Responding to Fukushima-Daiichi

Michael Weber
Deputy Executive Director for Operations
U.S. Nuclear Regulatory Commission

Institute for Nuclear Materials Management
U.S. Nuclear Infrastructure Council Meeting
Washington, DC
January 31, 2012

Good afternoon. It is a pleasure to participate in this meeting on the important topic of spent or used fuel management. I would like to thank the organizers of the meeting, including Jeffery England and David Blee for the opportunity for NRC to participate. I'd also like to thank you, the audience, for participating this afternoon. The events that precede this meeting have been momentous, including the nuclear emergency at Fukushima-Daiichi last spring and the release of the final report and recommendations by the Blue Ribbon Commission on America's Nuclear Future at the end of last week. The emergency at Fukushima-Daiichi occurred during the deliberations of the Blue Ribbon Commission and commanded a significant amount of attention by the Commissions, both the Blue Ribbon Commission and the Nuclear Regulatory Commission. The emergency at Fukushima-Daiichi also heightened the awareness and interest of the public about nuclear safety, both for the nuclear power plants and for the spent fuel that they produce. Indeed, during the emergency, there was a considerable amount of concern about the safety of the spent fuel at Fukushima-Daiichi and the potential consequences of a large release from one or more spent fuel pools. Spent fuel in the dry casks at the site weathered well the earthquake, tsunami, and nuclear emergency, but we experienced several anxious days until the operators and the Japanese authorities confirmed that the spent fuel in the pools was safe.

Consequently, in my presentation this afternoon, I will summarize the Nuclear Regulatory Commission's response to the emergency at Fukushima-Daiichi. I'll place special emphasis on what are we doing based on the lessons we have learned, as well as on the safety and security of spent fuel, which is the overriding theme of this meeting. At the outset, I would like to express my sympathies to Japan for the tragic loss of life and devastation caused by the earthquake and tsunami that preceded the nuclear emergency and my respect and appreciation to all who responded to this tragedy and ensured the safety of the nuclear power plants and spent nuclear fuel. Plant conditions continue to stabilize and the reactors and spent fuel pools no longer pose an immediate threat. The response in Japan has progressed with continued stabilization and control of the plants, cleanup of contamination, and the long process of assessing the damage, decommissioning, and waste management.

The nuclear emergency at Fukushima-Daiichi began with the earthquake and tsunami on March 11, 2011. NRC promptly responded and that response continues to this day. Once we concluded that U.S. citizens were safe and while conditions at the site were stabilizing, the Commission promptly directed the NRC staff on March 23rd to convene a task force and conduct a methodical and systematic review and recommend whether NRC should make near-term improvements to our regulatory system. The Near-Term Task Force was comprised of several of the agency's most experienced and expert staff. They concluded their review and released a report with recommendations on July 12, 2011.

Based on the Commission's initial review of the report, the staff recommended how to proceed with the Task Force's recommendations, taking safety, priorities, and resources into account in early September and October. The NRC divided the recommendations and actions into 3 tiers, with Tier 1 being the highest priority and most pressing. The Commission approved proceeding without delay with the highest priority recommendations in October after some consultation with external stakeholders. In December, after additional consultation, the Commission approved proceeding with the next highest priority recommendations. At about the same time, the Japanese authorities announced that cold shutdown of Fukushima-Daiichi units 1, 2, and 3 had been achieved. Today, we are actively working within the NRC and with external stakeholders in preparation for issuing orders to require specific enhancements and requests for information.

Of greatest significance is the Task Force's conclusion with respect to current safety of nuclear power plants in the United States. The task force concluded that a similar sequence of events is unlikely to occur in the U.S. and that existing mitigation measures could reduce both the likelihood of core damage and radiological release. On this basis, the Task Force concluded that there is no imminent risk from continued operation of nuclear power plants in the United States and from continued licensing, both existing and new nuclear power plants. Notwithstanding these conclusions and in light of the expectation that over 100 reactors will continue to operate for decades to come, the Task Force concluded that enhancements to safety <u>are</u> warranted. This conclusion has been embraced by the NRC staff and the Commission, and fuels our focused and dedicated efforts today to achieve the enhancements as quickly and effectively as practicable.

So what are these enhancements? The first three enhancements that we are pursuing aggressively are re-evaluating external hazards, including seismic and flooding hazards, performing walkdowns of the nuclear power plants to ensure the effectiveness of design and mitigating measures, and modifying our existing requirements to enhance the ability of the plants to mitigate a prolonged Station Blackout event, where sites lose offsite and onsite AC power sources. We expanded the first enhancement beyond what was recommended by the Near-Term Task Force at the direction of Congress in the Fiscal Year 2012 appropriations law.

The next three Tier 1 enhancements are requiring licensees to provide mitigating strategies for beyond design basis events, such as the large earthquake and tsunami that occurred at Fukushima-Daiichi, provide reliable hardened vents in Boiling Water Reactors with Mark I and II containments in case containment venting is required during a severe accident, and provide spent fuel pool instrumentation with reliable indications of the level of water in the pool and other conditions. You may recall that there was considerable uncertainty during the emergency at Fukushima about water levels in the spent fuel pools. More on that later.

The last two Tier 1 enhancements are to strengthen and integrate onsite emergency response capabilities and to require site staffing for emergency responses involving multi-unit events and prolonged Station Blackout events.

In addition to the Tier 1 recommendations, the NRC staff also identified a number of Tier 2 and 3 recommendations. Tier 2 recommendations are those high priority actions that cannot be initiated in the near term due to resource and skill set limitations on the NRC staff. This includes actions that need further technical refinement and alignment or are dependent upon the Tier 1 actions. These actions do not require long-term study and will be initiated when sufficient technical information and resources become available.

Tier 3 recommendations require further staff assessment to support a regulatory action, have an associated shorter-term action that first needs to be completed, are dependent on critical skill sets, or are dependent on resolution of Near-Term Task Force Recommendation 1. Recommendation 1, you may recall, was that the Commission should establish a logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense in depth and risk considerations. The Commission placed a higher priority on the shorter-term, important to safety enhancements. Once the staff has completed its evaluation of the impacts of Tier 1 and 2 recommendations, the staff will more accurately assess the Tier 3 recommendations.

The staff also identified additional issues beyond those listed in the Task Force report, which the staff believes should be considered as part of the longer-term review. Issues are identified, assessed, and screened for safety significance by the NRC staff and then considered by a committee of senior NRC managers. What are these issues? Filtration of containment vents, enhanced seismic monitoring instruments, reconsideration of the adequacy of the existing sizes of Emergency Planning Zones, potassium iodide (KI) should be pre-staged beyond current planning zones. The emergency also raised questions about the potential benefit of offloading spent fuel from the pools into dry casks sooner to reduce risks. We are also planning to examine the risk significance of the loss of an ultimate heat sink at U.S. plants. Interruption of access to the ultimate heat sink is being considered as a Tier 1 issue. Losing the water source that is the ultimate heat sink is being considered as a Tier 2 issue.

The NRC is not alone in our quest to understand what happened at Fukushima-Daiichi and to make enhancements to nuclear safety based on these lessons learned. The Japanese, other nations, multilateral organizations, other agencies, the Institute for Nuclear Power Operations, Nuclear Energy Institute, licensees, American Nuclear Society, and standards organizations are working together to pursue this quest. We are participating with the IAEA, OECD's Nuclear Energy Agency, G8 and G20 groups of nations, ICRP, National Academy of Sciences, and other organizations at the multinational level and national level to discuss the lessons learned and work together toward making them lessons implemented.

The staff is currently pursuing the near term enhancements, Tier 1 actions, through orders, requests for information, and rulemakings. We're also seeking additional input from stakeholders. We expect these interactions will help identify what needs to be done to implement the recommendations, how they should be implemented, and how the NRC should assess the implementation. The Commission will review and approve any orders and regulations that are issued to impose new requirements. The 50.54(f) letters request licensees to provide information on the adequacy of the design basis, whether the plant configuration is in compliance with the design basis, and other matters. The staff is also planning to issue an Advanced Notice of Proposed Rulemaking on the Station Blackout rule changes.

As compressed as we thought our schedule was, Congress directed that we accelerate the schedule. NRC's current plan is to issue the Tier 1 orders and information requests by the March 11 anniversary date of the earthquake and tsunami. We are planning to provide drafts of the orders and letters to the Commission no later than mid-February, and then the Commission will direct the staff on how to proceed. Our overall goal is to complete the enhancements within 5 years. We recognize that this is an ambitious schedule. As we proceed, we will be particularly focused on enhancing safety and in avoiding unintended consequences that could be detrimental to safety and security.

Licensees would be required to provide responses to orders and the requests for information. NRC will review the responses and establish the necessary framework for regulatory oversight, including using the Reactor Oversight Process for inspections and codifying the orders through rulemaking. The information obtained in response to the requests will be used for determining appropriate actions, such as ordering additional enhancements or modifying the regulations.

Given the focus of this meeting, as I pointed out in the beginning of my presentation, it is important to dwell a bit on the safety of spent fuel. In the U.S. and abroad, a large inventory of spent fuel is stored in spent fuel pools at nuclear power plants and other installations. Typically a quarter to a third of the nuclear fuel in the core is replaced with fresh fuel every 18 to 24 months, and the highly radioactive and thermally hot spent fuel is removed to the spent fuel pools. In the U.S., spent fuel is stored in the pools for a minimum of 5 years after offloading from the reactor. During this storage period, thermal and radiation levels decline significantly.

Spent fuel pools were originally designed for limited storage of spent fuel until it was removed off site, nominally in the 3 to 5 year range. During this storage, safety is achieved primarily by maintaining the fuel in a large pool of water for cooling and radiation shielding, as well as through maintaining the geometry of the fuel and use of soluble and fixed boron for criticality control. Re-racking of the fuel in the 80s and 90s allowed for denser packing and higher inventories in the existing pools. The pools are robust structures built to withstand a variety of design basis insults, such as earthquakes, floods, and weather-related missiles. If the concrete and steel pool crack and cause a large drain down of the water in the pool, the fuel can be uncovered, heat up, and ultimately cause the large release of radionuclides.

The risk of this occurring is quite low due to a variety of factors, including the very low likelihood of damage to the thick reinforced pool walls and floors. The NRC has estimated the likelihood of a fuel uncovery accident is on the order of one in a million per year. If it does occur, however, the potential consequences of such an event could be large resulting from the heatup of the pool ultimately leading to a zirconium fire and large release of the inventory of radionuclides in the spent fuel, including Cesium-137 and other radionuclides. The spent fuel pools are generally located outside of primary containment. Although secondary containment provides some confinement in the event of a release, it is not nearly as robust as primary containment as we saw at the Fukushima-Daiichi plants. Consequently, if there was a large release from the pool, the release can reach the environment much easier than from the reactor core.

The NRC evaluates the safety of spent fuel rigorously in licensing and overseeing the operation of the nuclear power plants. After the terrorist attacks of 9-11, the NRC and other organizations, such as the National Academy of Sciences, extensively re-examined the safety and security of spent fuel storage. These re-evaluations confirmed the low vulnerability of the spent fuel to attack and also identified active and passive measures that could be taken to further reduce risk. Licensees improved the configuration of the spent fuel in the pools to substantially improve the passive cooling through natural convection.

NRC also required licensees to install a spray capability to improve active cooling should it be necessary in a pool uncovery event. In addition, licensees conducted site-specific evaluations, installed additional measures, and were inspected by the NRC to confirm the adequacy of these measures. As a result, the coolability of fuel within the pools has been enhanced and the risk reduced. The NRC is conducting additional research to confirm our understanding and validate our risk and consequence assessments.

For example, over the years there has been considerable debate about whether zirconium fires in a spent fuel pool were possible. NRC worked with Sandia National Laboratory and other organizations to assess the likelihood of such a fire, especially the conditions in the pool that would affect the initiation and propagation of a fire. Here you see the experimental configuration of a prototypic simulated full length 9x9 BWR fuel assembly. We conducted similar experiments with simulated PWR assemblies.

And here are the results. As you can see, under representative conditions that could occur in the spent fuel pools in the event of pool drain down, the zirconium cladding in the simulated fuel assembly caught fire, burned energetically, and formed very weak zirconium oxide residue. These experiments confirmed that zirconium fires can occur under the right conditions.

In response to experiments like these, risk and consequence assessments, and the nuclear emergency at Fukushima-Daiichi, we have been considering whether there are potential benefits of removing spent fuel from pools earlier than planned and achieving lower density storage in the spent fuel pools. It is important to point out that there are several competing factors that need to be considered. Although removal of the spent fuel would decrease the inventory of radionuclides in the pools, it also raises risks of cask drops and increases worker doses. Consequently, we are currently conducting a Spent Fuel Pool Scoping Study for an initial quantitative assessment of the impacts on risk associated with offloading the fuel.

This graph depicts the potential reduction in thermal loading of a spent fuel pool by removing spent fuel older than 3 years and 5 years. For a large spent fuel pool with many assemblies (2500 or so), removing the spent fuel older than 3 years achieves as much as a 25% reduction in thermal load. The reduction of radionuclide inventory would be significantly greater, and may be a significant contributor to reducing potential land contamination, but may not have a significant impact on any prompt fatalities from an unmitigated spent fuel pool release.

To better assess the potential benefits of removing older fuel from the spent fuel pools, the Spent Fuel Pool Scoping Study will estimate the change in accident consequences associated with removing the fuel and placing it in dry storage. As a scoping study, we have limited the scope to a single representative spent fuel pool and operating cycle for low and high density racking. At this stage, we are not planning to consider the tradeoffs associated with impacts of moving fuel, but this kind of analysis would be needed to support a broader determination.

The scoping study is using realistic, expedient, and technically defensible deterministic methods and assumptions, including seismic and structural assessment, accident progression, emergency planning assessment, and offsite consequence analysis. Our current schedule includes publishing a draft of the analysis this summer for public review and comment. We are also continuing with our assessment of integrated spent fuel management, including extended storage and transportation, reprocessing, and ultimate disposal. With the delay in the availability of a geologic repository, the Commission's updated waste confidence decision in late 2010 signaled the expectation that spent fuel may need to be stored safely and securely for a longer period than previously estimated. NRC's objective remains to ensure that such extended storage and associated spent fuel management alternatives remain safe and secure. Our other objective is to conduct our regulatory oversight of spent fuel management most effectively and efficiently. You will hear more about these topics from NRC presenters later in the meeting.

As I hope my presentation has made clear, the NRC has already taken a number of actions to ensure nuclear safety, in light of the Fukushima nuclear emergency. Based on all that we have reviewed to date, we continue to have confidence in the safe operation of nuclear power plants, including spent fuel pools and dry storage facilities, and other nuclear facilities in the United States. Consequently, we are continuing with license renewal and new reactor licensing, as well as licensing of other new nuclear fuel cycle facilities. We recognize, however, that our work is far from done. We will continue to move forward with the post-Fukushima enhancements on an aggressive schedule. As we receive more information about the causes and consequences of the Fukushima-Daiichi emergency, we will evaluate that information and take the appropriate actions working in the open and engaging a full array of stakeholders. One thing will not change – spent fuel must be managed safely and securely. We must remain focused on ensuring the safety and security of existing inventories of spent fuel.

On behalf of the NRC, thank you for your attention and best wishes for a successful meeting. I would be pleased to respond to any questions or to listen to your comments.