Chapter 5
Strengthening the Global Nuclear Safety Regime

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Contents

Abstract Nuclear power is an important component of the global response to climate change. Nuclear power provides continuous electricity and can overcome the intermittency of the renewable energy sources dependent on wind and sun. Assurance of nuclear safety is essential for further expanding nuclear power as a part of the global response to climate change. The commitment to safety must be a universal priority, as the prospects for nuclear power everywhere would be adversely influenced by the public outcry following a serious nuclear event anywhere. The importance of the global nuclear safety regime was revealed by the accident at the Fukushima Daiichi NPP. The accident reinforced that in addition to the need to have a competent *national* nuclear safety system in place, it is ultimately important to have an *international* system that ensures that the relevant national institutions diligently and effectively fulfil their roles. This chapter examines the current global nuclear safety regime and suggests improvements, including through safety inspection, greater transparency measures, increased harmonization of standards, and others.

Keywords Nuclear safety · Nuclear power · IAEA fundamental safety principles · Global nuclear safety regime · Advanced reactors · Regulator (regulatory body) · Harmonization of standards · Safety inspections · Safety and security integration

The world must urgently confront the need to move to carbon-free sources of energy if it is to overcome the devastating effects of increasing greenhouse gas concentrations in the atmosphere. Nuclear power should be an important component of its response. Today nuclear power provides about 10% of the world's electricity generation and

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nearly a third of carbon-free power generation.[1] But its role could become much greater. Although renewables will no doubt be deployed at a much larger scale than today, there will be a continuing need for carbon-free dispatchable power to overcome the intermittency of renewables. Nuclear power plants (NPPs) can fill that need and join renewables in responding to the existential challenge that climate change presents.

To pave the way for the expansion of nuclear power, the assurance of nuclear safety is essential. The commitment to safety must be a universal priority, as the prospects for nuclear power everywhere would be adversely influenced by the public outcry following a serious nuclear event anywhere. It is therefore particularly appropriate to examine the nuclear safety system that is in place and to assess whether improvements should be made.

As emphasized in the IAEA's Fundamental Safety Principles, the operator must assume the primary obligation for safety.[2] The operator controls the plant and is in the best position to assure continuing safety performance. The operator must have the engineering, financial and management capability to ensure that the plant operates with safety as the highest priority. The national regulator, in turn, undertakes the reinforcement of the operator's obligation to ensure safety by defining the operator's responsibilities and policing the operator's actions to ensure that those responsibilities are fulfilled.[3] The regulator must be independent, capable and sufficiently staffed and funded to perform its functions. Every regulator should be tough and thorough (while also fair) in assuring that every operator meets its responsibilities.

Although the operator and the regulator play essential roles, they benefit from an important backstop: the global nuclear safety regime.[4] The regime is a collective international web of stakeholders and relationships that sets a level of performance expected of all operators and regulators and that seeks to build competence and capability among them. The global nuclear safety regime is made up of several components:

- Intergovernmental organizations. The principal participants are the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). The IAEA sets safety standards and, at the request of a Member State, conducts inspections in a variety of areas and provides advice on nuclear activities. The NEA is involved in international cooperative safety research and the study of safety and regulatory issues.
- Multinational networks among regulators. Examples include the International Nuclear Regulators Association and the European Nuclear Safety Regulators Group. These networks enable regulators to exchange views and information and coordinate activities.

[1] https://www.iaea.org/newscenter/news/nuclear-power-proves-its-vital-role-as-an-adaptable-reliable-supplier-of-electricity-during-covid-19. Accessed 11 July 2021.

[2] IAEA 2006.

[3] Ibid., p. 7.

[4] The nature and importance of the global nuclear regime was described by the International Nuclear Safety Group (INSAG). INSAG-21 provides the backdrop for this paper. See INSAG 2006.

- Multinational networks among operators. The most important of these networks on the international stage is the World Association of Nuclear Operators (WANO). Among other activities, WANO provides peer reviews of operator activities and serves as a clearinghouse for the exchange of information. Owner groups, comprised of operators who share a particular design, provide a similar information sharing role. The World Institute for Nuclear Security (WINS) serves the same function on security related matters.
- The international nuclear industry. This includes vendors who design and sell NPPs, international equipment suppliers and service organizations, and the architect/engineering firms and contractors that build plants around the world. These firms transfer knowledge relating to NPPs and have strong incentives to encourage safe operations.
- Multinational networks of scientists and engineers. Scientific and engineering societies encourage and enable communication among experts in many nations.
- Standards development organizations. These include the American Society of Mechanical Engineering (ASME), the Institute of Electrical and Electronics Engineers (IEEE), the American Nuclear Society (ANS) and counterparts around the world. Compliance with detailed standards is an important component of the strong quality assurance requirements demanded of nuclear installations.
- Other stakeholders. Nuclear activities understandably attract attention. Non-governmental organizations and the press play a significant role in monitoring activities and can provide an important stimulus for ensuring safe operations.

The various components of the global nuclear safety regime and the web of arrangements that link them to each other are depicted in Fig. 5.1.

The importance of the global nuclear safety regime was revealed by the accident at the Fukushima Daiichi NPP. Japan had a sophisticated operator and an experienced regulator, but the accident could not be prevented. Deficiencies in the design basis for the plant, in the national institutional arrangements and in emergency preparedness (at operator and government levels) were overlooked because of a prevailing belief in Japan that the plant was adequately safe.[5] The fundamental lesson learned was that, in addition to the need to have a competent *national* nuclear safety system in place, it is ultimately important to have an *international* system that ensures that the relevant national institutions diligently and effectively fulfil their roles.[6]

In addition to the need to ensure exemplary safety performance that will enable nuclear power to contribute significantly to the response to climate change, there are other considerations that reinforce the importance of re-examining and strengthening the global nuclear safety regime. There are reports that 30 countries that currently do not rely on nuclear power are considering, planning or starting a nuclear power

[5] IAEA 2015, p. 67.

[6] INSAG has discussed the importance of an interlocking web of open relationships among operators, regulators and stakeholders in order to ensure that the overall system serves to provide "strength in depth". See INSAG 2017.

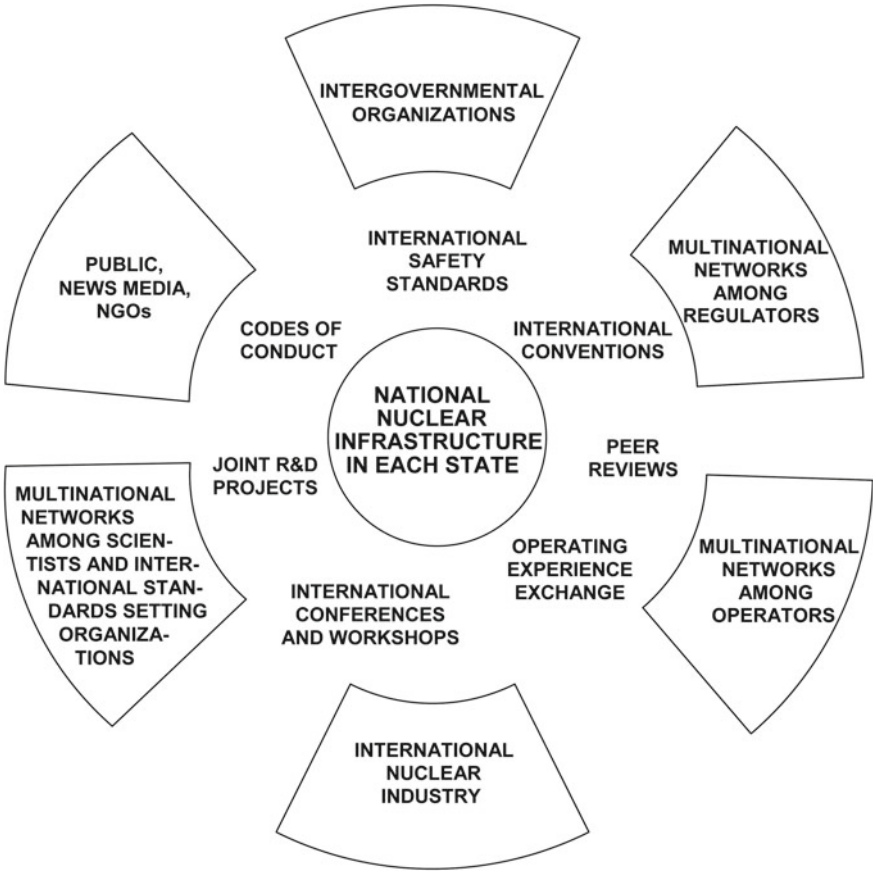

Fig. 5.1 The various components of the global nuclear safety regime. *Source* International Nuclear Safety Group 2006

programme, and another 20 have expressed an interest.[7] Many of these countries are in the developing world and their interest in exploiting carbon-free sources of electrical power is a welcome development from a climate change perspective. However, their efforts to use NPPs to address energy needs present a challenge because many of the countries do not have nuclear experience and must build a capability that does not exist today.[8] The global nuclear safety regime should play an important role in enabling these nuclear programmes to be successful in meeting safety and security obligations.

At the same time, the systems that ensure safety now face a new challenge. Although there will no doubt be continuing reliance on existing and new light water

[7] https://world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx. Accessed 11 July 2021.

[8] INSAG 2012, pp. 1–4.

reactors (LWRs) in the coming years, there has been a resurgence of recent interest in advanced reactors. Many advanced reactors use different coolants (gas, liquid metal or molten salt) and different moderators. The vendors are hopeful that the new designs will offer electrical output at lower cost per kWh, thereby making nuclear power more competitive with alternative power sources. Moreover, the new designs promise significantly improved safety through, for example, the use of simplified, passive, or other means to achieve essential safety functions. Many vendors are contemplating NPP designs that produce a much smaller output than most existing LWRs, with the result that the unit capital cost may be more manageable for some owners. Furthermore, the smaller size may be particularly attractive to countries with small grids,[9] which likely will include many newcomers. Unlike for many current LWRs, for which security and non-proliferation related elements were largely an add-on to existing plants, security and safeguards can be enhanced for contemplated plants by accommodating them in the basic design.

Although there is great promise from advanced reactors, they present particular safety challenges. Careful analyses will be required to establish that the innovative safety systems are effective in the variety of circumstances in which there is dependence on them. It will be important to maintain adequate defence in depth and to ensure a balance between accident prevention and mitigation. At the same time, sodium-cooled fast reactors, for example, will require consideration of sodium–water and sodium–air chemical reactions, while molten salt reactors will require careful examination of corrosion issues and the freezing of molten salt in piping. In short, the participants in the safety system will have to confront significant challenges in establishing and analysing the safety case for an advanced reactor and in adjusting regulatory requirements, which currently focus on issues arising in LWRs, to very different technologies.[10] The global nuclear safety regime can promote cooperation among the countries that are deploying advanced reactors and facilitate sound decision making.

Moreover, many NPPs that are currently operating were built many years ago and are close to or past the end of their originally anticipated 40-year lifetime. The plants have benefitted from detailed surveillance, maintenance and replacement of components over the years and many are running reliably. As a result, operators in several countries are contemplating an extension of operations well beyond 40 years. Indeed, in the United States of America, some NPPs have had their licences extended to 80 years.[11] However, ageing plants present unique safety challenges: systems, structures and components can deteriorate over time through mechanisms that may not be fully understood; spare parts may be difficult to find; and certain safety features found in more modern plants may not be available. Continuing the

[9] As a rule of thumb, no power plant should constitute more than about 10% of the capacity on a grid so as to enable the plant to shut down for refuelling or for safety reasons without seriously disrupting power availability.

[10] The many challenges that must be overcome to enable the deployment of innovative advanced reactors are discussed in the Letter from R. A. Meserve to R. M. Grossi. See INSAG 2021.

[11] https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html. Accessed 11 July 2021.

operation of older plants therefore requires attention to ageing mechanisms, with heightened focus over time on surveillance, maintenance and the replacement and upgrading of systems, structures and components. The global system should provide guidance to countries that must deal with ageing plants so as to ensure that safety margins are maintained.

These considerations are sufficient to justify the careful scrutiny of the global nuclear safety regime. But what should change?

As noted above, the existing safety regime is premised on the obligation of operators to ensure safety, subject to rigorous oversight by a national regulatory entity. One might imagine a different regime in which an international regulator with sweeping transnational authority ensures the adequacy of the safety performance of every operator. Such an approach might be seen as a way to ensure that all nuclear activities, regardless of location, conform to high safety standards. The approach might facilitate the harnessing of safety capabilities from around the globe in an efficient and effective manner for the benefit of all.

It is unlikely, however, that such a regime can arise in a form in which an international regulator would displace national regulators. Populations living in the vicinity of a nuclear facility will no doubt demand that its safety is pursued by a politically responsive body, rather than by a distant international regulator. Moreover, it is doubtful that any nation would willingly surrender its sovereign authority over critical energy infrastructure. As the safety system must operate within each nation's legal, economic and social culture, adaptations of the regulatory system to fit local conditions are probably necessary in any event.[12]

As a result, a global nuclear safety regime premised on a single and strong international regulator is likely to be unachievable and and may not be desirable. Nonetheless, there are a number of things that should be considered to augment the existing global nuclear safety regime and to strengthen the capacity of operators and national regulators to fulfil their essential safety roles.

- Safety inspections. The IAEA offers an extensive array of inspection services that are available to Member States.[13] However, the IAEA does not have the power to undertake safety inspections without the invitation of the Member State, and many States do not request inspections. Moreover, the IAEA has no enforcement authority to deal with deficiencies that it uncovers. Given the importance of nuclear safety, the IAEA should be given the powers to undertake inspections wherever and whenever it finds inspections to be appropriate. Furthermore, it should have the capacity to seek compliance with any deficiencies that are uncovered. The aim should be to provide the IAEA with powers in the safety arena that are analogous to its powers on safeguards matters under the Additional Protocol. An

[12] See Meserve 2009, pp. 105–106.

[13] https://www.iaea.org/services/review-missions. Accessed 11 July 2021.

amendment of the Convention of Nuclear Safety would be the logical vehicle for the establishment of these powers.[14]

- Transparency. The results of the inspections undertaken by the IAEA are made public only with the consent of the Member State. However, if the report remains hidden, serious deficiencies can remain uncorrected. The results of the IAEA inspections should be made public—albeit perhaps after review by the affected Member States to address errors—allowing other elements of the safety regime to learn of the deficiency and to press for correction. The International Nuclear Safety Group (INSAG) has emphasized the "strength in depth" that can arise from open interaction with regard to safety issues among operators, regulators and affected stakeholders.[15]
- Harmonization of standards. Many of the vendors of advanced reactors are hopeful of international sales. In the light of the anticipated efficiencies that may result from serial factory production, substantial foreign sales may be an essential part of their business plans. Given that licensing is (and will remain) the responsibility of each national regulator, there is a danger that adaptations or modifications may need to be made to obtain licensing in each country in which a plant is sold. This is obviously likely to increase costs and diminish prospects for international deployment. On account of the need for extensive use of NPPs to respond to climate change, efforts should be intensified to harmonize regulatory requirements so that inappropriate or needless modifications can be avoided. Indeed, there are strong benefits in ensuring that each regulator profits from the knowledge of others and that needless regulatory differences in approach are eliminated.

  Efforts are under way to encourage harmonization. The IAEA process for setting standards, which involves the development of international consensus, nurtures common approaches. The IAEA is now also working on the establishment of a technology neutral framework for safety, security and safeguards, which should similarly facilitate the development of harmonized safety understandings. The NEA's Multinational Design Evaluation Programme focuses on harmonizing the licensing process for new reactors; it enables regulators to leverage the resources and knowledge of the national regulatory authorities that are tasked with the review of a new design for a nuclear power reactor, while preserving the sovereign authority of national regulators for all licensing and regulatory decisions. The programme encourages convergence and harmonization of codes, standards and regulatory approaches.[16]

  There is one aspect of the current efforts that could productively change. Each national regulator now makes its own decisions as to the application of IAEA standards. The system might benefit if full compliance with IAEA standards were the norm (subject to IAEA inspections), while respecting the authority of the national

[14]The establishment of such strengthened inspection and enforcement authority would likely take years of difficult negotiation, followed by a time-consuming process to bring an amendment of the Convention into force. In the meantime, the other changes outlined below should be considered.

[15]INSAG 2017.

[16]https://www.oecd-nea.org/mdep/index.html#2. Accessed 11 July 2021.

regulator. The aviation industry could provide a model in this regard. Binding international minimum standards are established by the International Civil Aviation Organization, thereby facilitating international air travel using standardized aircraft designs. Each nation sets its own airworthiness codes, but the differences from State to State have not proven to be significant. Perhaps the role of the IAEA standards could be strengthened, enabling the IAEA to perform a function similar to that of the ICAO by supporting the harmonization of nuclear requirements, while allowing individual nations to maintain sovereignty.[17]

- Integrating safety and security. Safety and security are clearly linked and steps taken to improve one can benefit the other. For example, the massive structures of reinforced concrete and steel of an NPP serve both safety and security objectives. However, some plant features and operational practices that serve one purpose can on occasion conflict with another. For example, access controls that are imposed for security reasons might limit emergency safety response or obstruct entrances and exits in the event of a fire or an explosion. In short, there can be synergy and antagonism simultaneously between safety and security. This suggests that safety and security responsibilities on the site of an NPP should be vested in a single body so that objectives can be balanced appropriately.[18] Moreover, continuing efforts are appropriate within the IAEA to integrate the safety and security guidance provided by it.[19]
- Operating experience. The communication of operating experience has served over time to improve the performance of NPPs. Communications concerning accidents and near misses, design or equipment deficiencies, and other operational experiences enable operators and regulators to learn from each other and to strengthen safety performance. In addition to national systems for the sharing of such information, operators and regulators also report safety related information through existing global systems. The IAEA and the NEA jointly operate an incident reporting system (IRS)[20] that is available to participating countries; WANO provides access to operating information on a private and confidential basis to its member operating companies. However, not all relevant events are reported, particularly to IRS, and not all those who have access to these repositories of information make full and effective use of the data. This may in part be because there are inadequate mechanisms to sort and analyse the information, distil and prioritize the lessons that should be learned, and propagate the information in a user-friendly fashion. The system should be upgraded to facilitate the exchange of accumulated knowledge from operating experience to further the common interest in avoiding accidents. Access to such information is particularly important for newcomer countries so that they do not need to relive the hard-learned lessons of their predecessors in the nuclear enterprise.

[17] See World Nuclear Association 2013 and 2020.

[18] INSAG 2010.

[19] A forthcoming report being jointly prepared by INSAG and AdSec (the Advisory Committee on Nuclear Security) will reinforce the importance of coordination between safety and security.

[20] https://www.iaea.org/resources/databases/irsni. Accessed 11 July 2021.

- International research and development. Cooperation takes place today in research and development on nuclear matters. For example, the NEA facilitates international cooperation in the research into nuclear matters from which all benefit. However, these efforts could be expanded. As noted above, many NPPs are operating beyond their design lifetime and a further shared understanding of ageing phenomena can help to ensure that safety is preserved over time. Modern digital instrumentation and control are being applied to both old and new plants, raising different safety issues from the analogue systems that are being replaced. These issues have even more prominence with the growing challenge of assuring cybersecurity. Moreover, advanced reactors present many new safety issues, and a deep understanding of them will be necessary to ensure that the promised safety enhancements are in fact realized.[21] Coordinated research programmes to increase knowledge of advanced designs will help to ensure that the necessary data are in place to facilitate licensing decisions.

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The global nuclear safety regime provides an important means to ensure the safety of existing and future NPPs. The opportunities to improve the regime should be pursued in order to ensure that nuclear technology can be harnessed safely for the benefit of all humankind.

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[21] There is a full discussion of these issues in the letter from R. A. Meserve to R. M. Grossi. See INSAG 2021.

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