

LESSONS LEARNED
from the Fukushima Nuclear Accident
for Improving Safety of U.S. Nuclear Plants

Briefing to the U.S. Nuclear Regulatory Commission

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NAS Committee on Lessons Learned from the Fukushima Nuclear Accident
for Improving Safety and Security of U.S. Nuclear Plants

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Background

- Requested by Congress in conference report from the Consolidated Appropriations Act of 2012 (P.L. 112-74)
- Sponsored by the U.S. Nuclear Regulatory Commission (USNRC)
- Carried out by an expert committee appointed by the National Academy of Sciences (NAS)

Abbreviated Statement of Task

1. Causes of the Fukushima nuclear accident.
2. Re-evaluation of conclusions from previous NAS studies on safety and security of spent nuclear fuel and high-level radioactive waste storage.
3. Lessons that can be learned from the accident to improve commercial nuclear plant safety and security systems and operations.
4. Lessons that can be learned from the accident to improve commercial nuclear plant safety and security regulations.

➤ **This report addresses Tasks 1, 3, and 4. Task 2 will be addressed in a separate report.**

Study Objective

NAS study is intended to be a broad-scope and high-level review of lessons-learned from the Fukushima Daiichi accident to improve safety and security of U.S. nuclear plants:

- Study considered many previously published reports on the Fukushima Daiichi accident, including the report from the USNRC's Near-Term Task Force.
- Study also evaluated previously published accident timelines to obtain a better understanding of key events and unit interactions at the Fukushima Daiichi plant.

Report Findings and Recommendations

- Lessons learned presented as “findings.”
- Suggestions for implementing lessons learned in the United States presented as “recommendations.”
 - Recommendations are not prioritized.
- Report does not make policy recommendations that involve non-technical value judgments.

Selected Findings in Brief

Causes of the Fukushima Accident

The Fukushima Daiichi nuclear accident was initiated by the March 11, 2011, Great East Japan Earthquake and tsunami. Personnel at the plant responded to the accident with courage and resilience; their actions likely reduced its severity and the magnitude of offsite radioactive material releases. However, several factors relating to the management, design, and operation of the plant prevented plant personnel from achieving greater success and contributed to the overall severity of the accident.

Overarching Finding

Nuclear plant licensees and their regulators must actively seek out and act on new information about hazards that have the potential to affect the safety of nuclear plants.

Selected Recommendations in Brief

Nuclear Plant Systems

USNRC and U.S. nuclear industry should give specific attention to improving

- DC power for instrumentation and safety system control.
- Tools for estimating real-time plant status during loss of power.
- Decay-heat removal and reactor depressurization and containment venting systems and protocols.
- Instrumentation for monitoring critical thermodynamic parameters in reactors, containments, and spent fuel pools.
- Hydrogen monitoring and mitigation.
- Instrumentation for onsite and offsite radiation and security monitoring.
- Communications and real-time information systems to support communication and coordination between control rooms and technical support centers, control rooms and the field, and between onsite and offsite support facilities.

Training

USNRC and U.S. nuclear industry should give specific attention to

- Staffing levels for emergencies involving multiple reactors at a site, that last for extended durations, and/or that involve stranded plant conditions.
- Strengthening and better integrating emergency procedures, extensive damage mitigation guidelines, and severe accident management guidelines.
- Training of operators and plant emergency response organizations
 - on the use of ad hoc responses for bringing reactors to safe shutdown during extreme beyond-design-basis events.
 - to reinforce understanding of nuclear plant system design and operation and enhance operators' capabilities for managing emergency situations.

Risk Assessment

- U.S. nuclear industry and USNRC should strengthen their capabilities for assessing risks from events that could challenge the design of nuclear plant structures and components and lead to a loss of critical safety functions. The USNRC should support industry's efforts to strengthen its capabilities by providing guidance on approaches and by overseeing rigorous peer review.
- USNRC should further incorporate modern risk concepts into its nuclear safety regulations using these strengthened capabilities.
- The report highlights the advantages and disadvantages of PRA but does not recommend a specific risk analysis methodology.

Offsite Emergency Response

- U.S nuclear industry and organizations with emergency management responsibilities should assess their preparedness for severe nuclear accidents associated with offsite regional-scale disasters.
- U.S. nuclear industry and organizations with emergency management responsibilities should examine and, as needed, revise their emergency response plans, including the balance among protective actions, to enable effective responses to severe nuclear accidents.

Nuclear Safety Culture

- USNRC and U.S. nuclear industry must maintain and continuously monitor a strong nuclear safety culture in all of their safety-related activities. The leadership of the USNRC must maintain the independence of the regulator.
- USNRC and U.S. nuclear industry should examine opportunities to increase the transparency of and communication about their efforts to assess and improve their nuclear safety cultures.

Comparison of NAS and Other Studies

- Many findings and recommendations in this NAS report mirror those made by other organizations, including the USNRC Near-Term Task Force.
- However, the NAS report provides different perspectives on some issues.

Report Perspectives

Accident causes (Chapter 4)

- Emphasizes the challenges that plant operators faced in responding to the accident.
- Emphasizes the important role that operators played in lessening the severity of the accident; operators were a source of resilience and their improvised solutions were a key strength of response efforts.
- Emphasizes the “game changing” nature of hydrogen explosions on managing the accident.
- Notes that events at Fukushima Daiichi represent a “cliff edge” in accident management capabilities; the loss of all AC and DC power at Fukushima Daiichi precipitated a series of cascading failures that overwhelmed operators.

Report Perspectives (2)

Plant improvements (Chapter 5)

- Emphasizes the availability, reliability, redundancy, and diversity of plant systems and equipment for
 - DC power for instrumentation and safety system control
 - Tools for estimating real-time plant status during loss of power
 - Instrumentation for onsite and offsite radiation and security monitoring

Training (Chapter 5)

- Emphasizes specific training on the use of ad hoc responses for safe shutdown during beyond-design-basis events and more general training (e.g., coordination between Technical Support Center and control room) to enable more effective responses to unanticipated complexities.

Report Perspectives (3)

Risk (Chapter 5)

- Emphasizes need for strengthening capabilities for identifying, evaluating and managing risks from beyond-design-basis events and better estimating the broad range of offsite health, environmental, economic, and social consequences.
- Emphasizes the inadequacy of the “design-basis accident” as a paradigm for preventing core-melt accidents and mitigating their consequences.

Report Perspectives (4)

Offsite emergency response (Chapter 6)

- Emphasizes the importance of scalability of emergency response capabilities to deal with accidents associated with regional disasters.
- Emphasizes the need for assessing the balance of protective actions.

Safety Culture (Chapter 7)

- Emphasizes the importance of a strong nuclear safety culture, an independent regulator, and greater transparency and communication.

Extra Slides

Full Statement of Task

1. Causes of the Fukushima nuclear accident, particularly with respect to the performance of safety systems and operator response following the earthquake and tsunami.
2. Re-evaluation of the conclusions from previous NAS studies on safety and security of spent nuclear fuel and high-level radioactive waste storage, particularly with respect to the safety and security of current storage arrangements and alternative arrangements in which the amount of commercial spent fuel stored in pools is reduced.
3. Lessons that can be learned from the accident to improve commercial nuclear plant safety and security systems and operations.
4. Lessons that can be learned from the accident to improve commercial nuclear plant safety and security regulations, including processes for identifying and applying design basis events for accidents and terrorist attacks to existing nuclear plants.

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PRA Discussion in Chapter 5

PRA: Advantages

- PRA is based on well-established risk assessment principles.
- PRA is already being used to assess and mitigate internal hazards at nuclear plants and to establish maintenance and test protocols. Consequently, plant licensees are familiar with its use.
- PRA can be used to identify non-rare-event scenarios that result from plant design or operational flaws that may not be uncovered in the design-basis regulatory review.
- PRA can provide an integrated examination of plant design and operations.
- If executed properly, PRAs can provide a systematic examination of external hazards and their potential consequences.

PRA: Disadvantages

- PRAs are expensive and can be time consuming to produce and maintain.
- Extending the scope of PRAs will require additional technical expertise, especially in containment response analysis and offsite impacts. Obtaining this expertise could be difficult for industry and the USNRC.
- PRAs that have been performed generally do not adequately account for human error in design, construction, maintenance, and operation of nuclear plants or for intentional sabotage.
- The results of PRAs are limited by experts' ability to recognize all relevant phenomena, including potentially important external hazards, and by uncertainties and incompleteness of estimates of accident probabilities and consequences.
- The results of full-scope Level 3 PRAs are also limited by the ability to validate phenomenological modeling of core damage and radioactive release as well as consequence modeling.

PRA Practices in Japan

- Not required by rule prior to the Fukushima Daiichi accident.
- Japan Nuclear and Industrial Safety Agency (NISA) did require plant owners to perform PRAs to support license issuance and renewal—generally Level 1.5.
- PRAs included internal events only, but they covered both full-power and shutdown conditions, and guidelines for earthquake PRAs did exist. The PRAs did not quantify uncertainties.
- PRAs were on a unit-by-unit basis.
- No dedicated PRA staffs at the plants or operating company headquarters.
- No one-to-one correspondence between PRA scenarios and training.
- PRA does not play a major role in decision-making or compliance.

PRA Practices in the United States

- Not required by rule for existing plants.
- If PRA is a basis for license renewal or to support a modification, USNRC requires it to be current.
- All plants have some level of a PRA—generally Level 1 and elements of Level 2.
- PRAs are used extensively by both the industry and the regulator.
- New plants require Level 1 and Level 2 PRAs.
- PRAs include limited scope treatment of external events.
- Only a few include external floods and low-power risks.
- PRAs are on a unit-by-unit basis.