressed. Moreover, it was regarded as crucial for this common understanding to be established between specialists and non-specialists within regulatory bodies. In order to address this challenge, the speakers recommended the implementation of training in the field along with the development of practical tools for inspections.

2. MAIN CONCLUSIONS

Efficient and effective safety culture oversight is integrated, systemic and systematic and includes, in a complementary manner, both general inspection activities with limited safety culture aspects and specific inspections focused on safety culture or leadership for safety culture.

Observing and assessing safety culture may not be seen as a core activity by engineers and other technical staff working as safety inspectors. Therefore, specific training and coaching in the field are needed to ensure efficient and professional conduct of the observation processes. Everyday findings of safety inspectors constitute a very important part of an effective safety culture oversight process.

As regulators are part of the larger system, safety culture must also be assessed and improved in their organizations. This activity was mentioned in many of the presentations as being implemented in recent years.

Constructive dialogue with licensees is essential to provide feedback but also to get a common understanding of safety culture, define the oversight process and help to develop self-assessment programmes.

Safety culture is — and will be more and more in the future — subject to public interest. In some countries, the regulatory bodies have succeeded in involving relevant stakeholders, including the general public, in the development of new safety culture oversight practices. However, this practice is not common everywhere at the moment. Despite this, the importance of open and transparent communication with the public related to safety culture should be recognized as essential in countries where the involvement of stakeholders is not prescribed by law.

3. MAIN SUGGESTIONS

The session resulted in the following suggestions:

— Member States should develop tools and training programmes to help non-specialists in conducting observations and data collection regarding safety culture as well as peoples' behaviour and organizational performance.
— Regulatory bodies need to involve all stakeholders in the process of defining and understanding the concept of safety culture, as well as in developing specific and objective based approaches.
— Continuous improvement of the oversight process should be carried out using event analysis, constructive dialogue with licensees and exchange of best practices not only with other countries, but also other industries.

CHAIRPERSON'S SUMMARY

TOPICAL SESSION ON BUILDING A CULTURE FOR SAFETY

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The main focus of parallel session TO3 was on enhancing safety culture and human performance for suppliers who provide services and equipment to utilities having nuclear power plants. There were five presentations on this subject, each providing a unique perspective on the issue. The presenters included those from utilities from Finland and Canada, service providers from France and Canada, and support organizations, namely, the Institute for Nuclear Power Operations (INPO) and the CANDU Owners Group (COG).

In addition to these presentations, the session also contained a presentation by the Ibero-American Forum of Nuclear and Radiological Regulatory Authorities (FORO), elaborating their pioneering project on developing safety culture in organizations, facilities and activities using sources of ionizing radiation. FORO has developed a comprehensive guidance document on safety culture, including theoretical basis and practical tools to assess safety culture across medical, industrial and research activities as well as radioactive waste management and transportation of radioactive material.

1. BACKGROUND: THE NATURE OF THE PROBLEM

The concept of safety culture emerged as an important issue following the accident at Chernobyl in 1986. It was recognized, following this event, that in order to assure nuclear safety, it was necessary, but not sufficient, to design plants with multiple layers of engineered barriers. It was also necessary to ensure that the people operating and managing those plants did so in a healthy nuclear safety culture that saw nuclear safety as the overriding priority. Within the speakers' own organizations, utilities have made significant improvements in human performance and safety culture supported by a strong community of practice through INPO and WANO.

The accidents at the Fukushima Daiichi nuclear power plant revealed that a healthy nuclear safety culture needs to extend beyond the utility operating the nuclear power plant itself to include the entire nuclear energy sociotechnical system. Over the past five years, regulatory bodies have stepped forward and placed increased emphasis on their role in the oversight of safety culture in nuclear power plants as well as within their own respective organizations. This conference dedicated topical session TO2 to the activities of regulators in this regard.

Another group that plays a key role in the nuclear energy sociotechnical system is the supplier community. In recent years, utilities have been making increased use of suppliers and non-nuclear support organizations for many vital functions such as:

— Design and manufacturing of nuclear fuel, replacement parts, and components;
— Engineering, manufacturing, construction, and installation support for plant modifications and upgrades;
— Staff augmentation and/or service to engineering, maintenance, operations, radiological protection, and outage support;
— Corporate public relations, government affairs, supply chain, legal, licensing, and environmental support;
— Design, construction, inspection and maintenance services in support of their nuclear power plants.

There have been several recent high profile events involving the supplier community that have led to significant losses for utilities. These events may have been either prevented or mitigated had a healthy safety culture, as well as strong human performance and risk management programmes, been in place. In addition to these high profile events, utilities have observed a larger number of recurring lower level events with different suppliers. This is not entirely surprising. Until recently, there was no infrastructure for, or expectations of, sharing of lessons among suppliers. Furthermore, in recent surveys conducted within the supplier community, it was found that views varied widely on the sharing of lessons. At the heart of the issue is one fundamental concern shared by all suppliers, namely, that their sharing of lessons may result in the loss of their competitive advantage.

Suppliers and non-nuclear support organizations in general recognize the need and desire to improve the performance of their workforce. The processes, programmes and infrastructure that INPO and WANO have developed and refined over several decades are in the initial stages of emulation in many of the large supplier organizations.

A key expectation from utilities is that suppliers must own and implement their own safety culture and human performance programmes, led by their own senior executives, and not by utility executives. The choice to improve performance standards resides with the supplier and non-nuclear support organization leadership. Without a commitment to establishing and maintaining high standards, quality assurance, and continuous improvement, there is little prospect for improved vendor performance.

2. THE NEED FOR SUPPLIER COLLABORATION

There is recognition among suppliers that collaboration has the potential to allow them to significantly enhance their own safety cultures and human performance, and thereby improve their products and services. The resultant prosperity of the nuclear power plants would translate into prosperity for the industry at large as it would provide a continued stream of work for the supplier community.

The supplier community is confronting a number of significant, industry wide challenges whose resolution necessitates collaboration across the industry, including the following:

— Competitive market forces have led to the maturation of the nuclear supply chain. This is substantiated: by the presence of increased numbers of suppliers offering comparable skills making it difficult to sustain some highly specialized skills; by the arrival of multinational suppliers through local expansion or acquisition; by the utilities' increased pursuit of external services; and by the utilities competitive pursuit of external services to reduce operating costs.
— The knowledge and skills of the suppliers and non-nuclear support organizations are eroding due to the change in age demographics. There is also a wide variation in the quality of supplier programmes, such as initial and continuing training, corrective action and quality assurance. Such variation occurs both domestically and among foreign vendors. The ever-increasing number of foreign workers, whose performance standards vary nation-by-nation, adds to this complex risk calculus. Finally, low nuclear market demand invites vendors to supply a less profitable nuclear industry with less costly and less qualified workers.
— The improving standards and performance that have been achieved in the utilities' workforces is not resident to the same level in supplier and non-nuclear support organizations. There has also been a shift to a

global supply chain that includes many foreign subsuppliers that provide substandard, sometimes counterfeit, parts.

3. THE NATURE OF SUPPLIER COLLABORATION

Collaboration is not limited to different suppliers working together to share operating experience and lessons learned, and to develop common solutions to industry wide issues. It also includes collaboration between:

— Suppliers and their host utilities. This form of collaboration would involve aligning objectives and programmes between suppliers and utilities. One of the presenters reported on a practice where suppliers and the utility involved in the construction of a new nuclear power plant had jointly agreed to one common safety culture policy, and any new suppliers joining the project were required to commit to abiding by the policy.
— Suppliers and their sub-suppliers. This would involve extending the alignment achieved between suppliers and their host utilities to the tier 2 and tier 3 suppliers.

4. PRACTICAL APPROACHES TO COLLABORATION

The following provides a brief listing of actions taken or planned to enhance supplier performance through collaboration:

— Clear performance principles developed and communicated. This is facilitated through application of and self-assessment (Principles for Excellence in Nuclear Supplier Performance (INPO 14-005)).
— Improved alignment between suppliers and utilities. This is facilitated through:
  • Increased and more effective supplier executive engagement in utility performance;
  • Use of supplier–utility forums for exchanging perspectives on issues and issues affecting performance of both communities;
  • More consistent industry standards and expectations of suppliers;
  • Increased use of partnership models between suppliers and utilities, as compared to lowest cost bidder.
— Improved sharing of lessons learned through supplier operating experience being routinely submitted and used. This is facilitated through:
  • Use of a standard template to ensure consistency and quality in reporting;

  - Use of established processes for collecting, trending and disseminating operating experience and lessons learned;
  - Use of a database to share industry feedback on supplier performance.
- Supplier performance understood (measured) and monitored. This is facilitated through the use of standard methods or metrics for assessing supplier performance.

5. A PATH FORWARD

Utility support organizations, such as INPO and COG, both of which also have supplier participant programmes, have a key role to play in working with suppliers and utilities to advance the actions listed above. They have already commenced this task. Other utility support organizations might consider similar approaches, if they have not already done so.

A systemic approach to nuclear safety needs to include the supplier community. In this regard, it was appropriate for the IAEA Conference on Safety Culture to include a topical session pertaining to the supplier community. This practice should be continued for future international events pertaining to human and organizational factors (HOF).

There is also much work to be done to build collaboration between suppliers and utilities, and between suppliers, to improve safety culture and human performance. It is appropriate that the initial focus should be on the tier 1 suppliers. The next step will be to widen the net and to cascade the collaboration and alignment efforts to include tier 2 and 3 suppliers, and possibly other significant players, such as labour unions.

The workforce is constantly changing. There is a need to continually modify and adjust programmes to accommodate changing demographics and new entrants to the workforce.

SUMMARY OF OUTCOMES

DIALOGUE SESSIONS

Lead facilitators:
N. Afghan; T. Bannerman; L. Carlsson; W. Carnes; F. Dermarkar; D. Engström; V. Goebel; M. Haage; S. Haber; H. Mansoux; K. Heppell-Masys; L. Kecklund; C. Kopisch; K. Koves; D. Mcharg; O. Makarovska; K. Mrabit; H. Rycraft; C. Ryser; B. Skarbø; D. Tasset

Thirty-six topical dialogue sessions, designed to provide interactive forums enabling the exchange of perspectives, ideas, thoughts and practices, were arranged in the afternoon on days 2, 3, and 4 of the conference. The conference speakers and subject matter experts were appointed to co-facilitate a dialogue session based on their contributions to the conference. The dialogue sessions allowed time for deeper conversations and reflections, providing new insights towards improving safety performance. At the end of each dialogue session the lead facilitator summed up the highlights from the conversations, and these were consolidated and presented during the conference Chairperson's daily plenary summary.

The concept of shared space was a common theme throughout the conference, and a central objective of the dialogue sessions was to introduce how shared space works in practice. Shared space is defined as the space:

> "... existing between the individual and the people (individuals, groups) in its surrounding. A good shared space is characterized by:
>
> — Mutual trust and respect;
> — Decreased power dynamics;
> — Openness: free flow in sharing of thoughts and ideas;
> — Individuals who have interest in learning from each other and are curious of different perspectives;
> — Individuals who feel able to express views related to their inner thoughts and feelings about a particular issue without fear of recrimination or exclusion;
> — Conversations that go deeper than sharing facts;
> — Dialogue instead of discussion/argumentation.

> A good shared space is an essential part of a strong safety culture as its characteristics create opportunities to build a shared understanding of safety within the culture."[1]

Participants and facilitators of the dialogue sessions reported on the difference a good shared space makes in helping people communicate and understand each other's viewpoints. D. Engström, one of the dialogue session facilitators, reported that:

> "These cross over dialogues between regulators, researchers, licensees and representatives from other high risk organization were very valuable. During these days we heard a lot about the importance of interaction and communication for safety and if I could make one wish, it would be that we would meet more often. We have so much to learn from each other and taking part in other people's experiences is what makes us grow and see things in a different light."

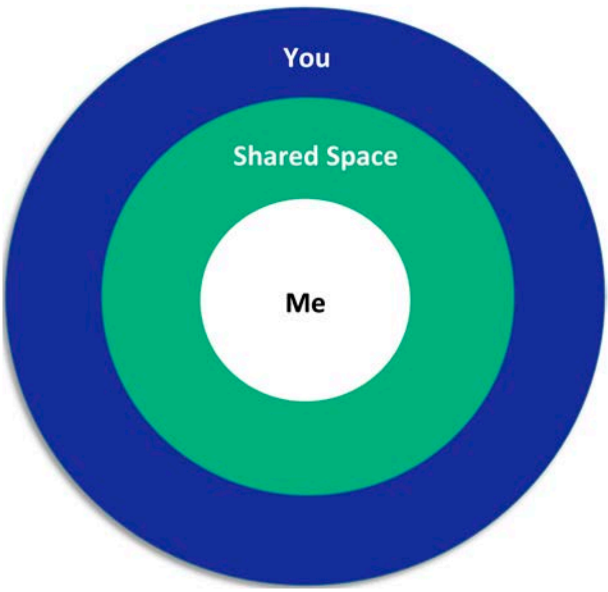

FIG. 1. The concept of shared space.

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, OSART Independent Safety Culture Assessment (ISCA) Guidelines, IAEA Services Series No. 32, IAEA, Vienna (2016).

The main themes coming out of the dialogue sessions were presented during the closing session by C. Hart, Chairman of the US National Transportation Safety Board. The results echoed the overall conclusions of the conference, focusing on:

- — The challenge of making safety culture more tangible, working to make ‘safety first’ an integral part of the organizational culture. It was argued that it is a leadership task to translate the intangible into tangible expectations and actions.
- — Application of a systemic approach and how it can help enhance the understanding of defence in depth and how safety outcomes are produced in practice. It was argued that practical systemic tools need to be developed.
- — The need to avoid that concepts such as ‘safety culture’, ‘resilience’ and ‘systemic’ become detached from the reality in the field — as a theoretical concept is not worth anything unless it helps us improve in practice.
- — The role of communication and collaboration for improving safety and the need to bridge the gaps between organizations and disciplines, as well as hierarchies and formal organizational structures.
- — The complexity of organizational learning and the need to apply stories from real life and embed learnings into systems and processes, enabling people to reorient their thinking based on new insights. The importance of learning when to exercise flexibility and when to proceduralize was lifted as an important issue.
- — Eight subject matter experts submitted papers that contributed directly to the dialogue session. These papers are included in the CD-ROM accompanying this publication.

CLOSING SESSION

Chairperson

M. WEIGHTMAN
United Kingdom

CLOSING KEYNOTE STATEMENT

REFLECTION, INTERROGATORY, PROVOCATION

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Abstract

What has been learned about human and organizational factors 30 years after the accident at Chernobyl? What is yet to be learned to envision and design nuclear organizations for 30 years in the future? The paper attempts an overview of these questions as represented by the rich and insightful presentations and dialogues during the totality of the conference. It employs a concept map derived from presentation abstracts, and groups recurring concepts by emergent themes to produce a plausible conference synopsis. Potential implications of the themes are expressed as a series of provocations intended to stimulate reflection and prompt discussion of areas for research, development and application. In summary, 30 years of exploring culture has shifted paradigms from human error as cause, to a systemic perspective. While human error is no longer an accepted default explanation, blaming culture and the organization may have replaced blaming the person. Invocation of complacency and admonitions to focus on the big picture, while perhaps well intended, may contrarily be merely the most recent manifestations of hyperculture. Perhaps the key lesson of this conference is a reminder that technology is simply an aid to rise above human physical limitations, and similarly that the 'technology' of HOF enables us to rise above psychological and social limitations, such as politics, ambition, greed, competition and individual limitations of perception and cognition. In rising above, we join together to harness science and technology in service of the betterment of the human condition. The challenge is to cease attempts to manage culture, and begin to manage culturally.

1. PROLOGUE

The conference organizers requested an overview grounded in the collective conference presentations and dialogue to aid consideration of next steps for human and organizational factors (HOFs) and culture. Many of the contributions represented the results of scholarly research, structured investigations or formal organizational improvement efforts. This paper should be understood as informal reflection on the past, present and future of our nuclear community: Where do we think we are? Are we better off as an industry based on what we have done? Where do we think we need to go? What do we think we need to do? Why do we think these things?

Our coming together marks 30 years since the publication of INSAG-1.[1] As we reflect on the past, perhaps it is time to pose a series of questions. Are we sustainers of a mature technology that is in some places declining and being replaced by other energy sources? If we consider nuclear a mature technology, should we focus most on operational excellence with renewed attention to managing the unexpected? Or, is innovation still a vital part of our industry?

After three decades have we fallen into a pattern of true believers [1] chanting mantras about culture and HOFs, or are we actively mindful of the organizations we create and inhabit? Do we see safe operations as something to be maintained, or something to be created daily? Are we aware of what it is like to do work, at all levels within the ecosystem?

Have we matured beyond blaming the workers, constraining them with ever more prescriptive rules to the point that the very humanity, innovation, and sense of accomplishment through a job well done is literally squeezed out of people's daily experience? Have we gone beyond the mystique that training, procedures, processes promote perfection; have we begun to recognize, reward and nurture relationships and human interaction as foundational to processes and systems?

With the advent of big data do we suffer from quantitative fixation, or measurement myopia? The oft-repeated phrase, if you can't measure it, you can't manage it misattributed to W. Edwards Deming, is in fact a myth [2]. His quote was the exact opposite: "It is wrong to suppose that if you can't measure it, you can't manage it — a costly myth". He admonished managers:

> "It is the relationship with people, the development of mutual confidence, the identification of people, the creation of a community. This is something only you can do. It cannot be measured or easily defined. But it is not only a key function. It is one only you can perform".

Are nuclear managers even aware of the significance of subcultures and the uniqueness of each? Do we help managers develop skills of humble inquiry and helping so they can enhance the experience of doing work, as well as the outcomes?

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

Finally, how do we as an HOF/culture stewardship community perceive ourselves? Are we writers of guidance, analysts, advocates, and sometimes critics? Do we see ourselves as helping shape the future environment in which new generations of workers in our industry and other high hazard technologies will have different and better experiences of what it is like to do this work? Do we consider the implications of the Internet of things? Likewise, do we consider the implications of the values, learning styles and social styles of the Millennial generation? Are we probing how work is changing; can we learn how organizations can manage so that change does not threaten but to the contrary makes life simpler, work more rewarding?

The author W. Gibson has suggested that, "The future is already here — it's just not very evenly distributed" [3]. Does our field work seek to find out what the future looks like? Should we expand collaborative field research? Should we focus less on workers and more on managing organizations and our ecosystem? Might we better contribute and communicate by freeing ourselves from some of the constraints of traditional academic and institutional information channels and controls? Can we be more foresightful; can we acknowledge that other energy industries and technical domains such as health care have built upon our foundations, may now be innovating beyond our industrial structure models, and engage collaborations that view towards the future rather than seeking to cure the past? It was with such musings that the effort was undertaken to look across the breadth of all the conference presentations and discussions to glean what might be learned about such questions.

2. A FEW WORDS ABOUT METHODOLOGY

If we seek to make sense of how we got to where we are from 30 years ago, our retrospective stories will differ considerably, but may in some important instances intersect, and by examining those intersections, perhaps we might understand some important things about our nuclear world. The journey of sensemaking for this paper was guided by one principle, three questions, and a modelling technique.

2.1. The principle

Seeking to fix the past, the future passes you by. Colleagues at the Center for Catastrophic Risk Management expressed a similar idea as Errors of the 3rd Kind, solving the wrong problem precisely [4]. The authors commented on the tendency to solve only technical issues that go wrong in crises, and failing to recognize and address the HOFs. As engineers and psychologists, they explored approaches to risk modelling that could be used to avoid E3.

An alternative approach to understanding HOFs is suggested by sociologist H. Becker's view of real worlds:

> "A 'world' as I understand it consists of real people who are trying to get things done, largely by getting other people to do things that will assist them in their project...The resulting collective activity is something that perhaps no one wanted, but is the best everyone could get out of this situation and therefore what they all, in effect, agreed to" [5].

Sociologists seek to describe; perhaps we should do likewise.

2.2. The three questions

Studies of expertise suggest that people progress through various stages, advancing from ignorance, to complying with rules, to institutionalizing rules into practice, and ultimately to a reliance on principles with respectful mindfulness of the uncertainties of all knowledge. Often, such principles are expressed tacitly as questions. For example, the philosopher I. Kant wrote that all our questions of human reason and speculation combine into three questions: what can I know, what ought I to do, what may I hope? [6]

Without pretence or hubris of intellectual similarity, the author's 40+ years of experience in assessing/evaluating organizations have honed a fascination for trying to understand how individuals and organizations think, undertaking the exploration guided by a three part recursive interrogatory:

— What does good look like?
— How are you doing?
— How do you know?

2.3. The model — Concept maps

The plenary presentation overview of this paper began by suggesting that the audience please not pay too much attention to the presentation. This was admittedly a humorous rhetorical device intended to relax and enliven the audience at the end of an intellectually intense week; however, there was also a scientific reason to attempt to shift the audience's attention focus.

Studies of visual acuity illustrate that it is not possible to pay detailed attention and to see the whole [7]. This fundamental characteristic of human perception underlies the concept model used to structure this presentation. Just as it was impossible for individual conference attendees to experience the totality of the conference by participating attending all topical sessions, so too is it impossible to perceive an entire organization or the larger ecosystem by attending to specific details of individual daily work activities. To see systems, we have to learn new ways to look and to see.

Concept maps began as representational tools to visualize relationships among ideas in science education [8]. They were seen as a way to illustrate how individual ideas cluster to shape larger wholes. Concept maps are often used to stimulate creativity and generate new knowledge. They can also be used as a map to guide application of diverse knowledge types necessary to explore novel research and create comprehensible representations of complex systems.

3. CONCEPT MAPPING — THE CONFERENCE AS A WHOLE

The anchoring nodes for the concept map were the topical areas listed in the call for papers: human and organizational factors, safety culture/culture for safety, leadership and management for safety, the systemic approach to safety, resilience engineering, and high reliability organizations (Fig. 1).

Looking at the overall concept map one may note varying degrees of detail associated with each of the six primary nodes. The amount of detail represented by sub-nodes and tertiary nodes should not be construed as any reflection on the quality of the presentations that informed the themes. Rather, a more accurate interpretation may be that those topical nodes showing fewer subsidiary nodes are more mature thus there may be more agreement on the content of concepts of or

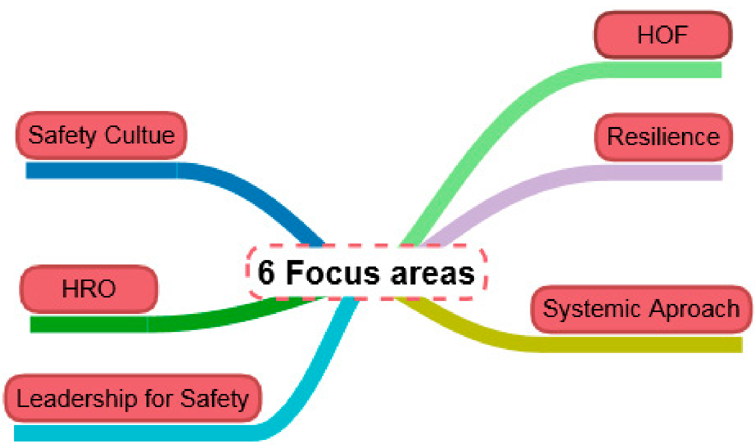

FIG. 1. Concept model of full conference.

the application of the concepts. An alternative explanation might be that in nodes containing less detail innovation may be occurring or there is less consensus and more variation in interpretation or practice.

For example, in the HOF node the first reference is to HOFs being well established or legitimized by the regulators. Turning then to the safety culture node, one sees that there is a considerable amount of detailed discussion about regulator culture. Indeed, looking at these two nodes together one might conclude that for traditional human factors the value effective techniques is considered to be well established, and the methods are well validated and considered their use is accepted practice. The role of the regulator is also recognized as being extremely important, the level of detail reflected in the safety culture node likely indicates that there is a tremendous amount of activity exploration and innovation in the role of the regulator as well as shaping operational safety culture and of regulators focusing internally on appropriate and supportive regulator culture.

As another example, one can see considerable detail in both the safety culture and systemic approach nodes. Exploring the details in each node, one can see that activities are not discretely associated with the individual nodes, but seem in many cases complementary and reinforcing; for example, that culture and systemic approach are areas of rich experimentation and innovation. Further, it might be construed that human factors have well established techniques validated and agreed upon by the industry, the regulator, and relevant stakeholders, whereas culture and systems approach have not reached an equivalent level of maturity or agreement. However, the quantity of detail could be construed as evidence of the importance accorded to these two areas and as illustrative of industry commitment to pursuing these areas to assure that the approaches, methods and techniques become institutionalized to a similar degree as human factors.

Or none of the above may be true. Concept maps do not provide truth or prediction, rather they provide a representation of concepts and relationships as provide a basis for discussion, reflection and generation of insights. Concept maps are an aid to representing complex systems; they do not discover truth, they help us to identify and explore relationships, generate new insights, and can serve to map the knowledge universe to chart new discoveries.

3.1. Human and organizational factors (HOFs)

The topical area of human and organizational factors reveals three primary themes. The first is that human factors are well established and there is a considerable body of data within the industry. While these data are valuable in their own right, particularly in the area of human and equipment interface and design of more effective operational concepts, speakers observed that this treasure trove of data should now be reexamined in light of what we know about culture and organizational factors (particularly data related to accidents and events) to see what else the existing data may teach us about the influence of those factors.

The second theme is that the regulatory legitimacy of HOFs are an essential part of nuclear expertise and management focus. In particular, human factors are recognized within the regulatory community in guidance and the regulatory framework. Analytical guidance for human factors is well established. While the principles and methods relating to organizational factors have yet to reach the level of maturity as in human factors, there is agreement that the legitimacy of organizational factors is similarly well established within organizational science and within international regulatory frameworks.

The third theme represents growing recognition of a need to further understand and promote awareness about human ingenuity and adaptability in the face of uncertainty. Often we have seen a tendency (particularly following crises) to presume that every conceivable accident can be anticipated, that sufficiently prescriptive procedures and guidance can be developed to respond to mitigate any potential situation, and that in so doing future accidents can be prevented [9]. This mindset seems particularly prominent in hyperculture environments where public relations and political assurances seem more important than scientific understanding of social and organizational influences. Time and time again thoughtful inquiry into serious events demonstrates that human ingenuity, dedication of the workforce, mutual trust and respect between management and the technical experts, and incredible human bravery in the face of physical danger remain the most important resources for mitigating harm and protecting the civilian population. Stories of heroism are to be found throughout all of our major accidents. These deserve thoughtful study for our learning as an industry, teaching new generations about what it means to be professionals in nuclear community, and for broader awareness of the genuine dedication of the professionals to the service other communities and the protection of the public (Fig. 2).

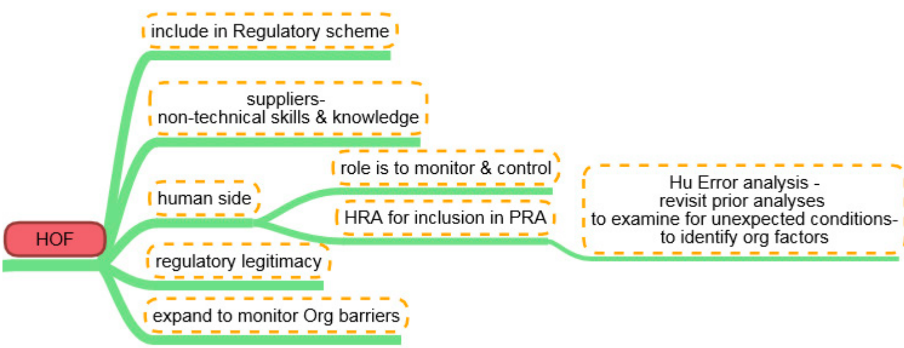

FIG. 2. Concept model: HOF node.

3.2. Safety culture/culture for safety

Three themes emerge from this node. The first has to do with hyperculture versus sustainability [10]. The presentations and discussion indicate considerable concern within the industry about how culture is portrayed by the public media and often by officials and investigation bodies. Too often they exhibit at least in public pronouncements a superficial understanding culture and in fact may be perpetuating a myth of culture as cause. This of course is contrary to the scientific understanding of culture.

For example, pronouncements of good or bad safety cultures are recognized by knowledgeable practitioners and the scientific community as reflections of ignorance, naïveté or attempts to avoid confronting real organizational or system issues that need to be addressed. The sense of concern about misunderstanding culture is one of warning; first urging the industry to be aware of cultural phenomenon and examples of hyperculture manifestations, and secondly to reinforce that culture is a highly developed area within social sciences that require expert knowledge, just as understanding nuclear reactions requires knowledge of physics. The warning to management as well as regulators is to urge that competent knowledge and expertise be institutionalized within operating organizations, support organizations, and within the regulator organizations. All parties need to able to ascertain whether discussions about culture are scientifically valid, or merely protestations for public relations or absolution of responsibility, as a façade rather than substantive understanding to aid correction of less than desirable conditions needed for safe performance.

The concern about hyperculture has stimulated language change currently in transition; the evolving use of 'culture for safety' in preference to safety culture. Language carries meaning, and the language of 'safety culture' has become misunderstood, with negative connotations that somehow safety may be different from quality, finance, security or other of the numerous factors that must converge for safe and reliable technologies. The language of culture for safety is becoming the accepted norm of expression to convey the more appropriate understanding that culture is how we have learned to work together to be successful, and if our learning becomes flawed and our actions ill-suited to the complexity of our technologies, then the outcomes of our collective decisions and actions could be disastrous (Fig. 3).

Sustainability is the antithesis of hyperculture. It is achieved not by doing more things, but by being mindful of the things being done. The mental shift requires one to cease with the idea that a culture has to be created, to the view that culture is unceasingly being created. It is impossible not to be creating a culture with every act. Sustainability begins with not doing, noticing instead of doing, asking rather than telling. Before taking action, ask what effect one

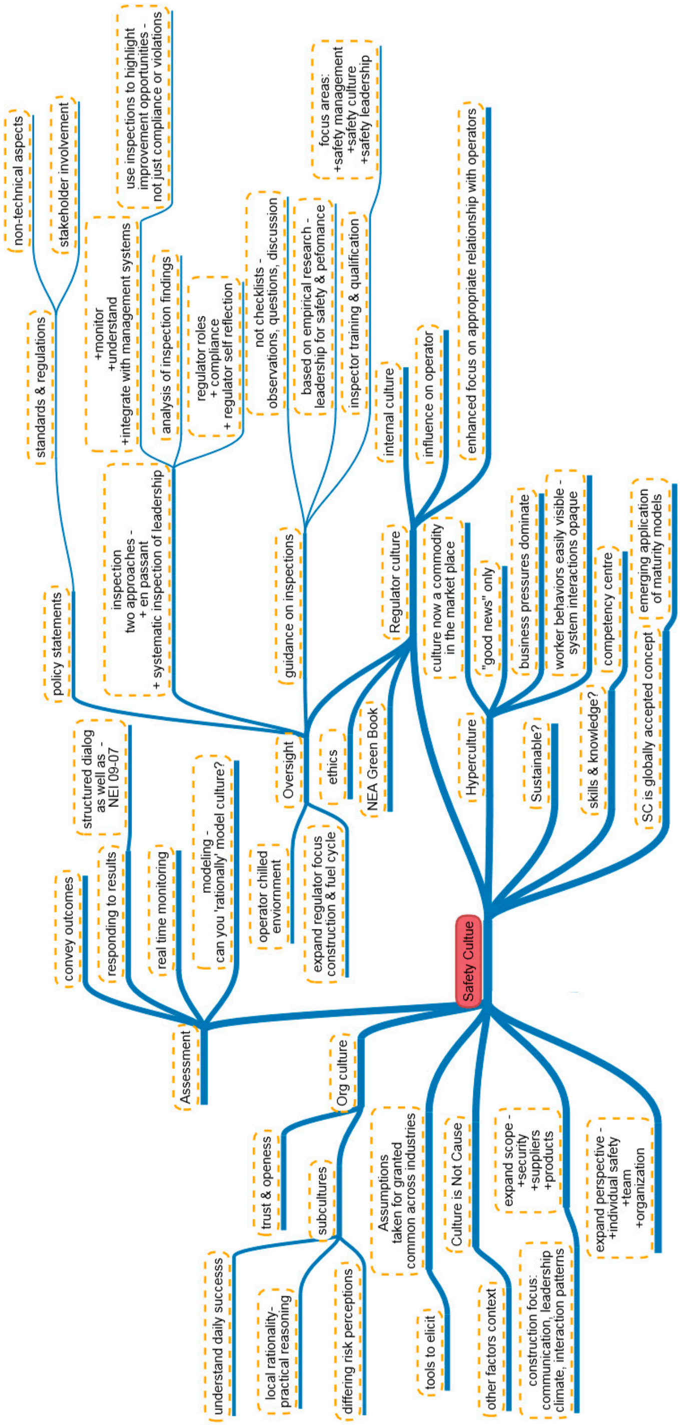

FIG. 3. Concept model: safety culture/culture for safety.

expects the act to have, then ask if the assumptions about cause–effect have any basis in reality. "…it has often been said that the battle cry of scientific discovery is not "Eureka!", but rather "Hmmm, that doesn't look right. So, how can that be?" [11]. A similar approach is advocated by Miller's Law in linguistics: "In order to understand what another person is saying, you must assume that it is true and try to imagine what it could be true of" [12].

The second theme relates to the relative maturity of culture as a concept. The term 'concept resolution' is intended as a digital analogy to illustrate that we in the nuclear community have a much clearer collective picture today of what intended by those who originated the term 'safety culture' 30 years ago. By no means should this suggest that what we have learned about culture collectively is fully understood by each nuclear organization, nor should it imply that each organization is equally mature in understandings or utilization in nuclear operation or strategic development of what is known and knowable. It should, however, indicate that a well developed body of knowledge, validated approaches and methods are available, and these have proven to have considerable value in promoting safe nuclear operations. Far from being a mere hypothetical concept, now 30 years later culture is well established as a prerequisite body of knowledge and practice necessary for mastery by any organizations seeking to be a responsible partner within the worldwide nuclear profession.

The third theme is likewise reflective of relative maturity. There is consensus that methods for assessing culture have matured to a level that they are deemed reliable and valid. This is not to suggest that all methods have equal reliability and validity, but such tools are within the nuclear domain that can provide quality and data for decision making. However, there is less agreement on the qualification of practitioners to employ such tools or to the qualifications and competencies necessary to analyse data to provide such quality data to decision makers.

A tendency has been noted for regulators to resist prescribing culture assessment methods or qualifications, except in a general sense for investigation of serious events. The nuclear industry as a whole has invested considerable energy and resources to develop and implement culture self-assessment models. While laudable, there remains the question of the validity and relevance of the results of such self-assessments, not in data collection per se, rather in analytic competence. Similar concerns have been noted in other industries seeking to understand social issues and conduct ethnographic inquiries [13]. In 1978, the Xerox Palo Alto Research Centre (PARC) started a new research area called 'Cognitive and Instructional Sciences'. This became the fertile crescent for developing many of the human centred design approaches that made possible the ubiquity of personal computing and the anticipated Internet of things. But more important than the devices were the design approaches developed by the introduction of social science research methods.

Culture is a specialized field within social science (Fig. 3). As with established nuclear fields such as nuclear engineering, chemistry, or health physics, formalized skills, knowledge, education, and training are necessary to achieve the status of competent practitioner or professional and thus have credibility within the larger technical community. As the PARC team worked to translate social science research methods into technical organizations, three phases of maturity were identified: Level 1: Basic Field Methods at the Toolkit Level; Level 2: Teaching and Learning Deep Analytic Competence; Level 3: Growing Strategic Competence. There are not yet generally accepted standards and practices as qualification criteria for what constitutes culture/HOF professionalism in the nuclear world. Clearly, widespread knowledge of culture and consideration of culture in internal assessments are desirable states to achieve, yet familiarity or layperson knowledge and citizen science are no substitute for including professional level knowledge and skills in the competency repertories of complex organizations and industrial ecosystems. Might the PARC maturity levels and the PARC ethnographic journey serve as useful mirrors to reflect on the status of social science approaches in the nuclear world and serve as useful trajectory for future developments?

3.3. Systemic approach

Along with culture, the systemic approach is a rich domain of inquiry and experimentation, and is perceived as essential for designing a safe nuclear future (Fig. 4). Three themes emerge from the presentations related to the systemic approach. First is the recognition that focusing on the operating plant as a homogenous self-contained entity ignores the influence of the broader ecosystem in which our plants operate. While we must always be aware of the day to day operating practices of our nuclear facilities, we must likewise be aware of the larger institutions factors such as policies, budgets, regulations, legal frameworks, future workforce education, future strategies for the nuclear community and the larger electric generation, transmission and distribution system, as well as consumer values, behaviours, and choices. It is only by attending to the influence of all actors comprising the larger ecosystem and designing cultures for safety aligned across actor communities that we can more reliably promote current and future safe operations across the full fuel cycle. It is of particular interest to note that influences of strategic scenario informed planning for future electrical transmission grids and distribution systems was not a prominent topic of discussion as context for forecasting the future of nuclear technology [14].

FIG. 4. Concept model: systemic approach node.

The second theme is recognition that we need to apply the same level of thinking about HOFs to projects as we endeavour to apply to facility operations. For example, construction of new facilities or modifications to existing facilities historically were sometimes undertaken with mindsets that they were in some way isolable activities with discrete inputs/outputs that may be ‘manufactured’ and merely ‘plugged’ in to existing or future operations. The many discussions that were heard during the conference about culture with in the subcontractor community, for example about adoption of human performance and organizational learning approaches, reflect that HOF thinking must be applied in every activity associated with nuclear technology.

The third theme relates to change and continuous learning. It is becoming more generally recognized that change and improvement cannot be driven by a forward engineered approach. That is, change within organizations is not as simple as a routine mechanical maintenance change. Organizational change requires the engagement, participation, and agreement of large numbers of people within different organizations, each with different skill sets and backgrounds. While clearly it is desirable to have a general idea of what the future condition after change might look like, there is growing realization that an end state cannot be described to the level of detailed technical specifications, nor can change be accomplished through a clearly delineated plan of action.

Organizational change is an ongoing process of learning. It must be guided by thoughtful experimentation, iterative and controlled to minimize unanticipated adverse consequences, to recognize and capitalize on innovation, and to share and leverage the learning from such experimentation. The term ‘strategic learning’ is used to imply that learning should be intentional, should be undertaken consistent with the strategic direction of the institution and the industry as a whole. Strategic organizational learning differs in scope from traditional training and operating experience in that it asked the questions what does the organization need to know and do to position itself for success and resilience in the future [15–17]. By engaging in scenario supported forecasting informed by operating histories and environmental scanning, institutions may more reliably and be able to focus valuable resources on developing capabilities to promote success and avoid adverse consequences in the future.

3.4. Leadership and management

Five key themes emerged in these areas, each in some fashion addressed by the plenary keynotes in the opening session. The first theme is prerequisite to the others, that above all leaders and managers must be committed to creating environment of psychological safety for all persons in the organization, in a larger sense for all persons involved in the institutions in the larger systems (Fig. 5). While this responsibility cannot be undertaken naïvely it should nonetheless be the prime commitment of leadership. In reality there are always power and status gradients in organizations in all cultures. For people to have the courage to contribute their insights and concerns leaders must demonstrate by actions in addition to words that such contributions are desired and valued. Fear of refusal, retribution, or embarrassment in the event that concerns might prove to be not fully informed sow seeds of distrust and discord. Telling and blaming create distance; asking, listening and acting create community. The shift that is needed: from managing culture, to managing culturally [18].

The second theme is that leaders collectively must embrace a systems view. Clearly managers responsible for day to day operations and specific technical areas such as maintenance or engineering must be keenly attuned to the technical disciplines. However, the organization must determine what the functions of management must be and how to monitor detailed technical activities to answer

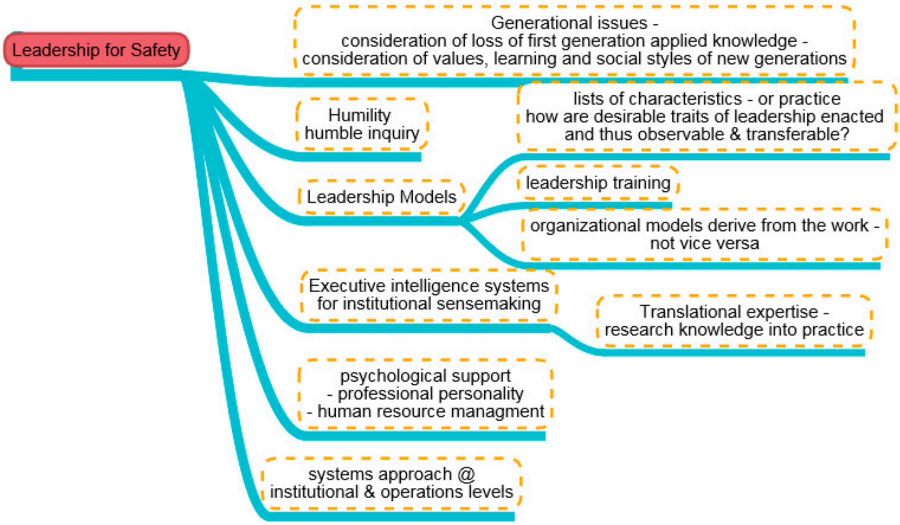

FIG. 5. Concept model: leadership for safety node.

the key questions of how are we doing, how do we know, and how we decide what to do based on what we know.

The third theme gives us approach for succeeding in the first two themes. By learning the skills and practices of humble inquiry and humble consulting, the organization the organization can become proficient in understanding what is going on in the organizations that what needs to be done about what's going on. This is a skill set not taught in traditional academic MBA curriculums or in most corporate leadership training programmes. Historically, those who had such abilities achieved them over years of careful observation, mentoring experimentation and self-study. No wonder that such leaders are rare and not the norm.

The fourth theme has to do with organizational design. Leaders' beliefs about reality govern design. As referred to earlier there is a tendency to presume that all the possible interactions of complex technical systems can be predicted and controlled through engineering, detailed specification of procedures, intense training observation and reinforcement, discipline of personnel for infractions, and ever increasing regulation, thereby preventing all accidents. Most mature nuclear communities know that this view is simply a myth maintained more for public and political reassurance than for any technical and operational value. In fact. what is needed particularly by leaders is to understand that even the most robustly validated knowledge has degrees of uncertainty, that there is a relationship between schema (our theory or mental maps of how work should be done) and the actual routines or practice by how work is performed in reality. The relationship of specifications versus practice varies from task to task and oscillates within only vaguely defined control parameters over time. Understanding the relationship between schema and technique, between explicit and tacit knowledge associated with practice should be a focus of management. Such a focus is essential to determine if job practice stays within acceptable parameters of variation consistent with changes in technology and the work environment, to determine if and when it is necessary to revise understanding what acceptable parameters should be.

The second aspect of design is more tangible, what people are expected to do, in particular what managers are expected to do. The functions necessary to manage organizations are numerous and diverse. No one individual can be expected to have mastery or even familiarity with more than a few. Much literature on leadership would have us believe that there is some super race of humans who have infinite knowledge, patience, skill — and never sleep. To the extent that an organization demands such super humanity from its leaders, that organization is doomed to failure. When formal job descriptions are woefully disconnected from the realities of managing, then the difference between disaster and success is merely luck. The distinction between good performers and poor performers is often more about an organization's clarity about functions and tasks of management, the skills and knowledge associated with these tasks, and proper allocation of functions and tasks within the management team. Leaders must be free to do what is most important to help all others in the organization to succeed.

The fifth and final theme relates to the equation between schema and routine. How does one know, how does management monitor this relationship? Maintaining effective operational control calls for executive intelligence systems grounded in operational experience, interpreted with insights from social science (respecting requisite variety) focused on foreseeing potential unanticipated future conditions. What does a holistic intelligence system look like; one that includes scientific research findings, professional judgement, stakeholder values and concerns, as well as organizational data as frames for reflecting on operational data to understand 'what's going on around here'.

3.5. Resilience

The topic of resilience has emerged more prominently during the past decade as a positivistic presumption of full 'know-ability' of cause–effect began to lose reliability when confronted with massively complicated technological systems within complex social ecologies (Fig. 6). Success with such complexities requires more nuanced understanding of relationships and levels of uncertainty. Five themes emerged from discussions about resilience.

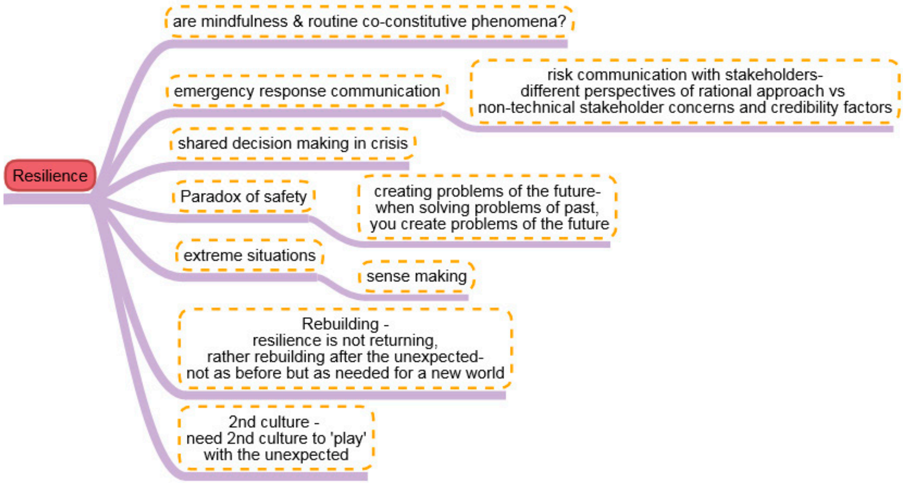

FIG. 6. Concept model: resilience node.

The first is the tenuousness of normalcy. It is generally thought that individuals crave stability and routine. We know however that some individuals seem to thrive on the adventure of confronting the uncertain and overcoming adversity. One of the milestones in our 30 year journey was to begin to understand that nuclear operations are dynamic and should not be presumed to be static day after day. Recognizing the so called normal human desire for stability there were many calls to simply be more attentive and to avoid complacency, in other words one could override the normal human condition by admonitions. As we have explored the ideas of resilience many have come to recognize that concepts such as complacency require much more nuanced understanding. For example, what some might call complacency may in fact have its roots in factors such as training and education, environmental conditions that place unreasonable demands on human cognitive processing, social pressures that dictate conflicting goals, etc. Perhaps instead of relying on admonitions we might be better advised to look to designing techniques and cognitive support tools which aid us to sense subtle changes in system behaviours and be mindful of such changes [19].

The second theme is that of dynamic crisis. In the early stages of the 30 year journey it was tempting to design a limited set of accident scenarios to bound our attention to preparing for emergencies. As we learn more about the varieties of uncertainties that might indicate declining operational conditions we have begun to understand the crisis management is not in fact merely preparing for anticipated scenarios but in fact developing capabilities to respond to the unexpected. Therefore, considerable attention has been and is being focused on flexible crisis management with ongoing analysis of operating events being used to construct alternate scenarios which then can be used for training purposes to help plant personnel develop diverse metal models that can be called upon in conditions of uncertainty to innovate novel mitigation strategies when presented with heretofore unanticipated events.

The third theme is one of collaborative decision making under crisis. This theme has two major components, one focused internal to the operating organization and how decisions can be made using relevant input from all technical disciplines. The other extends to the systemic perspective, the need for collaborative decision making involving all relevant parties, enabling decisions informed by those with the most relevant knowledge, and considering implications of decisions according to shared values of protection and consequent mitigation.

The fourth theme is about recovery. Early on in our industry, thinking about post-accident activities implied an assumption that actions could be taken to return to a state that existed prior to the accident. Today that mindset is being replaced by an understanding that there is no returning to normalcy, that the world post-accident will be much different than the world pre-accident, and that recovery needs to be seen as a process of engaging all parties affected by the actions in mutual efforts to envision desired future conditions, negotiating what is possible compared with what might otherwise be ideal, and preceding in an incremental manner via small wins towards a new future.

The fifth and final theme is related to systems to support leadership and management. This theme is labelled as ‘dual operating systems’ for navigating the unexpected. A body of knowledge has been accumulated for describing, analysing, understanding, and managing complex systems. Some of the concepts are being included in academic curriculums in management studies and multidisciplinary science, technology and engineering (STEM) programmes. There are frequent references to complexity theory within the within the popular media. However, translating the learnings from resilience and related high reliability theory have been piecemeal, driven in large part by anecdotal experiences. Adoption of such concepts into nuclear management as well as management of similarly high consequence technologies remains in relatively early stages.

Identifying, analysing and developing capabilities to deal with the unexpected require specialized knowledge and dedicated effort. It is unrealistic to expect traditional line operator management to have the time, abilities or inclination to develop more than a familiarity with this specialized body of knowledge. Thus, the idea of separate or parallel operating systems within organizations has been advocated to perform for precisely those task of monitoring, detecting, analysing and recommending actions in consideration of present and future uncertainties.

3.6. High reliability organizations (HROs)

The final topical node that completes the conference concept map relates to experiences in other high reliability organizations. Three themes emerged from those discussions. The first is the growing awareness that while technologies and the nature of hazards do in fact differ among the safety significant disciplines, precursors and assumptions that distinguish high performing versus low performing organizations are common across a broad range of safety significant technologies.

The second theme is that theory and associated HRO frameworks provide useful vocabulary and concepts for advancing organizational analysis and design. Consistent with the IAEA's focus on systemic approaches, there is a sense that the high reliability frameworks should be extended beyond individual organizations to advance understanding of the broader ecosystems.

The final theme is about assessment. While high reliability theory is fairly well established, tools for assessment and methods for translation of theory into practice are not as well established. More work is needed on translational research and developing consensus on validated analysis methods that may be used confidently to inform decision making (Fig. 7).

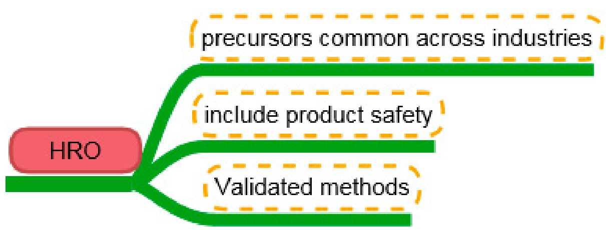

FIG. 7. Concept model: HRO node.

4. PROVOCATIONS

Informed by themes emerging from the conference, the following provocations are intended to stimulate reflection, discussion and further research to set the course for the next 30 years for using HOF to institutionalize cultures for safety across the nuclear technology life cycle. The provocations are advanced within the context of two bounding principles: fixes of the past shape problems for the future, and models derive from the work, not vice versa.

Provocations:

— Where are real data on what good leadership and management practice look like?
— There is an abundance of lists of characteristics and behaviours of effective management and leadership in nuclear operations, less so for regulators and other key actors in the nuclear community. To what extent are such lists theory driven or based on scientific observation and correlation? Scholars such as Henry Mintzberg have argued that management is a practice that is discernible best through observation of what managers actually do [20]. Where is the ethnographic data that might be examined for correlations with plant performance, and what ethnographic techniques could be employed to produce useful insights?
— Is management by evidence, or anecdotal opinion, and are there better ways? As technologies have become more complex, and as the rate of knowledge generation has increased, the nature of decisions has become increasingly complicated and management is increasingly called upon to solve 'messes'. Professions like medicine and science research have been highly dependent on mentorship and peer review to transfer and validate accepted practices, but the explosion in generation of new scientific knowledge render old ways of knowing and transferring knowledge obsolete. Management literature, particularly in health care, has focused attention on evidence based decision making. Some nuclear utilities have focused on using data from operating experience data based with algorithmic decision processes. Others argue that evidence for management can never approximate the reliability of evidence in the physical sciences; thus management can never be evidence based, only evidence informed. Some of these scholars take the perspective that organizations are co-created and co-defined by multiple actors, the notion of 'evidence oriented organizing' is more realistic than a search for 'evidence based management' [21, 22]. Still others argue that evidence based management at best helps avoid errors, but that change and innovation come from shifts in mindsets which occur only by insights, and that focusing on preventing error keeps us from having insights [23]. Is it possible to do both?
— Is career by development or Darwinian selection? The electric power industry has a strong tradition of selecting high performing technical personnel, providing them with general management training, and promoting them over time into progressively higher levels of management. Following the accident at Three Mile Island, utilities in the USA and Europe adopted a number of management development practices from navy nuclear programmes; these were then adopted more broadly internationally

via IAEA and WANO guidance. Such guidance focused predominately on nuclear plant operations, less attention has been placed on institutional management and leadership of utilities, vendors or regulators. The needed skills, knowledge and competencies of future leaders, managers and technical staff are speculated to be even more diverse than past and present generations of nuclear professionals. Development of nuclear professionals requires considerable investment and years of experience to develop proficiency and expertise. So what approaches are necessary to develop and retain the workforce of the future?

— Do we co-create the nuclear ecosystem or react to it? The concept of technical ecosystems examines the relationships among multiple actors who influence the research, design, construction, and operation of complex technologies across the complete technology life cycle. This is the intended scope of the IAEA focus on a systemic approach. There are important distinctions among the discussions of adaptation, resilience and co-creation; adapting to changes in the environment as the changes occur, coping with the unexpected, or directly engaging with other actors in the ecosystem to create the future. Not all organizations pursue the same strategies of response or engagement. What is known or knowable about the strategies being pursued by the more successful nuclear actors?
— Can we reliably differentiate between hyper and sustainable culture? Simplistic promises abound in popular literature and even official pronouncements about preventing all accidents by fixing safety culture or enforcing stringent standards of accountability. Far too many examples illustrate the fallacies of culture change by fiat and slogans, check list action plans, ever more detailed procedures, and increased behavioural observation of workers with increased discipline for infractions. Sustainability derives from trust, mutual respect, psychological safety, communication, and ongoing focus on making it easier to do good work. Do we know how to tell the difference?
— Is the HOF role main stage, or bit player? There is HOF, and 30 years of culture. But are the skills and knowledge of HOF centre stage? A few individuals educated and trained in social sciences cloistered in human resources departments do not place HOF knowledge as central to operations and decision making. To what extent is knowledge of people, organizations and social systems valued comparably to knowledge of engineering, operations or finance? What does good look like?

5. HOF — THE NEXT GENERATION?

There is consensus in the industry, as exemplified in this conference, that HOF/culture is considered essential at the highest levels of industry operations and regulation. There is also consensus that even more emphasis is essential for the future promises of nuclear technology. But what does good look like? Is HOF a profession, community of practice, or…? How might we know what our field of inquiry and practice might become?

Being enmeshed within a highly technical community, it is sometimes difficult to be mindful that our ways of knowing are only a small part of what it is to be human. Throughout history we have experienced many ways of knowing – though art, philosophy, religion, politics, physical conflict. Science is said to be unique in that it is empirical, it relies on the physical senses observing and from the observations hypothesizing, testing, theorizing and ultimately applying.

Many notables of the scientific community have commented on the different ways of knowing and the niche occupied by science, in particular Nobel laureate in physics Richard Feynman. In his own delightfully idiosyncratic way, Feynman communicated in stories, metaphors, poems — and sometimes with bongos. In his essay The Value of Science, he comments on the folly of (physical) scientists presuming to address social problems [24]. Scientists, he tells us, do not (or should not) spend much time looking at social problems because "we don't have any magic formula for solving social problems, social problems are very much harder than scientific ones, and…we usually don't get anywhere when we do think about them. I believe that a scientist looking at non-scientific problems is just as dumb as the next guy —…" Author Phillip Pullman also tells stories about the human condition, and explains that stories are essential: "There are some themes, some subjects, too large for adult fiction; they can only be dealt with adequately in a children's book" [25].

So we may find a glimpse of the possible future of HOF in stories of how things might be. Star Trek is considered to be one of the most internationally popular science fiction franchises, marking 50 years of continued popularity in the fall of 2016, with more yet to come. The original television series was characterized as a 'space western' often featuring good guys and bad guys engaged in interstellar conflict. The second series, Star Trek: The Next Generation, was noted more for explorations involving sociological and political relationships with alien cultures, as well as exploring what it means to be human. In contrast to the action hero demeanour of the first series captain, The Next Generation's Captain Picard was portrayed as a more cerebral, reflective individual often engaged in diplomacy and negotiation to resolve conflict or establish relationships with new civilizations.

An important new addition to the crew of The Next Generation was the position of Ship Counsellor. As the series progressed, the role of Ship Counsellor evolved from one of psychologist advising on crew morale and psychological perspectives on alien leaders to a broader role of co-equal in the ship command hierarchy sitting in the bridge command centre supporting the Captain, along with the First Officer, Chief Operations Officer, Security Chief, Chief Medical Officer, and Chief Engineering Officer. The role of counsellor expanded sociologically to advising on mission planning and conduct, strategizing in complex negotiations and crises, serving on 'away teams' engaged in off-ship explorations, and qualifying to serve a Bridge Officer.

Not to overextend a metaphor, Star Trek: The Next Generation might serve as an aspirational model for the status of HOF in the next 30 years. The role of HOF practitioners is not to decide, but to help decision makers make better decisions; not to plan missions but to help maximize the potential for mission success; not to direct co-constitutive relationships within the larger ecosystem but to help conduct analysis, design strategy and facilitate such relationships; not to be an expert on nuclear technology but to possess unique social expertise co-equal in significance to technical knowledge, yet with a familiarity level knowledge of nuclear science and technology operations, along with sufficient management training to be able to qualify for other positions of management responsibility should the need arise.

6. EPILOGUE

After 30 years of exploring safety culture, what remains to be learned to continue the mission of advancing the safety and performance of our nuclear technologies? Other science and technology communities have looked at what our industry initiated in 1986 and examined similar phenomena within their domains applying different lens. Seeing the same thing differently can give clarity to organizational myopia and provide new insights.

Design thinking is an innovation approach that builds upon the industrial engineering statistical process control traditions that gained wide spread attention beginning in the 1980s. It advances those traditions by applying perspectives from social and cognitive sciences. Fundamentally, design thinking can be viewed as tools for simplifying and humanizing [26]. Perhaps this might be the best of all advice for the nuclear industry as a basis for going forward; begin with simplifying and humanizing.

The typical way of thinking about management of nuclear organizations is not wrong, it is just not correct. Phrased differently; the propositional formulaic thinking models (explicit knowledge) that are intrinsic to the nuclear industry are necessary, but not sufficient. The concepts, theories and tools needed to think socially (using insights from social and cognitive sciences) are complex as appropriate to deal with complex problems. However, a paradox revealed by complexity sciences is that complexity may be best understood by seeing simply. The simple is more memorable that the complex. Writing about the role of science in decision making, J. Ausubel offers an example of such simplicity: "Let us define cultures simply as formulas for survival and science as a rigorous syntax, a system for error-correcting" [27].

C. Geertz offers another powerful simple distinction: "culture is not a power, something to which social events, behaviours, institutions, or processes can be causally be attributed", it is a context for description, and analysis of culture is "not an experimental science in search of law but an interpretive one in search of meaning" [28].

Nuclear managers need simple, powerful understandings they can use to guide their actions. Long lists of characteristics and behaviours do not serve well what managers actually do. P. Pullman gives us another clue of simple understandings: "We don't need a list of rights and wrongs, tables of dos and don'ts: we need books, time, and silence. *Thou shalt not* is soon forgotten, but *Once upon a time* lasts forever". At the most simple level, managers need to know that people organize not by charts on paper, but by stories. Stories tell us what it means to be human, what it's like to live in our organizations. And stories come from engaging with others.

A pioneer of organizational learning, I. Nonaka, speaks about the concept of 'Ba' as shared space for emerging relationships to nurture knowledge creation. Philosophically, Ba is the world where the individual realizes himself as part of the environment on which his life depends [29].

In navigation a point in space (a location) is determined by the convergence of measurements from two different points. The idea is that one can be more confident with a result if different methods lead to the same result, the approach is called triangulation. The same approach is used in social science, validation of data is accomplished by cross-checking different measurements to determine if the results converge. The point to this discussion? How many data sources are necessary to come to the simple conclusions; create safe spaces, create shared spaces, listen to stories and act upon what you learn? By so doing you make culture happen rather than having culture happen to you.

From a 40 year career assessing organizations, meeting people of many professions in research, construction, operations and regulation — across nuclear and other safety critical professions — I'm constantly impressed with how much people are engaged with their work and how much they know. Whether I'm conducting culture assessments, or simply walking around a facility talking with people, what consistently seems to interest people most is talking about their work. Sure, on occasion they may complain about management or how they may not have been treated fairly. But mostly they want to tell you about their work, how they do it, what they are good at, and what they've accomplished — often in the face of bureaucratic barriers and apathy. Yet there is a large body of survey research indicating that the majority of people are not engaged [30]. That is not entirely accurate; people are highly engaged with their work, they are just not engaged with their organizations and managers.

What can we learn from this? Leaders in health care improvement advocate that the exciting future possibilities of health care rest upon creating joy and meaning at work [31]. Research on job crafting reveals that people who translate their work tasks into high value contributions to society are more productive, happier, and have fewer illness and injuries [32] This way, for example, hospital house-keepers become first-line infection control staff. The difference is not simply terminology, the difference is meaning and status conferred though meaning. V. Frankel wrote powerfully of how meaning enables people to survive even the unimaginable [33].

The preamble for this paper described three questions that served as the recursive inquiry for developing and interpreting the concept model of the conference as a whole. As mentioned, Kant maintained that all questions about human reason and speculation combine into three questions; What can I know? What ought I to do? What may I hope? Kant then added a fourth question: What is the human being?

Likewise, we conclude with a fourth and final question that emerged from this inquiry: is your organization imbued with an atmosphere of honourable purpose and meaning? As managers and leaders do you take this as your responsibility? Do our organizations support people in their desire for purposeful, meaningful work, do they identify as members of a respected professional community, and do we collectively pursue our work for betterment of the societies in which we live? So as we begin our voyage of the next 30 years, are you prepared to: Make it so?

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CLOSING SUMMARY

Chairperson

M. Weightman
United Kingdom

I'm afraid that now, according to the programme, you have got to hear from me again. So forgive me for that. But, I just want to reflect on some of the important points that have been brought up during the plenary presentations.

I said at the start of this conference that I believe that it was most timely, most important, and for me, promised to be most exciting, as it could be the foundation stone for a new dawn for safety, at a time of great change, challenge and opportunity. What I have seen and heard over the last four and a half days has fulfilled that promise and wish, but I think it beholds on us all now to do something about it, and with the outcome. It has confirmed the advances in the tools and thinking, and provided new tools and ideas on how we can advance, provided us with a vision of the way forward, and now, as we have heard, the future is in our hands. It is up to us to go away and make it happen.

We heard from many, many excellent speakers, probed our understanding with incisive questions, (I hear some say, 'when the chair allows'); had dialogue sessions to take it further, and swapped ideas and explored other's work and thoughts; and, we have had the benefit to look around some excellent posters giving further ideas of development. In providing my summary today I will not do justice to all of this and everybody's contribution, but I will try to give a bit of a flavour of our week.

I must first, however, thank you all for your attention, involvement, and patience at times. As well, as thanking you all, I must thank all those behind and in front of the scenes that have made it happen; all those speakers come from far and wide, the poster exhibitors, subject matter experts, dialogue facilitators, co-chairs, and rapporteurs, but also I want to point out that this would not happen without the conference organizing team, the conference services team, buildings maintenance and management services, cleaning staff, those who provide the food and means for us to exist. Perhaps last of all, but not least, Monica's excellent team. Thank you. (applause) And perhaps a personal note of how I have seen Monica and Helen and others in their team drive through all the challenges and carry them forward with determination, perhaps all the obstacles that perhaps also I put in your way at times. Thank you all.

Now let me try to provide a few thoughts about what we have heard.

1. LEADERSHIP

We have heard about leadership and creating a culture for safety. Brilliant speakers, providing some very personal insights from their own experience. Insights such as:

— Leaders need to be extremely clear about their job.
— My job, is to continuously improve the safety culture of this company.
— Workers are a resource that we must harvest.
— I am here to make a difference.
— Judge me by my actions, not my words.

And most basic of all; leaders must engender a climate and earn trust and openness by humble leadership. If they don't, they won't know what needs fixing and they won't be able to make change.

2. CULTURE FOR SAFETY

The culture of an organization starts at the top, but a long lasting robust culture comes from embedding the values throughout the organization. In taking forward improvements in cultures for safety in an organization, be aware though, of creating a 'hyperculture', or at least an impression of one — where some view the culture as: just pretty words, not practical things to change, or just another way of management beating me around the head.

Do not use culture for safety characteristics as a check list, but as a framework for understanding. It is the outcome that matters. The culture for safety change in an organization is transformational, not about how can we change them. Finally, two essential points:

— Culture for safety is intangible and cannot be regulated; it is culture for safety, and for every other sort of outcome – for success, for security, there cannot be more than one culture in an organization.
— And for everybody, safety; culture for safety, is not just about NPPs, it's about all those activities that use nuclear energy for peaceful purposes.

3. STAKEHOLDERS AND A SYSTEM FOR SAFETY

A powerful reminder was made about the role of stakeholders and how they view the nuclear community. Society decides whether things are safe or not, not the industry and not the regulatory body. It is with the tolerance of society that we operate these plants and regulate them. They only accept the risk because they perceive some benefits from it. They make the decisions, not us. We have also heard about the many benefits of a collaborating approach, rather than an adversary approach, and how evidence from the US aviation industry show the benefit, not just in safety performance, but also in the bottom line of business success. And, this resonated in many ways, especially in fostering and understanding of the need — the vital need — for a systemic approach among the various areas of science and engineering. We do need each other; stop just working in your own box. It also highlighted the need to promote a culture for safety in regulatory bodies and an understanding of how in their work, they can impact on the culture for safety in the industry they regulate. That impact could be for better, or worse. Looking to the future, points were made on how we can embed a culture for safety, such we do not have to use the term, as people will say it is the way we do things around here.

Also, despite all the change that will come from increased automation, and plant–man–human interfaces, humans will be involved, and will need leading and management. We also heard about how our kids and grandkids may think differently to us, and how we have to take that into account and how can we make a culture for safety as part of their thought processes. Society in the future will demand ever more information and involvement and we have to respond to that. And perhaps, and no doubt it will, the centre of nuclear power will shift away from the western world, and a wider range of cultural norms will be needed to be embraced, welcomed, and utilized to make us all so much better.

4. INVOLVEMENT AND COMMUNICATION

A very important area was touched on: that of stakeholder involvement and risk communication as the key to making a more resilient safety culture, determining how they hold us to account, how we are explaining our actions and decisions to them, makes us stronger — that challenge makes us all so much stronger. We also heard about risk communication from real experience after Fukushima Daiichi, as the key to a more resilient culture for safety. Some crucial points were made: lay people and experts differ in perspective, society will address risk from an emotional standpoint, while experts tend to use numbers and Cartesian logic. People tend to see natural things as safe, whereas person made things are inherently unsafe. From Fukushima Daiichi we learned that people did not want science and classroom education, but simple information about how to deal with the situation and their fears. We also heard that risk communication is about listening and understanding, and using language that the public and others can understand. Perhaps the same applies to us experts in one area, when we try and communicate with another area. Do not forget that having control changes perception of risk, so the involvement of public is essential. I remember the statistics about car driving or going on a train; we all think we are in control in a car, but it's more dangerous.

Overall, we need to up our game to improve communication, between generations, between cultures, between managers and workers, between experts and public, and perhaps making it a natural thing that we do. And perhaps we can hear as we have, that more storytelling is a very useful way of passing on the cultural lessons to future generations, that is how the human race has done it for decades, for centuries, for millennia — storytelling embeds cultures.

5. CHANGE

And of course, we had very many opportunities to listen to the latest advances in the science behind human and organizational aspects of safety. This morning we heard how internal decline in an organizations and outside pressure could lead to degradations to the extent that what happens can happen or not be effectively handled. Perhaps through a lack of commitment of top management. But now we have heard about massive important reform that is in hand, starting at the top and taking root right through the organization. We have also heard from our colleagues in Canada how utilities can change and that there are mechanisms of doing it. We have also heard, how, with a challenging speech, about how we can combine resilience engineering into our thoughts about nuclear safety; shifting control, earning trust. Can we allow an increase in the number of smaller events to be better prepared to deal with the large unknown events?

We have also heard from a review of the history of nuclear power and safety and a reflection on the past that it can help in guiding our work into the future, noting that nuclear power is going to grow, and perhaps we need a real step change in safety. That is against the background of more challenge, while the infrastructure around us in terms of resources, both financial and in people perhaps is diminishing or spread even thinner. It will take time and some effort to really distill out and set down all the insights and advances in understanding from this conference. For that, I hand over the work to the excellent IAEA team. But for now perhaps, DDG, if you will allow me, perhaps some views on the outcome, and they will be personal, to you. I started to write this as a letter:

Dear Deputy Director General,

It has been my very great pleasure, privilege and honour to chair this most timely, most important and for me, most exciting conference. Congratulations, for an excellent and exceptional conference. But could it be the last of this type? Let me explain a little what I mean. But forgive me, I am not diminishing the work that is done to date.

One of my biggest concerns is 'why do we not seem able to learn the lessons'? Is it because we are not able to identify the right lessons? Or is it because we don't know how to learn? Or is it because after a time, we just turn the page, we become complacent? Or is it a combination of many things? Perhaps, and I believe it is, it is the last one. One of the clear messages from this conference and I would suggest, from the TEPCO Fukushima Daiichi accident, is that we must and cannot any longer just look at safety from the comfort of our own fortress of knowledge and understanding. We must see things from others' vantage points; break down the fortress walls surrounding each area of understanding science and engineering. Join together, playing our own favourite instruments perhaps, but in great harmony; really embrace a systemic, holistic approach to safety. And what we need though, is a conductor, to bring out the best, in making sure we play is such a way, that beautiful music of holistic safety for all, in all circumstances, for all times, for all facilities, is there. And it is so powerful, that none cannot be enhanced and embraced by it. So, I look to the IAEA to be our conductor. That catalyst for change, that leader of the way ahead. So if I may, I humbly provide some overview of the main outcome, perhaps to light the way a little bit for you.

A systemic, holistic approach to safety is essential at all levels, but we do need more understanding and practical tools. It should be behind all what we do, and perhaps should be the basis for all the IAEA products and services, or at least some thought given, in how it can be used in such a way that the existing materials are better joined together, filling the gaps where needed. It has to be based on outcomes, not just be a set of processes, just to provide a new set of beautiful words and pictures and tools — not a hyperculture. Thus, it has to be founded in delivering practical products, to help deliver change in organizations, and the way people think and behave. Some first steps may be the tools and steps available to the Member States, to help us change to a holistic culture for safety; to nurture a culture for safety and security and safeguards and success in the bottom line. Based on collaborating and learning with and from others; pinch with pride ideas, methods, and tools from other industries, other sectors of work within industries using ionizing radiation, other disciplines. We have much to learn in advocating for a cultural change. And understanding that safety means listening and learning, based on seeing the world as others see it, looking *through their windows on the world, to recognize the importance of including all stakeholders in the system, it is the public who determine whether a plant is safe in reality. And perhaps fundamentally, testing the IAEA products and services against a holistic view of the safety system, not just the components, but most importantly, the interfaces and interactions between the components.*

Let me finish now, by thanking the IAEA through you DDG, for this opportunity to contribute to what may be seen as the next leap forward, the new dawn for nuclear safety to better serve the peoples of this world.

Thank you.

CLOSING STATEMENT

J.C. Lentijo
Deputy Director General,
International Atomic Energy Agency,
Vienna

Good afternoon. Firstly, thank you Mr Chairman for giving us this excellent summary of the major outcomes of the conference that surely will constitute an excellent guidance for the future activities of the Agency in this area.

It is obvious that we all have to learn from experience — this is essential in all sectors, especially in those dealing with risks, and for with nuclear risks, it is even more important. And I would say that in this sense, this conference has been a relevant instrument, providing a good opportunity for all of you to evaluate and assess the practices and the progress around the human and organizational aspects of assuring nuclear safety, as this is one of the sectors in which we really need to learn from experience.

In the same context, it is obvious that it is absolutely important that lessons learned are linked to the realities, including the human realities that were associated to accidents, to the serious, but also to the minor ones. And it is also very important to link these lessons learned to the daily realities that happen continuously — as a way to ensure nuclear safety.

Working hard today is the best way to ensure that we are building a better future. As Chairperson M. Weightman mentioned, it is important to establish the foundations to create, to build this better future as both nuclear safety and security are concerned. You have discussed several elements these days and I envisage that these could be the main elements to guide the way the Agency is dealing with this issue in the future.

You have mentioned how to evolve from the theoretical concept of safety culture through the more practical and implementable concept of culture for safety and security. Identifying practical programmes and practices that can make a difference to an organization and avoiding ‘hyperculture’ situations are also relevant elements to build this future upon. You have mentioned also the need to build a systemic approach to safety. In my view, this is essential as a way to implement the safety culture and all the improvements needed in the organizational and human factors in a way which is practical, which is harmonized and that could be benchmarked with other situations. In this context, it is obvious that collaboration and cooperation among the main players is absolutely necessary, especially for the complex situations which are related to the nuclear sector.

Be sure that the Agency is taking this commitment. That we will act, as you, Mike, suggested, as the focal conductor for building this new future, we will take all the conference outcomes to build an action plan on how to address these outcomes for the future.

Let me now join Chairperson M. Weightman in his thanks to all of you, to all the participants for your contributions, I would also like to express personal gratitude, and gratitude on behalf of the Agency to all the speakers, panellists, session chairs and co-chairpersons for their very active and essential contribution to the conference. Let me recognize and congratulate my very good friend Mike for successfully chairing this conference and also my good friend A. González for taking this tenancy for some time.

And of course, let me join the Chairperson, M. Weightman, in expressing our gratitude to all the people who made this conference possible, the Secretariat, the scientific secretaries and all your teams, thank you so much for that. I think that you are really tired after the week of hard discussion about this topic, and that you wish to finish the conference, so I will not take any more time and let me end and wish you a safe travel to your homes.

ABBREVIATIONS

AM	asset management
ASSET	Analysis and Screening of Safety Events Teams (IAEA)
CAP	corrective action programme
CARB	corrective action review board
CAS	complex adaptive systems
CAST	Commercial Aviation Safety Team
CEO	Chief Executive Officer
CNO	Chief Nuclear Officer
CRM	crew resource management
DID	defence in depth
ECC	emergency core cooling
EPRI	Electric Power Research Institute
ERC	Emergency Response Centre
ERI	equipment reliability index
FLR	forced loss rate
FORO	Ibero-American Forum of Radiological and Nuclear Regulatory Agencies
GSR	General Safety Requirements
HOF	human and organizational factors
HTO	human, technology and organization
HRA	human reliability analysis
HRO	high reliability organizations
IC	isolation condenser
ICRP	International Commission on Radiological Protection
ICS	incident command system
ICT	information and communications technology
IESO	Independent Electricity System Operator
INPO	Institute of Nuclear Power Operations
INSAG	International Nuclear Safety Group
IRRS	Integrated Regulatory Review Service
ISCA	Independent Safety Culture Assessment
ISiD	Institutional Strength in Depth
ISV	integrated system validation
LOCA	loss of coolant accident
MMES	man–machine–environment system
OE	operational experience
OECD/NEA	Organisation for Economic Cooperation and Development/ Nuclear Energy Agency
OEF	experience feedback

OPEX	operational experience
OSART	Operational Safety Review Team
PRA	probabilistic risk assessment
PSA	probabilistic safety assessment
QMS	quality management systems
SCSA	safety culture self-assessment
STPA	systems theoretic process analysis
TC	technical cooperation
TMI	Three Mile Island
TSA	thematic safety areas
TSO	technical support organization
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VMB	visual management boards
WANO	World Association of Nuclear Operators
WHO	World Health Organization

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Parallel sessions on leadership, management and culture for safety	B. TYOBEKA	South Africa
Parallel sessions on approaches to safety of other high reliability organizations	A.J. GONZÁLEZ	Argentina
Topical session on learning from the past, going forward	M. STEINBERG	Ukraine
Topical session on safety culture oversight	I. KUBÁŇOVÁ	Czech Republic
Topical session on building a culture for safety	F. DERMARKAR	Canada

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Annex

CONTENTS OF THE ATTACHED CD-ROM

The following papers presented at this conference are available on the attached CD-ROM. The papers are listed by the order of presentation during the various conference sessions.

Parallel Sessions on Leadership, Management and Culture for Safety

F. GONZÁLEZ − Experience of Tecnatom in Developing a Strong Culture and Leadership for Safety and Performance

J.A. JULIUS − Use of Human Reliability Insights to Improve Decision Making

F. GUARNIERI − Entering into the Unexpected: Managing Resilience in Extreme Situations

D.J. WILLIAMS − Leadership and Safety Culture

L. AXELLSON − NEA/CSNI Working Group on Human and Organizational Factors, WGHOF

E. FISCHER − Leadership and Safety Culture: Leadership for Safety

L. HU – Cultivating and Development: 30 Years Practice of Safety Culture in China

Parallel Sessions on a Systemic Approach to Safety

N. MESHKATI − Operators' Improvisation in Complex Technological Systems: The Last Resort to Averting an Assured Disaster

F.L. LEMOS − Evaluating Safety Culture Under the Socio-Technical Complex Systems Perspective

N. GOTCHEVA − Enhancing Safety Culture in Complex Nuclear Industry Projects

Parallel Sessions on Approaches to Safety of Other High Reliability Organizations

N. DECHY − Learning Lessons from TMI to Fukushima and Other Industrial Accidents: Keys for Assessing Safety Management Practices

Topical Session on Learning from the Past, Going Forward

H. KHALAFI − Enhancing Organizational Effectiveness in Teharan Research Reactor (TRR)

S.M. HANG − An Evaluation Method for Team Competencies to Enhance Nuclear Safety Culture

E. GISQUET − Build New Solutions to Cope with Chaos

Y. SHEYKO − Developing and Strengthening of Safety Culture at Ukrainian NPPs: Experience of NNEGC ‘Energoatom’

Topical Session on Safety Culture Oversight

V. POTAPOV − Safety Culture Activities of Russian Regulator (Rostechnadzor) TSOs

J.T. KIM − Insight and Lessons Learned on Safety Culture from Analysis of Inspection Findings and Events

W. FASSMANN − The Regulatory Approach for the Assessment of Safety Culture in Germany: A Tool Recommended for Practical Use for Inspections

B. BERNARD − Lessons Learned from a Five Year Evaluation of the Belgian Safety Culture Oversight Process

M. TRONEA − Improvements of the Regulatory Framework for Nuclear Installations in the Areas of Human and Organizational Factors and Safety Culture

D. SIERACKI – U.S. Nuclear Regulatory Commissions: Safety Culture Oversight

Topical Session on Building Culture for Safety

Dialogue Sessions

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