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EXPERIENCE OF TECNATOM IN DEVELOPING A STRONG CULTURE AND LEADERSHIP FOR SAFETY AND PERFORMANCE

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Abstract

This paper presents experience and insights of Tecnatom in the support of internal and external clients to develop a strong Leadership for Safety. Several cases are presented briefly: (a) The leadership and culture change activities for a utility, a radwaste company, and for Tecnatom itself. One important characteristic of the work performed is the detailed consideration of the underlying organizational culture that underpins the safety culture. Measurable improvements have been achieved and some of the key insights are shared in this paper. (b) The development and implementation of a leadership model with 17 competencies, including safety explicitly. One benefit of this model is that allows to perform a quantitative assessment of leadership effectiveness, something vital to be able to ensure that leadership development actions are truly supporting safety. The model uses an approach to development oriented to strengths and the use of companion competencies to further develop leadership. Moreover it aims to produce significant improvements on safety but also on performance, since both are not competing goals when the proper leadership model is selected. The training material prepared was shortlisted in the 2014 Nuclear Training Awards. (c) The design and implementation of a training development program on Safety Culture, and required competencies of Leadership, for Top Managers of the nuclear industry, as part of the project NUSHARE of the European Commission´s 7th research framework program. The program is sensible to the reduced time availability of Top Managers and uses a combination of learning approaches (webinars, micro-e-learnings, web meetings) that provides higher flexibility for the learner, but complemented with other proven methods (group dialog, journaling, mentoring, etc.) to ensure that the program is effective. All these experiences reveal that to improve the organizational Safety Culture we need to enhance Leadership for Safety and Performance.

1. INTRODUCTION

The classical roles of management: planning, organizing, directing and controlling, is well understood. These managerial tasks can produce good results in the organization. But the results are dependent on the managers' knowledge and understanding of everything that is going on, something extremely difficult in a complex installation or organization as those in the nuclear sector.

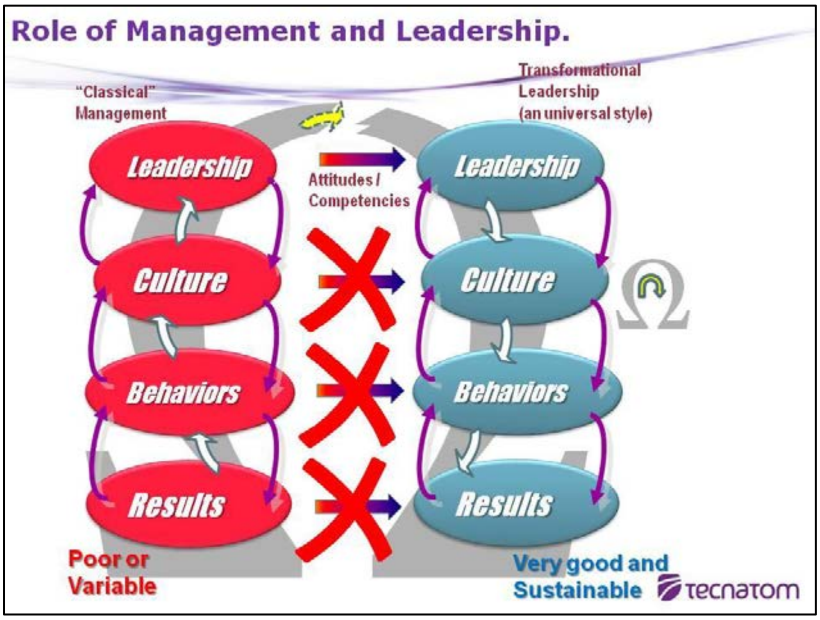

FIG. 1. Role of Management and Leadership.

If the organization pursue excellent results in safety and performance, their leadership team must manage behaviours and results. Organizational culture is a driver of behaviours and results, and leadership is the fundamental lever to develop the culture.

When a decision is being taken to develop the leadership in an organization some potential problems should be considered:

- Selection of one model/approach to leadership reduces accountability and improvement options
- Consideration of leadership for safety only, may cause a leadership that is very poor for economic performance.
- Consideration of only the relation of leadership for safety and safety culture may demotivate the consideration of Organizational Culture for Safety.

- To base the development of leadership only on training sessions does not produce significant changes, especially regarding interpersonal skills.
- To be isolated and not taking the opportunity to learn from others industries that face similar problems.

Some potentials actions shall be analysed:

- Establish in standards the essential characteristics of a sound process to develop Leadership for Safety and economic performance.
- Some elements of the process may be:
    - Selection of a model/approach.
    - Implementing. Systematically employ “follow up” after leadership training.
    - Measuring results against “norms”
    - Keep improving
- Move from “Safety Culture” to “Organizational Culture for Safety”. It is essential to understand Organizational Culture to be effective in Organizational Culture for Safety.
- Foster and support the exchanges with other industries facing similar problems.

In this paper we present three experiences on leadership:

- Essential Leadership Competencies, oriented towards competencies and skills needed to improve behaviours and generate awareness and change attitudes.
- The Extraordinary Leader for Safety, a sound model based on science.
- Development of a training program for Top Managers in Leadership and Culture for Safety as part of NUSHARE Project.

2. ESSENTIAL LEADERSHIP COMPETENCIES

What are the essential leadership competencies that promote a constructive culture for safety? Based on the literature and our experience, there are specifics competencies and skills that a nuclear leader should show in his daily work as habits.

- Set expectations
- Be a model
- Inspire others
- Reinforce right behaviours
- Coach behaviours that do not meet the expectations
- Correct unsafe behaviours

To reach a high degree applying these competencies to drive behaviours, leaders have need to understand what role the emotions play. It is important to work first emotional intelligence to build up the essential competencies. According to [1], these competencies may be grouped in:

— Self-awareness
— Self-regulation
— Self-motivation
— Social Conscience
— Managing relations

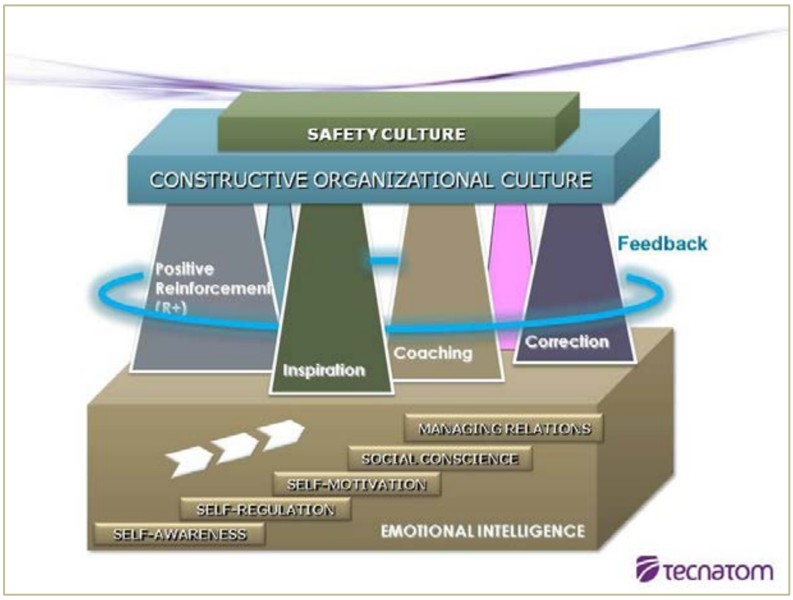

FIG. 2. Essential Leadership Competencies.

A specific issue to work in the organizations is to generate the attitude and competencies to lead a cultural change that produces an organization with excellent results in safety and production, together with excellent relations and helps to understand the desired culture and how to align with it.

This type of workshop typically lasts three days, with 30 participants from different hierarchical levels and organizational units. It requires several facilitators. This workshop is very experiential and participative and is convenient to be hold outside the facilities of the organization.

The basic content of Leadership for Cultural Change Workshop includes:

- Organizational Culture
- Results of the assessment of their organizational culture
- Simulation: living different cultures
- Change levers: leadership
- Influence of Leadership in the culture
- What kind of culture I drive
- What culture I want to produce: image of successful culture
- Action Plan for Cultural Change

The method to run this workshop has to be very experiential and participative, and includes graphic facilitation, simulations, work by groups, individual work, self assessment (Life Style Inventory), and personal action plan and follow up.

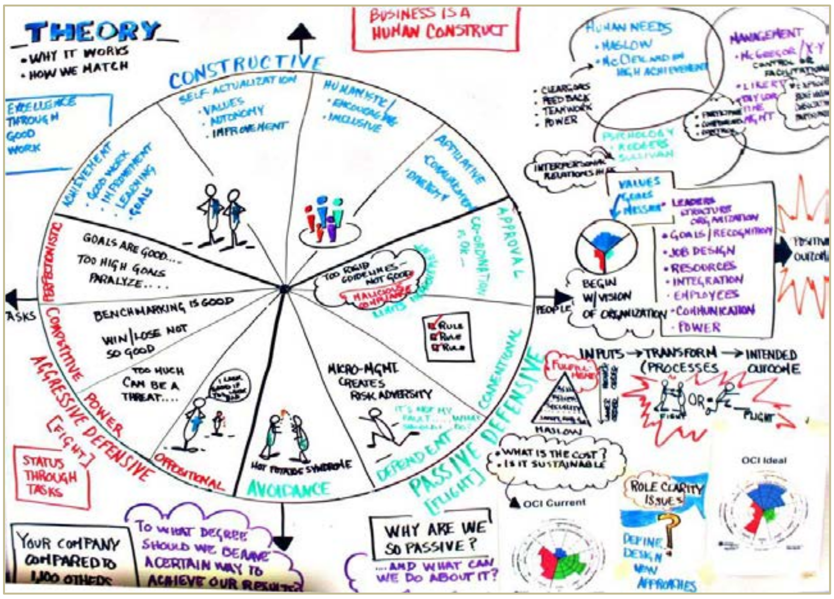

FIG. 3. Example of a scribing (Graphic Facilitation)

3. THE EXTRAORDINARY LEADERSHIP FOR SAFETY

The Extraordinary Leader [2] is a remarkable combination of expert insights and extensive research. The authors, J. Zenger & J.Folkman, analysed more than 200.000 assessment describing 20.000 manager – by far the more extensive research ever conducted.

The main characteristics of this leadership competencies model are:

- It is based on a huge amount of statistical data.
- It has proven economic benefits (something that today is considered a question of survival, being safe is not enough).
- It has been used and tested in all world regions.
- It is based on "strengths".
- It uses "companion competencies" that support the critical competencies (similar to what athletes do in their training).
- Provides several "norms". There are continuous revisions of norms corresponding to different percentiles (an example: the norm for the leaders in the 10% of the best) to compare with.
- Uses a 360º assessment producing a some 40 pages report to each leader with information and orientations in how to improve.
- Aims to develop all leaders to become extraordinary leaders. Good leaders are not enough. Moreover, improvement of a few leaders is not enough. This is especially important for safety where just one leader (for instance in the mechanical maintenance function) can cause a significant event.
- The leadership competencies are aligned with a strong constructive organizational culture that is a fundamental foundation of a strong safety culture.
- Has valuable complementary programs: The extraordinary coach and The Inspiring Leader, covering two essential competencies of leaders.

Tecnatom, in collaboration with Zenger&Folkman and his distributor for Spain, South America and Middles East, has included in the model "Safety" as a essential competence.

This competence model is based on the 16 competences (17 including safety) that distinguish the more effective leaders getting a bigger engagement in people. Engaged workers are safer and more reliable.

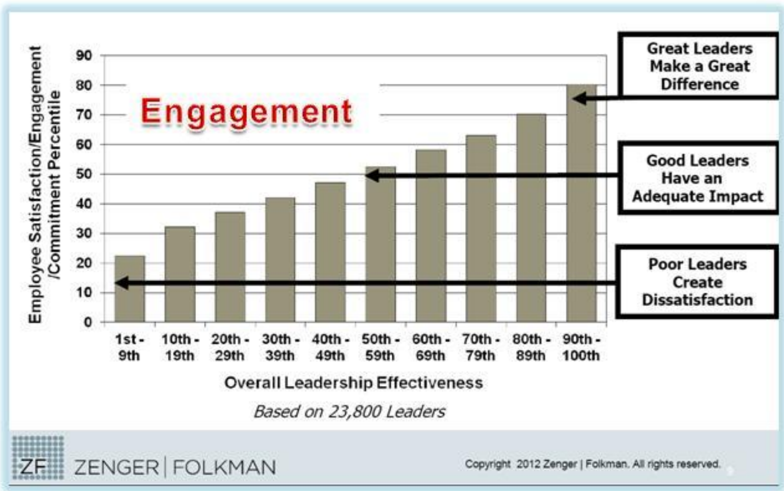

FIG. 4. Employee engagements and leadership effectiveness.

The wide analysis performed by Zenger&Folkman shows that leaders with three or four strengths in competences, get better results in their organizations. So, to be an effective leader, you must be extraordinary doing three or four competences. The training focus changes: you do not have to be perfect doing all, you should be extraordinary in some of the 16 competencies. You should reinforce yours strengths.

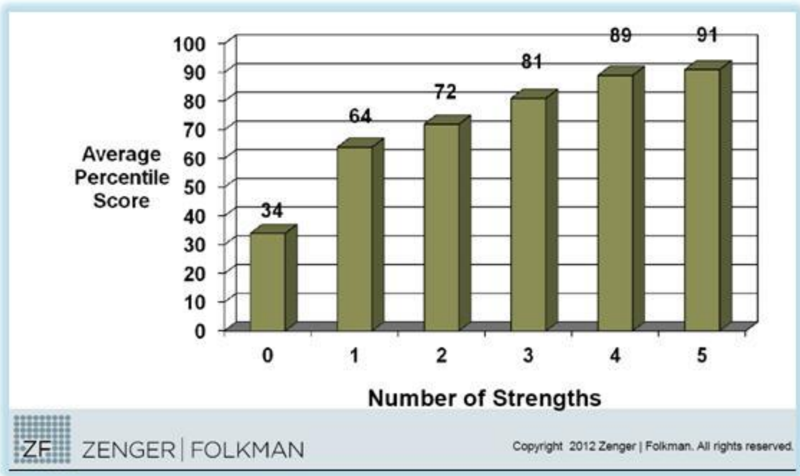

FIG. 5. Number of strengths and leadership effectiveness.

How to work your strengths? The answer is not easy. You cannot train and practice the same competencies again and again. But here we can learn from other people: sportsmen, musicians, ... They train companion competencies. Leaders should train companion competences to get strengths. And these companion competences are well known.

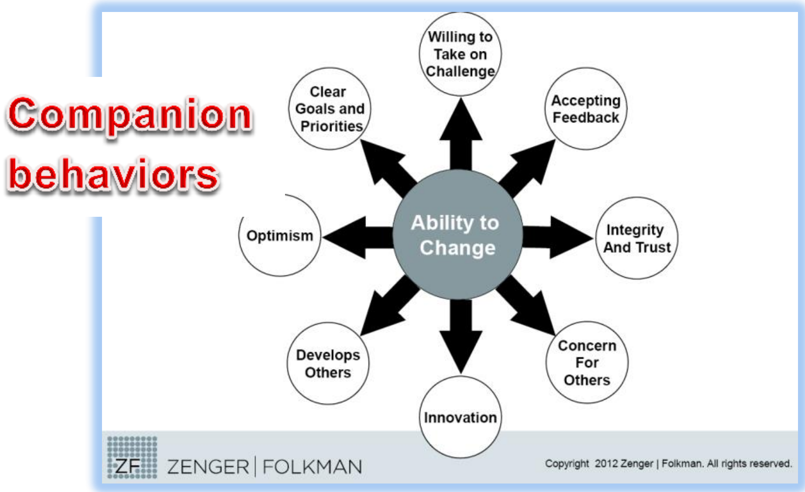

FIG. 6. Companion behaviours and competencies

This competencies model has been proven for different geographical areas and cultures.

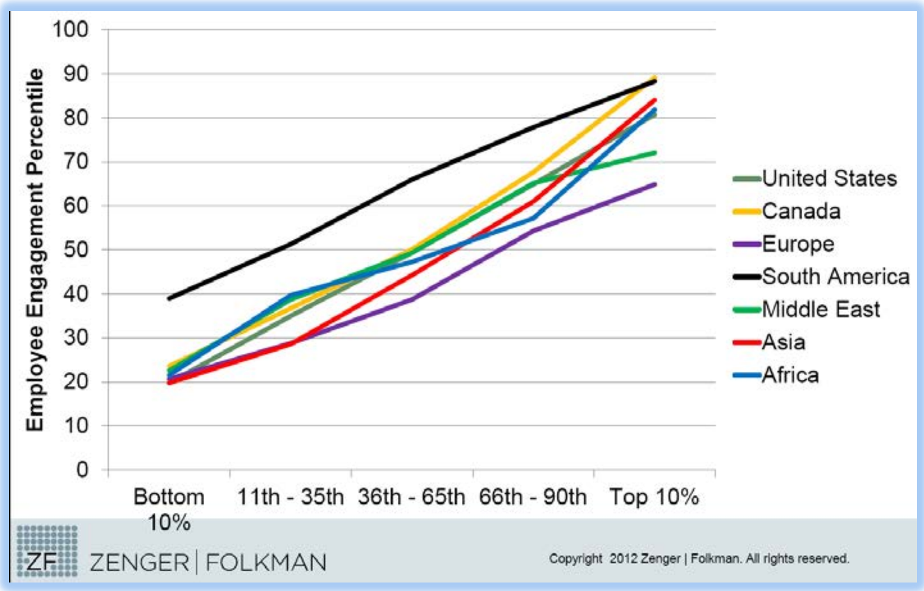

FIG. 7. Comparison with different geographical areas.

Extraordinary leadership for safety identify 17 competencies. Leaders who are really good in some of these competencies, influence positively in their direct reports. These 17 competencies are shown in figure 8.

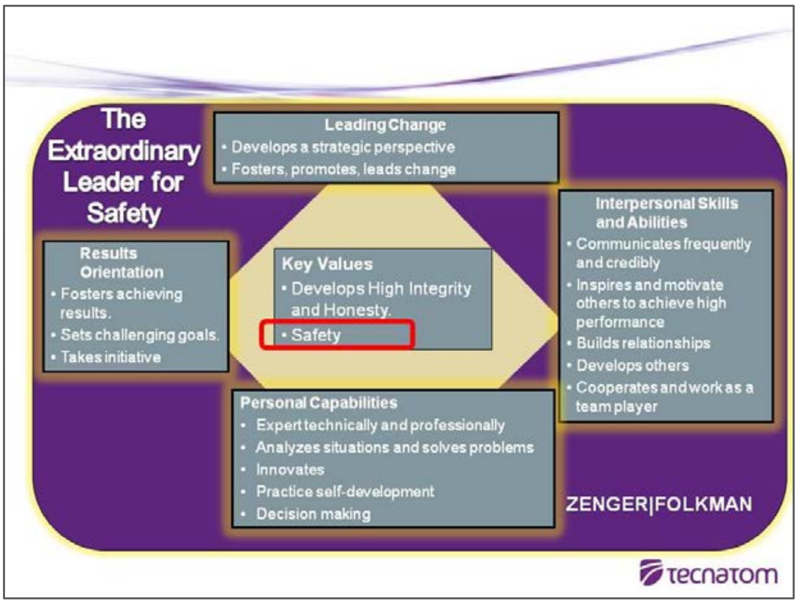

FIG. 8. Extraordinary Leader for Safety.

4. TOP MANAGERS TRAINING: NUSHARE PROJECT

The NUSHARE project originated as a Euratom Education, Training and Information (ETI) initiative proposed by the Cabinets of former Commissioners Mrs Máire Geoghegan Quinn (Research and Innovation) and Mr Günther Oettinger (Energy) after the Great East Japan Earthquake on 11 March 2011. It is a "Support action" of 4 years duration, launched under the modified Euratom work programme 2012 through a "grant to named beneficiary", the ENEN association.

The objective of NUSHARE is to develop and implement Education, Training and Information (ETI) programmes aimed at strengthening safety culture in the nuclear sector and at sharing relevant best practices at the European level. Special attention is paid to safety culture competences in nuclear power plants and other nuclear installations, but other nuclear activities and security culture aspects will also be treated.

Target Group 3 (TG3): Electric utilities and systems suppliers at the level of responsible personnel, in particular managers, of organizations operating nuclear facilities (electric utilities) and of suppliers of such facilities (vendors, engineering companies). As for sharing and developing nuclear safety culture, the industry target group for training and information actions within this project should be restricted to decision makers (i.e. upper and middle line management), safety and quality managers, and research and development managers in industry.

That is why addressing top managers of nuclear operators, and suppliers, including those acting at the front end and back end of the supply chain, the focus should be laid on societal, legal, organizational and safety culture issues, personal values and attitudes.

Learning outcomes of this training program are:

— Understanding of the safety case.
— Importance for Safety of the Culture.
— Evolution of regulatory systems and relation to culture. Inclusion of Safety Culture in the regulatory systems.
— Understanding of Culture.
— Development of Safety Culture. Main Steps.
— Assessment of Safety Culture.
— Learning from other industries.
— Levers to change the Culture. The main lever is Leadership.
— Approaches to develop Leadership competencies in an effective manner

Considerations used in the design of the program have been:

— Responsive to time limitations of top level managers.
— Including different learning modalities:
  - workshop;
  - mentoring;
  - webinar;
  - micro-mobile-e-learning;
  - web meeting;
  - journal;
  - action plan.

FIG. 9. Display of a micro mobile-learning/

The pilot training program was run during last quarter of 2015. The participants in this pilot training evaluated positively the approach, method and content of this program and identified some minor improvements. Next training is planned for second quarter of 2016.

5. SUMMARY

As main conclusions of this paper it may be highlighted:

— Establish in standards the essential characteristics of a sound process to develop Leadership for Safety and economic performance.
— Some elements of the process may be:
  - Selection of a model/approach.
  - Implementing. Systematically employ “follow up” after leadership training.
  - Measuring results against “norms”
  - Keep improving
— Move from “Safety Culture” to “Organizational Culture for Safety”. It is essential to understand Organizational Culture to be effective in Organizational Culture for Safety.

— Foster and support the exchanges with other industries facing similar problems.

In this paper, three different experiences in leadership training program implementation have been described following the approach above mentioned.

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USE OF HUMAN RELIABILITY INSIGHTS TO IMPROVE DECISION MAKING

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Abstract

This paper describes insights obtained during the development and application of human reliability analysis (HRA) as part of a probabilistic risk assessment (PRA) to support decision-making, including improvements to operations, training, and the plant design; ultimately improving plant safety and safety culture. 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 three decades. These models consist 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 insights from the HRA. The subsequent quantification in the HRA effectively prioritizes the contributors to the unreliability of operator actions, and the process facilitates the identification of the factors that are important to the success of the operator actions. The HRA and PRA tools and techniques also facilitate the evaluation of key assumptions and sources of uncertainty. The end results have 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. Examples of the types of insights are presented in the paper.

1. INTRODUCTION

The purpose of this paper is to describe insights obtained during the development of the human reliability analysis (HRA) as part of a probabilistic risk assessment (PRA) to support risk-informed applications which involve decision-making.

PRA is an analytical tool that systematically evaluates the systems, components and operator actions important to risk. Development of a PRA, especially the human reliability analysis portion, provides insights that can support Safety Culture; directly and indirectly. Insights have been gained from the development and application of HRAs and PRAs of nuclear power plants in the USA, Europe and Asia over the last three decades. These models consist primarily of Level 1, Level 2, and sometimes Level 3 PRA models.

HRA and PRA insights and risk models have historically supported decision-making regarding plant improvements to operations, training, and the plant design; ultimately improving plant safety and safety culture. HRA and PRA are well-suited for this purpose as they both provide a structured, systemic approach to evaluate the proposed change. The approach has been improved and refined during the last 30-years, with several HRA improvements coming from the Electric Power Research Institute (EPRI) HRA Users Group.

The EPRI HRA Users Group has chartered missions in four areas, and has grown in membership to include all USA utilities, the US NRC, vendors, and international users on all continents with operating nuclear power plants. The EPRI HRA approach and associated methods use human factors information to improve the qualitative insights on the reliability of operator actions, given the context of the scenario. The subsequent quantification in the HRA effectively prioritizes the contributors to the unreliability of operator actions. The overall HRA process facilitates the identification of the factors that are important to the success of the operator actions. The HRA and PRA tools and techniques also facilitate the evaluation of key assumptions and sources of uncertainty. The EPRI HRA methods have been benchmarked as part of an international study at the Halden Reactor Project in Norway. The benchmarking compared HRA predictions of crew response with simulator observations.

The end results have been used to effectively support decision-making for day-to-day plant operations as well as supporting 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. Examples of the types of insights experienced in five representative countries are presented in this paper.

This paper is organized as follows.

(1) Introduction
(2) Overview of HRA and PRA.
(3) EPRI HRA Users Group (mission, membership, activities, and approach).
(4) Halden Benchmarking.
(5) Examples of PRA and HRA in Decision-Making
(6) Summary
(7) References

2. OVERVIEW OF HRA AND PRA

PRA is an analytical tool that systematically answers the questions 1) what can go wrong, 2) how likely is it, and 3) what are the consequences. Development of a PRA, especially the human reliability analysis portion, provides insights that can support Safety Culture; directly and indirectly. PRA can directly support Safety Culture by identification and prioritization of issues based on risk-significance. PRA also can indirectly support Safety Culture by promoting organizational awareness of Risk and consider questions asked by PRA. For example, the Safety Monitor tool used to support configuration risk management was also used by system engineers to improve their understanding of risk-significance within their systems.

Insights have been gained from the development and application of HRAs and PRAs of nuclear power plants in the USA, Europe and Asia over the last three decades. These models consist primarily of Level 1 (core damage) and simplified Level 2 (large early release) PRA models. These models address internal events such as system failures during operations at power that lead to reactor trip. The more extensive PRA models also address external hazards such as seismic events, high winds, and external floods. Additionally, the more extensive models include shutdown modes of plant operation. Sometimes full Level 2 (release) and Level 3 (health effects) models are also developed to capture the impact of the radionuclide release to the public.

HRA and PRA insights and risk models have historically supported decision-making regarding plant improvements to operations, training, and the plant design; ultimately improving plant safety and safety culture. HRA and PRA are well-suited for this purpose as they both provide a structured, systemic approach to evaluate the proposed change.

The approach has been improved and refined during the last 30-years, with several HRA improvements coming from the EPRI HRA Users Group.

3. EPRI HRA USERS GROUP

The history of the EPRI HRA Users Group has been documented in several conference papers. The overview presented below in this section has been extracted from the PSAM12 conference paper [21]. The primary objective of the EPRI HRA

Users Group is to develop a software tool, and to provide associated training and HRA guidelines which standardize the selection and application of HRA methods in developing human failure events into human error probabilities. There are two goals associated with this objective. The first goal is to obtain comparable human error probability results when evaluating human interactions of similar tasks on plants of similar design, training, procedures, and cues. The second goal is to improve the reproduceability and traceability of the human reliability analysis such that it clearly demonstrates compliance with the human reliability (HR) elements of the ASME/ANS Combined PRA Standard [1]. The long-term goal for the group is to enable and promote convergence on a set of common HRA methods.

As part of the long term goal, the HRA methods and data need modification to address the needs of current users (such as PRA modelers of advanced nuclear power plants) and also to address changes in the state-of-the-art in HRA. In helping to advance the state-of-the art in HRA, the developers of the EPRI HRA Users Group have participated in several joint projects with the US NRC, including an international study to benchmark predicted human error probabilities against empirical data collected on the Halden simulator. During the Halden benchmarking project, EPRI participated in both the assessment (control) group of the study and also (independently) as one of the groups predicting results.

This portion of this paper summarizes the EPRI HRA User Group activities as background information on the HRA process and summarizes the EPRI HRA User Group experience with the Halden benchmarking project.

EPRI historically sponsors many initiatives in the development of both probabilistic risk assessment (PRA) and human reliability analysis (HRA) tools and techniques to improve the consistency, quality and capability of nuclear power plant PRAs and HRAs in the United States, and in member countries internationally. Scientech has collaborated with EPRI, utilities, and other industry participants; and has been a key contributor in support of these efforts. Scientech has developed new tools and techniques, and has also put into practice many of these initiatives. One such initiative that started in the year 2000 was to establish the EPRI HRA User Group. The EPRI HRA User Group facilitates the standardization of the HRA process through development of an EPRI HRA Calculator® software tool. The EPRI HRA Calculator® is a software tool to quantify and document individual human error probabilities, and to automate a substantial part of the dependency analysis for PRAs. One of the main objectives in developing the EPRI HRA Calculator® was to demonstrate compliance with the ASME/ANS Combined PRA Standard [1] as implemented by USNRC Regulatory Guide 1.200 [2].

During the US Individual Plant Examination era, when every US plant was required to develop a plant-specific PRA, EPRI HRA projects focused on developing a framework for conducting a human reliability analysis [4, 5] and on the development of cognitive HRA methods [6, 7] to complement the USNRC methods [8, 9]. These efforts were conducted between 1984 and 1992. In the year 2000 the EPRI HRA Users Group was formed with a different focus. The new focus was to develop a consistent approach to HRA based upon the strengths of existing methods used in the United States nuclear power industry.

Mission. The primary objective of EPRI HRA User Group is to assist the industry in converging on a consistent, common approach to human reliability in order to enable different analysts to obtain comparable results when using similar inputs. The specific objectives of the EPRI HRA Users Group are listed below.

(a) Allow the HRA models to produce consistent, realistic results through development of a software tool.
(b) Help assure the HRA receives addresses supporting requirements of the ASME/ANS Combined PRA Standard in order to develop quality analyses as confirmed during industry PSA Certification Reviews.
(c) Coordinate the development of HRA methods with other groups such as the USNRC, for example spatial/external events, severe accident management, and shutdown.
(d) Provide the capability to electronically interface HRA results through the EPRI R&R Workstation for input to PRA Tools (such as CAFTA, WinNUPRA, RISKMAN, and Risk Spectrum).

Membership. The members of the EPRI HRA / PRA Tools User Group direct the development of the EPRI HRA Calculator®. Since 2000, the EPRI HRA / PRA Tools Users Group has grown to represent all of the USA nuclear power plants in the United States, complemented by the US Nuclear Regulatory Commission and corporate members (AREVA-Framatome, Bechtel-Bettis, Rolls Royce, Westinghouse, and Scientech). Additionally, the EPRI HRA Users Group has included international members such as members EdF-France, EPZ-Netherlands, ESKOM and PBMR-South Africa, RELKO-Slovakia, Angra-Brazil, UNESA-Spain (representing eight plants), KEPCO E&C-Republic of Korea and the CANDU Owner's Group.

HRA Users Group Activities. The HRA Users Group conducts several activities annually. Each year starts with a user's group meeting where the priorities and plans for the year are established. The annual meeting also provides users a good forum to exchange "best practices" as well as "lessons learned" in the development and application of HRA. Additionally, guest speakers are typically invited to provide a presentation on a particular aspect of PRA. For example, for several years the HRA Users Group followed the human performance studies being conducted in Norway at the Halden Reactor Project.

For the first five years of the EPRI HRA Users Group, the primary historical activity sponsored by the HRA Users Group was the development and improvement of the EPRI HRA Calculator® software [10]. This software tool assists the analyst in conducting the HRA of an individual basic event in a comprehensive, systematic approach designed to satisfy the requirements of the ASME/ANS Combined PRA Standard [1] as implemented by USNRC Regulatory Guide 1.200 [2]. Recently, this was supplemented by a module to automate and document the HRA dependency analysis. In the last few years, the focus on the EPRI HRA Users Group has been on joint EPRI/USNRC projects such as Fire HRA and Halden benchmarking. For 2012 and 2013 the primary technical focus of effort was to develop/refine HRA methods and to develop guidelines for the HRA modeled in Seismic and External Events PRAs [3]. In 2014 and 2015, the activities focused on providing guidance to analysts.

The EPRI HRA Users Group also conducts one to two training sessions per year to allow PRA analysts to develop the skills to evaluate human interactions in a systematic, consistent manner.

EPRI HRA Approach. The HRA approach applied in the EPRI HRA Calculator® is summarized below.

- HRA Framework. The ASME/ANS Combined PRA Standard high level requirements nominally follow the EPRI SHARP and SHARP1 framework [4, 5], defining the fundamental process and framework for evaluating all types of human interactions. This framework has been incorporated into the EPRI HRA Calculator®.
- The qualitative portion of the EPRI HRA approach borrows concepts from human factors such as task analysis, cues, procedures, training and timing. Then the EPRI HRA approach provides a standardized, structured process to collect and evaluate this data as "performance shaping factors" that potentially affect operator response.
- Human errors consist of two elements (generally): a cognitive element for detection, diagnosis, and decision-making; and an execution element modeling the manipulation or implementation of a task.
- Cognitive methods. The EPRI Cause-Based Decision Tree Method (CBDTM) [10] is the default method, and either the Human Cognitive Reliability/Operator Reactor Experiments (HCR/ORE) [10] or the ASEP time-reliability correlation methods [9] is used for time-critical actions.
- Execution modeling. Techniques for Human Error Rate Prediction (THERP) [8] for quantification of execution errors of omission and commission is the approach for both latent (pre-initiator) human interactions as well as dynamic (post-initiator) human interactions. Additionally, the Accident Sequence Evaluation Procedure (ASEP) [9].
- Recovery. Both cognitive and execution errors have the potential to be mitigated by recovery actions.
- Dependency between Human Failure Events. The software tool also has a module to support the dependency analysis, identifying combinations of operator actions within the same cutset(s), calculating the importance of the combination, flagging where operator actions overlap in time, and applying rules to provide suggestions on levels of dependence.
- The EPRI HRA Users Group approach follows the ASME/ANS Combined PRA Standard high level activities for HRA (identification,

screening, definition, quantification, dependency evaluation, and documentation).

This approach is conducted for all types of human failure events (HFEs), whether pre-initiator (latent) or post-initiator (dynamic). However, some elements may not apply to certain types of human failure events. For example, the cognitive portion is not applicable to latent (pre-initiating event) human errors such as miscalibration and restoration failures. The software has developed and matured since 2001 and the current software [10] addresses dependency modeling between human failure events and adds the capability to conduct SPAR-H modeling [11].

HRA Methods. If you need to subdivide the sections of your paper, use the headings shown below. You can use second and third level paper headings. To subdivide further, please use lists numbered (a), (b), and so on, but this is usually not necessary in a paper of normal length.

This section summarizes the selection and integration of HRA methods in order to support the different types of operator actions being modeled in a typical PRA (e.g. latent errors and post-initiator operator actions of a Level 1 PRA). The intent was to produce a “tool box” of methods within the EPRI HRA Calculator® software to best fit the type of operator action and the performance shaping factors. The integration of these methods required some evolutionary, minor modifications to methods in order to apply these methods in a consistent manner and to address lessons learned during the last 20 years.

The EPRI Cause-Based Decision Tree Method [7] (CBDTM) is the default approach to modeling and evaluating cognitive errors (those associated with the detection, diagnosis, and decision-making of the operator action). This method systematically looks at four failure mechanisms for the man-machine interface, and four more for the man-procedure interface. Evaluating post-accident cognitive errors is implemented as on-screen, interactive forms that the user fills in. The user enters context information such as the PRA scenario (initiating event and the sequence of successes and failures that have occurred up to the point where the modeled action is in the model). The user also enters subjective information such as the procedures used, timing data, and cues.

The user then reviews each decision tree one at a time and selects the appropriate branch associated with each failure mechanism, from a drop-down type list box. For example, if the information is misleading and there is not training or warning of this condition then the human error probability for that particular failure mechanism will contribute to the total. For each failure mechanism, the user is able to select a recovery factor (also from a drop-down list). Based on the data entered, the cognitive error probability is calculated with and without recovery.

Cognitive errors for immediate actions or time-critical actions should also be quantified using the EPRI HCR/ORE method [7]. Quantifying post-initiator cognitive errors using the HCR/ORE correlation also follows on-screen, interactive forms. The user enters additional information such as the duration of time window available, the median response time, the manipulation time, and the variation between crews.

Dependencies. Dependencies within a HFE (through recovery modeling) are addressed in both the cognitive and execution models via THERP zero, low, medium, high, complete levels of dependence based on performance shaping factors such as time available. Dependencies between HFEs are addressed in the documentation process during the qualitative identification and characterization of the human failure event, which allows for links such as common cognitive elements between HFEs. Once the HFEs are modeled, the most recent version of the EPRI HRA Calculator® (Version 5.0) employs a new tool to identify and evaluate combinations of HFEs. This version has the capability to import and filter cutsets from WinNUPRA or CAFTA or RISKMAN, and to use newly developed importance measures to focus the dependency analysis process. Once the combinations of events have been identified then the dependency level is evaluated using a similar approach to that used within an HFE (e.g. zero, low, moderate, high or complete). The HRA Calculator software facilitates the efficient conduct of the dependency analysis portion of the HRA through the identification of sequences of multiple HFEs and the evaluation of their importance.

4. HALDEN BENCHMARKING

The evaluation of HRA methods via benchmarking studies has been documented in several conference papers [12-18] and a summary of these papers is presented below in this section.

Benchmarking Study Overview. The Halden benchmarking study evaluated the ability of a set of HRA methods to predict the human performance observed in a simulator. Reference 12 provides a detailed overview of the Halden benchmarking study. A summary of that paper has been reprinted below. The assessment was based on the following:

- Predictive HRA analysis, performed without knowledge of the experimental results.
- The collection of empirical data through simulator experiments.
- A comparison of the experimental results with HRA method predictions.

The overall design of this study was to divide the effort into two portions – the first portion being the HEP predictions and the second portion being the development of the empirical data. In the initial (pilot) phase, twelve (12) teams of HRA analysts participated. The collection and analysis of simulator data was performed by Halden reactor staff. The comparison of HRA predictions with experimental outcomes was the responsibility of the assessment group.

The Empirical Study has been conducted in three phases. Phase 1 was a pilot to test the study methodology. In Phase 1, the HRA teams performed HRA analyses to predict human error probabilities for nine (9) human failure events (HFEs). The first sets of scenarios were two variations of Steam Generator Tube Rupture (SGTR) scenarios, one scenario was a simple SGTR case and the other scenario was a complex SGTR case. All the empirical data was collected during Phase1, but only two HFE comparisons were conducted. In Phase 2, the remaining SGTR HFE and HEPs were evaluated for qualitative as well as quantitative insights. During Phase 3, feed and bleed HFEs were evaluated. The first two phases were designed to pilot the approach and to allow the study participants (Halden, assessment/evaluation group, and the HRA teams) to review the study methodology and the initial results and, in particular, the HRA teams to provide feedback on the methodology. A workshop on the first pilot phase was held in October 2007 and the second phase in March 2009. This first phase is documented in a Halden Working Report (HWR) [13] and an associated international NUREG report [14]. The overall design of the study is summarized in [15].

Human Error Probability Predictions. Most existing HRA methods were initially developed to model the impact of operator actions in the context of PRAs/PSAs of nuclear power plants. However, some HRA methods only provide methods and guidance to conduct the quantification of an HEP and do not address other aspects of the HRA process such as HFE identification. The current study focused on the analysis in support of estimating the failure probability of an HFE (including the qualitative analysis performed in support of this quantification) but not on the identification or definition of the HFEs.

In Phase 1, EPRI used the Cause-Based Decision Tree and THERP method. The insight from this phase was that the blended EPRI HRA approach (CBDTM supplemented by HCR/ORE) was better, especially for time-limited HEPs. The blended EPRI HRA approach was then used for the remaining SGTR and Loss of Feedwater in Phases 2 and 3. The March 2009 workshop showed that the EPRI predictions matched well the overall magnitude and trend in the HEPs (meaning that the easier HFEs had lower HEPs empirically, and this matched the EPRI predictions). The Phase 3 evaluations are currently ongoing.

Study Insights. The first phase was only used to develop insights into the method and the approach, and not the HRA methods. The first phase of established a methodology for an assessment of HRA methods based on empirical data obtained in a simulator study. The experience, feedback, and results show that the developed methodology is working fairly well. Some considerations for improvements were identified and implemented in Phases 2 and 3. The comprehensive reports on the first phase of the empirical study, revised to account for the feedback and inputs obtained from the study participants during and following a workshop, are available for review [13, 14].

Phases 2 and 3 were initiated in 2008. Phase 2 consisted primarily of completing the comparisons based of the SGTR scenarios. These comparisons addressed the quantitative HRA predictions as a measure of the level of difficulty associated with the complete set of HFEs. The methodology for the comparison of the HRA quantitative results with the data will be tested. By addressing more HFEs and an additional set of scenarios (the two LOFW variants in Phase 3), these phases are also intended to allow a more conclusive, broader-based assessment of each method. In particular, it is important that the assessment of each method's performance is based on a more representative set of operator actions, reflecting more of the range of actions and performance conditions that need to be addressed in a PRA.

The results of the Halden empirical study to date have demonstrated the value of performing comparisons of HRA predictions with empirical data. For instance, the pilot has identified specific areas where additional guidance for HRA would be beneficial, notably in the scope and detail of the qualitative analysis. Other sources of variability in HEPs were not addressed in the international empirical study. One example is the variability among teams applying a given method, which would require a study design with multiple teams applying each method. This study was undertaken in the USA but the results have not yet been published.

5. EXAMPLES OF HRA AND PRA IN DECISION-MAKING

PRAs in the USA are used as a tool for day-to-day operations, and additionally for licensing considerations (such as for the evaluation of risk-informed prioritization and risk-significance). The EPRI HRA Calculator® has been used in the following applications of a typical PRA analyst in the USA.

<u>Example-1 United States</u>**:**

- Fire Protection Program change to NFPA 805, risk-informed performance-based:
    - Recovery Actions to mitigate variances from design requirements
    - Recovery Actions to reduce radioactive release such as Containment Isolation & H2 Igniters
- Configuration Risk Management:
    - Develop contingencies for events occurring in certain plant line-ups
    - Examples, protected train & high risk evolutions
- Feedback to Operator Training:
    - Identification of PRA-important Scenarios & Procedures
- Address Licensing Issues:

- Impact of plant design modification such as Timing/Instrumentation
- Post-Fukushima insights such as actions in advance of External Flooding
    - Timeline & cues from other organizations

— Evaluation or prioritization of proposed plant changes

As shown above, PRA models are being employed in a wide variety of applications. Internationally, the focus includes new build and next generation power plants.

Example-2 Netherlands**:**

- Part of the 10-Year Periodic Safety Review.
- Level 1 Insights to Reducing Risk:
    - In 2015, plant conducted its 3rd Periodic Safety Review
    - Hardware modifications have eliminated significant operator actions
    - HRA provided insights into staggering calibration
    - Still finding / addressing new challenging, potential initiating events
- Level 2 Insights to Reducing Risk:
    - Impact on Public Health & Safety is important
    - Plant, like all NL industries, has individual risk and societal risk goals
- All Modes, All Hazards PSA:
    - Peer Review 2013

Example-3 United Kingdom**:**

- Some plants in the General Design Assessment (GDA) phase of licensing.
- PRA (Level 1, 2 & 3 PRAs) is assessed against Regulator requirements as well as the ASME/ANS PRA Standard:
    - Some supporting requirements (SRs) cannot be met by a plant in the design phase.
        - Example, operator interviews.
        - SRs that cannot be met are not assessed.
    - Intent of some SRs can be met.
        - Example by considering generic information or information from similar plant/s.
- Some inputs often need to be assumed to perform HRA:
    - Appropriate operator-information interface will be developed.
    - Procedures will be developed.

- Operators will be trained to perform their procedures.
- Such inputs will need to be validated in later phases of design (or transition to operation).

— Inputs available at this stage:
  - Timing & Success criteria

— Uncertainties in applicability of current HRA methods to digital I&C as well as the digital plant interface.
  - THERP was used based on analog instrumentation & data from 1980's or before.
  - New failure modes e.g. "tunnel vision"?
  - CCF of digital interface a concern warranting analog backup I&C for systems important to safe shutdown.
  - All HEPs can be considered screening HEPs as many inputs are assumed, so OK for GDA process.

— Apparently less reliance on operator actions than earlier generation:
  - PRA does not credit operator actions within first 30 minutes per the design basis, but may have to in future iterations if PRA needs them (e.g. Anticipated Transient With Failure to Scram).
  - At-Power: About a dozen post-initiator Level 1 operator actions, similar for Level 2.
  - Shutdown: About 10 Level 1 operator actions, no additional operator actions for Level 2.
  - Spent Fuel Pool: Several operator actions for Level 1, with 1 late action for Level 2.

Example-4 United Arab Emirates**:**

— First 4 plants developing all modes, all hazards PRA as part of the FSAR to support obtaining an operating license.

— Similar experience to the UK (see Example-1):
  - PRA (Level 1 & LERF) is assessed against Regulator requirements as well as the ASME/ANS PRA Standard.
  - Some inputs often need to be assumed to perform HRA:
  - Inputs available at this stage are limited to Timing & Success Criteria, and some procedures.
  - Uncertainties in applicability of current HRA methods to digital I&C as well as the digital plant interface.

— Generally, less reliance on operator actions than the earlier generation:
  - Example, MCR Abandonment is low as the plant essentially has a 2^{nd} MCR.
  - Exception: reduced safety goal levels have increased the importance of beyond design basis events, which has led to the need for more operator actions.

Example-5 Japan:

- Many plants in re-start, or working on re-start.
- Level 1 internal events:
  - In 2015 EPRI provided Risk Professionals training, including HRA.
  - Working on incorporating insights from new methods (IDHEAS).
- Fire PRA:
  - After re-start, some plants working on Fire PRA.
  - Generally, follow the NUREG/CR-6850 FPRA approach, including NUREG-1921 guidance.
- Seismic PRA:
  - All have re-evaluated their peak ground acceleration.
  - Looking at HRA improvements to better support larger earthquakes.

6. SUMMARY

EPRI in collaboration with Scientech (Curtiss-Wright) has been at the forefront of the development of analytical tools and methods for use in HRA for over 30-years. The objective of these analytical tools is to improve human error modeling techniques in PRAs and thereby improve understanding of nuclear plant safety. These projects are developed under the direction of EPRI and Scientech, with the participation of utilities, industry experts, and researchers.

The EPRI HRA User Group developed the EPRI HRA Calculator® software as a tool to provide a standardized approach to HRA. The EPRI HRA Calculator® incorporates the most widely used HRA methods into an analytical tool that provides a comprehensive and well documented approach to HRAs. The EPRI HRA Calculator® interfaces seamlessly with other PRA tools such as CAFTA and WinNUPRA, and with other tools via a comma separated value file. The current version also facilitates the efficient conduct of the dependency analysis portion of the HRA through the identification of sequences of multiple human interactions and the evaluation of their importance.

The EPRI HRA Users Group has grown to represent all nuclear plants in the United States and includes the US Nuclear Regulatory Commission as a user. Additionally, the EPRI HRA Users Group has seen strong corporate and international growth. The EPRI HRA Calculator® has been successfully used in an HRA update at dozens of plants. Several plants have used the HRA Calculator® to develop and document the HEPs of recovery events that were added to the PRA model in support of a Phase 3 significance determination process (SDP) evaluation where a quick, comprehensive, consistent evaluation was necessary.

Feedback from the users of the EPRI HRA Calculator® has proven that the software is a valuable tool for the consistent development and documentation of human error probabilities. The work of the EPRI HRA Users Group is focusing on evaluating existing EPRI HRA methods with empirical data from Halden, and developing HRA guidelines to support fire, seismic and external events analyses.

Technically, HRA needs to support an increased PRA Scope such as Level 1 Spatial Hazards (internal and external). For example, HRA methods supporting the analysis of Fire and Internal Flood which have both a plant impact (on operating systems) and also a site impact (such as preventing access to the fire/flood affected area. Additionally, external hazards such as Seismic, External Flood, High Winds (events with a regional impact in addition to the plant and site impacts). Additional technical areas which would benefit from improvements are HRA for Level 2 and Level 3 PRA, and also Shutdown PRA including Spent Fuel Pool PRA. HRA for Digital Control systems is an issue for advanced reactors.

In addition to technical issues, organizationally new analysts and decision-makers would benefit from the following. The EPRI HRA UG supports each of these areas.

- Training
- Guidelines
- HRA Tools implementing new/updated methods.

Conclusions:

- PRA & HRA have provided insights to improve decision-making for over 30 years.
- EPRI HRA Calculator® approach meets all the current U.S. industry needs for PRAs used in regulatory requirements.
- EPRI HRA UG has 15 years of successful HRA improvements and the approach meets all the current U.S. industry needs for PRAs used in regulatory requirements.
- Approach/methods satisfy the ASME PRA Standard & the NRC Good Practices in Implementing HRA.
- Annual Users Group Meeting – January, Juno Beach, Florida
    - Sharing technical improvements & best-practices
- Developing new methods and monitoring research work by others to determine if other improvements can add value to its mission using these criteria:
    - Traceable, Defensible, Consistent
    - Extend HRA beyond Level 1, internal events PRA
- PRA & HRA provides a structured, systematic approach.
    - Address challenging issues and situations
    - Evaluate with a model
    - Address considerations such as uncertainty

– A strong Safety Culture considers risk insights and makes risk information available to decision-makers:
    - Plant Design and Engineering
    - Plant Operations, Maintenance, and Training
– PRA process and results (risk-significance) can support Safety Culture.
    - Directly by identification and prioritization of issues based on risk-significance.
    - Indirectly by promoting organizational awareness of risk, to consider the questions asked by PRA – "what is the most likely thing to go wrong" & "what is the most consequential"

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ENTERING INTO THE UNEXPECTED: MANAGING RESILIENCE IN EXTREME SITUATIONS

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Abstract

This article introduces the concept of the extreme situation, which is tightly linked to the concept of resilience and more specifically, entry into resilience. The latter is defined as the moment when an individual (or group) gradually resumes normal business following a period of immobility due to a shock of unprecedented brutality. The classical approach is the well-known concept of sensemaking drawn from the work of Karl Weick. Nevertheless, this historical perspective merits a fresh look that incorporates new sources of hitherto untapped data and/ or a review of existing material. The accident at Fukushima Daiichi serves as a demonstration for this new interpretation.

1. INTRODUCTION

Accident management is usually associated with the unexpected, notably through the process of sensemaking [1]. In an extreme situation, the ‘surprise’ (‘reality shock’ [2]) takes the form of stupor or stunned shock. The individual is suddenly unable to act, blindsided by an event that is beyond their frame of reference [3]. Astonishment marks a time when individual concerns are no longer relevant. For those in this state of shock, time may appear to be suspended or futile. Those affected are overwhelmed by an ongoing unprecedented situation and lose the ability to understand or take action. This powerlessness leads to anxiety, fear and dizziness. Such feelings gripped Masao Yoshida, the director of the Fukushima Daiichi power plant, and his teams, who were struck on 11 March 2011 by two natural disasters (an earthquake and a tsunami) in under an hour. These events caused a technological failure on an unprecedented scale (the loss of most on- and off-site power generators which would lead, in the course of the following days, to the release of radioactive materials from several reactors), “*at the time, to be quite frank, I was destroyed. Myself, I mean. I said to myself that we were facing a terrible situation*” [4].

However, on 11 March, this phase was particularly short. Yoshida and his teams quickly became aware that they were facing an extreme situation and had to find a way to cope [5] ("*... feeling sorry for ourselves would serve no purpose*" [4]).

In phenomenological terms, the extreme nature of a situation is affirmed when living conditions become inordinately intense, or unbearable [6]. The person who undergoes the experience is on the verge of an abyss [7]; they are faced with violence of unprecedented brutality, a radical upheaval that threatens life itself. In psychosocial terms, the extreme situation leads to the loss of the usual points of reference and can undermine identity. This is because individual identity is shaped by the relationship with current social norms, hierarchical relationships, adherence to shared values, responses to social expectations, etc. The rupture of the (past) value system causes irreparable change and results – or not – in the emergence of a new system of shared values.

The analysis of the extreme situation therefore focuses on subjects who must face the unthinkable [6] and what holds them together. At Fukushima Daiichi, the unthinkable took the form of three "*entities*" that became uncontrollable as they were "*unleashed*".

Faced with this exceptional adversity and predictions of "*certain death*" [4], Yoshida and his teams successfully entered into a positive dynamic, through mobilizing resources which, although limited, allowed them to survive, then to recover an acceptable level of control over a devastated nuclear facility. This process can be described as 'entry into resilience'.

2. FROM RESILIENCE 'IN GENERAL' TO ENTRY INTO RESILIENCE 'IN PARTICULAR'

Words, ideas and concepts do not have exactly the same definition from one scientific discipline to another. The concept of 'resilience' is no exception to this rule. The English word 'resilience' comes from the Latin verb 'resilire' that means to 'bounce back'. As the word does not exist in Japanese, the English term is used. Some approximations are *kaifuku-ryoku* (buoyancy or power to recover), or *fukugen-ryoku* (the power of restitution), *dan ryoky sei* (elasticity), or *teikou-ryoku* (in the context of disease).

Given these multiple meanings, the scientific community looks like the famous biblical description of the Tower of Babel. This myth provides a useful way to talk about resilience. In the Bible, after the Deluge, men began to build a city and a tower that reached to the sky. Seeing their arrogance, God confused their language so that no-one could understand each other anymore. He then spread them over the whole of the Earth. By creating a multitude of languages, God created confusion and misunderstanding. Like the Babel fish (the fruit of the imagination of the genius English writer, Douglas Adams [8]), Google translate still has a lot of progress to make. Rather than develop a universal language, humankind, and particularly scientists have developed a 'preferred' language – English – to build a taxonomy.

The ‘resilience’ taxonomy takes many forms depending on the discipline. In science, the concept enjoyed its first moment of glory in 1901 when French engineer Charpy attempted to measure the resistance of a material [9]. In the 1970s, the term reflected the capacity to absorb and overcome the effects of significant, unexpected and brutal ecological disruption [10]. Hybrid definitions have since emerged in many disciplines: geography [11], psychology [12], sociology [13], organizational science [14] and, more recently, ergo-psychology [15].

Despite this plethora of definitions, the concept can usefully be summarized into two complementary representations that can be given different weights – leading to a radical change in the nature of scientific knowledge. An allegory illustrates the point; rather than Plato’s cave, we use an Indian and the Indian elephant.

Figure 1 very schematically summarizes two perspectives of resilience. On the top, a blind Indian man balances on the back of an elephant. Why is he there? We do not know. To keep his balance, his body and mind continually respond to stimuli of varying intensity that come from the elephant and the environment. Whether the road is in good or bad condition, or whether there is wind or rain, he strives with all his might to stay balanced on the elephant’s back. The keywords here are balance, anticipation, adaptation, etc. and are usually found in the field of ecology [10] or cognitive ergonomics [15].

In the drawing on the bottom, the Indian is on the ground, but he has lost his glasses and his cane. Here again, please do not ask what has happened. We do not know. Perhaps an unforeseen sequence of complex interactions has occurred [16]. The key point here is that the Indian must quickly find his glasses and cane. If he does not he will be in real trouble. He will face an extreme situation, to the point that his life is at stake [6]. He might never find his way and could starve to death. On the other hand, he could find himself on a tiger’s dinner plate. The blind Indian is forced to go beyond his limits if he is to survive and return to a normal life. Here, this means finding the elephant and balancing on its back.

In the context of our work, we exclude the first perspective and focus on the second. The concept of resilience is therefore considered in the context of damage, loss, accident or trauma. Pre-accident, prevention, precaution or prudence takes priority. Resilience is an accessory to survival. The concept has positive connotations and represents an asset or progress.

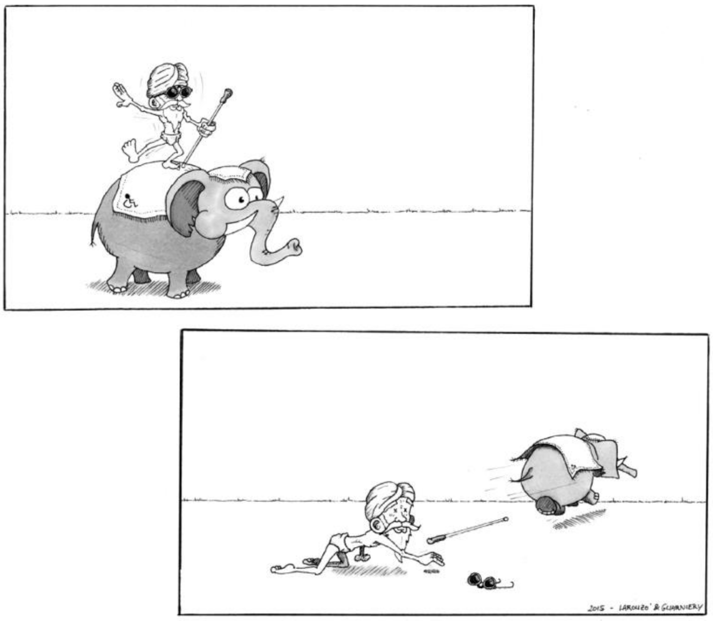

FIG. 1. What is "resilience"?

3. ENTRY INTO RESILIENCE: A HEURISTIC APPROACH

The term 'entry into' usually describes the passage from one place to another and underscores the transitional situation that characterizes it. The question of the place through which one enters is another issue, which leads to the question of the direction of the transition. The temporal dimension is important as 'entry into' implies a dynamic, leading to a change in state [17].

Figure 2, inspired by [18], is a schematic of what we understand by 'entry into resilience'. It illustrates the dynamics of autonomous agents and institutions in crises. Referring to Hurricane Katrina studied in [18], the red curve depicts the action of teams of volunteers who spontaneously tried to re-establish communications. They acted autonomously and auto-instituted their action framework. The black curve shows the evolution of the formal organization, i.e., institutions which formalize a social mode of being and evolved throughout the crisis. Note that the amplitude of the curves and their development over time does not have an absolute value and is shown only to illustrate the positioning of the phenomena. The parallel with what happened at Fukushima Daiichi is obvious, at least for the period from 11 to 15 March 2015. Here, the entry into resilience occurs during the emergence of a radically new ephemeral organization in response to the consequences of the accident and the physical and social disorder that ensued. It

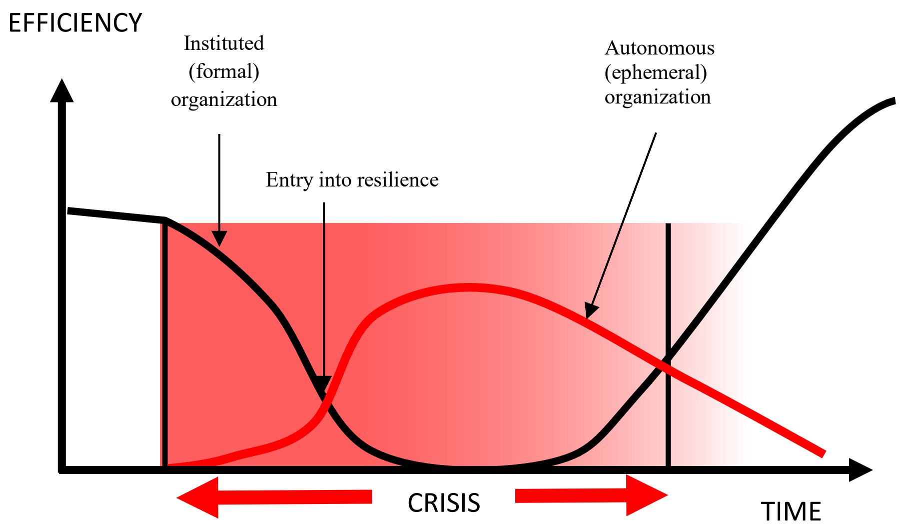

FIG. 2. How to explain what "entry into resilience" is…

ends when new institutions take over responsibility for collective action and ensure the long-term control of the recovered situation.

Entry into resilience appears as a window in the usual space-time, a period of exploration in which the aim is to understand sequences in order to better manage them. A learning phase and re-appropriation of the environment is necessary. It is difficult to rationalize this exploratory phase before or during the process as it is essentially a form of cognitive do-it-yourself that is very different to the usual rational-instrumental understanding of the world (which does not mean that it cannot be effective) [19]. At best, it may be possible to define some principles that enable people to react in an extreme situation. While this would not eliminate risk, it would reduce it to a level lower than that resulting from the substantive rationality [20]. However, it is not possible to define strict rules that would ensure the entry into resilience, as creativity play a role in the process. Entry into resilience translates into the *de facto* creation of a new system [21] when the ecological, economic or social structures make the initial system untenable.

Given our lack of knowledge, it is clearly very difficult to characterize the determinants of entry into resilience. Some disciplines have made more progress than others. This is the case for psychology [12] and ecology [10] for example. These disciplines have the advantage of developing a 'clinical' approach by studying extremely well documented cases.

In the latter case, a further challenge lies in the need to generalise the study of a particular situation. In the field of management science and human resources, the work of Powley [22] is particularly interesting as the author proposes both a data analysis methodology and a useful model for understanding the mechanism by which collective action can be reconfigured following a trauma.

Alongside these innovative avenues, the classical route used to decipher the mechanisms implemented by individuals (or groups) when faced with adversity is sensemaking, meaning the ongoing, *a posteriori* construction of a sense of ‘reality’, which enables people to find direction and decide on the actions to be taken.

4. WHEN SENSEMAKING DOES NOT MAKE COMPLETE SENSE

According to the sensemaking perspective, as classically described by Karl Weick [1], action plays a determining role in cognition, notably through a verbal understanding of a part of the range of experience. Based on their preconceptions, individuals extract cues from the endless stream of events and develop a plausible representation of the overall situation. This authorises societal action; through actions that are consistent with this representation, individuals ‘enact’ their own world. “Enacted environments contain real objects such as reactors, pipes and valves. The existence of these objects is not questioned, but their significance, meaning and content is” [23]. Therefore, “the concept of sensemaking keeps action and cognition together” [1]. The result of the enactment is itself added into the course of history, as a tangible and orderly social construction that is subject to multiple interpretations.

Although the construction of meaning in the world and the "world" itself is retrospective, at the same time, it prospectively directs action or the search for cues. This process is invoked to explain the control that humans can have over an environment. Control means acting on the environment, while ‘acting’ is understood in the sense of enacting, thus both representing and constructing meaning. Actions are linked by preconceptions, while actors react to the environment that is enacted by others; these two factors structure the response to failure and may trigger a crisis (if the failure is exacerbated). Decision processes, as such, are of secondary importance in the study of accident dynamics, and the conditions under which individuals can pursue their activities in a way that makes sense to them takes precedence.

This approach is inspired by social constructivism [24,25], according to which experience and knowledge of reality are constructed from a particular social position. However, management sciences typically bypass a major ontological problem – namely absolute relativism that prohibits any form of generalization – instead pragmatically noting the existence of organizations, ‘objectified’ perennial institutional figures based on a complex set of representations (myths, rituals, procedures, cult objects, etc.).

According to this view of sensemaking, the individual is described as unique and idiosyncratic, rather than a simple object that can be decomposed into factors. Enactment has two inseparable facets, one public and the other private. The public version is the visible part of the process, and is at the origin of social constructions; the private version refers to if-then mappings that are constructed from individual experience [26]. However, sensemaking theory gives a dominant role to communication processes and thus to language and the cognitive dimension of action [27]. At the level of the organization, individual actions that contribute to the group's work, the representation of this work and the resulting subordination of their own actions embody an overriding schema of the whole that Weick and Roberts [28] refer to as the "collective mind".

Reduced to a logic of control and therefore performance evaluation, the sensemaking process is inevitably associated with a managerial ideal, to the point that the origins of a catastrophe begin to resemble the 'Failure of Foresight' model [29]. The accident is explained by a departure from the ideal, and 'causes' are found, for example, in the weakening of the social structure that authorises sensemaking [30]. In this context, 'resilience' is the capacity to adapt in order to preserve shared interpretive schemas by adjusting (in particular) formal and informal social links (hierarchies, roles, etc.), and the associated communication flows. However, to the best of our knowledge, there are no studies that demonstrate the usefulness of these requirements for the entry into resilience of a group that has been hit by upheavals on the scale of those experienced by Fuksuhima Daiichi personnel. This clearly shows that in the extreme situation, the intensity and variety of stimuli should not be ignored.

The most recent approaches argue that the concept of sensemaking must take more account of emotions [31] to reflect the scope of 'sense' more accurately. The historical Weickian [32] perspective would benefit from distancing itself from an overly restrictive view of the retrospective nature of sensemaking, and focus more on the goals, expectations and projections of the individual in the future [33]. For some, sensemaking should be defined as the process by which "*an individual [...] grasps external reality through cognitive elements, the aims of the individual and the emotions and sensations that they feel*" [34]. Furthermore, it should include the social dimension that creates the 'individual', and interactions between different objectives, expectations or representations [35]. Consequently, the Fukushima Daiichi accident provides an excellent opportunity to demonstrate the merits of a revised and expanded definition of sensemaking.

5. THE VALUE OF SENSE IN-THE-MAKING IN AN EXTREME SITUATION

Our demonstration is based, *inter alia* on an in-depth analysis of the many official reports produced following the accident [36–42]. However, it goes beyond the reconstruction of facts and recommendations to examine the raw testimony of actors in the crisis provided to the various investigators. The value of this corpus is unprecedented and considerable. On 11 September 2014, the Japanese Government published the hearings of the plant's director, Masao Yoshida (400 pages reflecting 28 hours of examination). On 25 December of the same year, it published 127 new hearings.

Yoshida's testimony is both edifying and instructive. The director of the plant unambiguously reports the fear and pain experienced by on-site personnel as they battled with the facility and tried to contain the damage. His lexical register attests to this; he speaks of "*three entities*", "*three nuclear units that were unleashed*" against which he attempts the "*impossible with very few staff*" to "*tame this thing*" [4]. In this context of a new awakening of the senses, his impressions and perceptions would have a strong impact on his decisions. His order to evacuate the site is one example.

In this context, emotions should not be seen simply a disruption of the surrounding order and well-regulated planning. Damasio [43] shows that they are an essential component in the development of rationality. Several experimental results have since confirmed the need to rehabilitate emotion as part of the process of conceptualization. It has been demonstrated that individuals produce concepts according to their perceptual experience [44]. These studies show that the embodiment of emotion serves as conceptual grounding. As an illustration, Yoshida testified that after the explosion in reactor building 1 (when pressure was about 500 kPa), the number "500" put him "*ill at ease. I knew this was totally irrational, it was just a feeling*" [4]; this feeling would influence his decisions about the other reactors.

Such considerations appear in the work of Leontyev [45], for whom human activity is the substance of consciousness. It is a back-and-forth process between a subject and an object, guided by a schema and determined by physical contact with the outside world. Beyond these circular processes that guide interactions between the organism and the environment, Leontyev argues that mental representations are governed through physical contact with the real world and the subject obeys its intrinsic properties and relations. The object's resistance breaks the circle of internal mental processes and provides an opening to the outside world. Similarly, Vygotsky [46] showed that activity, aided by tools and signs, is social in nature and always occurs in the presence of others. Recent studies characterize the moderating role of social relationships in the subject's relationship with their body as a tool for conceptualization, the "*current (social or other) context influences the way in which a concept is represented in a conceptual task and the extent people recruit embodied information to solve it*" [44].

In line with these theoretical results, embodied embedded cognition (EEC) theory considers that meaning is grounded in the bodily processes of perception and action. The organism's bodily interaction with the environment is of crucial importance to its cognitive processes [47]. What is meant here by the 'body' is not the body as a functional system with input and output, "*but rather the body as an adaptive autonomous and therefore sense-making system"* [48]. The 'first technical object' [49], the body appears as a support for and creator of sense. "*It is impossible for a man to not be permanently changed and transformed by the sensory flow that runs through him. The world is the emanation of a body that translates it in terms of* *perception and sense, one does not exist without the other. The body is a semantic filter*" [50].

However, the influence of the physical world on individual and social representations is not as determinant as usually suggested. The subject should be considered as a whole, characterized by their intentions, affect and capacity for representation. In this context, representation concerns the "*presentation by and for the living being, by means of which the living being – starting from what are for it only mere shocks […] – creates its own world*" [51]. The imagination is at the centre of meaning processes. The above examples illustrate the importance of the imaginary in the on-site management of the Fukushima accident. Moreover, Castoriadis [52] showed the articulation between the individual imagination and the social imaginary through sublimation. In turn, the social imaginary that holds the group together orients emotions in order to provide a coherent way of being and representation of the world. This was seen at Fukushima, where a group that was determined to fight together experienced powerful emotions. Thus, after the explosion in reactor building 3 on 14 March, Yoshida "*experienced one of the greatest emotions of [his] life. They all wanted to return to the field, they even pushed each other out of the way*" [4].

The decisions of the plant's director were influenced by the need to preserve the physical and mental integrity of his employees [4]. When the manual opening of a valve located in a highly radioactive zone proved to be the only option for venting reactor 1 and preventing an explosion, technicians were ready to take action. The director explained, "*we decided to do the operation by hand, as a last resort. We decided to do this because we thought we would succeed if all that was needed was to be exposed to radiation*" (Ibid.). The economics of the situation could have dictated such a decision from the start, as the loss of a few employees could have resolved the crisis without jeopardizing remaining resources. However, such a decision could only be made acceptable following a personal and interpersonal progression, through action, which constituted a particular value system that made suffering acceptable.

Immersed in an unprecedented sensory universe, Fukushima Daiichi operators had to make the world make sense again. High levels of radioactivity, unbearable temperatures, debris, seismic aftershocks, floods, darkness and explosions formed the apocalyptic scene in which they were required to act. Action was shaped by physical contact with this material and social reality through physical challenges, and the mutual care and attention of teams at the scene.

A group is organized around an object, a representation of its activity (the "collective imaginary" [53]). This imaginary object enables (or not) subjects to invest in the group, to the extent that it facilitates the identification process. Based on this theoretical framework, it could be said that the tsunami swept through, not only the relevance of operational procedures, but also the collective imaginary of operators at Fukushima. To act, subjects had to restore an enabling imaginary. Yoshida immediately paved the way for action by sending the teams on site to collect information on the status of reactors and prepare for the injection of water using fire trucks. This action plan provided an initial fixed point for the emergence of a collective imaginary, while it subsequently evolved as a function of the hazards and operational constraints.

The group's representation (the collective imaginary) are constructed from active social imaginary significations (among others). Individuals rework these significations depending on their situation. In this case, the representation of the Fukushima Daiichi accident in public opinion hinged on the incompetence of TEPCO [54]. This negative image contrasted strongly with the mutual respect of workers on site, and the heroic allegories they used to describe their actions, notably to save their families' land. It appears that the group that remained on-site became closer as the days went by; by distancing themselves from social stigma they created an ideal image of themselves that justified the sacrifices they were making. In fact, the actions of on-site operators were only fully acknowledged long after 11 March 2011. Three months after the accident, workers reported an unusually high level of psychological distress linked to the social discrimination they suffered in their contacts with the Japanese population [55].

In order to understand decision-making in extreme situations we must understand the development, necessarily mediated by the bodily experience of the situation, of the collective imaginary significations. The study of the dynamics of entry into resilience must focus on the mutation of imaginary meanings. At Fukushima, this enabled group action to develop around creative solutions that followed the initial period of stunned shock. Beyond sensemaking, i.e. repeated rounds of analysis, we are interested in sense-in-the-making, which includes the processes by which meaning initially arises.

6. CONCLUSION

Investigations into the accident at Fukushima Daiichi highlighted deficiencies in communication, and a lack of foresight and anticipation by some operators in some of their decisions. These analyses implicitly refer to a variety of possibilities that begin with a known state, and reduce decision making to an optimization exercise. The focus is naturally on the lessons learned from shortcomings in coordination between the operator's headquarters, the government and the plant, redundant measurement systems, or the effects of stress on behaviour. It is of course clear that we need to look more closely at the impact of stress or emotions on actions or decision making [56]. However, paradoxically, this approach (often found in the safety sciences) seeks to exclude those who act from a theory of humanity, and instead focuses on bloodless social mechanisms. In the case of nuclear power, managers are also sometimes tempted to resort to formalisms to demonstrate control, to the extent that they deny the problems operators face [57]. In extreme situations, the risk is that the factors that determine 'entry into resilience' are ignored [58].

The options in terms of normative conceptual models are legion. However, the fact remains that we know very little about the teams, groups and organizations that must face the unthinkable. This ignorance invites us to favour an on-the-ground approach that attempts to delve deep into the mechanisms at work in an extreme situation. The Fukushima Daiichi accident is remarkable due to the profusion of data that has been published or will be released, notably the testimony of the plant's director [4]. This material, which is very much a personal account, makes it possible to understand the reactions of engineering teams who faced an unprecedented situation and provides some initial food for thought regarding the concept of engineering in extreme situations [58].

The lessons learned so far conceal some key processes related to how the action unfolded in the eyes of subjects who faced annihilation. The concept of the extreme situation invites us to supplement these lessons by reintroducing physical, emotional and kinaesthetic aspects, which constitute the socio-sensual structure for action, into our initial relationship with the world.

The study of action in extreme situations therefore implies decrypting accounts of such experiences; such experiences are punctuated by radical changes that cannot readily be globalized into a 'logical' description. It also means focusing on representations that are created by subjects themselves, rather than seeing them as fantasies that muddy the description of an 'objective' reality. These imaginary creations establish a new balance between individual impulses and social reality on the one hand; and between the infinity of individual perspectives and collective requirements on the other [51].

From this epistemic perspective, the 'extreme situation' refers to the collapse of meaning at group level, when control of the production facility is lost and group members are held responsible by society for an unavoidable danger. The subjects in extreme situations are torn between an urgent need to act (driven by society) and the physical impossibility of taking action within the established framework (crisis management procedures in particular) [59].

In extreme situations, the group reforms around a "magma" of imaginary significations [60] that can conflict with those created by institutions further from the action. At Fukushima, the difficulty of managing the on-site situation was compounded by instructions issued by a remote headquarters. In this context, the conflict between staff at the plant and the executive powers cannot be reduced to a failure to exchange information. Because actors had a very different relationship to a situation that was far beyond of what could be communicated, they were unable to understand each other. This highlights the need to give subjects autonomy to handle an extreme situation, and consequently to articulate the various registers of temporality and 'rationality'.

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LEADERSHIP AND SAFETY CULTURE

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Abstract

There are many contributors to declines identified in some US plants. For example, the poor use of operating experience, unawareness of true current performance, inadequate training, lack of knowledge transfer, and inadequate performance by supplier personal. While these may seem like very different contributors there is a common thread of ineffective leadership or ineffective leadership teams. In contrast, strong leaders and leadership teams were identified as essential to sustaining high levels of plant safety and reliability. To address this issue INPO developed the leadership and team effectiveness principles which have been codified in INPO 15-005. This document is used by nuclear power stations in the United States to improve leadership and team effectiveness to support high levels of plant safety and reliability.

1. INTRODUCTION

The *Great Challenges* in the United States nuclear power industry are actual or potential barriers that must be overcome to continue moving the industry towards excellence. These challenges are:

— A lack of self-awareness regarding plant performance as seen in undetected declines, a number of significant events at a high performing plants, and a few surprises in the accreditation of training programs;
— Poor use of industry operating experience as seen in a number of events that occur for which there is operating experience that was not well applied or slow organizational responses to declining trends;
— Gaps in worker proficiency as seen in events due to poor understanding of fundamentals, inadequate identification and mitigation of proficiency challenges and poor knowledge-management during transition to a new generation of workers;
— Supplier performance becomes more concerning with the an increased level of work performed by supplemental personnel;
— Some weaknesses in external event resilience. Challenges faced by implementing equipment and operational lessons from the Fukushima nuclear accident, along with equipment/design issues, human performance, and leaderships issues;
— Slow recovery of low performing plants. Some plants have several false starts before actual recovery begins, or have a shallow understanding of the issues that drove declines, so they remain unresolved.

While the above challenges are moderately self-contained there are additional challenges that are more cross-functional in nature. These cross-functional challenges are:

— Some weak leaders and weak leadership teams. Some challenges seen in role confusion between the site, corporate, and INPO, some lack of adaptation to changing performance, and of the impact of leadership on nuclear safety culture;
— The cumulative impact of demands by the regulator, INPO, insurance agencies, etc. as that place demands and distractions on leaders.
— Economic considerations, and lack of understanding of integrated risk and the decisions are made and the impact on safety and margins.

2. RESULTS

A common thread between many of these challenges is that at times, site and corporate leaders are either unaware of declines or are slow to react to them. In addition, the demands of sustaining the highest levels of nuclear safety in an ever-changing business environment continuously challenge nuclear leaders.

Strong leaders and leadership teams are essential to sustaining high level of plant safety and reliability. The link between the presence of effective leaders and leadership teams and the resultant high levels of sustainable performance is supported by numerous examples throughout our industry's history. After reviewing industry strengths and areas for improvement, interactions with high-performing organizations, and applicable research with industry groups and executives, nine leadership attributes and five team attributes were found to be associated with high performance. These attributes were documented in *INPO 15-005, Leadership and Team Effectiveness Attributes*. [1]

While recognizing that other positive attributes may exist, the presence of the following leadership and team effectiveness attributes is foundational for excellent performance. There are nine Leadership Effectiveness Attributes:

— *Promoting a Clear Vision and Strategy to Achieve Excellence*. Leaders promote a clear and compelling vision and strategy to achieve organizational alignment, establish common priorities, and foster continuous improvement. They set a personal example by their own behaviors.
— *Implementing a Strong Talent Management and Leadership Development Strategy*. Leaders implement a development strategy that creates an organization comprised of diverse, qualified, capable, and proficient individuals able to sustain long-term performance.

— *Fostering a Learning Organization – Continuous Improvement*. Leaders foster a learning organization that recognizes small signs of decline and uses appropriate methods for aggressively closing performance gaps.
— *Developing an Aligned and Engaged Workforce*. Leaders develop an aligned and engaged workforce who understands their role in meeting organizational goals and is willing to strive for and sustain excellence.
— *Inspiring, Motivating, and Communicating*. Leaders, by commitment and example, create an environment where individuals are engaged, inspired, and motivated.
— *Building and Sustaining Trust with Employees and External Stakeholders*. Leaders build and sustain trusting relationships with employees and external stakeholders by listening, acting, and communicating with integrity while ensuring the purpose of goals and strategies is well understood.
— *Providing Effective Coaching and Feedback in an Environment of Healthy Accountability*. Leaders provide candid and timely feedback, reinforce positive behaviors, correct shortfalls, and nurture ownership — creating a culture of healthy accountability to improve performance. Coaching is used for motivation as well as for accountability.
— *Making Effective Decisions and Appropriately Managing Risk*. Leaders ensure decisions are made at the appropriate organizational level and involve diverse perspectives to make certain that potential unintended consequences are recognized and that risk is appropriately managed.
— *Achieving Sustainable Results*. Leaders achieve sustainable results by shaping organizational behaviors and by relentlessly reinforcing high standards to achieve ownership and accountability for performance.

The five Team Effectiveness Attributes are:

— *The Team is Aligned Around a Common Purpose, Vision, and Goals*. The leadership team aligns itself, its organizations, and its priorities around a common purpose, vision, and goals to achieve organizational results.
— *Members Are Committed to the Success of the Team*. Teams are most effective when members are committed to the success of the team by accepting personal accountability for the collective outcomes.
— *Team Talent, Roles, and Responsibilities are Clear*. Teams are proficient when requisite knowledge and skills are available, and team members are prepared to execute their roles and responsibilities precisely.
— *The Team Creates a Positive Atmosphere of Mutual Trust and Respect*. Leaders create a level of trust within the team and with external organizations such that team decisions and results are understood and accepted as fair and appropriate and support organizational goals.

— *Team Decision-making and Conflict Resolution are effective*. Teams effectively leverage the collective talent of diverse team members to make sound decisions.

The Leadership and Team Effectiveness attributes are grouped together based on how they relate to supporting and developing essential outcomes in the organization: Set Direction, Maximize Competence, Engage the Workforce, Cope with Risk, and Achieve Sustainable Results.

— Set Direction
  - Promoting a Clear Vision and Strategy to Achieve Excellence;
  - The Team is Aligned Around a Common Purpose, Vision, and Goals.

— Maximize Competence
  - Implementing a Strong Talent Management and Leadership Development Strategy;
  - Fostering a Learning Organization – Continuous Improvement;
  - Team Talent, Roles, and Responsibilities are Clear.

— Engage the Workforce
  - Developing an Aligned and Engaged Workforce;
  - Inspiring, Motivating, and Communicating;
  - Building and Sustaining Trust with Employees and External Stakeholders;
  - Providing Effective Coaching and Feedback in an Environment of Healthy Accountability;
  - The Team Creates a Positive Atmosphere of Mutual Trust and Respect.

— Cope with Risk
  - Making Effective Decisions and Appropriately Managing Risk;
  - Team Decision-making and Conflict Resolution are effective.

— Achieve Results
  - Achieving Sustainable Results;
  - Members Are Committed to the Success of the Team.

INPO 15-005 supports the achievement of the performance objectives and criteria by providing more detailed descriptions of, and focus on the attributes of leadership and team effectiveness. This document describes observable attributes seen in effective US organizations; the specifics of "how" these outcomes are achieved will vary from plant to plant, based on such variables as history, culture and the style of the leaders themselves. While INPO 15-005 provides a detailed description of leadership and team effectiveness attributes and outcomes, it is not intended to be a "checklist." It is not required that the wording used to describe the attributes be duplicated in site- or company-specific documents; however, it is expected that these attributes be present and evident in the daily activities, behaviours, and outcomes of a US nuclear organization. This document also includes discussion questions that can be used in assessments, training, and other forums to identify actions needed to improve leadership and team effectiveness.

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Abstract

The Working Group on Human and Organizational Factors (WGHOF) has the principal mission to improve the understanding and treatment of human and organisational factors within the nuclear industry in order to support the continued safety performance of nuclear installations and improve the effectiveness of regulatory practices in member countries. Membership in WGHOF is comprised of human and organisational factors experts from regulatory bodies, technical safety organisations, research institutions, and industry. WGHOF serves as a forum to share information and expertise and undertake cooperative activities to address emerging human and organisational factors (HOF) issues.

1. INTRODUCTION

The paper provides an overview of the OECD (Organisation for Economic Co-Operation and Development) Nuclear Energy Agency's (NEA) work on HOF over the past few years, with an emphasis on recent developments and a look forward based on current issues of interest.

2. OVERVIEW OF WGHOF

The NEA's Committee on the Safety of Nuclear Installations (CSNI) has recognized the growing importance of HOF to nuclear safety since the 1980s. This area started as the subject of specialized task groups, and has grown to become the focus of a permanent Working Group on Human and Organisational Factors (WGHOF). The principal mission of WGHOF is to improve the understanding and treatment of human and organisational factors within the nuclear industry in order to support the continued safety performance of nuclear installations and improve the effectiveness of regulatory practices in member countries. WGHOF is comprised of human and organisational factors experts from regulatory bodies, technical safety organizations, research institutions, and industry.

WGHOF serves as a forum for exchange of information and operating experience, and for identifying HOF issues, methodologies and practices. Surveys, workshops and proceedings, technical opinion papers and state-of-the-art reports have been produced in the past by WGHOF on various topics. The resulting products can be loosely grouped around the following topics:

- Plant Maintenance: Human and organisational factors have been shown to make a significant contribution to nuclear plant incidents. Of particular concern is the impact of these factors on the planning, management and delivery of plant *maintenance* activities. (One of the contributing factors to Three Mile Island was valves left in the incorrect configuration following maintenance). Errors during maintenance may not always be revealed by commissioning tests and may remain undetected for extended periods until the affected system is called upon to function. For these reasons it is prudent to consider how best to defend against the incidence of maintenance errors or mitigate their effects. WGHOF hosted a workshop on better HOF practises during maintenance [1], leading to a Technical Opinion Paper [2].
- Plant Modifications: Operating experience repeatedly shows that changes and modifications at nuclear power plants (NPPs) may lead to safety significant events. At the same time, modifications are necessary to ensure a safe and economic functioning of the NPPs. To ensure safety in all plant configurations it is important that modification processes are given proper attention both by the utilities and the regulators. The operability, maintainability and testability of every modification should be thoroughly assessed from different points of view to ensure that no safety problems are introduced.WGHOF has hosted a number of workshops related to plant modifications [3, 4, 5, 6], and issued an associated Technical Opinion Paper [7].
- New Plant Technology: New plants are an opportunity to apply the experience and learning gained from operating plants. There are also some unique challenges posed by newer technology, particularly the use of complex digital systems for monitoring and control. WGHOF has hosted workshops [8, 9] and produced a Technical Opinion Paper [10] on HOF practises for new plant technology.
- Oversight: Many of the attributes of a high-performing organisation including nuclear are not easy to quantify or measure and thus managerial and regulatory oversight is particularly challenging. WGHOF has hosted several workshops on topics such as Management of Change, Safety Management, Oversight of Safety Culture, Organisational Suitability, and

Leadership and Management for Safety [11, 12, 13, 14, 15]. State-of-art-reports [16, 17], and Technical Opinion Papers [18, 19] have been produced relating to these topics identifying good practices in managerial and regulatory oversight. An important characteristic of high-performing organisations is their ability to learn from occurrences and events. WGHOF worked with another NEA group, the Working Group on Operating Experience (WGOE), to host a workshop on effective consideration of HOF factors in event analysis [20].

By its position within the NEA CSNI community, WGHOF can easily draw in expertise within other working groups, such as the working group on risk assessment, WGRISK, to assist in the conduct of multi-disciplinary studies such as those in human reliability assessments [21]. Another of the standing technical committees of the NEA, the Committee on Nuclear Regulatory Activities (CNRA) is supported by separate working groups in the areas of inspection practices, operating experience, the regulation of new reactors and finally public communication. Many of the tasks that WGHOF members have led or supported have been jointly carried out with the participation of CNRA WGs (e.g., inspection practices and operating experience principally). The NEA structure allows for and encourages a strong multi-disciplinary approach to the conduct of studies.

Over the years, WGHOF has benefited significantly via its strong cooperation with the NEA joint international research project's Halden Man Technology Organisation (MTO). This interaction has involved the direct participation of a Halden Reactor Program (HRP) representative within regular WGHOF meetings as well as cooperation on specific projects in advancing the knowledge on human factors and human performance as it relates to new technology within the nuclear field [3, 4, 8].

International organisations such as IAEA and EC are also represented. Their participation in WGHOF meetings and activities is important to fostering broad international collaboration. Through their participation, information is exchanged between organisations and some of the WGHOF tasks are co-organized.

3. RECENT WORK

3.1. Integrated System Validation

With progress in the use of complex systems to aid operators in the control and operation of nuclear plants, there has been increased interest in how to ensure the effective performance of the combination of operating staff and control equipment, referred to as Integrated System Validation (ISV). In February 2015, WGHOF conducted a workshop on ISV which brought together nearly 30 experts from 11 different countries. These individuals, who included representatives from regulators, reactor design organisations, and research organisations, were encouraged to share their experiences and views through white papers submitted prior to the workshop. They then engaged in 3 days of discussions focused on achieving reasonable confidence in the Human Factors Engineering (HFE) validation of integrated nuclear power plant control room systems. Considering both design modifications and new builds, the experts explored opportunities for improving confidence in design validations from early in the design process through design implementation. The workshop was successful in identifying recommended practices and areas where additional research and guidance development will be needed. In general the results suggest that a multi-phase approach is a promising pathway toward enhancing confidence in the validation of main control room designs and modifications. A report on the outcomes from the workshop should be available in 2016.

3.2. Fukushima follow-up

Over the past few years, WGHOF has also been closely engaged in ensuring lessons learned from the accident at Fukushima Daiichi are properly addressed. The group carefully reviewed the influences of national characteristics on safety culture (one of the concerns expressed in Japan's DIET report). It was concluded that while national characteristics are an important consideration for organisations in ensuring an effective safety culture, no changes are required to the currently accepted safety culture framework.

Also in the area of safety culture, WGHOF has contributed to an effort led by the NEA's Committee on Nuclear Regulatory Activities (CNRA) to develop a guidance document on best practices for ensuring an effective safety culture for regulatory bodies.

A particular concern highlighted by Fukushima Daiichi was the challenge of implementing mitigation strategies in the aftermath of an extreme event.

3.3. Human performance under extreme conditions

WGHOF hosted a workshop in February 2014 in Brugg, Switzerland to gain insights on human performance under extreme conditions and how to ensure organisational resilience. From the discussions at the workshop, it is clear that the accident at Fukushima has illustrated the challenges that can face operations and emergency response staff in dealing with a major nuclear incident. In addition to the complexities of understanding what is happening in the reactor and taking appropriate actions, people were exposed to a harsh environment (e.g. loss of power, radiation, lack of tools, fatigue, etc.) and demanding psychological factors (e.g. shock, disbelief, uncertainty and fear related to personal and family situations, etc.).

Moreover, the Fukushima accident had fundamental implications for our understanding of accident management. The traditional approach to such accidents is to seek improvements in reliability that should prevent recurrence and provide staff with measures (procedures and equipment) that can be applied. The difficulty with this approach is that the increased complexity can lead to unanticipated situations that render the pre-planned responses inapplicable and ineffective. One of the fundamental conclusions from the workshop is that in addition to reliability, the focus should be on increasing resilience through improving flexibility. The resulting suggestions for good practices and areas requiring further research in the areas of human capabilities, organisation and infrastructure have been documented in workshop proceedings released in 2015 [22]. The main results are presented here with good practices and further research needs summarized in Appendix A.

3.3.1. Human capabilities

In responding to severe accidents, human capabilities pose both advantages and disadvantages. People can be very resilient – when faced with a problem, they can find creative solutions. For example, people use pattern-matching to help make sense of new situations and determine appropriate actions. At the same time, the stress associated with a severe accident can limit human performance. People can become over-whelmed and mentally fatigued leading to poor cognitive behaviour and decision-making.

3.3.2. Organisation

Managing for the unexpected and developing resilience requires organisations to broaden their processes. Two important attributes in this regard are the ability to understand and communicate complex situations to staff (provide a sense-making story), and the ability to recognize when the situation has evolved or the current sense-making story needs adjustments (watch for anomalies).

Ensuring organisational performance for both design-basis events and severe accidents poses a significant challenge. The organisation has to achieve a balance in centralized and decentralized processes for decision making, and a balance in a rigid adherence to procedures and a flexible response to symptoms.

3.3.3. Infrastructure

The infrastructure required to respond to severe accidents includes both off-site and on-site capability. This infrastructure should include resources and equipment that is sheltered from potential initiating events (earthquakes, severe weather, etc.), and capability to move equipment to where it is needed. Specific consideration needs to be given to multiple failures that could result from a common cause – e.g. severe weather events impacting multiple units on the same site, or on different sites.

4. CURRENT AREAS OF INTEREST

Going forward, WGHOF is cooperating with sister working groups within the CSNI and CNRA on human reliability considerations for external events and for digital control rooms, and on the challenges associated with ensuring the effectiveness of operating organisations for new reactors. In addition, WGHOF members have identified three topics to be pursued:

— Lessons learned from exercises conducted in response to Fukushima: As part of their implementation of post-Fukushima actions, licensees are beginning to conduct validations of manual mitigation actions, training, drills and exercises to test and demonstrate the effectiveness of their capabilities to mitigate severe accidents. This task involves identifying and developing a means (e.g., surveys) to gather and share lessons learned from the implementation of these exercises throughout the international nuclear community. The objective would be to facilitate/accelerate industry learning of best practices and identify areas requiring additional research and development.

— Assessment of resilient organisations: As identified from the Fukushima accident, organisational resilience is required to ensure safety in normal conditions (design basis) and when facing the unexpected (beyond design basis). The objective of this task is to explore the link to safety culture, safety management systems and other concepts already in use, identify the gaps to resilience (set of skills, practices required), and then to evolve these concepts as a basis for a true systemic approach to safety for coping with the unexpected.

— Human Performance: It has been estimated that human performance plays a key role in 60 – 80% of events in high reliability industries. In past years, efforts to improve human performance have been equated with the use of event free tools to prevent human errors. Research and experience has shown that this approach may not produce lasting changes. A more holistic view of human performance strengthens the factors which promote desirable human performance. The objective of this task will be to identify the individual, technological and organisational factors which may affect human performance, describe current approaches to the implementation of human performance programs and identify best practices in regulatory oversight.

5. CONCLUSIONS

WGHOF has evolved into an effective means for HOF experts from regulatory, technical and operating organisations to share information and expertise and to undertake cooperative activities to address emerging HOF issues.

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APPENDIX A

CNSI/NEA WGHOF Workshop on Human Performance under Extreme Conditions with Respect to a Resilient Organization – Good practices and further research needs

Human Capabilities

Good Practises:

- Put in place pre-planned responses for the very early stages of a severe accident – e.g. preparatory activities, mobilization of resources, information gathering. This allows personnel to get over shock, gain some understanding of the situation, and start on a successful note.
- Use realistic exercises to test and develop response capability. These are particularly important to testing lines of communication, decision-making, improvising and re-planning capabilities, leadership and team behaviour.
- Recognize that stress will be a reality and ensure that there are mechanisms for addressing stressors such as uncertainty in family situations, and that there are staff rotation plans in place.
- Establish an observer role – a person responsible for watching team dynamics, fatigue, when, for example, teams are stuck. Such a role is important to helping make changes before stress and fatigue have an adverse impact. Train personnel that will be in leadership roles in the requisite interpersonal and communications skills. This should include sense-making (see below).

Research needs:

- Error modes during extreme events: The existing extensive database on human error during more routine events should be built on to include what might be expected during extreme events. In particular stress research needs to be integrated into cognitive psychology.
- Extent of realism required for exercises: There are ethical considerations in the introduction of stressors and uncertainty in the benefits of pushing scenarios to failure. For example, should situations requiring sacrifice decisions be included.

Organisation

Good Practises:

- Ensure that accident management teams are provided with clear lines of communication and clear authorities for distributed decision making in advance of any incident.
- Establish an emergency management process that involves regular "stop-points" to review the current situation and determine if the plan of action needs to be revised (watching for anomalies).
- Identify reserve capacity (people and equipment) that can be used to provide necessary flexibility to respond to the unexpected.

Research needs:

- Transition from rule-based procedures to knowledge-based approaches (compliance to resilience): Normal operations and design-basis accidents rely on rule-based procedures to guide staff actions, whereas severe accidents use a knowledge-based approach. This represents a shift in both decision-making authority and processes that would benefit from research on how to ensure the transition is effective.
- How can organizations be flexible and agile during emergencies while maintaining reliability during normal operation?
- Regulatory oversight practises for resilience: The traditional approach to regulatory oversight is to assess organizational compliance using pre-established criteria and processes. As resilience is based on ensuring flexibility, a different approach to regulatory oversight may be required. Resilience measures: What are leading and lagging indicators of organizational resilience?

Infrastructure

Good practises:

- Provide redundant infrastructure and equipment (including transportation equipment) necessary for resilient emergency response; and ensure the infrastructure and equipment is adequately sheltered.
- Pre-establish inventory of systems and components that may have an alternate use during emergencies (e.g. electrical systems, water-supply systems including fire pumps).

- Ensure consideration is given to events that unfold over an extended time period – how will transitions between response teams be managed? – how will the basic living requirements (e.g. housing, food, clothing) be met?
- Involve off-site emergency response capability in exercises to ensure lines of communication are effective and overall emergency response will be effective.

Research needs:

- How should updated risk assumptions (event frequency and consequence) drive changes to the emergency response infrastructure?
- Resilient procedure use: Can resilient procedure use, i.e. adapting existing procedures to unanticipated situations, provide an approach to smoothing the transition between a rule-based approach to a knowledge-based approach?

LEADERSHIP AND SAFETY CULTURE
Leadership for safety

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Abstract

Following the challenge to operate Nuclear Power Plants towards Operational Excellence a highly skilled and motivated organisation is needed. Therefore Leadership is a valuable success factor. On the other hand a well-engineered safety orientated design of NPP´s is necessary. Once built a NPP, it constantly requires maintenance, ageing management and lifetime modifications. etc. E.ON Kernkraft GmbH tries to keep the nuclear units as close as possible to the state of the art of science and technology. Not at least a requirement followed by our German regulation. As a consequence of this we are continuously challenged to improve our units and the working processes using national and international operational experiences too. A lot of modifications are driven by ourselves and by regulators. These institutions – authorities and independent examiners - contribute significantly to the safety success. Not that easy all the day. The relationship between the regulatory body, examiners and the utilities should be challenging but should also be cooperative and trustful within a permanent dialog. To reach the common goal of highest standards and status regarding nuclear safety, all parties have to secure a living safety culture. Without this attitude there is a higher risk that safety relevant aspects may stay undetected and room for improvement is not used. Nuclear operators should always be sensitized and follow each single deviation. Leaders in a NPP-organisation are challenged to create a safety-, working- and performance-culture based on clear common values and behaviours, repeated and lived along all of our days to create at least a strong identity in the staffs mind to the value of safety, common culture and overall performance.

1. BACKGROUND

The meaning of leadership for safety in the nuclear industry is pointed out hereinafter. This topic became an increasing rank since the German “Energiewende”. Despite the phase-out of the German NPP´s nuclear safety and the belonging safety culture needs to be well maintained. This is a challenge for the whole organisation.

2. GENERAL

Due to its physical characteristics, the nuclear technology is a unique and special one. Without question our business belongs to the numbers of high risk technologies. From the very beginning in the early 50th up to nowadays several significant events demonstrate and underline this statement very evidently. Constantly design weaknesses, misunderstanding and lack in human performance were causes and contributors that lead to catastrophic outcomes. Don´t forget know-how gaps and burning ambition. On the other hand the safe and successful operation of our NPP´s is evidence that the risks are manageable and our business could be sustainable in the future.

It is our highest priority to protect peoples live, environment and real assets from these risks. Our daily pursuit should be to minimize error traps by optimization of our processes. Each utility has written its nuclear safety policy or similar documents. These policies are describing a plurality of detailed attitudes, values and expectations as part of our lived safety culture.

To fulfil the set goals it is necessary to establish an effective and sustained leadership and management for safety in our organizations. We have to maintain, assess and improve effective leadership and safety culture continuously. This includes the regulatory body and other authorities, independent examiners, as well as corporate organizations that are responsible for operational management. Each part has to work properly to be able to perform as an effective set-up with a common target: Nuclear safety.

For sure we are challenged to operate our units just as well out of the view of economic aspects. At least we are responsible to generate benefit towards our owners. Presently a demanding and challenging additional burden is given, because of low prices in the European electricity markets.

3. STATUS QUO IN GERMANY

The German NPP´s are very often listed in the top 10 of the world's best performing units. This success is based on the employee's performance, a technical mature, robust design plus a close cooperation and dialog with the authorities, regulatory body and its associated independent experts as well as suppliers.

The utilities and these institutions have understood how to motivate, coach and encourage their staff in the sense of nuclear safety, safety culture and Operational Excellence. Unfortunately we missed the chance to convince the public and politicians in a manner that a majority in the public is willing to accept our business. As a consequence the "German Phase- out" defines and shapes our further acting. To preserve our standards in the new framework will be a challenge. Leaders and managers are asked a fortiori to take "care" of their staff and organisation and competencies to ensure nuclear safety in the long term. Leadership therefore nowadays is more important than ever.

4. LEADERSHIP FOR SAFETY

Man, Technique and Organization (MTO) should be harmonized in a holistic approach in such a robust manner that all safety goals are met and all risks for people and environment are eliminated as far as possible. A distinct safety culture inside the utility should be developed and clearly lived by the whole organization and plant hierarchy. Therefore managers shall demonstrate and live leadership for safety and commitment for safety. They have to establish behavioural expectations, set standards and to foster a strong safety culture. What is meant by this statement or objective?

4.1. Leadership versus management

First of all we have to differ between leadership and management. But thinking about standards let's have some illustrative words ahead. The following definition might explain the idea behind:

- **Standard:** "An accepted or approved example of something against which others are judged, measured or rated." Setting standards is what leaders are asked to do.
- **Leader:** "A leader is an individual who inspires, coaches and influences people to accomplish organizational goals while adhering to core values".
- **Manager:** "A manager is an individual assigned to managerial or supervisory position. Managers control, direct, plan, organize coordinate and staff the organization to achieve safe reliable station operations".
- **Alternatively:** The difference between Management and Leadership can be stated simply: Management is a formal, authorized function for ensuring that an organization operates efficiently and that work is completed in accordance with requirements, plans and resources, while Leadership is the use of capabilities to give direction, to influence and communicate with aim of achieving the commitment of all individuals to appropriate goals, shared values and behaviour.

4.2. Leadership principles and attributes

Under consideration of this difference leadership for safety calls for the following principles:

- Take over responsibility;
- Strive for Operational Excellence;
- Convince people to understand changes as a chance;
- Encourage people to challenge the status quo;
- Promote innovation;
- Show a critical scrutinized attitude;

— Lead by example.

High performing nuclear organisations present some attributes. Excellent performance without these attributes is unlikely:

- Effective Leadership(team);
- Vision and plan for Excellence;
- Core values and behaviours;
- Engaged Employees;
- Healthy Accountability;
- Effective Processes and Structures;
- Identity.

4.3. Safety Culture

Next we have to define safety, respectively safety culture. An updated definition was developed three years ago by WANO:

> "Nuclear Safety Culture is defined as the core values and behaviours resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and environment."

Nuclear Safety Culture is a leadership responsibility. Leaders recognize that safety culture is not all or nothing but has to be rather improved continuously. As a result there is a comfort in discussing culture within the organization as well as with outside groups such as authorities and regulators. Nuclear operators need to understand that at least this discussion or better dialog is one of the essential keys to success.

4.4. PDCA Cycle

The PDCA-Cycle demands for field presence of the leaders. Leading by example requires visibility. Visibility facilitates to encourage people and to foster core values, standards and behaviours. How to show a critical scrutinized attitude without being present? At the end of the day, the story is nothing else than a simple cyclic process. In this context the well-known PDCA cycle (**P**lan **D**o **C**heck **A**ct) is feasible too. That is no hidden secret at all.

Set Standards and expectations. Communicate them and convince about that. Monitor standards and if necessary reinforce them. Don´t accept any deviation. Never fail to correct shortcomings. If so a new standard would be set.

4.5. Barriers

But why is it that hard to follow and to live this thesis? For several years the German nuclear utilities collected regularly Areas for Improvement (**AFI**) regarding leadership whilst WANO Peer Reviews, despite a good performance. Obviously not a result based on leadership but more owed by a professional (technical) conduct and habit.

Actually a common working group under the umbrella of VGB tries to develop an understandable and traceable leadership model as a countermeasure. Extensive training is scheduled to bring leadership basics to the employees mind. This is realized, because we understood that the new challenges need improved leadership attention. The framework of our business changed. Operational Excellence is no longer the only target. Decommissioning is asking for more concentration. Managers and leaders are asked to develop new perspectives and business models (cases). They have to prepare their staff towards new tasks. Change management pops up. Motivation must kept maintained.

We have to deal with a hit list of popular excuses/barriers on our way:

- Lack of time;
- Other priorities;
- Lack of resources;
- A problem does not exist;
- Technical problems need more attention;
- Framework in nuclear business does not allow any activities;
- We are technicians (not psychologists);
- Not necessary/no benefit up to phase out.

To understand the mechanism behind it is helpful to dig in a little deeper to find the suitable tool "for cracking the nut" (slacken the knot). The main task is to see and to take care of the necessary stuff needs. Therefore we should think about some contributors that could explain these excuses. The following attributes might be a thinkable solution (approach).

- Affinity to technique;
- Lack of willingness to change;
- Convenience;
- Unconsciousness;
- Presumption;
- Complacency.

4.6. Our virtual translation

The notable German situation is asking for task oriented leadership. Positive reinforcement is one successful and growing technique used by leaders to attain desired goals. The targets we have to reach are clear defined.

- Operate the units in a safe, conservative manner under fulfilment of all requirements in line with nuclear safety;
- Transfer into safe and reliable service operation;
- Development of decommissioning strategies;
- Illustrate staff perspectives;
- Securement of sufficient and qualified staffing;

Theoretically it is a clear picture and simple game. The topics and agenda are known. So what is left?

Just do it. Don’t step into the same error traps mentioned before.

- Promote your vision and values;
- Respect and appreciate people;
- Be present and visible;
- Close the cycle;
- Assess the results;
- Communicate consequences or successes;
- Never fail to correct shortcomings or that will be the new standard.

Leaders need to review how they are doing and should raise the bar whenever possible. Reviews should be used to discuss and evaluate observations to be able to identify trends and to define plant improvement plans as part of corrective actions.

5. FINDINGS

Already since 2001 the German nuclear industry has used a concept to assess safety culture. The belonging assessments are conducted self-dependent. In June 2012 the German utilities issued a new revision adopting this plan to newest international standards. Although these evaluations are not part of our regulators supervision. Some results were reported to our authority in support of certain issues.

Corresponding the mentioned plan all units including the phased-out ones were rated. A generic analysis of the total results concludes that no noticeable weakness do exist.

From our perspective we are on track. The organisation is sensitized and awake. Our commitment regarding nuclear safety has not changed. Erosion is not acceptable and not visible. It is very important not to stop our activities otherwise regress will set in.

6. SUMMARY

Following the challenge to operate Nuclear Power Plants towards Operational Excellence a highly skilled and motivated organisation is needed. Therefore Leadership is a valuable success factor.

On the other hand a well-engineered safety orientated design of NPP´s is necessary. Once built a NPP, it constantly requires maintenance, ageing management and lifetime modifications. etc.

E.ON Kernkraft GmbH tries to keep the nuclear units as close as possible to the state of the art of science and technology. Not at least a requirement followed by our German regulation. As a consequence of this we are continuously challenged to improve our units and the working processes using national and international operational experiences too. A lot of modifications are driven by ourselves and by regulators.

These institutions – authorities and independent examiners - contribute significantly to the safety success. Not that easy all the day. The relationship between the regulatory body, examiners and the utilities should be challenging but should also be cooperative and trustful within a permanent dialog. To reach the common goal of highest standards and status regarding nuclear safety, all parties have to secure a living safety culture. Without this attitude there is a higher risk that safety relevant aspects may stay undetected and room for improvement is not used. Nuclear operators should always be sensitized and follow each single deviation.
Leaders in a NPP-organisation are challenged to create a safety-, working- and performance-culture based on clear common values and behaviours, repeated and lived along all of our days to create at least a strong identity in the staffs mind to the value of safety, common culture and overall performance.

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CULTIVATING AND DEVELOPMENT – 30 YEARS PRACTICE OF SAFETY CULTURE IN CHINA

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Abstract

The safety culture has been cultivated and promoted in China since it was proposed by IAEA right after the Chernobyl Nuclear Accident. The 1st phase – exploration in the early years – is from 1984 to 2006, in which the concept of safety culture was introduced by regulatory authority and used by the industry. The basic ideas, such as the basic principles and directing ideologies for the nuclear safety, were established in China. The 2nd phase – practice and growing up – is from 2006 to 2014, the safety culture was promoted by the government as well as the industry. The nuclear industry was encouraged to develop their safety culture into vivid form. The 3rd phase – Rapid developing – is from 2014 to now. The Chinese President XI announced the Chinese Nuclear Safety View in 3rd Nuclear Security Summit in March 2014. The policy declaration was issued by different departments together and the Specialized Action for Nuclear Safety Promotion was carried out by the NNSA. Thorough 30 years effort, the nuclear safety culture was cultivated both in the government and industry organizations with great achievement. Facing the rapid development of nuclear power in China, The NNSA

will take the Nuclear Safety Culture construction as one of its major mission to consolidate the protection for nuclear safety.

1. INTRODUCTION

Nuclear safety is one of the important parts of national security in China. Knowing the decisive effect of the culture element on the safety, the Chinese government always attaches great importance to the nuclear safety culture construction. The NNSA (National Nuclear Safety Administration) takes “leading and inducing by culture” as the first among 10 items of experiences for it successful conduction nuclear safety regulation in the past 30 years. The NNSA adheres on promoting the nuclear safety culture of the industry by means of inspecting, rules making, staff training, etc. In recent years, the development of China's nuclear power and nuclear technology utilization is rapid, there are 26 units under construction and 30 units in operating. The number of radioactive sources devices also showed a trend of fast increasing year by year. The nuclear safety is ensured by the methodologies based on good nuclear safety culture. In order to guarantee the nuclear safety insistently, it is more needed to strengthen the culture both for the operators and the regulators.

2. THE HISTORY OF NUCLEAR SAFETY CULTURE IN CHINA

Since 1984, the China's nuclear safety culture development has experienced 30 years, it was formed, from the initial safety consciousness, to the introduction of international safety culture concept, and then, to the process of absorbing and digesting, and finally became one of the cornerstone of the nuclear safety regulation edifice of China [1].

2.1. Phase 1: The exploration in the early years (1984-2006)

During the 1980s-1990s, Chinese people were converting their focus from the revolution to the economic development, the economic development was taken as the center of the society activities and the risk of the industrial production has not been noticed. In the early days, the importance of the nuclear safety was recognized only by the consciousness of the pioneer who mainly came from the nuclear weapon producing industry with limited knowledge and skill for safety.

Alarmed by the Chernobyl accident in 1986, the Government of China realized the destructiveness of severe nuclear accident and the vital of the nuclear safety. The State Council decided to conduct a review on the safety features of the Qinshan and Daya Bay nuclear power plant which are under construction then, to assure that the adequate protection has been given by the design and construction. The ideology of “safety first” was required by the State Council during this countermeasure meeting of Chernobyl nuclear accident by the former Premier.

Sooner later, it was adopted as the guiding principle for the safety related activities for nuclear installations by the first issued ordinance for nuclear regulation in China – *Regulation on the Safety Regulation on the Civil Nuclear Installations.* The industry realized that the safety should be the lifeline of their career.

The basic conception of nuclear safety culture formed in the background of nuclear accident in the world and early development of nuclear power in China. During the early days, the concept of Safety Culture played an important role for the establishment of the national infrastructure. A set of nuclear safety regulations was established in line with the IAEA safety standards, and it is believed to be capable of maintaining the high level safety for nuclear installations.

The concept of Safety Culture was adopted by NNSA once it was defined in the INSAG 4 by IAEA in 1991, and soon it was noted by the industry. During that time, the main activities of promoting the Safety Culture were to make the exotic concept accepted by the workers. The activities, such as STAR (Stop, Think, Action, Review) methodology, PDCA (Plan, Do, Check, Action) requirement, by which the good nuclear culture was exhibited, were popularly adopted by operators to keep the workers following the operation procedures and qualification programs.

A operating management system was established in the Qinshan nuclear power plant in which the safety was taken as the prime object, and it became the prototype of management system in CNNC (China National Nuclear Company) affiliated nuclear power plant. The Daya Bay nuclear power plant of CGN (China General Nuclear Power Group) deeply referenced the safety culture of French nuclear power plant by sending trainees to France, and adopting the management system of French nuclear power plant. The inner nuclear safety supervision system and the Production Quality Management Manual (PQOM) were established. Through the introduction and cultivation, the concept of the Safety Culture was accepted by the Chinese nuclear industry.

2.2. Phase 2: Practice and growing up (2006-2014)

The fast economic development in China brought frequent industrial incident in the early new century, especially in the coal mining industry. The government of China determined to stop the arising trend of the destructive industrial incident happening. The industrial safety was stressed in the highest top policy document of the government [2].

The nuclear power engaged the high speed gear from 2006 (table 1). It became an important issue for government of China to keep the safety of a large fleet of nuclear power plants. The nuclear safety culture was stressed in an important nuclear power policy document – *Long-term Development Plan of the Nuclear Power (2007-2020)*, by the government of China.

TABLE 1. The amount of units approved for construction in each year from 2006 to 2010

year	amount
2006	2
2007	1
2008	7
2009	9
2010	10

In reference to the Fukushima Daiichi nuclear accident lessons learning, the government of China published the T*welfth Five Year Plan for Nuclear Safety and Radioactive Pollution Remedy*, in which it was required that the nuclear safety culture should be cultivated and maintain in high level by the combinative effort of political, management and working level both in the nuclear industry and the regulatory authority, and the evaluation system of nuclear safety culture should be developed [3].

The NNSA established its ideology for nuclear safety regulation based on its nuclear safety culture: Independence, Openness, Legitimacy, Rationality, Effectiveness. With the issuing of the *Regulations on the Safety Regulation for Civilian Nuclear Safety Equipment by the State Council*, the NNSA take the nuclear safety equipment vendor into the scope of nuclear safety regulation. As the vendor became licensee, the nuclear safety culture was introduced to the area of component manufacturers. By the education of nuclear safety culture, the vendor in China realized meaning of their products on the nuclear safety and endeavored to assure the quality of their production.

The industry conducted the self-assessment for nuclear safety culture to identify the short board of the barrel in their safety management system. The CNNC organized specialized review teams to conduct the self-evaluation and self-assessment for their affiliated operator, using the model of WANO [4], with the standard evaluation process of the IAEA. The CGN develop their safety culture self-evaluation guideline in 2013, in reference with the 10 traits of a healthy nuclear safety culture of INPO [5].

2.3. Phase 3: Rapid developing (2014 – now)

This phase symbolized by the China President XI's announcement for the Chinese Nuclear Safety View in the Nuclear Security Summit in Hague in the March 2014. He stated that China will "foster and develop a nuclear safety (security) culture". Encouraged by the opinion of top political leader, the safety culture was strongly promoted by not only the government departments and industries, but also the society.

The NNSA conducted series activities such as publish policy and organizing specialized action to promote the nuclear safety culture in the whole industry. By the supervision on safety of radioactive source utility, the NNSA extended the coverage of nuclear safety culture into that area.

After the long-term exploration and practices, the Chinese industry took effort to develop a set of safety culture that not only in line with the international practice but also fit for the Chinese special conditions. The safety culture was effective for improving the safety performance of the nuclear industry.

The China Nuclear Energy Association (CNEA) deeply involved into the promotion of nuclear safety culture and played unique role for coordinating activities, such as organizing academic communication, technology cooperating, training course conducting, and information distributing.

3. THE ACHIEVEMENT OF THE SAFETY CULTURE CONSTRUCTION

The fruitful results and beneficial experiences were gained through the practice of the 30 years in China.

3.1. Government

3.1.1. The Chinese Nuclear Security View

The Chinese Nuclear View announced by President XI on the 3rd Nuclear Security Summit in Hague in March 2014 became the highest level instruction for the nuclear safety oversight. The nuclear safety was listed as one part of the state security in April 2014 in the 1st Sate Security Commission Meeting.

The position of the top level of the nation made the nuclear safety one of the most important issues of the national political decision. Driven by the impetus from the political level, the nuclear safety regulation framework is consolidated and complemented. The 12th congress absorbed the Nuclear Safety Act in its legislative plan. The government departments allocated more resources for the nuclear safety regulation. The construction of Technical Center of Nuclear and Radiation Safety Supervision was approved by the government, in which 0.145 km^2 earth was allocated, 93,000 m^2 building was planned, and the 115,000,000 USD was to be invested.

3.1.2. The Publication of Policy Declaration for the Nuclear Safety Culture

The Policy Declaration of the Safety Culture [6] was published by the NNSA together with NEA (National Energy Administration) and CAEA (China Atomic Energy Agency). As the first declaration for the nuclear safety culture, it announced the basis position of government regarding the nuclear safety and nuclear safety culture, with the following innovations:

- Giving a nuclear culture definition in Chinese style basing on the international common recognition.
- Giving 8 principles for the construction of nuclear safety culture, each of which can be used as the traits of a good nuclear safety culture.
- Giving the responsibilities of the government, operating organization, and the personnel for nuclear safety construction separately.

3.1.3. The Specialized Action for Nuclear Safety Promotion

In the first half of the 2014, several events happened in the industry, some cases were serious and unbearable for the regulatory authority, for example, The DEC (Donfang heavy machinery) conduct welding operation by violating the procedure and forged the record and lie to the inspectors. The NNSA believed that the nuclear safety culture in this organization was inadequate that the quality of their product could not be trust any more.

As one of the countermeasures, the NNSA launched a large scale action – The Specialty Action of Nuclear Safety Promotion, with the object of “eradicating the operation that violates the procedure, eradicating the forging and lying”, by education program “covered the every key position in the each licensee”.

Form the September 2014 to the August 2015, totally 19,000 people are trained directly by the NNSA and its regional office, 500,000 people are trained by different local environmental authorities. During this process, more than 2,000 potential risk sources are found and eliminated. The licensee’s general understanding and acknowledgement on the nuclear safety were improved greatly in this process.

3.2. Industry

3.2.1. The CNNC

The CNNC developed a nuclear culture evaluation system based on not only the international industry practice but also the Chinese culture elements. They used 8 simple Chinese characters to symbolize the 8 traits for the 8 principles for good nuclear safety culture: *Me, Doubt, Lead, Confidence, Safe, Nuclear, Constant, Learn,* in English separately. In 2015, the CNNC added 2 Chinese characters – *Fluent* for communicating and *Peace* for the concord with the public – by renewing with the publication of Declaration of Nuclear Safety Culture. These Chinese characters are easy to be recognized and understood by the workers, and it is very attractive for eyes when they were hanged on the wall as slogan. To translate the abstract concept of nuclear safety culture into the simple character is considered to be a good method for the localization international conception.

3.2.2. The CGN

The CGN has established a mature nuclear safety culture which has the following characteristics:

- Built up the safety management system that takes the nuclear safety as the core object.
- To take each individual as the last safety barrier.
- Highly transparency for the information to encourage error correcting and experiences feedback.
- To encourage the staffs finding and reporting deficiencies and problems.

A good nuclear safety culture are maintained by the effective running of the inner safety supervision system, which are authorized to conduct inspection, making safety decision in case of emergency, censoring the implementation of PQOM, conducting the nuclear safety culture evaluation [7].

3.2.3. The SNPTC (State Nuclear Power Technology Co.)

The SNPTC notified the importance of the policy on the cultivation of the nuclear safety culture. They issued the policy document *Five Years Planning of the Nuclear Safety Culture Construction* in 2013, in which the object and main task of nuclear safety culture construction were integrated, to illustrate clearly its position on nuclear safety culture.

The SNPTC are practicing a "3C" organization culture in which the basic idea of nuclear safety culture was embedded. The first "C" is "core", which means the core activity is nuclear power and nuclear safety is its core value; the second "C" is cooperation, which means the member of the organization should be coordinate for the same objective and gained the maximum produce; the third "C" is concord, which means that the a harmony atmosphere exits in the organization, and the organization should be harmonized with the community.

4. THE DEVELOPMENT OF NUCLEAR SAFETY CULTURE IN THE FUTURE

Facing the rapid development and the pressure of keeping nuclear safety, the NNSA is endeavored to promote the nuclear safety culture continuously in the future.

4.1. Developing nuclear safety evaluation and assessment system

In order to promote nuclear safety culture in a scientific and efficient way, the NNSA is devoting to developing a set of nuclear safety culture evaluation and assessment system for nuclear power plant, based on the 8 principles in the Declaration. The system is composed of 8 traits and 36 attributes, they are:

A. *Policy levels demonstrate nuclear safety concept and commitment to safety.*

A1. Commitment for the priority of safety.
A2. Safety first in decision making.
A3. Authorization for operation by the policy level.
A4. Allocation adequate resources for safety management.

B. *Management levels demonstrate the good example with correct attitude to safety.*

B1. The Managers acts as good examples.
B2. The safety responsibility was clarified by managers.
B3. Resources allocation based on the safety importance.
B4. Insisting on inspecting.
B5. Conservative decision making.

C. *All individuals plays indispensable role to safety and personally responsible.*

C1. Respecting and following for the rules.
C2. Following the procedures and instructions.
C3. Knowing for the responsibilities.
C4. Team cooperation.

D. *Organizational and constant learning is embraced.*

D1. Systematic training.
D2. Evaluating and improvement.
D3. Comparison with good examples.
D4. Atmosphere of learning.

E. *Complete and effective management system is established.*

E1. Clear organization structure.
E2. Adequate recourse for safety keeping.
E3. Process control.
E4. Deficiency distinguishing.

F. *Proper working climate is created.*

F1. appropriate workload with adequate facilities and tools.
F2. Fare personnel promotion arrangement.
F3. Fluent communication.
F4. Resolving confliction.
F5. Atmosphere for trust.

G. *Mechanism of questioning, reporting and experience feedback to safety issues is established.*

G1. The understanding for the nuclear safety.
G2. Encouraging for questioning.
G3. Atmosphere for concerning safety.
G4. Responding for safety report.
G5. Experience feedback.
G6. Prevention of human error.

H. *Harmonious public relation is created.*

H1. Understanding the appeal of public.
H2. Public communication.
H3. Public relationship.
H4. Bearing the society responsibility of the nuclear industry.

4.2. Systematically promoting the nuclear safety culture

The NNSA is developing a new plan for further more promote the nuclear safety culture. The NNSA will take effort to consolidate its internal nuclear safety culture, by modified and optimize the working procedure which takes the nuclear safety culture as the core value, appointing nuclear safety coordinator in each substantial organization for information sharing, cooperation organizing, and special programs implementation. The NNSA will insistently promote the nuclear safety culture in the industry, by intensifying the inspection on the licensee for their nuclear safety culture construction and cultivation, by conducting the evaluation and assessment for the nuclear safety culture of the licensee to finding out the deficiency exiting in the peoples mind and value, and by establishing the demonstration bases of nuclear safety culture study and development.

5. CONCLUSION

The nuclear safety culture should be emphasized in all the session by all the participants, because it is a determined factor that functioned by effecting the people’s behavior mode to effect the safety of nuclear installations and nuclear activities. The construction and cultivation of nuclear safety culture need the consistent effort of all stakeholders including the government and industry. The impetus of the government might become the main driven force for the country in which the skill of workers is not fit for its ambitious nuclear power development plan. The government of China will continuously take effort to push forward the nuclear safety culture localization to make it more adaptable to Chinese people, and share experiences with the international society to promote the global nuclear safety.

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