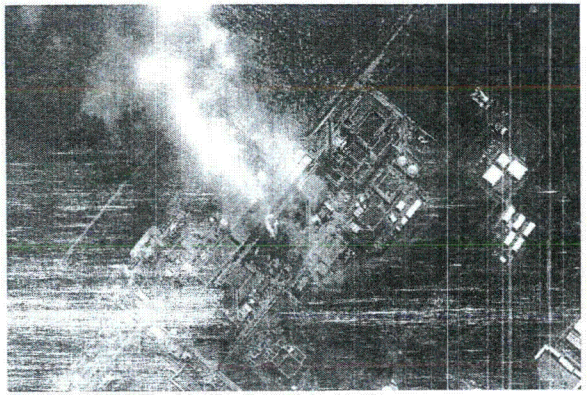


U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Ensuring Spent Fuel Pool Safety

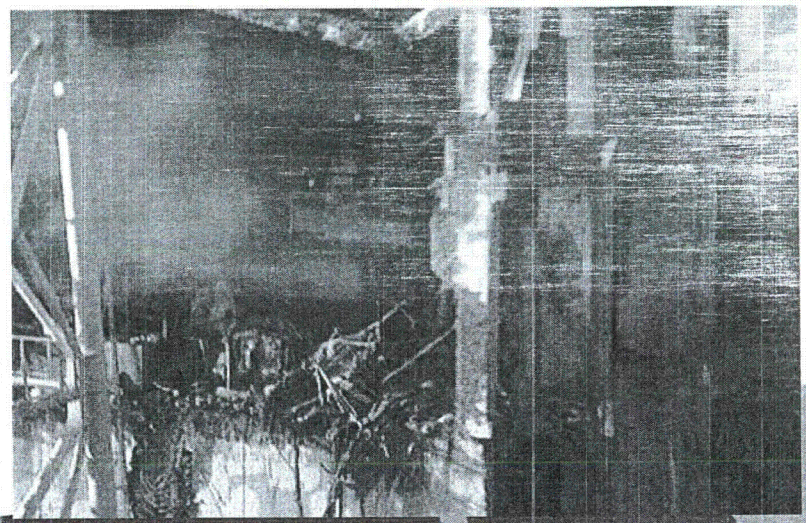
Michael Weber
Deputy Executive Director for Operations
U.S. Nuclear Regulatory Commission

American Nuclear Society Meeting
June 28, 2011

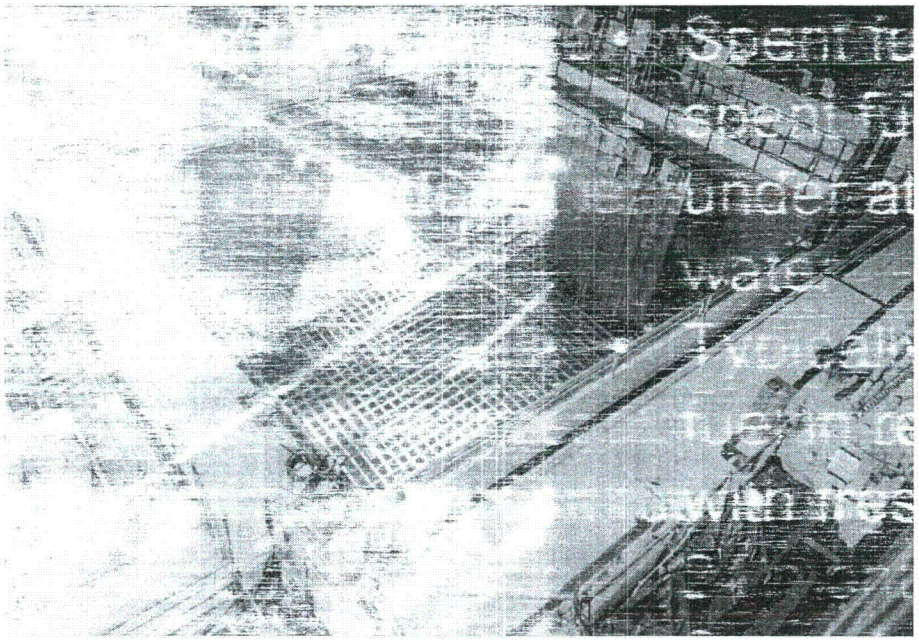
48

Insights from Fukushima

- Nuclear emergency at Fukushima-Daiichi
  - 3 nuclear reactors
  - 4 reactor spent fuel pools
  - 1 common spent fuel pool



U.S. Spent Fuel Pools



- Spent fuel rods stored in spent fuel pools (SFPs) under at least 20 feet of water
- Typically ~1/4 to 1/3 of fuel in reactor replaced with fresh fuel every 18 to 24 months
- Spent fuel stored in pools minimum of 5 years

U.S. SFP Safety

- Spent Fuel Pools (SFP) originally designed for limited storage of spent fuel until removed off-site
- Safety of spent fuel in pools achieved primarily by maintaining water inventory, geometry, and soluble boron (PWRs)
- Drain down can lead to uncovered fuel, heat-up, and the release of radionuclides to the

Risk of Large Release

- SFP risk is low, due to the low frequency of events that could damage the thick reinforced pool walls
  - Frequency of fuel uncovery; 6E-7 to 2E-6/yr. – NUREG-1738
  - Consequences have been assessed to be large due to the potential for heatup of all the fuel in the pool
  - Heatup of the fuel in the pool can lead to "zirconium fire" initiation and propagation
  - Large inventory of Cs-137

SFP Safety and Security

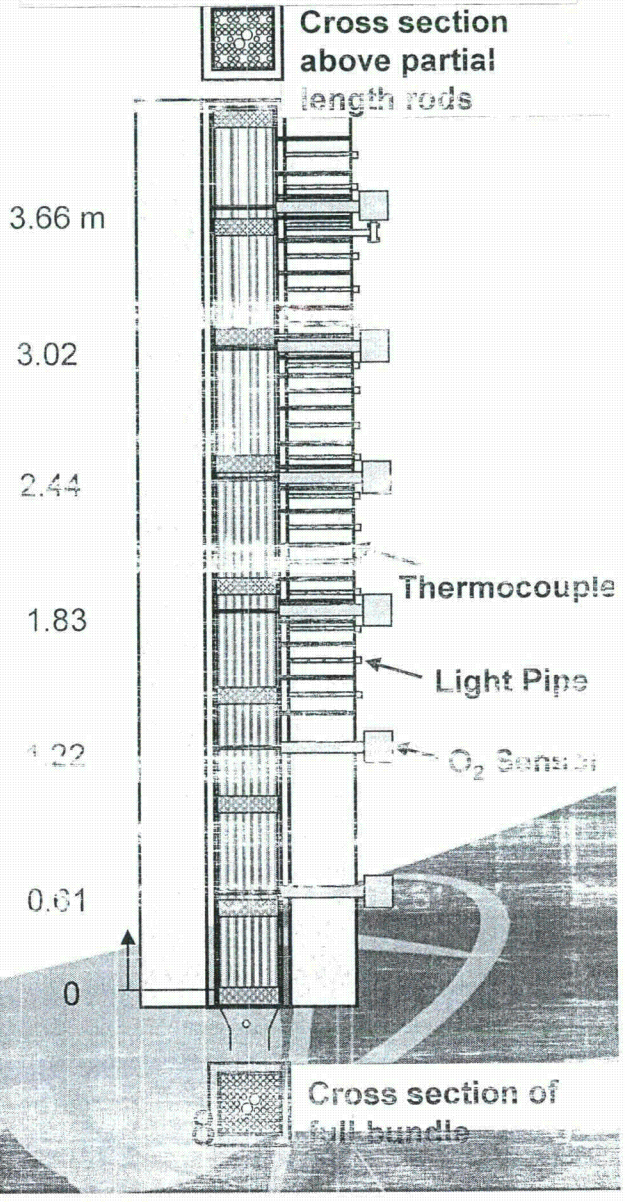
- NRC extensively reexamined pool safety and security after 9-11 attacks
  - Vulnerability to attack
  - Significantly improved analysis of fuel coolability / heatup
  - Assessment of mitigation measures to improve coolability of fuel
    - Improved fuel configuration within the pool achieves substantially greater passive cooling capability by natural convection

SFP Safety and Security

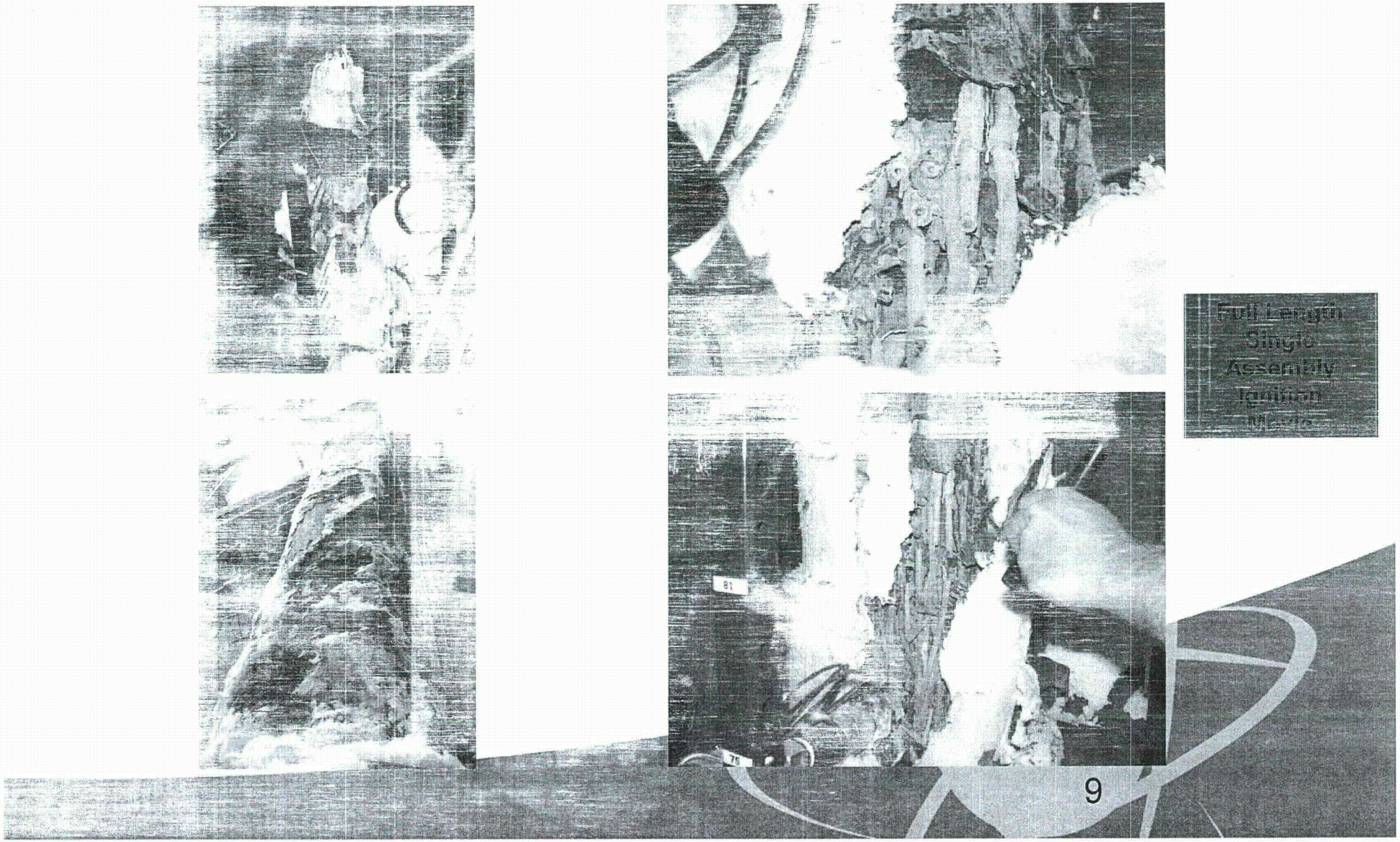
- Additional analyses of a spray system for spent fuel pool cooling
- NRC required spray capability for each site to improve active cooling capability
- Licensees performed site-specific assessments; NRC inspected
- Coolability of fuel within pools has been enhanced by measures identified and assessed as part of post-9/11 research
- Conducting research to confirm understanding and validate analytical modeling

Zirconium Fire Investigations During SFP Loss of Coolant Accident (LOCA)

- Prototypic full length 9 × 9 BWR hardware
  - Single pool rack cell
  - Upper & lower tie plates with seven spacers
  - Water tubes and channel box
  - 74 electric heater rods with Zr-2 cladding (eight partial length)
  - 5000 W simulating a 100 day old assembly
- Measurements
  - Temp profiles: Axial and radial
  - Induced flow: Effect of ignition on flow
  - O_2 concentration: Determine depletion
  - Nature of fire: Initiation location & axial burn rate



Zirc Fire Investigations During SFP LOCA – Postmortem

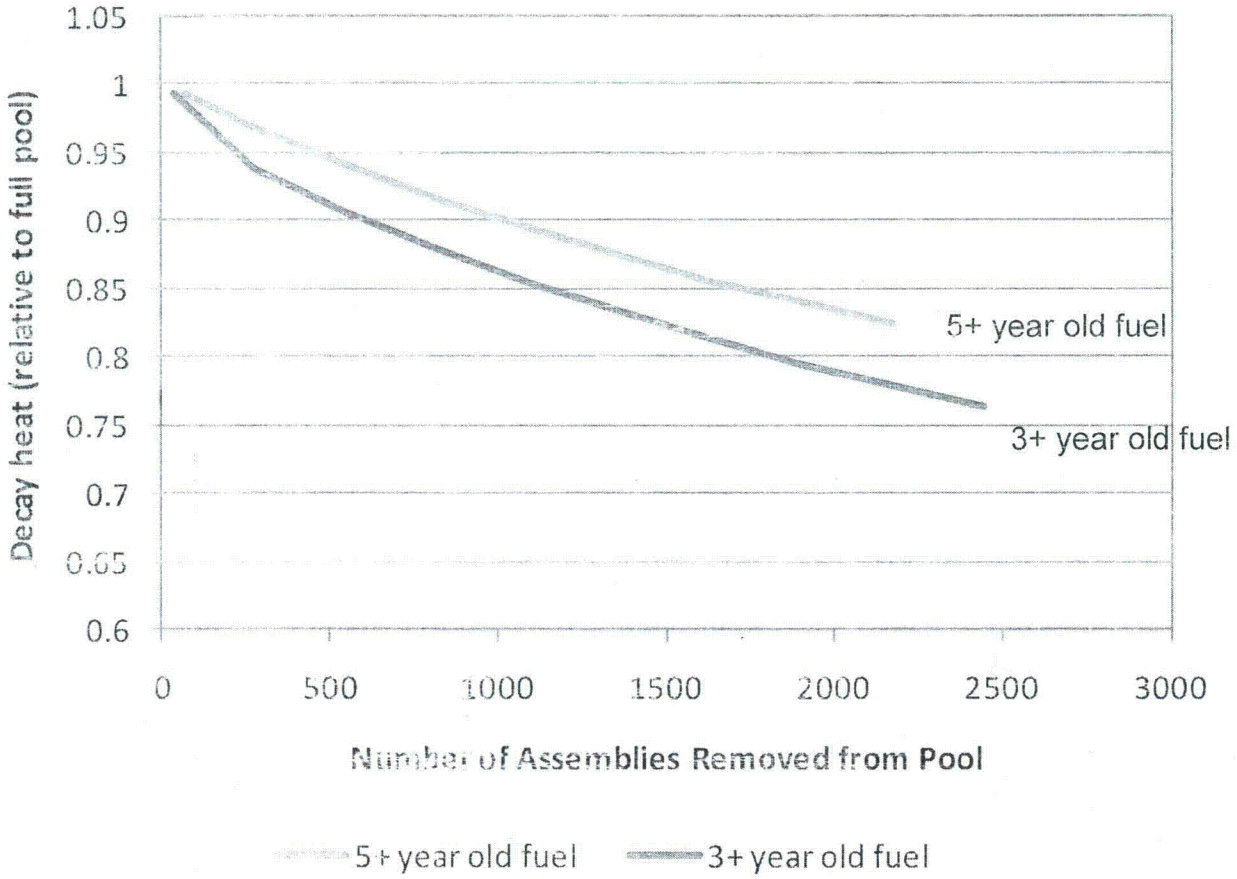


Removing Fuel from Pools

- NRC has considered benefits of removal of fuel from the pool and returning to a low density racking type configuration
- There are competing factors in such a consideration
  - Storage in dry casks must be consistent with certificate
  - Discharging of fuel increases the risk of cask drops and worker doses
  - Removal of fuel will decrease the inventory of Cesium-137
  - Removal of fuel does not appreciably reduce decay heat (most of the decay heat is from recently discharged fuel)
  - Reduction in potential land contamination and economic impacts, if a large release occurred

Impact of Removing Assemblies

Reduction of pool thermal heat load



Comparative Consequence Study

- NRC is initiating an updated SFP study
- Estimate the change in accident consequences associated with removing older fuel from the SFP and placing it in dry storage
- Limited scope analysis (e.g., single SFP/operating cycle for low/high density racking)

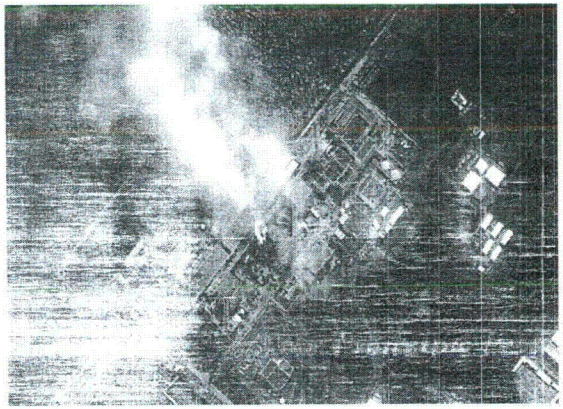
Comparative Consequence Study for SFP

- Technical approach relies on realistic analysis using expedient but technically-defensible deterministic methods and assumptions.
- Elements of study include
  - Information gathering
  - Seismic and structural assessment
  - Accessibility, decay heat, and radionuclide inventory assessment
  - Accident progression (MELCOR) and offsite consequence analysis (MACCS2)
  - Emergency planning assessment

Conclusions

- No immediate safety concerns based on Fukushima nuclear emergency
- Confirmed the existing safety measures for SFPs
- Examining both the near-term and long-term reviews
- Spent fuel needs to be managed safely and securely

OK To release



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

RESPONDING TO FUKUSHIMA-DAIICHI

Michael Weber
Deputy Executive Director for Materials, Waste, Research, State, Tribal, and Compliance Programs
U.S. Nuclear Regulatory Commission

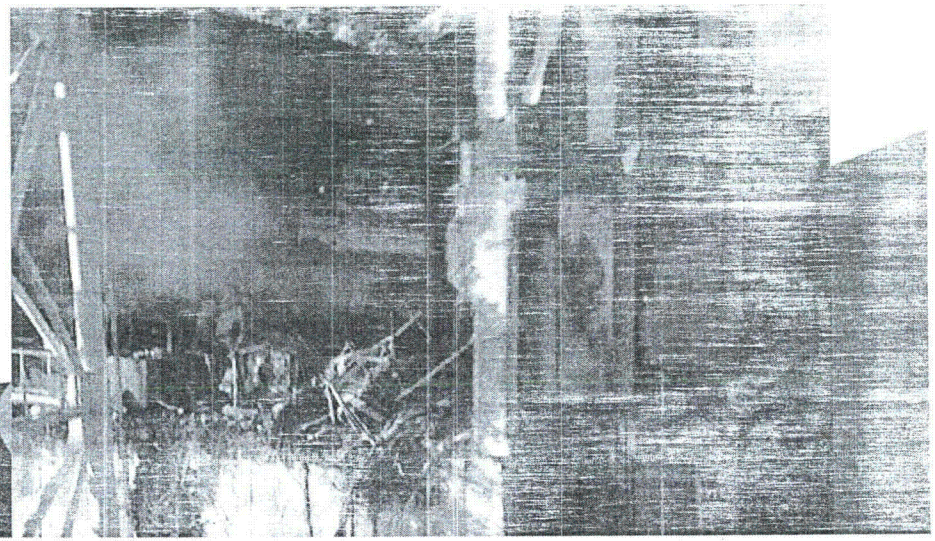
INMM – U.S. NIC Meeting
January 31, 2012

INMM
INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

Overview

United States
NIC
Nuclear Infrastructure Council

- Timeline
- Near-Term Task Force
- Enhancements
- Spent Fuel Safety
- Conclusions



Timeline

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

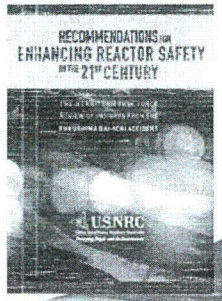
TODAY
Ongoing Stakeholder involvement as staff prepares to issue orders and requests for information

December 16, 2011
Japan Announces Cold Shutdown Fukushima Units 1, 2, and 3

December 15, 2011
Commission approved proceeding with next highest priority recommendations

October 18, 2011
Commission approved proceeding with high priority recommendations

July 12, 2011
Near-Term Task Force Report

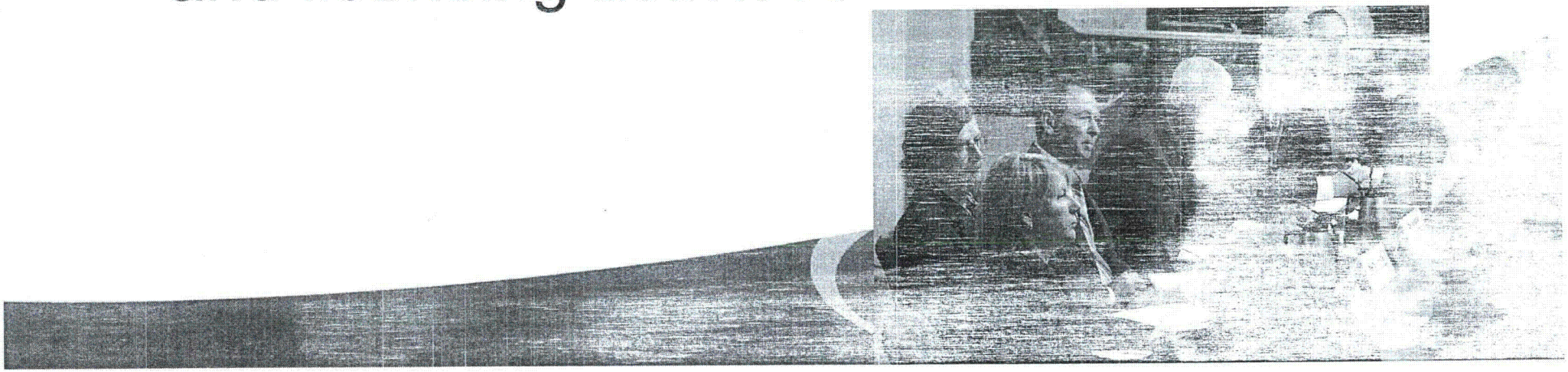


March 11, 2011
Earthquake, Tsunami, Nuclear Emergency

Current U.S. Plant Safety

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

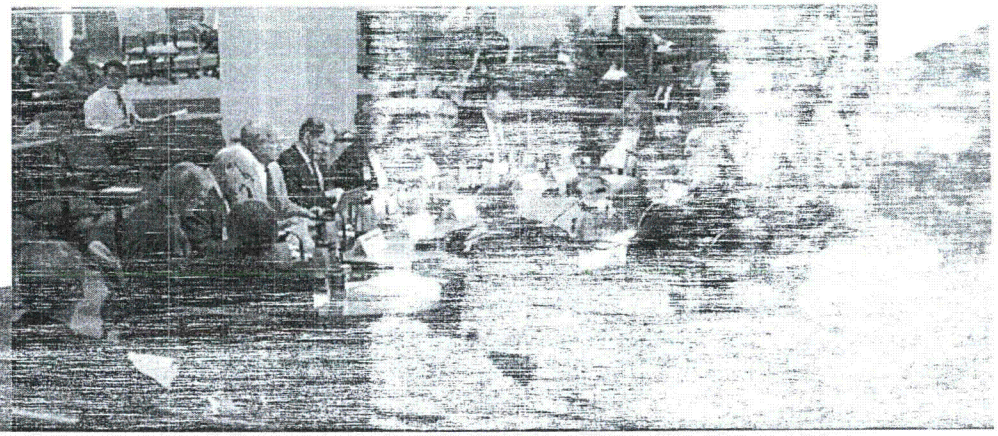
- Similar sequence of events in the U.S. is unlikely
- Existing mitigation measures could reduce the likelihood of core damage and radiological releases
- No imminent risk from continued operation and licensing activities



Approach on Near Term Enhancements

USNRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

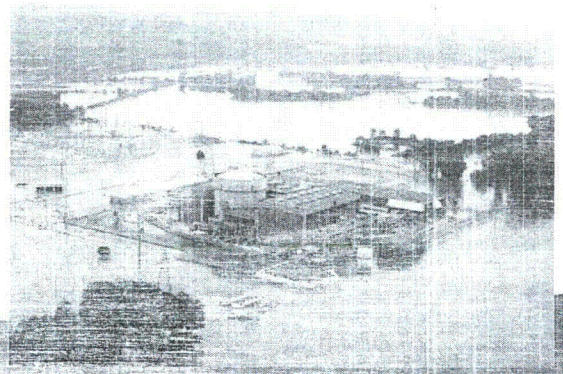
- Commission approved implementation of specific recommendations
  - Issue orders, requests for information (50.54(f) letters), and new regulations
  - Seek stakeholder input in determining action on each recommendation



Enhancements without Delay

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

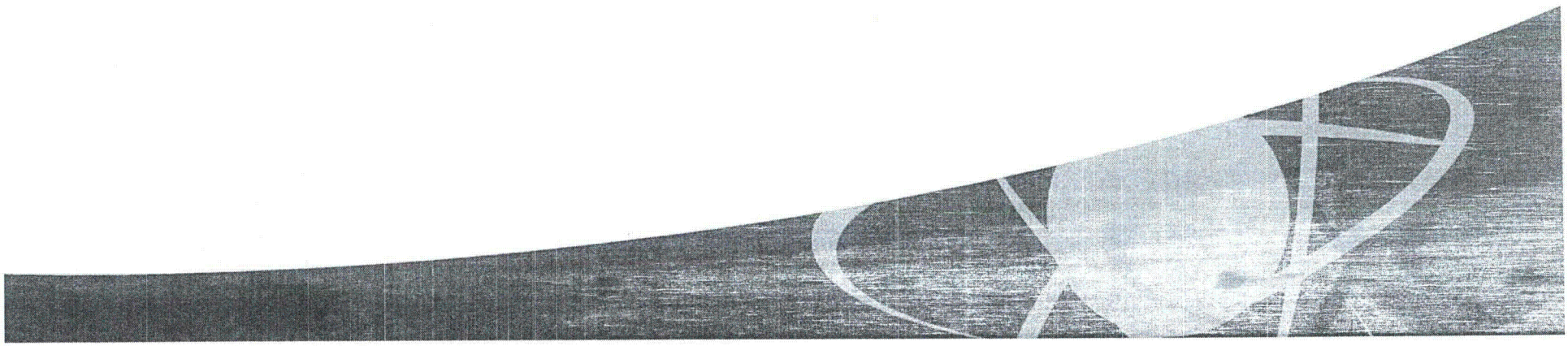
- Reevaluate external hazards, including seismic and flooding hazards
- Perform seismic and flooding hazard walkdowns
- Modify SBO rule to require enhanced capability to mitigate prolonged SBO



Enhancements without Delay (cont'd)

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

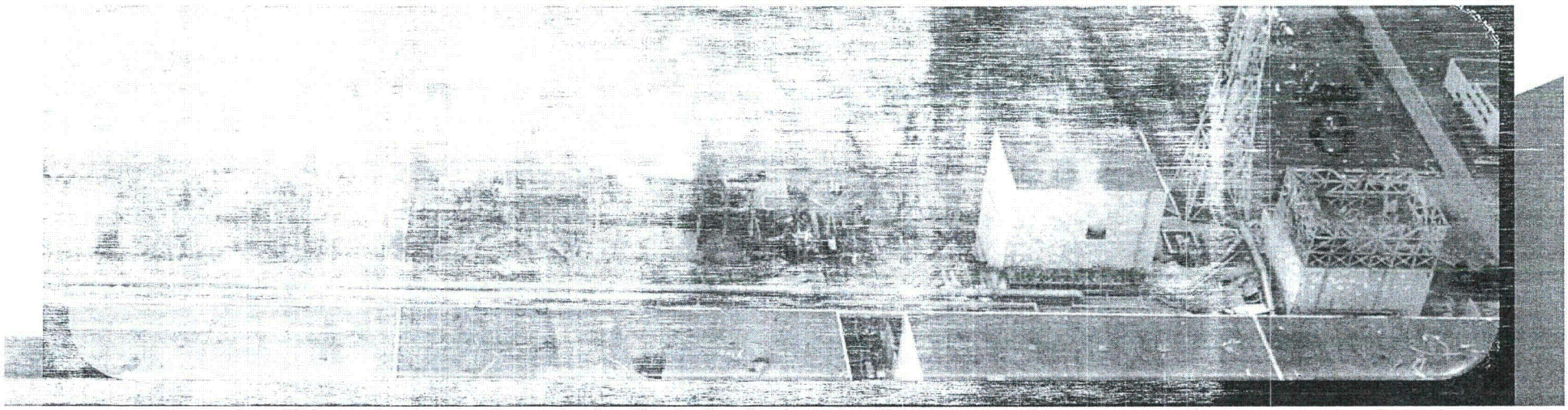
- Mitigation Strategies for Beyond Design Basis External Events
- Require reliable hardened vent designs in BWRs with Mark I and II containments
- Enhancement of spent fuel pool instrumentation



Enhancements without Delay (cont'd)

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

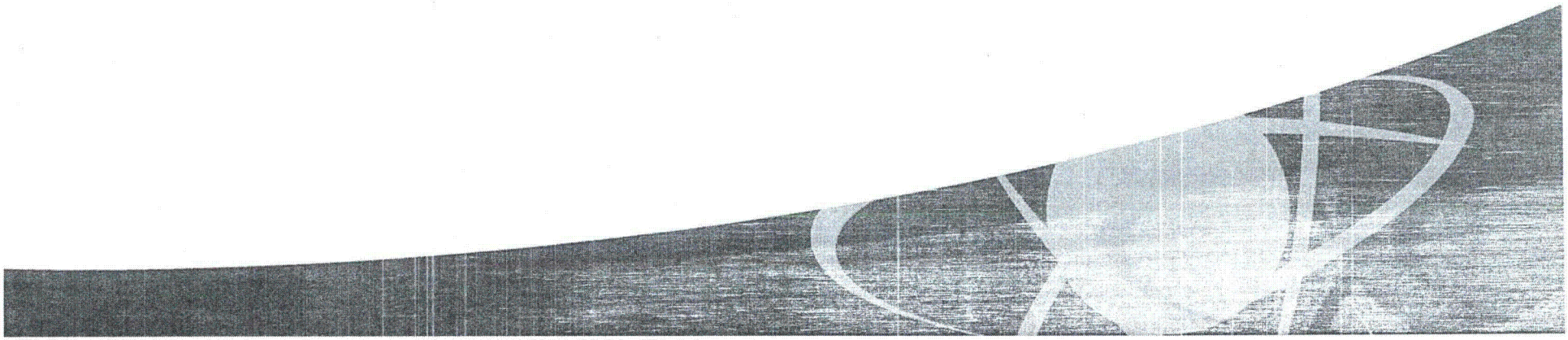
- Strengthen and integrate onsite emergency response capabilities
- Require staffing and communications equipment to respond to multiunit events and prolonged SBO



Recommendations for Other Actions

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- Tier 2 Recommendations -- Could not be initiated in the near term due to resource or critical skill set limitations
- Tier 3 Recommendations -- Require further staff study to support a regulatory action



Additional Issues

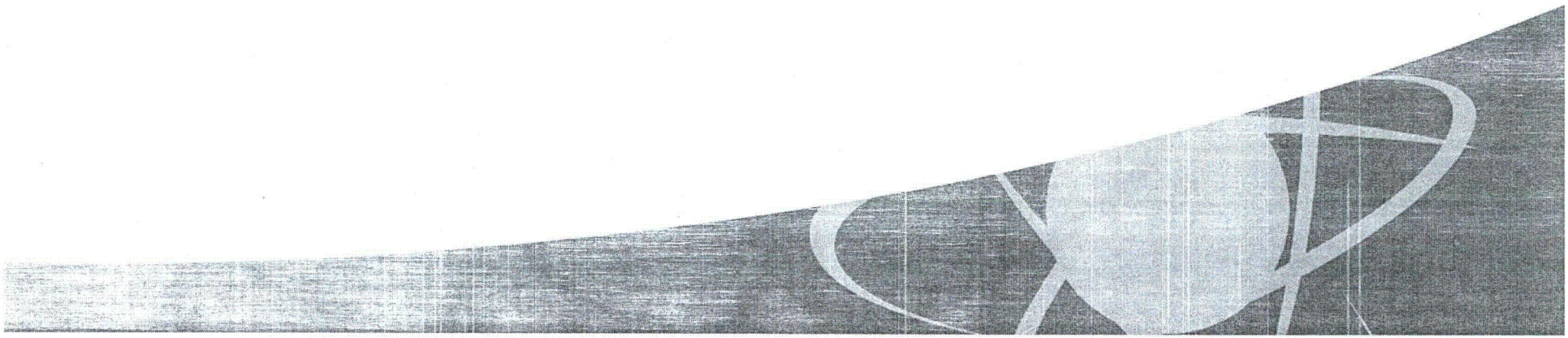
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- Filtration of Containment Vents
- Seismic Monitoring Instruments
- Emergency Planning Zone Size
- KI Beyond 10 Miles
- Dry Cask Storage
- Loss of Ultimate Heat Sink

Schedule

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

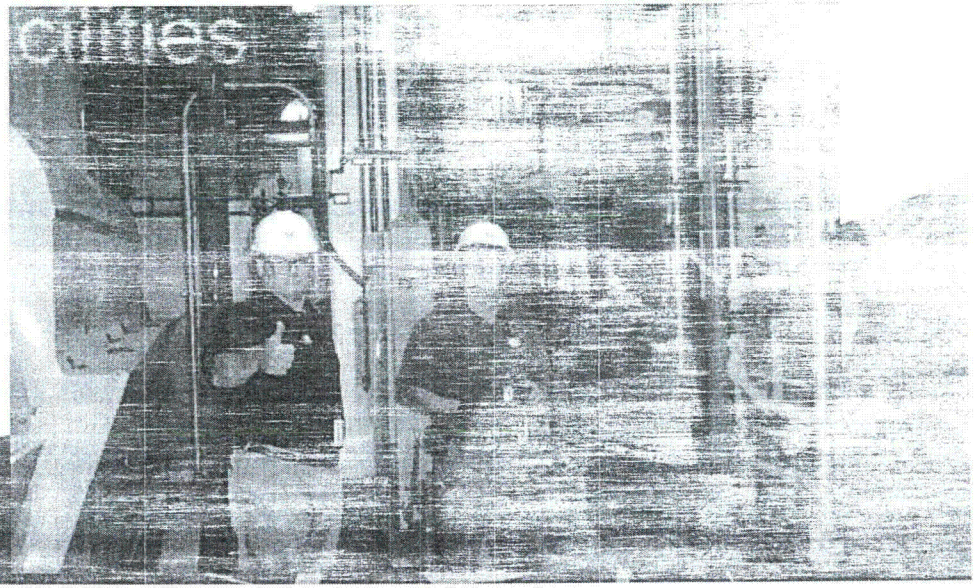
- FY2012 Appropriations -- Accelerate schedule
- NRC goal is to issue Tier 1 Orders and 50.54(f) letters by March 11th
- Planning to submit to the Commission by February 17; Commission will direct the staff
- Overall Goal -- Complete enhancements in 5 years



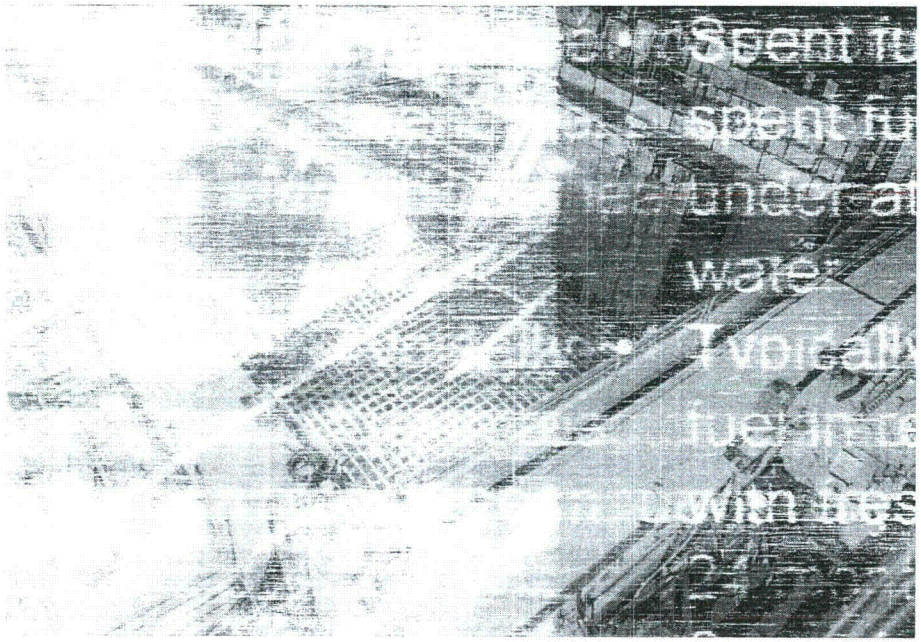
NRC Follow-up

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- Review and assess licensee responses
- Establish necessary regulatory framework
- Inspect to ensure compliance with all new regulatory requirements
- Consider implications for other nuclear facilities



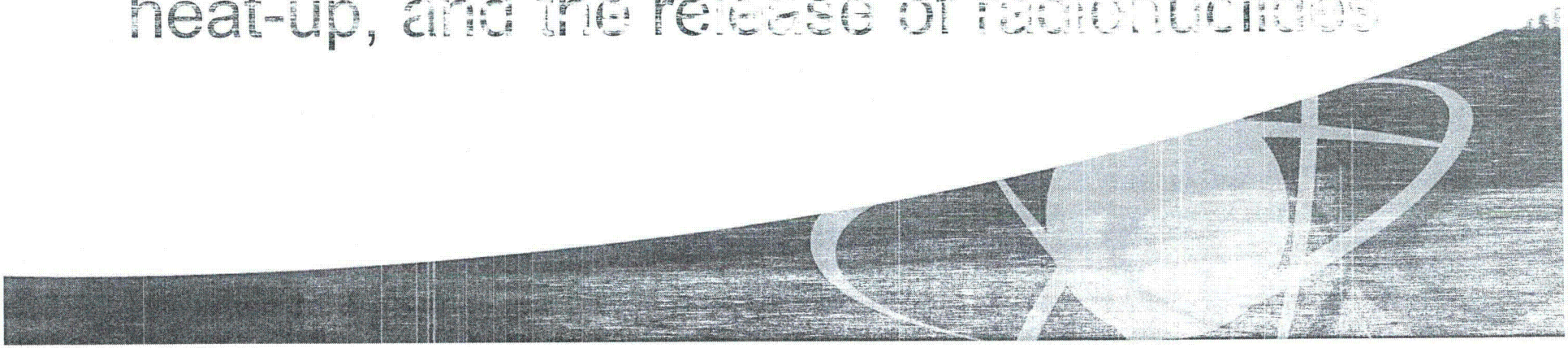
U.S. Spent Fuel Pools



- Spent fuel rods stored in spent fuel pools (SFPs) under at least 20 feet of water
- Typically ~1/4 to 1/3 of fuel in reactor replaced with fresh fuel every 18 to 24 months
- Spent fuel stored in pools minimum of 5 years

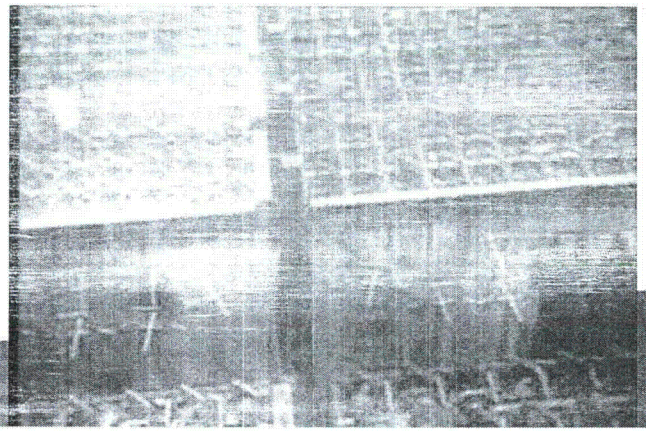
Spent Fuel Safety

- Spent Fuel Pools (SFP) originally designed for limited storage of spent fuel until removed off-site
- Safety achieved primarily by maintaining water inventory, geometry, and soluble boron (PWRs)
- Drain down can lead to uncovered fuel, heat-up, and the release of radionuclides



Risk of Large Release

- SFP risk is low, due to the very low likelihood of events that could damage the thick reinforced pool walls
  - Likelihood of fuel uncovery is low; 6E-7 to 2E-6/yr (NUREG-1738)
  - Potential consequences may be large due to heatup of the fuel in the pool
  - Heatup of the fuel in the pool can lead to "zirconium fire" initiation and propagation
  - Large inventory of ^{137}Cs available for release

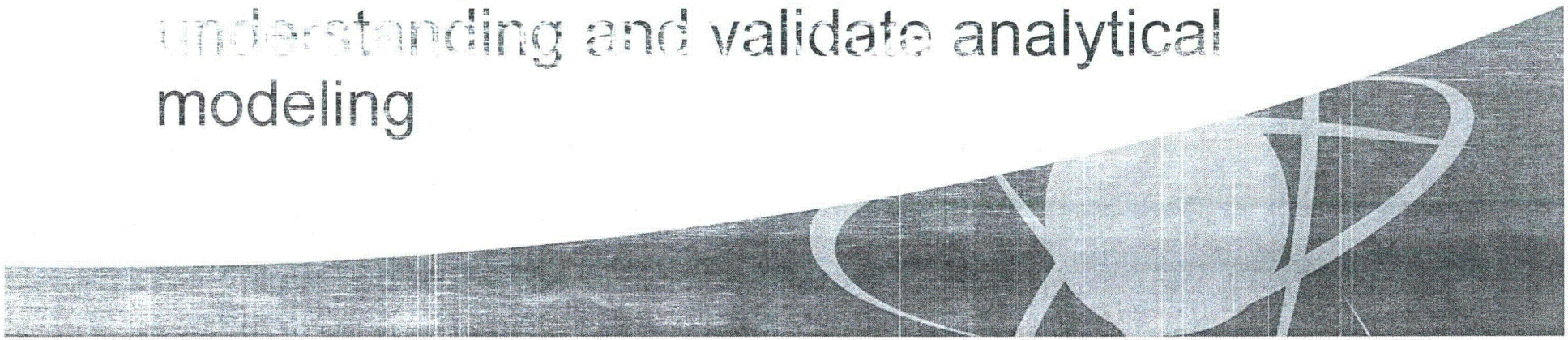


Spent Fuel Safety and Security

- NRC extensively reexamined pool safety and security after 9-11 attacks
  - Low vulnerability to attack
  - Significantly improved analysis of fuel coolability / heatup
  - Mitigation measures highlighted potential coolability of fuel
    - Improved fuel configuration within the pool achieves substantially greater passive cooling capability by natural convection

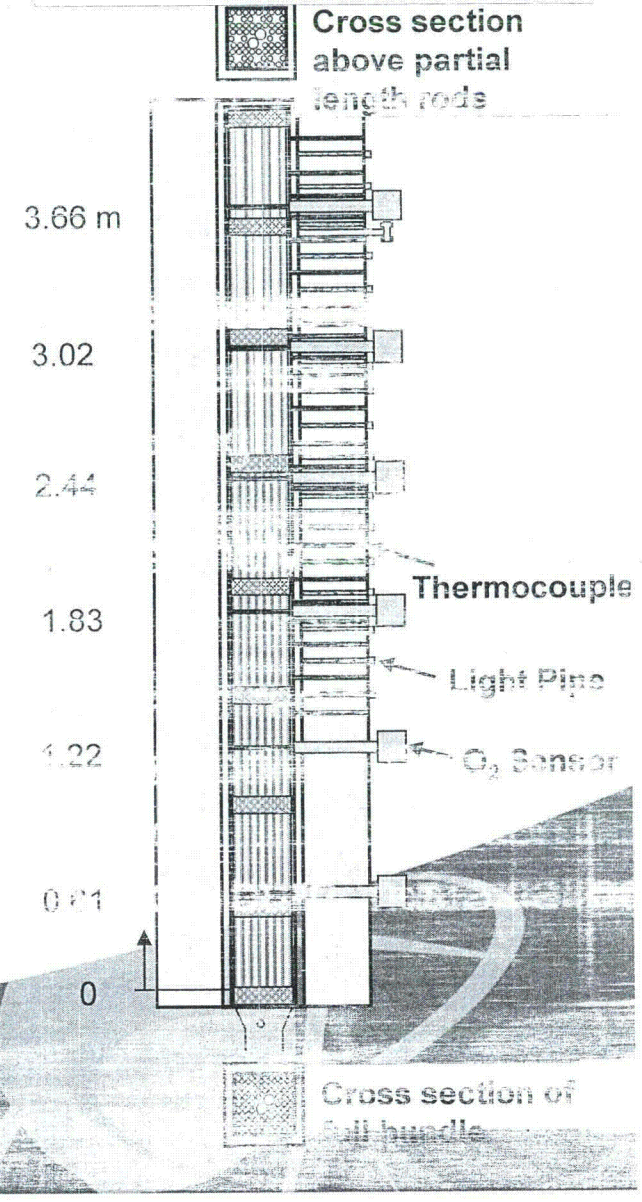
Spent Fuel Safety and Security

- NRC required spray capability for each site to improve active cooling capability
- Licensees performed site-specific assessments; NRC inspected
- Coolability of fuel within pools has been enhanced by measures identified and assessed as part of post-9/11 measures
- Conducting research to confirm understanding and validate analytical modeling

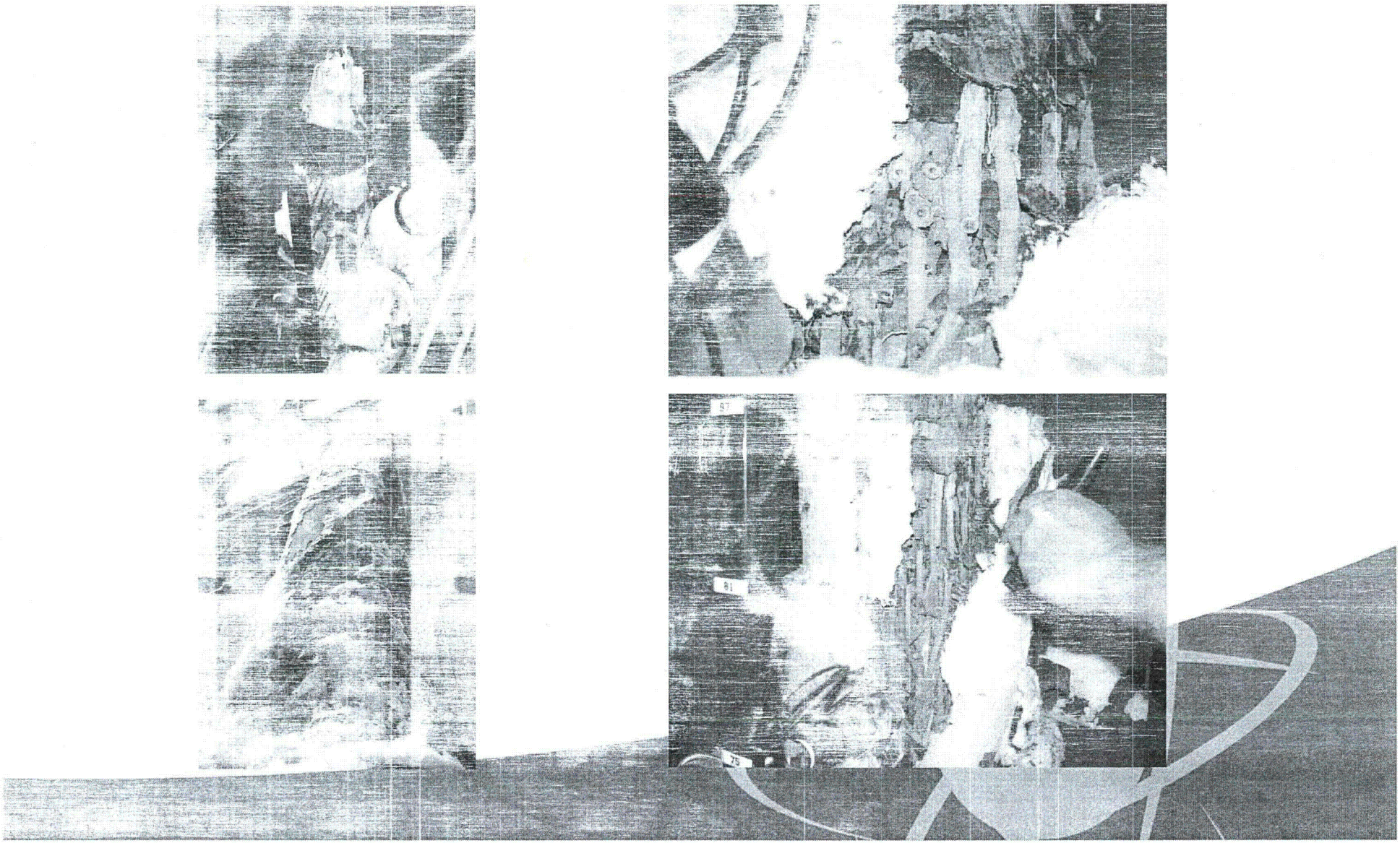


Zirconium Fire Investigations During SFP Loss of Coolant Accident (LOCA)

- Prototypic full length 9 × 9 BWR hardware
  - Single pool rack cell
  - Upper & lower tie plates with seven spacers
  - Water tubes and channel box
  - 74 electric heater rods with Zr-2 cladding (eight partial length)
  - 5000 W simulating a 100 day old assembly
- Measurements
  - Temp profiles: Axial and radial
  - Induced flow: Effect of ignition on flow
  - O_2 concentration: Determine depletion
  - Nature of fire: Initiation location & axial burn rate

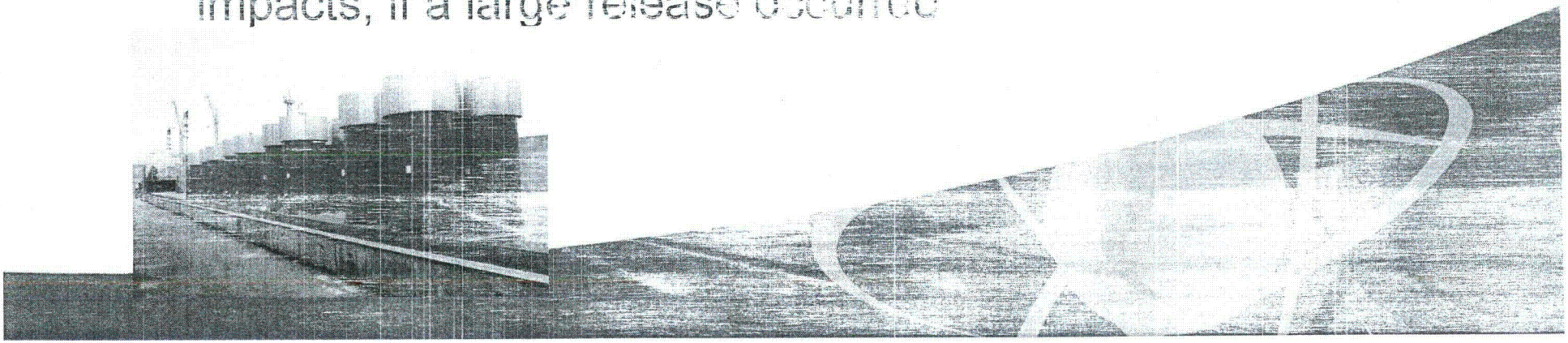


Zirc Fire Investigations During SFP LOCA – Post-test



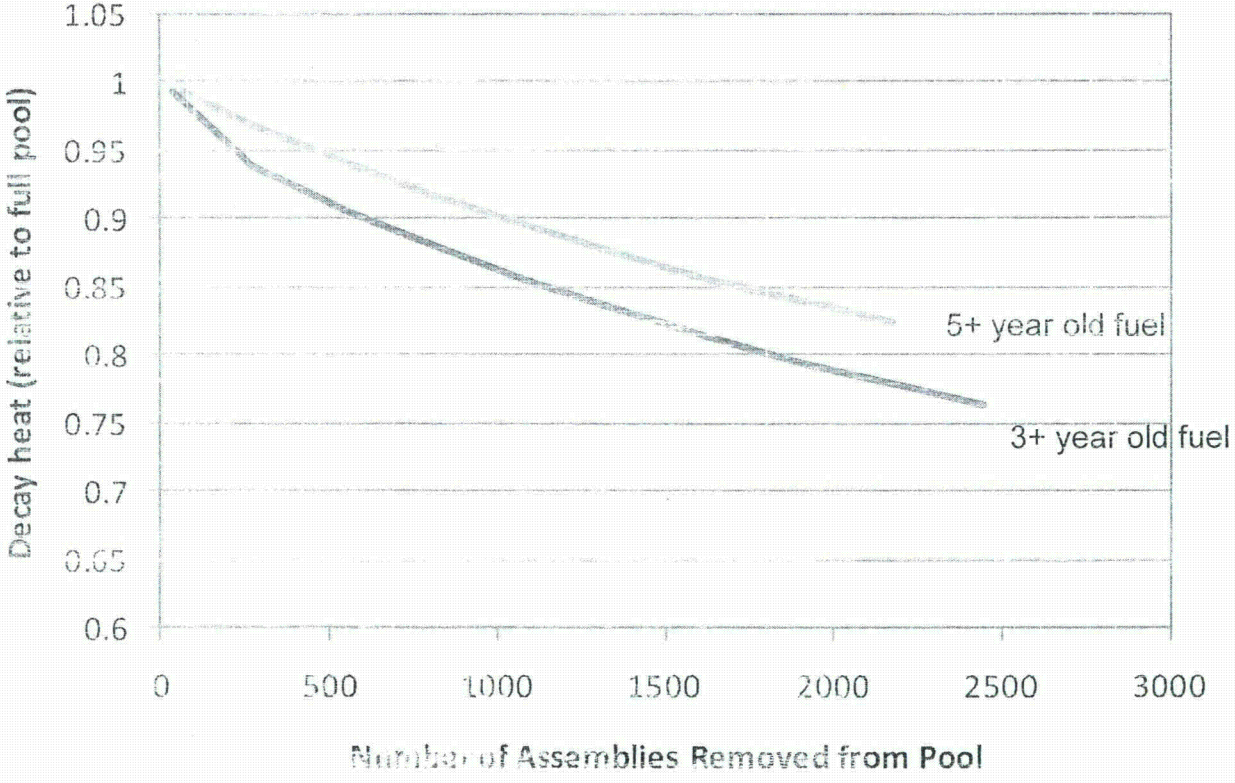
Removing Fuel from Pools

- NRC has considered benefits of removal of fuel from the pool and returning to a low density racking type configuration
- There are competing factors in such a consideration
  - Storage in dry casks must be consistent with cask design
  - Discharging of fuel increases the risk of cask drops and increases worker doses
  - Removal of fuel will decrease the inventory of Cesium-137
  - Removal of fuel does not appreciably reduce decay heat (most of the decay heat is from recently discharged fuel)
  - Reduction in potential land contamination and economic impacts, if a large release occurred



Impact of Removing Assemblies

Reduction of pool thermal heat load

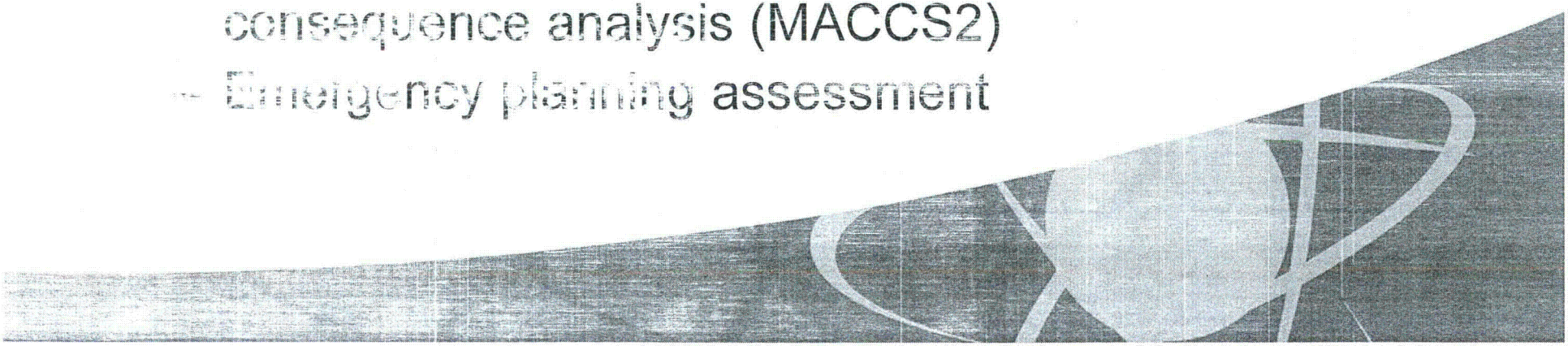


Spent Fuel Pool Scoping Study

- NRC has initiated an updated SFP study
- Estimate the change in accident consequences associated with removing older fuel from the SFP and placing it in dry storage
- Limited scope analysis (e.g., single SFP/operating cycle for low/high density racking)
- Does not comprehensively consider competing factors (e.g., impact of fuel moves)

Comparative Consequences

- Technical approach relies on realistic analysis using expedient and technically-defensible deterministic methods and assumptions
- Elements of study include
  - Information gathering
  - Seismic and structural assessment
  - Accessibility, decay heat, and radionuclide inventory assessment
  - Accident progression (MELCOR) and offsite consequence analysis (MACCS2)
  - Emergency planning assessment



Conclusions

- No immediate safety concerns based on Fukushima nuclear emergency
- Confirmed the existing safety measures for nuclear power plants, including SFPs
- Moving forward with nuclear power plant enhancements
- Examining additional near-term and long-term reviews
- Spent fuel must be managed safely and securely