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Institutional Strength in Depth in the Nuclear Industry to Sustain Operational Excellence

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INSTITUTIONAL STRENGTH IN DEPTH IN THE NUCLEAR INDUSTRY TO SUSTAIN OPERATIONAL EXCELLENCE

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

This publication discusses institutional strength in depth introduced after the accident at the Fukushima Daiichi nuclear power plant. Following the accident, a tremendous amount of effort was exerted to further enhance the safety of nuclear power plants, particularly in technical and engineering areas. It was recognized that a more comprehensive approach to sustaining operational excellence was needed — one that could further minimize the risk to people, the environment and the nuclear owner/operator organizations by focusing on human and organizational aspects of the accident at the Fukushima Daiichi nuclear power plant and collectively incorporating them into the management systems of owner/operator organizations of nuclear power plants.

This publication is intended to provide the nuclear industry with information that supports the development of institutional strength in depth. It is meant to support the strategic actions that better ensure nuclear safety and the continuous achievement of performance excellence. The publication discusses the key attributes that contribute to strengthening each of the respective areas in the industry that relate to institutional strength in depth. It also describes how to effectively achieve institutional strength in depth through the systemic interface of organizations in the nuclear sector.

The IAEA officers responsible for this publication were A. Kawano and L. Lande of the Division of Nuclear Power.

CONTENT

1. INTRODUCTION

1.1. BACKGROUND

Following the Fukushima Daiichi Accident, a tremendous amount of work was undertaken to learn the lessons and take necessary actions to improve nuclear safety. Action plans were developed and implemented by operators, vendors, designers, suppliers, regulators, government, national and international organizations, and other stakeholders. This work often focused on the technical and engineering aspects of the accident which has resulted in a rigorous and comprehensive revision and enhancement of the associated international safety standards.

The reports from the Fukushima Daiichi Accident, including The IAEA Director General report on the Fukushima Daiichi Accident [1], also highlighted that there were significant human and organizational factors which contributed to the accident. The deficiencies within the institutional systems and governance were specifically highlighted as a major gap. Therefore, the International Nuclear Safety Group (INSAG) explored applying the defence in depth concept that had been and continues to be successfully applied within an engineering context to the wider nuclear safety system framework. The output from this work is reported in INSAG-27 [2].

Applying the institutional strength in depth (ISiD) concept to the nuclear safety system leads to the identification of three institutional sub-systems to prevent a nuclear accident from happening namely the nuclear industry, the nuclear regulators, and the wider external stakeholders. To ensure ISiD all three need to function and interact effectively i.e., the systems, associated functions, and channels of communication.

The primary responsibility for safety rests with the owner/operating organizations of nuclear power plants (NPPs). The purpose of this publication is intended to further explore the key attributes of ISiD in owner/operating organizations of NPPs and how to foster effective relationship with the regulator and other key stakeholders to achieve the wider ISiD.

Improving the ISiD both within and beyond owner/operating organizations of NPPs has also been recognized as one of the most significant areas to be improved for the nuclear industry to sustain operational excellence and is discussed in the IAEA NE Series Guide *Sustaining Operational Excellence at Nuclear Power Plants - Principles and Challenges* [3].

1.2. OBJECTIVE

The objective of this publication is to provide senior managers and leaders of the nuclear industry with information that supports their efforts to improve safety and to sustain operational excellence by fostering ISiD in the whole nuclear system[2]. It describes the key attributes of ISiD in owner/operating organizations of NPPs and how to effectively manage external interfaces with the regulatory body and with other stakeholders by providing suggestions to

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[2] For the purposes of this publication, the term “nuclear system” comprises the human, technical and organizational sub-systems that operate both independently and co-dependently within it, and within and across all NPP owner/operating facilities and organizations, their regulatory and oversight bodies, and all manner of stakeholders.

identify gaps and to develop specific actions/initiatives for continuous improvement. It also provides good practices from within and outside of the nuclear industry.

1.3. SCOPE

This publication sets the stage to explain ISiD and how it can be developed, with an exploration and review of the Fukushima Daiichi Accident and considerations on the challenges and opportunities in the nuclear sector. It discusses specific initiatives and actions of NPP owner/operating and other associated nuclear industry organizations to further enhance safety and sustain operational excellence, including management system, leadership, independent oversight, technical competence, decision making, resilience and operational risk management. It also discusses effective interfaces between industry, regulator and other associated stakeholders.

This publication is intended for senior managers and leaders of NPP owner/operating organizations. It is also intended for other associated stakeholders such as manufacturers, vendors, contractors, and national and international industry organizations. It is also valuable information for government organizations and the regulatory bodies.

This publication can be applied for organizations operating other nuclear facilities and installations like waste storage and fuel processing plants.

1.4. STRUCTURE

This publication is comprised of six sections.

Section 1 sets out the need for the publication i.e., why the publication has been produced, the objective and hence the purpose of the publication, sets the bounds of the publication, the users and how it has been structured to allow ease of use.

Section 2 identifies the human, organizational and cultural learnings associated with the Fukushima Daiichi Accident and why it is necessary for all senior managers and leaders to consider the lessons learnt from this accident.

Section 3 provides the key attributes of ISiD in owner/operating organizations of NPPs. This starts in Section 3.1 with the management system, which sets out the important factors to consider in defining how the organization functions. Section 3.2 explores the key elements required from the leadership team to ensure the organization is driven (See Fig. 1) effectively. The importance and key attributes in managing risk is discussed in Section 3.3. thereby providing the effective dashboard for where attention should be focused. The attributes that lie at the heart of the organizational engine (See Fig. 1) are explored further in Sections 3.4 to 3.6. i.e., effective decision making, resilience and competence management. In Section 3.7 the importance of having an independent oversight organization is discussed to provide the necessary feedback and challenge.

Section 4 looks at the broader nuclear system and presents ideas on how to foster effective relationships and trust with key stakeholders to achieve effective ISiD.

Section 5 looks both inside and outside of the nuclear industry to view the lessons learnt from good practices.

Section 6 summarizes and concludes the publication.

Examples of established and enhanced institutional strength in depth are provided in the appendices.

The structure and flow of the publication is also shown in Fig. 1.

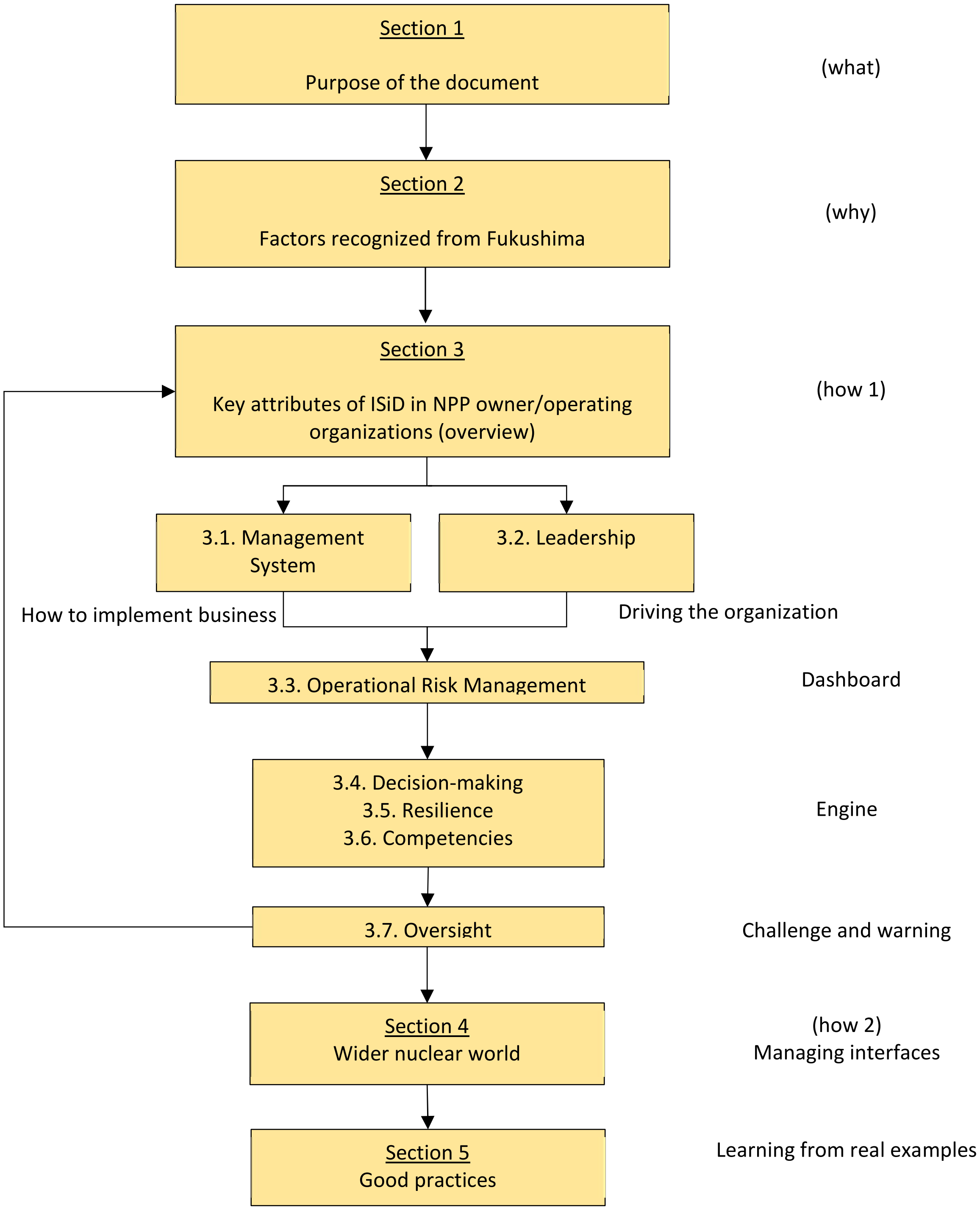

FIG. 1. Structure and flow of the publication.

2. HUMAN AND ORGANIZATIONAL FACTORS RECOGNIZED IN THE FUKUSHIMA DAIICHI ACCIDENT

The robustness of the technical nuclear safety system and its formalization such as accident management procedures and provision, international standards, regulations and management system for beyond design basis accident (DBA) have evolved significantly for the last 50 years.

Safety, as it relates to human and organizational factors, has developed in the shadow of the technical side of safety. For example, the Kemeny report [4] after the TMI (Three Mile Island) accident had said, "No amount of technical fixes will cure this underlying (attitude) problem". After the Chernobyl event, the INSAG-4 Report [2] recommended that organizations address safety culture through desired attitudes and practices of management. Despite all of these efforts, the focus has remained almost exclusively on technology.

The IAEA Director General report on the Fukushima Daiichi Accident [1], specifically Section 2.6 in Technical Volume 2, highlights the organizational and human aspects and discusses lessons as follows:

> "Individuals and organizations need to consciously and continuously question their own basic assumption and their implications on actions that impact nuclear safety.
>
> Nuclear organizations need to critically review their approaches to emergency drills and exercises to ensure that they take due account of harsh complex conditions and unexpected situations.
>
> A systemic approach[3] to safety needs to be taken in event and accident analysis, considering all stakeholders and their interactions over time.
>
> Licensees, regulators and governments need to conduct a transparent and informed dialogue with the public on an ongoing basis".

The most essential lesson learned from this report is that the nuclear industry and its stakeholders benefit from continuously learning from, fully understanding, and actively strengthening the human and organizational factors that contribute to ISiD and ultimately the safe, secure, and excellent performance of NPPs.

Tokyo Electric Power Company (TEPCO)'s Nuclear Safety Reform Plan (March 2013) [5] discusses technical issues that led to the accident but also elaborates in depth: a) on human and organizational issues in the background of these technical issues and lack of preparedness to extreme external events; and b) on necessary institutional reform including internal oversight and advice from outside. .

Institute of Nuclear Power Operations (INPO)'s Fukushima Daiichi lessons learned report [6] also discusses in depth the human, organizational and cultural aspect.

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[3] The systemic approach to safety addresses the whole system by considering the dynamic interactions within and among all relevant factors of the system — individual factors (e.g. knowledge, thoughts, decisions, actions), technical factors (e.g. technology, tools, equipment), and organizational factors (e.g. management system, organizational structure, governance, resources).

Below are listed some specific examples which highlight the human, organizational and cultural learnings associated with the Fukushima Daiichi Accident. All of these are further analysed and discussed with suggested actions in Section 3:

- High priority was placed on economics and decision and actions for safety improvement were delayed when cost and possible interruption of operation by modification work were significant [5, 7];
- The decision-making approach did not provide for independent challenge or second checks by other groups within the organization as was seen at the site emergency response centre the decisions to stop unit 1 isolation condensers, to stop unit 3 high pressure core injection pump [6]. There was limited scrutiny from the corporate level, the nuclear division of Japanese utilities, and other nuclear experts.;
- No independent oversight nor external advisory group on nuclear safety has ever been installed in TEPCO [5]. Regulatory body oversight did not function well [1];
- Nurturing questioning attitude and raising concern was not part of training [6];
- Reduced sense of ownership for resolving potential nuclear safety issues in a timely manner [6];
- TEPCO had multiple unit installation for its three nuclear plant sites and the number of staffe was significantly low as compared with global standards (e.g. IAEA TECDOC-1052 [8]), presumably due to size effect and heavy outsourcing to Contractors and Sub-contractors for practical works. There is a concern that his heavy outsourcing, generally speaking, tends to lead to reduced level of ownership, governance[4] and technical competence, sense of responsibility, design knowledge training, and risk management capability;
- Limited risk communication with the public [1, 5];
- Japanese NPPs are known for heavy preventative maintenance by thinking component reliability assures not only high availability but also safety, which led to over-confidence on safety as basic assumption [1] and weakness as a learning organization. Examples include gaps from IAEA standards and Boiling Water Reactor Owners Group (BWR-OG) standard procedures, and weak learning from operating experience [6];
- There has been observed 'group think' or accepting unverified assumptions when making decisions [6];
- Risk-related decision-making: Most of the probabilistic safety assessment (PSA) in TEPCO was outsourced to the original supplier of the plant and there was limited risk analysis by its affiliate. TEPCO's management failed to add tsunami to risk matrix because of uncertainties over assumptions and methodology [6]. Attention in PSA to extreme external events was limited [1] and consideration to cliff-edge effect (item 5.73. in Ref.[9]) was not given even though TEPCO completed tsunami PSA [10] and possibility of 15.7m tsunami height was calculated in a hypothetical calculation [11], both before the accident. No consideration of multiple unit accident possible by extreme external event due to common cause failure was given in PSA;
- Due to lack of regulatory framework for uprating and upgrading plant safety in relation to the characteristics of the site, the Fukushima Daiichi NPP's site related characteristics (external events and environmental issues) were not reassessed in a systematic and comprehensive manner [1];

[4] WANO (World Association of Nuclear Operators), as Industry's watchdog, allowed autonomy of regional centre, which resulted in lack of attention to governance issue. This issue was addressed, and WANO had changed review system in the aftermath of the accident including addition of corporate function review.

- Limited training, for example, on how to manually operate systems such as the unit 1 isolation condenser and fire trucks as an alternative source for low pressure water injection [1];
- During the course of accident, cases of confusion of role and responsibility including the prime minister. Leadership was not clear [3].

Although most post-Fukushima lessons learned reports looked at what went wrong, it is inappropriate not to look at what went right [12]. This applies to human and organizational aspects as well. TEPCO's Accident Analysis Report raised team efforts [11] and willingness to sacrifice. Contractors and sub-contractors were willing to support TEPCO at the time of accident, despite no contract beforehand. On the part of design, there were continued efforts to reassess design basis external events based on new findings and modify, including seismic design and tsunami.

It would be worth to look at units 5 and 6 at Fukushima Daiichi nuclear power station and four units at Fukushima Daini nuclear power station (Appendix I), all of which had escaped core damage, the former due to limited damage from tsunami and availability of power from air-cooled emergency diesel generator (EDG) and accident management provisions, and the latter from various factors including availability of one off-site alternating current (AC) power line, leadership of site manager [13] to follow the accident management procedures and, to procure and install necessary equipment for recovery of safety functions.

3. KEY ATTRIBUTES OF INSTITUTIONAL STRENGTH IN DEPTH IN NPP OWNER/OPERATING ORGANIZATIONS

As recognized in Ref. [2], there are three institutional sub-systems that serve to ensure safety i.e. a strong industry, a strong regulator and a strong set of stakeholders. To ensure institutional strength in depth all three need to function effectively as a whole i.e., the systems, associated functions and channels of interaction.

In Section 2 the human and organizational factors which contributed to the Fukushima Daiichi Accident were identified. These highlighted the negative spiral associated with the functioning and governance of the TEPCO organization which in turn led to deficiencies in safety awareness, engineering and technical capability and communication capability [5]. This combined with gaps in the institutional strength in depth in the regulators and wider stakeholder framework resulted in the overall safety system being ineffective.

Discussed in this section are the key attributes that need to be in place within the nuclear industry to provide the necessary institutional defence in depth. This includes the need to ensure there is a strong mutually reinforcing interface with the regulator and other stakeholders. The key attributes associated with the other institutional sub-systems are discussed further in Section 4.

The foundation of all high performing NPP owner/operating organizations is the effective implementation of a clearly defined management system with a well embedded healthy nuclear safety culture and effective nuclear leadership. This is simply represented in Fig. 2.

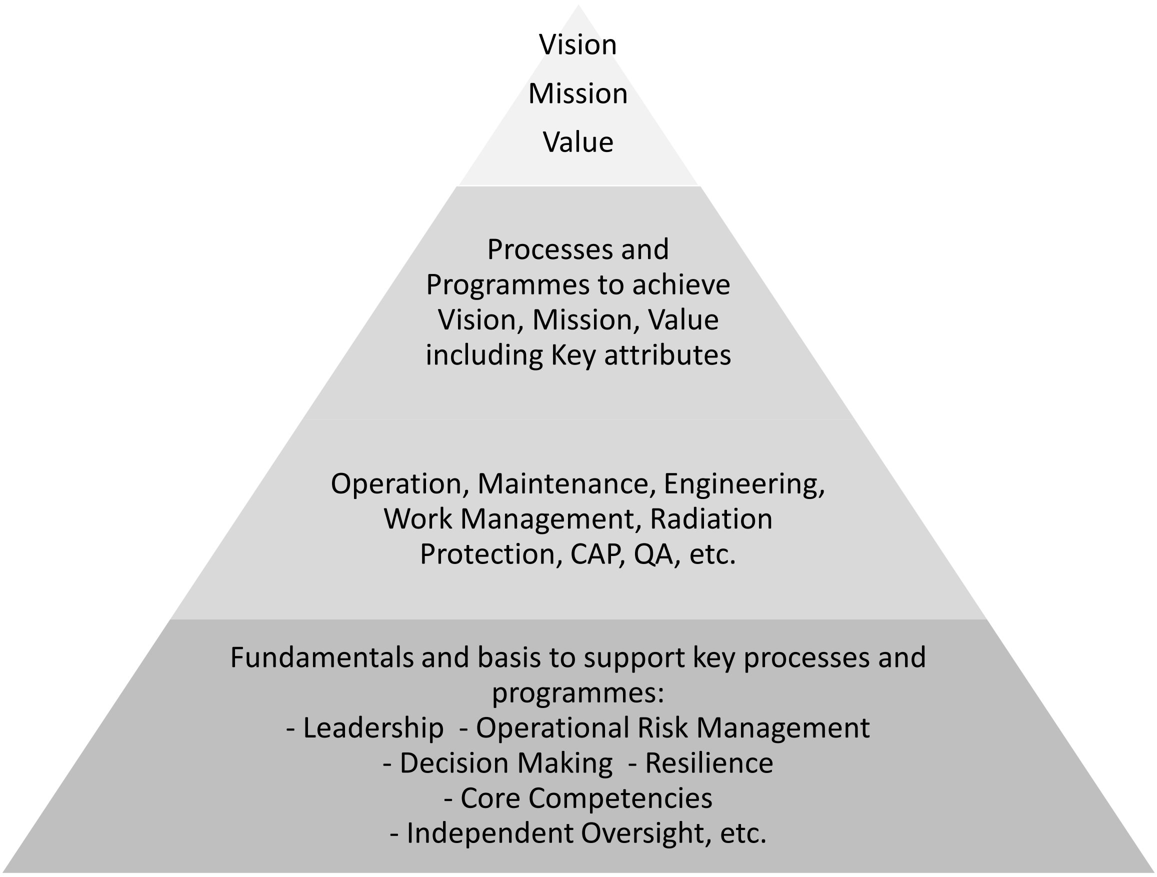

FIG. 2. Clearly Defined Management System

Effective governance i.e., implementation of these fundamentals is essential to protect NPP owner/operating organizations against the significant internal and external challenges and changes, which will inevitably arise throughout the operational lifetimes of the nuclear assets.

The learning from the Fukushima Daiichi Accident highlights the importance of constantly assessing and challenging the key attributes that make a NPP owner/operating organization strong, i.e.:

- Management system;
- Strong leadership;
- Operational risk management;
- Decision-making;
- Resilience;
- Core competencies;
- Effective independent oversight.

Each of these key attributes are discussed further in the following sub-sections with the aim of identifying actions that can be taken to build institutional strength in depth to ensure nuclear safety and continuously achieve excellent performance.

3.1. MANAGEMENT SYSTEM

Organizations operate in accordance with their management systems. The management system defines the way the organization functions, behaves, makes its decisions, and executes its core, supporting and management processes. The rigorous development, clear communication and effective deployment of the management system has been proven to be a key success factor in all high performing NPP owner/operating organizations.

Factors to consider in the design and development of an optimized management system for a NPP owner/operating organization, keeping the end-user in mind, include:

- Ensuring the plant is operated in a safe manner in compliance with regulatory requirements;
- Demonstrating clear links from the high-level policies and processes through to the working level documents (golden thread);
- Enabling relevant information to flow up through the organization;
- Clearly defining the roles, responsibilities and authorities (including legal and regulatory);
- Clearly demonstrating how the key activities are managed, performed and assessed;
- Illustrating how the organization is governed and describe how functional responsibilities, levels of authority and interfaces between different groups are controlled and managed such that the overall objectives are achieved in a safe, efficient and effective manner;
- Supporting an environment where organizational barriers are removed, and people are working together to achieve the desired results;
- Clearly describing the interfaces with regulator and other key stakeholders and the way these interactions be conducted to ensure alignment.

The management system is a living system which integrates the external and internal drivers (political, social, economic, legal and environmental) and provides clarity of purpose at all levels of the organization.

It encompasses governance arrangements by which an organization is controlled and operates, and the ways by which it, and its people are held accountable. For a NPP owner/operating organization as well as the normal corporate responsibilities there is an overriding priority to ensure there are arrangements in place to ensure effective governance of nuclear safety and performance. This includes:

- Establishment of the organizations nuclear safety, security, industrial safety and environmental protection policies, in order to comply with legal, regulatory and best practice requirements and to monitor performance against these;
- The setting of nuclear safety and operational strategy, mandates and targets and monitoring performance against these;
- Assuring continuous review of safety, operations and business e.g.:

  - Resources skills and capability including technical competence (See Section 3.6);
  - Organizational resilience (See Section 3.5);
  - Effectiveness of processes and procedures;
  - Management of change;

- Ensuring robust oversight and independent oversight arrangements are in place and effectively functioning which also include external inputs (See Section 3.7). Examples include:

  - Independent nuclear oversight organization to independently monitor and inspect and assess nuclear safety performance and report directly to the board;
  - Independent reviews (IAEA OSART missions, WANO peer reviews etc.);
  - Nuclear safety committee with independent membership of senior nuclear experts to review and advise on significant modification, safety case and change programmes;
  - Training standards and accreditation boards with independent external membership to review, assess and accredit the nuclear safety significant training programmes;
  - Nuclear safety review boards in which external industry experts review the nuclear operational performance of the organization and report finding directly to the board;

- Ensuring the effective functioning of the risk management system (See Section 3.3);
- Confirmation that decisions are effectively being made and acted upon at the right level of the organization (See Section 3.4);
- Safe call arrangements to enable anonymous whistleblowing of safety concerns.

The management system should also cover interaction/liaison with regulatory body and interfaces with all other nuclear industry entities associated with the safety of the plant, including vendors, contractors and suppliers to ensure that safety and processes are consistently and effectively applied throughout i.e., the licensee is an informed customer and vulnerabilities/disconnects do not occur within the wider supply chain/support infrastructure.

Organizations with informal/less well-structured, or poorly maintained management systems, are highly dependent upon the leadership at a current point in time. They can be vulnerable to drift in the ways of working and poor communication between function (organizational drift and silo working). This results in significant disconnects within the organization and with the wider support infrastructure and therefore a weakening of intuitional strength over time or during periods of high levels of change. These vulnerabilities also exist if there are weaknesses within any of the three subsystems (industry, regulator and stakeholders) or in the interfaces between the subsystems. The investigation into the Fukushima Daiichi Accident highlighted there were weaknesses in all parts of the nuclear safety management system and between the constituent sub-systems.

The main suggestions on management system in terms of institutional strength in depth are:

- The management system including governance arrangements need to enable a holistic view of the performance of theNPP owner/operating organization to be undertaken. There needs to be alignment of the governance arrangements within the NPP owner/operating organization between corporate and the operational units and between the NPP owner/operating organization and the wider supply chain/support infrastructure. The discontinuities in the management systems resulted in separate working and significant risks not being identified or ineffectively acted upon;
- The management system including governance arrangements need to describe the interface with the regulatory organization and stakeholder organizations. This will enable the health of the relationship to be effectively monitored and actions placed in the event of any divergence. (See details in Section 4).

3.2. STRONG LEADERSHIP

Leadership is the backbone of the nuclear enterprise, bolstered and complemented by its management system and the remaining attributes contributing to ISiD. Nuclear operational excellence is achieved by ensuring the existence of a healthy safety and organizational culture, by maintaining strength in depth of their organization and continuously driving for excellence in performance. The full extent of the challenge to achieving this goal becomes apparent when:

- The full lifecycle of the assets is considered (i.e., when design, construction, operations and decommissioning are taken into account the operational lifecycle of a nuclear asset can easily exceed 100 years); and
- The increasing rate of change of the external environment is considered.

The leaders' role throughout is to provide a clarity of purpose to both preserve the core nuclear safety attributes whilst effectively responding to the external challenges i.e., political, economic, social, technical, social, environmental, and legal changes which the organization will inevitably face.

Central to any organization operating in a high hazard environment is the need to create a culture which fosters behaviours which enhance safety. In the nuclear industry safety culture has been a central topic since the concept was coined in 1986 after the Chernobyl nuclear accident. Significant work has been undertaken by international organizations to define and describe the core attributes and traits of a healthy safety culture [14–19].

This publication will not expand beyond these attributes and traits, other than to recognize that they sit at the core of all nuclear industry organizations. Performance against these traits needs to be constantly reviewed and this can be achieved by self-assessment or through an independent assessment conducted by an external party. IAEA is offering the service of both independent safety culture assessment (ISCA) as well as training on how to perform safety culture self-assessments (SCSA) [20].

Leaders are also responsible for creating an environment where all workers are encouraged to share ideas, recommendations, and concerns without fear of retribution. This type of relationship is fundamental for institutional strength in depth within the organization, and between and across all three sub-systems. The more an organization shares without fear, the more trusting and better performing the organization will be.

Commonly applied approaches to improve safety and organizational culture include proactively monitoring and remaining vigilant for signs of cultural decline. A variety of cultural assessments, carried out every 3-4 years, is common practice. Leaders are trained to improve their awareness of signs and symptoms of a weakening or unhealthy culture that can jeopardize safe performance. Different hands-on tools are used to proactively foster healthy culture for safety. Examples are humble inquiry, listening levels, surfacing assumptions, reflecting teams.

Seven main suggestions for evolving a vibrant leadership and culture for safety while strengthening the institutional defence in depth are:

- Drive for results - set clear expectations, focus on impact, rigorously seek to close gaps in excellence, resolve issues and take action at the right level of the organisation and follow through to closure;
- Be humble - egocentric behaviours and myopia prevents learning; be open to alternative views, perspectives and the unexpected; learn from others internally and externally to grow the competence needed for safe operations;
- Learn continuously - seek to find new insights, views, and information that extends learning; implement and capture this knowledge in the management system; since nuclear facilities have operated over several decades, it is essential to accumulate and maintain this knowledge in a corporate memory; incorporate the lessons learnt into processes, procedures and policies, etc.;
- Demonstrate personal and collective responsibility – Ensuring a sense of value and purpose, individual and collective, for all in the workforce fosters integrity, accountability, alignment, and a willingness to raise concerns;
- Nurture open inclusive and collaborative relationships - continuously enhance the shared space to ensure inclusion; build trust-based relationships and break down silos to foster partnerships and cross functional collaboration; solicit and welcome different perspectives; seek and be open to feedback and respond with appreciation for the opportunity to reflect and learn;
- Encourage engaged thinking to inspire others - ask open ended questions, use questions to ignite thinking and encourage participation; provide positive reinforcement for others' contributions; highlight strengths to foster potential; keep messages and tasks as simple as possible in order to support understanding and accurate follow through;
- Senior leaders and managers should demonstrate the ability to manage risk, break down silos, build on strengths, and 'trust and verify' to ensure the effective functioning of the organization.

3.3. OPERATIONAL RISK MANAGEMENT

NPP owner/ operating organizations with a robust and resilient ISiD have a deep understanding of operational risks across all hazards and operating conditions. Companies with strength in ISiD have operational risk management (ORM) appropriately incorporated in all company organizations and at all organizational levels. For ISiD, ORM is specifically included in NPP station procedures, processes, required training, etc.

The items discussed in this section represent areas for management self-review to identify gaps and improvements relative procedures, processes, training, and decision making. Weaknesses in these areas contributed to TEPCO's decision making processes that created vulnerabilities in process and decision making to known external events. Organizational weaknesses were also seen in preventive/mitigative measures as well as design and operational decision making that significantly precluded the station's ability to respond to a severe external event, prevent core damage, and subsequent radiological release.

For the purposes of this report, ISiD is focused on nuclear safety but also imply that in general the enterprise level risk needs to be managed. Operational events that result in business interruptions (e.g., involuntary plant trips) or other adverse economic impacts are also important elements of comprehensive operational risk management programs. Enterprise risks include many other types of events that, although do not represent public health and safety threats, can result in significant economic consequences (e.g., involuntary extended plant outage). This is further discussed later in this section.

3.3.1. Organizational concepts for operational risk management programs

Nuclear industry leaders and leaders of regulators have the responsibility to ensure that organizational provisions are in place to address and manage hazard sources commensurate with their significance to safe, reliable plant operations. Nuclear safety analyses (deterministic safety assessment (DSA) and probabilistic safety assessment (PSA)) provide comprehensive coverage of entire spectrum of postulated initiating events and plant states. In this context, the PSA is a powerful tool which input could be effectively used for risk management and in general for risk-informed decision making. This operational risk management area also represents gaps as identified in Section 2 that existed at Fukushima and throughout the TEPCO organizational structure and can exist at other NPPs. It was also recognized that formal procedural controls, communication to site personnel, and situational awareness based on PSA insights were not required nor implemented.

3.3.2. Operational risk management structural framework

This section provides a discussion on organizational elements of ORM Programs necessary for effective NPP risk management. Figure 3 provides one of typical ORM programs and their elements. There can be different variations of where and in what form these elements exist in risk management programs of NPP owner/operating organizations, but all need to exist in some form in NPP procedures and/or processes. Operational risk management represents an essential organizational competency. Traditionally, it has been assumed by NPP companies that risk management concerns are primarily focused on design basis events and the capability to meet prescriptive design basis requirements; however, ORM extends beyond design basis to include additional events based on industry experience and PSA insights. The ORM elements described in this section represent potential organizational gaps based on the Fukushima experience that all NPP owner/operating organizations should internally evaluate.

Utilities incorporating and assigning ownership of these elements have the advantage of being capable of assessing internal and external risk levels from routine day-to-day station operations. The level of ORM detail and robustness vary from utility to utility, but in all ORM areas there should be emphasis on continuous improvement. Effective ORM programs enables NPPs to assess operational trends as it relates to risk contributors and other threats to safety levels and production. In organizations that use ISiD, the insights from active ORM programs are valued and used to provide organizational awareness, actions, and communications to improve risk awareness and overall station performance.

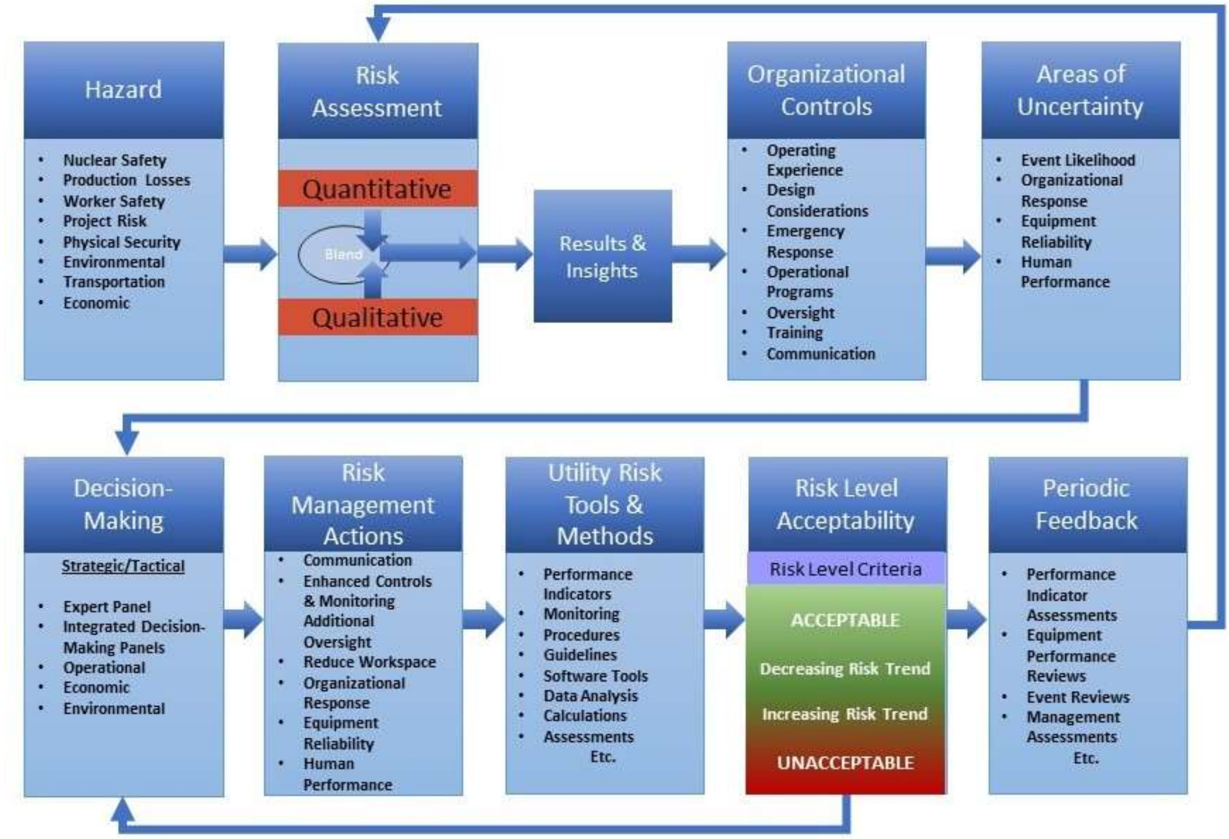

FIG. 3. Key Elements of Operational Risk Management Programs (courtesy of R. Grantom)

In the process flow above, hazards are identified, evaluated, and assessed through quantitative methods, qualitative methods, or a combination of both. The results of these various elements produce risk knowledge and insights that can be then transferred or communicated into organizational controls through existing facility programs and processes. A short description of each key element is provided below:

- Hazard - “The potential for harm or other detriment, especially for radiation risks; a factor or condition that might operate against safety.”, as defined in the IAEA Nuclear Safety and Security Glossary [21].
- Risk Assessment – the risk analysis tool that is used to assess the severity either qualitatively or quantitatively from which risk measurements are made (e.g., qualitative risk matrix, PSA). These tools are expected to meet industry standards, as applicable, and be under configuration control processes. NPP ownership and capability in using risk assessment tools (i.e., PSA) is an essential ORM element and core competency for organizational development.
- Results and Insights – Clearly defined figures-of-merit for nuclear safety (e.g., core damage frequency, large release frequency) are required to measure risk levels. All factors like results of deterministic safety assessments, operational experience information etc. are necessary to be taken into account for it as well. Other risk measures are developed for hazards that may not be associated with nuclear safety, such as worker safety, project risks, etc. Key organizational stakeholder acceptance or ‘buy-in’ to the risk measures are critical for ensuring decisions are technically based. Key stakeholder organizations include the NPP, regulatory authority, and others that may impose requirements on the NPP.

- Organizational Controls – this ORM step accounts for NPP company policy and other governance documents that have to be in effect to ensure procedural processes, roles, and responsibilities, and associated supporting organizational requirements (e.g., training) are in place and active in accordance with station processes and requirements.
- Areas of Uncertainty – These process steps enhance risk assessments to enable decision makers to become familiar with situations and their identified risk contributors and associated uncertainties. This could be the result of either previous operating experience or other feedback. Once uncertainties have been characterized, risk management actions serve to manage and mitigate risks. As an aid in discussing areas of high uncertainty, using a 'conditional probability' approach can help to provide the proper background and context for evaluating. For example, 'given a long-lasting station blackout event, what is the probability that a core damaging event will occur?'(See Section 3.4.3)
- Decision Making - ORM is a normal part of high-performing station decision making processes. This includes plant processes that support daily decisions for continued safe, reliable power production and for other decision-making processes such as long-range planning (e.g., outages, strategic initiatives). Some utilities implement special actions such as standing committees or multi-disciplinary committees specially trained in plant-specific risk insights.
- Risk Management Action - The Risk Management Actions (RMAs) are important ORM tools for ISiD. The identification and development of RMAs should be controlled by procedure and specifically identified as an RMA that will be applied to given situation. RMAs are documented actions intended to monitor, identify, and take action to minimize or eliminate contributors to adverse outcomes.
- Utility Risk Tools and Methods – There are risk management analysis tools available in the industry. These tools range from formal software to in-house evaluation tools. Benchmarking efforts can be used to identify best practices.
- Risk Level Acceptability - With the development and use of properly designed risk tools (e.g., risk monitors, periodic risk assessments, risk related performance indicators, etc.), it is possible for NPP management to establish risk acceptance criteria (e.g., acceptable, alert, required action level, unacceptable). A well performing ISiD organization creates a proper and safe environment for identification and escalation of issues based on risk acceptance criteria. The creation of a safe environment is essential to facilitate risk informed decision making. This represents an important capability of ISiD: the establishment of risk acceptance regions and associated thresholds. The risk acceptance criteria and associated thresholds thus create 'trigger points' for organizational execution of risk management actions or other organizational responses (i.e., management notifications such as 'margin management').
- Periodic Feedback - Periodic assessments and feedback processes allow the collection of operating experience (facility specific and industry specific) and lessons learned since the previous periodic assessment. In periodic self-assessments, other information can be collected and evaluated to provide data, recommendations, or other insights supporting improved corporate and facility-specific knowledge, and thus, providing continuous improvement in ORM.

3.3.3. Corporate enterprise risk perspectives

From a corporate enterprise risk perspective, ISiD needs to be developed throughout the organization both at headquarters and at each plant site. Since the corporation owns or is responsible for its individual assets, then they own the risk. In this regard, risk exists for all levels of a company organization including vendor and contractor organizations. Therefore, when discussing company enterprise level risk, the risks associated with hazard sources at each facility is identified, evaluated, and escalated, as necessary. It is important to understand what asset-specific hazards are being evaluated. It is more important to define responsibilities and magnitude of liabilities that could be imposed on the corporation should a consequential event occur.

Corporate headquarters can impose an enterprise risk management approach by developing and deploying ORM elements to each of its assets, as appropriate. In high-performing ISiD organizations, corporate headquarters generally apply an enterprise risk management approach. Figure 4 shows the concept of risk transfer from individual assets to the corporate level, as well as the imposition of corporate controls (i.e., performance indicators) to better ensure acceptable performance results are shown.

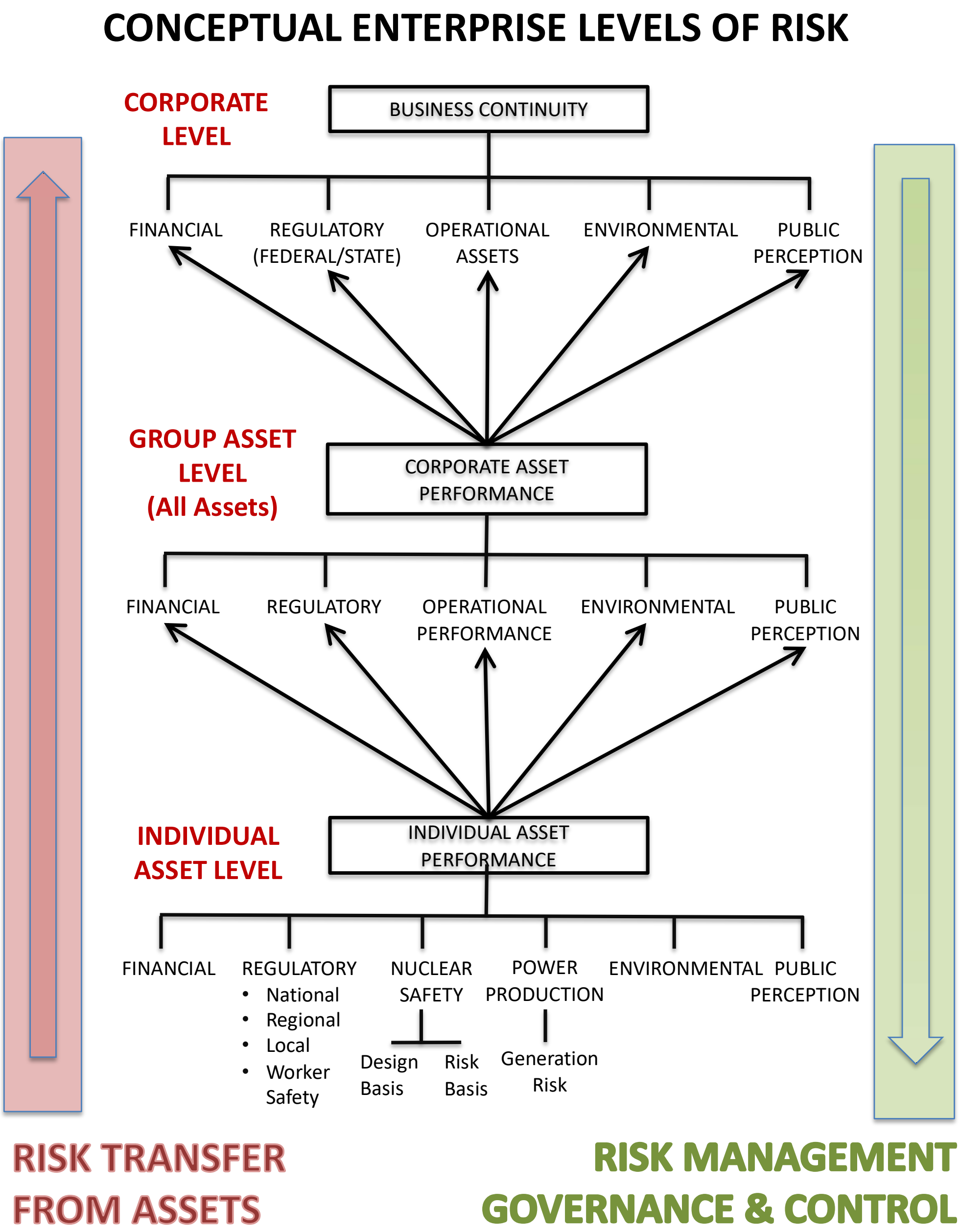

FIG. 4. Conceptual Enterprise Levels of Risk.
(courtesy of R. Grantom)

The discussion above is intended to emphasize the importance of understanding the relationship between corporate objectives, performance metrics, and risk metrics, as well as the understanding that facility risk hazards and consequences are ultimately transferred from different organizational levels to the corporate level. Thus, for robust ISiD, the management of risk at the corporate level involves monitoring performance and risks from the top level down to the individual assets (i.e., the NPPs).

Once the various risk sources have been evaluated and prioritized, then company resources can be focused on addressing the dominant risks. Companies can now have the capability to better identify underperforming areas, more closely monitor status and trends, and identify where specific improvements are needed. In so doing, the corporation increases the robustness of ISiD. In many cases, improvement areas will be associated with communication, procedures, processes, training.

The main suggestions on operational risk management in terms of institutional strength in depth are:

- Develop organizational core competencies in operational risk management and analysis. In-house risk management and analysis capability is required both at corporate and at the plant site. However, outside expertise may be used for special risk management work activities (e.g., seismic expertise);
- Establish formal PSA modeling and update processes to reflect the as-built, as-operated plant. This includes provisions to properly reflect actual plant processes that impact risk levels. For example, risk levels may increase due to changes in plant system/component configurations (e.g., planned maintenance);
- Ensure there is an approved process for implementing risk management actions or other risk mitigation compensatory actions;
- Develop strategic plans including budget requirements for formal periodic PSA updates to reflect the as-built, as-operated plant;
- Evaluate current corporate/plant procedures and processes for the incorporation of risk management elements and attributes consistent with the key elements of operational risk management shown in Fig. 3;
- Extend operational risk management processes to include enterprise risk management considerations as shown in Fig. 4.

3.4. DECISION-MAKING

Safety and performance of an NPP depends on sound decisions, be it about design, procedure, emergency action, etc. Examples of critical decisions pertaining to the Fukushima Daiichi Accident include locating the electrical equipment room and EDGs below the ground level, and stopping operation of the isolation condenser at Unit 1 etc.

3.4.1. Decision-making system

Below are key elements of a decision-making system:

- Who, what and how:
  - Before deliberation (*who and what*): define what needs to be decided, who should be involved in the decision-making process and the level at which the decision is to

be agreed. Graded approach is taken depending on the importance of the subject (what), in a way less important issues will be decided at a lower level;

– Process (*how*): define decision approach (top-down or bottom-up), establish the goal and weighted decision criteria, collect information, evaluate options, and recording;

- Clarity of responsibility and effectiveness of the decision:

  – Decisions need accompanying information on who is held responsible to take action to implement. This information needs to be clear and be notified to employees involved in implementation or affected by the decision. Effectiveness including practicality and risks in implementation needs to be a part of consideration before the decision is made;

- Building decision-making competency:

  – In a decision-making process, any organization, group or individual cannot escape the limitation of available experience and information (including those from external advisors, from cognitive bias (organizational and cultural), from time pressure, emotion, short-sightedness, various constraints (political, societal, financial) etc. Training in decision-making tools such as Delphi method (use of a panel of experts, who responds to several rounds of questionnaires, and the responses are aggregated and shared with the group after each round to reach conversion to the consensus view) for consensus building, of critical thinking, of tolerance/strength to listen to a variety of alternative views will support improvement of competency in this area. Further, decision analysis would assist competence building by use of an analytical method such as multi criteria decision analysis (MCDA): to include evaluation of multiple conflicting criteria);

- Value-impact aspect:

  – One of the important elements for consideration in decision-making is value vs. impact aspect, in which value is expected benefit such as risk reduction or performance improvement and impact is typically an investment to obtain the benefit or adverse effect such as on equipment availability, safety, etc. Value vs. impact covers wider issues than cost vs. benefit. For example, stopping operation of isotope production reactor [22] due to concern over safety (value in risk reduction) may contradict with shortage of supply of medical isotope (impact in overall health).

3.4.2. Consideration of diverse views

In a certain culture that place high value on harmony/consensus or on cohesiveness rather than independent critical thinking, there is a phenomenon that people prefer not to oppose majority view by setting aside own view.

In this groupthink, chances are lost to look at things with different perspectives and to reach elevated level in quality of decision through discussion [23]. Various case studies [24] show that a group consisting of different-minded people can avoid collective blindness and reach a better understanding (avoiding mistakes, reducing blind spots and adding alternative viewpoints), a better solution, and even ‘recombinant innovation’ than a group consisting of like-minded members. However, it has to be noted that, if diverse view is not presented, this cognitive diversity yields no result, which is often the case in a group with hierarchy dominance [24].

Recognition of this tendency of group think in an organization or a society or a region [25, 26] may help remove biases in decision-making. There are methods to avoid groupthink that can be institutionalized such as:

- Inviting external advisors for different perspective;
- Encouraging every participant to make critical review of the proposed options;
- Dividing a meeting to small groups to solicitate diverse views;
- Assignment of a 'devil's advocate' [27] who is supposed to raise incisive questions or provide an alternative view. Decision sheet records questions raised by 'devil's advocate' and related discussions before reaching a conclusion.

The organization, group or decision-maker needs strength to listen to alternative views with respect, which is important in case there is tendency to dominance hierarchy [24].

3.4.3. Risk-informed decision-making

IAEA safety standards encourage integrated application of both deterministic and probabilistic approaches for risk-informed decision-making. [9, 28] The framework of integrated risk-informed decision making is provided in Refs. [29] and [30]. This dual approach takes advantage of risk information and is because neither of them is complete. Risk-informed is different from risk-based, where risk-based approach is solely based on the results of a risk assessment, risk-informed approach considers other factors such as operating experiences and engineering judgement.

For robust safety decision, consideration needs to be given to aleatoric and epistemic uncertainties[5] inherent in risk information. Practically decision-makers may face a situation where uncertainty is significantly large such as in external events. Some approaches are taken in those cases such as inviting experts panel (such as SSHAC[6] [31] in earthquake), in an attempt to reach a consensus view, to reduce epistemic uncertainties caused by lack of knowledge or incomplete modelling. Adequate considerations to uncertainties, particularly assuring safety margins to avoid cliff edge effect, have to be given in safety assessment (para.5.73. of Ref. [9]). This may be applied to such threats having cliff edge effect as in flooding and tsunami, though likelihood is not neglected where reaching a certain level triggers loss of safety functions. This approach can be generalized as use of conditional probability in decision-making. IAEA TECDOC-1909 [30] provides information for preparation, assessment, selection of options, process of decision-making with examples. Some decisions may require consideration of tolerable risk level or safety goal, which regulators in some jurisdictions provide information. The IAEA provides TECDOC-1874 on hierarchical safety goal [32] and Ref. [9] para. 2.13 requires "offsite contamination would be avoided or minimized. Event sequences that would lead to an early release or large release are required to be 'practically eliminated."

[5] Aleatoric uncertainty arises from the inherent variability in the physical process and is irreducible, whereas epistemic uncertainty arises from lack of knowledge, lack of understanding, modeling limitation, limited data etc. and is generally reducible.

[6] SSHAC (Senior Seismic Hazard Analysis Committee) is an expert panel organized to discuss epistemic uncertainties in the inputs to hazard analysis for PSHA (Probabilistic Seismic Hazed Analysis).

3.4.4. Organizational traits in decision-making

Any organization or group or individual cannot escape from own bias and hidden assumptions. Understanding such bias and assumptions helps reduce influences from them for robust decision. One example is to analyse 'Why bad decisions were made in your organization?' to recognize organizational traits, weaknesses and bias/assumption to change for the better. The pie chart illustrates an example of distribution of causes of bad decisions, where lack of competence on the part of decision-maker is not included (See Fig. 5).

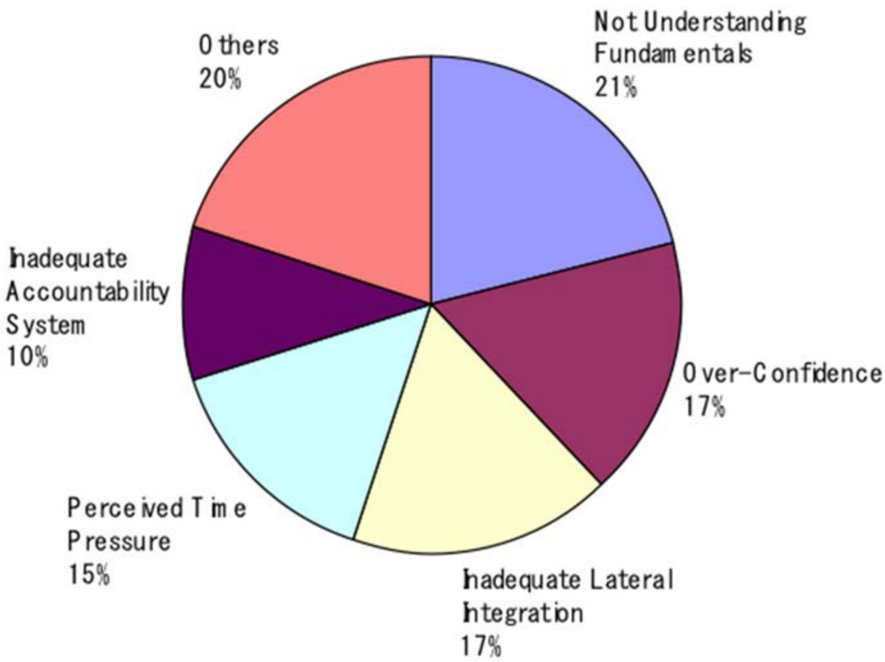

FIG. 5. Example of distribution of bad decision in owner/operating organization of NPP.

The main suggestions on decision-making in terms of institutional strength in depth are:

- Institutionalize decision-making system that defines who (at the right level of the organization) and how, responsibility for implementation;
- Invite diverse views to avoid group think, collective blindness and reach a better understanding (devil's advocate: one method);
- Build decision-making competency;
- Include value-impact assessment to eliminate options that may not commensurate the benefit of risk reduction;
- Systematically analyze factors contributed to bad decisions.

3.5. RESILIENCE

Resilience in a nuclear system (including human, technology, organization, and its interface with outside) is the ability of the system to recover from or adjust to events, challenges or changes which threaten the safe operation performance of the asset. It is important to note that the system characteristics below are all critical to optimize resilience, and the traits are those aspects that foster resilience [33–37].

3.5.1. Key characteristics of resilience of nuclear system

There are four characteristics of a resilient system as illustrated in Fig. 6 [33, 34]. Every nuclear system and the technological, organizational, and human sub-systems comprised within it, has resilience embedded within it, either by design (as is the case in nuclear technology and the NPP owner/operating organization) or naturally (in humans as living organisms). For example, resilient features are embedded in design of plant systems, are found in an organization's emergency preparedness measures, and emerge naturally, or through development, when humans are faced with challenge. These four characteristics of resilience assist the system safely recover from or navigate through performance disruptions.

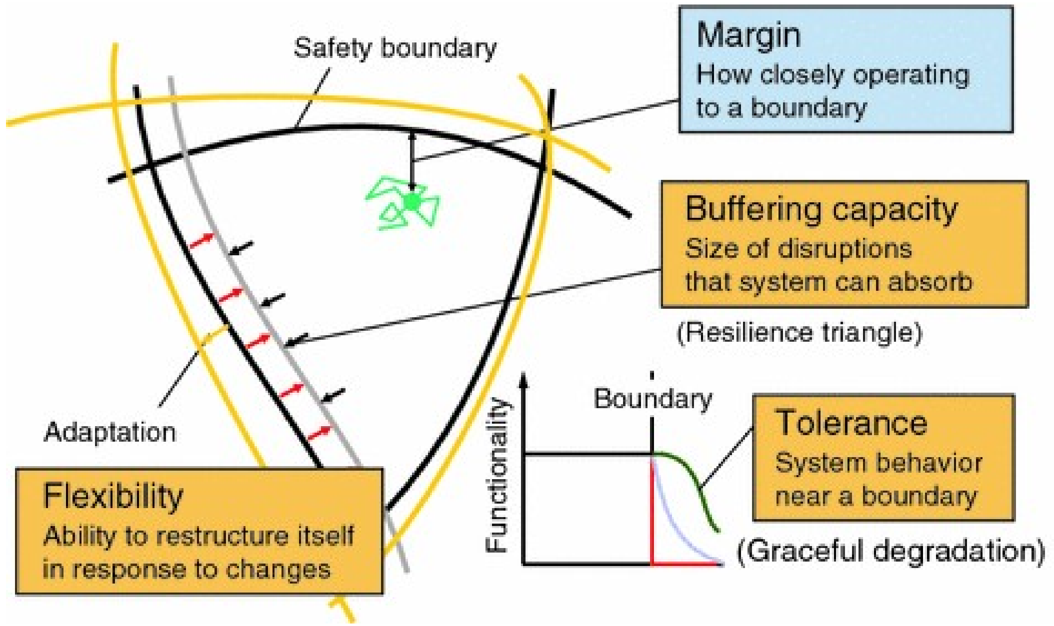

FIG. 6. Key characteristics of resilience.
(reproduced from Ref. [33] with permission courtesy of K Furuta, The University of Tokyo)

Each of these four characteristics are explained below:

- Margin is an indication of how closely the system is operating to boundary limits. Any system is designed to have (or naturally have) a certain amount of margin that allows for continued performance in the event of emergent disturbances. This is true for technical, organizational, and human systems. It is evident in the events of Fukushima, that the design margin was insufficient to safely protect against the 3.11 tsunami.
- Tolerance defines system behaviour near the safety boundary and whether approach to that boundary is graceful, allowing for additional adjustments, or leading to a sharp and immediate halt to performance. It is necessary to look beyond the safety boundary to ensure that there is no significant intolerable increase of consequence (cliff edge). For example, flooding typically has a sharp cliff-edge where submerged components hold no tolerance. And, at Fukushima Daiichi nuclear power station, the electric equipment room was submerged by flooding, and all supply of AC/ direct current (DC) was instantly lost. NPPs provide personnel with training, knowledge and skills to enable individuals to effectively respond and tolerate stress from adversities, by use of simulations and emergency exercises.
- Buffering capability equates to the degree of disruption the system can absorb or withstand without experiencing a fundamental breakdown in performance or system structure. While margin changes depending on operational status, the buffering capability

of a system does not change. Technical examples include designs that consider how heat will be absorbed in BWR pressure suppression chambers in case of accidental isolation from a heat sink. Or the 100% turbine bypass capacity that allows the reactor to continue producing steam without a trip (scram) so operations can resume quickly when the disturbance is removed. As a human example of buffering capacity, consider a reserved team member or other competent shift operation personnel who steps in when a team/member cannot serve. Multi-skilling training of staffers also adds buffering capabilities.

- Flexibility and adaptability refer to a system's ability to adjust performance in response to unexpected circumstances. It is a system's efficient way of retaining performance, by not resisting but instead accommodating change. A well-known case of successful, spontaneous, adaptive behaviour during an unexpected situation is found in the spaceship, Apollo 13. The spaceship's crew survived and returned safely to earth by managing the dwindling electricity and by reducing the amount of carbon dioxide through use of innovative and resourceful tactics. In a nuclear system, provisions and procedures prepared under the 4th layer of defense in depth are supposed to cope with beyond DBA conditions. However, at Daiichi site, they lost their ability to function because water and power were unavailable. In response, various spontaneous and adaptative actions were taken, such as the use of mobile power sources as means to get AC power, collection of batteries from automobile to supply alternative DC power, use of fire-fighting engines to inject seawater to the reactor core etc. Some were successful but some not, which reminds of importance of prior preparedness to unexpected.

Besides these characteristics, it is worth noting that response actions for resilience are time--related such that timely recovery and timely (and under time-pressure) decision-making. The evaluation of resilient capabilities reminds us of importance of time, recovery, and human and organizational factors that are not explicitly discussed in defence in depth [38].

3.5.2. Key organizational traits that contribute to a resilient system

Behind a nuclear system's ability to perform resiliently, there is a set of organizational traits that help to ensure the nuclear system operates with sufficient margin, tolerance, buffering capability and flexibility. Each trait alone and all in combination play a critical role in strengthening a nuclear system's resilience. In addition, each and all require a healthy, systemic interplay between human, organizational, and technical factors:

- Anticipation and preparedness: Risk reduction is enabled by thinking, analysing and developing solutions beforehand on how to be prepared for unexpected and in the situation when the ordinary procedures do not work. Use of PSA helps anticipation and blind drill helps successful implementation by recognizing what is missing in coping capability.
- Leadership and culture: Core to ISiD itself but also key to a resilient system, lies a strong safety and performance culture and the leadership to realize it. Leaders at all levels of NPPs should consistently retain a primary focus on core cooling, reliable access to power and water, and containment of radioactivity in all circumstances. A culture that is safe, secure, and excellently performing is realized through the consistent and correct behaviours, attitudes and beliefs demonstrated daily by its leaders throughout the NPP. Organizational culture and leadership are the two sides of the same coin [35]. The adaptive behaviour demonstrated at Fukushima Daini nuclear power station illustrate the outstanding role of leadership and the incredible power of teamwork (see Appendix I).

- Flexibility and adaptability: Flexibly and adaptatively adjusting to new contexts requires an ability to use and repurpose existing resources in innovative and creative ways as a means of navigating through the unexpected. These resources can be anything – from tools, to finances, to humans. Getting staff comfortable navigating through the unexpected by switching assigned roles, and training through and drills are two examples of ways to strengthen resilience.
- Collaboration: Recovery actions at Fukushima Daiichi nuclear power station were not possible without cooperation with parties outside of TEPCO including other utilities, fire disaster management agency, Self defense force, and international aids such as supply of tall water-pumping machine from China. Success of Apollo 13 was also not possible in isolation, and required collaboration with National Aeronautics and Space Administration (NASA). These examples imply that resilience is built upon human and departmental interactions and collaborations, which need to be a part of preparedness.

3.5.3. Human aspects of resilience

The leadership, teamwork, support from outside of the NPP and consequential success to safe shutdown of four units at Fukushima Daini nuclear power station (Appendix I) would not have been possible without human resilience. The positive attitude and determination not to be a victim of the harsh circumstances emerge from emotional strength, mental toughness, flexibility (in using all available resources), and adaptability (to the existing environment) of the leader. These human factors, e.g., emotional regulation, self-esteem, psychological well-being etc. help build resilience by improving coping capabilities. These human-factor related capabilities can be strengthened through training and development efforts.

The main suggestions on resilience in terms of institutional strength in depth are:

- Examine the PSA results, performance of the organization and events that have occurred to track both positive and negative trends within the teams, work practices or plant areas; proactively integrate good practices and address potential risks.
- Assess the resilience capabilities using the four characteristics and organizational traits. Overall performance is measurable in terms of damage and time for bouncing back (see Fig. 7) (reproduced from 24.6.2 of Ref. [33]) [39]. For example, a stress test was widely used in post-Fukushima accident era to measure safety margin against extreme natural hazards. Additionally, tools and models have been proposed to measure resilient performance of an organization such as RAG[7] [40].

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[7] RAG (Resilience Assessment Grid) was proposed by Eric Hollnagel to measure the potential for resilient performance of an organization in responding disturbances; i. e. the potential to Anticipate, to Learn, to Monitor, and to Respond. Appendix VII discusses organization's resilient performance at NPP as were seen in the Fukushima Daiichi Accident and this study indicated the RAG tools (questionnaire) could be useful in assessing the resilient performance of an organization.

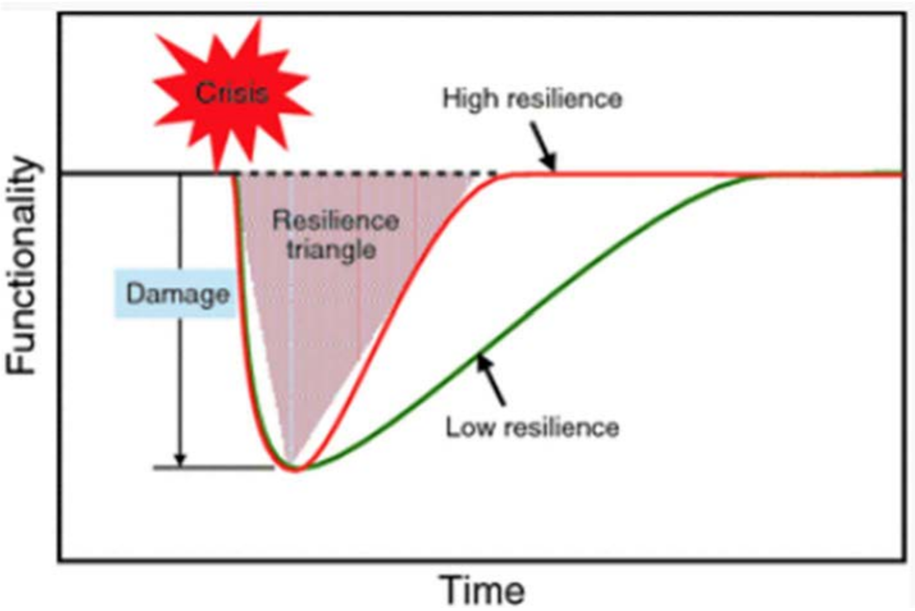

FIG. 7. Resilience triangle.
(reproduced from Ref. [33] with permission courtesy of K.Furuta, The University of Tokyo)

- Foster empowerment and engagement of NPP staffers. Encourage 'what if' discussions that allow for consideration of potentialities under varying conditions. For example, thinking 'what can go wrong' in pre-job briefs and considering actions to address these.
- Solicit independent oversight to consider challenges and solutions from a diverse perspective.
- Measure resilience capability and nurture resilience capability and mental strength through training and development efforts.

3.6. CORE COMPETENCIES

Whilst technical competencies are of primary importance, it is also vital people and organizational capabilities are effectively developed.

Owner/operators of NPPs outsource many activities such as maintenance, training, core management calculation, PSA with contractors to be efficient and focus on core business of operation. However, operators are expected to be an intelligent customer having knowledge of the product or service supplied from contractors as well as the capability to evaluate and decide on them.

The following subchapters describe some topical areas where owner/operators will gain strength for excellence by institutionalizing the system.

3.6.1. Mapping of competence, continuous education/training and qualification

One ISiD aspect of technical competence is for the NPP owner/operating organization to have an institutionalized system with the well-structured process of:

- Mapping of competence required to perform a job in an effective and efficient manner;
- Continuous education and training to acquire experiences and update expected competence; and

- Qualification or recognition.

Required competence is not limited to technical knowledge and skill but also may include personal and behavioural aspects for fitness-for-duty as well, including mental health. Having a job position in the organization that requires a certain specific technical expertise does not assure competence. It also includes assessment of a gap between required competence and existing one [41].

It is possible that this process of competence mapping, education and training, and qualification applies to the individual as well as the group. This competence mapping of a job position or group relates to nuclear knowledge management (NKM) of the organization as an integral part of its management system.

3.6.2. Nuclear knowledge management

Knowledge management is about identifying, preserving and transferring knowledge in a systematic manner, which, in today's environment surrounding nuclear energy, bears significant importance, given that competitive electricity market requires downsizing of human resources, the attrition of baby-boomers who played a key role in nuclear industry and increased amount of information in this technology. Competent operators establish inhouse NKM infrastructure for sharing plant information and knowledge (configuration, design, procedures, operating experience (OPEX) etc.), access to internet and networking. Knowledge is contextualized information within the hierarchy of data, information, knowledge and wisdom. This assists informed decision-making. Sharing of practical information among experts of specific area is enabled by networking and formulating community of practice.

IAEA NE Series NG-T-6.10 "Knowledge Management and Its Implementation in Nuclear Organizations" [42] provides NKM elements and experiences at NPPs.

3.6.3. Excellence is learning driven

Technology evolves with accumulated experiences of its use. Learning from others by, for example, knowing best practice and benchmarking is an important attribute of culture for safety. This learning does not limit itself to technology but also human and organizational aspects as well. Like safety is learning driven [15], so is operational excellence. One of the enablers of significant increase of nuclear electricity in a decade around the turn of the century was possibly learning from best practices (globally, but especially the East) and consolidation to those perform the best under increasing market pressure of competition (the West).

Management should establish the way for the employee to learn to strengthen their competence. In the case of control room operator, training and learning are an integral part of duty in a way training course is alternating with periods of shift assignment. International or country specific industry organizations such as WANO, INPO, JANSI (Japan Nuclear Safety Institute), owners groups also worked for sharing of OPEX to assist competence through learnings. Incident Reporting System by the IAEA and OECD/NEA are disseminating information, by not only describing incidents, but also root cause, lessons learned and corrective actions.

3.6.4. Knowledge of design and design authority

Knowledge of 'how the plant system and equipment are designed' and 'why designed so' are an essential part of technical competence for operation of NPPs. However, a long time since the plant is handed over from designer/contractor to operator or as engineers moved from designer/contractor to operator are lost due to attrition, this design knowledge starts to erode and, as plant ages, facility is renovated and modified to reflect new findings, new regulations, and to benefit from innovative technologies. Original supplier of a component may have disappeared from the market.

Nevertheless, NPP owner/operating organizations have to have a capability to function as a 'design authority' after the NPPs start operation, since it is the only organization that can maintain the integrated knowledge of design to achieve the ultimate responsibility for safety. As an example, lack of design knowledge by Operator led to misunderstanding of its operating status and premature shutdown of the Isolation Condenser system at Unit 1 in the response to the Fukushima Daiichi Accident.

> "An operating organization must set up internally a formal process to maintain the design integrity as soon as it takes control of the plant. This may be achieved by setting up a design capability within the operating organization, or by having a formal external relationship with the original design organizations or their successors. There must be a formally designated entity within the operating company that takes responsibility for this process." (INSAG-19, 2003 [43])

The design authority is responsible for maintaining the integrity of the plant's design basis and reviewing and approving any change to the plant configuration. By linking with all the engineering divisions, it may be able to take an integrated position on safety and assume a part of safety oversight as well. However, challenges may be:

- Who or what entity to assign as design authority in a power company and how to obtain design information from a contractor. WNA (World Nuclear Association)/CORDEL'S implementation guide "Design Knowledge and Design Change Management in the Operation of Nuclear Fleets" [44] and practices at Électricité de France (EDF) (Appendix V) would help.
- Newcomers and small Utility with a small fleet will face difficulties for ensuring that design knowledge is transferred to power companies and for capacity building to become an eventual design authority. They may benefit from ensuring transfer of design information from designers at the time of contracting for configuration management, inhouse PSA etc. They may also learn good practices from IAEA, WANO and Owners Groups.

Also, industry's competence in design needs attention. Such design deficiencies as reactor water level measurement (TMI), positive void coefficient at low power region (Chernobyl), and placing electrical equipment (EDG, switchgears etc.) below ground, if they were corrected at some stage, these core melts would not have occurred.

3.6.5. Risk management and crisis management

Risk management and crisis management [45] is an essential part of technical competence at NPPs.

For ISiD, operators of NPPs should minimize the impact of initiating events, their likelihood of occurrence (if possible), and associated consequence of accidents, especially events leading to severe accidents that could result in a large release of radioactive materials. NPP operators need to organizationally establish a system for risk management which includes:

- Risk analysis (which may use experts outside of the company) across all plant operating modes;
- Risk evaluation and internalization of risk results and insights (which is internal to the NPP operator with possible advice from external experts);
- Risk management actions development (internal to the NPP operator); and
- Risk management action implementation (internal to the NPP operator), where appropriate, including timely decision-making, management notification criteria, timely activation of onsite emergency management and timely communication with public authorities for offsite emergency management.

The above is intended to provide information and timing of initial actions immediately after an event and to provide actions to mitigate consequences. These actions are time based depending on the severity of the event and the accident progression as it relates to nuclear safety design and operational parameters.

Details of these risk management system including organizational settings is discussed in Section 3.3.

Very often, crisis management is considered a part of risk management after the occurrence of an event leading to accident conditions based on the timing of organizational actions (immediate responses, diagnosis, entry into abnormal and emergency procedures, etc.). Crisis management includes an institutionalized systems for command and control, collect and use operational information, identification and knowledge of accident progression, and execution of coordinated actions and activities both internal and external to the NPP Operator. Success has its basis on such competences as knowledge of key characteristics of the accident (such as decay heat levels, reactor/containment parameters, land contamination, and other emergency actions), sensitivity to alarming signals and precursors followed by sharing of alarming information[8], decision-making authority during and after the event, roles and responsibilities (legal framework), communications and contingencies to use all available resources[9] both onsite and offsite, including multi-organizational leadership and teamwork exercises.

3.6.6. Other competences

Engineers and scientists at NPPs are trained and educated with disciplines of science and technology but typically have limited formal education on such disciples as economics, law, psychology, sociology, and communication.

Nevertheless, management of NPPs in today's environment requires competence in systematic management of complex social and technical systems, with extensive interfaces with outside. Rather than starting to learn disciplines other than science/engineering when he/she took highly managerial position, institutionalizing a 'technology management' training system will help extension of competence to non-technical areas. Of importance is leadership and management, for which Utilities should have a systematic training program in place. Some universities even

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[8] Reference can be made to such events as below. Sensitivity to alarming signal: accumulated rust in ventilation filter at Davis-Besse (RPV top bottom corrosion); Sensitivity to precursors: Seawater leakage at the basement (Fukushima Daiichi, 1991), Flooding at Blayais NPP, 1999, accident at Leningrad unit 1(precursor to Chernobyl), Davis-Besse condensate water system transient (precursor to TMI). Experience at Leningrad Unit 1 accident was not shared with Chernobyl. Importance of sensitivity and sharing information for prevention were also cited in 9.11 Investigations Report (terrorists sent to US flight training school, FBI Phenix report etc.).

[9] Reference can be made to Use of batteries collected from automobile when faced with total loss of all DC power (Fukushima Daiichi), and even non-nuclear cases such as Apollo 13 when faced with loss of oxygen tank, landing of US Airways flight 1549 landing on Hudson River when faced with loss of all engines.

formulated, under the support of the IAEA, International Nuclear Management Academy (INMA) for universities that provide master's degree programmes focusing on management for the nuclear and radiological sectors. ("INMA'S programmes in nuclear technology management" in Ref. [46]) It is expected that INMA becomes accessible to currently employed nuclear professionals by distance learning or by short courses.

The main suggestions on core competencies in terms of institutional strength in depth are:

- Establish a systematic process of development of competence mapping, implementation of education/training and/or providing opportunities of experience for continuous improvement (through learning) and qualification of a group or individual;
- Take a strategic approach to competence mapping, ensuring that owner/operating organizations of NPPs and/or associated supporting organizations like contractors, vendors, suppliers, technical support organizations (TSOs), etc.:
    - Continuously monitor the organization's capacity and capability to meet current and future needs, including coverage of specialist and niche capabilities and skills e.g. digitalization of instrumentation and control, artificial intelligence (AI), reactor internal ageing, etc.;
    - Clearly identify and address any potential vulnerabilities and risks with specific preventative and/or mitigating actions e.g., qualification programs, and securing the minimum number of reactor operators and the experienced and skilled in-house staff and/or contractor workers, etc.
- Incorporate the critical non-technical competencies that bolster technical skill application, improve individual and team performance, and fully optimize diversity of experience and perspective Establish an in-house nuclear knowledge management system and portal;
- Institutionalize a design authority;
- Build a risk management capability;
- Institutionalize a technology management training under systematic approach.

3.7. EFFECTIVE INDEPENDENT OVERSIGHT

One of the key attributes that will elicit institutional strength in depth is the independent oversight function in the NPP owner/operating organization. This addition to the existing line management oversight process (peer checking, self-assessment, etc.) creates another layer of defence by strengthening licensee capabilities to improve performance and more effectively manage risk. Such functionality and process had been lacking in TEPCO`s management system and other utilities in Japan before the Fukushima Daiichi Accident.

In addition to oversight performed by line management, independent nuclear safety and performance oversight can be used to strengthen safety and operational excellence and enhance senior management's ability to respond promptly to safety and performance declines or other safety and performance related nuclear industry challenges.

Typical nuclear safety and performance oversight function is shown in Fig. 8.

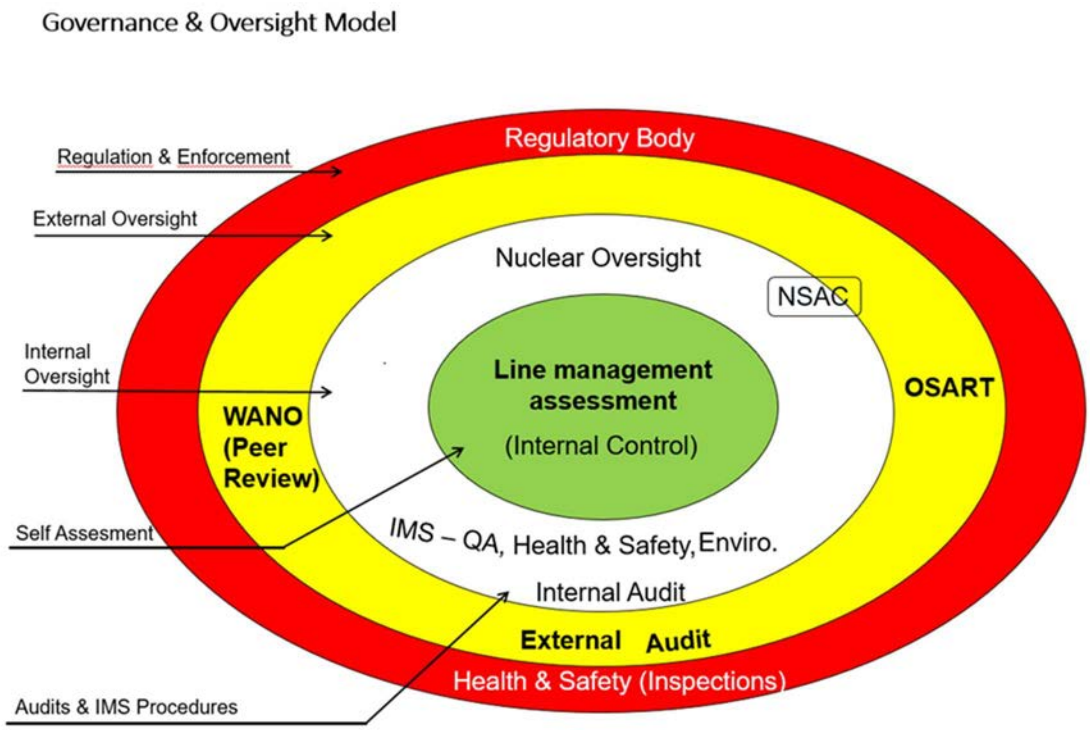

FIG. 8. Typical Nuclear Oversight Functions.
(courtesy of J. Zlatnansky)

Note:

- Red colour - represents oversight of compliance with legal and safety requirements;
- Yellow colour - represents both: compliance with international standards and performance gaps compared to best practices and excellence in safety performance;
- White colour – represents internal company's compliance-based integrated mangement system (IMS) and quality assurance (QA), environmental, and health and safety audits and performance-based independent nuclear safety assessment reviews; Nuclear Safety Advisory Council or Committee (NSAC) consisting of senior external nuclear experts providing outside perspectives;
- Green colour – represents line management oversight.

The independent oversight provides senior managers and leaders of NPP owner/operating organizations up to the board of directors (BoDs) with relevant safety and performance gap information through the application of organization-wide, independent, and objective assessments. It also provides them with opportunities for further improving a primary focus on nuclear safety and performance and reinforcing an integrated approach to ISiD. The independent nuclear oversight function has been created in many nuclear utilities to strengthen organizational defence-in-depth, improving safety, and helping to achieve excellence in performance. In performing independent reviews, focus should be on those processes critical to safety, reliability, and efficient operation as well as performance of all NPP units. The effective independent oversight function should also identify areas for improvement of those behaviours practices and processes affecting safety to prevent safety related events and major accidents from occurring.

An effective independent oversight function assures senior management of NPP owner/operator organizations that the assessment activities of safety and performance are undertaken at various levels within the organization to provide assurance that risks are being effectively controlled and reported to decision makers from independent internal and external sources.

The establishment and organizational interface of independent oversight function needs to take the other layers into account and adjust accordingly. Examples of layers are shown in Fig 18. These layers are part of the management system and should be effectively implemented to ensure that performance is monitored in several independent ways by different people with diverse perspectives, using various methods to avoid common mode risk.

The setup of an effective nuclear safety and performance oversight should be developed according to the unique structure and culture of the NPP owner/operating organization. Different approaches to an effective oversight, including independent nuclear safety and performance oversight, are also based on the number of operating units, the licensees with multiple sites, corporate functions, and stakeholders' expectations (owners of nuclear assets, regulatory bodies, other shareholders etc.).

The independent assessment activities should be coordinated with corporate line management assessment activities and compliance-based audits to identify broad organizational and process weaknesses and opportunities for continuous safety and performance improvements. Desired assessment outcomes and metrics should be clearly defined to reflect industry highest standards, underpinned by strengthening focus on underlying behaviours for success.

The Independent Oversight includes the internal independent oversight groups and external oversight - senior experts from outside the utility (Nuclear Safety Advisory Councils or Committees (NSAC). All members of NSAC should have access and reporting lines to all organizational levels up to the Board of Directors of the owner/operator (see FIG. 9). An elevation and escalation process should be clearly defined in the management system manual of the licensee. External oversight should also include findings from international safety reviews by WANO, IAEA or other external reviews.

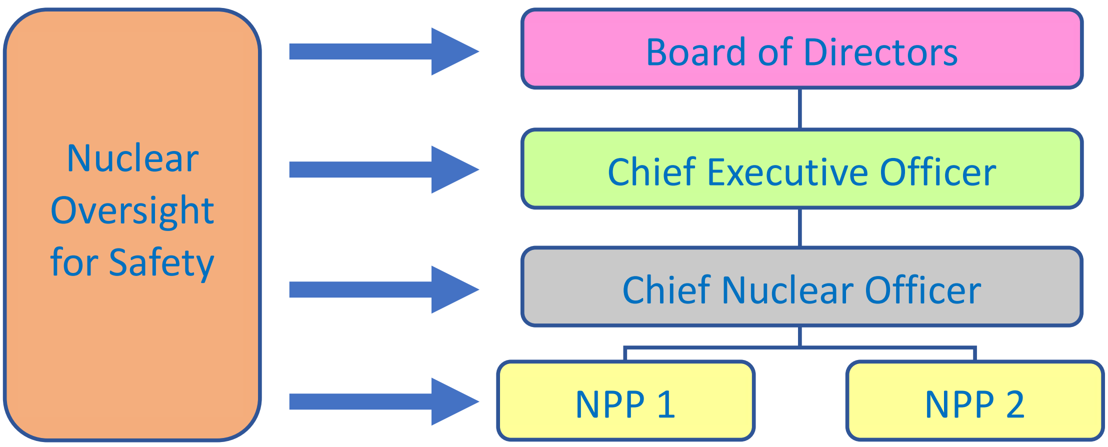

FIG. 9. Typical independent oversight reporting lines.

The strategic direction and day to day management and control of the effective nuclear safety and performance oversight function should be sufficiently independent from operational management and corporate line management to ensure that it is seen and regarded by all levels in organization as another independent layer. Individuals undertaking and reporting independent assessments should be free to raise 'bad news' without fear of sanction.

Individuals undertaking independent nuclear safety and performance assessment activities should have the necessary experience, training, skills, and credibility to conduct the work to identify performance shortfalls and recognize good practices and highest standards in the nuclear industry. The company operating NPPs, with multiple sites and with a large corporate organization, may need an independent oversight function at the corporate level that includes the level of owner of the nuclear assets. This will complement the independent oversight activities as carried out by the independent oversight units on the plant level and/or license holder at the corporate level.

The overall effectiveness of corporate governance in the management system and independent oversight should be periodically assessed. Corrective actions should be taken for performance shortfalls or opportunities for continuous improvements.

NPP owner/operating organizations should create key performance indicators for the independent oversight function to monitor and measure its effectiveness and its proactive approach to achieve sustaining operational safety excellence and strive for and continued benchmarking and safety improvements.

To achieve this, the purpose of the independent oversight function is to verify that the utility has the full capability to perform in a manner which achieves these safety and performance functions through appropriate staffing, processes, activities, actions and monitoring.

Guidelines to support nuclear operators in developing and implementing their own independent oversight function, which is a vital part of an effective safety management and main principles for the planning, undertaking and reporting of independent assessments are available in following documents:

- IAEA General Safety Requirements GSR Part 2 [47];
- WANO GL 2018-01/IAEA Guideline on Independent Oversight [48];
- Independent Oversight - A Nuclear Industry Good Practice Guide – by the cross-industry Internal Regulation Working Group (IRWG) [49].

The main suggestions on independent oversight in terms of institutional strength in depth are:

- Ownership of independent oversight by top management - Senior executives (chief nuclear officer (CEO) and chairman of BoD) support independent oversight function with it`s clearly defined mission;
- In case the owner of nuclear assets is not the licensee, it should not usurp responsibility and management of independent oversight - responsibility should remain with licensee;
- Regardless of organizational structure the internal part of independent oversight should have adequate staffing with arrangements related to succession plans for senior line management positions;
- External part of the independent oversight should be rotated based on safety and performance challenges for the utility;
- Leadership commitment at all levels of organization - Ensure improvements are sustainable;
- Monitor delivery and results -qualitative and quantitative key performance indicators of independent oversight should be determined to address effectiveness of the independent oversight process.

4. EFFECTIVE MANAGEMENT OF EXTERNAL INTERFACES

Establishing effective relationships with key stakeholders is a central aspect of establishing institutional strength in depth, as no organization can function effectively in a vacuum. Stakeholders include regulatory bodies, legislators, media, government agencies and policy makers, NPP owner/operating organizations, suppliers, workers, communities near actual or potential sites, neighbouring countries, non-governmental organizations, and the public. The most influential stakeholders and societal opinion leaders will vary across countries and could include national and local government officials, heads of business and industry and leaders of non-governmental organizations [50].

Taking a systemic view of how the operator is interlinked with other key players can help understand the complexity, the interfaces and hence the influence of other key players.

Figure 10 helps the organization to enhance the understanding of what the operators have power to influence and what they do not have power to influence. It also provides a better picture how the different key players are connected and can present new information which is important for the operator.

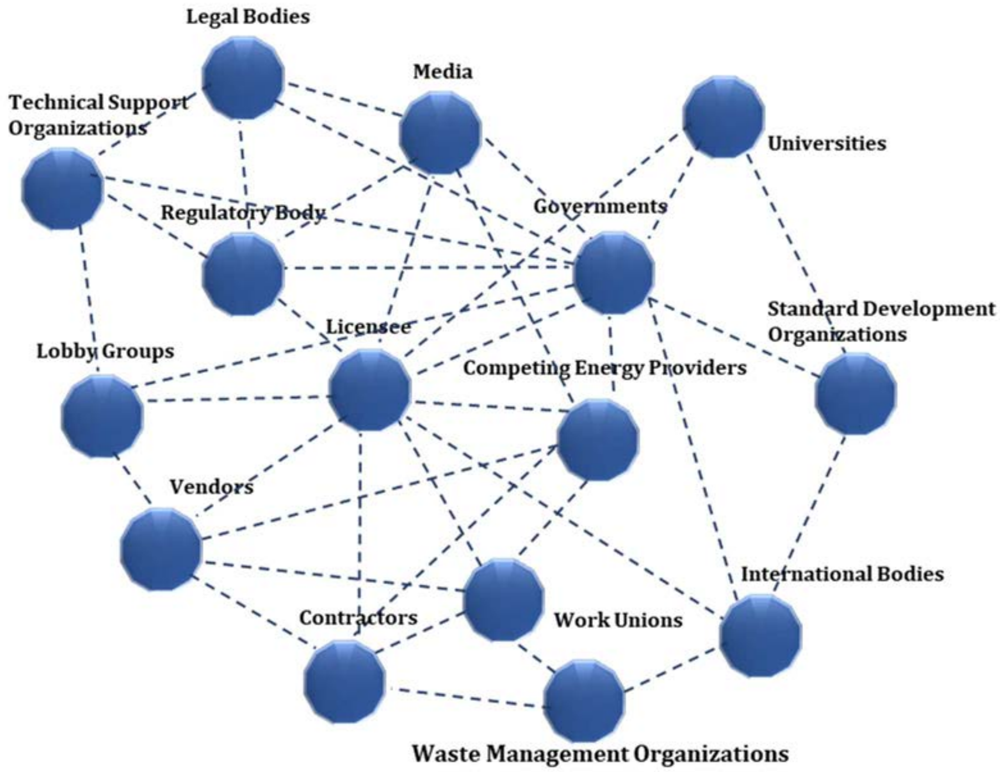

FIG. 10. Example of Systemic View of Interactions.

This chapter will present ideas on how to foster effective relations and establish trust with key stakeholders in order to achieve effective ISiD.

4.1. INTERFACE WITH REGULATORS

The culture, behaviours, and ways of working between the regulator and the licensee are strongly interconnected and trust and communication between them are essential elements for safety.

The role and responsibility of the regulator is to establish and maintain the regulatory framework and to verify and, where appropriate, enforce compliance with regulatory requirements to provide a high degree of confidence that nuclear facilities are operated with an adequate level of safety. The role and responsibility of the nuclear licensee is to operate to performance standards, which will generally exceed compliance standards to ensure safe and reliable operation of NPPs.

It is important to develop a constructive approach between licensee (owner/operators) and regulators. The way in which the NPP owner/operating organization interfaces with the regulator very often determines how the regulator in turn responds and vice versa. In the worst cases the relationship becomes very prescriptive i.e., the regulator says what needs to be done and the licensee simply responds. This behaviour results in a shift in perceived responsibility for nuclear safety from the licensee to the regulator with the following outcomes:

- The regulator keeps asking for more and more information;
- The licensee challenges back to reduce the demands on the organisation.

The result is a net reduction in nuclear safety i.e., a compliance culture rather than a performance culture.

From a nuclear operator perspective, it is important to recognize the mandate of the regulating bodies and engage with them in a constructive manner. In particular, the following are considered important elements in the establishment of that effective working relationship:

- An effective internal oversight structure, which includes a strong independent internal oversight organisation. This gives confidence to the regulator that there is strength in depth within the licensee organisation and that nuclear safety is not overly dependent upon the external regulator. (See Section 3.7);
- An open and transparent relationship with the regulator. Constructive, committed, open and early engagement to avoid surprises and build trust. A good balance of formal and informal communication will enable trust between the regulator and the licensee (owner/operators);
- A clear and transparent event reporting system, rigorous event investigation an effective corrective action programme;
- A graded approach to communication with the regulatory bodies to ensure that priorities are established, understood and agreed. These arrangements will enable issues and concerns to be effectively dealt with at the right level of respective organisations and with an elevation and escalation route to ensure concerns are promptly and effectively addressed;
- To work with the regulator to establish an effective regulatory interface protocol and ensure that this is consistently reviewed to identify, at an early stage, problems with the relationship. This needs to include a willingness to address blockers, distractions and unnecessary bureaucracy;
- To focus on outcomes rather than exclusively on processes.

Nuclear industry managers and leaders also need to support any opportunity for open dialogue with regulators at various levels. Examples could be national nuclear forum and/ or events organized other non-government organizations at the national level, European Nuclear Installation Safety Standards (ENISS) initiatives at the regional level or IAEA meetings/ workshops at the international level. This can lead to better informed decision making on difficult technical issues.

In the best case scenarios the regulator adopts an enabling approach to regulation [51] i.e. a constructive approach to enable delivery against clear and prioritized safety outcomes. An enabling approach i.e.:

- Includes consideration of strategic factors in regulatory decision making;
- Recognises that the speed at which improvements can be realised is often a key aspect in the risk balance and a pivotal factor in identifying the best safety or security outcome;
- Considers the economic impact to the industry from regulatory activities, in terms of the impact of frontline work and the cost impact of work required as a result of those activities to bring the industry into compliance with the law and the expected compliance standards.

Effective engagement between the nuclear licensee and the regulator will facilitate this shift towards more effective enabling regulation.

The main suggestion on interface with regulators in terms of institutional strength in depth is:

- The nuclear industry managers and leaders should work continuously towards the development of a constructive working relationship with the regulator i.e. constructive dialog, resolution of mis-understanding and work on issues to strengthen mutual trust.

4.2. PUBLIC STAKEHOLDER ENGAGEMENT

Engagement with the public is key for owner/operators, regulators and other authorities and is critical to build and maintain stakeholder trust in their respective roles and responsibilities. Public stakeholder groups can contribute significantly to the success or failure of a nuclear project and ultimately contribute to ISiD.

4.2.1. Principles of public stakeholder engagement

The key principles of public engagement for the nuclear industry are founded on building trust, demonstrating accountability, exhibiting openness and transparency, practicing early and frequent consultation, and communicating benefits and risks. Effective implementation of these principles supports the ability of these key organizations to reach their nuclear power programme’s strategic and organizational objectives and show due regard for the interests and concerns of stakeholders. It is critically important to have public stakeholders involved in decision-making related to issues that are relevant to them. Communicating broadly about all topics related to stakeholder interest, including those that might not seem directly relevant, will help to demonstrate a genuine interest in engaging in a comprehensive manner and thereby gaining greater trust that the decisions made relative to the nuclear industry are appropriate and supported. At the same time, it is important to recognize that the aim of an effective public stakeholder engagement programme is less about gaining consensus and more about understanding the basis for a decision. It is important to note that trust is both a principle as well as a fundamental outcome of effective stakeholder engagement.

The key principles of public engagement represent values, behavioural and procedural qualities and expected outcomes. They form the basis for conducting effective public stakeholder engagement [50] and include the ability to:

- "Build trust;
- Demonstrate accountability;
- Exhibit openness and transparency;
- Practice early and frequent consultations; and
- Communicate benefits and risks"

Some actions that can be taken to implement these principles include:

- Proactively share information and facts related to nuclear power programme and its positive impact on society (e.g. for the environment, for energy supply security). It is important to convey factual information about nuclear energy so that the public understands the basis for decisions and that public trust in operations grows. Such information might include how nuclear energy contributes to the achievement of commonly held goals for the planet, and how it impacts the community in positive and personal ways;
- Maintain an open-door policy to enable the public to gain an understanding of the nuclearsector and the impacts on society and the environment. This can be achieved through public information centres, plant tours, and engagement with schools, external societies and Non-Governmental Organizations;
- Provide open and timely reporting and communication on the operational performance of the nuclear assets including events, emissions, and their potential environmental impact during emergencies;
- Demonstrate rapid reactive response to media and to public request for information;
- Deliver positive and proactive communications of significant events affecting nuclear facilities in other utilities, states or countries (news items affecting the nuclear industry) [52];
- Follow through on commitments, ensuring words are matched by actions
- Adapting communication to the level of technical understanding of the audience and ensuring the message addresses audience concerns.

4.2.1.1. Build trust

In a modern society, confidence building would necessitate the following:

- Confidence in the operator decision-making that they will minimize risk to the public and make conservative decisions;
- Transparency which requires open communication;
- Demonstration of public value (sustainable development);
- Adequate regulation over the industry to protect the public;
- Economic viability.

Actively pursuing these issues through public engagement, will help address many of the concerns regarding nuclear accidents, radioactive waste, and economics.

Local communities or the public who live closer to a nuclear site may have an increased level of interest about the performance of the site and are generally more supportive of nuclear power than those living further away from the facility. Therefore, additional focus needs to be given to satisfy their needs through regular updates with community representatives and greater proactive communication about site activities. This can be achieved through local media sources and focused meetings with representatives of local communities, for example. Careful planning is critical to ensure meeting success with local communities and the public. Meetings with local communities are to be part of the broader communication plans of NPP owner/ operating organizations and need to be clearly defined in public engagement strategies. In any stakeholder engagement programme, clear goals with measurable steps to reach them are supported by simple, concise messages that resonate with target audiences. A compelling message is tailored to the audience to whom it is being delivered, and in this way more effectively builds trust [50].

Strategies need to also clearly define different roles and responsibilities of operating organisations in public communication and the different roles of other bodies. Leaders at all levels in the nuclear industry, like in other industries such as aviation, have to be accountable for public engagement. They are encouraged to balance technical actions (event prevention, damage mitigation etc.) and communication with the public.

Public confidence and acceptance of nuclear power varies significantly in many states and countries due to concerns over nuclear accidents, radioactive waste and economics. If the public perceives that these issues are well managed and regulated, then the use of this technology can be a more acceptable risk and considered a positive value to society. Nuclear industry managers and leaders need to constantly strive to achieve excellence in operational safety and remember that public trust and support is essential to sustain the continued operation of the nuclear assets. Trust can be strengthened by demonstrating technical competence and adherence to high standards both in performance and reporting but also by speaking to the concerns and interests of all stakeholders.

4.2.1.2. Demonstrate accountability

Senior leaders in nuclear industry need to demonstrate accountability for stakeholder engagement and assure that all parties communicate their activities clearly and concisely, which is an important contributor to building and maintaining trust. Accountability of leaders in the nuclear industry for public engagement also includes competent and prompt communication to the public in case of events or unlikely situations, including in facilities and activities around the world. Responsible organizations and their senior leaders have to be accountable and need to ensure clear routes for reporting on final decisions, strategies or implementation plans to the public and other stakeholders.

4.2.1.3. Exhibit openness and transparency

Open communication with all stakeholders needs to address their respective interests in and concerns with the programme as completely and consistently as possible. Communicating facts about the technology as well as decision making related to nuclear programme implementation, siting, construction, operation and decommissioning of NPP remain important through all phases of the NPP life cycle. Managers and leaders in NPP operating/ owner organizations and regulatory bodies need to devote significant resources and attention to developing and demonstrating effective stakeholder engagement. It requires a commitment to welcome challenge, to listen, to respond openly, to learn and improve, and to engage positively with all the issues of interest to the public and especially local communities. As stakeholder engagement is a recognized strategic element throughout the entire lifespan of nuclear facilities, each organization that holds responsibility in a nuclear programme — the government, the owner/operator, the regulator — has a role in carrying out effective open transparent stakeholder engagement activities.

Lessons learned from the Fukushima Daiichi Accident and other major accidents reminds managers and leaders in the nuclear industry that they need to act and provide the public with prompt, honest and relevant information.

Transparency, knowledge (familiarity), necessity (positive value to society), and consistency (reliable, responsible) are all attributes that foster trust by the public and local communities in NPP operations and decision-making processes. When members of the public have personal experience or knowledge related to a potential or perceived risk of an activity, a technology or an industry, they are more inclined to make up their own minds as to whether or not that risk is acceptable. However, when they lack direct or indirect experience with a potential risk, they might rely more on the people, organizations, or media whom they trust. Because stakeholder engagement involves partnerships and relationship built in large part on communication, it cannot be carried out effectively without the full support and participation of senior management and the active, conscious effort of all internal stakeholders – the workforce.

Transparency increases the motivation and probability that individuals and institutions will meet their corporate and social responsibilities. It is important to recognize that transparency holds its own challenges, as senior managers and leaders need to make difficult decisions as to the timing and appropriateness when sharing critical information. It is also important for organizations to build trust so that stakeholders understand when confidential information cannot be released.

Arrangements for transparent public communication, including for a long-duration, multi-unit event, are suggested to include:

- Strategies for different public groups are defined;
- Clearly defined roles and responsibilities for the NPP owner/operating organization (licensee) and for local and national authorities including the interactions between the NPP owner/operating organization (licensee) and the authorities. Arrangement needs to be regularly tested in exercises;
- A strategy and the infrastructure to receive, organize, and share the enormous amount of information provided;
- Procedures, information organizing methods, and communications protocols are developed and used periodically as part of personnel training;
- Arrangements with regulators and other industry bodies clarified to ensure consistency of messaging and accuracy of information;
- Channels of reporting identified;
- Trained spokes persons available.

4.2.1.4. Practice early and frequent consultations

While safe and reliable operation is the nuclear industry's goal, leaders at all levels also benefit from understanding that a rapid and effective local, national and international response capability to any unlikely significant event, incident or accident is a responsibility of the nuclear industry.

In the unlikely case of a safety significant nuclear event, the needs of the public change. While the trust in the owner/operating organization of NPPs could be severely eroded, there will be an increased demand for event specific information. It is essential that the nuclear owner/operator has arrangements at all levels of the organization in place to help satisfy these changing needs of different public groups. Even if a nuclear event occurs at another site, utility or country, the local NPP owner/operating organization will be required to provide timely and specific information about the event.

Redundant ways to communicate a unified message to the public during a safety significant event need to be developed to ensure consistency in information communicated at the national, local, and owner/operator levels. Additional strategies are required to clearly communicate crises during a safety significant event and imminent evacuations.

4.2.1.5. Communicate benefits and risks

Risk communication can be considered in different ways, for example [53]:

- Care communication is communication about risks for which the danger and the way to manage it have already been well determined through scientific research that is accepted by most of the audience;
- Consensus communication is risk communication to reach a decision about how the risk will be managed (prevented or mitigated);
- Crisis communication is risk communication in the face of extreme, sudden unexpected accident at an industrial plant, the impending break of an earthen dam, or the outbreak of a deadly disease. This type can include communication both during an unexpected accident and after the emergency.

Looking back on past significant incidents, events and accidents like TMI, Chernobyl and Fukushima Daiichi, it is apparent that the nuclear industry and government organizations have an opportunity and need to more effectively prepared for the unexpected and unanticipated particularly in communicating risks to the public. As demonstrated when communicating the severity of the Fukushima Daiichi Accident to the public, the nuclear community including governments and owner/operating organizations of NPPs were hesitant and slow to share information. Because it was falsely believed to be more effective to have all information about each event before sharing it with counterparts, there were long delays in communicating important details that would have ultimately allowed for more agile decision making and response [7]. These delays in communication by the industry caused confusion, lack of trust and in some cases, resulted in negative impacts on the public safety risk and some unnecessary protective actions taken in some countries. Therefore, prompt and frequent communications to stakeholders and public, during and after an event, and even if incomplete, have to be an integral part of risk management and public engagement strategy of NPP owner/operating organizations. It not only keeps the public up to date on the status of the event, it also serves to convey how importantly the NPP owner/operating organization values and cares for the protection of people, the environment and property.

After the Fukushima Daiichi Accident in 2011, some countries and governments reacted to media hyped reporting. The nuclear industry did not communicate effectively nor in a timely way ahead of those reporting and thus lost the confidence of some governments, stakeholders, and the public.

In order to build and sustain trust and fulfil public expectations, prompt, open, transparent information to the public during unexpected incidents, events and accident is an important part of strength-in-depth in the nuclear industry. A proactive approach to risk communication during unexpected potential events need to be part of the unified nuclear industry strategy for public engagement. These risk communication strategies have to be prepared, practiced, and regularly updated in NPP owner/operating organizations, international nuclear associations and agencies. The IAEA Nuclear Communicator's Toolbox [10] is available for scientists, engineers and

[10] See: https://www.iaea.org/resources/nuclear-communicators-toolbox

communication professionals who work in the field of nuclear science and technology applications or regulate their safe and secure use.

As part of these risk communications strategies, senior managers and leaders in the nuclear industry need to be able to better explain operational events and accidents so that the public trusts the industry and understands the magnitude of the risks. They also need to better communicate all the operational measures in place to prevent an incident and all of the processes/procedures in place to mitigate, minimize and terminate the event.

4.2.2. Integrated approach

The nuclear industry needs to understand acceptable, realistic, science-based biological radiation dose limits for nuclear workers and the general public and implement actions and measures to protect workers and the public (i.e. dose limits, exclusion areas, protective measures such as sheltering actions, radioiodine pill ingestion etc.)

The nuclear industry has demonstrated that when it works together and is united in its actions, it can achieve the common goal. That is how the nuclear industry can be in public stakeholder engagement. The industry needs to be unified in stakeholder engagement to communicate to the public risk and event response actions more effectively. This will help to build and maintain public stakeholder trust and support although in cases when events happen in the nuclear industry.

A stakeholder engagement strategy can only be put into action if it is supported by strong and well entrenched leadership throughout the industry, including clear and coordinated messaging with associated plans and strategies for implementation.

Public stakeholder engagement differs from country to country, and managers and leaders in the nuclear industry need to also consider political environment and cultural aspects. Benchmarking and implementation of good practices from other countries could be beneficial to improve public engagement, however strategies, processes, and tools to better engage different public groups are to be modified based on the situation in the respective country or region.

In Appendix XII an example of stakeholder engagement in local government, the case of Fukui prefecture in Japan with 13 commercial reactors is provided.

The main suggestions for effective public stakeholder engagement as a part of strengthening ISiD are:

- The arrangements for public stakeholder engagement within the NPP owner/operating organization's existing management system, needs to enable a clearly defined internal and external communication process. The alignment of the arrangements between corporate and operational units have to be clearly defined to ensure timely response to and communication with the public, the regulatory body, and other NPP owner/operating organizations;
- Top management and leaders have to demonstrate personal accountability for open, transparent, and proactive communication with the public in all situations including the willingness to hear and accept raised concerns;
- In case of a significant nuclear event, managers and leaders are encouraged to be proactive and provide status information, even when all causes may still be unclear or undefined;
- Public stakeholder engagement strategies that will be used with local communities and the general public, need to be regularly reviewed and improved as needed based on lessons learnt.

4.3. INDUSTRY INTERFACES

Cross industry support has been a strength of the nuclear industry. It has been shown that nuclear operators who actively engage with and seek feedback from across the wider industry consistently demonstrate higher levels of safety and operational performance.

The Fukushima Daiichi Accident demonstrated, however, that more needs to be done to strengthen cross industry collaborations and to identify plants and organizations that need help and provide the additional necessary support to help address performance deficiencies. The challenge applies to industry collaborative organizations, industry owners' groups and intergovernmental organizations like the IAEA and the Nuclear Energy Agency (NEA) in the Organisation for Economic Co-operation and Development (OECD) all of which need to work together with the industry to continuously improve NPP performance and sustain operational excellence.

The principal industry body is the World Association of Nuclear Operators (WANO) which is a not-for-profit international organization with membership being mainly the owners and operators of NPPs. The WANO mission is to maximize safety and reliability of NPPs worldwide by working together to assess, benchmark and improve performance through mutual support, exchange of information and emulation of best practice.

In the aftermath of the Fukushima Daiichi Accident the industry came together to take the learning from the event and implement common set of improvement activities across the industry. This revised model is being implemented through the WANO 'Action for Excellence' programme with clearly defined goals based upon overall industry/plant performance improvement. The success of this programme and the wider WANO mission is, however, dependent on the engagement and support from within the nuclear industry by:

- Provision of appropriately experienced and trained staff to industry programmes;
- Member expertise support and challenge;
- Open sharing of data/information on events;
- Participation in benchmarking exercises and peer evaluations;
- Responding to feedback from benchmarking, peer review and other review findings.

Similarly, the success of any industry wide improvement programme associated with sustaining or improving operational excellence is dependent upon the engagement of the senior managers and leaders within the nuclear industry. Any improvement programme or project can only be effectively implemented if it is effectively owned by those who are responsible for its delivery.

The desire, capability, and ability of all NPP owner/operating organizations to engage and effectively participate in and effectively deploy these improvement programmes varies significantly. The main suggestion on industry interfaces in terms of institutional strength in depth to senior managers and leaders within the nuclear industry therefore is to take the responsibility to collectively come together to:

- Facilitate the delivery of these industry programmes;
- Challenge peers who are not effectively participating;
- Support those who are struggling with implementation;
- Work with industry interfaces to prioritise and effectively link the various improvement programmes so that the benefits are effectively optimised;
- Share data/information from events and good practices to facilitate wider learning.

5. LEARNING FROM GOOD PRACTICES

5.1. GOOD PRACTICES ON ISID IN THE NUCLEAR INDUSTRY

While key attributes of ISiD and effective management of external interfaces are discussed in the previous sections, it is understood that effective and efficient implementation is often difficult. Considering various external situations and limited resources it is important for the nuclear industry to clarify what should be preserved, deleted and/or changed among strategies and initiatives and to prioritize them well. Flexible and often very quick decision making is expected to senior management in owner/operating organizations of NPPs.

Here, good practices on ISiD in the nuclear industry are listed. The details including background, implemented initiatives, success factors, outcomes etc. are described in Appendices:

- Good practice on leadership, management, decision making, technical competence, and resilience in Japan: How four units at Fukushima Daini nuclear power station escaped core damage (AppendixI):
  - This describes how effective decision-making and necessary arrangements to save the plants were made based on strong technical competence, how they were supported by strong leadership, and why responders could be resilient under the overwhelming situations at Fukushima Daini nuclear power station in Japan on March 11, 2011 and after.
- Good practice on management system in the UK: Management system manual in EDF Energy UK Nuclear Generation (Appendix II):
  - This provides key success factors which enabled the management system to be understood well by the people in associated organizations and stakeholders, to be embedded in their minds and effectively implemented in the EDF Energy UK.
- Good practice on leadership development in the UK: Nuclear leadership programme in EDF Energy UK Nuclear Generation (Appendix III):
  - This provides key factors of successful implementation of the nuclear management development programme and operation shift manager development programme in EDF Energy UK. It includes flexible registration system, full involvement of executive/leadership teams, diverse participation, post-programme arrangement for gaining rapid direct benefits.
- Good practices on leadership, management, and others from Operational Safety Review Team (OSART) and Integrated Nuclear Infrastructure Review (INIR) (Appendix IV):
  - This provides the overview of good practices on leadership, management and others identified in the recent OSART and INIR missions of the IAEA.
- Good practice on decision making in France: EDF Safety Issues Assessment approach for effective decision making (Appendix V):

- This provides the case how EDF France assesses their safety issues and makes effective decision for implementing necessary design modifications. It describes the background, evaluation process, arrangement of groups, success factors and expected outcomes.

- Good practice on resilience in Japan: Organization's resilient performance to the unexpected at NPP as was seen in Fukushima Daiichi Accident. (Appendix VI):

  - This provides the study on what enables resilient performance to the unexpected of an NPP owner/operating organization and how its resilient capability can be enhanced by analysing resilient actions taken by the staff to avoid and mitigate the damage in the response to the Fukushima Daiichi Accident.

- Good practice on technical competence: Design authority in EDF France (Appendix VII):

  - This provides the case how a big fleet like EDF France maintains its technical competence and compliance with regulation through effective use of design authority function. It describes organizational arrangements for design authority, roles and responsibilities of design authority in design modifications and relevant works, interactions between design authority and other associated organizations in EDF and regulatory authority.

- Good practice on technical competence: Nuclear Engineering Support at Fortum in Finland (Appendix VIII):

  - This provides the case of Fortum in Finland, and especially describes why Fortum developed and is maintaining strong in-house nuclear engineering support with its history divided into three periods. It also clarifies its benefits support from the viewpoints of costs, operational reliability, safety, waste management and long-term operation (LTO).

- Good Practices on management and independent oversight in Japan: TEPCO's reform plan and nuclear safety oversight, nuclear industry reform and oversight of the regulatory body in Japan (Appendix IX):

  - This provides how TEPCO in Japan implements its organizational and cultural reform through establishment of internal independent oversight function and external oversight committees after the Fukushima Daiichi Accident. It also introduces how nuclear industry organizations were restructured to enhance utility-wide safety, risk management capability, interface with regulatory body, etc.

- Good practice on independent oversight in the UK: An inclusive approach to Independent Nuclear Safety Oversight (INSO) training to support improved organizational oversight defence-in-depthin EDF Nuclear Generation. (Appendix X):

  - This provides learning from EDF Nuclear Generation (NG) INSO training activities that points to relevance of this training, and INSO principles more generally, to others with safety oversight responsibilities, including leaders. The paper suggests that improved understanding of what constitutes effective organisational oversight defence-in-depth might be achieved through recognising these synergies, and in adopting an inclusive approach to associated training.

- Good practice on independent oversight in Slovakia (Appendix XI):

  - This provides an example of independent oversight function in Slovenske Elektrame (SE) in Slovakia. It was established as a part of the Performance Excellence Initiative, in which the drivers for excellence are clearly defined. Unique aspects include that effectiveness of nuclear oversight function is well monitored by indicators to understand how its ability influence plant safety and performance.

- Good practice on public stakeholder engagement in Japan: Stakeholder engagement in local government Fukui in Japan (Appendix XII):

  - This provides the case of Fukui Prefecture (local government) in Japan, in which it has been taking a role to bridge nuclear utilities, national regulatory body and local stakeholders for improving public trust on those nuclear-related organizations and their decision-making. Specific initiatives and their success factors are also discussed.

5.2. GOOD PRACTICES ON ISID FROM OTHER INDUSTRIES

Other industries are often more innovative and advanced not only technically but also in ways of thinking than the nuclear industry, and there are a lot of opportunities for learning from their practices. It is now more necessary for the nuclear industry to learn good practices and experience across organizations, industries and countries and apply them for its continuous improvement and even for survival.

Here, good practices from the aviation and oil and gas industries, that also need to manage large risks in the same way as the nuclear industry, are listed. The details including background, implemented initiatives, success factors, outcomes etc. are described in Appendices:

- Good practice on effective management of external interfaces in the US aviation industry: The power of collaboration to improve safety (Appendix XIII):

  - This provides good practice on effective collaboration among all stakeholders in the US aviation industry to improve safety. The Commercial Aviation Safety Team (CAST) is highlighted as a key initiative. The common goal of further reducing fatal rate was shared between industry stakeholders and regulators in CAST, and their voluntary efforts achieved the goal without any enhancement of regulation.

- Good practice on effective industry interfaces in oil and gas industry in Norway: (Appendix XIV):

  - This provides good practice on collaboration for developing and effectively using a common standard in oil and gas industry in Norway. This creates an environment where the industry continuously drives contractors to focus on performance improvement in a transparent manner.

6. CONCLUSIONS

The publication highlights that there were critical human and organizational factors which contributed to the Fukushima Daiichi Accident. Points of weakness within the institutional systems and governance were specifically highlighted as major gaps, especially evident in the wider nuclear safety system framework. However, the primary responsibility for safety of NPPs has to always reside with the owners/operating organisations of NPPs. This publication therefore explores the key attributes of ISiD to assist senior managers and leaders in NPP owner/operating organizations and other associated organizations in the nuclear industry to fulfil their obligations safely and effectively.

Three main courses of action are proposed:

- Make efforts to consider all the key attributes of ISiD discussed in Section 3 are fully understood at all levels of NPP owner/operating organizations and implemented with strong leadership. It is also important that these attributes are understood by all other associated organizations in the nuclear industry, and applied within and implemented in those organizations. When the attributes are implemented at-large by the entire nuclear industry in a harmonized and collaborative manner, ISiD will be further reinforced in order to continuously enhance safety and improve NPP performance.

- Focus on effectively developing and managing external interfaces. Senior managers and leaders of NPP owner/operating organizations are encouraged to remain aware that more critical issues that could lead to decline in plant safety and performance exist beyond plant management. It is believed these issues can be resolved most effectively through collaborations and discussions with stakeholders. Maintaining a systemic view and understanding the interrelationships between key organizations and how they are closely interlinked and reliant on others, is critical to nuclear system performance. If trust is developed and continuously maintained across these entities, a synergetic effect where the totality of all entities together, outperform how any would operate alone.

- Learn and apply the good practices from other companies, other countries and other industries. By more actively and proactively promoting opportunities for collaboration among them, synergies will yield benefit. The nuclear industry has great opportunities to improve its management system and decision-making capability by learning from others and allowing for risks to be explored in situations where it is safe to fail (e.g., through institutionalized training and development protocols and programs). It may also extract more potential of synergies between organizations within the nuclear industry and with external stakeholders.

APPENDIX I.
GOOD PRACTICE ON LEADERSHIP, MANAGEMENT, DECISION MAKING, TECHNICAL COMPETENCE, AND RESILIENCE IN JAPAN: HOW FOUR UNITS AT FUKUSHIMA DAINI NUCLEAR POWER STATION ESCAPED CORE DAMAGE

Fukushima Daini, nuclear power station located 12 km south of Fukushima Daiichi nuclear power station, consists of four BWR 5 reactors. All four units were operating at full power when earthquake hit and triggered automatic scram. Tsunami damage was less severe as compared with Daiichi. AC and DC power were available (one local AC line was intact, Electric Equipment Room was not flooded except unit 1), but, as was identified by immediate walkdown, ultimate heat sink (UHS) was lost for unit 1,2,4 due to damage to seawater pump motors by tsunami.

Senior site managers decided on a strategy to depressurizing the reactors using the safety relief valves and to maintain reactor coolant inventory by Reactor Core Isolation Cooling (RCIC), and later High Pressure Core Spray (HPCI) and Make-Up Water Condensate (MUWC). However, with no decay heat removal capability, Suppression pool water temperatures on Units 1, 2 and 4 gradually increased. Having in-depth knowledge of the electrical distribution system including plant manager, they developed plans for emergency procurement and replacement of seawater pump motors and installation of temporary cable to power the pumps from electrical distribution panels in the radioactive waste treatment building to other buildings located at the ocean front (the total length of installed cable was 9 km). Corporate procurement personnel located motors at the Toshiba factory and at the TEPCO's Kashiwazaki Kariwa nuclear power station (more than 300 km away), identified a source of the needed cable, and arranged for transportation to the site. Transportation was not easy due to some roads damaged by the earthquake and helicopter was also used. Installation of approximately 9 km of temporary cables was completed in one day, which would usually necessitate 20 personnel for a month, and replacement of pump motors finished as well. Beginning in the early morning of 14 March, decay heat removal was sequentially restored until cold shutdown of all units on 15 March.

INPO Lesson Learned report [6] recommends leaders to establish, early in the response to an event, clear strategies for core cooling and recovery actions, and to communicate to the main control room and personnel in the emergency response centre while establishing priorities and providing direction and oversight to enable the strategy to be implemented effectively.

The plant manager later raised success factors for crisis management at Fukushima Daini nuclear power station as:

- Teamwork and dedication;
- Sharing information among people involved in emergency response;
- Making everyone feel that they are making progress;

Harvard Business School picked up this in the case study as 'adaptive behaviour' called 'sense-making' and described the plant manager offered data, giving the workers an opportunity to confront and process the uncertainty for themselves.

APPENDIX II.
GOOD PRACTICE ON MANAGEMENT SYSTEM IN THE UK: MANAGEMENT SYSTEM MANUAL IN EDF ENERGY UK NUCLEAR GENERATION

A management system manual has been developed which sets out clearly how the Nuclear Generation business operates. This includes all the necessary core elements of a management system from the vision, mission, and key policies to individual responsibilities, governance arrangements and documentation structure. In addition, the following key elements have been identified as good practice:

- The document is maintained as a live document and is updated in line with all organisational changes;
- The document is structured to allow effective linkage to all supporting documents thereby maintain a consistent framework across the organisation i.e., there is effective link form the policy document, company standards and specifications to the working documents thereby enabling clarity and configuration control;
- The management system is expansive and provides linkage to relationship with all key stakeholders including regulator, key suppliers and public;
- Training is provided on the management system to all staff to help provide clarity on their role, expected behaviours, interfaces as well as providing clarity on how the organisation functions.

APPENDIX III.
GOOD PRACTICE ON LEADERSHIP DEVELOPMENT IN THE UK: NUCLEAR LEADERSHIP PROGRAMME IN EDF ENERGY UK NUCLEAR GENERATION

A comprehensive, and detailed nuclear leadership program has been effectively deployed to all leaders and emerging leaders. As well as generic leadership principles and models the program also targeted important nuclear leadership principles and behaviours.

In 2008 EDF Energy UK Nuclear Generation were experiencing mixed performance across the fleet, some plants were having significantly higher plant losses and more safety events than others. Considerable work had been undertaken on improving technical processes over the preceding 5 years and although overall performance had improved it was acknowledged even more could be done by helping every plant to deliver their full potential. It was decided to launch the EDF Energy leadership academy, believing that excellent leadership would be the catalyst for change.

The leadership program was not compulsory, the view was that the leadership program needed to be so good that people would leave them informed and energized and encourage colleagues to sign up i.e., leveraging the power of positive reinforcement.

The initial programme comprised of three one-week workshops.

The key success factors of the program were:

- It was fully supported by the executive team who actively participated in training modules, attended as delegates, and openly shared their experiences and stories;
- The programme was actively supported by the power station leadership teams. Everyday managers from the plant visited the programme to show support to their staff who were attending the programme;
- The comprehensive nature of the programme i.e., all leaders were involved including leaders from within the wider supply chain;
- Cross functional participation in workshops to help break the silo attitudes within departments. Different levels of leaders from different cross functional areas learnt together;
- There was a social element to the programme to help break down barriers and create a positive learning environment.

Upon completion of the program people applied the knowledge back at work under the guidance of a mentor. Each cohort was given a ‘director’s challenge’ where they were set to work to solve a real plant problem. This enabled the success of the program to be directly measured as well as providing rapid direct benefits.

The overall success of the program was demonstrated through a sustained improvement in top tier safety and performance metrics over a sustained period of time.

This has subsequently evolved into a systematic approach to leadership and behavioural interventions through identifying performance gaps through trends in condition reports, engagement surveys, Significant Operation Event Reports (SOERs) and bespoke leadership survey for leaders. This has been feedback into the initial and continuing leadership programs.

The program is also structured to support leaders on their leadership journey with effective linkage to international leadership development programs and targeted interventions for key groups e.g. The shift manager development program which has been organized in association with WANO Paris Centre.

The role of the shift manager is unique in the nuclear industry and requires individual who, by their commitment and example, inspire coach and influence people to achieve excellence in nuclear operations.

This role extends across shift teams and bridges the wider organization. shift managers are key players in ensuring excellence in plant operation and in diving operational focus. Their operational leadership directly influences safe and reliable plant performance.

The objective of the program is to bring together Ihift managers from diverse plants and cultures in an environment where they will gain new insights and hone their skills through interactions and learning exchange with other shift managers and experienced leadership behavioural facilitators.

APPENDIX IV.
GOOD PRACTICE ON LEADERSHIP, MANAGEMENT AND OTHERS AS WERE IDENTIFIED IN OSART AND INIR MISSIONS

IV.1. GOOD PRACTICE ON MANAGEMENT SYSTEM FROM OSART MISSION (BRUCE B, CANADA)

Use of a visual management board (VMB) together with daily meetings are used to communicate safety related issues and align the organization's priorities in a consistent manner.

The VMBs facilitate an increase in a leader lead discussion with staff to reinforce the safety-first message, company values and increase staff awareness of their contributions to overall safety performance. The objective of the VMB is to provide a standardized, visual focal point for organizing information used to display the current status of:

- Safety messages and employee concerns including nuclear, industrial, radiological and environmental safety;
- Plant conditions and crew specific station condition records. Work crew/section/department expectations, targets and priorities;
- Planned work for the next three days. Other crew specific information such as human performance, training, and radiation protection.

Currently a couple of hundred VMBs are actively used across the plant. Since inception of the VMB process, more than 9000 formal VMB observations have been documented in the observation and coaching database. During initial leader training, the VMB process and expectations are reviewed with the trainer leading the attendees through a simulated VMB meeting.

IV.2. GOOD PRACTICE ON HUMAN RESOURCE MANAGEMENT FROM OSART MISSION (ARKANSAS, USA)

The established human performance program effectively supports the culture of continuous improvement. The plant has a focus on behavioural improvements that result in prompt feedback that drives continuous improvements. The focus on behavioural improvements is evident throughout the organization including the management positions and individual contributors. Feedback is provided and accepted freely. The feedback occurs from supervisor to individual contributor, from peer to peer and from individual contributor to supervisor. The behavioural focus has become engrained in the fleet culture where emphasis is placed not only on what is done but how it is done, and the behaviours exhibited. Behavioural feedback has become natural, accepted, and even sought by all levels of staff and contractors.

Various tools are utilized to provide structure for the behavioural improvements. For example, leadership effectiveness logbooks are utilized as a simple means to document the coaching interaction. Goals are utilized on the number of interactions to help ensure interactions occur. The database is used to analyse the data for trends. During refuel outages the data is compiled and analysed daily. Behaviour improvement messages are formulated based on the analysis. The message is communicated daily and represents the focus area for the next days' coaching. The subsequent days' data analysis is a means of checking for penetration of the message.

The mental and physical wellbeing of the employees is monitored by observation of their behaviours. By observation of the employee, the supervisor establishes a baseline of behaviours. The supervisor observes for deviations from the established norm. Supervisors are trained annually on what behaviours to observe. All employees (including contractors) are covered by this programme.

The foundation for the human performance programme is based on formal procedures. The procedures describe the roles and responsibilities as well as the process elements. The procedures also describe the various behavioural traps (time pressure, shift change, etc.) and provide tools (self-check, peer check, etc.) to counteract the traps.

The fundamental benefit of the focus on improving behaviours is that it results in a culture of continuous improvement. The free flow of behavioural feedback both reinforcement (positive) and correction (negative) results in continuously driving to new levels of performance. Errors are reduced and thus plant performance improved because of the feedback on human performance. Employee well-being is improved because of early identifications of behavioural issues. Corrections are made before significant consequences are experienced. Additionally, the human performance programme fosters an environment which encourages the development of complementary programmes within the plant.

IV.3. GOOD PRACTICES ON LEADERSHIP FROM OSART MISSION (BARAKAH, UAE)

A leadership development programme adapted to the multi-cultural, multi-national nature of the organization, to ensure that the cultural diversity is addressed, maintained, and leveraged to build strong teams with a focus on safe operation of the plant was established.

The Excellence in Nuclear Leadership Programme (EiNLP) is a leadership development programme implemented in 2016 to define and reinforce the plant leadership fundamentals and behavioural expectations irrespective of experience either in Western or Korean power plants.

While grounded on the INPO leadership attributes, this safety-focused development programme aims at reinforcing the plant espoused leadership competencies for an organization that is Emirati-led, multicultural and multinational.

The programme is a strategic initiative designed to harness the culture of safety principles and leadership skills and create robust organizational leadership capabilities for the safe operation of the plant. Some of its unique differentiators compared to other leadership programs are:

- Leaders Teaching Leaders: Leadership engagement in the programme implementation is key to its success. As such, executives, senior management and subject matter experts are facilitating several modules throughout the programme and sharing their nuclear knowledge and experience as well as their anecdotal stories with the organization. In addition to the line managers, each leadership cohort or class has an assigned executive sponsor to support the learning journey;
- Experiential Learning or Learning by Doing: a foundational principle for the programme is offering leaders the opportunity to practice their new skills and tools at the workplace to ensure the Return on Investment (ROI);
- Multi-Cultural Program: In the context of the multi-cultural, multi-national nature of the organization, the programme participants are carefully selected to ensure that the cultural diversity is addressed, maintained and leveraged to build strong teams with a focus on safe operation of the plant;
- Diagonal or Vertical Slice: Implementation of leadership cohorts with participants from different functions and different levels of hierarchy (heads, managers, directors and senior executives).

IV.4. GOOD PRACTICE ON INDEPENDENT OVERSIGHT FROM OSART MISSION (EDF)

Nuclear Inspectorate in DPN (Division of Nuclear Power at EdF) and overall review process EGCI in DIN (Division of Nuclear Engineering at EdF) provide independent assessment by a highly competent and experienced staff, whose insights are acted upon by line management. Nuclear Inspectorate (NI) conducts a full-scope Overall Excellence Assessments (EGE) covering a broad scope of 13 functional areas. This function is resourced by 40 staff members of specific expertise with acquired experience and training. NI conducts EGEs on a 4-year cycle on all NPPs, and the EGEs are coordinated with WANO peer reviws and are conducted with highly competent staff experienced in operation. Assessors are highly respected by both station managers and corporate senior managers. NI authorities laid down in DPN quality management document, sub process for “Risk Management and Internal Control “- NL PIL 90 N, N PIL 100 N, and MP1 defines duties, responsibilities and authorities for on escalation process with NI. NI management manual procedure on qualification of all NI staff requires Maximum four years term for inspectors in independent assessment group of NI, Minimum requirements for NI staff include at least 5 years of operational experience on NPPs, and Team Leaders are required to have held a senior managerial position on an NPP.

Independent assessment of all engineering centres is carried out within engineering division (DIN). Independent verification process ensures that all plant modifications are well defined and performed in such a way as to ensure safety is the overriding priority and thus strengthening the role of design authority. Significant design changes and modifications are evaluated and approved in CSNC (Committee for Nuclear Safety at the design stage). All engineering centres are systematically reviewed by independent assessors every three years using the EGCI. The EGCI external independent assessment team focuses on safety issues in engineering activities. The team consists of well qualified and experienced staff with experience in plant operation as well as engineering. Independent audits are also performed as topical inspections based on management request. The effectiveness of EGCI independent assessments is reviewed on an annual basis during DIN Nuclear Safety Management Review process and during analysis of events.

Benefits are: Highly competent staff whose independent assessments are regarded by line managers, and this provide value to operational safety improvement. The DPN, DIN, CSNE (Committee for Nuclear Safety during operation) are provided with diverse information by independent assessment line on safety issues as needed. The EDF structure and arrangements ensure that corporate independent assessment line has a duty to raise significant safety issues to IGSNR (Body that reports directly to the Chairman of EDF its assessment of nuclear safety and radiation protection within the EDF Group) and thus escalate any safety concern. The EGE functional areas reviews are well coordinated with WANO Peer reviews in four-year cycles and EGCI reviews are performed every three years. The EDF mobility program and rotation of experience staff between corporate assessment units and line management promotes self-assessment activities and ensures highly competent assessors for EGE and EGCI reviews.

IV.5. GOOD PRACTICES ON TECHNICAL COMPETENCE FROM OSART MISSION (BUGEY, FRANCE)

The plant’s training department has used digital technologies in an innovative way to reinforce the use of human performance (HU) tools. The plant has utilized digital technologies to improve the quality of its human performance training. The 3D immersion technology and camera goggles are used to complement initial and refresher training. These technologies have also enabled greater feedback from the instructor to trainees on the use of error prevention tools:

- *3D immersion technology and virtual reality:* The use of 3D immersion technology allows trainees to apply HU tools in a totally modelled environment, fully immersed, without exposing them to any kind of risks. The virtual consequence of not using these tools properly will be experienced by the trainee and will reinforce the importance of using HU tools when performing tasks in the field. The current set of scenarios are designed to reinforce the use of self-check, peer check, situational awareness, and 3-way communication. This will be further developed in 2018, applying it to the plant's industrial premises (water-filled systems, relays, electrical panels, etc), thereby directly connecting 3D training to the plant environment. It can also be tailored to the various plant departments. The modelling costs are similar to those of a real mockup and this virtual tool can be used throughout a fleet, which would limit the additional deployment costs to those of the computer and headset purchase.
- *Camera goggles:* The plant training department has developed video googles for use during training of HU champions. The videos are used to replicate the activity as experienced by the trainee, showing what he/she has actually seen, said and heard. The goggles can be operated by the instructor using WIFI. The videos are subsequently viewed during post training critique.

IV.6. GOOD PRACTICE ON ESTABLISHED CLUSTERS TO IMPROVE KNOWLEDGE AND SKILLS FROM OSART MISSION (OLKILUOTO, FINLAND)

Plant systems, structures and components have been divided into 20 groups, called clusters. A cluster is a 'know how' entity group of technical people that can support each other due to similarities in their technical skills. Clusters do not substitute in-depth training on European pressurized reactor (EPR) technology. However, they can be a very useful tool for collecting and sharing knowledge on particular systems. A cluster consists of a multidisciplinary team of people responsible for systems, modifications, and components. Depending on the level of criticality of the systems, responsibilities have been shared in some cases with five different people. Each cluster has a named responsible person who oversees the cluster. Status of development in the clusters is reported to upper management three times a year.

The observed benefits of clusters are:

- New staff in engineering and maintenance have a support network from different expertise areas. Familiarization and training needs are identified, and knowledge transfer is done inside the clusters. Assuring the competence of the clusters is described in the picture;
- Reduced individual work load sharing their tasks with other individuals and ensuring that knowledge and competences are not resting on single individuals;
- The management of the clusters documentation and changes needed in the plant configuration are identified faster than previously;
- Progress follow-up and traceability of remaining tasks are clearer than before;
- Competences and knowledge are shared between several people who can support each other.

IV.7. GOOD PRACTICE ON ESTABLISHMENT OF DESIGN AUTHORITY FROM INIR MISSION (BARAKAH, UAE)

The establishment of a strong engineering team within Nawah, which will evolve to become the plant design authority, supported by design transfer arrangements and participation on Korea Electric Power Corporation's (KEPCO's) design interface control board.

The Nawah site engineering team has the role of ensuring the control of the plant's design basis; it will eventually become the plant design authority. The site engineering team collaborates with Emirates Nuclear Energy Corporation (ENEC)'s engineering group of the chief programme office, that is originated from ENEC's chief nuclear officer engineering group.

The site engineering team:

- Ensures alignment with top industry standards of equipment reliability to minimize equipment failures that could impact the safe, reliable and cost-effective operation of the plant;
- Establishes programmes and processes that verify, through monitoring, inspection and testing, that the plant structures, systems and components remain within their design limits and where appropriate, that allow the identification of actions to maintain adequate design margins;
- Establishes the programmes and processes required to ensure that design changes are performed in a controlled manner, that their impacts on the original design basis is assessed and documented, and that the plant configuration is maintained; and
- Maintains control of plant design, configuration management, and other programmes necessary to protect the safety of employees, the public, plant assets and the environment, and to meet regulatory commitments throughout the plant life cycle.

The design authority role and functions are under development, with a target of being fully established by unit 1 operating license approval. The Site Engineering group currently consists of 48 engineers with an average experience of 20 years. There is a plan to increase the number of staff up to 78. An agreement between all design stakeholders has been concluded, whereby Nawah receives prior notification of proposed design changes to the Units under KEPCO design authority control, for operational impact input and assessment, e.g., revision and necessary updates to procedures, training, and the simulators, before such approved changes are implemented.

IV.8. GOOD PRACTICE ON RISK MANAGEMENT AND CRISIS MANAGEMENT FROM INIR MISSION (BELARUSIAN NPP, BELARUS)

Effective coordination and systematic approach in developing, reviewing, testing, updating emergency and contingency plans and training at all levels for all organizations involved has been established in Belarusian Nuclear Power Plant (BNPP).

The emergency exercise planning is completed within a five-year planning cycle with the current programme. During the exercises the response and actions of the government bodies and forces of the state emergency service, as well as Belarusian NPP were assessed including regulatory oversight from GAN (the nuclear regulatory body in Belarus). The exercise reports included the identification of areas for improvement were used to review and amend the off-site and on-site emergency plans and to further develop the training of emergency response personnel. Belarusian NPP has a regular programme of training, drills and exercises of varying scope and frequency. There is an annual plant wide drill more frequent department drills covering all shifts. GAN monitors and observes on-site emergency exercises using approved GAN guidance.

APPENDIX V.
GOOD PRACTICE ON DECISION MAKING IN FRANCE: EDF SAFETY ISSUES ASSESSMENT APPROACH FOR EFFECTIVE DECISION MAKING

V.1. BACKGROUND

As part of long-term operation of the French NPP fleet, EDF is facing a challenging program of design modifications in order to fulfil high level safety requirements and aim towards Generation 3 (GEN3) safety goals.

In this context, an effective and objective decision-making process that considers all relevant factors (safety of the design, human and operational factors, security, environment protection, costs) will be a key to select, prioritize appropriate design and operational options when looking at improving plant safety levels. In order to set-up such approach, EDF has developed with other nuclear industry operators a method for Safety Issues Assessment which relies on a set of criteria and items reviewed by a multi-skilled pluri-disciplinary group. Figure 11 shows the process.

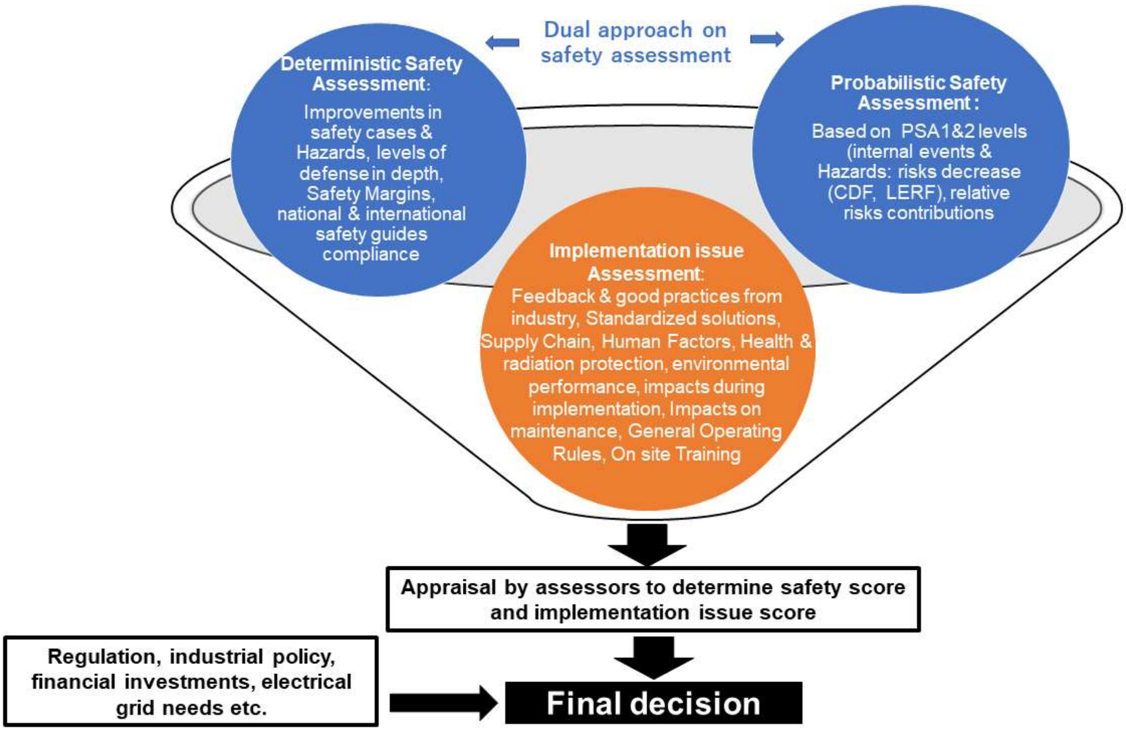

FIG. 11. Safety and implementation Issues Assessment and decision-making. (Courtesy of Électricité de France)

V.2. PLURI-DIMENSIONAL EVALUATION OF MODIFICATIONS IMPACTS

EDF has been working on a common approach with the French nuclear facility operators (Commissariat à l'énergie atomique et aux énergies alternatives (CEA), ORANO, FRAMATOME). This allowed to define robust general criteria adaptable to different types of plants configurations or nuclear facilities. The result of this work has been documented in a guide approved by all the operators and communicated to the French regulator (ASN). The method relies on a pluri-dimensional evaluation of modification impacts:

- Plant components or systems' changes as well as operating procedures' modifications are considered.

It has to be pointed out that PSA calculations undergo an iterative process with design modifications. The PSA assessment will therefore become progressively more and more accurate as the periodic safety review (PSR) process is performed. Engineering judgement, skilled knowledge of safety sequences and lessons drawn from similar PSA performed on other similar NPP series are useful tools at early stages of the assessment.

The issues of the different categories are appreciated by a group of 'assessors' who will bring, everyone on his scope, the required skills to give a global appreciation of the issues, stepping back from a strict approach relying on quantitative criteria.

The group will gather project engineers, systems designers as well as safety oversight representatives, such as design authority. The goal is to have an assessment which will be challenged from the various points of view and the results are to be commented, in order to avoid restrictive understanding of the exercise or partial considerations.

The different criteria and quantified results cannot be valued on their own; they have to be reviewed by the assessment group.

Finally, it has to be pointed out that the present approach should not be taken as the only parameter in decision-making: regulation aspects, industrial policy, financial investments, electrical grid needs may enter into account in the final decision.

V.3. PRACTICAL APPLICATIONS IN PSR

The safety issues and impacts are appreciated at every stage of the PSR program build-up:

- Decide if a modification brings enough safety benefit with acceptable impacts on site;
- Select between various options, which one is the most adequate;
- Set a safety prioritization for appropriate timely implementation of the modifications on the NPP.

On the last point, it has to be underlined that an LTO PSR on EDF French NPP fleet represents more than 150 modifications. The associated works and operating changes have to be progressively implemented in order to have a sustainable industrial program in terms of amount of work to be performed on an outage and successive manageable steps for the staff on site to integrate operating procedures changes and plant modifications. The issues assessment brings an insight which looks both at safety benefits in terms of design as well as operational aspects, some of them potentially affecting safety: an increased complexity in operation would be an aspect to be carefully monitored.

The scoring baseline adopted for this application is given in Figures 12 and 13, and is organized in three levels: high, medium, limited benefit or impact.

The operational aspects are focused on industrial aspects and on-site impacts.

In the present example, the costs are not part of the exercise at this stage of PSR, since the design/operating changes options have been reviewed and selected.

Safety issue scoring	Criteria
3 – High	✓ Modifications contributing to **a safety criterion fulfilment for accident studies** ✓ Modifications contributing to **a safety goal in hazards studies** ✓ Modification **stemming from key lessons of Level 1/Level 2 PSA[11] studies**
2 - Medium	✓ Modifications increasing **safety margins for situations close to safety criteria** ✓ Modifications **bringing margins towards cliff-edge effects**
1 – Low	✓ Modifications for **extreme residual risks**
0 – Negligible/None	✓ Modification **with negligible/no safety issues**

FIG. 12. Assessment of safety issues.
(Courtesy of Électricité de France)

Operational issue scoring	Criteria
3 - High	Items to be assessed on a scale going from low to high: ✓ Operator **training** (practical and theoretical) ✓ **S.I. tools (renewal, up-date)/Human Machine Interface** ✓ Volume and frequency of **operating/maintenance activities/new components** or **technology** ✓ Operational **burden:** on site organisation impacts, health and radiation protection, operating rules, activities planning ✓ **Co-activities, physical access, physical modifications of the components** ✓ **Plan Operation during modification works**
2 – Medium	
1 – Low	
0 – Negligible/None	No new operating activities and no evolution of existing operating activities

FIG. 13. Assessment of operational impacts.
(Courtesy of Électricité de France)

V.4. OUTCOMES AND BENEFITS

The safety issues assessment approach has been co-developed by the various nuclear operators, which enables to have a generic method which may be adapted to the different types of plants at various steps of their operating life.

As far as EDF is concerned, one field of application is PSR.

The success factors are:

- Developing PSA studies covering internal events as well as major relevant hazards for the plant (typically fire, flooding, explosion);

[11] Level 1 PSA assesses the probabilities of core melting risk. Level 2 PSA assesses probabilities of radiological consequences risks

- Drawing lessons from PSA calculations, going beyond absolute numerical values of risks: seek for balanced contributors to the global core damage frequency (CDF), large early release frequency (LERP), track relative weight of sequences within a given family of events;
- Having as objective as possible criteria to appreciate on site impacts, in order to measure operational aspects which may be challenging on site and may require time for implementation;
- Relying on a pluri-disciplinary group to draw recommendations from the assessment;
- Associating as early as possible the NPP to be part of the assessment and fully aware about issues and impacts in the decision making process.

The expected key outcomes are listed as follows:

- Safety and operational issues assessment including the impact on NPP operation and potential additional complexity for the operator which can been seen as a 'cost' of the modifications;
- Factual analysis on design changes choices or renouncements or change to an ~~on~~ adequate implementation planning, considering impacts on site. The results can be submitted to the regulator to justify industrial choices performed by the operator;
- Definition of standardized batches of modifications in order to obtain high reliability in modifications implementation, by repeated operations on site and professionalization of the industrial partners in charge of performing works on site.

This approach can also be used for different needs:

- Assess individual design modifications or operating changes. This enables to select the relevant options to be implemented, take investment decisions and submit design evolutions to the regulator, based on objective technical facts;
- Set up timely implementation of modifications;
- Develop new NPP design: compare various design options and select the ones that provide the best performance and safety level;
- Select strategies for clean-up or dismantling activities, by comparing various options according to safety issues, industrial constraints and schedule.

APPENDIX VI.
GOOD PRACTICE ON RESILIENCE IN JAPAN: GOOD PRACTICES LEARNED AT FUKUSHIMA DAIICHI NUCLEAR POWER STATION TO MITIGATE DAMAGE AND IMPROVE PERFORMANCE THROUGH RESILIENCE

VI.1. INTRODUCTION

What enables resilient performance of an organization and how can an NPP enhance its resilience to maintain safety and performance even in the face of unexpected situations for maintaining safety? This appendix describes the study that sought answers to the above questions. It analysed a number of the resilient countermeasures employed by the staff of the Fukushima Daiichi nuclear power station to avoid and mitigate the damage when the plants were hit by the big earthquake and tsunami on March 11, 2011.

Although many of the countermeasures that were taken to respond to the Fukushima Daiichi Accident did not prevent the meltdown of reactor cores and hydrogen explosions, several good practices and demonstrations of resilient actions were seen. These actions taken by the responders and others, helped to avoid the further progression of the accident and mitigate the damage. In this appendix, some practices, picked up from Ref. [54] and [55], are introduced including the education and training that contributed to these resilient actions, all of that were conducted in a severely abnormal situation and with little time to consider, think and act. All of these aspects contributing to resilient performance are analysed in this study.

VI.2. EXAMPLES OF GOOD PRACTICES FOR RESILIENCE IN THE FUKUSHIMA-DAIICHI ACCIDENT

VI.2.1. Good practice 1: Securing water injection line by fire engines for Units 1 and 2

Although water injection into reactor vessel using available electric power was described in emergency operation procedure, no AC and DC power was available due to the strong shock of earthquake and the following big tsunami, the plant staff came up with an alternative method to inject water from fire protection water tanks by fire engines to cool the cores.

Enabling factors of this good practice were:

- Education of operators on the alternative countermeasures that are parts of accident managements to respond to emergency situations including core cooling using fire protection system; and
- Shared knowledge from the experience of Niigata Chuetsu-oki earthquake at Kashiwazaki Kariwa nuclear power station in 2007 that piping systems including fire protection system located inside the reactor buildings were intact and survived the big earthquake[12].

[12] Important plant damages were transformer fire caused by relative displacement between building and structure, and spill-over of water from the spent fuel pool due to sloshing.

VI.2.2. Good practice 2: Using automobile batteries to open main steam safety relief valves (SRVs) to depressurize reactor pressure vessel and to restore instrumentation

Depressurization of reactor pressure vessel is necessary to enable injection of water using low pressure system such as fire engine. However, DC power to actuate solenoid valves of these safety relief valves was unavailable due to flooding of battery room. Operators collected batteries from automobiles, brought them to the main control rooms, and produced DC power necessary to open the solenoid valves as well as for instrumentation to monitor the condition of reactors.

Enabling factors of this good practice were:

- Education of the specifications of power supply system to open SRV; and
- Flexible thinking to come up with non-conventional method to save the plant.

VI.2.3. Good practice 3: Emergency undocking of a tanker

At the time of big shock of the earthquake, a heavy oil tanker docked on a berth adjacent to Units 5 and 6 and was refuelling to a tank through the pipeline. Before stating the work in the day, workers in the toolbox meeting (TBM) discussed what to do and how (procedure) to minimize the risk in case tsunami hit the tanker, by considering the possible earthquake and tsunami which hit the area two days before. (This magnitude 7.3 Sanriku-oki earthquake on March 9 in the north is considered as a foreshock of the magnitude 9.0 earthquake on March 11.) After feeling a big shock, the workers thought that a tsunami induced by the big shock might come and took counsel with the captain of the tanker. The captain decided to take an emergency undocking to evacuate the tanker from the port in preparation for possible tsunami that may follow, so that oil may not leak out and the tanker may not to be washed up onto the land and damage various facilities and tanks installed there. Although the pipeline is blown to remove the oil inside pipes and the oil fences surrounding the tanker are collected by boats in the normal undocking procedure, the workers skipped blowing the pipeline and abandoned to collect the oil fences by boats from the viewpoint of emergency and decided to cut them. The tanker successfully evacuated off the coast because of both the decision and skilful ship handling.

Enabling factors of this good practice were:

- Education and training for undocking a tanker in emergency;
- Foreseeing what may happen after a big earthquake; and
- The traits of organizing a TBM to confirm emergency procedures before starting the day's work.

VI.2.4. Good practice 4: Drilling vent holes of reactor buildings of Units 5 and 6

When 3.11 earthquake (magnitude 9.0) hit Fukushima Daiichi nuclear power station, both units 5 and 6 were finishing refuelling outage and ready to restart with reactor pressure vessel head closed. Although power from air-cooled diesel generator (DG) and water supply to the reactors were available, ultimate heat sink to cool reactors was not fully ensured. In light of the possible (not yet determined as such then) hydrogen explosions occurred at units 1, 3, and 4, operators at units 5 and 6 considered that hydrogen explosion was possible in units 5 and 6 in case core damage occurred. Then, the plant staff drilled vent holes of reactor buildings of units 5 and 6 to release the hydrogen that might accumulate in the buildings with the voluntary help from the director of a local construction company in high dose condition. The resilient decision was made because the plant staff came to mind the possibility of hydrogen explosion. In addition, they suitably estimated the amount of hydrogen generated considering the small residual heat compared with those of units 1 to 3.

Enabling factors of this good practice were:

- Education of possible phenomena that may happen at NPPs such as Zr-water reaction and explosion limit of hydrogen; and
- Flexible thinking to come up with non-conventional method to save the plant.

VI.3. COMMON SUCCESS FACTORS FOR RESILIENT ACTIONS EXTRACTED FROM THE GOOD PRACTICES

By analysing the good practices conducted in the Great East Japan Earthquakes including the ones introduced above, several success factors (patterns) in common that enabled resilient (flexible) actions were found:

- Foreseeing accurately the future progress of the event and taking actions beforehand based on the knowledge, experiences and assessment of the current situation;
- Anticipating possible threats in the future and taking countermeasures proactively when there is spare time to do so;
- Understanding that the prepared countermeasures have little effects and then coming up with and conducting new non-conventional countermeasures to face the threats; and
- Making a suitable decision with sacrifices in the case that all available countermeasures have undesired influences.

VI.4. EDUCATION AND TRAINING TO BE STRENGTHENED

Based on this analysis, the following education and training programs for the staff of emergency room and plant operators should be strengthened to make them act resiliently in unexpected conditions:

- Sharing the knowledge on the events and plant behaviors in response that are caused by the past natural disasters and accidents;
- Education of the integrated specific knowledge on working principle, conditions, and effects of systems and components of NPPs;
- Education of emergency operation procedures and severe accident management guidelines along with their critical points and technical background;
- Training of emergency operation procedures to assure successful implementation of the procedures even in a high mental stress condition; and
- Sharing the knowledge of findings in other utilities and research institutes.

APPENDIX VII.
GOOD PRACTICE ON TECHNICAL COMPETENCE IN FRANCE: DESIGN AUTHORITY FOR EDF FRENCH NUCLEAR FLEET

VII.1. DESIGN AUTHORITY SET-UP AT EDF

Design changes occur regularly over the plant's operating lifetime: international feedback (e.g. ultimate diesel generator after Fukushima), safety level enhancement through periodic safety reviews (e.g. dedicated cooling system in case of core melting), fuel management optimization (e.g. additional control rods for mixed oxide (MOX) fuel introduction).

To maintain a high level of safety, it is necessary to check that the modifications are consistent with the plant design, do not have negative side-effects and do not excessively increase the complexity of the plant operation or systems maintenance.

This has been driven EDF to set-up a rigorous plants modification process and to create a design authority, in accordance with the INSAG-19 principles.

VII.2. EDF NUCLEAR ACTIVITIES ORGANIZATION AND DESIGN AUTHORITY POSITION

Since the French nuclear program launch, nuclear activities were organized around two key finalities: nuclear generation and nuclear engineering.

In March 2015, the nuclear activities were reorganized in two divisions, attached to chief executive officer (CEO):

- One division is dedicated to power generation (DPNT), covering nuclear generation, nuclear fuel, projects on existing fleet (major refit program for long term operation) and engineering for existing fleet;
- The other division is in charge of the new build (DIPNN), covering new projects and specialized engineering centers.

The key principles for setting up EDF design authority were:

- The design authority has to be next to the NPP operator, in order to be visible and audible. The design authority belongs to the DPNT division;
- The design authority has to be independent from NPP Generation issues;
- The design authority has to be placed within a technical environment covering design and related safety skills.

As a result, EDF opted for a design authority based within nuclear engineering division (DIPDE), but strongly connected with the engineering centres, who are designated responsible designers in their respective technical fields: reactor physics and thermal hydraulics for safety studies, conventional island and heat sink, components manufacturing, nuclear island systems and hazards safety studies.

The design authority and responsible designers have formally described their roles and responsibilities.

VII.3. MODIFICATION PROCESS

The modification process is structured in various successive mandatory steps: goal of the modification, design studies, risk analysis through a cross-impacts list (safety classification, protection against hazards, electrical architecture, impacts on civil work, requalification …), human factor and organizational impacts, safety documentation changes in terms of general operating rules (GOR) (technical specifications, periodic systems testing and incidental and accidental procedures) and safety analysis report (SAR) content.

According to the modification relevance towards safety, different levels of validations are possible, with an escalation approach, according to the safety issue:

- Technical committee, headed by the project for minor modifications, with attendance of the design authority and the responsible designers;
- Design Integrity meeting, co-chaired by head of design authority and responsible designer, with participation of engineers from the different specialized engineering centers and the project;
- GOR committee, with participation of engineers from the different specialized engineering centers, the project, the operator;
- Safety Review Board, chaired by the head of the nuclear generation division, technically assisted by the design authority.

As part of EDF internal control of the modifications, the final design of all significant modifications is independently checked before Safety Authority information or submittal.

VII.4. DESIGN AUTHORITY MISSIONS

The design authority is organized around two assignments:

- Technical advice, assisting the operator in its decisions on plants modifications, by bringing awareness of the global on-going activities on design changes, safety authority relationships and operation technical feedbacks;
- Technical control of the modifications at key steps of the engineering process, in order to guaranty design integrity, during all the nuclear plants operating time.

The organization is shown in Fig. 14 with four groups and a technical pole for safety.

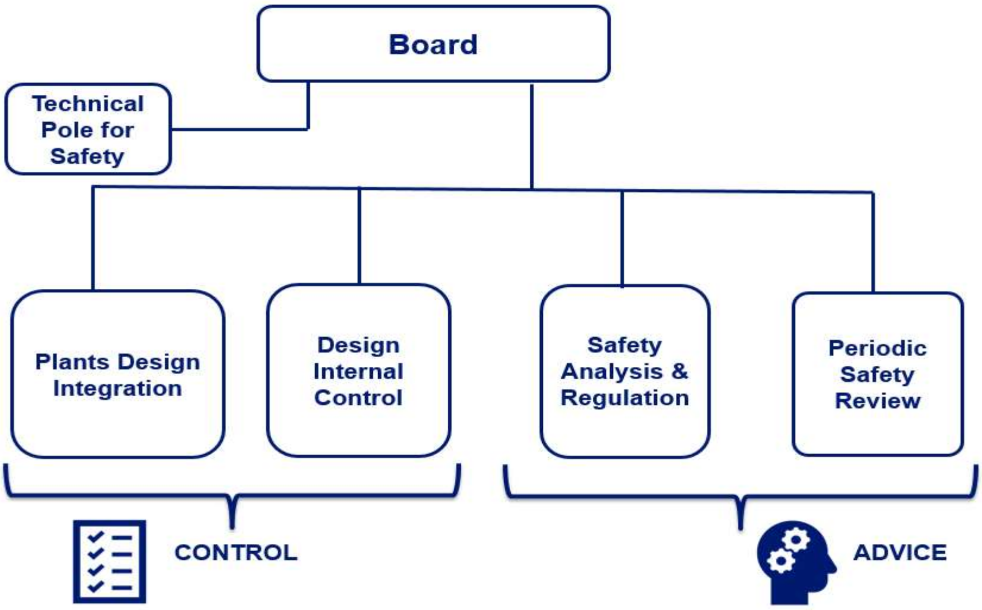

FIG. 14. Organization related to design authority in EDF.
(Courtesy of Électricité de France)

VII.4.1. Skills and knowledge

In order to fulfil its assignments, the design authority need strong skills and knowledge of the design and operation of the plant. The staff come from the various engineering centres and from NPPs, to cover the full range of technical skills. The engineers share their analyses to enhance collective knowledge, by providing training in the field safety and newly hired engineers mentoring.

The technical pole for safety is composed by skilled engineers with a long experience through different positions in different divisions, engineering centres and operation on NPPs. These engineers have the responsibility of domains and advise the members of the four groups.

VII.4.2. Advice

The two groups in charge of advice assist the projects and the operator in their decisions towards design and related safety issues.

The safety analysis and regulation group coordinate the update of SAR consistently with the modifications implemented on the plant. A digital tool is used to ensure that the SAR is at every time compliant with the NPP state. The SAR gives the overview of the design and overall basis of the safety demonstration. This group takes part to compliance analyses of EDF nuclear fleet towards the French regulation and international safety standards.

The periodic safety review group coordinates the safety options file and related safety goals which are submitted to the safety authority as part of the licensing process in PSR. It participates in the choices of the modifications to fulfil the safety goals and ensures with the responsible designers the licensing of the safety studies, design and operating changes. It establishes with the responsible designers the formal report with the PSR conclusions which presents all the modifications finally needed in order to reach the safety goals and regulator requests. This report is approved by each nuclear site director who is responsible for the modification's implementation on his plants.

In case of points to be checked in terms of safety issues, the members of these groups can report the problem to the groups in charge of control or the technical pole for safety. If necessary, these groups give a written independent position to the project and the nuclear generation division.

VII.4.3. Control

The control is performed at key points of the modification process: before the modification file sendal to the safety authority, and upstream the outage during which the modification has to be implemented on NPP.

The internal control design group check independently the file of a new modification, before it is transmitted to the safety authority, as requested by the French regulation. For the most significant safety modifications EDF has to wait for the regulator formal authorization, before implementing them. For the modifications with moderate or minor safety impact, the safety authority is simply informed and EDF can implement them once the recommendations of the internal control issued by the design authority have been taken into account.

The plants design integration group issues a summary report (identity card of the plant) before each plant outage which compiles the modifications to be implemented during the outage, the related safety documentation changes (safety analysis report and general operating rules), and the design deviations to be treated, if any. The group checks that the correct implementation after plant restart and issues warnings to the nuclear generation division safety director, in case of lacks in design upgrades.

VII.5. A VISIBLE AND RECOGNIZED DESIGN AUTHORITY

The participation of the design authority in every step, from the PSR safety options to the validation of the modifications of the plant, allows the design authority to have a full overview of the process and the activities impacting the design from a safety point of view. It allows to check the modifications changes at strategic milestones in the decision process.

Taking part to key activities in relation with safety enhancement and design control makes design authority visible and recognized within EDF but also by the regulator and its technical support organization, being a technical counterpart for safety files and issues licensing.

APPENDIX VIII.
GOOD PRACTICE ON TECHNICAL COMPETENCE IN FINLAND: NUCLEAR ENGINEERING SUPPORT AT FORTUM

Fortum started operation of Loviisa VVER-440 Units 1 and 2 in 1977 and 1980, respectively. Nuclear engineering expertise to support the safe operation of these units was built within the owner's own organisation from the beginning of plant construction in early 1970s. Fortum (then Imatran Voima Oy) initially wanted to build the plant on the turn-key basis. When the supply negotiations emphasized the need for significant modifications in comparison to the reference VVER-440 plant, it became necessary that Fortum took the role as the architect engineer of these units. Currently Fortum owns minority assets in all Nordic NPPs. As a minority owner Fortum provides some engineering services to them under contractual terms. The description below focuses on the support to Loviisa power plant, since it explains historical reasoning, why Fortum has developed and maintained strong in-house nuclear engineering support.

After completion of the Loviisa units and start of commercial operation new operational experience was gained e.g., from neutron flux causing more serious embrittlement of the reactor pressure vessels than expected and from severe accidents (Three Mile Island in 1979 and Chernobyl 1986). These caused needs for extensive plant modifications. The role of own engineering support was crucial in solving these issues, as the support from the plant vendor had decreased significantly after the commissioning works.

The nuclear engineering support capability have developed along the Loviisa power plant's lifetime that can be divided to following periods:

- I - Design, construction and commissioning: years 1970-1979;
- II - Period of the operational support and major backfits: years 1980-2003;
- III - Plant life management (PLIM) to support long-term operation: years 2004 to present.

The major achievement during the design and construction period was redefinition of the plant's design basis. The emergency core cooling system (ECCS) and ice condenser containment were added to the original VVER-440 design to cope with the full break of a primary cooling loop. In addition to working on these design extensions the Fortum engineers participated actively in all commissioning activities.

During 1980s and 1990s a series of significant backfits and refurbishments were done to further modify the plant to cope with new safety requirements. These include:

- Plant modifications to improve the reactor pressure vessel resistance to pressurized thermal shock (PTS). Introducing dummy fuel bundles to the core periphery, heat-up of emergency core cooling system (ECCS) water, modification of high-pressure safety injection system and extension of the plant protection system. Finally, the reactor pressure vessel of unit 1 was thermally annealed to recover the ductile properties of the weld on the core elevation;
- Improved control of the primary-to-secondary leakage accidents (PRISE): additional ECCS tank, system changes and structural modification of the steam generator primary collector in the steam generator;
- Reinforcement of the emergency feed water system: introducing additional system with dedicated diesel-driven pumps;
- Various backfits based on the PSA studies: the full in-house living PSA is an essential part of operational support;
- Plant modernization and uprating the power with 10 percent;

- Severe accident management (SAM) was developed and implemented based on the essentially in-house program including extensive hardware changes.

These backfits as well as the living PSA have been carried out by the owner's own personnel. External contracts were placed for certain consultancy services and of course, for manufacturing, supply and installation of hardware.

The most extensive PLIM program was renewal of the plant instrumentation and control systems with digital automation during first two decades of this century. Fortum's nuclear engineering support had a key role in completion the renewal successfully together with the suppliers.

Fortum has implemented the function of design authority into the Loviisa power plant organization. Thus, it can fulfil its role being independent from the Nuclear Engineering Support that has role of responsible designer in most plant modification projects.

Fortum has in-depth competence in all nuclear engineering areas needed for successful technical support covering reactor physics, fuel management, thermal hydraulics, material technology, structural analysis, process analysis and design, safety analyses, instrumentation and control, electrical systems, PSA, quality control (QC) and QA, PLIM and radwaste and decommissioning.

Benefits of having technical support within the NPP owner/operating organization are:

- *Costs:* According to benchmarking to some other European NPPs the costs have been clearly less (from two to fivefold) - even during the period when Fortum carried out extensive backfitting and refurbishment programs.
- *Operational reliability:* The own operational support has ensured a fast access to needed services and thus contributing to the high availability. The in-house living PSA is an important everyday tool also for increased reliability.
- *Safety:* The deeper understanding that has been obtained from the plant's design features and operational support contributes to the plant safety. In particular, the better management of the interfaces among various disciplines and competence areas has been obtained that governs the whole history of the plant lifetime occurrences. Apros, the in-house process and safety analysis tool that is jointly developed with VTT Technical Research Centre of Finland is widely applied to the full spectrum of various safety and process analyses. The safety significance of the modifications is routinely checked with PSA.
- *Waste management:* The radioactive waste management has benefitted of in-house projects to construct low and intermediate level waste (LILW) facility as a deep geological repository on site, as well as liquid waste solidification plant and continuous upgrading of the plant decommission planning.
- *LTO:* The own nuclear engineering support has contributed significantly to the long-term operation of the Loviisa power plant. The reconstitution of the design bases turned out to be necessary, when designing and implementing plant modifications. The essential tool for the reconstitution have been application of in-house tools Apros and PSA. Currently the operational licences of Loviisa units are valid to 2027 and 2030. Fortum has announced the intention to apply for the continuation of operational licences up to 2050.

APPENDIX IX.
GOOD PRACTICE ON MANAGEMENT AND OVERSIGHT IN JAPAN: TEPCO'S REFORM PLAN AND NUCLEAR SAFETY OVERSIGHT, NUCLEAR INDUSTRY REFORM AND OVERSIGHT OF THE REGULATORY BODY IN JAPAN

Following the completion of the Fukushima Daiichi Accident analysis report [11], TEPCO released its reform plan [5] that consists of a) reflections on tsunami assumptions, b) lessons learned based on the analysis of TEPCO's response to the accident, c)analysis of the root cause of the accident, and lastly d) reform plan. The root cause analysis focused on its organizational and cultural aspects and described, inter alia:

- Safety culture: Corporate senior management failed to place high priority on nuclear safety;
- Outsourcing and competence: High reliance on contractors eroded technical competence, knowledge of plan design and ownership;
- Communication: Low level of risk communication with local government and communities.

With the above as the background, TEPCO's reform plan included many elements such as safety culture, education and training, oversight, dialogue along the line of organizational hierarchy, defence-in-depth, risk communicator system, realigned incident command system, technical competence.

IX.1. EXTERNAL OVERSIGHT

To have these reform initiatives monitored and advised (specifically related to safety culture, technical competence and communication) by a third-party, Nuclear Reform Monitoring Committee (NRMC)[13] was established in 2012. The board consists of several members, mostly from outside of Japan, including the ex-chairman of the Nuclear Regulatory Commission (NRC) in the US.

In 2017, the Nuclear Safety Advisory Board (NSAB) was established emulating Nuclear Safety Review Board (NSRB) in Europe and the United States. The NSAB is comprised of experts with a plethora of experience working in the nuclear power industry overseas and serves as an advisory body for the chief nuclear officer (CNO). The NSAB reviews, and provides advice pertaining to, issues that have the potential to impact safety and equipment reliability, such as safety performance, management, human performance and departmental/culture issues at Headquarters and power stations (See Fig. 15).

IX.2. INTERNAL OVERSIGHT

In 2013, the Nuclear Safety Oversight Office (NSOO) was established to strengthen oversight functions pertaining to nuclear safety. Working together with licensed reactor engineers and other experts stationed at each site, the NSOO provides independent oversight and assessment of nuclear power-related departments and gives regular reports of these assessments to the Board of Directors (See Fig. 15).

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[13] See: http://www.nrmc.jp/en/

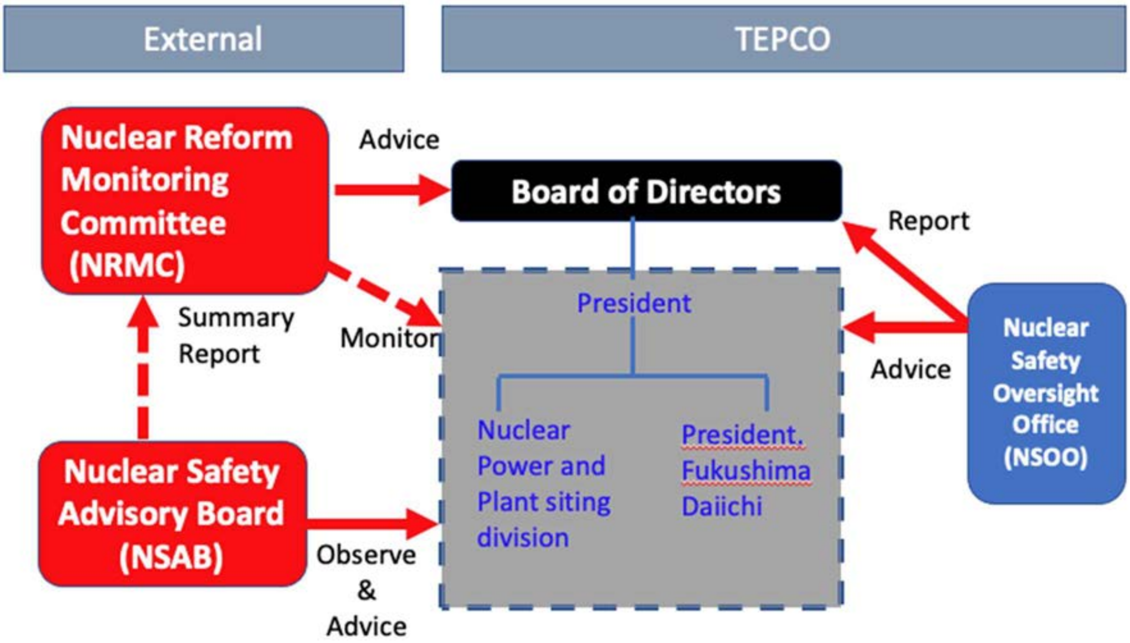

FIG. 15. Oversight function in TEPCO.
(Courtesy of Tokyo Electric Power Company Holdings, Inc.)

The extent of improvements by reform activities is continuously evaluated using performance indicators in three areas of technical competence, safety awareness, and communication.

Many of its nine nuclear utilities, after the Fukushima Daiichi Accident, established more or less internal and/or external oversight systems on nuclear safety. They sought for external advice on safety, technology, communication, and other managerial issues.

IX.3. TRADE GROUP'S CONSORTIUM

Nuclear utilities and the nuclear industry jointly established trade group's consortium as follows.

IX.3.1. Japan Nuclear Safety Institute (JANSI, since 2012)

Japan Nuclear Technology Institute (JANTI) was established in the process of reform of Japan Atomic Industrial Forum (JAIF) in 2004, whose function was basically to emulate INPO on peer review. JANSI is supposed to focus more on safety, but its activity includes a wide variety of areas such as:

- Peer review;
- Safety culture assessment;
- Organizing seminars;
- Sharing operating performance and experiences;
- Publishing reports and guidelines on such topical areas as emergency preparedness drill, evaluation of active faults, and configuration management;
- Function as accreditation organ for shift superintendent.

IX.3.2. NRRC (Nuclear Risk Research Center, since 2014)

As a part of Central Research Institute for Electric Power Industry (CRIEPI), a research wing of power companies in Japan, it is supposed to support capacity building of nuclear utilities in their risk assessment, risk management and risk communication. It takes advantage of research facilities owned and operated by CRIEPI such as shake table and tsunami hydraulic test facility to produce technical basis for risk evaluation and management. For the purpose of linkage with global knowledge on advanced methodologies, most of the members of its technical advisory committee are invited from outside of Japan.

Its supports utilities in their plant-specific PSA using most up-to-date methodologies. In the aftermath of the Fukushima Daiichi Accident, it focuses on advancing analytical methods of extreme external events, multi-unit accident, and human reliability in harsh environment (stress and radiation from the accident).

IX.3.3. Atomic Energy Association (ATENA, since 2018)

Jointly established by nuclear utilities and Industry, ATENA has its primary function for interface with the regulatory body (NRA).

IX.4. OVERSIGHT OF THE REGULATORY BODY

In the aftermath of the Fukushima Daiichi Accident, the Diet enacted a law to create an oversight committee to the regulatory body (Nuclear Regulation Authority (NRA)) in both Houses, namely the House of Representatives and the House of Councillors. An external advisory committee by experts from outside of Japan is organized once a year.

All the above efforts in Japan were made in a strategic manner by conscientiously looking at what other countries were doing and then adapting it to the local culture and benchmarking it to ensure follow-up actions.

APPENDIX X.
GOOD PRACTICE ON INDEPENDENT OVERSIGHT IN THE UK: AN INCLUSIVE APPROACH TO INDEPENDENT NUCLEAR SAFETY OVERSIGHT (INSO) TRAINING TO SUPPORT IMPROVED ORGANIZATIONAL OVERSIGHT DEFENCE-IN-DEPTH IN EDF NUCLEAR GENERATION OVERVIEW

The WANO Independent Nuclear Safety Oversight Working Group (INSO-WG) emerged from initial collaboration between four European utilities in 2010 to share best INSO practice and training. EDF Nuclear Generation (NG) has been a leading member of this group from the outset. The INSO-WG now supports WANO's ambition of establishing strong INSO capability across its members. The group worked closely with IAEA in jointly publishing the first industry guideline for INSO in 2018 [48].

The INSO-WG commissioned an INSO initial training course to help drive guideline objectives. Delivery began in late 2017 and has been supported by train-the-trainer events to formally accredit course instructors across the industry. Covid-19 has slowed progress with both delivery and accreditation but efforts to regain momentum are underway.

EDF NG took the lead in developing this training. This included reference to a previous INPO INSO course and reviews of relevant training materials provided by INSO-WG members. It also drew on EDF's own mature independent nuclear assurance (INA) training programme and the significant commitment made to this over the years.

The Section X.5 below contains an outline of the initial training course content.

X.1. ESTABLISHING AN EFFECTIVE INSO FUNCTION

GL 2018-01 explains that INSO is only effective if empowered by senior leaders – and is most effective when senior leaders seek INSO views and communicate INSO value to line managers. Yet industry evidence can be seen where INSO is not sufficiently valued or where the nuclear organisation does not use INSO effectively. INSO may consequently become too reactive, or compliance focused; operate at the wrong level within oversight arrangements or lack independence. There may be an over-reliance on INSO (a sampling function) to detect shortfalls in safety performance.

An effective nuclear organisation will have a clear understanding of what safety oversight excellence looks like and how best to use its INSO resource. With this in mind, and in addition to the guideline and initial training, the INSO-WG has identified a need to promote better understanding of the role of INSO. Importantly, this needs to set INSO in the context of overall organisational oversight defence-in-depth. In other words, it is necessary to be clear about the responsibilities of providing safety oversight at all levels of the organisation – and the role INSO plays in providing oversight of oversight.

X.2. THE INCLUSIVE APPROACH

In EDF NG, it is recognised that INSO training aims and objectives are, in many cases, relevant to others in the organisation with oversight responsibilities, notably Functional Fleet Managers (core functional area manager (CFAM) equivalents). It is not always recognised, for example, that escalation and missed opportunity processes should be adopted more widely. Similarly, some of the challenges faced by these oversight groups are consistent with those faced by INSO. This is particularly true when moving beyond technical and oversight process knowledge into more personal attributes: intrusiveness, critical thinking, influencing without line authority, personal resilience, delivering critical messages and effective communications being some examples.

EDF NG has, as a result, taken an inclusive approach to delivering INSO training, both internally and also to external organisations that have sought NG support. Mixed cohorts (independent and functional oversight) can explore the different expectations, perspectives and outcomes relating to their oversight roles as well as share experience around some of the common challenges. It is important to stress, however, that INSO independence, and how this is achieved, remains a core objective of the training.

Experience has shown that to accommodate the above, training delivery needs to include a strong element of facilitation and, where possible, introduction of practical and experiential elements. In a number of cases where EDF NG has provided external support, initial training has been extended to include workshop elements to target specific performance gaps. These have included effective safety reporting and influencing skills.

The option of mixed cohort training does not preclude running INSO only events. This can still be important as part of establishing team alignment and cohesion. Similarly, INSO training has been used as the basis for functional manager training. The key here is recognising the training synergies between these groups and how these can be used to strengthen organisational oversight.

In EDF NG these synergies are further explored – and shared - across respective training committees (and the INSO-WG). This then informs continuing training programmes. This approach has played a part in a demonstrable improvement in corporate oversight in recent years.

X.3. LEADERSHIP UNDERSTANDING OF INSO

While training has so far focused on oversight peers, a consistent observation from course delegates is that many of aspects of this training would also be valuable to a broader range of leaders, not least to ensure wider alignment around some of the core principles of effective safety oversight. The importance of senior leaders reinforcing the value of INSO has already been mentioned – but this should not lead to a disproportionate reliance on INSO. Events and degraded performance identified by INSO are indicative of failures in the other oversight barriers that exist below it. This is not always fully considered.

The INSO-WG, and EDF NG as a lead member, can help play a role in developing this understanding. This topic will now be a work stream for the INSO-WG training sub-committee with an intention of producing leadership training to support this.

X.4. CONCLUSION

There has, in recent years, been a renewed appetite among WANO members to drive improvements in independent nuclear safety oversight. An already strong working group is now underpinned by an industry guideline and initial training programme. EDF NG has sought to play a leading role and has been active in developing and delivering INSO training. In not limiting its scope to independent oversight, the relevance of this to others with oversight responsibilities has been demonstrated. Additionally, feedback has offered evidence of a further need, also identified by INSO-WG, for leadership awareness training in relation to INSO.

It can be an easy trap to misinterpret independence for isolation. INSO needs to part of a coherent set of integrated oversight arrangements in which the standards, expectations and competencies of oversight that sits below and above INSO are understood and reinforced. In this way, INSO can be truly effective. An inclusive approach to INSO training may assist with this.

X.5. REFERENCE - INSO INITIAL TRAINING COURSE STRUCTURE

The following outlines the 4.5-day INSO initial training course, its terminal objectives and titles of the 11 core modules. Pre-course work also guides delegates in self-assessing their oversight organisation against relevant WANO Performance Objective and Criteria (PO&C) and area for improvement (AFI) previously raised on INSO organisations.

Although INSO is repeatedly referenced here, the course can be made relevant to others with safety oversight responsibilities – and adjusted to suit organisational maturity and differing utility structures.

Each module can be expanded in scope and depth to accommodate specific performance needs, typically though additional sessions, or continuing training. The use of case studies and experiential workshops, in particular, can allow for greater exploration of the personal and collective attributes associated with successful oversight practitioners and their teams.

X.5.1. Terminal Objectives

- Identify the characteristics of a healthy nuclear safety culture. Explore the role of INSO in assessing and reinforcing these;
- Explain organisational oversight defence-in-depth and expectations for achieving this. Explore where deficiencies in these arrangements have resulted in events;
- Describe the role of independent nuclear safety oversight in these arrangements. Explain how independence is understood and achieved;
- Explain typical INSO methods and approaches for assessing and evaluating safety performance;
- Describe how INSO can communicate its findings and judgements so as to positively influence safety performance;
- Apply observational, interpersonal and analytic skills in identifying and reporting safety performance gaps;
- Explain how INSO ensures satisfactory resolution of safety-related issues;
- Identify ways in which INSO can understand its own performance and improve.

X.5.2. Course Modules

- Nuclear safety culture;
- Nuclear safety oversight;
- Independent nuclear safety oversight;
- Focus areas;
- Observation skills;
- Interviewing;
- Problem statements and insights;
- Influence: Writing skills;
- Influence: Interpersonal communications;
- Follow-up (elevation and escalation);
- INSO continuous improvement.

APPENDIX XI.
GOOD PRACTICE ON INDEPENDENT OVERSIGHT IN SLOVAKIA

A comprehensive independent nuclear oversight function has been effectively implemented in Slovenske Elektrarne (SE) after the privatization of the nuclear utility in 2006-2007. The main shareholder of the SE company introduced and deployed this function in SE. The Independent Nuclear Oversight (NOS) unit has been established in 2006 as the important part of the overall Performance Excellence Initiative. The key success factors of the Performance Excellence Initiative included:

- Senior leaders' commitment to improve safety performance of the company and to strive for operational excellence in all units at both NPP sites;
- Drivers for excellence in performance in the following main areas:

  - Organizational culture (values, behavioural model and safety culture improvement);
  - Management processes;
  - Human performance;
  - Equipment performance;
  - Independent oversight function.

Before reaching top management's decision to implement the Performance Excellence Initiative, the company experienced a mixed performance at both NPPs' sites. The key performance indicators (KPIs) of both NPPs in operation were mostly in the second quartile of WANO KPIs. Nuclear power units had planned power production losses equal to average annual outage duration of about 42 days and experienced a relatively high number of safety incidents and events including scrams in comparison to numbers of incidents or events at similar NPPs around the world.

The independent oversight function was created within two years (2006-2007) as a part of the overall performance excellence initiative to assess and review the overall performance and to provide diverse information to senior management and shareholders up to the chairman of the Board of Directors (BoD). The Independent Nuclear Oversight unit (NOS) started to fulfil the role of the off-line critical function in SE nuclear company. The setup of the independent oversight function was developed according to the structure of SE company and changing culture of the organization after the privatization process.

An independent oversight function in SE consists of:

- NOS - Nuclear oversight (internal unit);
- NSAC - Nuclear Safety Advisory Committee (external part of the independent oversight function, external experts and peers);
- International safety reviews (WANO, OSART, including corporate reviews).

Independent assessments of functional areas and/or overall performance are conducted by the internal NOS unit and external experts – members of the Nuclear Safety Advisory Committee. NSAC consists of external senior nuclear experts from outside of Slovenske Elektrane. Both NOS and NSAC report directly to the relevant levels of the utility up to the Director General (DG) and the Chairman of the BoD.

Independent assessments are performed on the risk-based and performance-based approach to determine the adequacy of performance and assess the level and the adequacy of processes (operation, maintenance, training, work management, design authority, quality assurance, and monitoring the safety culture). The scope and the methodology of NOS regular reviews is similar to WANO or OSART review methodology of functional areas in nuclear companies.

The organization structure of the NOS unit has been agreed with the chief nuclear officer (CNO) and approved by the Director General. The NOS unit consists of four staff members with operational experience, who are permanently located at both NPP sites and six staff members at the SE headquarters (the corporate level). Based on the needs of the company the number of NOS staff varies and selected NOS staff with good performance is promoted to higher line management positions. The head of NOS assures that responsibilities, accountabilities, and authorities for those providing independent assessments are clearly identified, understood and implemented. The NOS review team for the functional area consists of four to six permanent NOS staff members supported by the specialists from the other NPP site or the foreign companies (if needed) or in case of the independent assessments of selected repeated events. The main reason for inviting other specialists to the NOS review teams is to bring a fresh look at the issues to be reviewed, to improve the competence of NOS review team, and to increase the depth of experience in international best practice in reviewed area.

The head of NOS unit attends weekly senior corporate management meetings and monthly informs DG and the chairman of the BoD on the NOS monthly report i.e independent oversight findings and potential opportunities for improvements. NOS monthly reports and NOS annual reports are discussed with plant managers and the other relevant senior managers before their submissions to the DG and the chairman of the BoD.

Planning, undertaking of reviews, and reporting of results from the NOS independent assessments are coordinated and agreed with the senior corporate management, the CNO and the plants' managers.

The NOS unit develops and agree with SE senior management on the following annual plans:

- Independent assessments of functional areas including corporate functions and/or processes;
- Independent safety culture reviews (bi-annual);
- Nuclear Safety Advisory Committee meetings including topics or issues to be reviewed by NSAC members.

The overall independent oversight function is targeted to provide the performance-based assessments to the organisation and the programme is co-ordinated with other units or organizations undertaking inspections, audits and assessment activities i.e. quality assurance group performing the compliance-based audits, external audits and/or international review teams.

The external part of the independent oversight function (NSAC) is comprised of four to five external senior experts from the nuclear industry. The NSAC members are approved by the DG based on the proposal from the head of NOS. Based on the SE needs and priority areas or gaps in safety performance and operational issues, rotation policy for NSAC Chairman position and other members' positions are applied. The rotation of senior experts in NSAC also depends on availability of relevant senior foreign experts. The SE company experienced an average rotation of the NSAC chairman – within about five years - and some other NSAC members are rotated within two or four years.

The agenda for NSAC meetings and review areas are proposed and prepared by the head of NOS in close cooperation with plants' managers and CNO. The NSAC exit meetings are attended by the DG, the chairman of the BoD, the CNO and the plants` managers. During the exit meetings all NSAC members express their personal independent views on the reviews, issues, or the areas of assessment.

Independent oversight function (NOS and NSAC) provides SE top managers with the findings, identifies the opportunities for improvements in all areas of performance, challenges the decision making processes and behaviours within the organisation with the aim to confirm that the safety and environmental requirements and standards are met, provides plants' management and senior corporate management with the identified problems or gaps and their potential causes, and supports continuous improvement of overall SE performance.

Plant managers, heads of relevant divisions and key process owners evaluate the results of the independent assessments and take the necessary actions to implement the improvements. In case the relevant manager is not able to implement the NOS finding or the identified opportunity for improvement, an elevation or an escalation process is used by the NOS and the issue or the finding is reported to the higher management level in the SE company. Escalation process is used only in case if relevant management level did not address the NOS finding in time.

In 2010, OSART review team concluded that the independent nuclear oversight function in SE is a 'good practice'. A good practice is an outstanding and proven programme, activity or equipment in use that contributes directly or indirectly to operational safety and sustained good performance.

Based on the benchmarking visit to INPO, the NOS effectiveness indicators have been developed in 2014. The indicators are used to better monitor effectiveness of the independent oversight function (including NSAC). The main goal of these indicators is to measure the NOS and the NSAC ability to influence the safety and operational performance. In 2015 WANO corporate review mission concluded that nuclear oversight function in SE is 'strength' in sustaining plant safety and operational performance.

XI.1. CONCLUSION

Considerable work had been undertaken in SE on improving safety and technical and management processes particularly from 2007 to 2013. The independent oversight function has had an important role and contributed to the overall performance improvement in SE at all NPP units. It was acknowledged when all four operating units in SE company achieved the highest level among VVER units of performance based on INPO Index – the weighted performance indicators (see Fig. 16).

The unit capacity factors of all four units achieved top decile based on WANO KPIs, outages have been reduced to the average duration of 20 days, collective radiation exposure per four operating units was reduced by more than 50%, number of scrams in all four units have been reduced to zero, the new culture and processes reviewed by independent oversight function also reduced industrial safety frequency rate (SE and contractors), etc. – see also below the selected indicators and the results achieved from 2006 to 2013 since the independent oversight function has been deployed in the SE company. The independent oversight function contributed to the results achieved in the performance improvement.

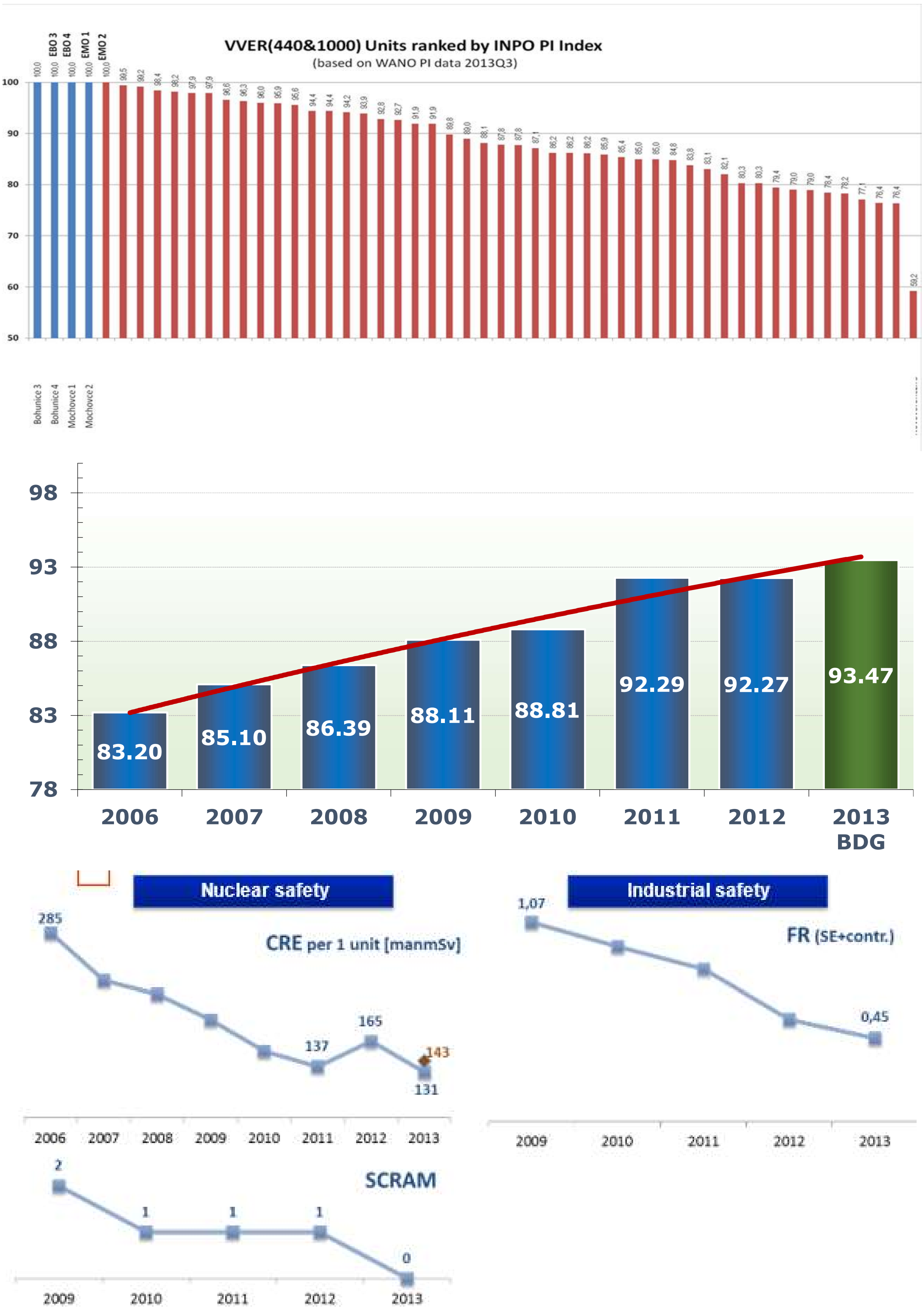

FIG. 16. Selected performance indicators in SE company (indicators are cumulative for four NPP units. (Courtesy of Slovenske Elektrame, Slovakia)

Since 2016 the SE company and its top management is facing the competitive energy market and the delayed construction of two units at Mochovce site. The independent oversight function (NOS and NSAC) continues to further improve the institutional strength and the operational safety performance of the company. The NSAC members have been rotated step by step and since 2020 the NSAC consists of four members from UK, Spain, France and is chaired by the former CEO of WANO.

APPENDIX XII.
GOOD PRACTICE ON PUBLIC STAKEHOLDER ENGAGEMENT IN JAPAN: FUKUI LOCAL GOVERNMENT

The local government in Japan is responsible, as a baseline, for the development and implementation of off-site emergency preparedness and response (EPR). The government of Fukui prefecture, having 13 commercial NPPs, has a role beyond that, standing by the side of local residents, sharing information, analysing safety issues and voicing local resident concerns, while not violating the authority of the regulatory body belonging to the central Government but somewhat supplementing its role.

XII.1. INFORMATION SHARING, SAFETY ISSUE ANALYSIS AND LOCAL COMMUNITY LIAISON

INSAG-27 [2] explains “Public involvement differs from country to country, and has cultural and political nuances that mean that a detailed one-size-fits-all approach is not appropriate.” It can also be said that “public involvement differs from prefecture to prefecture” within Japan.

XII.1.1. Sharing correct information when something happened

In order to improve public understanding of nuclear power, it is important to ensure transparency and provide timely information not only in normal times but also when an event occurs.

When an event occurs at an NPP in Japan, the utility is obliged to report to the regulatory authority according to the event’s significance, as stipulated in the Nuclear Reactor Regulation Law.

The Fukui prefectural government also requests reports on minor events that do not fall under these laws and regulations but are covered by the prefecture’s safety agreement with nuclear utilities. Furthermore, the prefecture itself analyses events to determine whether the events indicate any deterioration in safety culture or reveal an emerging pattern of similar events. In addition, the Fukui prefectural government holds press conferences to explain the results of the prefecture’s analysis, so that local residents can access this explanation through TV or newspaper. During the period when 13 commercial reactors were in operation before the Fukushima Daiichi Accident, press conferences occurred about 20 to 30 times in a given year.

Whether or not the media can fully understand the information provided by the prefecture depends largely on the experience, behaviour, and credibility of the explainer. Fukui prefecture has built a trusting relationship with the media by holding detailed press conferences for many years. In order to maintain this relationship in the future, it is necessary for the prefecture to develop its human resources, by employing and training individuals who can play the role of spokesperson without relying too much on the utilities.

XII.1.2. Safety issue analysis and local community liaison

The Fukui prefectural government hires nuclear experts and develops internal expertise to hold technical discussions with the utilities and regulatory authority, as well as independently monitoring nuclear safety. However, unlike Japan’s regulatory agencies, which employ roughly

1000 technical staff, the Fukui prefectural Government has less than 10 staff, so it is difficult to technically cover all areas of nuclear safety.

For this reason, Fukui Prefectural Government maintains a nuclear safety expert committee (established in 2004) which consists of 12 experts in nuclear reactor physics, materials / mechanical engineering, seismic engineering, and so forth, mainly from local universities. Nowadays, every local government with NPP(s) in its jurisdictional boundary has a similar committee.

Together with this committee, Fukui prefecture, standing by and representing the local residents, and independently from the regulatory body, asks utilities and the national regulatory authority for detailed explanations, and independently confirms the safety of the prefecture's nuclear plants in terms of hardware systems and management systems alike. The committee summarizes the results of these discussions in a report, which makes the following types of recommendations to utilities and the regulatory authority.

Recommendations to the utilities:

- Local residents often express particular concern about NPPs operating for more than 40 years, so particular care should be taken to collect information on the operating experience of overseas NPPs which have surpassed this ageing threshold.
- In addition, utilities should incorporate international knowledge and recommendations to improve the safety of their plants by receiving the IAEA Safety Aspects of Long Term Operation (SALTO) review.
- Utilities should focus on developing human resources with profound knowledge of machinery/equipment, and who can provide a bird's-eye view of the entire plant system to a range of stakeholders with various levels of expertise. In addition, establish measures to secure human resources during the assumed operating period.
- In order to maintain and improve the safety of power plants, instead of taking local safety measures in response to individual events, make continuous improvements to the entire reactor fleet based on actions responsive to local stakeholder concerns.

Recommendations to the regulatory authority:

- Discuss issues with utilities whether safety measures undertaken based on new regulatory standards are optimal from the perspective of the entire plant system; deepen mutual understanding and improve safety regulations.
- Ensure that the regulatory authority participates in nuclear disaster prevention drills conducted by the utilities, then evaluates the utilities' performance. It is also necessary to ensure, in turn, that the utility provides constructive feedback about the performance of the local emergency response center that acts as the on-location staging ground for the regulatory authority's own crisis management system.
- Strive to ensure transparency of the results of regulatory inspections conducted under the inspection system introduced in 2020, such as by maintaining a public database, and utilizing it as a tool for explaining safety findings to local residents.

XII.2. CHANGES AFTER THE FUKUSHIMA DAIICHI ACCIDENT, PLAN FOR THE FUTURE AND CONCLUDING REMARKS

In the years since the Fukushima Daiichi Accident, the participation of local stakeholders in critical decision-making processes has greatly expanded. These processes include the restart of

NPPs, extending reactor operating life beyond 40 years, as well as decisions regarding decommissioning.

'Local government' and 'media' are mentioned as layers of social subsystems in INSAG-27, and both play important roles in the decision-making process in Fukui Prefecture. The success factors can be explained as follows:

- Fukui Prefecture, which hosts13 NPPs, has the advantage of clarifying a wide variety of safety issues, and has been working to create stronger bridges between the utility, regulatory authority and stakeholders, that consequently build trust with residents and the media.
- As shown by the efforts of the Fukui prefecture nuclear safety expert committee, activities are being carried out regularly to close the gap between the national regulatory authority, nuclear utilities and local stakeholders.

In particular, Fukui prefecture plays the role of 'translating' the concerns of local residents into recommendations on technical matters, which can be used for continuous safety improvement of utilities, and then 'explaining' the relevant activities to local residents.

APPENDIX XIII.
GOOD PRACTICE ON EFFECTIVE MANAGEMENT OF EXTERNAL INTERFACES IN THE US AVIATION INDUSTRY: THE POWER OF COLLABORATION TO IMPROVE SAFETY

Within the aviation industry in the US, the Commercial Aviation Safety Team (CAST)[14] played a major role in reducing the fatal aviation accident rate by more than 80% in less than ten years. The catalyst for CAST was the realisation by the US airline industry in the early 1990s that the accident rate, after declining for decades, was reaching a plateau. At the same time, the volume of flying was projected to double within 15-20 years. The combination of the flat rate and the doubling volume would soon generate an unacceptable number of crashes. The administrator of the Federal Aviation Administration (FAA), the US aviation safety regulator, opined that the best way to resume the accident rate decline from the plateau was not more enforcement or more regulations, so a different and new approach was needed. The FAAand the airline industry had the common objective to improve safety. Their proposed approach was a voluntary collaborative effort, founded upon the common goal of improving safety. They therefore called for a meeting with the major industry participants – including airlines, manufacturers, pilots, air traffic controllers, airports, and the FAA -- to collaboratively find solutions on how to jointly improve safety.

In addition to reducing the fatal accident rate by more than 80%, CAST improved productivity, which was crucial because improving the bottom line made it sustainable (to this day, more than two decades later), and CAST also helped minimize unintended consequences, which is always a challenge when making improvements in large complex systems of coupled subsystems. Last but not least, CAST created this significant safety improvement without generating any new regulations, which demonstrated that the FAA Administrator was correct that the solution for getting off of the plateau was collaboration rather than more regulations, and it also demonstrated that the focus of CAST was not compliance with regulations but improving safety.

One of the major sources of safety improvement information for CAST has been information about errors and near misses. Crucial to the willingness of the participants to share such information voluntarily was the FAA’s agreement not to use the information for enforcement, but to use it to help identify and address potential problems in the system.

CAST engaged all participants in identifying problems and developing and evaluating remedies:

- Airlines;
- Manufacturers:
  - With the systemwide effort;
  - With their own end users;
- Air traffic organizations;
- Labor:
  - Pilots;
  - Mechanics;

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[14] See: https://www.cast-safety.org/apex/f?p=102:1:14493125834281::NO::P1_X:history

  - Air traffic controllers;

- Regulator(s).

They were able to decrease the fatal accident rate with 83% in less than ten years.

Another aviation industry example to learn from is collaborative decision making (CDM). It is similar to the CAST approach but is a more structured process. In CDM, all the different stakeholders in the aviation system participate in the process to collaboratively make decisions that improve safety and efficiency. It creates win-win situations and increases the understanding of the different stakeholders' perspectives. Eurocontrol [56] has used CDM with excellent safety, environmental and business results.

In addition to the above good practices, the framework 'global aviation safety roadmap'[57], in which all stakeholders, including states, regulators, operators, airports, manufacturers, professional organizations, safety organizations and air traffic service providers jointly establish passenger safety goal and check each party's achievement periodically, was established. It was to guide and coordinate safety policies and initiatives worldwide and to reduce global accident risk in commercial aviation. This framework ensures oversight of the progress towards safety standards and maximizes the use of resources by better coordinating safety strategies and avoiding duplication of efforts worldwide. Here the key aspect is that different entities work together to achieve the jointly agreed safety goal. Global nuclear community can learn from it.

APPENDIX XIV.
GOOD PRACTICE ON EFFECTIVE INDUSTRY INTERFACES IN OIL AND GAS INDUSTRY IN NORWAY:

From the oil and gas industry in Norway, lessons can be learned on how to increase safety with focus on the vendors/contractors. The different oil and gas companies have created a joint safety, health and environment Standard called NORSOK-SHE[15]. This standard is used as a leading indicator for the contractor/vendors to self-evaluate their SHE performance. Each segment has four levels, which provides a good overview for the contractors regarding what to strive for. The self-evaluation results are part of the contract arrangements, which adds a competitive element. This drives the contractor companies to focus on improving their SHE performance to become more attractive on the market. The oil and gas companies perform audits to evaluate if the self-scoring is correct. The audit results are shared amongst the oil and gas companies. This transparency reduces the contractor's ability to skew the self-scoring.

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[15] See: https://www.standard.no/en/sectors/energi-og-klima/petroleum/norsok-standard-categories/s-safety-she/

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ABBREVIATIONS

AC	alternating current
BoD	Board of Directors
BWR	Boiling Water Reactor
CAST	Commercial Aviation Safety Team
DBA	design basis accident
DC	direct current
EDF	Électricité de France
EDG	emergency diesel generator
IMS	integrated management system
INIR	Integrated Nuclear Infrastructure Review
INPO	Institute of Nuclear Power Operations
INSO	Independent Nuclear Safety Oversight
INSAG	International Nuclear Safety Group
ISiD	institutional strength in depth
LTO	long-term operation
NPP	nuclear power plant
NSAC	Nuclear Safety Advisory Council or Committee
OPEX	operating experience
ORM	operational risk management
OSART	Operational Safety Review Team
PSA	probabilistic safety assessment
PSR	periodic safety review
SE	Slovenske Elektrame
TEPCO	Tokyo Electric Power Company
TMI	Three Mile Island
QA	quality assurance

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