Richard A. Meserve

The global nuclear safety regime

Today, there are approximately 440 nuclear power plants (NPPs) around the globe contributing roughly 16 percent of the world's total supply of electrical energy, and the contribution from nuclear power is likely to grow in the years ahead.[1] Energy is an essential underpinning for economic growth, and as the developing world advances, its demand for energy is projected to grow significantly. At the same time, the carbon-intensive energy sources the world now relies on – chiefly coal, petroleum, and natural gas – pose a grave threat because the growing concentrations of carbon dioxide in the atmosphere are bringing about climate change and ocean acidification. As a result, the world needs to turn to energy sources that are substantially carbon free. Nuclear power, by far the most significant current source of greenhouse-gas-free energy, must play an important part in the world's response to the increasing concentrations of greenhouse gases in the atmosphere. In addition, volatile fossil fuel prices, coupled with concerns about the security of oil and gas supplies, enhance interest in energy sources that do not pose the same costs and risks. Nuclear technology is attractive in this regard, too, because fuel costs are only a slight component to the costs of nuclear energy (most of the costs arise from the amortization of the plant) and because supplies of uranium are abundant and secure.

The current widespread interest in nuclear technology has been described as a "nuclear renaissance." Construction of new plants is under way or is contemplated around the globe. Some Asian countries have steadily pursued nuclear construction over the past few decades, and several are significantly accelerating their efforts. Many European countries that had turned away from nuclear power in the aftermath of the Chernobyl accident are reconsidering their positions and are either undertaking or exploring new construction. Although no generating company in the United States has placed an order for a new plant for more than 30 years, the Nuclear Regulatory Commission (NRC) has received 17 applications for combined construction-and-operating licenses for 26 plants, and it expects several more applications in the years ahead. Perhaps most important, many countries that do not currently have NPPs have expressed interest in acquiring one. (These countries are the socalled new entrants.) The International Atomic Energy Agency (IAEA) has reported that some 60 such countries have explored nuclear power in recent years, and that as many as 20 are seriously interested in proceeding with NPPs.

No doubt, the current worldwide economic decline will slow major projects of all kinds. Nuclear power is a capital intensive activity, and therefore financing a new plant will be a difficult undertaking until the economy recovers. Nonetheless, the pressures that created interest in nuclear power persist, and we should anticipate that significant new construction probably will occur around the world over the next decade or two.

The growth of nuclear power presents challenges. One, of course, is the concern that the spread of nuclear technology could enable more countries to pursue nuclear weapons. Reactors are not the principal concern in this regard; rather, expansion of nuclear power might result in new countries undertaking fuel-cycle activities that present proliferation threats. The need for an assured fuel supply could cause more countries to develop their own uranium enrichment capacity. (Most commercial NPPs require fuel enriched in the isotope uranium-235 to a level of 4 to 5 percent; natural uranium has 0.7 percent uranium-235.) Although commercial nuclear fuel is not usable in a weapon, the technology to enrich uranium to the level needed for fuel could be applied to produce highly enriched uranium (above 20 percent uranium-235) – a weapons-usable material. Moreover, the used fuel from NPP operations can be chemically reprocessed to recover plutonium, another weapons-usable material. Because the principal barrier to the construction of a nuclear weapon is the challenge of obtaining the necessary weapons-usable material, expanded enrichment or reprocessing capacity heightens the proliferation risk, a significant concern that is discussed by other contributors in this volume.

The public also has particular concerns about the safety and security risks that attend nuclear power. We must heed these concerns not only because the public who might be affected by an accidental release from a NPP must be protected, but also because the prospects for nuclear power everywhere would be influenced by the public clamor following a serious nuclear event anywhere.

The history of nuclear power reinforces the need to pay special attention to safety. In 1979, operators at the Three Mile Island Plant in Pennsylvania failed to respond appropriately to a pressure relief valve on a reactor that was stuck in the open position, resulting in the venting of coolant. There was extensive melting of fuel, and, in effect, the reactor was destroyed. But no radioactive materials in excess of regulatory limits were emitted into the environment because the containment structure that surrounded the reactor prevented uncontrolled releases. The Russian RBMK reactor at the Chernobyl Power Plant in the Ukraine did not have a containment system, with the result that, in 1986, a runaway reactor not only destroyed the reactor, but also released extensive radioactive materials into the environment, spreading radioactive materials across Europe. Understandably, these events dampened enthusiasm for nuclear power in the United States and Europe in subsequent years.

Events such as these reinforce the obligation of all those associated with nuclear power – operators, regulators, vendors, and contractors – to be ever-vigilant. Fortunately, the recent safety record has, in the main, been good. Plant-based safety indicators (for example, measures of such things as actuation of reactor safety equipment, availability of safety-related equipment, releases of radiation, worker exposure, and unplanned shutdowns) have shown reasonably steady improvement for more than a decade. These improvements, attributable to greater attention to operations, maintenance, training, advances in diagnostic and assessment technology, and system upgrades, are impressive and, as a general matter, reassuring.

Recent experience also shows that strong economic performance correlates with strong safety performance. In the United States, for example, the improvement in safety indicators coincided with a significant improvement in capacity factors (a measure of the energy production actually achieved weighed against the theoretical maximum from continuous full-power operation). This correlation isn't accidental: the attention to detail that improves safety also leads to plant availability and stronger economic performance.[2]

Nevertheless, noteworthy safety lapses continue to occur at NPPs around the globe, including at reactors in countries with extensive operational experience and strong regulatory capabilities. None of the recent events has resulted in a substantial off-site release of radioactivity,[3] but these events reinforce the reality that assuring safety is hard work. It must be embedded in the management and cultural practices of both operators and regulators; it is an obligation that demands constant attention.

One lesson from years of operations is that the operator must assume the primary obligation for assuring safety. The operator controls what happens in the plant and, as a result, can best assure continuing safe performance. The operator must have the engineering, financial, and management capability to ensure not only that the plant is built and operated in a safe fashion, but also that it operates with safety as the highest priority. In turn, a national nuclear safety regulator undertakes the reinforcement and policing of the operator, defining the operator's responsibilities and seeking to ensure that those responsibilities are being met. The regulator should be independent, capable, and sufficiently staffed and funded to perform its functions. Every regulator should aspire to be tough, but fair, to fulfill its obligations and to meet public expectations.

Although operators and national regulators play the essential roles, there is an important backstop to the licensee and regulator: the global nuclear safety regime. The regime is a collective international enterprise that sets a level of performance expected of all operators and regulators, monitors that performance, and builds competence and capability among both operators and national regulators. This global nuclear safety regime will be increasingly important as the nuclear renaissance takes full flower.

Ad hoc in nature, the regime has grown and developed over many years. It is made up of several components:

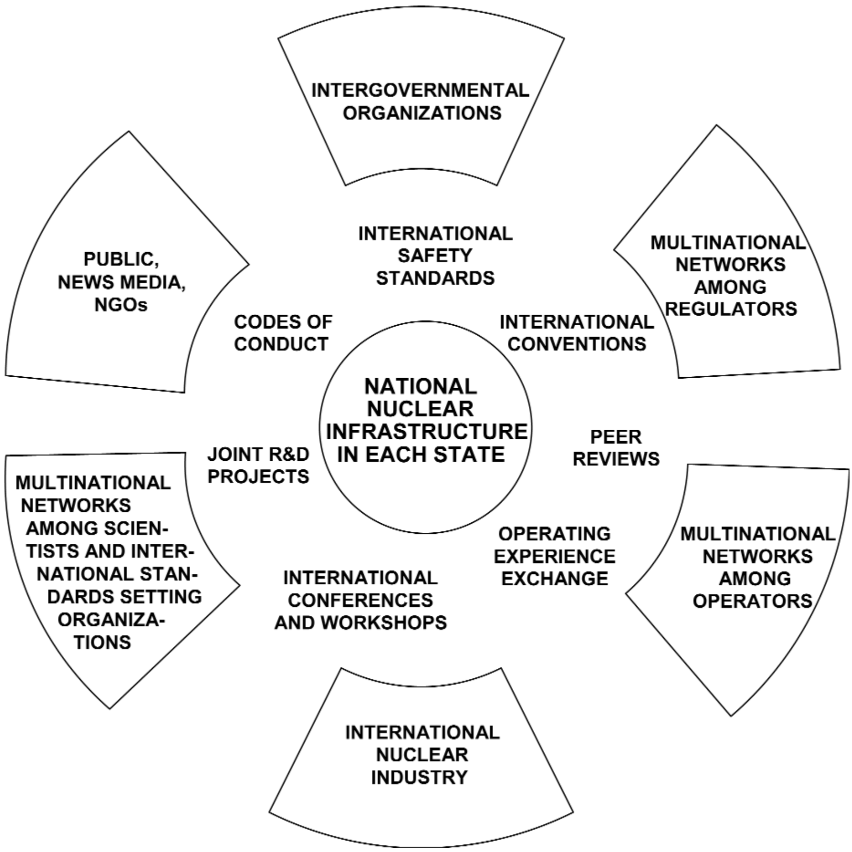
- Intergovernmental organizations such as the IAEA and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). The IAEA is a UN organization with responsibilities for nonproliferation, the safety and security of nuclear facilities, and the peaceful application of nuclear technology. In the safety and security arena, it provides standards and, at the request of a member country, inspections and advice on nuclear activities. The NEA is involved in international cooperative safety research and in the study of safety and regulatory issues. The IAEA and NEA jointly operate an international system for the exchange of operating experience.

- Multinational networks among regulators, including the International Nuclear Regulators Association and the Western European Nuclear Regulators Association. These networks encourage regulators to exchange views and information and coordinate activities.
- Multinational networks among operators, the most important of which is the World Association of Nuclear Operators (WANO). Among other activities, WANO provides peer reviews of plant operations and serves as a clearinghouse for the exchange of operating information between operators. WANO assessments and advice are held confidential. The World Institute for Nuclear Security (WINS) was recently created to serve a similar function on security-related matters at nuclear facilities.
- Stakeholders in the international nuclear industry. The vendors that design and sell NPPs are international businesses that market their products throughout the world. Similarly, the architect-engineering firms and the suppliers of equipment and services are worldwide enterprises. These enterprises provide a means for transferring knowledge from country to country.
- Multinational networks among scientists and engineers. Scientific and engineering societies encourage communication among experts in many nations.
- Standard development organizations – for example, the American Society of Mechanical Engineers (ASME), IEEE (formerly known as the Institute of Electrical and Electronics Engineers), and the American Nuclear Society (ANS) – and their interfaces with the International Organization for Standardization (ISO). Parts and components may originate in many different countries, and thus compliance with detailed standards is an important means of assuring appropriate quality.
- Nongovernmental organizations and the international press. Nuclear activities attract attention and interest around the globe, including from NGOs and the press. This attention provides an important stimulus for change.

A framework of international conventions, international safety standards, codes of conduct, joint projects, and international conferences and workshops holds the system together. These elements together provide the context in which every national nuclear program operates. (See Figure 1.)

Several overlapping factors serve to make the examination and revitalization of the global nuclear safety regime a pressing obligation. First, every nation's reliance on nuclear power is to some extent hostage to safety performance elsewhere in the world; a nuclear accident anywhere will have significant consequences everywhere, if only through an indirect impact on public opinion. Thus each country currently using or contemplating nuclear power has an interest in ensuring that there is attention to nuclear safety everywhere. The overall global improvement in safety performance does not tell the whole, or even the most crucial element of the

Figure 1
Global Nuclear Safety Regime



Source: IAEA, *Strengthening the Global Nuclear Safety Regime* (INSAG 21), 2006. Reprinted with permission from the International Atomic Energy Agency.

story. The web of nuclear safety is no stronger than its weakest link: all are vulnerable to the capabilities of the weakest performers. It is in the interest of all to identify and help those most in need of strengthening their safety performance.

The need for such international assistance is growing. As noted above, there is the prospect of substantial numbers of new entrants and of increasing numbers of NPPs around the globe. Many of the new entrants, by definition, have limited experience with nuclear energy, and nearly all lack the extensive national infrastructure common in most countries currently with NPPs. Constructing and operating these new NPPs in a safe fashion demands a strengthened international backstop.

Moreover, many currently operating plants were built years ago and are nearing the end of their originally anticipated lifetime of 40 years or so. The plants have had the benefit of detailed surveillance, maintenance, and replacement of components over those years, and many of them are running reliably and economically. As a result, operators in several countries are seeking to extend operations to 60 years and some are raising the prospect of operation for as long as 80 years. But aging plants present unique safety challenges because plants and equipment can deteriorate over time through mechanisms that may not yet be fully understood (for example, stress corrosion cracking); because spare parts may be difficult to find; and because older plants may not have all of the safety features of more modern designs. The continuing operation of older plants thus requires careful attention to aging mechanisms, with heightened attention over time to surveillance, preventive maintenance, and component replacement. Here again, the international system should help ensure that the safety margins of aging plants are maintained.

Second, the construction and servicing of NPPs has become a global enterprise, with vendors and contractors engaged around the world. Consequently, efficiencies and safety advantages have arisen from avoiding needless country-specific differences that require custom design modifications or that present unique operational challenges. Nuclear power must compete in the economic marketplace with other sources of energy, and the legal regime should further, rather than retard, economic efficiency, while simultaneously ensuring adequate safety. The global safety regime should reflect and respond to the changing structure of the industry by encouraging greater international harmonization.

Finally, there is also the simple reality that we have much to learn from each other. One of the most important ways to anticipate and prevent possible problems is to analyze and learn from the relevant experience of others, and to put in place anticipatory or corrective measures to forestall an accident. We now have about 13,000 reactor-years of experience around the world, and we benefit from putting systems in place to share the knowledge arising from that experience. Moreover, benefits are obtained by coordinating research activities and sharing research results, thereby reducing the cost of research to each participant and helping to ensure that all benefit from the growth in knowledge. The global safety regime should encourage the sharing of knowledge and nurture its expansion.

Any one of these reasons is sufficient by itself to justify the careful scrutiny of the global safety regime. Taken together, they offer a compelling argument for review. But what should change?

As noted above, the existing legal regime is founded on the fundamental obligation of operators to ensure safety, subject to rigorous oversight by a *national* regulatory entity exercising sovereign authority to protect the public health and safety. The national programs are augmented by an overlay of assistance provided by and through a variety of international organizations, chief among them the IAEA, the NEA, and WANO. But the decisions of each nation-state largely determine the extent and scope of international engagement.

One might imagine a different regime in which an international regulator with sweeping transnational authority ensures the adequacy of licensees' safety performance. Such an approach might be seen as a way both to ensure that all nuclear activities, regardless of location, conform to safety standards as well as to facilitate the harnessing of safety capabilities around the globe in an efficient and effective manner. It is very unlikely, however, that such a regime will soon be established, at least not in an extreme form, in which an international regulator displaces national regulators. Certainly, the population in the vicinity of a nuclear facility needs to be assured that its safety is guaranteed by a politically responsive body, rather than a distant and unaccountable international regulator. And the strategic importance of energy supply makes it doubtful that any nation would willingly surrender its authority over the continued operation of critical energy infrastructure, such as a NPP. Moreover, the safety system must operate within each nation's legal, economic, and social culture; adaptations of regulatory systems to fit local conditions are probably necessary in any event.

Accordingly, a global safety regime premised on a single and strong international regulator is implausible, perhaps even undesirable. This is not to deny, however, that we should encourage regional networks among regulators to share resources and capabilities, or that in the long term we should seek to establish the capacity of the IAEA to inspect and police the performance of the national safety systems, to ensure that at least minimum safety standards are achieved. The IAEA would then have strengthened capacity to ensure that the national systems were functioning appropriately.

At the moment, the IAEA does not have the power to undertake independent safety inspections absent the invitation of the member state, or the authority even to recommend sanctions for poor performance. Given safety's importance, the objective over time should be to enhance the IAEA's power to assure safety by giving the IAEA powers in the safety arena that are analogous to its powers on safeguards matters under the Additional Protocol – that is, the power to inspect nuclear facilities at a time of its choosing and to establish and seek compliance with standards. Because the national regulator will continue to have ongoing regulatory responsibilities, the focus of IAEA's increased role would be to monitor and assess the adequacy of the national regulator's efforts. An amendment of the Convention on Nuclear Safety (CNS) (discussed below) would provide the logical vehicle for the institution of these powers.

Establishing such strengthened inspection and enforcement authority would likely take many years of difficult negotiation and an arduous and time-consuming process to bring an amendment of the CNS into force. The difficulty of establishing the widespread implementation of the Additional Protocol in the safeguards arena illustrates the challenge that should be expected. In the meantime, however, the existing system can and should be reinforced and expanded in various ways. We must proceed now to augment national systems with a stronger overlay of international cooperation and engagement.

First, the safety services offered by the IAEA need to be enhanced. These services, which include voluntary inspections of nuclear facilities and of regulatory systems, currently receive only about 8 percent of the IAEA's regular budget. Given the need to assist the new entrants in establishing and maintaining appropriate national safety systems, the IAEA effort should grow significantly. There is an immediate need to provide training facilities for the staff of the operating companies and the regulatory organizations that will carry the primary responsibility for assuring safety at these new facilities. The IAEA (among others) has a very important role to play in making certain that the new entrants have the capacity and knowledge to fulfill their responsibilities.

Second, international security-related services need to be strengthened and coordinated with safety. Safety is focused on accidental events whereas, in the case of NPPs, security is aimed principally at preventing acts of sabotage that could result in releases of radioactive materials.[4] (Security at fuel-cycle facilities also focuses on the prevention of the theft of nuclear materials.) The security of NPPs has appropriately received greatly increased attention in the aftermath of the 9/11 attacks.

The security challenge will grow with the advent of more NPPs and more fuel-cycle facilities in more places. But the international network of security-related services, still in development, has not achieved the maturity that surrounds safety. Because of the need to keep security-related information confidential, there are challenges in designing and implementing international programs. This should be given high priority.

Safety and security are linked to each other. Common principles apply to both safety and security, such as a philosophy of defense in depth. The two objectives can reinforce each other: the massive structures of reinforced concrete and steel, for example, serve both safety and security objectives. But occasionally, plant features and operational practices that result from safety considerations conflict with those that serve security purposes. Access controls that are imposed for security reasons can inhibit safety, limiting access for emergency response or maintenance or for egress in the event of a fire or explosion. Similarly, if there were an attack, safety considerations may require access to an area at exactly the time that the security forces might seek to deny access. In short, the synergy and the antagonism between safety and security require careful evaluation.

This reality has national and international implications. At the national level, although the evaluation of security threats might appropriately be the responsibility of an intelligence or police organization, authority to determine the actions necessary to ensure both safety and security should be vested in a single body, so that safety and security are weighed at the same time and an appropriate balance is found. At the international level, the guidance and assistance that are now commonplace in the safety arena should be expanded to cover security, in a way that integrates security and safety advice. Both the IAEA and WINS should play a role in assuring that appropriate integration occurs.

Third, a universal, effective, and open network for sharing operating experience should be established to promote communication about near misses, design deficiencies, and even low-level operational events. Analysis of such occurrences can indicate ways of avoiding a serious accident. Currently, regulators and operators report safety-related information through existing global systems. The IAEA and NEA jointly operate an Incident Reporting System (IRS) that is available to the world's regulators; operators have access to operating information, on a private and confidential basis, from WANO. But not all relevant events and observations are reported, particularly to IRS. Moreover, there are inadequate mechanisms to sort and analyze the information, to distill and prioritize the lessons that should be learned, and to propagate those lessons widely in a user-friendly fashion. There is a need to find the means to preserve and facilitate access to the accumulated knowledge from operational experience in order to further the common interest in avoiding events that could lead to accidents. Access to such information is particularly important for the new entrant countries, so that they do not have to repeat the hard-learned lessons of their predecessors in the nuclear enterprise.

Fourth, to enhance the assurance of safety, national safety regulations should be harmonized, so that minimum requirements are met everywhere and greater compatibility is facilitated. The IAEA has developed three layers of documents – Safety Fundamentals, Safety Requirements, and Safety Guides – that provide a widely accepted foundation for nuclear safety and now serve as key references for national requirements. Safety Fundamentals establish the foundation that must be met without exceptions. Safety Requirements set mandates for new facilities and new activities, while setting a compliance target for existing facilities and activities to be met over time, if it is reasonable to do so. Safety Guides provide practical guidance on the state of the art in nuclear safety, but acknowledge that different means of providing equivalent safety are acceptable. While rigid application of IAEA safety standards may not be possible, particularly for existing facilities, IAEA standards do provide a common approach to which nations should be encouraged to conform, to the extent practical. The IAEA should pursue full awareness of and competence in the application of these standards.

At the same time, IAEA safety standards should be encouraged to evolve in two different directions. On the one hand, we should seek a global consensus on fundamental principles – how safe is safe enough – to guide the articulation of general safety goals, the expectations for new plants, and the requirements for safety improvements in older plants. This effort would seek to establish enduring fundamental goals, thereby serving the overall objectives of transparency, adequacy, stability, and harmonization. Compatibility can never be achieved unless there is common agreement on the fundamental goals.

On the other hand, the standards should be made sufficiently concrete, providing unambiguous guidance on the accepted and best practices in the multitude of areas in need of regulatory guidance. Again, compatibility can only be expected if the practical implications of the requirements are spelled out. However, safety standards must evolve to accommodate innovative new reactor designs. The existing standards, understandably, were written with current light water reactors in mind, and many of the requirements may not be appropriate, at least in their current form, for some of the new reactor designs being contemplated. (For example, the Safety Requirements document on design explicitly states in its introduction that it applies primarily to water-cooled reactors; similar statements are found in several of the supporting safety guides.) While the key elements of requirements can certainly be applied by analogy in some cases to different types of reactors, it would be beneficial to define a deeper set of principles so that the regulatory system can more readily accommodate, even encourage, designs that offer improved safety and other advantages.

Fifth, certain essential characteristics that extend beyond standards, but that are the foundation for success in achieving safety, must be encouraged. Prime among these is encouragement of an appropriate "safety culture": the cluster of organizational and individual elements that are fundamental to the achievement of safety. Organizational elements include the recognition by management that safety is the highest priority, as well as a commitment by management to organizational effectiveness, successful communications, a capacity to learn and adapt, and a workplace culture that encourages the identification of safety issues. Individual elements include personal accountability, a questioning attitude, and procedural adherence. These elements are difficult to define crisply and, hence, to regulate effectively. But they are foundational to safe operations, and the global nuclear safety regime should encourage their propagation everywhere. Similarly, the safety regime should encourage transparency, stability, practicality, and competence. Greater efforts must be undertaken to build these characteristics into regulatory and operator organizations around the world.

Sixth, while pursuing the amendment of the CNS along the lines described above, its current processes could be augmented without a formal amendment. The CNS calls for a meeting of parties at three-year intervals in which each state provides a report on its compliance with the various commitments set out in the Convention. Each national report is subject to peer review by the other parties, often resulting in recommendations for further improvement. The Convention offers no enforcement mechanism beyond the obligation to endure possible criticism from others in the review meeting.

Although the CNS has furthered its original purpose of promoting upgrades in national safety systems, the process still needs to be strengthened and refined. The review process could be more probing, perhaps by focusing on the most important safety issues, rather than by emphasizing a wide (and necessarily superficial) survey that is today's norm. The IAEA now reports to the meeting of the parties on conclusions drawn from its safety review missions and services, but the IAEA could contribute more centrally. The IAEA's report might, for example, provide more detail and be given more focused attention by the parties, perhaps by requiring affected nations to respond to the IAEA's observations. Perhaps most fundamentally, the perspective of the parties should change: rather than seeking to prove its own excellence in the review process, each country should instead welcome productive criticism and thereby collect useful ideas and lessons for safety enhancements. The questioning and open attitude that regulators expect of their licensees might also become the expected behavior of the parties in the review meetings.

Seventh, multinational design evaluation programs should be encouraged. As noted previously, the nuclear industry has become more concentrated, with the result that a small group of vendors seeks to construct NPPs around the globe. A group of countries is coordinating the evaluation of the designs, with the NEA serving as the secretariat for the group. Each national regulator retains its autonomous licensing authority, but can obtain guidance and information from the international evaluation process. This effort should be encouraged and expanded, with the aim to facilitate the construction of a given design in more than one country with only necessary modifications to accommodate local circumstances.[5] The multinational process facilitates the coordination of safety assessments, perhaps enabling more complete and thorough assessments than any one country could accomplish. It would also promote international trade, by bringing cost savings to the parties involved in licensing the plants and in constructing them. And it would further the general goal of advancing greater international consistency, thereby avoiding questions that may reasonably arise if significant differences in design were to be required from country to country.

Of course, because each country will retain its licensing authority, the final licensing actions must be taken at a national level. The coordination of design evaluation thus should not be seen to challenge the sovereign authority of national regulators. Clearly, site- or country-specific issues must be taken into account separately in connection with each construction application – issues such as site-related risk factors (for example, earthquake risk), reliability of off-site power, and the licensee's capability to build, operate, and maintain the plant. Indeed, the national regulator must be fully engaged in the details of design, construction, and operation if it is to be effective in the oversight of the plant. Nonetheless, a coordinated international design evaluation would streamline and strengthen the process, augmenting the capacities that any particular regulator could bring to bear.

At the same time, because the nuclear industry is part of a world economy in which production capabilities are globally interconnected, parts and components for nuclear plants may come from many areas of the world. The quality-assurance standards for nuclear plants are high, but no one regulator, vendor, or operator can readily have scrutiny over the quality of all these parts and components. As a result, there is a need for careful coordination among regulators around the globe to develop global standards and to ensure that those standards are being met.

Finally, increased efforts should be undertaken to advance international cooperation on research and development related to the safety performance of NPPs. Many existing plants were licensed in the years before there was extensive experience with nuclear power. Licensing decisions were guided by conservative engineering judgment and the application of fundamental design principles (such as defense in depth) to assure a robust capacity to mitigate or prevent accidents. But much has been learned over the years, and the resulting insights should be applied more effectively than is currently the case in many countries. For example, the insights from both probabilistic and deterministic analyses should be brought together and applied so as to assure focused attention on safety in all important areas. An international consensus on the application of these tools should be developed, to facilitate common understandings and standardized approaches. Moreover, coordinated research programs to increase knowledge bearing on advanced designs will ensure that necessary information is in place in time to facilitate decision-making.

There are opportunities for other international research activities that will benefit all. For example, aging phenomena that will affect performance of NPPs are not well understood at a fundamental level and, absent research, it is not clear that these issues will be dealt with properly. Further advances in nondestructive monitoring techniques will enhance the capacity to assess aging facilities. And although digital instrumentation and control offers great opportunities for safety improvements, there is a need for research to understand more deeply the safety implications of the increased reliance on digital systems. Many other such research opportunities present themselves.

The global nuclear safety regime provides an important and largely unrecognized means for helping to assure the safety of existing and future NPPs. It will have growing importance in the coming years, and there are opportunities for its significant improvement. These opportunities should be pursued in order to ensure that nuclear technology can be appropriately harnessed for the benefit of all humankind.

The global nuclear safety regime

ENDNOTES

[1] Many of the matters explored in this paper are discussed in an International Atomic Energy Agency (IAEA) document prepared by the International Nuclear Safety Group (INSAG); IAEA, *Strengthening the Global Nuclear Safety Regime* (INSAG 21), 2006.

[2] See Statement by IAEA Director General Mohamed ElBaradei, *Nuclear Safety: A Maturing Discipline* (October 14, 2003), http://www.iaea.or.at/PrinterFriendly/NewsCenter/Statements/2003/ebsp2003n022.html.

[3] The most serious recent event in the United States can be characterized as a near miss. In 2002, it was discovered that corrosion arising from a boric acid leak at the Davis-Besse Plant in Ohio had completely penetrated 6 inches of steel in the head of the reactor pressure vessel, leaving a pineapple-sized hole. The pressure boundary was preserved only by the stainless-steel cladding on the inner surface of the head – cladding that was not intended to provide pressure integrity. There had been clear clues of a significant problem – for example, containment filters clogged with corrosion products – that were ignored by the licensee and by the NRC inspectors, presumably in part because of falsified inspection reports by licensee staff.

[4] Some reactors are fueled with mixed oxide (MOX) fuel, which includes both plutonium and uranium fissile materials. Fresh MOX fuel also needs to be protected from theft or diversion at power reactors.

[5] Unfortunately, substantial modifications from country to country may be necessary in some circumstances. Consider, for example, the consequences of the differing national standards for electricity between the United States (60 Hz, 120 V) and Europe (50 Hz, 220 V). Frequency differences in particular can drive substantial design changes because they affect the sizes of motors and the buildings in which they are installed, which in turn affect seismic analyses and cooling requirements. Substantial design changes result directly from different national standards for electricity.