US Countermeasures for Fukushima Accident Lessons Learned

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US NRC Report

- **Recommendations for Enhancing Reactor Safety in the 21st Century defined cause of Fukushima Nuclear Complex Severe Accident as:**
- **The combination of the massive earthquake and devastating tsunami at Fukushima were well in excess of external events considered in the plant design.**
- **The Fukushima accident also challenged the plant's mitigation capabilities and EP.**

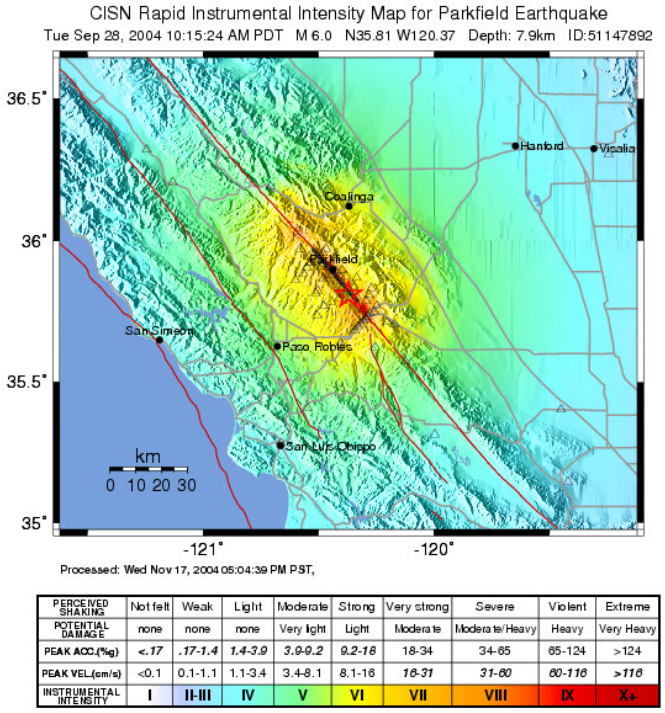
Key Elements of NRC Study

- **The elements of the NRC regulatory framework that play a part in providing protection from design-basis events, as well as events as severe and complex as the Fukushima accident.**

Elements include:

- **protection against seismic and flooding events (characterized as design-basis events)**
- **protection for loss of all ac power (characterized as a beyond-design-basis event)**
- **mitigation of severe accidents (addressing beyond-design-basis topics of core damage and subsequent containment performance) (as well as emergency planning).**

Example: New Interest in California acceleration data from the CCSN network used in regional ShakeMaps



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Virginia Earthquake Impacted North Anna Units 1, 2

- Earthquake occurred in Virginia near the North Anna site.
- Units shutdown and diesels provided emergency power.
- Units did not restarted until November 2011 after a comprehensive site wide safety evaluation was completed.
- Each US site must perform a new seismic analysis

US NRC Report's Conclusion

The Fukushima accident therefore highlights the full spectrum of considerations necessary for a comprehensive and coherent regulatory framework

Comparisons Drawn to the TMI -2 Accident, April 1997.

- Similar issues were raised by the TMI -2 accident, and many beyond-design-basis requirements, programs, and practices were derived from that experience and from the concurrent development of Probability Risk Analysis (PRA) as a practical tool.

Historical Approach to Design Basis Assumptions (50 Years Old)

- Design-basis events became a central element of the safety approach almost 50 years ago when the U.S. Atomic Energy Commission (AEC) formulated the idea of requiring safety systems to address a prescribed set of anticipated operational occurrences and postulated accidents.

US Current Operating Fleet of 65 PWRs & 35 BWRs Were Licensed in the 1960's -1970's

- That approach and its related concepts of design-basis events and design bases were used in licensing the current generation of nuclear plants in the 1960s and 1970s.

Rogovin Report on TMI-2 Accident

- **Following the TMI accident, numerous lessons-learned efforts were commissioned. One of those studies (NUREG/CR-1250, “Three Mile Island; A Report to the Commissioners and to the Public,” issued in 1980 and generally referred to as the Rogovin Report) evaluated the then-existing NRC regulatory approach (characterized in the report as “the so-called ‘design basis accident’ concept”).**

Report's Conclusion

- The report concluded that "More rigorous and quantitative methods of risk analysis have been developed and should be employed to assess the safety of design and operation."
- "The best way to improve the existing design review process is by relying in a major way upon quantitative risk analysis."

US Anti-Terrorism (9-11) Actions Deemed Transferable to Severe Accident Mitigation

- Following the terrorist events of September 11, 2001, the NRC issued security advisories, orders, license conditions, and ultimately a new regulation (10 CFR 50.54(hh)) to require licensees to develop and implement guidance and strategies to maintain or restore capabilities for core cooling and containment and spent fuel pool cooling under the circumstances associated with the loss of large areas of the plant due to a fire or explosion.
- The requirements led to the development of extensive damage mitigation guidelines (EDMGs) at all U.S. nuclear power plants.

Beyond-Design-Basis Defined

- The concept of beyond-design-basis requirements applies, for example, to ATWS, Station Black Out(SBO), aircraft impact assessment (AIA), combustible gas control, and extensive damage mitigation guidelines (EDMGs).
- Since fire protection is not based on a design-basis fire, it too can be considered beyond design basis.

IAEA Definition Reviewed

- the IAEA Draft Safety Standard DS 414 addresses considerations beyond the design basis, referring to them as those addressing “design extension conditions.
- the Task Force will refer to past considerations beyond the design basis using that phrase (e.g., “beyond-design-basis events”).
- “extended design basis” is the terminology of choice.

US NRC Major Elements

- **the major elements of the USNRC regulatory approach relevant to the Fukushima accident, or a similar accident in the United States, are seismic and flooding protection (well established in the design-basis requirements); SBO protection (required, but beyond the design-basis requirements); and severe accident mitigation (expected but neither the severe accident mitigation features nor the SAMGs are required).**

Evolution of DBA Resulted in Patchwork Approach

- approaches is largely the product of history; it was developed for the purpose of reactor licensing in the 1960s and 1970s and supplemented as necessary to address significant events or new issues. This evolution has resulted in a patchwork regulatory approach.

Value of Defense-in-Depth Approach

- **The Fukushima accident clearly demonstrates the importance of defense-in-depth. Whether through extraordinary circumstances or through limited knowledge of the possibilities, plants can be challenged beyond their established design bases protection.**

Reliance on Industry Initiatives

- **The Task Force concludes that the NRC's safety approach is incomplete without a strong program for dealing with the unexpected, including severe accidents.**
- **Continued reliance on industry initiatives for a fundamental level of defense-in-depth similarly would leave gaps in the NRC regulatory approach.**

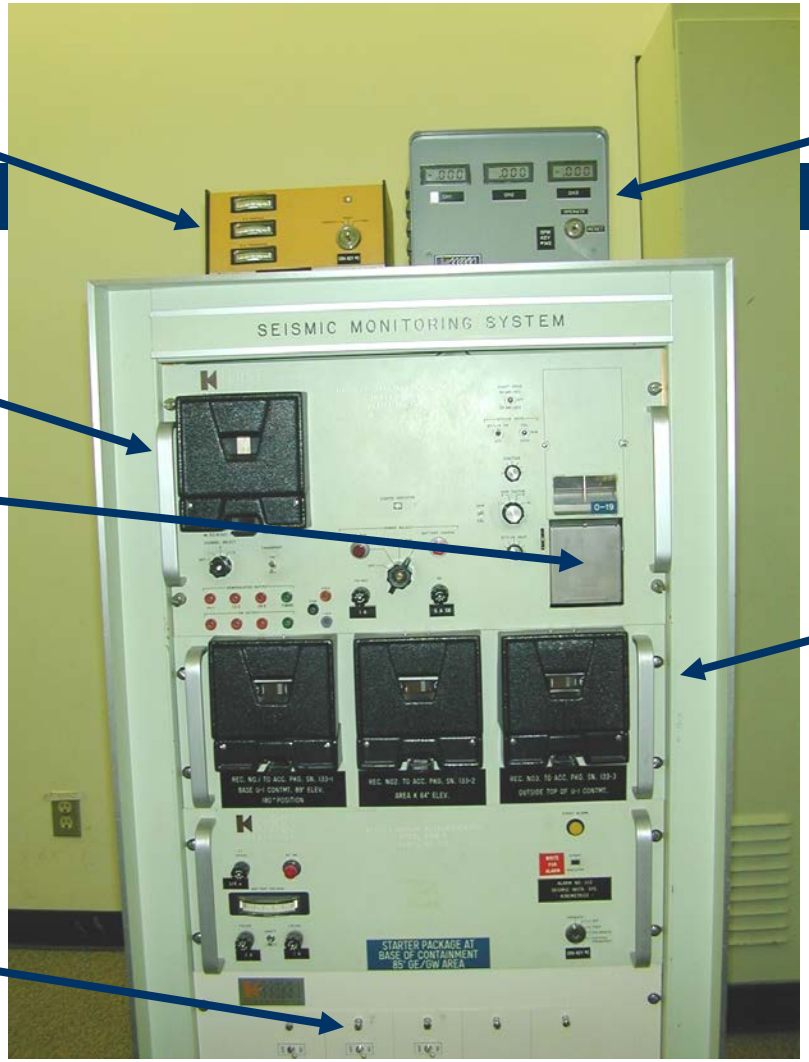
Recommendation 1

- **The Task Force recommends establishing a logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations.**

Recommendation 2

- **The Task Force recommends that the NRC require licensees to reevaluate and upgrade as necessary the design-basis seismic and flooding protection of SSCs for each operating reactor.**
- **Initiate rulemaking to require licensees to confirm seismic hazards and flooding hazards *every 10 years and address any new and significant information.***

Kinemetrics System



EFM

Digital Peak Indicator

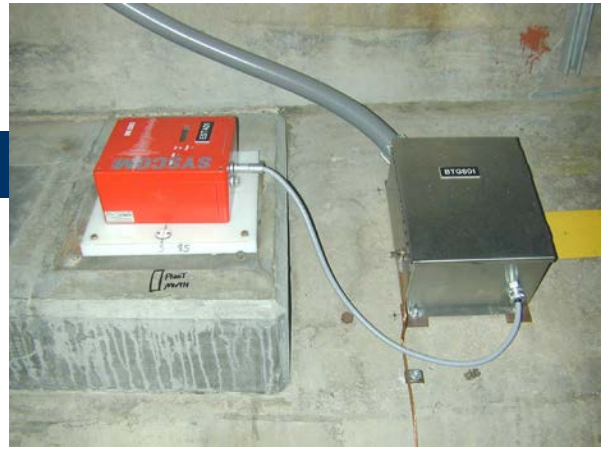
Magnetic Tape Reader and associated Strip Chart

Magnetic Tape Recorders

Digital Recorders

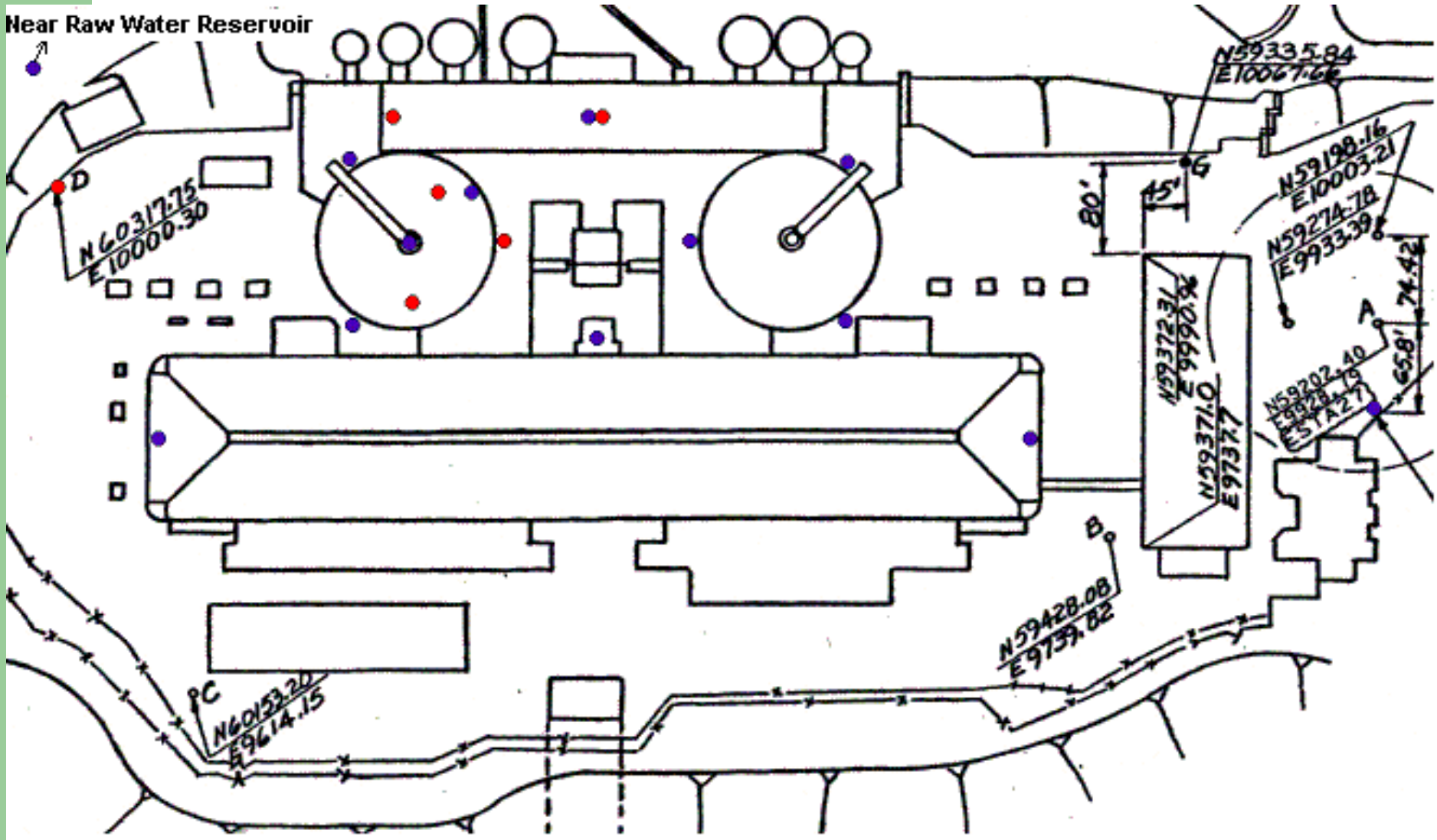
Syscom Seismic System

EFM Containment Base Recorder



- EFM Free Field Recorder

Seismic Recorder Locations



New Consolidated Seismic System

- Replaced former Basic and Supplemental systems with a new consolidated Syscom digital distributed seismic system consisting of:
  - 6 recorder RG 1.12 Basic system
  - 13 recorder FSAR Supplemental system
  - Process Rack in the Auxiliary Building
  - Control Room Computer
  - Plant Data Network (PDN) Interface

Terra Technology System

- Obsolete 1970s analog and digital technology. Vendor out of business and parts no longer manufactured or available.
- Centralized processing in the Aux Building Rack
- Rack powered by vital source with battery backup
- Required Vendor or contractor support for calibration, service and analysis
- Retrieval of data was cumbersome and time consuming

Licensees to Perform Inspections

- **Order licensees to perform seismic and flood protection walkdowns to identify and *address plant-specific vulnerabilities and verify the adequacy of monitoring and maintenance for protection features such as watertight barriers and seals in the interim period until longer term actions are completed to update the design basis for external events.***

Current Events Under Consideration

- **The Task Force evaluated various related concurrent events and determined that fires and internal floods induced by design-basis earthquakes warranted further consideration.**

Seismic Events & Fires

- **Seismically induced fires are frequent after earthquakes in urban areas. Seismic events have also resulted in fires at nuclear power plants.**
- **Seismically induced fires have the potential to cause multiple failures of safety-related systems and could create fires in multiple locations at the site.**

Fire Protection Systems

- Fire protection systems are not required to be functional after a seismic event; therefore, efforts to fight seismically induced fires may be impaired by degraded fire protection equipment.
- A seismic event may also impede offsite fire crews from reaching the site, further challenging the capability to respond to such an event.

Historical Earthquake Events

- The 2007 Japanese earthquake event also revealed insights regarding seismically induced flooding.
- The plants experienced flooding from sloshing of the spent fuel pool, fire suppression piping failure outside the Unit 1 reactor building that flowed into the plant through cable penetrations, and a condenser flexible connection failure.

Recommendation 3

- ***The Task Force recommends that the NRC evaluate potential enhancements to the capability to prevent or mitigate seismically induced fires and floods.***
- ***US experienced significant flooding challenges to operations in the summer of 2011 at Fort Calhoun (Nebraska) and Cooper Station (Kansas).***

Heavy Snowfall in Montana: Photo Taken June 17, 2011

Highway West & Southwest of Billings, Montana, June 17, 2011

- Spring Snow Melt Flows to Missouri River & Mississippi River.

Fort Calhoun PWR on Missouri River, June 2011

Fort Calhoun PWR Station
Nebraska, USA

Affected Access to Site Engineering & Support Services Buildings

Cooper BWR Station on Mississippi River, Summer 2011

Monticello, BWR, Minnesota

- In 2013, requested to maintain “preparation materials” for site flooding
- Includes supplies of sand and bags to allow crews to make an adequate number of sandbags if river flooding is anticipated

Water Tight Doors

Recommendation 5

- ***The Task Force recommends requiring reliable hardened vent designs in BWR facilities with Mark I and Mark II containments.***

Recommendation 6

- ***The Task Force recommends, as part of the longer term review, that the NRC identify insights about hydrogen control and mitigation inside containment or in other buildings as additional information is revealed through further study of the Fukushima Dai-ichi accident.***

Spent Fuel Pool Safety

- SSCs for spent fuel storage and handling have safety classifications that reflect their importance to safety.
- The storage capacity of U.S. reactor unit spent fuel pools ranges from less than 2,000 assemblies to nearly 5,000 assemblies, with an average storage capacity of approximately 3,000 spent fuel assemblies.
- Typically, the U.S. spent fuel pools are filled with spent fuel assemblies up to approximately three-quarters of their capacity.

Recommendation 7

- ***The Task Force recommends enhancing spent fuel pool makeup capability and instrumentation for the spent fuel pool.***

Safety-Related Instrumentation to Withstand Design-basis Natural Phenomena

- Order licensees to provide sufficient safety-related instrumentation, able to withstand *design-basis natural phenomena, to monitor key spent fuel pool parameters (i.e., water level, temperature, and area radiation levels) from the control room.*

Recommendation 8

- ***The Task Force recommends strengthening and integrating onsite emergency response capabilities such as Emergency Operating Procedures (EOPs), Severe Accident Mitigation Guidelines (SAMGs), and Extensive Damage Mitigation Guidelines (EDMGs).***

Recommendation 9

- ***The Task Force recommends that the NRC require that facility emergency plans address prolonged Station Blackout (SBO) and multiunit events.***

Recommendation 10

- ***The Task Force recommends, as part of the longer term review, that the NRC should pursue additional Emergency Planning topics related to multi-unit events and prolonged Station Blackout (SBO).***

Cook 1,2 Built Second Main Control Room Simulator: Allows Dual Unit EP Drill Scenarios

High Interest in US & Europe For Dual Unit Simulators After Fukushima Accident

- Diablo Canyon 1,2 Training Managers have benchmarked Cook Unit 1 and 2 control room training simulators and plan to be the second US site with same design
- EDF, France has visited the Cook 1, 2 simulators, also.
- Cook Facility also has new state-of-the-art four, rear projection plant parameter display emergency response training facility. Allows display of dual unit severe accident scenarios.

Recommendation 11

- ***The Task Force recommends, as part of the longer term review, that the NRC should pursue EP topics related to decision making, radiation monitoring, and public education.***

Impact on US New Construction

Aerial photograph of Vogtle site, with Vogtle 1 and 2 operating units to the left and Vogtle 3 and 4 construction site to the right. August 11, 2011

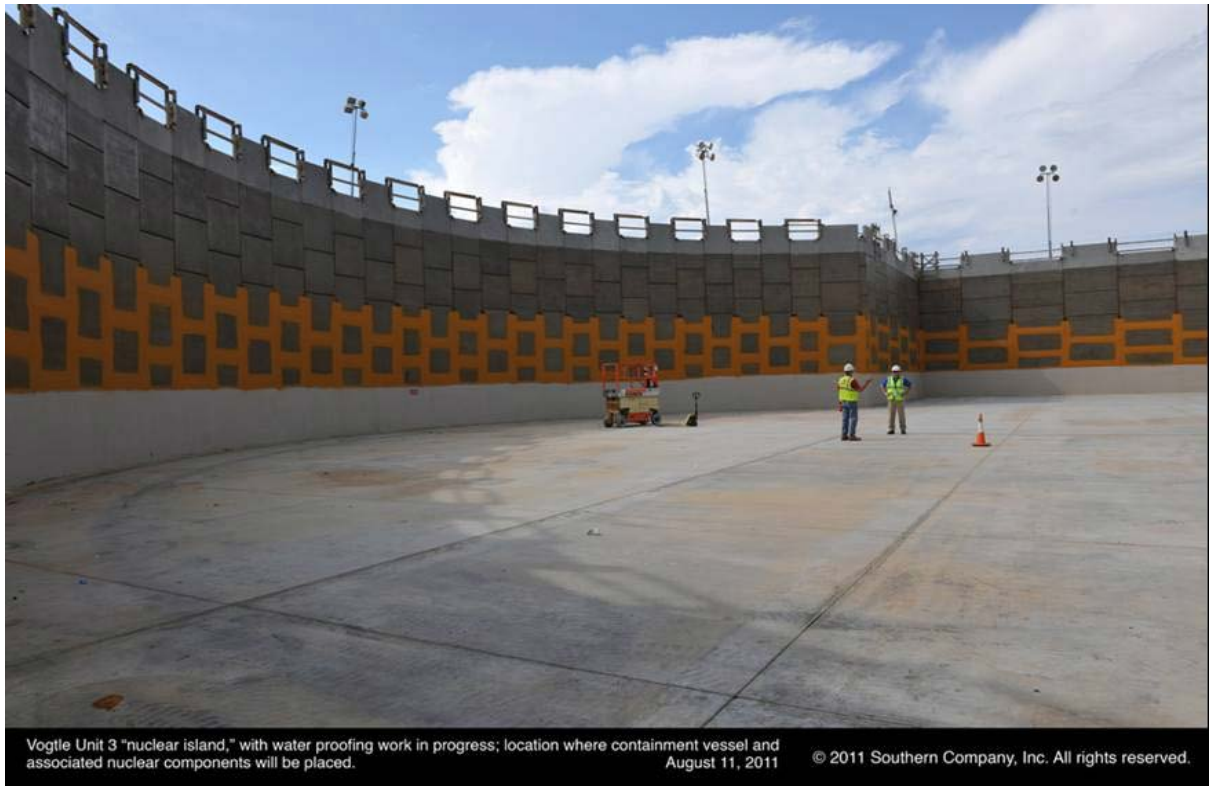
Vogtle Unit 3 “ Nuclear Island” Work In-Progress

Vogtle Unit 3 “nuclear island,” with water proofing work in progress; location where containment vessel and associated nuclear components will be placed. August 11, 2011

New Reactors Required to Address Severe Accident Requirements

- The Commission has clearly established such defense-in-depth severe accident requirements for new reactors (in 10 CFR 52.47(23), 10 CFR 52.79(38), and each design certification rule), thus bringing unity and completeness to the defense-in-depth concept.
- Eventually, operating reactors will also consider the same.

Vogtle Unit 3 Containment Vessel Base



Vogtle Unit 3 "nuclear island," with water proofing work in progress; location where containment vessel and associated nuclear components will be placed. August 11, 2011

Aerial Photo of Vogtle Unit 3 and 4

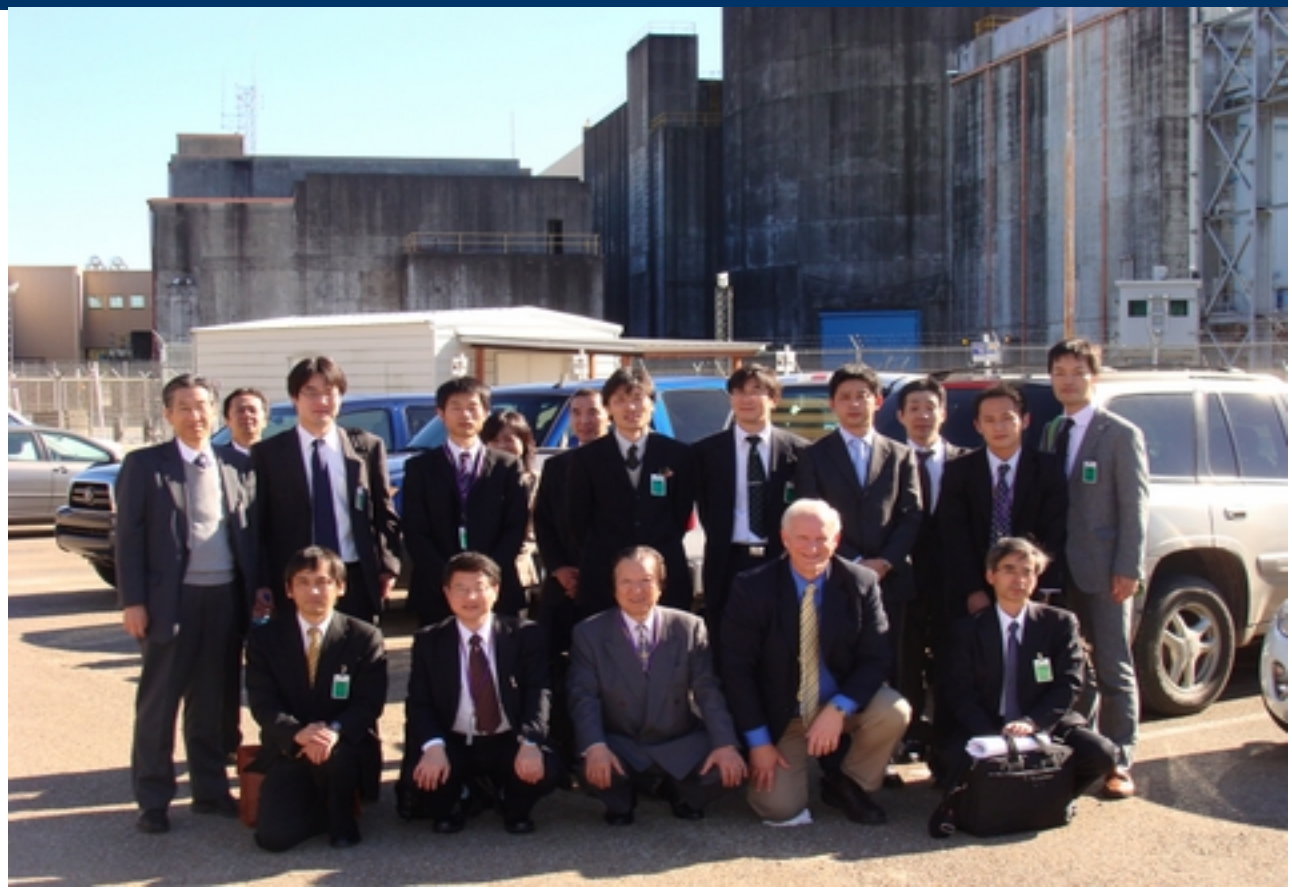
Aerial photograph of Vogtle 3 and 4 construction site. Unit 3 is located at left and top of photo and Unit 4 to the right and bottom. Heavy lift derrick crane foundation in center. August 11, 2011

US & Japanese Nuclear Professional Information Exchanges Via ISOE

- The late Wataru Mizumachi, ISOE Bureau Chair Emeritus, led 14 site visits to US operating nuclear units to improve Japanese Nuclear Plant Performance
- Seismic and Station Blackout considerations were of keen interest to the Japanese visitors to Diablo Canyon, River Bend, Peach Bottom
- US managers also learned from Japanese visitors

JSME Benchmarking Site Visits to learn US decision making, EP & engineering good practices: US sites visited include: Susquehanna, Diablo Canyon, River Bend, South Texas and others is an Important Process in Maintaining Excellence in Operations and Design Basis Assessments.

Japan Benchmarking Visit to River Bend



Utilities Currently performing Fukushima Self-Assessments (SA)

- Typical self-assessment covers two weeks
- First week, table top exercises
- Second week, field inspections and interviews with managers, operators and technical staff

Outline of Fukushima SA Scheduled Over Two Weeks in April 2014

- **Self Assessment (SA) is to be conducted to prepare for the Nuclear Oversight audit and the Regulatory Inspection on the implementation of Fukushima Response lesson learned and Operating Experience from the Fukushima Daiichi event in March 2011.**

Scope of Nuclear Oversight Audit:

- **The Nuclear Oversight audit on the Fukushima readiness is a cross functional review of:**
- **Review Fukushima lessons learned, and OPEX, confirming committed actions are completed, or are on track;**
- **Review the status of committed short, medium and long term actions to the regulator**
- **Look for gaps in utility response based on lessons learned from Fukushima.**
- **Assess status of WANO SOER 2011-2, 2011-3, 2013-2 recommendations.**
- **Review any Nuclear Safety Review Board insights.**

Outline, con’t.

- Review status of specific modifications, both in-progress and effective implementation of modifications.
- Review operating procedures implemented to support the lessons learned, including SAMGs (Severe Accident Management Guideline), Training and qualifications.
- Review of Emergency Preparedness actions implemented to support the lessons learned, including observation of any drills scheduled during, or before, the audit.
- Review Maintenance Plans of Equipment Purchased to support Fukushima Readiness.
- Assess the extent to which the current initiative deals with other Beyond Design Basis Events.
- Management Oversight / Learning Organization / Corrective Action Program – Findings, SA, O&C, RCA, Reporting, CAP effectiveness, and OPEX.
- Review interfaces with other programs / organizations.
- Review relevant Governance - implemented, effective, and compliant.

Overall Self Assessment (SA) Plan Timeline

- Issue overall Self Assessment Plan, detailed schedule March 28, 2014
- SA Team kick off meeting and assign tasks April 01
- Arrange for interview and field visit April 12
- Conduct SA April 14-25

- SA Team debrief meeting- preliminary conclusions and recommendations April 25
- Draft self assessment report for review May 02
- SA Report approved May 26

Results of SA available by emailing NATC Regional Director at dmiller@illinois.edu & UofIlMYBOX

Thank you for your Attention: Questions?