The Way Forward
U.S. Industry Leadership in Response to Events at the Fukushima Daiichi Nuclear Power Plant
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Executive Summary

In March 2011, an earthquake and tsunami devastated northeast Japan and led to an accident at Tokyo Electric Power's Fukushima Daiichi nuclear energy facility. The U.S. electric industry conducted rigorous reviews at the Japanese facility and compiled lessons learned from that event. In the past five years, companies that operate U.S. reactors have taken wide-ranging actions to further enhance the safety of American reactors. The industry has invested billions of dollars to verify that these reactors can withstand natural events even more severe than those assumed in their original design, to upgrade safety equipment, and to train plant workers on new equipment and procedures. That process continues today.

In the months following the accident, the Electric Power Research Institute (EPRI), the Institute of Nuclear Power Operations (INPO) and the Nuclear Energy Institute (NEI), in conjunction with senior utility executives, created a joint leadership model to integrate and coordinate the U.S. nuclear industry's response to events at Fukushima Daiichi. The Fukushima Response Steering Committee comprises leadership, operational experience and industry expertise across many facets of nuclear plant operations.

Infused with a commitment of collaboration and continuous improvement and a bias for action, the committee ensured that lessons learned were identified and well understood, and that response actions were effectively coordinated and implemented at all U.S. reactors. This was accomplished while these companies continued to ensure the safe and reliable operation of commercial reactors that produce nearly 20 percent of America's electricity.

Separately, the U.S. Nuclear Regulatory Commission conducted an independent assessment and ensured agency regulations reflect lessons learned from the Fukushima events. The industry and public stakeholders have met regularly with the agency since 2011 to ensure that industry actions and new regulatory requirements produce the greatest safety benefit and are implemented in the most efficient and effective manner.

Existing safety measures were verified in the days and weeks after the Japan events and safety enhancements continue to be implemented at nuclear power plants. Based on lessons learned from Fukushima Daiichi, the industry has already completed, or will soon complete, the following:

- Verified seismic and flooding protection at nuclear power plant sites with detailed inspections by the industry and independent NRC inspectors.
- Created and implemented additional layers of backup safety and response capability at each American reactor. This tailored and comprehensive solution—the FLEX strategy—is the foundation of the U.S. industry’s commitment to implement lessons learned from the Fukushima accident.
- Created and fully stocked two national Strategic Alliance for Event Response (SAFER) response centers, along with a transportation protocol that will deliver emergency backup equipment to any U.S. nuclear power plant within 24 hours.
- Updated and improved the integration of existing emergency operating procedures to enhance emergency response capabilities.

National response centers store 5 sets of safety equipment for deployment to any U.S. reactor within 24 hours.
• Updated a multi-organizational response framework, including EPRI, INPO and NEI, to coordinate industry support during any significant event.

• Performed a reevaluation of applicable seismic and flooding events and assessed their impact on safety at nuclear energy facilities.

• Installed new instrumentation in used nuclear fuel storage pools to improve reactor operators’ ability to monitor fuel pool conditions.

• Reinforced containment venting designs in some reactor designs and enhanced accident mitigation procedures to reduce the risk of radiation release in the event of a severe accident.

• Enhanced emergency response capabilities, including staffing and communications equipment, during extreme events.

The industry will implement almost all of the highest priority enhancements by the end of 2016. Additional safety enhancements (including containment venting enhancements and some detailed seismic and flooding analyses) will be completed after this date.

These safety enhancements have not been arbitrary; rather they are based on well-defined lessons learned from Fukushima. They have been coordinated by chief nuclear officers and technical advisors from throughout the industry and are being implemented at all U.S. nuclear power plants.

The industry’s post-Fukushima commitment represents an investment in resources, cutting-edge science and technological advancements. In total, the industry has invested billions of dollars in post-Fukushima safety enhancements. It has required thousands of workhours by plant personnel as they conduct inspections, upgrade or stage new equipment and train on new emergency procedures.

An integral aspect of the industry’s response has been the awareness and involvement of the industry’s stakeholders, including industry vendors, architect-engineering companies, industry owners’ groups and nuclear standards organizations. This ensured that broad industry expertise was incorporated into each step. In addition, there has been significant public input into this process through regular public forums hosted by industry and the NRC.

This overview seeks to answer the question: How has safety been enhanced at U.S. nuclear power plants since the Fukushima accident? It describes how the industry approached this challenge and how America’s nuclear power plants—already operating safely by any measure—have become even safer based on the industry’s commitment to implement lessons learned from the accident. It also summarizes the strategic goals and key stakeholders involved in the industry’s integrated response.
Meeting the Industry’s Strategic Goals

The objective of the Fukushima Response Steering Committee has been to improve nuclear safety by applying lessons learned from the Fukushima Daiichi nuclear accident.

The committee was formed within weeks of the events in Japan to develop the strategic response at American nuclear power plant sites. In 2012, the U.S. nuclear energy industry established strategic goals to maintain, and where necessary, provide added defense in depth for critical safety functions, such as reactor cooling, spent fuel pool cooling and reactor containment integrity.

As the U.S. response to Fukushima matured, the industry’s strategic goals were aligned with NRC initiatives and regulatory requirements. The industry’s original strategic goals listed below are matched to parallel NRC activities.

Most of these strategic goals are being met as implementation progresses at nuclear plants in 30 states.

The nuclear workforce remains focused on safety and operational excellence at all plants, particularly in light of the increased work that the response to the Fukushima event will represent.

Continued reactor operator focus on safe operations
Actions were taken at each company that operates nuclear energy facilities to manage the impact of additional work associated with the Fukushima response. In most cases, a dedicated team was assigned responsibility for conducting inspections, making modifications to plant equipment and introducing new or revised procedures.

To facilitate this operational focus, the industry continued an on-going initiative to increase the engagement of workers at all levels and to expand their understanding of operational risk and the use of operating experience. This initiative was further expanded to include a focus on reactor operating fundamentals, particularly by the control room crews when responding to complex transient scenarios. Improvements in control room crew teamwork, training, and the timely resolution of equipment issues have contributed to a steady reduction in the number and severity of operational disruptions.

Several new initiatives were undertaken to continuously improve industry performance. Most important was an effort to enhance station and corporate leadership and teamwork through the application of proven leadership and team attributes. Additionally, based on operating experience, the industry began to apply an expanded understanding of integrated risk, including the consideration and interactions between operational, project and enterprise risk. These actions have increased industry self-awareness, as well as the capacity for continuous improvement and organizational learning.

America’s nuclear energy industry has applied the attention and required resources to deeply learn from the accident at Fukushima. Concurrently, industry leaders increased their attention to the operation of the nuclear stations with a resultant steady improvement in plant safety and reliability.
Other personnel and groups remained focused on safe operation of nuclear energy facilities and were not impacted except when needed to provide specific input or reviews.

**Post-Fukushima safety inspections**

Shortly after the accident at Fukushima, the NRC required that the industry perform detailed inspections of seismic and flooding protection strategies at U.S. reactors.

The NRC also conducted independent follow-up inspections in these areas. Companies ensured the features met applicable requirements as well as identifying, correcting and reporting any degraded equipment. The industry completed detailed inspections by November 2012, and the NRC issued plant-specific assessments of the companies’ inspection reports. A limited number of non-compliance conditions were noted both by the industry and NRC reviews and corrected.

**Post-Fukushima Safety Enhancements at U.S. Reactors**
Institute of Nuclear Power Operations
During this process, INPO site inspections indicated continued excellence in performance and focus on safety. All of the fundamental industry performance metrics for safety and reliability remain at historically high levels. For example, the number of unintended reactor shutdowns in 2014 was at an all-time low, nuclear plant reliability remained above 90 percent and safety systems availability and reliability remained high.

Timelines for emergency response capability to ensure continued reactor fuel cooling, containment integrity and spent fuel storage pool cooling are synchronized to maintain fuel integrity following station blackout or challenges to the ultimate heat sink.\(^1\)

FLEX strategy implementation
The FLEX strategy is the foundation of the U.S. industry Fukushima response. It addresses the major problems encountered in Japan—the loss of power to maintain effective cooling—by stationing additional layers of backup equipment at each nuclear power plant and at the SAFER Response Centers. It is called FLEX because much of the additional backup safety equipment is flexible for multiple uses, while other equipment is tailored to specific safety applications. This flexible approach builds on existing, multi-layered safety systems to protect against unforeseen events and is being replicated by the industry in other nations. The equipment ranges from diesel-driven pumps and electric generators to ventilation fans, hoses, fittings, cables and satellite communications gear.

The new equipment is stored in protected locations at each site to ensure that it can be used if other systems that comprise a facility’s multi-layered safety strategy are compromised.

All U.S. nuclear power plants are scheduled to have FLEX implemented by the end of 2016, including installing on-site equipment and conducting training in the use and integration of that equipment into emergency response protocols. The industry plans to revise FLEX guidance as needed to guide the evaluation of emerging information on severe flooding and seismic hazards.

Two SAFER Response Centers – backups to the backups
The NRC has validated that the industry’s national SAFER Response Centers—which store multiple redundant sets of equipment off site as part of the FLEX strategy—are fully operational. Centers in Phoenix and Memphis can begin delivering—within 24 hours of notification of an event—additional complete sets of emergency equipment to a staging area near any U.S. nuclear power plant.

Equipment stored at the centers includes portable backup generators, pumps, standardized couplings and hoses. Each center houses five full sets of safety equipment, with four sets ready to be shipped to support U.S. nuclear power plants at all times. The equipment undergoes regular testing to assure its functionality. The industry has invested $87 million in the response centers and will spend $400 million over a 40-year period to maintain the centers.

\(^1\) The ultimate heat sink is the water source to which heat is transferred so that a nuclear power plant can safely shut down.
Utility agreements on sharing FLEX equipment

To augment existing industry protocols to share equipment and the SAFER response centers, nuclear plant operators have established protocols to allow sharing of FLEX equipment with other sites in the event of an emergency. The U.S. nuclear industry has common connections for the electrical and pumping equipment, which makes all of the equipment interchangeable.

The nuclear industry is capable of responding effectively to any significant event in the United States, with the response being scalable to support an international event, as appropriate.

Industry implements scalable response framework

Executives from INPO, NEI and EPRI in 2012 approved a new industry response framework, defining the roles and overall approaches to provide coordinated industry support during a nuclear industry event anywhere in the world. The approaches outlined by the framework will be aligned with the international response strategy being established by the World Association of Nuclear Operators (WANO).

Based on lessons learned during the response to the Fukushima accident and recent emergency response exercises, INPO, EPRI and NEI updated and refined their emergency response capabilities to facilitate monitoring of significant events and provide support as necessary. New industry response centers, the NRC’s Emergency Response Data System and WANO’s international monitoring capabilities are designed to work together to inform a coordinated response in the event of a significant nuclear accident anywhere in the world. INPO’s response center at INPO headquarters in Atlanta includes audio, visual and data communications capability and software applications to enable INPO to gain situational awareness during an event.

Comprehensive drills involving the three industry support organizations are conducted regularly to practice response to various types of event scenarios and test the preparedness of the industry response capability. These drills often involve staff from all three organizations responding in real time to a simulated event at a U.S. nuclear facility. The response is later assessed for lessons learned and ways to improve industry’s coordinated emergency response. The “Southern Exposure 2015” exercise (see “Major federal, state and local emergency response exercise on page 13”) validated these industry protocols and response capabilities.

Emergency Response Data System available to industry

During an event, the NRC has agreed to make the Emergency Response Data System available to INPO’s industry response center, which can provide important nuclear plant data as an event unfolds.
Procedures were developed to allow the exchange of information during an event through common emergency response management software used by sites and industry support organizations.

**WANO improves international monitoring and communications**

After the accident at Fukushima, WANO completed a detailed assessment of its operations and made the improvement of its support and communications to its members during a serious accident a top priority. In response, each WANO region created an emergency response center and is in the process of establishing protocols for notifications and support for an affected station. According to these protocols, WANO headquarters in London provides status information and any assistance requests to engage the broader nuclear community in responding to an event.

Work is underway to establish implementing procedures, with full implementation expected during 2016.

**Severe accident management guidelines, security response strategies, and external event response plans are effectively integrated to ensure nuclear energy facilities are capable of a symptom-based response to events that could impact multiple reactors at a single site.**

**Accident management guidelines and emergency operating procedures updated**

Emergency operating procedures are used in the initial stages of an accident. If an accident progresses in severity, operators are trained to transition to severe accident management guidelines that provide direction to operators and staff in the event of a severe accident.

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**The FLEX Strategy**

*By David Heacock, President and Chief Nuclear Officer, Dominion Nuclear*

The U.S. nuclear industry is well on its way toward implementing a flexible mitigation approach for responding to any event that may exceed the robust design of the nation’s nuclear power plants. This FLEX strategy, the outcome of the U.S. industry’s response to the 2011 Fukushima Daiichi accident in Japan, provides yet another layer of safety. This is in addition to the multiple back-up safety systems already available to protect the public and environment.

In effect, this strategy was demonstrated to successfully prevent damage to the reactor core at the Fukushima Daiichi nuclear power plant, only a short distance from its sister plant, Daiichi.

FLEX strategies provide the greatest safety benefit of all the options that could be implemented in a short period of time to further ensure public safety from extreme natural events.

Each site is equipped with portable equipment capable of providing electricity and pumping water to keep the nuclear core cool and stable. This equipment can be moved easily from protective storage buildings on the site to key locations in the plant to maintain reactor cooling until a longer-term solution is put in place. Two national response centers—in Memphis, Tenn., and Phoenix, Ariz.—provide additional FLEX equipment and resources that can be dispatched to any U.S. nuclear station within 24 hours.

More than half of the nation’s nuclear operators have implemented the FLEX strategy and the rest are making progress towards complying with this requirement in a timely manner.
The industry has had severe accident management guidelines in place since the late 1990s. These guidelines are being updated to capture lessons learned from the Fukushima accident and to better integrate them with emergency operating procedures and the FLEX strategy.

Maintaining severe accident management guidelines is an industry safety initiative at all U.S. nuclear plants and industry has committed to the NRC to make timely updates of these site-specific guidelines based on technical guides developed by the reactor owners’ groups. The guidelines also will reflect changes to each facility over time. The industry anticipates these fully updated guidelines—integrated with emergency operating procedures and the FLEX strategy—to be implemented at all nuclear plant sites within the next few years. As part of this effort, the industry is providing training on the updated guidelines to reactor operators and plant emergency response personnel.

**Enhanced emergency response capabilities for extreme events**

The Fukushima accident highlighted the need to have staff available to fill all necessary positions when responding to an extreme event. Additionally, it is important that communication equipment relied upon to coordinate the event response be powered and maintained. Each site has assessed these needs and is making adjustments where needed. The NRC’s proposed rulemaking on mitigating strategies includes new requirements to maintain staffing and communications equipment necessary to successfully respond to an extreme event.

The proposed rule will require companies to conduct periodic drills—in addition to those regularly carried out at plant sites—to demonstrate the capability to implement a variety of enhanced emergency response strategies, including the FLEX strategy.

**Safety margins for protection from external events are sufficient based on the latest analyses and historical data.**

**Seismic protection verified**

In addition to seismic inspections completed soon after the Fukushima accident, the NRC has asked for detailed analysis of seismic safety at each nuclear plant site. The first phase of NRC’s required earthquake safety analysis—revised earthquake hazard estimates—have been submitted by the industry for all nuclear power plant sites. These analyses estimate ground motion that sites could experience, but they do not predict how the plant might be affected by the earthquakes. At some plants, that will require a deeper examination of the plant’s seismic design and construction. These evaluations are underway.

Based on the results of these ground motion hazard estimates, 20 nuclear energy facilities must complete more detailed seismic probabilistic risk assessments. These assessments use the latest seismic models and computer analysis to determine how plant safety systems would respond in the event of a severe earthquake. They also will demonstrate levels of safety at these facilities beyond that needed to protect against strong earthquakes or identify potential plant design changes to enhance safety. These assessments will be complete by December 2019.

In the interim, expedited seismic evaluations have been conducted to verify that key safety functions would be maintained even in the event of an earthquake up to twice as severe as that which the plants were designed to withstand.

Licensees also will conduct assessments in 2016 to evaluate the effect of the reevaluated earthquake hazard on each plant’s FLEX strategy. These assessments will confirm that the FLEX strategy will allow the plant to withstand a severe earthquake or show that the plant must modify its FLEX strategy to maintain safety.

**Flooding protection verified**

The NRC has requested a detailed analysis of flood safety at nuclear plant sites, in addition to flooding inspections completed by the end of 2012 (see “Post-Fukushima safety inspections on page 6.”)

The NRC also asked for new flooding analyses as part of the industry’s response to the Fukushima accident. These analyses include revised flooding hazard estimates for each reactor.
SAFER Response Within 24 Hours to Any U.S. Reactor

By Michael Pacilio, Executive Vice President and Chief Operating Officer, Exelon Generation

After the U.S. Nuclear Regulatory Commission's acceptance of the industry's FLEX strategy, the industry immediately began development of a three-phased approach to mitigating beyond-design-basis events. In phase one, companies would use permanently installed equipment as an initial means of responding to a serious event. The phase two concept drove the acquisition and storage of portable equipment at each nuclear plant site to enhance the station's coping strategies. Finally, phase three drove the enhancement of existing inter-utility support agreements and the development of independent, national response centers that house portable safety equipment that can be delivered to any nuclear plant site in America within 24 hours.

The nuclear industry jointly established an implementation plan for phase three. Led by the Institute for Nuclear Power Operations, inter-utility memorandums of understanding were updated to reflect the need to maintain an inventory of on-site, portable equipment that could be moved from site to site as required. The memorandums also reinforced personnel support among utilities in need of specific expertise.

Through a proposal review and interview process, an industry team competitively selected an organization to procure, house and maintain additional portable safety equipment. The Strategic Alliance for FLEX Emergency Response (SAFER) team, comprised of the Pooled Equipment Inventory Co. and Areva Inc., was selected to manage the project. The industry determined bounding operational requirements for common equipment and industrywide standards were established for common pump connections and electrical cable connections.

Simultaneously, the SAFER organization developed strategies for storage, maintenance and movement of equipment to nuclear plants and created site-specific response playbooks to be used as a common reference for all parties involved in an event response. Ultimately, national SAFER response centers were established in Memphis, Tenn., and Phoenix, Ariz. The industry signed a contract with FedEx Custom Critical for the movement of equipment from either center to an affected site by road or air. Five complete sets of generic equipment—a robust mix of portable pumps, generators and supporting equipment—are maintained at each center. Additionally, equivalent sets of site-specific equipment were procured for each center.

Transportation of equipment from the centers to facilities in need have been assured by contracts with five commercial helicopter companies as well as utility-specific agreements with state Air National Guard units and an overarching letter of agreement established between the NRC and the Department of Defense for use of military helicopters. Any combination of these could be used to support local airlift of equipment if a site becomes isolated from roads during an event.
By the end of 2015, companies will have completed their reevaluation of site flooding hazards at 56 nuclear power plant sites; evaluations will be completed by May 2016 at the remaining sites.

The industry also will conduct assessments to evaluate the effect of flooding on each plant’s FLEX strategy. These assessments will have one of three outcomes:

- Confirm that FLEX strategy will allow the plant to withstand a severe flood.
- Show that the plant must modify the FLEX strategy so it can maintain safety.
- Show that the plant must adopt an alternative mitigating strategy to protect against severe flooding.

These assessments are scheduled to be completed by the end of 2016. In addition to the above two actions, some nuclear energy facilities, determined to be the most challenged by new flooding hazard revaluations, will complete integrated assessments of potential flooding effects on key plant components. These assessments should be completed by the end of 2018.

**Learning from new events to continue**

EPRI is leading an initiative to monitor information on credible external events. The project has begun and new information is being entered into plants’ formal corrective action programs and thoroughly reviewed to understand any potential nuclear and operational safety consequences. Interim actions will be taken to address these concerns, if appropriate, and relevant outcomes will be shared with other nuclear plant operators and industry organizations.

**Spent fuel pool cooling functions are fully protective during periods of high heat load in the spent fuel pool and during extended station blackout conditions.**

**Used fuel pool instrumentation installed**

Used fuel storage pools are robust concrete and steel structures that are designed to withstand extreme events such as earthquakes, floods, hurricanes and tornadoes.

All seven fuel pools at the Fukushima Daiichi power plant in Japan remained intact and the uranium fuel rods in the pools remained safely covered with cooling water.

In the early days of the Fukushima accident, there was speculation that used fuel storage pools at the site had been seriously damaged or that water, which cools the spent fuel and is a barrier against the release of radiation, had been lost from some of them. Later observations and data showed the speculation to be incorrect. The accident demonstrated the importance of being able to accurately monitor used fuel pool conditions.

The NRC is requiring new instruments to alert reactor operators of changes in the water level in used fuel storage pools, even under extreme conditions. Nuclear power plants are installing additional instrumentation in the storage pools to provide reactor operators with vital information about cooling water level and temperature. The remaining facilities will do so by the end of 2016.

**Primary containment protective strategies can effectively manage and mitigate post-accident conditions, including elevated pressure and hydrogen concentrations.**

**Containment venting strategies enhanced**

Industry and NRC research have shown that the best way to reduce the risk of radiation releases in the event of a severe accident is through active reactor fuel cooling and controlled venting from the containment building. Vents in some containment designs remove excess heat and pressure during an accident before potential damage to a reactor core and the plant’s containment structure occurs. Enhancing venting strategies for the primary containment of these designs is well underway in the U.S. nuclear industry and companies anticipate having these changes in place by 2019.

**External filters offer little safety benefit**

The NRC will not require the industry to install external containment vent filters for U.S. boiling water reactor designs. The agency said that safety enhancements already being taken by the nuclear energy industry effectively prevent containment failure in severe accidents.
This commission decision aligns with an NRC staff recommendation, based on extensive technical analyses by both the regulator and industry, which demonstrated that containment venting strategy enhancements make external filters unnecessary. Those venting strategies call for a combination of adding cooling water to cool uranium fuel and controlled containment venting. This approach sufficiently filters radiation inside the reactor containment building, removing the need for an external filtering system.

**Accident response procedures provide steps for controlling, monitoring and assessing potential radiation pathways during and following an accident, including timely communication of accurate information.**

**Major federal, state and local emergency response exercise completed**

The state of South Carolina, Duke Energy, the NRC and scores of other local, state and federal organizations last July conducted a fully integrated emergency response exercise involving a simulated event at the Robinson nuclear power plant near Hartsville, S.C.

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**U.S.-Japan Collaboration**

*By Jeff Archie, Senior Vice President and Chief Nuclear Officer, South Carolina Electric & Gas Co.*

Chief nuclear officers (CNO) representing U.S. energy companies have collaborated with their Japanese colleagues on leadership, safety and reactor operations during meetings in Japan and the United States and in personal interactions.

Since 2013, more than 30 U.S. CNOs visited the Fukushima Daiichi and Daini nuclear power plants in Japan to obtain a greater understanding of the events at each facility after the 2011 earthquake and tsunami. They met with Japanese CNOs to strengthen support and engagement between the two countries’ nuclear energy programs. In 2014, a second U.S.-Japanese meeting was held in Arizona. In addition to obtaining updates on safety enhancements in both countries, Japanese executives requested technical exchanges with U.S counterparts at the Sendai and Takahama nuclear facilities. These were conducted in November 2014.

A U.S.-Japanese CNO steering committee is organizing subcommittees on items of mutual interest identified during the Arizona meeting.

This steering committee initially met in 2014 by video conference and continues to meet quarterly to discuss industry issues. This collaboration also includes the pairing of Japanese and U.S. electric companies to establish interactions between those companies.

These exchanges in Japan have been beneficial in providing U.S. executives with a visual perspective of the accident’s impact, and access to key management insights, including those of the Fukushima Daini site vice president and Fukushima Daiichi shift supervisor during the 2011 events. Personal relationships built during visits to Japan and through the pairing relationships have resulted in a continuous exchange of information among representatives of the two nations.
“Southern Exposure 2015” was a full-participation nuclear power plant exercise coordinated at the federal level by the U.S. Department of Energy, the Federal Emergency Management Agency and the NRC. Portions of the exercise were graded by the NRC and FEMA. The exercise demonstrated the integration and response capabilities of industry organizations, including utilities, INPO, EPRI and NEI, along with federal, state and local governmental partners.

Assessing radiological releases from multiple sources
U.S. nuclear power plants have established the capability to perform offsite radiation dose assessments from all reactors located at a site. The capability to perform these assessments will help decision-makers determine appropriate measures for public protection in the event of an accident involving a significant radiological release.

EPRI gathered and evaluated Fukushima radiation data
In early 2011, data was collected within 30 kilometers of the Fukushima Daiichi Nuclear Power Plant. This data includes dose rate measurements, radionuclide measurements in soil, meteorological data and terrain data. EPRI has gathered, and evaluated the quality of the data collected to develop the Fukushima Radiological Assessment Tool to support research objectives. The data will also be used to review emergency response and computer-based radiation dose modeling codes used by U.S. nuclear power plants.

NEI collaborates on radiation protection best practices
NEI in 2014 hosted an international workshop on occupational radiation protection in severe accident management to identify best occupational radiation protection approaches. Detailed information was collected on radiation dose criteria used for emergency workers and responders, dose management criteria, protective equipment and recommended individual monitoring procedures.

Stakeholder Engagement by Industry
The industry’s strategic goals have been achieved due in part to proactive engagement among a variety of stakeholders.

General Public
The industry has ensured that the public is well-informed of its comprehensive response to the Fukushima accidents.

Special attention has been paid to engaging stakeholders (residents near nuclear power plants, elected officials and others) to share steps the industry is taking to enhance plant safety and its ability to protect public health and safety.

Public support for nuclear energy remains high across America. Sixty-four percent of those surveyed in a September 2015 public opinion poll said they favor the use of nuclear energy and 57 percent gave nuclear power plants a high safety rating. In a June 2015 survey of residents within 10 miles of U.S. reactors, 83 percent favor the use of nuclear energy. Ninety percent of nuclear plant neighbors are confident in the ability of the company to operate the plant safely and 82 percent are confident that the company has prepared the plant to withstand the most severe natural events in that area.

Industry employees
The industry has provided information and extensive training for its employees to help them understand the operating experience from Fukushima and to execute their jobs with excellence. This has included training for plant emergency response personnel, including reactor operators, on updated emergency procedures and the FLEX strategy.

Emergency response organizations
The industry has communicated and cooperated with federal, state and local emergency response organizations and government entities to ensure that emergency response plans reflect the lessons learned from Fukushima. This cooperation included the integrated industry and government emergency response exercise “Southern Exposure 2015.” Interactions have focused on increasing confidence in the industry’s and local government emergency preparedness programs.
NRC and industry leadership discussed measures being taken at nuclear energy facilities during frequent public meetings.

EPRI Software Helps Improve Accident Response Guidelines

By Neil Wilmshurst, Vice President of Nuclear, Electric Power Research Institute

Even as the events at Japan’s Fukushima Daiichi nuclear plant were unfolding, the U.S. industry began analyzing the situation and compiling data that would inform the industry’s lessons learned.

The Electric Power Research Institute’s Modular Accident Analysis Program (MAAP) software analyzes the progression of events during an accident. It captures many possible outcomes in a short timeframe. Unlike other codes, MAAP runs faster than accidents progress so it can actually guide emergency responders. Now in its fifth version, the tool has informed changes to industry guidelines that plant operators use to respond to accidents.

Because of Fukushima Daiichi’s rapid power loss, there is virtually no plant data from the accident’s early hours, data critical to understand the incident’s progression. MAAP filled in many data gaps, leading to critical lessons to help the global nuclear industry improve plant design and accident response guidelines.

One lesson from MAAP: Plant operators need a detailed strategy for using portable equipment, such as pumps to inject cooling water into reactors. Portable equipment strategies should buy time for plant operators to retrieve the equipment. For boiling water reactor nuclear plants such as Fukushima, this might involve devising a way for the plant’s existing reactor core isolation cooling system to function temporarily after a loss of power. Nearly all U.S. companies that operate nuclear plants use MAAP analyses to develop the portable equipment plans they submit to regulators. Lessons from the MAAP Fukushima analyses have been incorporated into the industry’s severe accident management guidelines. That helps reactor operators prepare for and navigate potential accidents.
**Industry**
Utilities, industry vendors and owners groups, architect-engineers, manufacturers and organizations involved in the nuclear fuel cycle—working as a collective worldwide industry—continue to strive for operational excellence while implementing lessons learned from the Fukushima accident. NEI has hosted numerous industry workshops to coordinate, train and share implementation progress on safety enhancements made since 2011. These include six FLEX strategy workshops, three workshops on boiling water reactor vent order implementation, and various Fukushima lessons learned workshops.

**Regulators**
The industry has maintained strong relationships with federal and state regulators to ensure the industry participates in the regulatory process and can effectively implement any regulatory changes.

The industry and NRC Fukushima response steering committees have met in numerous public meetings to share lessons learned from the Fukushima accident and to share information regarding the implementation of safety enhancements.

Members of the public have been able to interact with and ask NRC and industry representatives questions during these meetings. The industry and the NRC have also held workshops and information sessions on the implementation of safety enhancements in response to Fukushima during the NRC's annual Regulatory Information Conference.

**Technical partners**
The industry is continuing to collaborate with technical associations and organizations to ensure information is disseminated and understood by all interested parties so that the benefits and positions of nuclear energy are appreciated and support the industry's long-term objectives.

One important example is EPRI helping to validate radiation data from the Fukushima accident. Other examples include two EPRI, DOE and NRC-sponsored studies characterizing seismic activity and its potential impact on nuclear power plant sites in the central and eastern United States. The U.S. Geological Survey participated in these studies, which are being used to predict potential ground motion at the sites during severe earthquakes.

**Policymakers and opinion leaders**
The industry communicates lessons learned and industry actions to policymakers and opinion leaders at the local, state and national level to underscore the unwavering industry commitment to safety and implementing lessons learned from the Fukushima accident. The industry will continue to focus on communicating steps it is taking to enhance the safety and response capability at U.S. nuclear power plants.
The industry has provided nuclear plant tours and briefings for members of Congress, administration officials, state leaders and the media to demonstrate progress toward implementing its FLEX program and other post-Fukushima initiatives.

International community
The industry has interacted with international nuclear energy companies and organizations to compile and assess recommendations and actions for U.S. facilities and to make the international industry aware of measures taken since 2011 at American reactors.

The industry has hosted three Fukushima Forums and a fourth is scheduled for early 2016 in Tokyo. In these meetings, senior executives share their organizations’ response to the Fukushima accident. Topics have included organizational resilience in extreme situations, improving safety margins, emergency response proficiency, and operator and emergency personnel training.

As part of this effort, U.S. and Japanese chief nuclear officers (CNOs) have been collaborating on several issues regarding reactor safety and potential nuclear plant restarts in Japan. In 2013, 24 U.S. CNOs visited Japan to tour the Fukushima Daiichi and Fukushima Daini nuclear energy facilities and discuss Fukushima lessons learned and steps companies from both countries are taking to enhance safety at their plant sites. In 2014, Japanese CNOs toured the U.S. nuclear energy industry’s SAFER response center in Phoenix as part of a reciprocal visit. The visit was conducted to facilitate sharing of lessons learned, discuss ways to improve safety within the American and Japanese nuclear energy sectors and to plan future exchanges.

Conclusion
Based on more than 50 years of experience and a philosophy of continuous improvement, the U.S. nuclear industry maintains one of the safest industrial working environments. Through rigorous training of plant workers and increased communication and cooperation with federal regulators, the industry is keeping the nation’s nuclear plants safe for their communities and the environment. Since the massive 2011 earthquake and tsunami in Japan, operators of nuclear energy facilities in the United States have taken steps to make already-safe nuclear power plants even safer. These include enhancements requiring billions of dollars and thousands of man-hours to implement. Ongoing training and exercises ensure these facilities and the workforce is prepared to successfully respond to and mitigate an array of potential accident scenarios. Each of these improvements is based on careful consideration of the lessons learned from the Fukushima accident. They were made after detailed analysis by industry and regulators of their corresponding safety benefit, with those of most significant safety benefit being implemented with the highest priority.

Chief among these enhancements is the FLEX strategy, which addresses the major problem encountered at Fukushima—the loss of power to maintain effective reactor cooling—by stationing yet another layer of backup safety equipment in well-protected locations. The FLEX strategy and other enhancements are well on their way to being implemented at plant sites across the country, with most of the work and highest priority items scheduled to be complete by the end of 2016. As part of its safety culture, the industry is committed to seeking new, significant information that can enhance nuclear safety.

The industry’s top priority is the safe operation of nuclear energy facilities, which is reflected in record levels of safety in several industry metrics that are tracked by the World Association of Nuclear Operators. The multi-year commitment by industry to respond appropriately to the Fukushima accident shows the depth and scope of this commitment to safety by the nearly 100,000 men and women who work in the nuclear industry. It is their focus and dedication to excellence in safety that has resulted in the safe operating record industrywide and their continued dedication that will carry this safety record far into the future.