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August 21, 2015

Mr. Yukiya Amano, Director General
International Atomic Energy Agency
Wagramer Strasse 5
A-1400 Vienna
Austria

Dear Director General Amano:

I am writing in my capacity as Chairman of the International Nuclear Safety Group ("INSAG"). INSAG's terms of reference state that INSAG should provide "recommendations and opinion on current emerging safety issues" to the IAEA and others. During my term as Chairman, I have customarily sought to fulfill this obligation not only through the various INSAG reports, but also with an annual letter. My past letters are available on the INSAG website at http://goto.iaea.org/insag. This correspondence constitutes this year's installment.

As you are very well aware, the accident of the Fukushima Daiichi plant has appropriately been the focus of attention of the nuclear community for the last several years. This letter will not explore the many lessons from the accident in light of the thorough evaluation that is provided in the IAEA's report, on which I and several INSAG members have served as contributors and advisers, that will be issued in September at the time of the General Conference. Instead this letter will explore one notable feature of the Fukushima Daiichi accident that deserves to be highlighted – the vulnerability of nuclear plants to natural external events. Such events include earthquakes, tsunamis, hurricanes, floods, volcanism, and the like. Human-induced external events can share some common features with natural external events, but are not covered by this letter since they can involve security-related issues.

The Fukushima Daiichi accident was initiated by a huge tsunami that overwhelmed the plant's safety systems. The accident was thus quite unlike the Chernobyl and Three Mile Island accidents, which were both initiated by internal events. The Fukushima Daiichi accident has thus appropriately resulted in additional

consideration of the vulnerability of nuclear plants to natural external events of all kinds. It turns out that the determination of the appropriate preparation for such events is quite challenging.

The evaluation of safety is guided by both deterministic and probabilistic considerations. *See* INSAG, *A Framework for an Integrated Risk Informed Decision Making Process* (2011) (INSAG-25). The evaluation of risks from internal events (e.g., failures of plant equipment or human errors) has been extensively pursued and the major fault trees have been carefully explored. Good data is available in most cases concerning the reliability of equipment and significant progress has been made in evaluating human performance, with the result that the risks from internal events are reasonably well understood. Modern reactor designs are developed to reduce those risks to very low levels and in many countries the operating fleets employing older designs have benefitted from improvements and modifications over the years that have similarly served to enhance protection from internal events.

By contrast, the evaluation of the risks from natural external events is characterized by very large uncertainties. To start with, the magnitude of an extreme external event and its associated frequency may be difficult to estimate reliably. Historical data is limited and not of sufficiently long duration. The communities that study natural external events (e.g., scientists who study earthquakes or volcanism) confront significant scientific questions and uncertainties in estimating the potential magnitude and associated frequency of extreme external events. Moreover, modeling of such events and of their consequences is complicated and also plagued with uncertainty. In addition, the relevant scientific communities may not be well connected to the nuclear community or to national organizations with responsibility for preparing for external events. And, as a result of climate change, some categories of external events may pose greater risks in the future. For example, the climate models suggest a growing probability for extreme weather events, presenting greater future risks from flooding or high winds. The observed rise in sea level will also present flooding risks that are obviously not encompassed by the historical data.

Additional complications arise from several other considerations. First, as the Fukushima Daiichi accident demonstrates, a natural external event that exceeds the capacity of the design can create a common cause failure that sweeps away several layers of defense in depth. That is, an extreme external event may cause failures in equipment at various levels of defense in depth, including equipment that is intended to prevent or mitigate the propagation of

an accident. It may also compromise the barriers to the release of radionuclides and damage both the on-site and off-site infrastructure associated with emergency response. By contrast, accidents resulting from internal initiating events typically require multiple independent equipment/human failures and hence the misestimate of one failure is not as consequential, given the backstop provided by other layers of protection. The single failure criterion – the requirement that there be a backup for safety components – is not helpful for external events that incapacitate or bypass multiple layers of protection. **The implication of these facts is that the predominant source of risk in modern reactor designs is likely from external events.**

Second, some extreme events, such as flooding, may present cliff-edge effects. Thus, a slight overestimate of the maximum flood may be sufficient to control the risk, whereas a slight underestimate could mean that the protection from flooding is overwhelmed. The non-linearity means that the consequences of a failure to estimate the external risk conservatively are greatly enhanced.

Finally, and again as the Fukushima Daiichi accident illustrates, external events may result in multiple challenges that must be confronted simultaneously. Earthquake and tsunami events are obviously correlated with each other which can, as at Fukushima, multiply their destructive impact. An external event may itself initiate an internal event that complicates the situation; it is easy to imagine an earthquake as a precipitating factor for a fire, for example. And, as the Fukushima Daiichi accident illustrated, an external event is likely to involve all the units at a site. This obviously increases the challenge and difficulty of responding to the event, which serves to increase risk.

This situation suggests that the response to the risk from external events should appropriately include several elements:

- The science underlying the estimation of the magnitude and associated frequency of extreme natural external events should be pursued, along with improved integration of the scientists with the nuclear community. Data associated with international past extreme events and experience should be taken into account to supplement national historical data. This scientific input should guide the development of more sophisticated modeling of the effects of extreme external events on nuclear plants. It should not be expected, however, that sufficiently reliable estimates of the magnitude/frequency of extreme events and their effects

will soon be forthcoming. But improved estimates would be valuable, particularly the determination of any limits on the magnitude of an extreme event.

- In light of the fact that the magnitude and likelihood of an extreme external event that could threaten a plant may not be well estimated, extra margin should be included to accommodate uncertainty. For example, a new plant should be sited at a height well above the estimate of the maximum flood. Existing plants that are potentially vulnerable could benefit from a specific international mission to review the adequacy of the protection against natural external hazards, including any vulnerability to cliff-edge effects.

- The design should also include extra margin to reflect the uncertainty in the threat from external events. The intent should be to assure defense in depth by avoiding fragility. For example, a plant might have a dike or sea wall that is based on a conservative estimate of flooding risk, but full reliance should not be placed on this barrier. Emergency equipment, such as diesels, could be placed at a high level in order to assure that any conceivable flood would not result in the loss of on-site power and other critical equipment might be placed behind water-tight doors.

- Severe accident management measures to prevent or mitigate core damage and radioactive releases need to be feasible and effective even under conditions arising from an extreme external event. The measures should reflect appropriate consideration of human behavior and performance under such conditions.

- Both on-site and off-site personnel who will called upon to respond to an extreme external event should receive appropriate training. The training should incorporate the reality that an extreme external event could result in the loss of significant on-site and off-site resources for emergency response. Off-site emergency planning should take into account the likelihood that many off-site resources may not be available.

- When a new study suggests that the level of protection of an existing plant against an external hazard may be too low, the design should be reviewed to assess the

plant's vulnerability and appropriate measures should be implemented to reduce the risk without awaiting full confirmation of the study.

We understand that work is underway at the IAEA to include considerations such as these as a formal element of the safety standards. INSAG is also contemplating some further work relating to external events.

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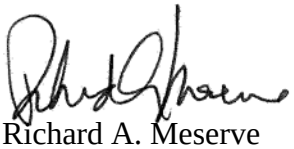
This letter is intended to highlight the special challenge to safety that is presented by external events. Of course, this challenge has not gone unrecognized by regulators and operators around the world; one of the common elements of the responses to the Fukushima Daiichi accident has been a careful reevaluation of the risks from external events, in particular flooding, and the assurance of a capability to respond to them. Nonetheless, the risk posed by external events justifies continuing attention in the years ahead.

As always, please feel free to contact me if INSAG can offer assistance on this or other matters.

Best regards.

Very truly yours,



Richard A. Meserve

cc: Denis Flory
INSAG Members