INSAG-27

Ensuring Robust National Nuclear Safety Systems — Institutional Strength in Depth

INSAG-27

A REPORT BY THE
INTERNATIONAL NUCLEAR SAFETY GROUP

INSAG

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ENSURING ROBUST NATIONAL NUCLEAR SAFETY SYSTEMS — INSTITUTIONAL STRENGTH IN DEPTH

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A report by the International Nuclear Safety Group

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

by the Chairman of INSAG

A strategy of defence in depth has become a fundamental aspect of the analysis of the adequacy of technical systems to ensure reactor safety. It provides a systematic means to analyse and ensure layers of systems to prevent or mitigate accidents. This publication is intended to provide an analogous philosophy to guide thinking about the institutional structures to ensure nuclear safety.

There are three institutional sub-systems that serve to ensure safety: a strong licensee, a strong regulator and a strong set of stakeholders. This publication describes the interfaces that should be nurtured among these sub-systems as well as within each sub-system. We recommend a careful analysis of the institutional sub-systems and of their interfaces, as well as the correction of any weaknesses as a means to enhance safety. We describe the establishment of a set of strong and mutually reinforcing sub-systems by the term 'institutional strength in depth'.

We are hopeful that the analysis of institutional strength in depth will join defence in depth as a fundamental tool in the never-ending quest to enhance nuclear safety.

The International Nuclear Safety Group (INSAG) is a group of experts with high professional competence in the field of safety working in regulatory organizations, technical support organizations, research and academic institutions and the nuclear industry. INSAG will be convened under the auspices of the International Atomic Energy Agency (IAEA) with the objective to provide authoritative advice and guidance on nuclear safety approaches, policies and principles. In particular, INSAG will provide recommendations and opinions on current and emerging nuclear safety issues to the IAEA, the nuclear community and the public.

EDITORIAL NOTE

The opinions and recommendations stated in this publication are those of INSAG and do not necessarily represent the views of the IAEA or its Member States.

CONTENTS

1. INTRODUCTION

1. Much work has been undertaken to identify and learn the lessons from the accident at the Fukushima Daiichi nuclear power plant. To date, these have primarily focused on technical lessons — see, for example, IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1]. As a result, global efforts to enhance nuclear safety have largely targeted engineering or operational improvements. Some attention has also been paid to implementing the institutional lessons from the accident, as shown by measures to improve individual peer reviews, particularly those undertaken by the World Association of Nuclear Operators (WANO). However, further actions are required.

2. The Director General's report on the Fukushima Daiichi accident [2] brought forward several core lessons from the analysis of the accident:

— "**In order to ensure effective regulatory oversight of the safety of nuclear installations, it is essential that the regulatory body is independent and possesses legal authority, technical competence and a strong safety culture.**

.....

— "**In order to promote and strengthen safety culture, individuals and organizations need to continuously challenge or re-examine the prevailing assumptions about nuclear safety and the implications of decisions and actions that could affect nuclear safety.**
— "**A systemic approach to safety needs to consider the interactions between human, organizational and technical factors. This approach needs to be taken through the entire life cycle of nuclear installations.**"

3. The report [2] noted that one of the contributing factors to the accident was a tendency not to challenge the level of safety. Additionally, it reports the presence of deficiencies in the regulatory system despite an Integrated Regulatory Review Service (IRRS) mission to Japan having been carried out in 2007 [3].

4. While it is important to continue to seek further enhancement of international safety standards and to propose technical improvements, these are not sufficient by themselves to ensure adequate implementation of design safety principles such as defence in depth; see INSAG-10 [4]. An advanced

nuclear industry, an experienced nuclear regulator and international peer reviews were not sufficient to prevent the Fukushima Daiichi accident from happening. There were deficiencies in the design basis for the plant, internal challenge as to the adequacy of the design, implementation of external peer review advice, regulatory challenge, emergency preparedness (both at operator and government level), and stakeholder challenge and involvement. As the report by the IAEA Director General noted [2]:

> "Before the accident, there was a basic assumption in Japan that the design of nuclear power plants and the safety measures that had been put in place were sufficiently robust to withstand external events of low probability and high consequences.
> "Because of the basic assumption that nuclear power plants in Japan were safe, there was a tendency for organizations and their staff not to challenge the level of safety. The reinforced basic assumption among the stakeholders about the robustness of the technical design of nuclear power plants resulted in a situation where safety improvements were not introduced promptly."

5. The root causes of the accident were identified by the Report of the Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan [5] as being cultural and institutional. That is, the overall safety system was ineffective.

6. The fundamental lesson is that while there may be rigorous and comprehensive safety standards and other tools in place to deliver high levels of safety, it is ultimately important to have a nuclear safety system that ensures that the relevant institutions diligently and effectively apply those standards and tools, taking into account human and organizational factors. In summary, to achieve high levels of safety in all circumstances and against all challenges, the nuclear safety system in its entirety must be robust.

2. ROBUST NATIONAL NUCLEAR SAFETY SYSTEMS

7. The national nuclear safety system comprises all those parties with an interest in the nuclear enterprise who in one way or another can or should influence the achievement of safety. While this publication is mainly aimed at nuclear power programmes, the concepts described within it can be applied to all nuclear facilities, with a graded approach being applied commensurate with

the hazard posed by the facility. The system involves many participants: nuclear designers, vendors, constructors, suppliers, operators, regulators, technical support organizations (TSOs), international bodies, governments, parliaments and other stakeholders (especially those related to the public).

8. To be robust, the system must not be vulnerable to any individual failure or combination of failures arising from a single participant's inattention to nuclear safety or be subject to a common mode failure that affects all components in the system.

9. This leads to the consideration of applying the principles of a 'strength in depth' (SiD)[1] philosophy to the nuclear safety system as a way of providing a framework for developing, assessing, reviewing and improving the safety system. The aim is to establish a foundation for a strong safety culture — the sustained and rigorous quest for continuous improvement. In this publication, the approach is termed institutional strength in depth (ISiD).

3. STRENGTH IN DEPTH APPLIED TO THE NUCLEAR SAFETY SYSTEM

10. The concept of SiD has a long history in military strategy where, rather than relying on one force or component, multiple forces and means were used. The principles established for implementing such strategies include the following elements:

— Multiple layers and components;
— Independence of layers;
— Layers built to include diversity, redundancy and separation of function;
— No possibility of single point failure or common cause failure.

11. Applying the SiD philosophy to the nuclear safety system leads to the identification of three main independent institutional sub-systems to prevent a nuclear accident from happening:

[1] In this publication, the terms 'strength in depth' and 'layers' are used so as to emphasize the positive aspects of a robust nuclear safety system and to avoid confusion with the use of 'defence in depth' and 'levels' in the technical application of the defence in depth concept.

— A strong nuclear industry;
— A strong nuclear regulator;
— A strong set of stakeholders who ensure a capable institutional framework.[2]

12. 'Strong' in this context refers to an inner strength to encourage and welcome challenge, to challenge others, to question and consider others' options and advice, and to possess the competence and capacity to fulfil functions and duties.

13. INSAG emphasizes that the primary responsibility for safety lies with the operating organization [6],[3] the primary responsibility for independent safety oversight lies with the regulator [7], and that the primary stakeholders for safety are those who may be directly affected by a nuclear accident — workers and the public; see IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [6].

14. Overarching these three sub-systems is the framework that is established by the government. Society depends on public representatives to act on behalf of the interests of all. Elected representatives and government administrators are responsible for ensuring an appropriate legal framework covering the obligations of the nuclear industry, the responsibilities of the regulator and measures, such as freedom of information, to ensure the openness and transparency that enables stakeholders to be effective. The government should ensure that each sub-system has the authority and responsibility to fulfil its clear and distinct roles and should build a framework that links them together into a system in which each sub-system reinforces the others.

15. Previous publications of INSAG have emphasized the important role of stakeholders, particularly INSAG-20 [8]:

> "Stakeholder involvement makes regulatory organizations and other authorities acutely aware that their actions are under public scrutiny.

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[2] The totality of stakeholders is taken to constitute an institution (people, non-governmental organizations, media, shareholders, neighbours), even if views among stakeholders may be different.

[3] 'Safety' in this context relates to the protection of people, society and the environment. It is noted that many of the concepts and requirements presented in this model of a robust nuclear safety system could also be employed when considering the robustness of a national nuclear security system.

Transparency increases the motivation of individuals and institutions to meet their responsibilities…"

In some systems, 'stakeholders' are referred to as 'interested parties'.

16. Similar considerations apply to stakeholders' involvement with the nuclear industry. Indeed, both the nuclear industry and the regulator have responsibilities to those who may be affected by their activities, and this especially means the public. In its overarching role to reinforce each sub-system, governmental or parliamentary committees, as representatives of the public, can act as a powerful challenge against complacency or lack of vigilance in the nuclear industry or on the part of the regulator.[4] Further, if such committees or governments determine that regulatory reform is needed, they can initiate a change in the law through the normal legal processes.

17. The public generally does not have the technical background to determine or judge all the different aspects of nuclear safety. However, both the nuclear industry and the regulator have an obligation to explain nuclear safety provisions and plant performance in an open, comprehensible and transparent way, and to respond to legitimate questions and challenges. This interaction with the public stimulates a sense of responsibility and accountability, and helps to ensure high levels of attention to nuclear safety in both the operational and regulatory organizations. Experts in the nuclear industry and in the regulatory body should be aware that some interested parties may misuse the information that they provide, but this should not in any way curtail the release of information or inhibit the response to questions.

18. Some general characteristics of a robust nuclear safety system include the following:

— Each sub-system is independent of the others, but is open and transparent to the other sub-systems.
— The IAEA safety standards establish that there must be a strong, vibrant safety culture. This is a prime responsibility of leaders (see Fundamental Principle 3, SF-1 [6] and IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [9]) in both the nuclear industry and the regulator. The cultures of each are interconnected. The way the

[4] Peer reviews can act in a similar way, but these may be perceived to be part of the nuclear industry or regulatory enterprises and therefore not truly independent. In addition, such reviews may not be completely open in order to ensure complete candour in the evaluations.

nuclear industry responds to the regulator reflects the culture within the organization and impacts the culture of the regulator. Similarly, the way the regulator goes about its duties can significantly impact the safety culture within the nuclear industry.

— While there has to be effective communication within and between the various sub-systems, each sub-system should be independent. For example, the regulator has to be independent from the nuclear industry, but this does not mean it should operate in isolation.
— For the third sub-system, the stakeholders, to be effective, both the nuclear industry and the regulator have to communicate with the stakeholder community effectively. That is, both the nuclear industry and the regulator must have a deep-rooted value of openness, transparency and accountability to stakeholders. Such communication can assist in enhancing stakeholders' trust and confidence. Rather than just providing information, both the regulator and the nuclear industry have to engage positively with all stakeholders: listening, responding, seeking to learn and taking account of alternative views. Leaders in both the nuclear industry and the regulator must devote resources and attention and, most of all, maintain a commitment to welcome challenge, to listen, to respond openly, to learn and improve, and to engage positively with all those affected by their activities.
— For SiD to work effectively, the system as a whole has to be robust. All sub-systems and all layers and components of layers, and all the interfaces between them, have to be strong and to operate effectively. Of special importance are the interactions between the sub-systems, and among the layers within a particular sub-system.

19. Crucially, the effectiveness of the application of these principles to both technical and operational safety and to the overall system depends on the people involved, their competence, their safety culture, and how they are organized and led. If the nuclear industry fails in its prime responsibility for safety, then the regulator can stop its operations, and if stakeholders observe that neither the nuclear industry nor the regulator is fulfilling their separate roles and responsibilities, then they can initiate action to enhance nuclear safety through political pressure.

20. Figure 1 shows a model of the system.

FIG. 1. A simple model of a robust national nuclear system. (Note: 'Regulation' includes all regulatory activities and controls, but a prime method of interaction and feedback is regulatory inspection activities.)

4. THE THREE SUB-SYSTEMS OF A ROBUST NUCLEAR SAFETY SYSTEM

21. The nuclear industry and regulatory barriers have SiD through layers and components built on the principles of redundancy, diversity, the absence of single point failure, and organizational separation. Some details of the three sub-systems are described in Sections 4.1 to 4.4.

4.1. STRENGTH IN DEPTH FOR A STRONG NUCLEAR INDUSTRY SUB-SYSTEM

22. The SiD measures provided by the nuclear industry constitute the prime sub-system for nuclear safety. It can be viewed as having four layers. First, there is the licensee, operator and designer layer, which includes each organization's internal safety review processes. Second, there is a layer created by the rest of the nuclear industry in that country (or region, for a small national programme), which holds each licensee and nuclear operator to account for safety. The third layer consists of international nuclear industry peer reviews (typically those carried out by WANO). The final layer involves international reviews by peers

under the auspices of non-industry organizations such as the IAEA. Each layer can have several components; see Fig. 2, which provides an example of the four layers.

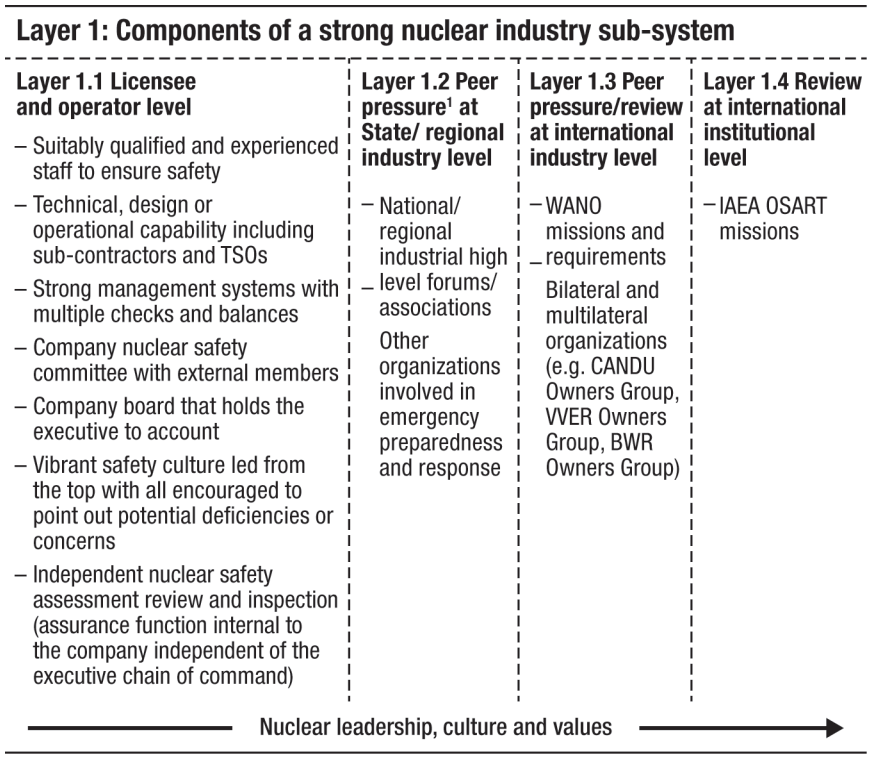

FIG. 2. Examples of components of a strong nuclear industry sub-system. (The licensee is the lead for Layer 1.1 of the nuclear industry sub-system. The licensee has the prime and enduring legal responsibility for the safety of the facility. This sub-system could be split further into the various parties involved, such as designer, vendor, architect or engineer, constructor, third party inspector, supplier, TSO, licensee, maintenance sub-contractor, etc. However, for the purposes of this publication, the sub-system focuses mainly on the licensee.)

4.1.1. A robust licensee layer

23. The licensee or operator has the prime responsibility for safety, and therefore must have strong ISiD. It must interact with and lead a common commitment to safety among all the other responsible nuclear industry entities associated with the safety of the plant, including vendors, constructors and suppliers. It has particular responsibilities for knowledge management and maintaining the integrity of the design though such mechanisms as an enduring and effective design authority; see INSAG-19 [10].

24. An example of the range of the operator's responsibility is provided by considering site selection. IAEA Safety Standards Series No. NS-R-3 (Rev. 1), Site Evaluation for Nuclear Installations [11], requires that the effects of external events, both human induced events and natural events, be evaluated. If there are any deficiencies that cannot be compensated for by means of design features, measures for site protection or administrative procedures, then NS-R-3 (Rev. 1) requires the site to be deemed unsuitable. This means that the operator must work with the designer at the site selection stage to ensure that the design is suitable for the site. ISiD would require that a robust process be in place to fulfil this responsibility.

25. A further example is that the licensee or operator has to ensure the proper application of ISiD throughout its supply chain and that suppliers have a similar approach to nurturing a strong safety culture. There is a compelling incentive for operator leadership and accountability for ISiD in the supply chain: the operator has the most to lose in the nuclear industry if the supply chain has safety deficiencies. Additionally, without operator leadership, the prime responsibilities become broadly diffused with the result that no single entity feels responsible. This is why the first layer of the nuclear industry barrier focuses on the licensee or operator.

26. Given its prime responsibility for safety, it is vital that the development of an effective internal ISiD system within the organization of the licensee or operator should follow the principles of an SiD philosophy.

27. First, the licensee or operator must have strong technical capability to underpin the safe operation of the plant and enable it to act as an 'intelligent customer' for its external services. All safety related posts must be filled by suitably competent and experienced staff.

28. Second, the licensee or operator must establish a strong management system with multiple checks for safety related decisions and actions. The executive hierarchy should allocate decision authority to those with the qualifications and experience for fulfilling the responsibility for safety.

29. Third, there should be a strong internal independent oversight of safety with responsibilities for safety policy, assessment and inspection (the licensee or operator's internal regulator or assurance function) that is outside the executive line management chain for operating the plant and that has independent reporting lines to the chief operating officer or chief executive officer (and perhaps an exceptional independent reporting line to the board level). This does not mean that workers should bypass normal management routes for reporting safety issues, as that is an essential part of a vibrant safety culture. The executive line management is also expected to seek advice on significant safety related issues from an independent diverse source, such as a company nuclear safety committee with independent nuclear expert membership.

30. Fourth, the board of the licensee or operating organization is expected to take active oversight of safety performance and to challenge the executive on safety matters. Board members may not have the technical background to understand the details of safety issues or to take action on them, particularly in a timely way. However, the board should ensure that the management and operating staff have in place arrangements and processes to ensure a high level of safety, including independent safety oversight and safety committees. Indeed, acting as the body corporate that holds the licence for the nuclear activities of the company, the board can be seen as having the legal responsibility to ensure safety. This responsibility has to be considered in all board decisions and means that the board must ensure, and be seen to ensure, that its responsibilities for nuclear safety come before profits and share value.[5] This is a crucial message for the board to send to the organization.

31. Finally, and perhaps most importantly, the licensee or operator must have a vibrant safety culture, led from the top. All workers must feel that they are key members of the internal safety system and guardians of the organization's safety culture. They are the first line of defence for safety and are frequently in a position to first notice and report a safety concern. Management at all levels has a key role in creating the right atmosphere in the workplace for worker

[5] It is noted that the board also has the fiduciary responsibility to shareholders to protect their investment in the plant. This is another reason why the board must ensure that all the components of a robust ISiD system are in place to prevent an accident.

empowerment with respect to safety, and workers and supervisors should take immediate action to address any problems that they identify. Also, management has a responsibility to establish, nurture and seek to enhance a robust, effective and responsive internal system where anyone can immediately report a safety issue and where such issues are addressed responsibly in a timely fashion. It is important for the health of the safety culture of the organization that workers in particular see management as being responsive and part of the solution, rather than part of the problem, and vice versa. Management, supervisors and workers are all part of the team working together to identify safety problems and resolve them to enhance safety.

32. All of these measures have to be based on leaders at every level of the organization developing a vibrant safety culture with mechanisms to facilitate a questioning attitude by all employees. Some indicators that this is effective are: concerns being raised routinely via the line management chain; openness and transparency being considered to be the normal way of working; and an embedded drive for continuous improvement being in place, facilitated by welcoming and responding effectively to internal suggestions and external peer reviews. The organization should have strong arrangements to learn from operating experience feedback as well as from research and development.

33. The elements of the ISiD system for the licensee or operator guard against single points of failure and common mode failure for organizations, such as inappropriate leadership and groupthink. They should also help to address one of the most important safety obligations, namely the need to overcome complacency.

34. WANO has defined the ‘traits of a healthy nuclear safety culture’ and provided relevant principles and guidance [12, 13].

4.2. STRENGTH IN DEPTH FOR A STRONG REGULATORY SUB-SYSTEM

35. The regulatory sub-system should have a series of layers similar to those of the nuclear industry sub-system. Again, internal capability, technical resourcing, organizational structure, processes and external peer reviews of the organization are examples of items that provide layers and components. Because these have been discussed for the nuclear industry sub-system, they will not be repeated here. Figure 3 provides a high level example of the layers and components for a regulatory SiD system.

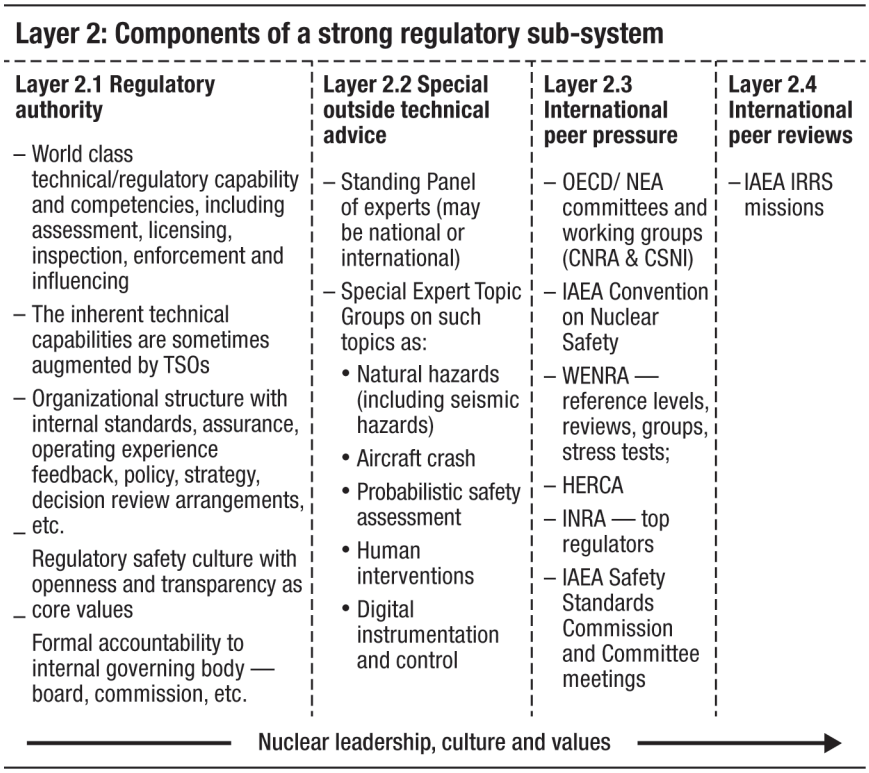

FIG. 3. Examples of the components of a strong regulatory sub-system.

36. The regulator has the prime responsibility for oversight of the licensee, and thus must have the authority, technical knowledge, capacity and capability to ensure that the operator has robust ISiD in place and that the protection of the public, society and the environment is secured at all times. However, to do this effectively, the regulator has to have ISiD firmly established in its own organization.

37. As for the operators, there is again a need for leadership in the regulatory body to develop such capabilities and, importantly, to nurture a culture that promotes openness, transparency and accountability; see the 2016 OECD/NEA publication on regulatory safety cultures [14]. This is illustrated by noting that one of the key tasks for the regulator is providing an example to the operator to fight complacency by not being complacent itself, but always seeking to improve, to welcome challenge both internally and externally, and to challenge the operator to do more to improve safety.

38. The regulator has to appreciate how its interactions with others can affect their behaviours and decisions. In particular, it is vital that the regulator at all levels understands the impact of its interactions with the licensee organization. For example, the way the regulator goes about its duties can affect the safety culture of the nuclear industry — for good or ill — and the way the licensee responds to the regulator's actions can affect how the regulator goes about its activities and what decisions it makes.

39. The regulator also has to be skilled at interactions with all stakeholders and to recognize their rights to be provided with information, including the rationale for decisions, to engage with them, to respond to their requests, to listen, to seek to understand, and, where needed, to learn and improve. The regulator should be accountable for its actions and decisions, normally through the government or parliament, to the public and workers affected by the nuclear activities that it is responsible for regulating.

40. INSAG-26 [15] provides some characteristics of a fully competent and mature regulator.

4.3. STRENGTH IN DEPTH FOR A STRONG STAKEHOLDER SUB-SYSTEM

41. There is a wide range of participants of a diverse nature that make up the stakeholder sub-system; an example is shown in Fig. 4.

42. The national government has a special role both as the architect and sponsor of the overall system for ISiD and as a source and means for stakeholder influence. The latter role is particularly significant because the procedures for stakeholder involvement with the regulator are typically established by statutes defining the regulator's obligations for engagement with stakeholders. A parliament can play a special role within the national government not only to encourage engagement, but simultaneously to ensure that the regulator is protected from inappropriate influence. That is, the parliament should also ensure the effective independence of the regulator so that it can maintain its singular focus on safety.

43. In some systems, public stakeholders become involved in the process of regulatory decision making, perhaps through being invited to present their views at decision making meetings. In other systems, there is less direct stakeholder involvement, although for some decisions (particularly those involving rule

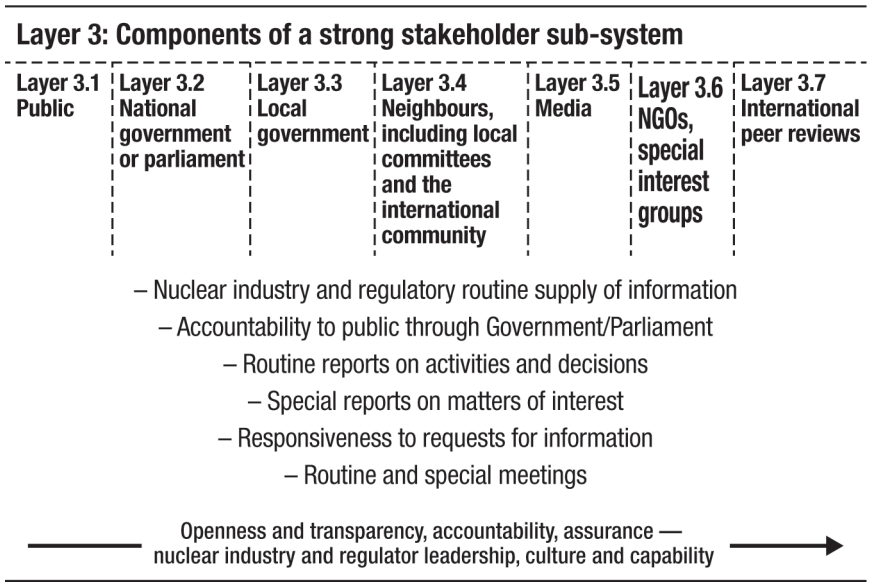

FIG. 4. Example of the components of a strong stakeholder sub-system.

or law making) there are formal consultation processes that include written comments.

44. Public involvement differs from country to country, and has cultural and political nuances that mean that a detailed one-size-fits-all approach is not appropriate. INSAG-20 [8] provides guidance in this area. While the public in general does not have the technical background to judge the nuclear safety of the plant, the requirement that it must be explained to them in public meetings is a way of keeping ISiD up front in both the operational and regulatory organizations.[6]

45. A public communication programme should be on-going throughout the life of a plant. This includes periodic meetings between the utility, regulator and the public or public representatives to discuss nuclear safety and how ISiD is in place to ensure high levels of nuclear safety. Both the licensee and regulator should

[6] Security concerns may in some circumstances limit the information that can be provided to stakeholders. However, care should be taken to ensure there is a clear necessity to withhold information.

produce periodic reports on their activities, and special reports for particularly significant activities or decisions.

46. In summary, those who would be most affected by a severe accident have a right to know what the designer, the operator, the rest of the nuclear industry and the regulator are doing to prevent an accident. It is not the intent that stakeholder involvement replaces the regulator's responsibility for oversight. Rather, stakeholder involvement is seen as a vital enhancement of the nuclear safety system; the obligation to explain in public how high standards of nuclear safety are being achieved can impact on the behaviour and decisions of the nuclear industry and regulator, and provide a vital feedback mechanism.

47. Governmental and parliamentary scrutiny of the regulator as a matter of routine or on particular topics again acts as a component of this system. This includes reviews to assess whether the regulator maintains an adequate focus on safety, has managerial and technical competence and capacity, and undertakes activities to fulfil its responsibilities for safety oversight and has the resources to do so. Additionally, it is a means whereby changes in the regulatory system can be initiated if the system is found to be performing below expectations. Such scrutiny has of course to be conducted in an open and transparent way so that the public and other stakeholders can be assured that their representatives are acting in the best interests of the people they represent. At the same time, stakeholders, especially governments, must be careful that their interactions or processes do not undermine, or are not perceived to undermine, the authority and independence of the regulator.

4.4. STRENGTH OF THE OVERALL NUCLEAR SAFETY SYSTEM

48. While the nuclear industry and regulator are responsible for their own parts of the system, the responsibility for the overall system is that of the government. It is the government that establishes the relevant laws governing the nuclear industry, the regulator, and the role of stakeholders (such as through participation opportunities and freedom of information rights). Although various aspects of the overall system are subject to international review (through, for example, the IAEA IRRS service), the only mechanisms at present that can look across the totality of the system are the IAEA Integrated Nuclear Infrastructure Review service and the review meetings of the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. These international mechanisms should provide a review of national nuclear safety systems to ensure the existence of robust ISiD.

5. CONCLUSIONS AND RECOMMENDATIONS

49. This publication applies the principles of SiD to the nuclear safety system and provides a model that identifies three main sub-systems to further the achievement of safety: (a) the nuclear industry, where the licensee or operator has prime responsibility for nuclear safety; (b) the regulatory sub-system with the national regulator responsible for independent oversight of the operator or licensee for nuclear safety; and (c) the stakeholders, including various institutions (predominately the public and their representatives) to whom both the nuclear industry and the regulator are accountable.

50. All three sub-systems are complex and involve various institutions. The stakeholder sub-system includes members of the public, who in themselves are not part of any formal organization. In contrast, the nuclear industry and regulator sub-systems are made up of institutions that can be analysed using the principles of SiD. However, all three sub-systems of ISiD must be in place and must be robust for the system to fulfil its overall function. Furthermore, the interfaces between the various sub-systems and layers must be effective, as must the underlying safety culture, including, crucially, a culture of openness and transparency. The interactions among the nuclear industry, regulator and stakeholders influence the way the different parties behave and communicate.

51. While existing international safety tools, such as the safety standards and existing international peer review processes, are constantly challenged and enhanced, the Fukushima Daiichi accident shows that these processes are not sufficient to ensure that robust ISiD is being achieved. Thus, INSAG recommends that:

— The IAEA should develop formal institutional SiD guidelines that cover the nuclear safety system model, overall principles and the three sub-systems of ISiD articulated in this publication. It may be useful for WANO to be involved in this exercise as it pertains to the operator.
— These guidelines should form the basis for the inclusion of ISiD in external peer reviews of the operator, regulator and national infrastructure.
— As part of this exercise, the IAEA should consider reviewing existing standards, guidance and peer review arrangements to identify any gaps in the application of the model, particularly standards, guidance and arrangements for interfaces, values and leadership, and seek to fill any such gaps. Again, WANO could join in such a review.

— Particular attention needs to be paid to new entrants, where the infrastructure, including development of the regulator, may not be as advanced as in established nuclear power countries. The concept of ISiD needs to be built in at an early stage of a new nuclear programme.
— Consideration should be given to encouraging the contracting parties to the Convention on Nuclear Safety and on the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management to report on the achievement of IAEA ISiD guidelines as part of the review arrangements.

52. These recommendations should be addressed with some urgency as a major outcome of the consideration of the core lessons from the Fukushima Daiichi accident, as highlighted in the 2015 IAEA report [2].

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