American Nuclear Society

Fukishima Daiichi's Impact on the Nuclear Power Plants Program in the USA

Donald R. Hoffman
President
American Nuclear Society
www.ans.org
President/CEO
Excel Services Corporation
www.excelservices.com

Introduction

- Accident Overview
- U.S. Nuclear Industry Response
- NRC - Regulator Actions
- U.S. Industry Major Accomplishments
- Major Work in Progress & Challenges
- FLEX Initiative

Accident Overview

- March 11, 2011 earthquake struck Fukushima Daiichi, a six-unit BWR nuclear power plant on the NE coast of Japan
- Reactors were shutdown based on detection of seismic activity
- Earthquake resulted in the loss of offsite power due to transmission line damage.
- Emergency Diesel Generators powered emergency cooling systems.

Accident Overview

(cont'd)

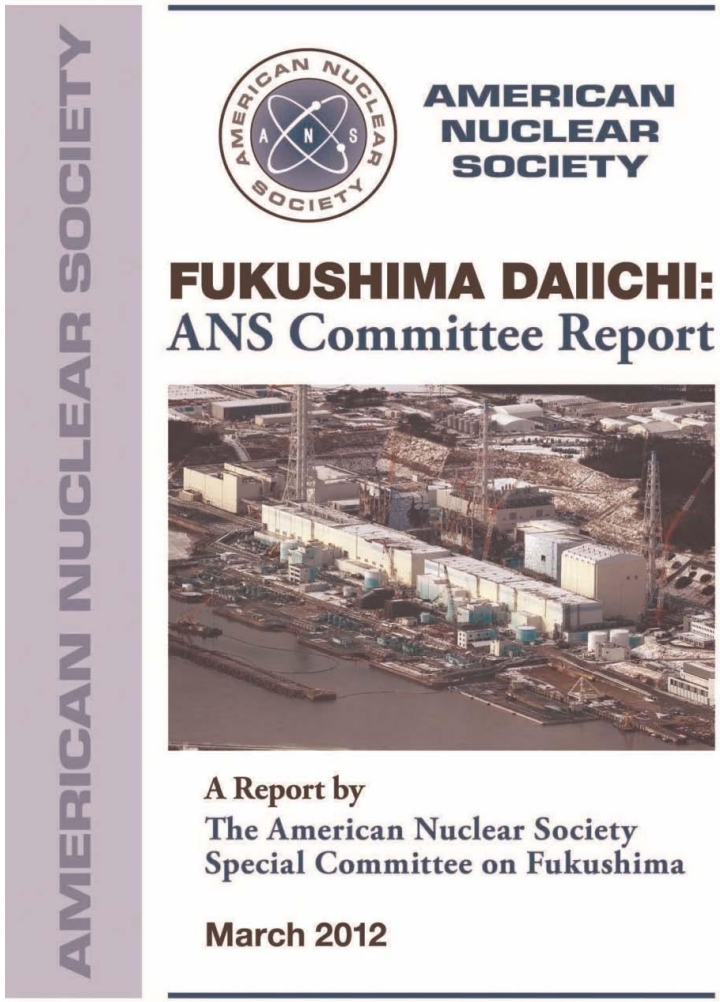
- An hour later, the station was struck by the tsunami. The tsunami disabled the diesel generators, AC buses, DC batteries (U1) and damaged service water that provides heat rejection to the sea.
- Loss of cooling resulted in substantial fuel damage while portable power supplies and pumps were being brought on-site to re-establish cooling.
- Containments leakage (U1-3) occurred as fuel cladding oxidized and hydrogen released from these processes combusted in the surrounding buildings.
- Spent fuel pools didn't suffer direct damage.

Accident Overview

(cont'd)

- Tsunami damage (20,000 dead; costs ~ $1T)
- Fukushima accident caused no loss of life (estimate of latent cancers <100 out of 10's millions)
  - Source: *World Health Organization 2013: Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami*

ANS Special Committee on Fukushima



- A special committee was formed to provide a clear and concise explanation of the events surrounding the accident to the general public.
- The committee's report and additional information is available at: **http://fukushima.ans.org**

ANS

U.S. Nuclear Industry Response

- Confirm safety of U.S. reactors
  - Verify operability and usability of portable mitigation equipment already on site
    - Mitigating Strategies Requirements from Security Order EA-02-026, Section B.5.b, and 10 CFR 50.54(hh)(2)
  - 10 CFR 50.54(hh)(2)
    - “Each licensee shall develop and implement guidance and strategies intended to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities under the circumstances associated with loss of large areas of the plant due to explosions or fire ....”

ANS

U.S. Nuclear Industry Response

(cont'd)

- Establish communication focal point
  - NEI, INPO, EPRI, Owners Groups, U.S. nuclear utilities
- Establish factual basis for action based on understanding of the events in Japan

U.S. Nuclear Industry Response
(cont'd)

- INPO Initiatives
  - Performed in-depth examination of accident mitigation with no AC power
  - Calculated time to used fuel pool boiling
  - Implemented stronger fuel pool equipment protections
  - Performing review visits at sites

NRC – Regulator Actions

- NRC actions are broken into 3 tiers
  - Tier 1: without unnecessary delay
    - To be completed by 2016
  - Tier 2: require critical skill sets or further technical assessment, depend on Tier 1 issues, or availability of critical skill sets
  - Tier 3: require further long-term study/ scoping, depend on Tier 1 or 2 issues, or availability of critical skill sets

NRC – Regulator Actions

- NRC Tier 1 Recommendations
  - Seismic and flood hazard reevaluations
  - Seismic and flood walkdowns
  - Station blackout regulatory actions
  - Mitigating strategies for beyond design basis events
  - Reliable hardened vents for Mark I and Mark II containments
  - Spent fuel pool instrumentation

NRC – Regulator Actions

- NRC Tier 1 Recommendations
  - Strengthening and integration of emergency operating procedures, severe accident management guidelines, and extensive damage mitigation guidelines
  - Emergency preparedness regulatory actions (staffing and communications)

NRC – Regulator Actions

- **Orders (issued March 2012)**
  - EA-12-049 – Mitigating strategies for beyond design basis events
    - Actions to be completed by 2016
  - EA-12-050 – Hardened vents for Mark I and II containments
    - To be complete by 2018
  - EA-12-051 – Spent fuel pool water level instrumentation
    - To be complete by 2016

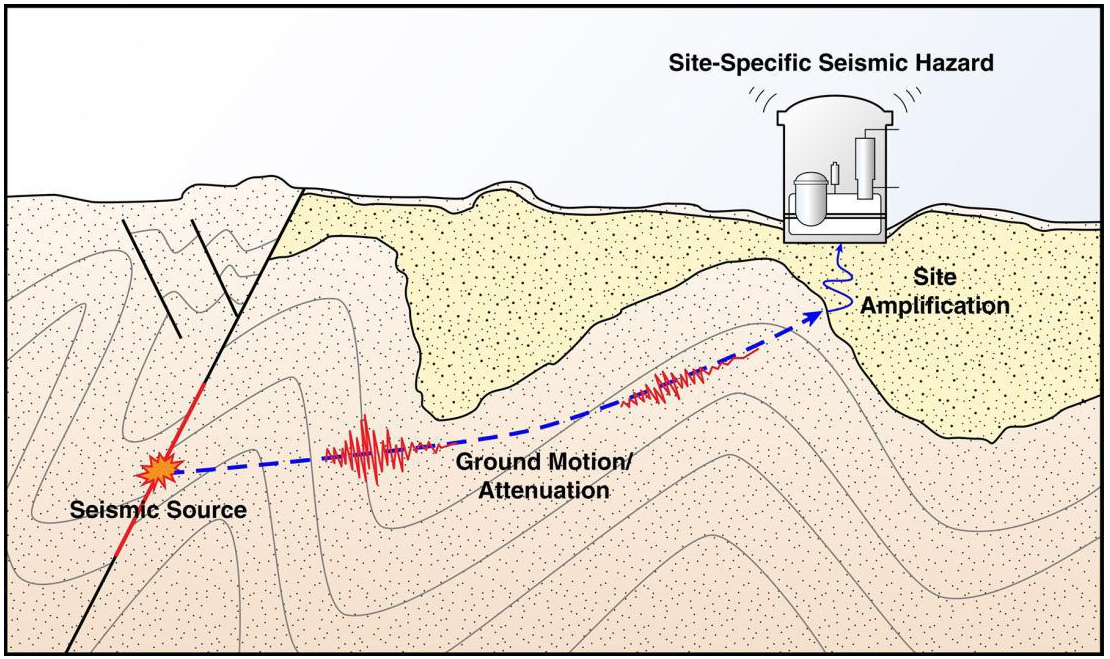
NRC – Regulator Actions

- **Request for Information (issued March 2012)**
  - Seismic and flooding walkdowns
    - Completed
  - Seismic and flooding reevaluations
    - Interim actions to be completed by 2016
  - Emergency Preparedness staffing and communications
    - To be in place by 2016
- **Rulemakings**
  - Station Blackout Mitigating Strategies (SBOMS)
    - To be in place by 2016
  - Enhanced Onsite Emergency Response Capabilities
    - To be in place by 2016

Seismic and Flooding Walkdowns

- Major undertaking by licensees
  - Walkdowns completed in November 2012
  - Addressing:
    - procedures that may not be feasible
    - temporary flood protection that may not perform as planned
    - degraded or missing protection features (e.g., seals)
    - Minor seismic anchorage issues

Site-Specific Seismic Hazard Development



- NRC has endorsed EPRI (2004, 2006) CEUS GMM and specified its use in 50.54(f) letter
- Industry proposes update of EPRI GMM to account for new data and scientific knowledge

Seismic Reevaluations

- General Agreement on industry proposal
- Focus areas going forward
  - Timely completion of the updated model and associated documentation
  - Endorsement of expedited evaluation guidance
- Staff preparing a response to industry proposal

Regulatory Framework

- NRC developing options for potentially significant changes to the regulatory framework
  - Options include fully risk-based regulations
- Commission paper due Dec 2, 2013

Longer Term Actions
NRC Tier 2 and Tier 3

NRC – Regulator Actions

- NRC Tier 2 Recommendations
  - Spent fuel pool makeup capability, and
  - Emergency preparedness regulatory actions
    - Both included in Station Blackout Mitigation Strategies rule being developed
  - Other External Hazards Reevaluation (tornados, hurricanes, drought, etc.)
    - Dependent on insights from seismic & flooding revaluations

NRC – Regulator Actions

- NRC Tier 3 Recommendations
  - Ten-year confirmation of seismic and flooding hazards
  - Potential enhancements to the capability to prevent or mitigate seismically-induced fires and floods
  - Reliable hardened vents for other containment designs
  - Hydrogen control and mitigation inside containment or in other buildings
  - Emergency preparedness enhancements for prolonged station blackout and multiunit events

NRC – Regulator Actions

- NRC Tier 3 Recommendations
  - Emergency Response Data System capability
  - Additional emergency preparedness topics for prolonged station blackout and multiunit events
  - Emergency preparedness topics for decision-making, radiation monitoring, and public education
  - Reactor Oversight Process modifications to reflect the recommended defense-in-depth framework
  - Staff training on severe accidents and resident inspector training on severe accident management guidelines

NRC – Regulator Actions

- NRC Tier 3 Recommendations
  - Basis of emergency planning zone size
  - Prestaging of potassium iodide beyond 10 miles
  - Transfer of spent fuel to dry cask storage

U.S. Industry's Major Accomplishments

- B.5.b equipment readiness affirmed by inspection and test
- Initial inspections completed for flooding and seismic vulnerabilities
- Station blackout procedures and equipment readiness validated
- Periodic maintenance and drills verified to exist or established for B.5.b equipment
- NRC endorsed the FLEX strategy
- Spent fuel pool monitoring enhanced

U.S. Industry's Major Accomplishments

- FLEX equipment specified, purchased, arriving at sites
- RRC (regional response centers) approved
- Event investigation with TEPCO completed
- Flooding guidance established, walk-downs completed
- Seismic guidance established, walk-downs completed
- Flooding hazards—scope and methodology approved

Major Work in Progress

- Seismic hazards—working on alternate methodologies
- Developing site-specific FLEX strategies
- Developing integration of EOPs, SAMGs, EDMGs and FLEX
- Reliable spent fuel pool wide-range level instrumentation in design
- Land contamination / containment pressure / H2 control
- Regional Response Center / Industry Infrastructure

MAKING SAFE NUCLEAR ENERGY SAFER AFTER FUKUSHIMA

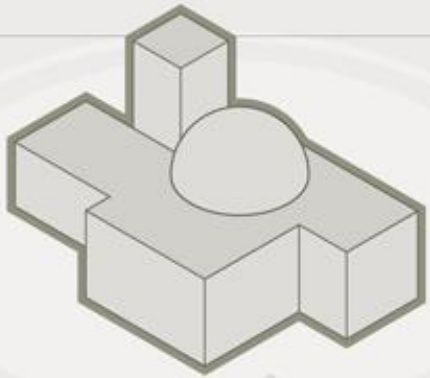
FLEX is a flexible and diverse strategy developed by the nuclear energy industry to quickly and effectively implement the Nuclear Regulatory Commission (NRC's) Fukushima task force recommendations. The FLEX protection strategy addresses the main safety challenges at Fukushima–the loss of cooling capability and electrical power resulting from a severe natural event that exceeded the plant's design basis–to make U.S. facilities even safer. It builds on safety steps taken by industry during the past three decades by providing a fast, effective and efficient way to apply the lessons learned from Japan's experience.

MULTIPLE LAYERS OF POWER SUPPLY

Backup generators provide reliable electrical power and cooling capability if an extreme event disables the normal plant equipment. Additional battery banks provide electrical power and cooling capability if an extreme event disrupts regular and other backup power supply.

ADDITIONAL SPENT FUEL MONITORING

Additional equipment in spent fuel storage pools will provide another layer of monitoring to ensure temperature and water levels are maintained.



ADDITIONAL PUMPS

To ensure cooling procedures are maintained during and after an extreme event, additional pumps can supply water where needed.

PREPARING OUR PEOPLE

Nuclear plant and emergency response workers will use the FLEX approach to support key safety functions across multiple reactors. Capabilities and training will be verified for nuclear plant workers to assure the continued viability and reliability of equipment. Communications capabilities will be expanded to include satellite phones and equipment to connect personnel at the plant with government emergency communications networks. Specific strategies include the following:

Enhanced Training

Expanded Maintenance and Testing of Equipment

Satellite Communications

REGIONAL CENTERS

Additional emergency equipment will be stationed in off-site support centers to provide another layer of safety and ensure prolonged reliable operation.

PUBLIC OPINION

74% of Americans believe that U.S. nuclear power plants are safe and secure

80% of Americans believe U.S. nuclear power plants have been made safer as we've learned from experience and added technology

ANS

Flex Strategy

- Origins from B.5.b
- Provides a Means to Respond to Extreme Events Known and Unknown
- Sites Have Already Improved Safety Margins as a Result

Flex Strategy

- Provides Diverse and Flexible Means to Protect Fuel
  - Provide Cooling for the Core
  - Protect the Containment
  - Provide Water Makeup to the Spent Fuel Pool

Three Phase Approach

- Initial Coping Relying on Installed Equipment
- Transition from Installed to Onsite FLEX Equipment
- Obtain Additional Capabilities and Redundancy from Offsite

Flex Onsite Equipment Staging

- N+1 Provides Redundant Equipment
- Diverse Storage Locations
- Reasonable Protection of Equipment
- Deployment of Equipment
- Common Electrical and Mechanical Connections

Diverse Options

- Provide Emergency Response Organization a multitude of options
- Allows deployment of additional mitigation capabilities in a swift and efficient manner
- Provides preplanned responses for a wide range of Beyond Design Basis events
- Symptom based procedures allows training to be used in any event.

Flex Redundancy

Consideration of Potential Failure Modes of Baseline FLEX Strategies

Functional Failure Mode	Failure Cause Leading to Core Damage	Relevant Contingency Provisions of NEI 12-06
Early Reactor Core Cooling Fails	RCIC/AFW fails to start	• Procedural direction to locally initiate RCIC/AFW
	RCIC/AFW fails to operate until portable FLEX equipment can be deployed	• Procedures for manual operation of RCIC/AFW • Procedural direction to align portable pump, even if transition is not yet planned
	DC control power lost	• Procedural direction to manually initiate RCIC/AFW
	RCIC/AFW water source unavailable	• Robust source of water initially required • Essentially indefinite supply of water
	Instrumentation inadequate	• Plant-specific reference source required to identify all available sources for required parameters, including self-powered instrument readings (w/o DC power)
	LOCA occurs	• Margin provided in BWR RPV/RCS makeup capabilities • Margin in PWR SG makeup rates to support cooldown

Consideration of Potential External Hazard Impairments to FLEX

Hazard	Hazard-induced Impairment	Relevant Contingency Provisions of NEI 12-06
Seismic (applicable to all plants)	Seismic damage to electrical equipment, e.g., DC control power	• Procedural direction to manually initiate RCIC/AFW • Plant-specific reference source required to identify all available sources for required parameters, including self-powered instrument readings (w/o DC power)
	Seismic damage to portable on-site FLEX equipment	• Structure provides reasonable protection or storage outside • Portable equipment secured • Seismic interactions considered
	Impairment to onsite transportation	• Transportation equipment reasonably protected • Review transportation route for soil liquefaction potential • Capability to open electric doors without normal AC power
	Seismic damage to plant structures	• At least one connection point and associated deployment location requires access to only robust structures
	Seismic-induced internal flood	• Connection and access consider potential for failure of non-qualified water sources
	Seismic-induced groundwater intrusion	• Water removal provision without AC power
	Seismic-induced loss of downstream dam required for water supply	• Strategies for providing water assuming unqualified downstream dam fails
	Impairment of delivery from regional response center	• Identify plant-specific strategies for delivery accounting for potential seismic damage to the surrounding infrastructure

Training

- On-site staff will be trained on the deploying and utilization of the equipment including timed drills
- Emergency Response Leadership including Senior Reactor Operators, Emergency Duty Directors and facilities leads will be trained on strategies and deployment

Industry Coordination & Sharing

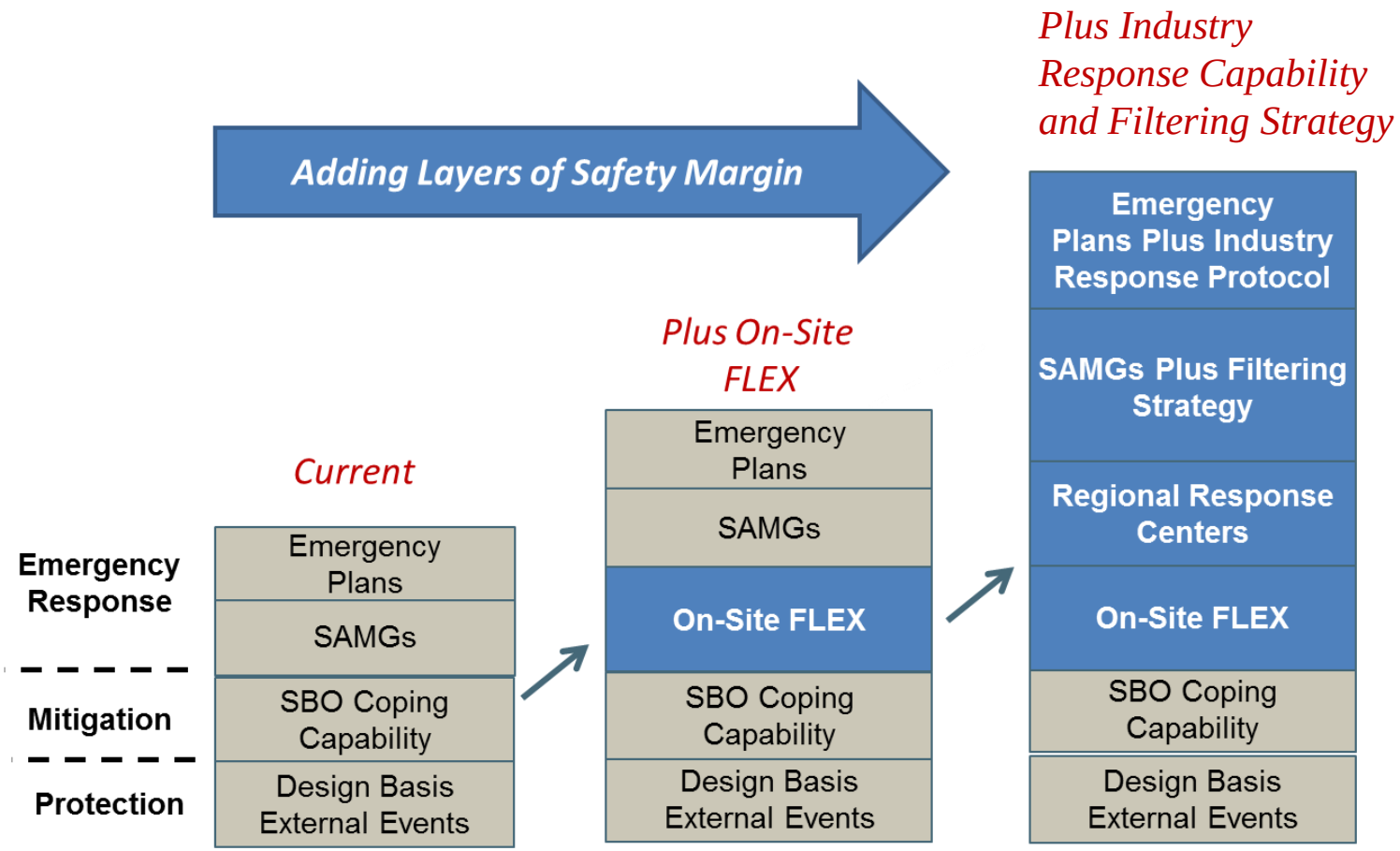
- Established Regional Response Centers to provide additional equipment and resources from outside of the utility involved in the event
- Expanded current sharing practices between utilities to include emergency equipment
- Expand current parts database to include emergency equipment
- INPO improved Emergency Response Center to coordinate industry response and support

Offsite Support

- 2 Regional Response Centers
  - Provide Additional Capability and Redundancy of Equipment and Supplies
  - Ability to Mobilize and begin delivery of equipment
- 65 Commercial Nuclear Power Sites
  - Complete list of Equipment Available at each Site

Regional Response Center Locations

U.S. Industry Post-Fukushima Actions



What Will This Cost?

- A recent survey of US nuclear power plant operators by the Platts news organization determined that the industry will likely spent nearly **$3.6 billion** over the next three to five years on modifications.
  - Average cost of $35 million per plant
  - The cost estimate includes US NRC-ordered capital expenditure on new equipment as well as the cost of conducting extensive engineering studies about each plant's resistance to such events.
- Companies also expect increases in operating and maintenance costs in connection with post-Fukushima requirements.

Summary

- The US nuclear industry response to the Fukushima accident will result in robust and extensive modifications to plants and the US regulatory requirements.
- Substantial safety enhancements will be implemented by 2016, with additional enhancements extending beyond 2016