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July 26, 2011

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Re: The Fukushima Accident

Dear Director General Amano:

I am writing on behalf of the International Nuclear Safety Group ("INSAG") in response to your letter of July 5, 2011. This letter report is intended to respond to your request for INSAG recommendations to guide future actions related to the Fukushima accident. It will constitute INSAG's annual safety-assessment letter for 2011.

I understand that the IAEA staff is preparing a report discussing the Fukushima accident, the Ministerial Conference of June 20-24, and various conclusions and recommendations drawn from the deliberations at the Conference. Rather than duplicate the staff's effort, I shall set out certain recommendations reflecting INSAG's insights. This letter report is intended to supplement the staff's effort. It will draw on information presented at the Ministerial Conference, our knowledge of various other efforts to analyze the accident, and the experience of INSAG members.

I should emphasize at the outset that this letter can constitute only an early effort to draw lessons from the Fukushima accident. At this stage, the world community has only a preliminary understanding of the accident and I anticipate that an extended period will be necessary before full understanding is achieved. In this connection, it is worth noting that a complete understanding of the Three Mile Island accident required an assessment of the condition of the core that was not available until six years after the accident. I anticipate that future reports by INSAG and others to extend and elaborate the lessons from the Fukushima accident will be appropriate as more is known. *All the lessons that should be drawn from the Fukushima accident cannot yet be known and thus aggressive efforts to learn from the accident should continue. Nonetheless, it is worth taking stock of the accident so that safety vulnerabilities that are now apparent can be addressed promptly.*

In Part I of this letter, I shall describe the responsibilities for ensuring safety. In Part II, I shall turn to certain of the substantive issues that arise from the Fukushima accident. Then, in Part III, I shall outline some INSAG recommendations, focusing on recommendations directed at the IAEA and the Member States.

I.

There is a hierarchy of responsibility for ensuring nuclear safety. The prime responsibility for safety rests with the reactor operator; 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. Operators and national regulators play the essential roles in ensuring safety.

There is an important backstop to the operator and regulator: the global nuclear safety framework. That framework is a collective international enterprise that seeks to define a level of performance expected of all operators and regulators, to monitor their performance, and to build their competence and capability. This overall framework has grown and developed in an *ad hoc* fashion over many years. It is made up of several components: intergovernmental organizations such as the IAEA and the Nuclear Energy Agency ("NEA"); multinational networks among regulators, including the International Nuclear Regulators Association and the Western European Nuclear Regulators Association; multinational networks among operators, the most important of which is the World Association of Nuclear Operators ("WANO"); the international nuclear industry, including vendors and architect-engineering firms; multinational networks among scientists and engineers, fostered by scientific and engineering societies; standard development organizations; and nongovernmental organizations and the international press. A web of international conventions, international safety standards, codes of conduct, joint projects, and international conferences and workshops holds the system together. They constitute the "glue" that connects the global enterprises to the national programs. See generally *Strengthening the Global Nuclear Safety Regime* (2006) (INSAG-21).

Every participant in this overall framework has the responsibility after the Fukushima accident to determine changes that should be made in its activities in order to address the safety vulnerabilities that the accident has revealed. The chief responsibility to identify necessary changes rests with operators and national regulators, but all have important roles to play.

II.

The IAEA fact-finding mission to Japan and the Ministerial Conference provided considerable information about the Fukushima accident. Although much remains to be learned, the Fukushima event revealed a variety of areas that warrant further scrutiny by those involved in nuclear safety. We note the following items not as a criticism of Japan, but as an identification of possible vulnerabilities that should be of concern to all those engaged in the nuclear enterprise.

1. Regulatory Structure. The nuclear regulator must have independence, legal authority, competence, and adequate human and financial resources to fulfill its responsibilities. See *Fundamental Safety Principles*, 3.10 (2006) (SF-1). The regulator should ensure that any significant safety deficiency is promptly addressed by the operator through design or procedural improvements. This obligation extends to insights that are derived from events and initiatives that occur outside of the regulator's home country. Every country should undertake an examination of these matters to ensure that an effective and appropriate structure for ensuring safety is in place.

2. Chain of Command. There needs to be clear and unambiguous definition of responsibilities within the management structure of the operator, the regulator, and the government more generally in the event of an accident. The objective is to ensure that there is a pre-defined command-and-control system to ensure that necessary accident management decisions can be taken promptly at the proper operational level. It is important to have a chain of command that can react swiftly to an accident and thereby minimize the overall consequences for society. Of course, responsibility and competence must go together.

3. Extreme Events. The Fukushima operators were confronted with a tsunami that far exceeded the design basis for the plant. One obvious response to the Fukushima accident involves the evaluation of extreme events – earthquakes, tsunamis, hurricanes, typhoons, floods, and the like – and of the adequacy of the capacity to deal with them. There may be the need to guard against extreme natural hazards of an intensity and frequency larger than those considered in the original nuclear power plant design. See Letter from R.A. Meserve to M. ElBaradei (Aug. 25, 2008) (2008 INSAG Safety Assessment Letter).

4. Severe Accidents. Nuclear power plants are designed with the capacity to respond to certain "design basis accidents" – accidents reflecting expected operational occurrences and certain postulated accidents, such as a loss-of-coolant accident involving a major pipe break. These events are used to establish the functions and capacities of safety-related plant systems, structures,

and components. Accidents outside the scope of the plant's design basis are termed "beyond-design-basis" events; if the plant is unable to cope with such events without significant damage to the reactor core, these events may progress to become "severe accidents." Because of the potential for the release of radioactivity from the plant once the core is damaged, these events represent the primary source of risk to the public from the operation of nuclear power plants. The Fukushima accident was a beyond-design-basis accident because the plant was threatened in ways that were unanticipated in the design, and it became a severe accident when the operator was unable to mitigate the consequences of the event prior to core damage in the three reactors that were operating at the time of the earthquake. The event reinforces the need for defense against severe accidents by reducing the likelihood of such events, by preparing the plants to respond without significant damage, and by limiting the consequences of a severe accident if one should occur. A recent INSAG report on the integration of the results of Probabilistic Safety Assessments and deterministic defense-in-depth considerations should be helpful in this respect. See *A Framework for An Integrated Risk-Informed Decision-Making Process* (2011) (INSAG-25).

5. Station Blackout. The various systems that were intended to provide core cooling at the Fukushima plant either failed or ultimately were unavailable, largely as a result of the loss of all emergency AC power. The accident shows that emphasis should be placed on assuring the availability of off-site power to the extent possible through redundancy in power supply lines and switchyard facilities, and on providing emergency diesel generators that are not vulnerable to extreme events. Consistent with the philosophy of defense in depth, there also is a need for assurance of the ability to cope with a station blackout for an extended period, including both on-site coping capacity and the ability to marshal off-site resources promptly. The backup power supply should be able to provide support of key important safety functions, including the cooling of the core and the inventory of spent fuel in pools, for several days of blackout.

6. Loss of Heat Sink. As a result of the tsunami, the Fukushima units lost the capacity to release the heat being produced by the cores of units 1-3 to the heat sink (the ocean). The event reinforces the need not only to evaluate the capacity to restore an ultimate heat sink promptly under accident conditions, but also to include in accident planning consideration of alternative means for providing an ultimate heat sink for an extended period in the event that normal and safety-related heat transport systems are unavailable.

7. Explosive gases. The reactor buildings at the Fukushima Daiichi plant were destroyed by the accumulation of hydrogen inside the buildings and its subsequent explosion. The accident should prompt a careful examination of the means to prevent the buildup of dangerous gases or to mitigate their capability to cause damage to key plant structures.

8. Spent Fuel Pools. The Japanese confronted considerable challenges in maintaining the water inventory in the spent fuel pools. Special examination is warranted to ensure that there are diverse and redundant means to monitor water temperature and level and to ensure the maintenance of water inventory in order to avoid a release from a spent fuel pool.

9. Emergency Planning. The Fukushima event reinforces the reality that the unexpected can occasionally occur. The event reinforces the importance of having an integrated emergency response capability that is in place at and in the area surrounding the plant site, at the national level, and at the international level. The emergency response plans should not assume the availability of infrastructure, such as communications systems, that could be unavailable as a result of an extreme event. Moreover, the Fukushima accident reveals that problems at one unit could affect the capacity to respond at the other units. A thorough review of emergency planning is warranted to ensure that there are reasonable response strategies for such circumstances. Careful training and realistic exercises should be conducted to verify the capacity to implement the strategies.

No doubt, many other issues will emerge as a fuller understanding of the Fukushima accident is obtained.

III.

Although, as noted above, all the participants in the nuclear enterprise have responsibilities for review of these matters and for the implementation of necessary responses, I know that you are particularly interested in actions that the IAEA and its Member States should undertake. Many of the items identified here were raised in your address to the Ministerial Conference and in the Chairmen's Summaries arising from that Conference.

1. Safety standards. IAEA safety standards provide important guidance for national regulatory requirements and serve as the basis for IAEA peer reviews. As a result, the IAEA safety standards serve as the common reference around the globe for all those involved in the nuclear enterprise. Because of the singular importance of the standards, the IAEA should seek to assess the Fukushima accident to determine whether it reveals deficiencies in the existing standards or rather in their implementation. As necessary, the IAEA should update the standards to incorporate the lessons learned from the accident. (Indeed, I understand that exactly this task will be undertaken the IAEA's Commission on Safety Standards.) We anticipate that assessment of the standards might cover many of the items identified above. The Member States should assure that their regulatory requirements are modified to reflect enhancements in the international standards.

As part of this process, it should be noted that the strength and validity of the IAEA standards is ensured by careful and methodical analysis by competent international safety experts and the development of consensus. We encourage involvement in the development of standards by all relevant parties, including not only experts from regulatory bodies, but also experts from vendors, manufacturers, operators, and research organizations, as appropriate.

2. Peer Review Services. The IAEA's various peer-review services provide an important means to enhance safety by revealing vulnerabilities that might not otherwise be apparent and by encouraging continuous improvement. It is expected that the Fukushima accident will provide a wealth of important information that should be embodied in the peer-review services. There are several aspects of the peer-review system that could be strengthened:

- All countries should be strongly encouraged to obtain the benefit of the variety of peer-review services on a periodic and regular basis. There should be follow-up missions to assess the adequacy of the responses to issues that are raised by earlier missions.

- Transparency with regard to the results of the peer-review missions, the response to them, and the follow-up missions should become the norm. The availability of these assessments is an important element in ensuring public confidence. It would be appropriate, in any event, to provide information about the use of the peer-review services by Member States, as well as the identification of those who have not participated.

- Many countries have undertaken an immediate review of the capability to respond to extreme and/or beyond-design-basis events and loss of safety systems and of the adequacy of the emergency response arrangements. (All countries should be encouraged to do so.) The IAEA should seek to assemble the broadly applicable lessons that can be derived from these efforts and incorporate them in its review services, as appropriate. The IAEA has an important role to play in nurturing the exchange of information and in offering assistance at the request of a Member State.

- The IAEA's mission to evaluate a nation's regulatory program (IRRS) includes a module for "regulations and guides." Review under this module might appropriately focus on an assessment of the consistency between the national regulations and the IAEA safety standards. The national regulators should prepare for an IRRS review by conducting a self assessment of consistency.

- Design review missions should become a regular practice in all Member States. They may be particularly appropriate in connection with periodic safety reviews or consideration of lifetime extension by national regulators. In order to enable a deep review, the efforts might focus on certain topical areas of particular importance to a given plant, such as protection from external hazards, diversity of means to transfer heat to a heat sink, or provision of means to protect reactor containment after a core meltdown.

3. International Emergency Preparedness and Response. Although the national operator and regulator each have different and special responsibilities for response to an accident, the IAEA can play an important role in facilitating their response and in helping to marshal international assistance. There are several elements of the IAEA's capability that should be strengthened:

- The Fukushima accident revealed a hunger for information about the accident by numerous regulators and other institutions. Unfortunately, much of the information of interest was simply not available, with the result that at times speculation substituted for fact. Although it would likely not be possible for the IAEA to provide information during the course of an accident that requires information about the detailed plant design or of modifications to the plant during its life, the IAEA could play a stronger role as a clearinghouse for information. It might be possible, for example, for the IAEA to provide some analyses of the progress of the accident, the estimation of the source term, and the projected radiological impacts on affected populations. In order to accomplish this role, the IAEA might have to augment its staff temporarily by making pre-accident arrangements for assistance from international experts with the necessary technical knowledge.

- The IAEA could play a stronger role in the future in coordinating the international emergency response. Many countries sought to help Japan, but there is a need to strengthen the means to ensure that assistance of the right type is made available promptly. The framework for such a system is in place through the IAEA's Response and Assistance Network ("RANET"), but it could be augmented. It is appropriate to follow up on the recommendations and conclusions of the plan to strengthen RANET that was prepared in 2009. The network would be enhanced if more Member States would register their special capabilities with RANET and if regional coverage were expanded.

- The International Nuclear Event Scale ("INES") did not serve the purpose of providing a simple and intelligible assessment of the severity of the Fukushima accident. It should be reviewed and possibly revised.

4. International Conventions. There are a variety of international conventions that bear directly on the response and evaluation of nuclear accidents: the Convention on Nuclear Safety (CNS), the Convention on Early Notification of a Nuclear Accident, and the Convention on Assistance in the Case of a Nuclear Accident. Although the various responses to the Fukushima accident described elsewhere in this letter should not be delayed, a longer-term effort should involve the evaluation of these conventions in light of the events at the Fukushima accident to determine if any modifications or amendments are appropriate. This opportunity will arise at a special meeting of the parties to the CNS to be held in 2012 to discuss the Fukushima accident. Because the amendment of a convention is a protracted and difficult process, efforts should also be made to improve the effectiveness of the conventions within the scope of their current terms. There has been criticism, for example, that the recent review meetings of the CNS no longer are as productive as the initial meetings. Means should be found to revitalize the review process by providing more focus to the review meetings. Perhaps the observations from peer-review missions to a given country could be the foundation of the review meeting for that country.

5. International Safety Research. The underlying technical phenomena associated with the Fukushima accident, including such matters as fuel and system performance, hydrogen generation, and behavior of the spent fuel in the pools, should be the focus of research programs. International cooperation on such research should be pursued through the existing NEA framework. The IAEA should seek to ensure that the results are reflected in its safety programs and that all countries benefit.

6. Remediation. The Japanese will confront a major challenge in remediating the lands that were contaminated by the Fukushima accident. The IAEA can play a role in marshaling international expertise to assist in the effort and, in turn, the IAEA should ensure that the lessons that are learned from the remediation are made available to the international community.

7. Other Matters. There are a variety of matters that, while not directly related to the Fukushima accident, warrant aggressive action by the IAEA. The Fukushima accident reinforces the broader reality that continued work across the spectrum of activities that enable safety is warranted.

- New entrant countries. It is noteworthy that the three major nuclear accidents – Three Mile Island, Chernobyl, and Fukushima – occurred in technically sophisticated countries with advanced nuclear power

programs. The lesson to be learned from this fact is that ensuring nuclear safety requires hard and dedicated work even in advanced countries. The challenge no doubt is greater in those countries without an extensive background in similarly sophisticated technology. But, as you know, there are many countries without experience with nuclear power that have launched programs to construct a plant or are advancing in that direction. There should be aggressive efforts by the IAEA – and by all others involved in the nuclear enterprise – to ensure that countries moving ahead with nuclear construction can be successful in ensuring safety. The IAEA should reach out to these countries to provide both the education about the necessary infrastructure that must be established and the services to monitor and assist their progress in complying with international standards. Vendors and the regulatory organizations in the vendors' home countries also have particularly important roles to play. Our thoughts concerning actions to respond to this important issue are explained more fully in my correspondence of last year. See Letter from R.A. Meserve to Y. Amano (Aug. 25, 2010) (2010 INSAG Safety Assessment Letter). See also *National Safety Infrastructure for a National Nuclear Power Programme Supported by the IAEA Fundamental Safety Principles* (2008) (INSAG-22).

- Operating Experience. Those who do not learn from the past are condemned to repeat it. The operating experience from existing plants can provide important lessons as to how to avoid accidents from which all should benefit. The operational feedback provided by WANO is very useful in this respect, but the content of this system is confidential and is available only to operators. There thus needs to be an effective system to provide operating experience feedback to regulators and others that is drawn from enhanced communication among the IAEA, operators, regulators, WANO, and no doubt others. This can best be accomplished through enhancement of the Incident Reporting System ("IRS") maintained by the IAEA and the NEA, as well as through topical reports on measures that should be considered for enhancing safety on the basis of lessons learned. INSAG has published a report that outlines the changes that we believe are required. *See Improving the International System for Operating Experience Feedback (OEF)* (2008) (INSAG-23). Although the need to enhance the system for operational experience feedback has been discussed in recent years, there is little apparent progress in reducing risks and enhancing safety on the basis of lessons from other countries' experience. This matter deserves increased attention.

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Let me close by noting that the IAEA is the central international body dedicated to improving nuclear safety. As the Fukushima accident has reinforced, this mission is of singular importance. The world was riveted by the events in Fukushima, reflecting the public expectation that high levels of safety must be achieved everywhere. The IAEA should play a central role in meeting this need.

Only about 9 percent of the most recent IAEA regular budget is allocated to safety and security. Although I do not dispute the importance of the various activities pursued by the IAEA, it is apparent that the staffing and budget for safety may need to grow significantly to meet the expanded needs that the IAEA must satisfy. In this connection, it appropriate to note that the cost increase associated with the IAEA's safety work is likely to be only a small fraction of the costs associated with a severe accident. Let me add, growth is necessary not only to allow a timely and effective response to the lessons from Fukushima, but also to reflect the need for substantial international assistance to enable the new entrant countries to succeed in their first application of nuclear power. Of course, any increase in the budget allocation for safety must be accompanied by a commitment by the IAEA to deploy those resources efficiently and effectively.

I hope that this letter is helpful to you. Please feel free to contact me if I can provide any further input or assistance.

Best regards.

Very truly yours,

Richard A. Meserve

cc: INSAG Members
Denis Flory