GLOBAL NUCLEAR ENERGY SUMMIT

Nuclear Governance and Nuclear Innovation after Fukushima

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1. I would like to begin by thanking the organizers of this conference, and especially Dr. KunMo Chung, for the opportunity to participate in this session. It is an honor to address such a distinguished and knowledgeable group.

2. The events at Fukushima make it inevitable that this year – 2011 – will be a milestone year in the history of nuclear energy development.

3. But 2011 is special for another reason too. This year is also the 100th anniversary of the discovery of the atomic nucleus. The practical achievements in the energy field that have flowed from this discovery have been nothing short of astonishing. Yet I believe that we are still only at the early stages of the nuclear energy story, and that what lies ahead may be even more remarkable.

4. I will return to this point shortly. But first I would like to make a few observations about the response of the nuclear energy community to Fukushima.

5. I know that everyone here, and I of course include myself and the Department of Nuclear Science and Engineering Department at MIT for which I am responsible, is fully committed to doing whatever we can to assist TEPCO, the Japanese government, and the Japanese people with the

crucial and immensely challenging task of safe, swift stabilization and cleanup at the Fukushima site.

6. For many people around the world, it is difficult even today, more than six months after the great earthquake struck, to bring the accident at Fukushima into clear focus. The seeming contradiction between the enormity of the accident and the fact that it has so far caused no radiation-related fatalities and that even in the long term the number of radiation-related health effects will be very small is disorienting and difficult to process.

7. There is still much to be learned about what happened. But a number of things are already clear. First, while the accident was not close to being a radiological health disaster, it is an economic and industrial disaster and it has exacted a vast human toll. Tens of thousands of people have been forced from their homes, many with no prospect of returning any time soon. There will likely be 100s of billions of dollars in cleanup costs. There is nowhere to put the resulting waste. Large numbers of Japanese nuclear plants have been forced to remain closed. And in a land-poor country, significant amounts of land have been contaminated.

8. What is also already clear is that, just as with TMI and Chernobyl, there was a breakdown of nuclear governance – of systems of management, control, and regulation. The proximate cause of the accident was, of course, a physical event. But at Fukushima, just as at TMI and Chernobyl, the consequences of the physical event were greatly magnified by failures of governance. It was what engineers often disparage as the 'soft' issues – the performance of people, the organizations they populate, the procedures they follow, the institutional structures they create – that aggravated what might otherwise have been a very serious but manageable accident. And, of course, it is the breakdown of the public trust in these institutions that will surely turn out to be one of the costliest legacies of the accident.

9. One of the consequences of this breakdown of trust is that it is likely to greatly complicate the already excruciatingly difficult decision-making process affecting who will and who will not be allowed to return to their homes in the evacuation region. And parenthetically, perhaps this is an area where the assistance of the international community in information

validation and distribution and decision support might be helpful in addressing adverse public perceptions of decision-making processes.

10. Another point that has come into clear focus as a result of Fukushima is that breakdowns in nuclear governance can occur anywhere. It is notable that the most serious breakdowns have occurred in vastly different national settings – in the U.S., in the former Soviet Union, and now in Japan. This covers a very wide range of economic, cultural, and industrial environments. At the very least this indicates that it would be imprudent for a country where no such breakdown has occurred to assume that it can never happen there because that country is different. On the contrary, on the basis of the available evidence we might reasonably conclude that there is no national system within which major failure cannot occur.

11. At the same time, we can also draw from the evidence some general principles of effective nuclear governance that are applicable regardless of national context. These include transparency of decision-making, independence of regulators, and the overriding importance of establishing and maintaining a safety culture in nuclear operating organizations.

12. It is not necessary to point out to this group that the immense power and destructive potential of nuclear energy technology demands a healthy respect on the part of nuclear operators as well as constant vigilance and scrutiny by those who oversee them. And in the aftermath of Fukushima one of the most urgent and important tasks facing the international nuclear community is to affirm, articulate and enforce a set of universal principles of effective nuclear governance.

13. It will be especially important to do this because we are likely to see a significant expansion of nuclear energy in the coming decades. Although a near-term slowdown in nuclear energy development seems inevitable, sooner or later the pace of nuclear energy development will accelerate again. Its fundamental advantages in displacing fossil fuels are too great to ignore.

14. Since last March there has understandably been a great deal of speculation about the impact of Fukushima on future nuclear energy development. The decision of the German government to phase out its

nuclear plants within about 10 years has attracted much attention as a possible harbinger of a more general withdrawal from nuclear. But for a number of reasons this may be a misinterpretation of events. Germany is of course a large and important economy, but it has not been a major player in the nuclear energy field for decades. The Germans stopped building nuclear power plants in the 1980s and today Germany accounts for just 5% of the world's nuclear energy capacity. Moreover, Chancellor Merkel's much-discussed announcement of a nuclear phase-out, coming just 2 days after the Japanese earthquake, in fact marked a return to a policy which had been in effect for most of the previous 15 years, and which had only been reversed a few months earlier. And while neighboring countries like Switzerland and Italy seem likely to follow suit, even in Western Europe other countries, notably the UK, have reaffirmed their commitment to nuclear expansion in the weeks and months since the accident.

15. And here in Asia, a number of countries are also pursuing plans for nuclear energy development with relatively little delay – the largest example, of course, being China.

16. In the U.S. the impact of Fukushima will also be fairly small, at least as far as nuclear expansion is concerned. But this is because it was clear, even before the accident, that only a very few plants were going to be built over the next decade in the U.S. anyway. For most American utilities, the high cost of nuclear power plants and the projected availability of inexpensive natural gas had already caused expectations of a nuclear renaissance to recede into an uncertain future.

17. The most interesting question concerns the large number of countries that have been considering embarking on nuclear energy programs for the first time. There are different estimates of the size of this group. My own estimate, made before Fukushima, was that about 20 countries might have new nuclear programs in place by 2030 (out of 50 or more that have communicated their interest to the IAEA.) I have not seen an authoritative update of this number since Fukushima. Nevertheless, the indications are that the majority of these countries are likely to proceed with their plans. It is obviously of the utmost importance that these countries embrace the highest standards of nuclear governance as they move to implement their

plans, just as it is important for existing nuclear countries to re-affirm and strengthen their own commitment to these standards.

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18. The second and equally important challenge confronting the international nuclear energy community concerns technological innovation. An already safe technology must be made demonstrably safer, as well as less expensive, more secure against the threats of nuclear proliferation and terrorism, and more compatible with the capabilities and limitations of most electric power systems and the utilities that operate them.

19. I mentioned at the outset that this is the hundredth anniversary of the discovery of the atomic nucleus. In fact, it is a little over 70 years since the nuclear fission reaction was first demonstrated. In chronological terms, we could say that this puts the field of nuclear engineering today roughly where the field of electrical engineering was in the year 1900. Think about what that field then brought about: the creation of the electric power grid, one of the greatest engineering achievements of the last century; radio and television; the revolutions in microelectronics, computation, telecommunications, and the internet; and much more – an astonishing series of advances, not one of which was anticipated by the electrical engineers of 1900, or by anyone else.

20. Likewise, no-one today can foresee the range of practical applications of nuclear science and technology at the end of the 21st century (except, of course, the antinuclear ideologues, who wish for no future at all.) The most that we can say is that the nuclear power plants of the year 2100 will have about as much resemblance to today's workhorse light water reactors as a modern automobile has to a 1911 Model T Ford.

21. We know, of course, about new technologies that are already in the pipeline. Some of them look more promising after Fukushima than before. For example, the new silicon carbide cladding material under development at MIT and elsewhere, which unlike the zircaloy in today's reactors doesn't react with high-temperature steam to produce hydrogen. Greater reliance on passive heat removal mechanisms is another important direction of advance. The new generation of light water reactors has moved in this

direction, but more advanced designs go further towards the goal of 'walkaway safety' – defined as the ability of reactors to shut down and cool down without any human intervention at all. Is it so unlikely, given recent events, that this goal will become a requirement for all nuclear power reactors 50 or 100 years from now?

22. Other longer-term possibilities include lifetime fueling, and integrated power plant-waste disposal systems, with spent fuel never leaving the power plant site and disposed of directly in modular deep boreholes several kilometers below the earth's surface in the stable, dry bedrock that is abundantly available in most countries.

23. (And just as an aside, the extraordinarily high levels of public anxiety we see today over even very low levels of radiation will not necessarily persist over these longer time frames. Unlikely as this may seem today, it is not entirely far-fetched to speculate that one consequence of the ongoing revolution in molecular biology will be to transmute the deep-seated fear of radiation as a hidden, silent menace into a somewhat more benign view of it as one of many pervasive and routine environmental insults, with well-understood consequences for human cells and human health.)

24. In the nearer term, much smaller nuclear power reactors will expedite the application of advanced manufacturing techniques, modular construction technologies, and dynamic economies of scale or learning effects. Reductions in capital-at-risk, shorter project lead-times, better matching with small power grids, and increased flexibility may make small reactors especially well suited to new nuclear countries, as well as to many nuclear operators in mature nuclear states.

25. In the nearer term, too, enormous gains in computing power already enable far more precise simulations of nuclear reactor behavior than ever before, and are opening up radically new and more efficient approaches to design. Computational advances may also make it possible to design and build radiation-resistant materials at the atomic level, and to create ultra-secure nuclear waste materials with lifetimes of tens of thousands of years. All of this can be imagined today. Far greater advances surely lie over the horizon.

26. The leaders of these innovations will not be the current leaders of the industry, but rather the smart, dedicated young men and women who for the last decade have been entering university nuclear engineering programs in increasing numbers across the United States and, I think, around the world. In my observation they are a serious, idealistic, and practical group. They see great engineering challenges in designing new nuclear power systems that are safe and economic. They see an opportunity to help ameliorate the grave threat of climate change. They know that nuclear energy is the only low-carbon energy source that is both inherently scalable and already capable of generating large amounts of electricity.

27. After Three Mile Island and Chernobyl, many of the brightest nuclear scientists and engineers left the field, and others chose not to enter it. This occurred partly because of the uncertain prospects for the nuclear power industry, but also because the industry itself became more cautious, inward-looking, and reluctant to change. For many promising young technological leaders, eager to make their mark in a dynamic environment, this was a signal that it was time to move on. The nuclear industry achieved a good deal over this period, especially regarding the management and organization of nuclear power plant operations. But technological innovation was slow and incremental. And with little new blood entering the field, the leadership of the industry grew older and more cautious.

28. That experience must not be repeated today. Now is the time to begin searching for new solutions to old problems, and to encourage new technological explorations whose outcomes cannot be anticipated today.

29. The need for the intellectual vitality, flexibility, and creativity of new generations of nuclear scientists and engineers has never been greater. And so we must confront the question: Will the effect of Fukushima be to starve the field of these new leaders, or will it attract them? In the end this may be one of the most consequential legacies of the Japanese nuclear crisis. And unlike the earthquake that triggered it, this is an outcome that can to some extent be determined by wise actions.

30. Educators can play a useful role in this process, and I would like to end by briefly mentioning some of the actions we are taking in the MIT Nuclear Science and Engineering Department along these lines.

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31. First, on the crucial question of nuclear governance in the emerging nuclear energy nations, we are launching a short course at MIT, in partnership with the Institute for Nuclear Power Operations, that is designed to meet the needs of the leaders of these new programs – leaders of nuclear operator organizations, regulatory leaders, government policy leaders, and even opinion leaders in these countries. We will draw on the best knowledge and instructors from around the world to explore, in an executive education environment, subjects that will be essential for the success of these leaders and their programs: How to ensure excellence in construction and operations; how to manage financial and technical risk; how to create strong, reliable regulatory institutions; how to address the proliferation concerns of the international community; how to communicate effectively with the public on complex issues such as reactor safety and waste management; how to strike a balance between technological innovation and technology standardization. The success of nuclear leaders in the 'new' nuclear countries in dealing with these questions will be important to their own societies, to neighboring societies, and to the international community as a whole.

32. Our new course will build on the successful experience we have had over the last 20 years with a similar course directed at the leaders of the U.S. nuclear utility industry, again in partnership with INPO. In that case, too, we focus on what is special about the management of nuclear technology, and what is needed to make a success of nuclear energy programs. More than a third of current U.S. nuclear CEOs are graduates of this domestic course. We will begin offering the international course next year.

33. Second, over the past year my MIT colleagues and I have been thinking hard about how best to prepare our own undergraduate and graduate students for the technical leadership roles that many of them will play in the nuclear energy field over the coming decades. And I want briefly to highlight one of the principles that has emerged from this process. It is the principle that our students, if they are to be successful engineering practitioners and leaders, must be equally at home in the worlds of science, of systems, and

of society. And so we will work to ensure that every student in Nuclear Science and Engineering is introduced, first, to the scientific fundamentals of our field; second, to the engineering methods – experimental, theoretical, and computational – for integrating these scientific fundamentals and specialized components into workable nuclear power plant and nuclear fuel cycle systems (as well as other kinds of nuclear systems); and third, to insights and tools for understanding how the nuclear systems we work on interact with society – including the economic, social, ecological, political, and international aspects. In short, we are developing and implementing a more integrated view of a world-class education in nuclear science and engineering, with a simultaneous focus on Science, Systems, and Society.

34. And the third and final point I want to make is more along the lines of proposal or a challenge than a description of what we are already doing at MIT. I have already commented on the need for new, higher standards for nuclear governance. As well as on the need for nuclear innovation. (And of course the two are closely related; certain kinds of nuclear innovation will reduce the burdens of nuclear governance and the demands placed on nuclear institutions – for example, modular methods of reactor construction; reactor designs featuring a philosophy of walkaway safety; perhaps also nuclear waste recycling and transmutation.)

35. Nuclear innovators will explore these and other possibilities. And in the end, competition in the marketplace will sort out the best approaches from the rest. But innovation moves gradually in the nuclear field. And there is often a long lead-time between the decisions of innovators about what to pursue and the outcome of those decisions in the competitive marketplace.

36. There is a worldwide interest in seeing that innovators move in good directions. Therefore, I believe that it is important to convene an international forum on nuclear innovation – or perhaps several parallel forums -- focusing on what would be desirable, what might be acceptable, and what could be achievable regarding standards of performance for future generations of nuclear power technology. What standards of performance should our industry seek to achieve by, say, mid-century?

37. In the wake of Fukushima, higher safety standards will clearly be

important. As I have mentioned, 'walkaway' safety may become an important design goal for future nuclear power reactors. But this concept obviously needs further development. Such standards should also address future requirements for operational performance, plant design, manufacturing, and construction methods, the storage and disposal of nuclear waste, and the security of nuclear materials at every point in the nuclear fuel cycle.

38. The answers to these questions should not be dictated by regulatory authorities. What is needed is a more open-ended process, with broad participation, and with some independence from particular points of view – whether of governments or of particular industry suppliers.

39. This is similar to the way standard-setting processes work in other sectors. It might also be thought of as a successor to the Generation IV Forum, with the appropriate lessons drawn from that experience of course. And, consistent with the emergence of multiple centers of excellence in nuclear energy technology around the world, this new process of standard-setting for nuclear innovation might take place in parallel in multiple locations.

40. I hope that this summit or a future summit might focus on the important question of how such a process might be organized. At MIT we stand ready to support a new, international, standards-driven phase of nuclear innovation and development to the best of our ability.

Thank you for the privilege of allowing me to speak to you on these important subjects.