Safety Reports Series

No. 74

Safety Culture in Pre-operational Phases of Nuclear Power Plant Projects

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SAFETY CULTURE IN PRE-OPERATIONAL PHASES OF NUCLEAR POWER PLANT PROJECTS

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SAFETY REPORTS SERIES No. 74

SAFETY CULTURE IN PRE-OPERATIONAL PHASES OF NUCLEAR POWER PLANT PROJECTS

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FOREWORD

Member States have experienced a resurgence of interest in building nuclear power plants (NPPs). Existing plants are being modernized, ageing plants are being replaced, and demographic changes are driving a need to revitalize the nuclear workforce and related educational and technical support programmes. The acknowledged environmental advantage of NPPs compared with fossil fuel based power plants has helped generate this renewed interest.

Member States that have never had an NPP are embarking on new build projects. New participants need to understand that achieving safety requires commitment, perseverance and hard work from the moment the decision is made to embark on an NPP project to final decommissioning and long term waste management. An essential aspect of achieving safety is a willingness to accept and learn from international operating experience.

Initial decisions have a significant influence on safety culture. This includes the important decision to select leaders who take ownership of their mandate to promote safety and who instil a strong safety culture in their organization. Leaders of new build projects often attain positions of influence in the nuclear industry and have a lasting impact on attitudes towards safety. Many designers, project personnel and construction personnel eventually transfer into operating organizations, regulatory bodies, vendors or technical and scientific support organizations. New participants entering the nuclear field present experienced leaders with the opportunity and responsibility to promote practices that ensure that protection and safety issues are given priority over production, schedule and cost at all levels of the organization. New participants must understand the more stringent requirements and greater accountability that come with NPP projects compared with projects involving conventional plants.

The IAEA produces a wide variety of publications that provide an international basis for the safe and effective implementation of nuclear power programmes in Member States. The majority of IAEA publications on safety culture, however, focus on operating environments rather than on the pre-operational phases of NPP projects. Much of the safety culture experience gained from operational phases is also relevant in the pre-operational phases. Nevertheless, knowledge transfer must take into account the different environments, the diversity of participants and the differing levels of experience associated with pre-operational phases. This publication provides guidance on safety culture challenges faced by participants in the pre-operational phases of NPP projects — from project conception through design, construction and commissioning up to the point of initial fuel loading.

The IAEA is grateful to all those who assisted in the drafting and review of this report. The IAEA officer responsible for this publication was M. Haage of the Division of Nuclear Installation Safety.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Enhanced safety culture in nuclear organizations has been the topic of a number of IAEA publications [1–9]. In most cases the focus has been on organizations that operate nuclear power plants (NPPs). However, there are many challenges during the pre-project, design, construction and commissioning phases of an NPP project. Nuclear safety begins at project conception, and a primary challenge is to ensure that the practices of a strong safety culture are applied from the outset of a project to avoid both latent and immediate deficiencies. Experience has shown that when the main focus is on technical aspects, project schedule and budget, insufficient attention may be given to human and organizational aspects. In some cases, the inadequate application of safety culture principles and practices in new build projects has been a contributing cause of safety issues during subsequent operation. For example, in one NPP construction project, poor on-site storage conditions for major safety related components provided by the vendor resulted in corrosion problems and safety issues related to the long term reliability of these components, and had an economic impact in terms of schedule and additional surveillance requirements during operation.

Key participants involved in new build projects, such as main vendors, power utilities and regulatory bodies, have expressed an interest in IAEA guidance on how to apply safety culture principles during pre-operational phases. Challenges associated with safety culture during pre-operational phases include the following:

— Organizations with limited direct experience may be involved and, in some cases, may have insufficient knowledge of nuclear safety requirements.
— Many different organizations are typically involved in projects, and they need to be coordinated and managed, with clear interfaces, accountability and protocols for exchanging information.
— Projects may involve many different nationalities and cultures, which can result in relationship and communication challenges.
— New build NPP sites may be located in countries where there is not a mature nuclear industry or the associated nuclear knowledge and infrastructure, or in countries with a mature industry but with limited or no recent nuclear construction experience.

— Conflicts between schedule, cost and safety objectives can adversely affect conservative decision making and the maintenance of a questioning attitude, or impair the ability to perceive links between short term actions and their long term consequences.
— The regulatory body may not be mature in a country embarking on a nuclear power programme, resulting in insufficient regulatory oversight.

This Safety Report addresses the application of safety culture principles during pre-operational phases for the benefit of Member States, utilities and vendors. It focuses on important practical aspects of safety culture to provide a common basis for communication and understanding among all participants, and to enable them to develop a strong safety culture during pre-operational phases. Although safety during pre-operational phases is often considered to be limited to industrial health and safety, experience indicates that pre-operational activities can subsequently have an adverse impact on operational nuclear safety when participants are not aware of the nuclear safety significance of their work.

Other IAEA publications which relate to pre-operational phases include a Safety Requirements publication on design [10] and a Safety Guide on commissioning [11], although these publications do not provide detailed guidance on safety culture. In addition, work is in progress to prepare guidance for the construction phase of a new NPP.

Safety culture can sometimes be perceived as being separate from other core issues that need to be addressed by a nuclear organization. This publication will aid in the understanding that safety culture, as a contributor to long term nuclear safety, is an important aspect of organizational culture during all phases of a nuclear project.

The safety culture supports the goals of all participants: the desire of governments to have a secure energy supply; the mandate of regulatory bodies to protect the public and the environment; the desire of vendors to build safe NPPs to ensure future business; and the desire of utilities to produce electricity safely, without technical or administrative problems.

1.2. OBJECTIVE

The objective of this publication is to provide practical guidance, based on current good practices worldwide, on how to develop and implement programmes to help strengthen the safety culture throughout the pre-operational phases of an NPP project, from project conception to initial fuel loading. Although pre-operational phases have a defined time interval, this publication

takes a longer term view, because the impact of early decisions and actions extends beyond the project phase into the operating phase of a plant.

1.3. SCOPE

Three pre-operational phases are identified in Fig. 1 [12]. The pre-operational aspects under consideration in this publication are:

— Phase 1: Pre-project. Occurs before a decision to launch a nuclear power programme is taken (from the pre-project phase to the production of a feasibility study).
— Phase 2: Project decision making. Includes preparatory work required after a policy decision has been taken to proceed with an NPP project (from making a project decision to the initiation of the bidding process).
— Phase 3: Construction. Includes activities to implement an NPP (from the construction phase to the start of commissioning). In this publication, Phase 3 is considered to end with the initial fuel loading.

As discussed in Section 1.5, this publication is intended to provide information to governments, regulatory bodies, owners, operators (future licensees), vendors (main vendors, subcontractors, manufacturers) and other interested parties such as designers and technical and scientific support organizations. It is also intended to support managers and personnel of shareholders/investors, and nuclear energy programme implementing organizations (NEPIOs).

1.4. STRUCTURE

Section 2 of this publication discusses safety culture attributes and background information related to safety culture and provides information on how to use this publication. Section 3 describes three special cases: (i) countries that are newcomers to nuclear power programmes; (ii) regulatory bodies; and (iii) vendors, manufacturers and contractors. Section 4 addresses eight generic challenge themes associated with pre-operational phases, each divided into: key challenges; desired state; approaches and methods to address the challenges; and examples and resources, including other IAEA publications. Finally, Section 5 summarizes the conclusions relevant to the development of a safety culture during pre-operational phases.

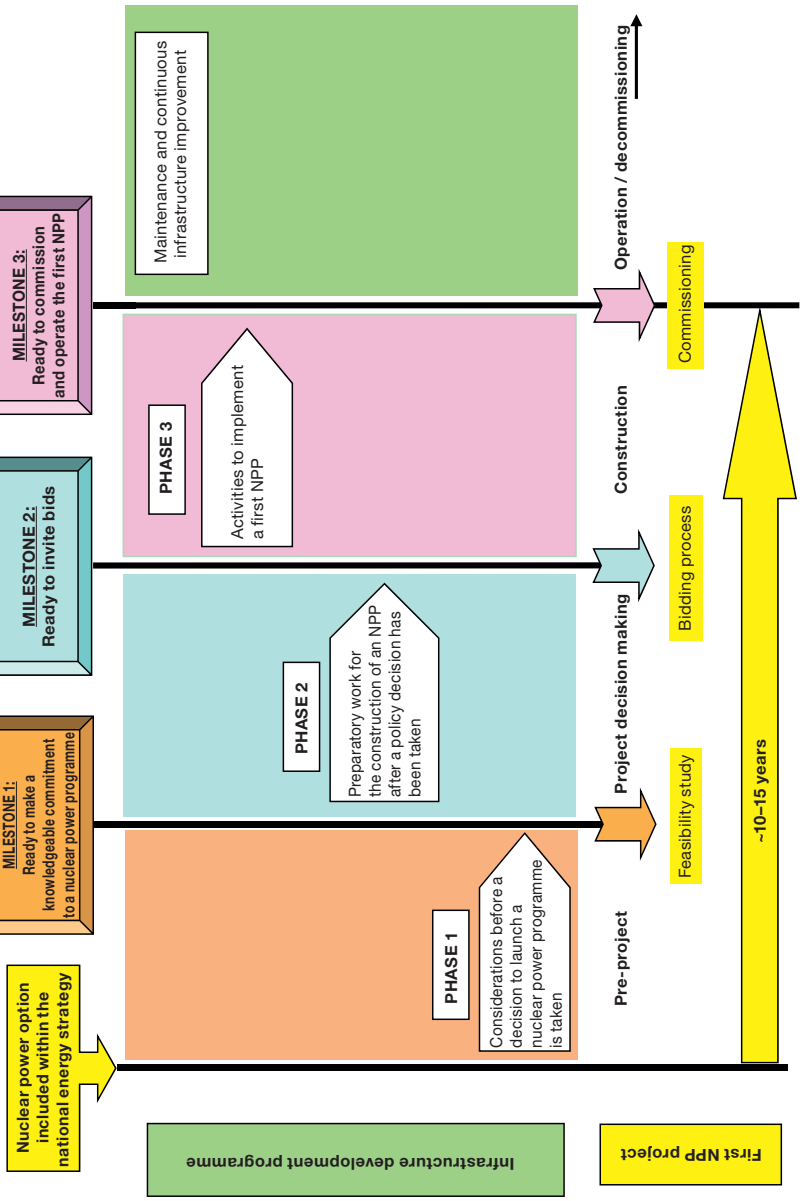

FIG. 1. Pre-operational phases of an NPP project (from Ref. [12]).

1.5. TARGET AUDIENCES

The target audiences for this publication have a variety of needs. The nature of the nuclear industry and the diversity of partnerships mean that participants may be located across the globe. Experience in the nuclear industry demonstrates that if all interested parties engage in the common pursuit of nuclear safety, NPP safety and reliability can be significantly enhanced. This section describes the attributes and interests of the various parties. In this publication, the term 'participants' is used to include all interested parties unless otherwise indicated.

1.5.1. Primary audiences

The primary audiences for this publication are: governments, newcomers to the nuclear industry, owner/operators, regulatory bodies and vendors.

Governments

It is important for governments and their associated bodies to recognize how safety culture can affect a new build project, as well as the importance of ensuring that nuclear power programmes incorporate safety culture principles from the outset. Governments are tasked with ensuring that nuclear safety is explicitly addressed in national policy frameworks. They are responsible for conferring clear powers of oversight and regulation on national regulatory bodies during all phases. Government decision makers need to recognize that nuclear safety requires considerable investment. The impact of a nuclear power programme extends well beyond any specific project, thus national accountability for nuclear power programmes cannot be delegated to owners and operators.

Regulatory bodies

Regulatory bodies need to influence, monitor and provide oversight of the safety culture during all pre-operational phases. They also need to establish their own safety culture and to recognize the influence of their safety culture on other participants. A common understanding and vocabulary among regulators, licensees and owners is of considerable value in promoting the safety culture. Oversight of a new build project is different from routine oversight, since each phase requires a different approach. New build projects typically include participants other than the licensee, and these may require additional regulatory attention.

NEPIO

Members of the NEPIO [12] need to recognize that an integrated approach to instilling a strong safety culture in participant organizations starts in the pre-project phase (Phase 1). This includes recruiting leaders who are committed to, and willing to accept personal responsibility for, developing a strong safety culture within their organization. Such leaders also recognize the importance of developing resource streams and management systems to ensure safety over the long term.

Owners

It is important for owners to recognize how the safety culture affects both the safety and the economics of an NPP. The establishment of a strong safety culture during pre-operational phases is important for successful operation and requires a complex system of interacting processes. Safety programmes; clear roles and responsibilities for all participants; specifications for quality, competence and training for different groups; and effective management systems to control design, construction, commissioning and operation are a few of the elements that rely on a strong safety culture for effectiveness. Considerable coordination and oversight are required, including safety and design review committees made up of international experts. For turnkey operations, it is important for owners to recognize that they retain full responsibility for nuclear safety during all phases, and that this accountability cannot be delegated.

Operator (future licensee)

Recognizing the importance of being engaged with a project through all of its phases — both to promote the safety culture and to monitor for potential issues that might compromise future operations based on a participant's lack of understanding of the safety significance of structures, systems and components — is essential for operators. Early development of an operational management system ensures transfer and retention of essential information from pre-operational phases.

Vendors

Main vendors. In establishing a strong safety culture, the main vendors, the owner and the future operator benefit from close collaboration and communication. Focusing on a common aim — the prioritization of safety as the paramount value in words and in actions — is essential. The collaboration is best

built on safety culture fundamentals such as trust and open communication, organizational learning, a questioning attitude and a proactive approach to safety. Good cooperation in relation to safety culture programmes and training within organizations is also important.

Subcontractors. It is necessary that subcontractors recognize that the safety context associated with an NPP project is different from and potentially of greater consequence than work on other types of project. In particular, the safety context extends beyond industrial safety to nuclear safety issues that can arise from deficiencies in materials or installation. Enhancing the safety culture in subcontractor organizations can help these organizations gain the benefit of lower costs through doing a job right the first time, and can help establish long term relationships with client organizations.

Manufacturers. Manufacturers and their vendors need to have a clear understanding of the requirements specified by the designer, owner and licensee and of why adherence to these requirements is important for safety. From a safety culture perspective, it is essential that manufacturers recognize the importance of controlling and communicating changes and seeking clarification of requirements that are not understood.

1.5.2. Other interested parties

Other interested parties who may benefit from information in this publication are shareholders/investors, designers and technical and scientific support organizations.

Shareholders/investors

It is necessary that shareholders and investors recognize the importance of safety culture at every phase of a project, from design through to operation. Investing in the nuclear industry requires a willingness to accept the additional costs of a strong nuclear safety culture. For example, a reasonable additional investment that makes a plant easier to maintain may facilitate subsequent operation and/or maintenance, thereby improving economic performance.

Designers

It is essential that designers recognize that in addition to the fundamental need for quality, code compliance and control of design configuration, the safety culture in their organization may have an impact on future operations of an NPP, including prevention of unplanned outages, ease of installation and maintenance, and equipment reliability. Safety culture involves working closely with the

construction, commissioning and operating organizations to understand their needs and requirements. This is particularly important in the case of new designs.

Technical and scientific support organizations

Technical and scientific support organizations, depending on their role, are expected to work with the operator to understand the safety relevance of the work they are performing in support of the NPP project.

2. SAFETY CULTURE

2.1. GENERAL

Organizations adapt to solve visible, routine problems. Over time, successful results ingrain behaviours, forming cultures and subcultures that directly influence all aspects of performance. These cultures perpetuate themselves on the basis of what works; as a result, daily and strategic decisions are taken in a manner that is almost automatic. In construction environments, cultural attributes such as schedule awareness, cost focus and urgency of problem resolution are reinforced because they are rewarded by immediate measures of success.

Nuclear safety risks are not as evident as cost and schedule issues. Hence, there is less opportunity to develop a self-regulating culture that learns from immediate feedback. Experience indicates that the causes of serious events are often linked to systemic failures, human errors or organizational weaknesses, some of which appear inconsequential in isolation. Latent organizational and technical errors from pre-operational phases may not surface until much later in a plant's operating life.

Pre-operational phases provide opportunities to apply defence in depth concepts which ensure that nuclear safety is given overriding priority. In plants with a strong safety culture, vigilance extends beyond avoiding deviations to enhancing the conditions that support safety.

2.2. SAFETY CULTURE RELEVANCE TO PRE-OPERATIONAL PHASES

Several important studies related to pre-operational phases [13, 14] provide valuable insight into issues concerning the safety culture of large projects. After several NPP construction projects experienced major problems related to design and construction quality in the late 1970s and early 1980s, the US Nuclear Regulatory Commission (NRC) examined lessons learned and issued NUREG-1055 [13], which identifies a number of significant problems that occurred during the construction phase of projects, including the following:

— The inability of owners or representatives to adequately control all aspects of the construction project, including planning, scheduling, procurement and oversight of contractors;
— Inexperience with NPP construction, resulting in utilities and their contractors not fully appreciating the complexity and difficulty associated with building an NPP, and therefore the importance of nuclear related standards;
— A false sense of security based on prior successes;
— Failure to establish an atmosphere encouraging the reporting and resolution of problems at all levels of the organization;
— Failure to delegate authority commensurate with responsibility;
— Lack of clear communication pathways across all project interfaces.

NUREG-1055 noted that the failure of management to control certain conditions — such as excessive design changes leading to large amounts of rework, the failure to complete designs sufficiently ahead of construction, uninformed supervision and a project environment that emphasized production to the detriment of quality — was a major cause of the sacrifice of the "quality craftsmanship [that] is necessary for achieving quality" in nuclear construction.

In 2006, the Finnish Radiation and Nuclear Safety Authority (STUK) identified the following causal factors related to construction problems at a Finnish construction site [14]:

— Poor communication between design and construction organizations and within organizations participating in construction;
— Overconfidence in personnel with little nuclear industry experience and with inadequate oversight and training;
— Ineffective problem identification, inadequate reporting and inadequate corrective actions;
— Unrealistic and aggressive schedules to complete designs sufficiently ahead of construction;

— Inadequate assignment of responsibilities and a lack of authority to control assigned work;
— Inadequate communication of NPP specific requirements for quality and quality control from the plant vendor to subcontractors at the tendering stage and in purchase agreements;
— Inadequate understanding by vendors and contractors of the special work practices required for performing work in the nuclear field;
— Inadequate training of subcontractors and manufacturers regarding the importance to safety of their work and the special requirements for the construction of NPPs;
— Excessive reliance on subcontractors by the owner.

More than twenty years earlier, NUREG-1055 [13] had identified conditions under which major quality problems might recur, including:

— Inadequate nuclear design or construction experience of a first time utility, or an architect/engineer, construction manager or constructors (vendors and fabricators);
— Very large growth in the number of NPPs being constructed, which could overwhelm industry and regulator capabilities;
— A long phase with little or no NPP construction activities, resulting in a shortage of experience in the industry.

The Finnish construction experience, along with experience gathered from new build and refurbishment projects in other countries, clearly demonstrates that the causal factors identified in NUREG-1055 continue to exist. The nuclear renaissance is creating conditions that have significant potential to cause quality and safety problems.

2.3. INTEGRATED FRAMEWORK MODEL

Systems thinking is an approach that considers complex systems in their entirety. It is based on the observation that the elements of a system are often best understood in the context of their relationships with each other and with other systems, rather than in isolation. Systems thinking takes into consideration the dynamic web of temporal, conceptual, social and logistical interactions rather than simple linear cause and effect relationships. A systems approach expands the traditional ‘plan–do–check–act’ cycle. A systems cycle involves analysing the entire system, planning for integration, organizing across the system, implementing programmes within the integrated system, monitoring system

performance and making adjustments while paying attention to the impact on the dynamic relationships within the overall system. For example, systems thinking would consider whether the capacity of a national regulatory body matches the oversight demands of an NPP project in relation to the resource capability and nuclear experience level of the Member State in question.

Nuclear power plant projects involve a dynamic network of interactions and relationships that can benefit from the application of systems thinking. In the case of NPP projects, the 'system' involves human–social systems, work processes, complex technologies and multiple organizations in a global economic, energy, environmental and regulatory context. Nuclear safety is merely one property of the entire system.

Generalized models or integrated frameworks are often used to highlight the factors influencing a system. Figure 2 provides an example of an integrated framework for management systems in a nuclear power environment. The figure represents one cell of the whole system, since every participant (including licensees and newcomers) has its own variation of this framework. International partnerships associated with recent NPP projects add additional dimensions.

Regardless of the specific systems created to support an NPP project through its various phases, the safety culture is strongly influenced by four external factors:

(1) International obligations and expectations;
(2) National, regional and corporate governance;
(3) Culture, including national, local and multicultural dimensions;
(4) Environment (business climate, financial and resource availability).

National, regional and local governance — including political climate and stability — affects a participant's ability to develop safety programmes and infrastructure. National and local culture and customs influence underlying beliefs and behaviours related to safety. Multicultural influences add complexity. Business climate, financial resources, workforce skills, and the availability and capacity of the local infrastructure also require consideration.

Within the context of these external influences, each participant (e.g. licensees and newcomers) develops a management system to suit its needs. This is illustrated in general terms by the integrated management system shown in Fig. 2. IAEA publications on The Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-R-3) [15], Application of the Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-G-3.1) [16] and The Management System for Nuclear Installations (IAEA Safety Standards Series No. GS-G-3.5) [17] provide guidance on

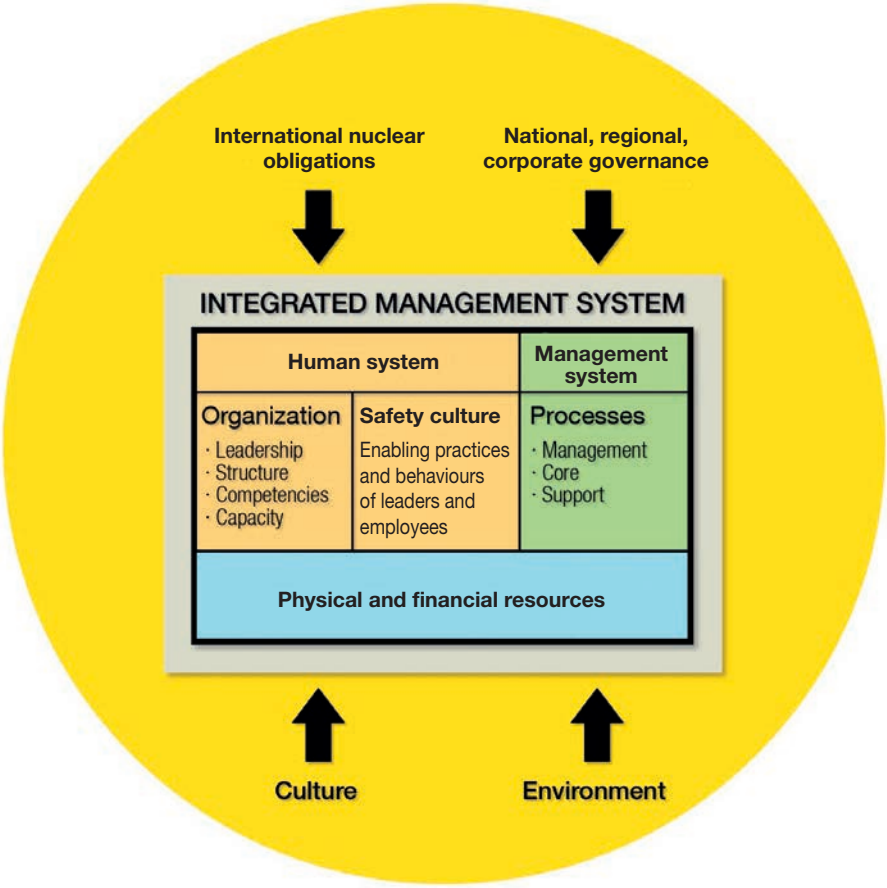

FIG. 2. One cell of an integrated framework for management systems in a nuclear power environment.

developing a management system based on management, core and supporting processes. Reference [17] also identifies generic management system processes that can be allocated to management, core or supporting processes, depending on the needs of a participant.

The core processes are different for each phase and organization. For example, core processes for construction organizations place greater emphasis on project management, construction planning and execution, contracts, and procurement. Core processes for regulatory bodies emphasize processes related to the development of regulations, licensing and the performance of inspections. Despite differences in core processes between organizations, many management and supporting processes are similar and can serve as interfaces between

organizations and as knowledge retention and transfer processes throughout all phases of a project.

As indicated by the central structure in Fig. 2, the integrated management system for any participant in any phase consists of three basic elements:

(1) A human system consisting of the organization and the people needed to perform activities to the required standards;
(2) A set of management system processes to provide a framework for the consistent performance of work in accordance with requirements;
(3) Financial and physical resources, including technology.

The human system is the complex, dynamic interaction of individuals and teams within an organization. Regardless of the robustness of the processes, procedures and technology, unless the human system is healthy and functioning, the results are unlikely to be effective. The human system is therefore a key consideration in this publication. Specific aspects of the human system include multicultural aspects (Section 4.2), leadership (Section 4.3), competencies and resource competition (Section 4.4), learning and feedback (Section 4.6), and effective communication (Section 4.8).

Nuclear power programmes involve multiple management systems (e.g. for design, construction, commissioning, operation, vendors and regulation). Countries new to nuclear technology may not have developed some of the required systems, or may choose to import them from selected vendors. It is important that the operating organization and owner develop an early understanding of the relationships and interfaces between participant organizations, including the robustness of their management systems. The operating organization needs to capture information from all phases, thus development of an operational management system needs to begin at the start of a project and to evolve with each phase. This is necessary to ensure retention and transfer of information related to design, construction, commissioning and procurement, all of which are relevant to the operating phase.

2.4. IAEA APPROACH TO SAFETY CULTURE

After the Chernobyl accident in 1986, the International Nuclear Safety Group (INSAG) introduced the concept of safety culture. Today it is a common and widely used concept in the nuclear industry and in other safety conscious industries. In Ref. [2], safety culture is defined as “that assembly of characteristics and attitudes in organizations and individuals which establishes

FIG. 3. Characteristics of a strong safety culture (from Ref. [17]).

that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance".

The IAEA Safety Glossary — 2007 Edition [18] provides an updated definition of safety culture as: "The assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, *protection and safety issues* receive the attention warranted by their significance." Additional IAEA information related to safety culture is provided in Refs [1–9].

Many other attempts have been made to define safety culture. The various definitions all indicate that the core meaning is to prioritize safety as a shared value within an organization.

It is important that organizations spend sufficient time to reach a common understanding of the concept of safety culture, since it is by its nature difficult to explain in a few sentences. Culture is a dynamic concept that encompasses everything that happens in an organization. It affects what people do, what they think and how they make sense of events and information — it is a collective understanding of reality. Therefore, to eliminate ambiguity, it is valuable for an organization to share perspectives about what the safety culture encompasses in day to day work related tasks.

In this publication, the safety culture framework is built on the five IAEA safety culture characteristics described in Ref. [17], as shown in Fig. 3.

The five characteristics are broken down into attributes that further describe important cultural aspects and provide a good framework for what needs to be in place to enable a strong safety culture. The IAEA has also produced guidance on how to identify a declining safety culture. This guidance [5–7] is valuable during every phase of a new build project.

2.5. A GUIDE TO USING THIS PUBLICATION

The first step of developing a strong safety culture is to identify the challenges being faced and to broaden the understanding of their nature and implications. This publication explores some of the challenges anticipated during pre-operational phases.

These challenge areas include special cases such as:

— Newcomer countries that lack existing nuclear infrastructure;
— Vendors, manufacturers and contractors, particularly in organizations less familiar with nuclear requirements;
— Regulatory bodies and their influence on the safety culture.

Generic challenges also exist, regardless of the organization. The eight generic challenge areas addressed in Section 4 of this publication are:

(1) Understanding nuclear safety and safety culture, particularly in organizations less familiar with nuclear power;
(2) Multicultural and multinational aspects of modern nuclear power programmes;
(3) Leadership and its role in strengthening the safety culture;
(4) Competency requirements and competition for experienced human resources;
(5) Management system processes to support the safety culture;
(6) Organizational learning and feedback of information;
(7) Cultural assessment and continuous improvement;
(8) Communication and interfaces.

One suggested approach to working with this publication is to identify which, if any, of the challenges listed apply in the circumstances under consideration. One can then select from the range of suggested approaches and methods, choosing those that may be of direct benefit and recognizing that any solution has to be tailored to the cultural and operational realities of an organization.

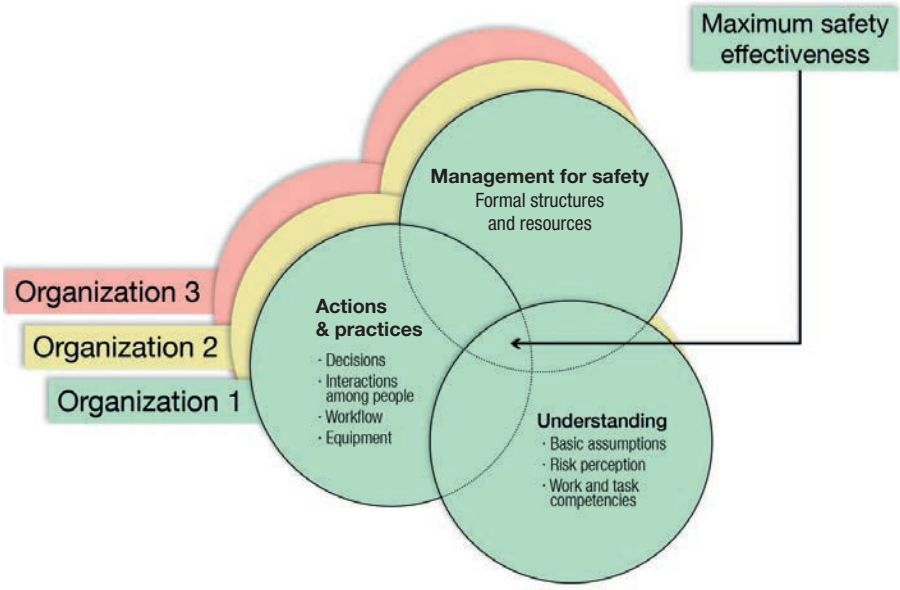

FIG. 4. A three element model for working with the safety culture.

Working with a simplified model of safety culture may help users of the guidance in this publication to understand the underlying components of each challenge, and may provide a useful structure for evaluating potential solutions. Figure 4 divides safety culture into three key interrelated elements. Each participant organization has its own set of elements, as indicated by the multilayered stack in the figure.

The component elements are as follows:

— Management for safety. This includes the formal framework for achieving the desired practices and outcomes, such as the regulatory framework, management systems, processes, procedures, risk management, organizational structure, specialist departments, and management programmes and plans.
— Actions and practices. This includes actual practices and actions such as decisions taken, leader and worker behaviours, learning focus, adherence to procedures, interactions between people, workflow and equipment, and interactions between organizations and other stakeholders.

— Understanding. This includes making sense of and understanding reality, on an individual and organizational level, and involves basic assumptions, risk perceptions, comprehension of the work or task, perceived centres of control, perceptions of cause and effect, and the comprehension that nuclear is ‘different’. It encompasses culture, beliefs and values.

The overlapping area between elements represents the interfaces. The central ‘triangle’ indicates an overlap of all three elements, or the area where safety performance has the most impact. If any element drifts away from the others, the central area decreases and the related interface areas get smaller, generating greater risk. For example, if ‘understanding’ shifts away from the other two elements, the interface between ‘management for safety’ and ‘actions and practices’ remains the same but the diminished alignment with ‘understanding’ introduces risk.

An expansion of the model considers the ‘stack’ of organizations involved in the NPP project. The central ‘triangle’ of the stack, if aligned through all organizations, is similar to a spinal column in anatomy. Any organization that shifts from the stack acts as a slipped disc that pinches a nerve or constrains the entire system. This is not to suggest that all organizations require identical systems or the same culture. Each organization simply needs to understand its role in contributing to the safety and effectiveness of the overall system, so that it can interact appropriately with the other participants.

To work with this model in practical situations, it is essential to use all three elements. For example, the specifications (i.e. ‘management for safety’ controls) for a welding job may be correct, but if the importance of following these specifications is not understood (i.e. ‘understanding’), the actual work (i.e. ‘actions and practices’) may be performed in a manner that is outside the defined safety envelope. If the nonconformity is not identified, it becomes a latent fault that could lead to a severe failure during the operational phase. Accurate specifications for the work, detailed safety briefings related to the work, and effective interactions and relationships between workers and supervisors will help avoid these problems. The three element model applies to work at all levels of an organizational hierarchy and is also helpful when exercising oversight. Its application avoids the common weakness of limiting inquiries to the formal framework of safety management.

Later sections of this publication refer to the three element model to assist the reader in relating the influence of each element to the suggested approaches and methods for addressing each challenge area. Understanding these influences will help ensure that each is considered during the development of specific approaches and methods applicable to the user. All elements of the model apply

in Section 3; however, in Section 4, specific elements have a more dominant influence, depending on the nature of the challenge.

3. SPECIAL CASES

3.1. STATES INITIATING A NUCLEAR POWER PLANT PROJECT

3.1.1. Key challenges

States embarking on a first NPP project face the greatest challenges in relation to nuclear infrastructure and experience. Key challenges include:

— The need for early development of an independent, effective nuclear regulatory body and the development of a regulatory framework that includes safety culture requirements;
— The lack of nuclear support organizations and infrastructure, including research capability, technical support and university training programmes;
— The need to train national personnel through foreign or domestic programmes within a time frame consistent with the overall programme;
— The need to develop long term, fully integrated strategies and plans for the NPP project from concept to decommissioning, including long term waste management;
— Global competition for nuclear expertise and suppliers of nuclear technology, services and components.

3.1.2. Approaches and methods

Despite these challenges, countries embarking on a nuclear power programme also have the greatest opportunity to learn from international experience, and to initiate steps to instil a strong safety culture from the outset. Some preliminary considerations include:

— Becoming a signatory to all applicable IAEA and international conventions, and committing to engage in international cooperation and support; reviewing international requirements and standards.
— Establishing intergovernmental agreements between participant and vendor countries to provide a foundation for contracts.

— Committing to transparency and openness to ensure that all participants and international agencies understand the chosen national strategy and plans.
— Determining the level of public acceptance, since this affects the ability to attract human and financial resources.
— Performing an early assessment of national and local cultural attributes in relation to safety awareness and attitudes toward risk. National and local cultures are the context within which a safety culture must be developed. It is important to direct efforts at strategies that counter attributes that would hinder the development of a strong safety culture.
— Assigning leaders with an understanding of and commitment to developing a strong safety culture. Such leaders have the courage to promote organizational learning by questioning established practices, revitalizing complacent organizations and helping those who are not familiar with best practices.
— Engaging external expertise in the early phases of an NPP project, specifically in the areas of safety, safety culture, human performance, organizational design, management system design and regulatory development.
— Developing the competency and capability to conduct technical reviews and assessments of nuclear safety through all phases of an NPP project.
— Establishing an effective regulatory organization in the pre-project phase, since the momentum associated with new build projects following a positive decision to proceed may leave a regulatory body unprepared. Regulatory skills, like operator skills, require considerable time to develop. It is important to establish a regulatory framework that includes requirements to support the development of a strong safety culture and to establish a management system in accordance with the requirements set out in The Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-R-3) [15] and other nuclear requirements.
— Establishing international cooperation and consortium agreements that include safety culture requirements and that address long term needs, and encouraging public scrutiny and engagement during the development of these agreements. Agreements assist in developing long term relationships between operators and vendors through such means as the establishment of consortia that include technology transfer arrangements. The global nature of the nuclear supply chain makes this aspect important for long term performance.
— Developing a national nuclear education and training plan that includes safety culture training as an important element; undertaking work exchange programmes to develop local expertise; participating in IAEA and other international nuclear industry information exchange programmes starting in

Phase 1; developing knowledge transfer arrangements to ensure the development of continuing expertise in nuclear safety and safety culture.

— Ensuring that project plans include safety culture elements and requirements to maintain continued focus on safety culture; developing project plan review checklists to confirm the systematic consideration of safety culture requirements.
— Establishing knowledge management and change management systems that ensure configuration management throughout all phases. Doing so will avoid the large costs associated with reconstituting lost or unclear design configuration during the operational phase, in which configuration issues pose a safety concern.

3.1.3. Resources

The IAEA has produced a number of publications that provide useful information for countries with little or no experience in nuclear power, including the following:

— Considerations to Launch a Nuclear Power Programme [19]. Although this publication does not provide specific guidance related to safety culture, it outlines the primary considerations for developing a nuclear power programme.
— Establishing the Safety Infrastructure for a Nuclear Power Programme (IAEA Safety Standards Series No. SSG-16) [20]. This publication provides detailed guidance on establishing a new programme in countries with no previous experience in nuclear power. Some of the many elements described in the publication include: transparency and openness; external support organizations and contractors; leadership and management for safety.
— Milestones in the Development of a National Infrastructure for Nuclear Power (IAEA Nuclear Energy Series No. NG-G-3.1) [12]. This publication emphasizes the importance of building a strong safety culture from the time a decision is made to proceed with nuclear power development.
— Evaluation of the Status of National Nuclear Infrastructure Development (IAEA Nuclear Energy Series No. NG-T-3.2) [21]. This publication describes an evaluation of the status of all aspects of an emerging nuclear power programme. Evaluation elements for Phase 1 include the "[r]ecognition of and commitment to the costs of training programmes to develop an appropriate safety culture in each of the relevant organizations to be established" and evidence of "[s]trategies for developing an appropriate safety culture and management in each of the future organizations".

— Managing the First Nuclear Power Plant Project (IAEA-TECDOC-1555) [22]. This publication provides useful guidance on each stage of a project, including pre-project preparation, decision making, construction, operation and decommissioning. It includes an appendix on international nuclear power agreements.

3.2. REGULATORY BODIES

3.2.1. Key challenges

The key challenges facing regulatory bodies are the following:

— Potential gaps that may exist in the national framework needed for the regulatory body to develop regulatory strategies that cover all participants at arm's length from the government. It is important that the regulator have legislative authority to conduct oversight of owners, operators, vendors, manufacturers and contractors and to require their related organizations to establish management systems that ensure nuclear safety.
— Establishing an integrated regulatory approach that includes nuclear safety, industrial safety, health, environment, security, quality and economics, as well as other considerations such as social responsibility.
— Having sufficient influence on government (i.e. monitoring the capability of the entire system and national infrastructure, and influencing legislation related to health, occupational safety, construction standards and other safety related issues).
— Ensuring that the owner retains accountability for nuclear safety, with no shift in responsibility to the regulatory body.
— Lack of clear accountability for nuclear safety in turnkey 'build, own and operate' agreements with foreign corporations, thus challenging regulatory oversight.
— Accessing lessons learned from the experience of others to conduct proactive oversight during all phases.
— Staying ahead of operating organizations in countries initiating nuclear power programmes.
— Remaining resource competitive in terms of number of staff, and staff disciplines, experience and salaries.
— Identifying regulatory strategies that positively influence the safety culture rather than make it worse by imposing time pressure or prescriptive approaches.

— Approving basic designs in an environment with multiple designs, new designs and evolving designs during the construction phase.

The establishment, within the legal framework, of an independent, transparent regulatory body that maintains public confidence in the regulator's ability to provide oversight of a nuclear power programme in the immediate and long term is important. This requires access to all participant organizations and related information to enable regulators to operate on the basis of facts. It also requires a sufficient number of staff and an interdisciplinary talent pool that possesses nuclear knowledge and experience at senior levels. An understanding of human systems improves regulatory ability to mediate complex relationships.

Impact of the regulatory safety culture

Regulators have an opportunity to influence their own safety culture and the safety culture of participant organizations from the outset. The regulatory safety culture can have a positive or negative impact on participants. An inspection mentality and/or assignment of blame through overzealous enforcement actions are not optimum strategies for positively influencing the safety culture. A human system approach is needed to complement a technical–prescriptive focus. Prescribing remedial action based on theory without understanding the realities and potential consequences of implementation rarely achieves the desired outcomes. Communicating a need to 'improve safety culture' is easy; however, a lack of clarity may cause owners and operators to respond with programmes that do not address the underlying causes of problems. An understanding of oversight methodologies related to nuclear safety and safety culture, a balance between formal and informal oversight, a proactive presence in the work environment, an understanding of human systems, and efforts to continuously improve the regulatory safety culture will have a positive influence on the overall safety culture and performance of all participants.

3.2.2. Approaches and methods

3.2.2.1. Regulatory strategies

Different regulatory strategies have different impacts on the safety culture. Although a mix of strategies is typically required, selection of a primary strategy is beneficial for organizational alignment and supports communication consistency with licensees. Below are six typical regulatory strategies [23]:

(1) Prescriptive strategy. Detailed regulations and requirements for conducting activities are established. Regulators require significant expertise to implement this approach. Detailed review and approval of licensee activities may cause a perceived shift in nuclear safety accountability to the regulator. Licensees may become dependent on detailed requirements, expectations and approvals from the regulator.
(2) Case based strategy. The regulator does not develop universal requirements that apply equally to all licensees of a particular type of facility. The regulator determines the safety performance of each licensee through individual assessments and considers the unique history of each facility. Although this approach takes into account specific circumstances, it may be perceived as arbitrary and inconsistent by operating organizations.
(3) Outcome based strategy. Specific goals for licensees are established but there is no specification on how licensees attain these goals. This approach allows the licensee to determine how it will conduct activities, but learning may be less proactive and may take place only after failures occur.
(4) Risk based strategy. In this approach, areas and systems of significant potential risk are identified. It requires regulators and operators to uncover the areas of an NPP likely to initiate an accident and to estimate how serious a resulting accident might be. This results in a safety focus on specific areas; however, not enough attention may be given to other areas, particularly the human system and organizational aspects required to support a strong safety culture.
(5) Process or system based strategy. The regulator identifies key processes and systems needed for safe operation and requires licensees to establish and implement these processes and systems effectively. This approach takes a systemic view of safety and includes physical and organizational aspects. The approach has a positive impact on the safety culture, since it covers the entire system yet allows the licensee to determine how the work will be done.
(6) Self-assessment based strategy. Licensees develop and implement a self-assessment programme to identify good practices and areas needing improvement. This approach fosters learning and adoption of best practices; however, the regulator may become too dependent on the licensee for information on plant performance.

The strategy selected will determine the relationship between licensees and other participants (e.g. the degree of dependence on regulatory expert knowledge of a facility's design, openness of reporting). It is best if the chosen strategy includes information about how to work with contractors. Combinations of strategies are typically used, depending on the situation and maturity of the

licensee. The process or system based strategy discussed above has the potential to positively influence the safety culture. For example, examining the process for developing a final safety report — which includes competencies, processes and the safety approach — may be more beneficial than a detailed review of the report itself. In the long term, a process approach promotes continuous improvement of the safety culture.

3.2.2.2. Competencies and resources

The regulatory strategy selected also affects decisions concerning resources. For example, process based approaches require a different set of talents than prescriptive approaches. Since talents or natural preferences cannot be 'trained in', they need to be considered during the recruitment stage. For example, process based approaches require systems thinking, whereas prescriptive approaches favour detail oriented thinking.

Regulatory activities are interdisciplinary by nature and require expertise in human behaviour as well as in nuclear technology. Required competencies vary by phase, since the technical knowledge and skills required during the design phase of an NPP are different from those required during construction. Outsourcing regulatory issues to specialist contractors in order to obtain an independent opinion is often not feasible, since scarce resources are typically shared within the nuclear community.

Senior personnel in regulatory bodies require nuclear knowledge equivalent to that of senior personnel in regulated organizations. This requires pay levels competitive with those in the industry, to prevent attrition and chronic understaffing and to counter the belief that regulatory bodies do not offer an attractive career path.

It is important that regulatory personnel recognize that regulatory strategies are more effectively implemented through asking questions and evaluating responses than through providing solutions. Regulatory personnel must be comfortable working with vendors, contractors, licensees, policy makers and the public. The public and appointed or elected policy makers may not be familiar with nuclear or regulatory activities and risks.

Early regulatory involvement in a new NPP project is important to enable planning of regulatory resources and to identify requirements and competencies. Reference [24] provides recommendations on the organization and staffing of a regulatory body for nuclear facilities: its structure and organization; its interaction with other organizations; and appropriate qualifications and training for regulatory personnel.

3.2.2.3. Other considerations

It is necessary to establish clear regulatory expectations that cover safety culture and safety management arrangements as well as technical issues for the pre-operational phase. Safety culture expectations for the pre-operational phase have been defined by some regulatory bodies in licensing or other regulatory guidance documents (e.g. as part of the requirements for a management system).

Encouraging participants to conduct a self-assessment of the safety culture during all phases, rather than relying on formal regulatory assessments of the safety culture, promotes ongoing learning instead of reliance on the regulatory body to interpret results. Nevertheless, training of regulatory personnel in how to effectively observe and positively influence the safety culture throughout a new build project is necessary, particularly if their role has typically focused on technical inspection and assessment. Temporary postings to or from countries with recent or current experience with new build projects can help to transfer experience and develop personnel. Arranging workshops on learning from industry experience and workshops for sharing good practices can also be effective. Self-assessment of the regulatory safety culture is also important, to ensure consistency with the regulatory strategy selected.

International experience shows that periodic safety culture assessments focus the attention of senior management on the topic. Some regulators monitor aspects of the safety culture (such as learning) during reviews of vendor/designer and future owner/operator safety management programmes.

Ongoing monitoring of safety culture characteristics as an integral part of regulatory oversight activities is important for obtaining information and influencing performance throughout the pre-operational phases. It is a good practice to discuss the safety culture during routine project meetings between the licence applicant, vendor and regulator. It is important for regulatory personnel to pay attention to behaviours (e.g. a questioning attitude) and other safety culture indicators (e.g. evidence of applying lessons learned from past projects, evidence that issues are being addressed expeditiously) during these meetings and other interactions, especially those involving senior management.

3.3. VENDORS, MANUFACTURERS AND CONTRACTORS

3.3.1. Key challenges

Vendors, manufacturers and contractors face the following key challenges in relation to nuclear safety:

— The large number of contractors, subcontractors and associated turnovers involved, both on-site and off-site through the supply chain, increases organizational complexity (e.g. Olkiluoto-3 in Finland involved 1800 subcontractors).
— Subcontractors may not have the appropriate experience, expertise or management systems to consider nuclear safety issues.
— Contractual arrangements related to safety culture expectations are often absent or are too general.
— Owner/licensee and regulatory oversight of vendors, manufacturers and contractors is more difficult because of the global nature of the supply chain.
— Contractor incentives are often driven by cost and schedule rather than by safety culture performance. In addition, the safety cultures of nuclear and conventional industries are significantly different.
— Vendors involved in an NPP project may not fully appreciate that the impact of their actions and their ethical and legal obligations extend far beyond the life of the contract.

3.3.2. Desired state

In the desired state, all participants share a common understanding of and a commitment to nuclear safety as an overriding priority. Participants have effective management systems in place to address nuclear safety.

Clear criteria ensure the selection of qualified and well equipped contractors who have a good understanding of technical and safety requirements. The number and level of subcontractors is optimized to minimize the complexity of organizational interfaces. Formal documents, such as contracts, are unambiguous and include arrangements for sharing risk.

Effective oversight of contractors is in place. Worksite observations and inspections to confirm worker understanding of safety requirements and their significance occur regularly.

Supervisors are effective coaches and enquirers, and confirm that participants understand requirements. Supervisors respect contract worker knowledge and skills, and confirm or supplement nuclear safety understanding. Supervisors work proactively to ensure that nuclear and industrial safety objectives are met. Managers and supervisors at all levels are clear in their interactions with workers in order to avoid providing conflicting or confusing instructions.

3.3.3. Approaches and methods

The following approaches and methods are applicable to vendors, manufacturers and contractors:

— Emphasize licensee requirements and expectations with respect to nuclear safety and the safety culture during the various stages involved in the awarding of a contract, so that these aspects are fully considered during planning. These stages include: pre-bid meetings, technical discussions and kick-off meetings prior to the commencement of a job. Gather information on contractor culture, performance and behaviours by contacting other clients or undertaking site visits where a contractor is working, both inside and outside the industry.
— Define expectations for the contractor to develop a strong safety culture. Ensure that the contractor's management system accounts for nuclear safety through a vision statement on safety culture, clearly defined roles and responsibilities, training, and safety procedures and practices.
— Include safety culture requirements in the contract to allow vendors to consider these aspects in the quoted cost.
— Include contractors in determining goals, objectives and indicators for safety performance and safety culture.
— Establish a reward and incentive programme for the overall project, with objectives for safety performance and rewards that are either monetary or in the form of future contracts as a long term partner. These may serve as a motivation that influences the overall culture within contractor organizations.
— Use models that support 'win–win' contracts with fair collaboration. One example is the 'open book' model, which includes open financial/accounting books so that finances are transparent to all parties. This type of model encourages the owner/licensee to be more engaged.
— Consider establishing tools to predict and track the total cost of contractors, including the hidden costs resulting from choosing low quality equipment or unskilled personnel, and the impact of rework on material, cost and schedule.
— Implement a safety culture assessment programme that allows the owner/licensee to confirm that the entire project is evaluated at reasonable intervals and that focused action is taken on issues requiring improvement. (See Section 4.7 for further information on cultural assessments.)

3.3.4. Examples

Good results in improving the safety culture of contractors have been achieved through joint efforts in Norway's offshore oil industry. The participating oil companies have agreed on a common safety standard that is applied to all contractors. There is collaboration both in the performance of safety related audits and in the sharing of results. Contractor safety records are shared in a jointly owned database accessible to all Norwegian oil companies. The results of this joint work have encouraged contractors to enhance safety proactively within their organizations in order to remain competitive.

4. APPROACHES TO GENERIC CHALLENGES

Section 4 describes the eight generic challenge themes identified in Section 2.5. Each theme includes a discussion of the key challenges, a description of the desired state, a discussion of approaches and methods, and examples and resources.

4.1. UNDERSTANDING NUCLEAR SAFETY AND SAFETY CULTURE

4.1.1. Key challenges

Key challenges related to understanding nuclear safety and safety culture include the following:

— Clarifying nuclear safety, as it is not tangible. Organizations with little or no direct nuclear experience may not be familiar with the risks inherent in nuclear technology. They may not be familiar with basic safety principles such as defence in depth, or with nuclear industry terminology such as 'safety classification' used to convey the safety importance of systems.
— Creating acceptance of the need to invest time and money in order to enhance nuclear safety understanding.
— Maintaining focus on nuclear safety during all phases, including project conception, design, vendor selection and construction.

— Motivating construction teams to learn about nuclear safety and safety culture. This involves building a greater understanding of the basis of nuclear practices and explaining why deviations from specifications and requirements may have consequences beyond the construction phase.
— Designing appropriate safety training for target audiences, including contractors and subcontractors. This may include some fundamental safety concepts such as defence in depth. A related challenge involves establishing criteria for determining who needs training and to what extent in terms of scope and depth.
— Ensuring that leaders are aware of the implications of the technical aspects of nuclear safety and that they regard the safety culture as a means to drive excellent performance rather than as a source of conflict in relation to cost and schedule, or as an externally imposed programme.
— Establishing an open reporting culture in complex environments with different national cultures, contractors and regulators.
— Countering assumptions that safety is limited to the industrial health and safety programme under the control of safety officers and inspectors. Having a strong industrial safety programme does not necessarily translate into a strong nuclear safety culture, because of the potential for introducing latent or intangible risks.
— Countering the mistaken belief that the safety culture is the primary responsibility of managers and supervisors, and that individual workers only need to follow defined procedures.
— Overcoming misperceptions that a safety culture cannot be established in rapidly changing environments such as those existing during the construction phase, when contractor turnover is high.
— Building nuclear safety understanding among individuals who lack the knowledge gained through first-hand NPP experience.
— Understanding why acceptable practices from non-nuclear environments may not meet nuclear standards because of, for example, the impact of radiation and the reliability requirements associated with the long service life of modern NPPs (potentially up to 100 years for new designs).

A strong nuclear safety culture includes the understanding that deviations from procedures and specifications, or the failure to understand the safety significance of structures, systems and components, may have unforeseen consequences in the future. For this reason, deviations need to be treated with more rigour and attention than may be necessary for activities with a lower level of potential risk. Corrective actions that are required during operation may be technically far more difficult and more expensive because of the presence of radiation.

While it takes a long time to develop a fully mature safety culture, cultivating the essential elements can be done quite rapidly. The value in developing an early, systematic approach to strengthening the safety culture at all levels is that many of the relationships established during pre-operational phases continue through the operation and decommissioning phases. Employees involved in pre-operational phases often transfer into operating, supplier or regulatory organizations. Experience demonstrates that it is far easier to build on a carefully laid foundation of safety awareness than it is to change inappropriate practices once they have become ingrained.

4.1.2. Desired state

The safety culture is based on a thorough understanding of nuclear safety, a willingness to develop structures and processes that support safety, and mindfulness towards the consistent application of good safety practices. Attributes of the desired state include:

— Understanding of the risks and benefits of NPPs, resulting in a nuclear safety focus that is maintained throughout the life cycle of the NPP, from conception to decommissioning, including long term storage of nuclear waste.
— National nuclear industry training programmes that include modules on human and organizational factors to support the development of a strong nuclear safety culture.
— Nuclear requirements that are rigorously applied to protect the public and the environment.
— An understanding on the part of all individuals as to how they contribute to safety. This includes self-posed questions such as: What influence do I have in this role in relation to nuclear safety, and what should I be aware of while performing this role? What relevance does this structure, system or component, or technical or social system have to nuclear safety, and what should I be aware of while performing tasks related to it?
— Standardization of nuclear terminology (e.g. site-wide glossary of terms) and full understanding of these terms among participants.

4.1.3. Approaches and methods

A variety of approaches and methods exist to promote the understanding of nuclear safety. The approaches and methods in this section focus on the ‘understanding’ element of Fig. 4 to promote the right ‘actions and practices’. It is important to adapt the approach taken to the tasks and organizations involved.

However, the following steps generally apply to all phases and participant organizations:

— Step 1: Establish scoping meetings between representatives of the partner organizations to identify general needs and approaches relevant to each target group. Develop a 'marketing campaign' to create awareness and move safety culture from an abstract concept to a subject that can be easily understood by everyone.
— Step 2: Identify the knowledge and strengths of the project participants, including cultural attributes that may help or hinder success. Consider different methods for identifying specific information needs at each phase, including:
  • Developing a list of organizations and people involved in the project. Information may include the name of the organization, its country of origin and branch office, the national origins and primary languages of the employees, and qualifications and professional backgrounds and skills associated with the participant and its employees.
  • Interviewing target groups to gain a deeper knowledge of their current understanding and attributes. This involves careful attention to the stories, examples and impressions of the group. A general sense of the organizational culture and authority preferences can be obtained during such sessions.
— Step 3: Define specific safety principles and learning materials on safety, including:
  • Establishing behavioural expectations in conjunction with the main contracting partners, including vendors, owners, constructors and regulators;
  • Conducting job hazard analyses, developing appropriate checklists and reviewing relevant incidents that occurred during previous projects.
— Step 4: Based on the results of this information, develop training curricula using experienced, trained instructors who are familiar with the cultural attributes of the intended audiences (project personnel, management, engineering and field workers). Include cultural diversity training for key individuals such as leaders and managers, as well as communications and quality assurance personnel. Use representations that are meaningful to the different audiences (e.g. pictures, stories, real life examples, workshops, role playing). Figure 5 illustrates the difference between conventional and nuclear safety thinking in a simple way. Ensure that the organization's safety training programme includes the elements identified in Table 1.

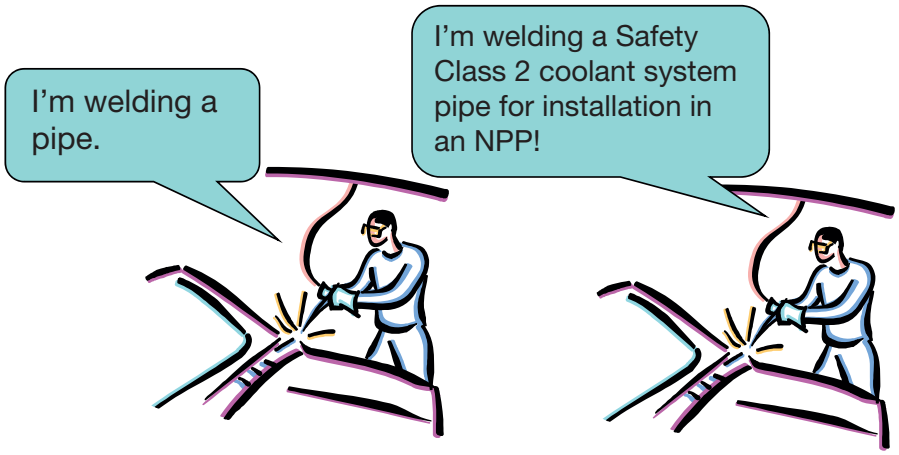

FIG. 5. Example of safety culture consciousness in welders.

TABLE 1. ELEMENTS OF A SAFETY TRAINING PROGRAMME

Organizational and cultural considerations	Nuclear industry practices
— Safety culture leadership — Managing potential conflicts between safety, schedule and cost — Safety culture expectations: why they are important and what the behaviours look like in practice — Open communication and reporting — Questioning attitude — Challenging unsafe conditions — Conservative decision making — Respect and fair treatment — Fit for duty — Due diligence — Managing change	— Nuclear safety principles and terminology, for example, defence in depth and multiple barrier models illustrated with pictures — Quality assurance and control — Procedural use and avoidance of workarounds — Effective pre-job briefings that have attributes similar to operating phase briefings in their identification of the safety significance of the planned work — Design specification modifications — Modifications during installation — Accuracy and completeness of documents and records

— Step 5: Provide pre-job briefings for field work teams that include:
  - Supplying task specific safety significance information while describing the technical boundary conditions in an understandable way so that participants understand the risks and their role.
  - Emphasizing that everyone is required to demonstrate initiative in asking questions and suggesting optimal approaches for the work at hand.

- Reminding workers that supervisors are not only interested in work progress, but are approachable and available to answer questions during work. Experience has demonstrated the benefit of appointing a small number of senior advisors to follow construction progress, talk to workers with the intention of resolving questions and concerns, and act on ideas and suggestions in a positive way.
- Review and reinforce desired safety practices.

Although one might conclude that the changing dynamics of the pre-operational phases make a strong safety culture more difficult to achieve, in reality projects extend over many years under relatively consistent leadership. A strong safety culture can be cultivated if it is initiated early and is rigorously promoted to incoming workers throughout each phase. Regardless of the approaches and tools applied, integration of the 'understanding' and 'actions and practices' elements in Fig. 4 is essential for success.

4.1.4. Examples and resources

4.1.4.1. Threaded rod assembly

In some cases, even the good intentions of a manufacturer can lead to problems. In one example, the blueprint for the manufacture of a threaded rod for a safety relevant application indicated the need for a rolled thread. When the manufacturer of the threaded rod was changed, the new manufacturer added an undercut at the end of the thread in order to remove the bulge and provide a better finish to the thread, thus reducing material stresses from the bulge. This procedure is very common in engineering, but in this case the action caused a reduction in the diameter in the area of the undercut.

Through removal of the bulge, the rod's material parameters (strength and durability) changed. The diameter is used to perform safety verifications. The modified rod had the potential to break uncontrollably during reactor operation.

During the manufacture of parts used in nuclear technology, the requirements of the designer must be completely fulfilled. This is a question not only of good quality management but also of good communication between companies and individuals to ensure that the implications of any changes are understood and agreed upon.

4.1.4.2. IAEA publications relevant to safety culture understanding

The following IAEA publications provide useful information on safety principles and safety culture understanding:

— Fundamental Safety Principles (IAEA Safety Standards Series No. SF-1) [1]. This publication describes ten fundamental safety principles that apply to nuclear activities. The ten principles cover: responsibility for safety; the role of government; leadership and management for safety; justification of facilities and activities; optimization of protection; limitation of risks to individuals; protection of present and future generations; prevention of accidents; emergency preparedness and response; and protective actions to reduce existing or unregulated radiation risks.
— Safety Culture (Safety Series No. 75-INSAG-4) [2]. The first IAEA publication devoted to safety culture, this report provides an explanation of the concepts.
— Key Practical Issues in Strengthening Safety Culture (INSAG-15) [5]. This publication expands on the information in Ref. [2]. Topics include: commitment; use of procedures; conservative decision making; creating a reporting culture; challenging unsafe acts and conditions; and the learning organization. Communication, clear priorities and organization are identified as key issues in strengthening the safety culture. An appendix contains a comprehensive list of questions that can be asked to assess the safety culture at all levels of an organization. Although intended for the operating environment, virtually all of the questions are relevant to pre-operational phases.
— Nuclear Safety Infrastructure for a National Nuclear Power Programme Supported by the IAEA Fundamental Safety Principles (INSAG-22) [25]. This publication stresses that an NPP "is operated by people, and thus the achievement of safety requires qualified managerial and operating personnel with an appropriately embedded safety culture."
— Developing Safety Culture in Nuclear Activities: Practical Suggestions to Assist Progress (Safety Report Series No. 11) [6]. This publication provides many practical suggestions for enhancing the safety culture, including the attributes of a strong safety culture, signs of a weakening safety culture and means of assessment.
— Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture (IAEA-TECDOC-1329) [9]. This publication provides a comprehensive review of safety culture information directed at safety culture practitioners and organizations that want to improve their understanding of safety culture. It includes exercises at the end of each chapter. PowerPoint presentations are available from the IAEA to support training.

4.2. MULTICULTURAL AND MULTINATIONAL ELEMENTS

4.2.1. Key challenges

The key challenges related to multicultural and multinational elements are the following:

— Projects often involve people of many nationalities with different languages, cultures, customs, values, religions and traditions, adding complexity to the establishment of a coherent nuclear safety culture.
— Establishing multinational teams is more resource intensive, and thus more time is required to achieve optimal team performance.
— Multi-industry, multi-contractor approaches may result in the assignment of short term project managers who do not consider or accommodate multicultural aspects.
— Each multi-organization relationship has its own organizational culture and approach.

The realities of a globalized market have made working environments increasingly multicultural. Such environments, because of their inherent diversity, offer unique opportunities to benefit from different approaches and perceptions. However, special managerial and leadership skills are required to help team members gain a common understanding of one another in culturally diverse environments.

4.2.2. Desired state

The desired state is to provide a work environment in which cultural diversity is respected and supported, and which offers facilities that accommodate cultural needs and requirements. Specific support systems, methods and training assist management in developing all personnel so that they work effectively in multicultural environments. Work processes and communication methods accommodate cultural learning styles. Facilitators and cultural review groups ensure that systems influenced by cultural aspects work effectively across the whole organization and that they support nuclear safety.

4.2.3. Approaches and methods

Approaches and methods related to multicultural and multinational elements focus on the ‘understanding’ element of Fig. 4:

— Consider the impact of the complexity introduced by multicultural issues, such as language, early in Phase 1, since related decisions will have a long term impact on the NPP project, including in terms of safety and cost. Multicultural teams need a longer and different type of project startup than other teams, and many organizations do not take this into account.
— Where possible, co-locate key personnel to enhance communication and interaction. Monitor the organizational culture of 'parent' organizations to assess their impact (constraints) and influence on safety.
— Involve regulatory bodies in the effort to develop a mutual understanding of the safety culture associated with nuclear power programmes. In early phases, regulators may be at an organizational development and understanding stage with little direct knowledge and experience.
— When recruiting personnel for key functions, consider not only their 'technical' competency and experience but also their value system and multicultural views, including their attitude towards care, risk, responsibility and safety.
— Select personnel with an agreed upon level of literacy for employment on NPP projects. Additionally, ensure that personnel transferred to or employed on NPP projects are aware of the unique issues associated with safety in nuclear environments.
— Core workers (i.e. workers continuously employed on long term contracts) are an essential component of NPP projects. They transfer organizational knowledge and specialist skills to the externally contracted or outsourced elements of the project as well as aspects related to the safety culture. Core workers need to have a high degree of development regarding the safety culture and its application across all aspects of the work. This includes acting as role models who reinforce safety practices at the field level. Provide core workers with a comprehensive development package to ensure that they have sufficient knowledge of nuclear safety and model safe work practices.
— Include in the development programme clear methods of dealing with non-compliant employees, irrespective of their employer.
— Provide training and development information in a manner consistent with language and learning preferences, rather than simply loading people with manuals and instructions. This is necessary to ensure that safety information is clearly understood and applied.
— In situations involving a large number of cultures and employees who are unfamiliar with nuclear safety, managers and supervisors need to be more directly engaged in work oversight. Since the span of management control is often too wide, provide adequate numbers of 'supervisory grade' employees to ensure that safety management is applied effectively. Assign

supervisors and project leaders for a long enough period to allow them to become familiar with the specific multicultural environment associated with the project phase.

— Establish an experience feedback system accessible to all employees, including provision for anonymous reporting. This is particularly important in multicultural environments.
— Consider establishing a cultural review group or panel to ensure that audits and other systems are working effectively across the organization. Include all levels of the participant organizations to ensure that the review group is aware of the working environment at a practical, day to day level and not simply at the conceptual level.
— Assign experienced people in the areas of cultural understanding, languages, facilitation and mediation, and make them available for use as necessary. A pool of on call contract people can be used on an as needed basis supported by a simple policy. Avoid complex or bureaucratic processes, since prompt resolution is necessary in some situations. It is important to understand that interactions in multicultural environments take place at the social relationship level as well as at the work level.

4.2.4. Examples and resources

Some organizations draw analogies that characterize the workplace as ‘your other home’ when promoting issues such as safety and housekeeping. Diverse communication approaches such as videos, storyboards, mascots, human performance simulators and role playing designed by individuals who understand behavioural and social sciences from a cultural perspective are also useful.

Safety campaigns can extend into, and involve, the community. Engaging representatives of the local culture to identify what might help or hinder safety behaviours is especially useful when designing entry level training programmes, which benefit from being as practical and hands-on as possible. It is important for entry training to be introduced by senior management, to emphasize the importance of nuclear safety, communication and open reporting.

4.3. LEADERSHIP

4.3.1. Key challenges

Key challenges related to leadership include the following:

— Lack of clarity about the difference between management and leadership and the importance of both in developing healthy organizational and safety cultures;
— Ensuring leadership continuity through all phases of development in order to maintain and build a safety focus;
— Constraints set by governments, owners or corporate bodies, which may emphasize business and economic concerns and may show a lack of understanding of the unique requirements involved in nuclear energy production;
— Avoiding the selection for leadership roles of people who prefer focusing on tasks or ideas rather than on people;
— Ensuring alignment of individual leaders' personal goals with organizational objectives, including avoiding the appointment of leaders for reasons other than competency;
— Cultivating leadership talent in organizations that have a strong focus on task and technical issues management and that tend to emphasize and reward a focus on short term tasks and results at the expense of longer term capacity and culture building.

Organizational management encompasses a range of behaviours that includes managing issues, systems and resources through the application of expectations, rules, rewards and corrective actions. In addition, it involves leading individuals and teams, and introducing change through serving as a role model and through providing inspiration, challenges and support. These elements are needed to establish a healthy human system and a strong safety culture.

Leaders who are trustworthy, fair, encouraging and motivating, and who work on team building create more adaptive cultures, with organizational members attaching importance to achieving organizational goals, professional development, helping and supporting each other, and being active team members. As a result of increased commitment, learning and focus, adaptive cultures produce significantly better results than less adaptive cultures. Conversely, leaders who are dictatorial, egocentric, irritable and uncommunicative constrain employee engagement and motivation, and contribute to creating less adaptive organizational cultures.

4.3.2. Desired state

Leadership has everything to do with the impact that one individual has on others and the environment created as a result. During pre-operational phases, circumstances require dynamic leadership that can adapt to a rapidly changing

environment and help workers to understand their role in nuclear safety. The desired state during the pre-operational phase is one where leaders:

— Demonstrate nuclear safety awareness and expect safety accountability from all workers. This includes the establishment of clear ethical guidelines.
— Facilitate learning, the sharing of ideas and collaboration, and create an overall sense of competency, so that people willingly engage to achieve results and meet expectations.
— Engage with different audiences while maintaining sensitivity to national, functional, gender and generational differences in culture.
— Recognize and resolve issues that can compromise safety while considering their systemic nature. This includes promoting integration of information and people, and recognizing patterns that indicate breakdowns in communication and collaboration.
— Build organizational capacity through continuous investment in development of the knowledge and skills of the workforce. Leaders demonstrate an approach focused on learning and coaching.
— Acknowledge human fallibility and foster learning for teams and individuals. This includes demonstrating a willingness and ability to allow opposing views to surface irrespective of the position of the speaker in the organization.
— Demonstrate awareness and willingness to act when political, commercial or other interests undermine nuclear safety.
— Develop leadership capability in others by demonstrating self-awareness, self-motivation, self-directedness and self-teaching.

To achieve the desired state, the process for selecting leaders needs to emphasize the following knowledge, skills and abilities:

— Nuclear safety knowledge;
— Human factors, human performance and organizational knowledge and understanding;
— Safety culture awareness;
— Project or operational experience applicable to the phase involved (e.g. project management, planning and logistics skills, organizational skills);
— Ability to deal with ambiguity and manage risk consistent with conservative decision making;
— Ability to maintain focus on nuclear safety when under pressure;
— Commitment to safety, quality, cost and achieving timely results.

4.3.3. Approaches and methods

Approaches and methods focus on the competencies needed to integrate all three elements of Fig. 4 into a living organizational system. Consider several or all of the following four options for developing leadership strength in an organization:

(1) Recruiting leadership talent from outside the organization;
(2) Developing personnel with leadership potential and placing them in influential positions within the structure;
(3) Developing a culture that harnesses the latent leadership capabilities within the entire workforce (team level leadership);
(4) Implementing programmes that compensate for leadership practices that should be occurring but that are not being carried out by existing leaders.

Establish a leadership development plan to ensure that effective leadership is present during all phases. This means getting the right talent into the right leadership roles and ensuring the strength and continuity of leadership for safety.

Define the suitability requirements for different organizational levels and select individuals with natural strengths in those areas to increase the likelihood of effective performance. Selections made with consideration for the role and team fit of an individual can further strengthen overall leadership.

Select individuals with a clear talent for leading others. This includes people who are able to:

— Envision new directions and engage others;
— Anticipate the need for change and promote new ways of doing things;
— Inspire involvement and commitment to accomplish more;
— Focus on a higher purpose common to all in the organization;
— Challenge others to be innovative problem solvers;
— Build the capacity of others through coaching and mentoring.

Design compensation packages to encourage people who are good at accomplishing work through task delegation to assume leadership roles while at the same time permitting those who enjoy focusing on tasks and technical issues to advance in technical streams without a loss of income earning potential. This reduces the likelihood of individuals selecting themselves into ‘poor fit’ roles, or being appointed into ‘poor fit’ roles as a means of recognizing exemplary performance.

Provide leadership development focused on helping leaders to cultivate competencies that will enable them to understand and address individual, team and organization level effectiveness issues. Some of the practices needed to

support an open, proactive, safety minded environment, as well as some options for developing these talents, are listed in Table 2.

TABLE 2. LEADERSHIP PRACTICES AND DEVELOPMENT OPPORTUNITIES

Desired leadership practices	Methods to enhance learning
— Model asking for help to demonstrate that doing so does not make one 'weak' — Use stories to share values and lessons learned — Pay attention to breakdowns in human interaction and use mediation techniques to ensure collaboration between people — Use active listening, empathy and open ended questions to help others think things through for themselves — Provide emotional support to help individuals with personal problems — Explain the relationships between time periods/horizons and decision making to help resolve competing priorities — Monitor organizational effectiveness to uncover where sharing, learning, cooperation, or contributions to nuclear safety are not taking place — Establish acceptable behaviours and results, and make sure they are known to everyone involved — Use individual development plans to help achieve desired performance and to identify consequences if support does not help bring about needed changes — Establish relationships and have crucial conversations before problems arise	— Teach leaders how to construct and tell stories to convey the importance of safety in memorable ways in multicultural settings — Provide meaningful 'walk a mile in my shoes' experiences to help leaders gain insight into why avoidance of safety behaviours occurs — Facilitate discussion forums to help leaders from different functions or organizations hear one another's challenges — Use organigraphs [26] to help leaders understand how different functions or organizations fit together in order to reduce the risk of non-cooperation and lack of understanding by parties as to how to be good 'customers' and 'suppliers' — Conduct exercises or explore case studies related to the paradoxes leaders face on a regular basis (e.g. procedural compliance versus a questioning attitude) and provide coaching on how to resolve these paradoxes — Simulate decision making in a fast paced, complex environment to help leaders identify risks in their own approaches — Conduct live simulations to teach leaders about organizational function/dysfunction and their role in integration across levels and functions — Establish mentoring opportunities using computer media so that mentors and individuals seeking longer term coaching can discuss how to be more effective

4.3.4. Examples and resources

A useful resource is the work of the Global Leadership and Organizational Behavior Effectiveness (GLOBE) research project [27], an extensive, ongoing effort to understand cross-cultural interactions and the relationship between culture and leadership effectiveness. Using quantitative methods to study the responses of 17 000 managers in more than 950 organizations representing 62 different cultures throughout the world, the project has identified 22 desirable and 8 undesirable leadership attributes.

4.3.4.1. IAEA publications relevant to leadership

The following IAEA publications provide useful information on leadership and organizations:

— The Operating Organization for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-2.4) [28]. This publication provides guidance on setting up an operating organization that encompasses the most important organizational elements contributing to a strong safety culture and good performance.
— Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-2.8) [29]. This publication describes factors important for consideration in order to ensure that the operating organization has a sufficient number of qualified personnel for safe operation. Although it is focused on operating plants, some of the elements are relevant to other phases of plant development.

4.4. COMPETENCIES AND COMPETITION FOR EXPERIENCED RESOURCES

4.4.1. Key challenges

The key challenges related to competencies and resource competition include the following:

— Nuclear power programmes are skills intensive at every phase of development, from the pre-project phase through to full operation.
— The range of required competencies — from professional management, project management and core technical disciplines to safety culture, human

factors and organizational development — is not well defined, and deficits in any of these areas can compromise the safety culture at various phases.
— Insufficient numbers of young people are entering the educational streams required by the industry.
— Mobility of resources, including short term turnover, creates a risk as the national nuclear power programme develops.
— Most countries, including those with existing nuclear power programmes, do not have enough people with nuclear power knowledge and experience to support the growing demand for skilled workers. Hence, there is competition for the limited pools of human resources with key skills.
— Existing university programmes may not provide the depth of learning necessary for the required competencies, including engineering and science fundamentals.
— Competency assurance is required for all participants, including regulators who provide oversight to the total system from its inception.
— There is a lack of clarity and guidance on how to assess competencies.
— The confidence gained through years of successful operation can cause the management of established programmes to underestimate the unique and necessary competencies that construction and project management professionals contribute to new build projects. This situation can result in insufficient skilled resources being available to and used for ensuring the safety of new build projects and new nuclear power programmes around the world.
— Few leaders are adept at managing complexity, managing the unexpected or managing during periods of chaos.
— Organizations often do not consider the need for diversity in leadership and teams to ensure the adoption of proactive approaches and broad decision making.

The competencies and organizational relationships required to set up a nuclear power programme are phase dependent and need to be defined at the outset. Because a new build project is a multi-year commitment, it requires long term workforce planning to ensure that sufficient numbers of skilled resources are available. Many participants need to work together to develop the required competencies. For example, governments have a responsibility to establish regulatory bodies and educational programmes to support an emerging nuclear power programme. Utilities develop required competencies through in-house training and partnership programmes with foreign utilities. Vendors support governments as well as utilities, in addition to building their own competency levels. In later phases, efforts shift from building infrastructure to ensuring that

utilities, vendors and regulators have the required competencies to support safe and effective operation.

An important consideration is to maintain capable project managers and technical support throughout pre-operational phases. No manager can be expected to understand all the technologies involved during these phases. In particular, future operators and licensees do not typically possess the technical knowledge of designers, contractors, manufacturers and installers, and therefore are dependent on the capabilities of support organizations during pre-operational phases.

4.4.2. Desired state

The desired state is one where sufficient numbers of appropriately skilled workers are employed for all phases, from the pre-project phase to full operation. This requires:

— Clarity as to the kinds of competencies needed;
— An industry presence and reputation that will attract needed talent;
— Active planning and investment in the development of programmes that will be used to train and educate students and workers;
— Effective methods for assessing/ensuring competencies;
— Retention strategies that ensure that skilled workers remain within the industry as competition grows;
— Commitment within the industry to partnerships that can help manage risks.

Table 3 identifies the breadth of competencies required in addition to the technical skills normally associated with nuclear power programmes. Considerations for ensuring effective competency planning and development, as well as options for managing the risks associated with resource competition are also provided in the table.

4.4.3. Approaches and methods

The spectrum of competencies required to support a nuclear power programme touches on all three elements of Fig. 4: management for safety, actions and practices, and understanding.

One approach is to establish intergovernmental agreements to support collaboration between vendors, educational institutions and future licensees to ensure a long term supply of skilled resources for the national nuclear power programme. Figure 6 depicts this multilateral collaboration.

TABLE 3. COMPETENCY DEVELOPMENT AND HUMAN RESOURCES

Breadth of competencies	Considerations for competency development	Competency assurance
• All parties know how their work affects nuclear safety • Owners, regulators, contractors and vendors are fluent in safety culture concepts • All parties understand the issues related to human and organizational factors • Emerging best practices are a routine part of organizational learning • Organizational effectiveness is a primary accountability of managers • Human relations skills are emphasized during personnel selection and are cultivated within the organization • Project managers are selected who have a focus on the cognitive competencies required for the scale of the project, i.e. they are able to combine a holistic view with safety- and results-mindedness • Multicultural sensitivity is a competency specifically selected for or developed in leaders	• Future operators participate in pre-operational stages • Time is taken to develop talent and development is initiated early • National education programmes are aligned to industry needs • National and international cooperation are emphasized to develop resources • There is a focus on knowledge, skills and credentials as well as on cognitive/emotional suitability for roles • Educational institutions encourage multicultural internships • Well developed benchmarks are created for common roles to support selection and development • A common safety focused 'value base' is promoted across the entire industry • Peer teaching/mentoring is an ongoing practice • Vendors participate in the training and education of workers and suppliers • Educational institutions participate in teaching vendors and supply chain participants • Gains in know-how are achieved through the assembly of expert teams within organizations, and by cooperation/contracts between partners	• Formalized professional criteria exist • Contractors are pre-qualified (e.g. safety passport system) • Each country has sufficient expertise to support its own nuclear programme • The nuclear industry has sufficient qualified resources to be able to 'select', because of a good balance between supply and demand in national and global workforces • There is an exchange of knowledge and workers between regulatory, technical and operations personnel • Interorganizational cooperation and commonality exists among vendors, licensees, contractors, etc. • Know-how gain is ensured through internships and peer exchanges • Long term planning exists for highly specialized skill sets

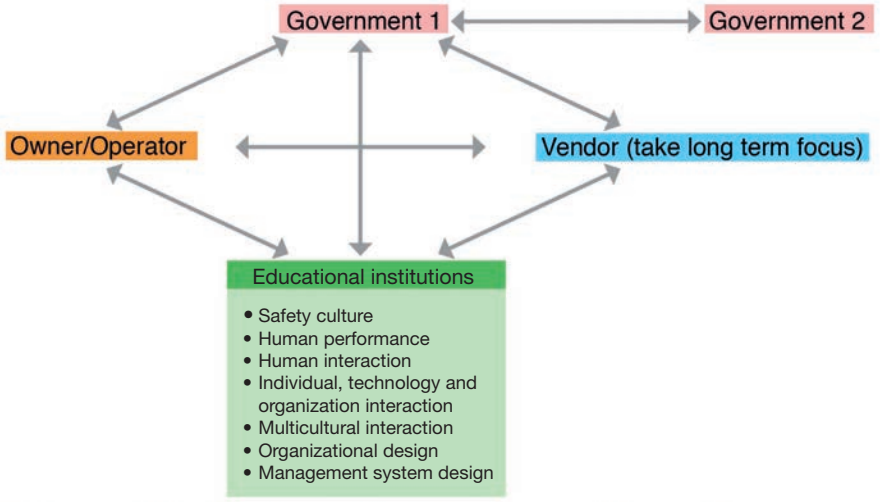

FIG. 6. Multilateral cooperation model: Industry focused and sponsored student exchange/internship programme with governmental cooperation to foster collaboration between educational institutions.

Another method is to secure access to seats in educational programmes in countries with established nuclear programmes for students from newcomer countries as an element of cooperation agreements or contracts. Safety culture, human factors, human performance, human interaction and multicultural concepts can be incorporated into educational programmes in order to better prepare students entering the nuclear industry.

Partnerships between educational institutions and established nuclear facilities could be used to further support the development of job-ready students. Through internship programmes, students could earn educational credits for practical experience in different nuclear organizations, roles and/or cultural settings.

In the early phases, consider using the consulting services of professionals experienced in NPP development, including those with recent new build experience, to provide required competencies. Establish consulting agreements that support the goal of self-sufficiency over the longer term. Consider a staged approach, whereby service providers progressively shift from performing their work to supporting learning through observation and coaching while managing risks, and then to assessing and recommending corrective actions in an 'arm's length' relationship.

Assemble core launching teams with the levels of purpose, results focus, perseverance, strategic thinking, conceptual thinking and ethics needed to ensure viable leadership throughout the early stages of a new build project or a new programme. Stability and continuity of leadership are essential to the development of a well integrated management system and a strong safety culture. Take into consideration team composition in terms of diversity of leadership approaches and behavioural preferences to increase team and organizational effectiveness.

Include organizational design and resourcing specialists as well as business development specialists in the core launching team to support development of an integrated management system and safety culture. These specialties require clear mandates for defining compatible and coherent structures, roles and job responsibilities, and for creating and executing comprehensive, long term workforce design, resourcing and development plans as the organization grows.

Use dedicated multidisciplinary teams to define the types of competency (knowledge, skills, credentials and cognitive/emotional preferences) required to recruit and select suitable candidates for roles at all phases of NPP operation, from the pre-project phase through to full operation. Expert consultants from countries with established nuclear power programmes can be very helpful in providing the breadth and depth of knowledge required in the early stages of the recruiting process.

Use human factors engineering specialists to validate design usability and, where appropriate, to request detailed design changes to address future maintenance and operation issues. These specialists can help develop detailed work practices and training programmes for commissioning and future operation.

Encourage retention of skilled resources through a mixture of desirable conditions such as a positive working environment, supportive leadership, favourable pension and benefit policies and progressive development programmes. Individualized learning and growth plans can be used as a flexible way to define and track student and worker competency development. Tailored to individual learning needs, these could be further supported by designated subject matter experts serving as mentors in participant organizations to expand technical and safety culture related learning. For example, IAEA internships and participation in conferences and missions can be used to increase knowledge transfer and retention in the industry.

During the construction phase, introduce contractors, suppliers and inspectors to issues and lessons learned in current build projects to increase their awareness of nuclear safety. Use simulations to prepare workers for complex tasks. Human factors engineering experts can also help to assess the future maintainability and operability of a plant.

Make independent translation services available when multiple languages are in use, to assist in conveying information, reinforcing standards and expectations, and resolving issues on the site.

4.4.4. Examples and resources

Some companies in the nuclear field have established cooperation agreements with universities and technical colleges to support nuclear research and education. For example, AREVA has established a technical college at the University of Karlsruhe.

4.4.4.1. IAEA publications relevant to competencies

The following IAEA publications provide useful information on competencies:

— The Operating Organization for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-2.4) [28]. This publication provides guidance on setting up an operating organization that encompasses the most important organizational elements contributing to a strong safety culture and good performance.
— Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (IAEA Safety Standards Series No. NS-G-2.8) [29]. This publication describes factors that are important to consider in order to ensure that an operating organization has a sufficient number of qualified personnel for safe operation. Although focused on operating plants, some elements are relevant to other phases of NPP development.

4.5. MANAGEMENT SYSTEM PROCESSES TO SUPPORT THE SAFETY CULTURE

4.5.1. Key challenges

Key challenges related to management systems include the following:

— New participants in an NPP project may not have established key elements of their management system, including processes for work planning and control that are required to ensure quality. Additionally, new programmes may not include elements that support the implementation of safety

requirements and a strong safety culture, including knowledge retention and transfer.
— The management systems of all participants, including implementation processes and procedures, are not always adequately developed, and/or the documented system is not always followed in practice.
— The right requirements may not be established or fully understood by all participants.
— Changes in practice may occur between phases without the requisite updates to the management system.
— Different organizations have different management systems and processes, which may be at different geographical locations. This can complicate information transfer.

It is important for the owner/licensee to take a lead role in ensuring interface control and reliable transfer of information between participants and phases; this is made more complex by differences in management systems between organizations. It is beneficial if the owner/licensee begins work early on the operating phase management system that will become the repository of knowledge transfer.

4.5.2. Desired state

The desired state is one in which participants have management system processes consistent with elements identified in Refs [15–17], recognizing that core processes differ for different organizations. The management systems of all participants ensure the effective transfer of information between phases. Safety culture, human performance and organizational experts are involved in the design of management system processes. Simple, lean, up to date and unambiguous processes work best. All necessary procedures are available and designed with a focus on the user. Participants confirm that the procedures used yield the desired results.

4.5.3. Approaches and methods

Approaches and methods concerning management system processes focus on the ‘management for safety’ element of Fig. 4.

4.5.3.1. Processes that support safety culture implementation

Although the design of the entire integrated management system shown in Fig. 2 needs to support the safety culture, a number of processes play a specific

role in supporting safety culture implementation and are applicable in all phases. These processes are all required in the operating phase, and it is best to initiate many in the pre-project phase, since they provide continuity across all phases. Core processes related to design, construction and commissioning, and related aspects such as work planning, work control and procurement, require a high level of rigour and quality to ensure that outcomes meet specifications. Although core processes differ depending on the main function of an organization, commonalities in management and supporting processes across organizations and phases provide opportunities for information transfer and interface control. Management and internal processes support the safety culture in the following areas by:

— Including criteria for safety culture in the recruitment processes, as indicated in Sections 4.3 and 4.4. It is similarly important for coaching and mentoring programmes to include the promotion of behaviours consistent with a strong safety culture.
— Including consideration of the safety culture in change management processes.
— Respecting the balance between long term safety implications and cost–schedule considerations in project management processes.
— Including risk informed decision making in risk management processes.
— Basing training on a graded systematic approach to training (SAT).
— Focusing personnel safety processes on aspects such as safety behaviours, pre-job briefings, and the reporting of unsafe acts and conditions.

It is important for assessment and improvement processes to include:

— Management oversight and review;
— Self-assessments;
— Independent audits and inspections (internal, corporate, third party and regulatory);
— Peer reviews (staged by phase);
— Corrective and preventive action processes;
— Incident investigation and root cause analysis;
— An operating experience (OPEX) process, including lessons learned from internal and external events;
— Benchmarking and technical assist visits designed to meet specific learning and improvement objectives rather than to serve as exercises in ‘industrial tourism’.

Knowledge management ensures continuity across phases, and it is beneficial to have processes for:

— Document management;
— Records management;
— Information technology processes;
— Communication processes;
— Reporting processes (open and anonymous reporting).

4.5.3.2. Design and development approach

Benchmarking and systematic planning can help to ensure the successful design and development of a management system. Experience indicates several beneficial approaches:

— Begin designing the operational phase management system early, to help identify processes that are best implemented in earlier phases.
— Use industry experience, good practices and industry forums to develop a top level model that shows the integration of processes and that is comprehensive enough to ensure the development of a strong safety culture.
— Use experienced facilitators familiar with the national and organizational culture to guide the process for developing the management system.
— Engage performers and users as well as subject matter experts in the development team for each process, ensuring a mix of both technical and non-technical talent. Support development by including specialists in safety culture, human performance, organizational design, and process design and implementation.
— Ensure that processes meet the applicable national and international standards.
— Design for simplicity and transparency, using modern human factors methodologies and visual representations that help make procedures understandable and meaningful.
— Ensure that the process is customer focused and provides value to the customer/participant.
— Include risk identification, risk analysis and risk informed decision making in each process, as applicable.
— Pay sufficient attention to interorganizational management system development, since interfaces and information transfer between organizations are critical in complex projects. Although management systems differ, some common processes may be identified and developed for mutual benefit. This may be achieved through interorganizational working groups on management system development.

4.5.3.3. Approaches to improve clarity and implementation success

Approaches that improve implementation include the following:

— Use storyboards, pictures, metaphors and other diverse representations as learning and communication aids. Some organizations have used innovative approaches such as 'visioning', poetry, stories, songs and role playing to enhance understanding and learning.
— Assign joint roles to process owners to share learning.
— Communicate the management system introduction and subsequent updates of processes and procedures.
— Encourage face-to-face contact by leaders, managers and process owners during implementation.
— Establish pride of ownership in process teams to foster continuous improvement.
— Train personnel in the requirements and functions of management systems.

4.5.4. Examples and resources

4.5.4.1. Safety culture enhancement in relation to management systems

— The National Nuclear Regulator of South Africa defined safety culture requirements in its regulatory document on Quality and Safety Management System Requirements for Nuclear Installations [30]. This document sets out requirements for management systems and key behaviours. It requires the licence applicant/licensee and suppliers of products highly important to safety to implement a safety culture enhancement programme and plan. This provides the framework for systematic consideration of the key elements of safety culture as part of the management system and is developed in consultation with personnel.
— The Health and Safety Executive of the United Kingdom requires licence applicants to submit a safety management prospectus (SMP) as part of their safety case. This is a strategic document that provides a description of how nuclear safety is managed within an organization in the context of specific hazards, risks and scale of operations. Among other things, it describes a strategy for developing and maintaining a licensable organization with suitable resources and competencies to deliver nuclear safety; outlines how a 'learning organization' approach is fostered; and describes an organizational approach to managing change. More information on the purpose and content of an SMP is available at: http://www.hse.gov.uk/foi/internalops/nsd/tech_asst_guides/tast072.htm.

— Some organizations that are anticipating new build projects, such as Eskom in South Africa, have identified key management system elements required to support a strong safety culture during the early design phase of these projects. The elements include integrated quality and safety management systems that accommodate the development of nuclear safety culture programmes for key suppliers.

4.5.4.2. Management system information and examples

— The Nuclear Energy Institute (NEI) in the United States of America, in association with the Institute of Nuclear Power Operations (INPO), has developed a Standard Nuclear Performance Model that includes processes for an operating plant. The NEI has also established, together with industry, a number of 'communities of practice' whereby specialists can exchange information on processes of interest. Information is available at www.nei.org.
— The Balanced Scorecard developed by Kaplan and Norton [31] provides a framework for developing a management system based on four elements: financial, customer, process, and learning and growth.
— The European Foundation for Quality Management (EFQM) Excellence Model provides a framework for developing a management system. Information is available at www.efqm.org.

4.5.4.3. IAEA publications related to management systems

As generic approaches to management systems such as EFQM, ISO 9000 or the Balanced Scorecard do not include requirements for nuclear safety or safety culture, IAEA requirements can be used to cover these aspects. The following IAEA publications provide useful information on safety culture in relation to management system development and implementation:

— The Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-R-3) [15]. This publication provides general requirements for management systems. Although focused on operating environments, many of the principles are appropriate for all phases and participant organizations.
— Application of the Management System for Facilities and Activities (IAEA Safety Standards Series No. GS-G-3.1) [16]. This publication provides additional guidance on implementing IAEA Safety Standards Series No. GS-R-3 and includes a section specifically on safety culture. Although focused on the operating phase, the attributes identified for a strong safety culture can be applied to any phase and any organization.

— The Management System for Nuclear Installations (IAEA Safety Standards Series No. GS-G-3.5) [17]. This publication provides supplementary information to the general recommendations provided in IAEA Safety Standards Series No. GS-G-3.1 on how to comply with the requirements established therein. It includes sections on safety culture, assessment of safety culture and signs of a weakening safety culture, and an appendix on achieving the attributes of a strong safety culture. This publication includes information relevant to all phases.

4.6. LEARNING AND FEEDBACK

4.6.1. Key challenges

Key challenges related to learning and feedback include the following:

— Knowing where to find practical information on actual experience during pre-operational phases. Systems for gathering experience during pre-operational phases are not widely accessible or interconnected.
— Lack of international guidance on and criteria for reporting experience from pre-operational phases.
— Access to pre-operational experience is often limited to owner/operator organizations. For proprietary and competitive reasons, there is not always open exchange of information by vendors.
— Lessons learned from non-nuclear industries are not generally included in existing databases, particularly lessons related to design, construction and commissioning.
— Operating experience feedback systems are often complex and not user friendly, making it more difficult to gather information in hands-on construction environments.
— Some organizations do not promote the level of openness and reporting required to achieve effective feedback and learning.

4.6.2. Desired state

Organizations learn by acquiring knowledge, seeking feedback, and fostering a climate of curiosity and innovation. Elements that help to identify risks and potential opportunities for improvement include:

— Creating a culture that encourages and supports continuous employee learning, openness, rigorous thinking and cultivation of new ideas;

— Seeking employee input and contributions;
— Gathering experience from both inside and outside the organization;
— Analysing the causes of unexpected deviations;
— Disseminating new ideas and knowledge throughout the organization for incorporation into day to day activities.

The nuclear industry assesses whether or not an operating organization is a 'learning organization' that has 'built-in' feedback mechanisms. Putting into practice some of the elements mentioned below during pre-operational phases is important because it prepares an organization for future performance requirements. Table 4 identifies attributes of an ideal learning environment and examples of expectations common in the industry. Additional considerations that promote and enhance learning and feedback are also provided in the table.

4.6.3. Approaches and methods

The following approaches and methods focus on the 'actions and practices' and 'understanding' elements of Fig. 4, supported by enabling processes in the 'management for safety' element.

Assign sufficient resources for information exchange and identifying lessons learned and good practices through all phases. Provide consistent methods for knowledge transfer and retention. Encourage open reporting and access to forums and information, so that individuals at every level of the organization can contribute experience and good practices.

Utilize existing operating experience feedback databases maintained by the IAEA and other agencies, and participate in expert missions to gain exposure to international practices.

Establish mechanisms to encourage learning across organizational functions and levels to overcome the inhibiting influences of conventional organizational structures. Consider team based, process based or matrix structures to facilitate cross-organizational learning and learning between different organizations.

Demonstrate a learning culture in all contact with personnel. Establish information exchange forums such as CEO feedback or 'town hall' meetings that are two way and focused on safety, organizational, improvement and technical issues. Allocate sufficient time for leaders to promote learning and feedback rather than having them focus all their time and attention on day to day project related activities.

Design physical workspaces to encourage learning, feedback and communication. Increase opportunities for informal interaction such as shared eating facilities and open office spaces to help break down hierarchical barriers.

TABLE 4. LEARNING AND FEEDBACK IN ORGANIZATIONS

Attributes of an ideal learning environment	**Examples of industry expectations that could assist interested parties in pre-operational phases**	**Additional considerations**
• Adaptive • Uses systems thinking • Adopts new practices • Aim/motivation is to continuously improve • Learns from successes as well as failures • Facilitative • Frequent dialogue takes place • Cross-fertilization of ideas across departments and organizations • Reflective • Rates high in trust and openness • Encourages curiosity and welcomes questions • Shares a common vision	• Systematic approach to training and learning is adopted • Leadership learning and development is encouraged • Management reviews are used to improve performance • Self-assessments and independent audits support continuous improvement • Peer reviews are undertaken • Benchmarking is used • Improvement action process is in place, with timely implementation of actions • Follow-up of changes is undertaken • Experience feedback is widely used (e.g. in pre-job briefings) • Reward system: behavioural expectations are clear and are met • Open reporting system • Root and apparent cause analysis is implemented • Human performance lessons learned are shared • Repeat failures are rare	• Various points of view and talent balance are considered in meetings, including non-technical input • Meeting behaviours promote learning and feedback • Storytelling, use of success stories and appreciative inquiry are implemented • High level of interaction takes place between leaders and personnel • Organized, open feedback sessions are implemented within teams and between departments to build trust • Forums are available for direct feedback to senior management • Meeting rooms designed to promote engagement • Nature of feedback favours positive rather than negative • Sensitivity is shown to the learning style of different cultures • Learning and change are embraced at the senior management level • Ombudsperson is available to mediate conflict

Co-locate senior and junior personnel to facilitate mentoring and coaching. Provide employees with clothing that meets their function rather than that discriminates by status or supervisory level.

Establish open space learning areas adjacent to areas containing technical resources to promote a culture that recognizes that learning requires space for reflection, discussion and study. Consider using problem solving teams without formal leaders and group facilitation techniques such as focus groups, Appreciative Inquiry [32] and Open Space Technology [33] to obtain valuable input from employees.

Identify leaders in the organization who are effective communicators of the importance of learning and feedback and who use these elements to identify learning opportunities that fit the cultural learning style of the organization. Use innovative approaches such as interactive terminals, simulators, mock-ups and engaging art displays and posters. Different learning styles require different learning tools, and often the written word alone is insufficient to engage workers.

Accommodate the short term learning needs of construction workers to supplement formal nuclear safety orientation training. For example, promote nuclear safety awareness through a pre-job briefing that identifies the safety relevance of the structure, system or component on which the day's work is focused.

4.6.4. Examples and resources

Westinghouse has developed a database called 'I-Know' that collects information on lessons learned (e.g. issues relating to containment vessel manufacturing). New employees are made aware of the database.

Case studies relevant to the project phase provide valuable information. For example, the Formosa Plastics event in 2004 (USA) highlights how design errors can have an impact on the safety of future operations. A number of good case studies from the nuclear and other industries are available from the US Chemical Safety Investigation Board web site at http://www.csb.gov/.

Some organizations define expectations for the use of operating experience during the development of design documentation through communications such as engineering bulletins (e.g. Eskom, South Africa).

Joint workshops on safety culture between future owners/operators and contractors have been undertaken by some organizations to ensure that expectations are clear and mutually understood and to share learning and experiences (e.g. through the use of case studies).

IAEA publications relevant to learning and feedback

The following IAEA publications provide useful information on safety culture in relation to feedback and learning:

— Safety Culture (Safety Series No. 75-INSAG-4) [2]. This publication discusses the importance of safety performance reviews and use of lessons learned.
— Key Practical Issues in Strengthening Safety Culture (INSAG-15) [5]. This publication identifies attributes of a learning organization and provides diagnostic questions to help identify the degree to which an organization embodies those attributes.
— Developing Safety Culture in Nuclear Activities: Practical Suggestions to Assist Progress (Safety Reports Series No. 11) [6]. This publication stresses that continuous learning and improvement processes play a central role in developing and maintaining a good safety culture. Learning includes learning from other organizations. The publication provides useful information on learning and feedback within organizations.
— A System for the Feedback of Experience from Events in Nuclear Installations (IAEA Safety Standards Series No. NS-G-2.11) [34]. This publication describes the elements of operational experience feedback systems necessary for gathering relevant information on events and abnormal conditions that have occurred at nuclear installations throughout the world. Although not specific to earlier phases, the basic approach is similar regardless of phase.
— Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture (IAEA-TECDOC-1329) [9]. This publication provides a comprehensive review of safety culture, including development of a learning culture and organizational learning.

4.7. CULTURAL ASSESSMENT AND CONTINUOUS IMPROVEMENT

4.7.1. Key challenges

Key challenges related to cultural assessment and continuous improvement include the following:

— Developing and maintaining an accurate picture of safety culture strengths and opportunities for improvement in a multi-organizational and dynamic project environment.

— Current safety culture assessment methods and approaches may not support the identification of safety culture deficiencies in the pre-operational phases. Although some safety culture assessment approaches and methods developed for operating NPPs can be applied to the pre-operational phases, others need to be modified or redesigned to ensure relevance.
— Performance indicators established for major projects often focus on the quantitative measures of industrial safety, schedule and cost. This can provide a misleading picture when compared with a balanced set of performance indicators that include quality, safety culture and nuclear safety.

4.7.2. Desired state

In the desired state, the senior management of participant organizations maintains a good understanding of their organization's safety culture through the use of validated safety culture assessments. They assign clear roles and accountability for assessment, monitoring and improvement of safety culture. They strive for excellence in their organization's processes, practices and safety performance through continuous learning and improvement.

4.7.3. Approaches and methods

The approaches and methods concerning cultural assessments and continuous improvement focus on the 'actions and practices' that provide insight into the 'understanding' element of Fig. 4.

4.7.3.1. Pre-assessment of safety culture for countries initiating nuclear power programmes

It is important for governments and regulatory bodies to assess a number of areas prior to undertaking a nuclear power programme for the first time. These areas relate to the understanding of duties and responsibilities when establishing a nuclear power programme. For example, a long term commitment is required to encompass issues related to decommissioning and waste management.

It is important to assess the level of support for and concerns about nuclear technology within the country. For example, what are the implications of initiating a nuclear power programme in relation to other societal activities and needs, and how does this affect public opinion? Is there clear leadership commitment to the nuclear power programme at the highest level of government? Are the identified needs based on energy requirements rather than on the desire to

participate in nuclear technology? Is there sufficient political stability to ensure fulfilment of long term commitments?

Prevalent national behaviours can be assessed to determine potential barriers to developing a safety culture consistent with the obligations inherent in a nuclear power programme. For example, simple polling instruments can be used to assess the level of openness and transparency reflected in:

— Historical and current levels of support from politicians, the public, technical experts and industry;
— Relationships with other countries using nuclear technology;
— Accepted and demonstrated societal values.

4.7.3.2. Ongoing assessment of safety culture during pre-operational phases

(a) Periodic assessment

Evaluate the organization's strengths and weaknesses against established safety culture characteristics or attributes. Existing IAEA and industry publications provide information on fundamental safety culture characteristics that can serve as a framework for assessments. However, the detailed attributes and assessment methods described in IAEA and industry guidance were primarily designed for operating NPPs. Modifying or redesigning the methods is necessary to ensure relevance to the various pre-operational project phases. Consider obtaining support from the IAEA or other experienced experts in safety culture assessments to assist in developing appropriate assessment methods. It is particularly important to include expertise in behavioural sciences (e.g. industrial psychology, organizational behaviour, social sciences) when designing, conducting and interpreting results.

Use a 'triangulated approach' to provide an accurate assessment in relation to the various safety culture characteristics. This involves the collection and comparison of data from multiple sources such as document reviews, surveys, interviews, observations and focus groups.

Consider the use of STEEPV (social, technological, economic, ecological, political and value) analysis and cultural web models to obtain cultural information. Such models require experienced users or user training to gain experience.

Assess all levels and functions of the organization. Consider wider influences on the safety culture such as 'parent bodies'. Consider smaller, targeted assessments in addition to periodic full-scale assessments.

Arrange peer and independent reviews of safety culture to identify opportunities for improvement and to learn about good practices from elsewhere.

(b) Ongoing monitoring

Consider incorporating safety culture observations into management system audits of main vendors and suppliers. Monitoring is also important during construction.

Use both qualitative and quantitative indicators to monitor the safety culture. Examples of qualitative indicators include observable expressions of the safety culture such as a questioning attitude, changes made by senior leadership based on internal/external feedback (including to their own practices and work processes) and effective communication (e.g. briefings and workshops involving participant organizations). Walkdowns and observations (e.g. of construction activities and project meetings) using task observation checklists are examples of specific tools to support the ongoing monitoring of the safety culture. Examples of quantitative indicators include backlogs of corrective actions, and the number and type of adverse conditions/deficiencies reported by personnel and contractors.

Develop suitable leading safety performance indicators (both qualitative and quantitative), paying particular attention to the balance between indicators related to safety and quality and those related to schedule and cost.

Senior managers can maintain a good sense of 'operational reality' through regular discussions with personnel and contractors and visits to work sites/offices. Senior managers have a responsibility to examine assessment information and data (e.g. key performance indicator reports) to ensure that they do not present an overly optimistic picture. Include safety and culture as standard agenda items on project review meeting agendas.

(c) Continuous improvement

Periodic safety culture assessments and ongoing monitoring often identify a large number of opportunities for improvement. Realistically assess the resources required to make changes, and establish priorities to avoid overburdening and distracting people from their core work.

Use root cause analysis techniques to understand the underlying causes of issues before identifying improvement actions. Involve stakeholders (personnel, contractors, unions, etc.) in identifying priorities and specific improvements. Consider establishing a safety culture steering committee with representatives from different levels and functions of the various organizations involved, to identify opportunities for improvement, share good practices and advise senior management.

Provide formal and informal channels for people to offer suggestions for improvement. Actively encourage people to suggest different ways of doing

things, and act on these suggestions so that changes are visible. Some organizations encourage the reporting of improvement opportunities (e.g. based on good practices seen in other organizations) as part of their 'condition reporting' process.

4.7.4. Examples and resources

— A safety culture survey used by Eskom, South Africa, for its operating NPP was adapted and used in conjunction with other methods such as self-assessment and key performance indicators to monitor the safety culture during the design phase of a project.
— IAEA safety review services include a provision for performing safety culture assessments for Member States.

4.7.4.1. IAEA publications relevant to cultural assessment and continuous improvement

The following IAEA publications provide useful information on cultural assessment and continuous improvement:

— Key Practical Issues in Strengthening Safety Culture (INSAG-15) [5]. This publication cautions that "Variations in national cultures mean that what constitutes a good approach to enhancing safety culture in one country may not be the best approach in another". The publication contains a detailed list of questions for all levels of an organization.
— Developing Safety Culture in Nuclear Activities: Practical Suggestions to Assist Progress (Safety Reports Series No. 11) [6]. This publication identifies three stages of development: Stage 1, in which safety is based solely on rules and regulations; Stage 2, in which good safety performance becomes an organizational goal; and Stage 3, which embraces the concept that safety performance can always be improved. The publication discusses influences of national culture and methods for assessing progress in the development of safety culture.
— Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture (IAEA-TECDOC-1329) [9]. This publication contains information on aspects to consider in safety culture enhancement programmes, including the various methods that can be used to assess safety culture.

4.8. COMMUNICATION AND INTERFACES

4.8.1. Key challenges

Key challenges for communication and interfaces include:

— Making the right information available to the right people in a way that is meaningful to them. Large volumes of 'raw data' are often shared without being sufficiently tailored to the needs and learning methods of the recipients.
— Communication may be confused because of differences between what is conveyed verbally or in writing (e.g. word choice, message content) and what is expressed through the non-verbal cues (such as demeanour, tone, physical posture, practices) observed by recipients and used to assess the importance, integrity and sincerity of the message.
— Selecting the best method (e.g. written, word of mouth, pictures, symbols) to inform recipients, and ensuring that the information has been interpreted correctly. There is often an overreliance on written communication.
— Reliance on computerized information systems that are often difficult to navigate and/or not available to all members of the intended audience.
— Differing agendas, priorities, personal styles, languages, etc., are sometimes allowed to hinder effective relationship building and communication between stakeholders.
— Identifying knowledge gaps within and between participant organizations and developing plans to address them.
— Providing seamless coordination among many participants, who often experience difficulties due to differences in methods of communicating, a lack of integrated information flow across multi-organizational boundaries, cultural differences and the results focus inherent in cost driven projects.
— Appreciating the effort required to effectively inform and engage the public in dialogue and debate on a new nuclear programme.

Communication encompasses many things, from conveying information and sharing ideas to posing questions and clarifying what is important. It is the foundation of good human performance and an effective safety culture, because it is the primary vehicle for building the understanding, acceptance and cooperation needed to ensure that behaviours and results meet expectations and requirements. At every phase — from engaging the public and building acceptance of a nuclear power programme, to ensuring adherence to high standards during construction, to achieving effective knowledge transfer between stakeholders, to operating

safely and reliably — it is the means by which people work together to achieve results.

4.8.2. Desired state

In the desired state, meaningful communication occurs among all participants. Effort is directed at establishing and cultivating communication patterns between people, teams and whole organizations, regardless of the number of organizations involved or the phase of the project. Communication systems are active, interactive and constructive, and the focus is on creating the levels of awareness, understanding, acceptance and engagement needed to ensure that desired actions or behaviours are embraced.

Research suggests that the most effective communication happens face to face. Communication strategies emphasize:

— Visible and facilitative leadership behaviours that engage others;
— Communal spaces and forums that enable informal networking;
— Availability of independent translators to bridge language barriers in multicultural settings;
— Language that is blame free and solution and opportunity focused.

4.8.3. Approaches and methods

The following approaches and methods focus on the ‘understanding’ and ‘actions and practices’ elements of Fig. 4.

Consider engaging communication professionals to help formulate and revise communication strategies for each phase, since the answers to several key questions will change, including questions such as: What needs to be communicated? Who needs to be influenced or needs to know? What barriers to acceptance or understanding need to be overcome? What outcomes need to be achieved? Well developed communication plans consider:

— The demographics (age, nationality, gender, profession) of the intended audience. This helps to identify value systems, personal and professional priorities, and lifestyle and entertainment preferences, which in turn provide insight into how members prefer to receive information.
— Methods that provide the emotional engagement preferred by members of a target group (e.g. rational explanations, humorous anecdotes, sobering messages, interesting facts). This helps in developing meaningful messages.

— (Pre-)existing perspectives and attitudes that need to be influenced or changed. This aids in ensuring that communications are focused on addressing specific issues and achieving desired outcomes.

Encourage the use of three way communication (verbal or written) on important issues, to ensure effective information and knowledge transfer.

Create environments that are emotionally safe, informative, inviting and helpful. Foster social and communication systems that include families and informal community leaders.

Establish outreach programmes to open communication with public officials, contractors and future employees of a nuclear power programme and NPP project. Consider the use of social media, web pages, blogs and interactive displays.

Accommodate different learning styles. Some people learn best through seeing images, others through hearing spoken words and sounds, and yet others through touching and doing. Provide information through several different media in order to meet these different learning styles. Consider tone, terminology and cultural sensitivities along with specific content in order to maximize the likelihood of clear understanding by recipients.

Provide documented knowledge bases (i.e. databases with state of the art information on standards, educational materials, procedures, historical documents and operating experience) to share information and support continuous learning. Provide information in primary working languages to reduce interpretation errors.

Consider providing a multifunctional space (similar to a town square) with information kiosks, commonly used services and multidisciplinary learning facilities that combine to create a communication hub where various work groups and cultures can converge and interact on a regular basis. User friendly places that visibly value different cultures (e.g. culturally oriented design of spaces, availability of foods from different nationalities) facilitate understanding, cooperation and integration between different groups. Include visual information on the structure and purpose of the organization(s) involved, key people and their positions, basic services for workers, site maps, important safety messages and project progress updates. For projects involving people from many different nationalities, provide independent translators to greet newcomers and orient them to each other and the project.

Establish reward systems that recognize successes in safety, ‘good catches’ that prevent incidents, and event free days. Celebrate these successes throughout the organization.

4.8.4. Examples and resources

International symbols and icons are common throughout the world, for example in the transportation industry. The design of safety information in multicultural settings requires attention to the representational methods used for safety signage and messages so that they are language independent and easily understood across cultures.

5. CONCLUSIONS

The complex, multidimensional nature of the safety culture in the pre-operational phases of an NPP project requires participants to focus on systems thinking and integration. Special attention needs to be paid to the exchange of information between participants and to the knowledge transfer requirements during the transition from one phase to another. It is also important to maintain focus on the fundamental concepts. Working with the safety culture requires that attention be paid to all three of the elements identified in Fig. 4: management for safety, actions and practices, and understanding. Effective integration of these elements will ensure the requisite outcome of nuclear safety.

Furthermore, it is necessary to make the importance of nuclear safety thinking tangible during phases where there are no radioactivity related concerns and where contractors may have little understanding of the nuclear safety significance of the structures, systems and components being installed. Technical competency and the capacity to assess nuclear safety implications are fundamental for building a strong safety culture within the nuclear industry.

For States establishing their first nuclear power programme, an early start and clear strategies are necessary to achieve success, including an exploration of the cultural attributes that may support or hinder the development of a strong safety culture. There is an abundance of safety culture information available from operating experience in the nuclear industry and from other industrial environments. The quality of national programmes has international implications, since severe accidents have an impact on the nuclear industry worldwide. Leaders in all participating organizations have a responsibility to seek and use such experience in order to build a strong foundation for the safety culture from the very start of an NPP project.

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