Challenges for Nuclear Safety from Viewpoint of Natural Hazard Risk Management

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Introduction

- Use of nuclear energy
  - ✓Involves potential risk associated with accidents (Clearly recognized by experiences during the Fukushima Daiichi NPP Accident)
- Analysis of the experiences before, during and after the accident is essential
  - ✓To discuss the public acceptance of nuclear power in the future
- Future challenges addressed by several reports on the Fukushima Daiichi NPP Accident are summarized from the viewpoint of natural hazard risk management

Lack of Understanding for Retained Risk

- Risk management is the process which consists of
  - ✓ Identification of risk
  - ✓ Assessment of identified risk
  - ✓ Evaluation of assessed risk
  - ✓ Treatment of evaluated risk
  - ✓ Monitoring of treated and/or retained risk
- Contingency plan, or emergency plan
  - ✓ For preparation for retained risk
- Nuclear operators together with regulator may fail preparing the contingency plan in case that risk becomes obvious
  - ✓ Risk assessment had been used to prove that a plant is safe enough
  - ✓ Probability of occurrence of accident was used only to judge whether risk is acceptable or not

Risk-informed Framework for Nuclear Safety

- Conventionally, risk R is defined as the mean value for possible adverse consequences as:

  $R=\sum i\uparrow\blacksquare C\downarrow i\, P\downarrow i$

  ✓ Where, $C\downarrow i$ is the consequence and $P\downarrow i$ is the probability of occurrence of $C\downarrow i$

- From the viewpoint of risk management, risk is defined more generally as (Kaplan & Garrick, 1981):

  ✓ What can go wrong? (Scenario)

  ✓ How likely is it? (Likelihood)

  ✓ What its consequences might be? (Consequence)

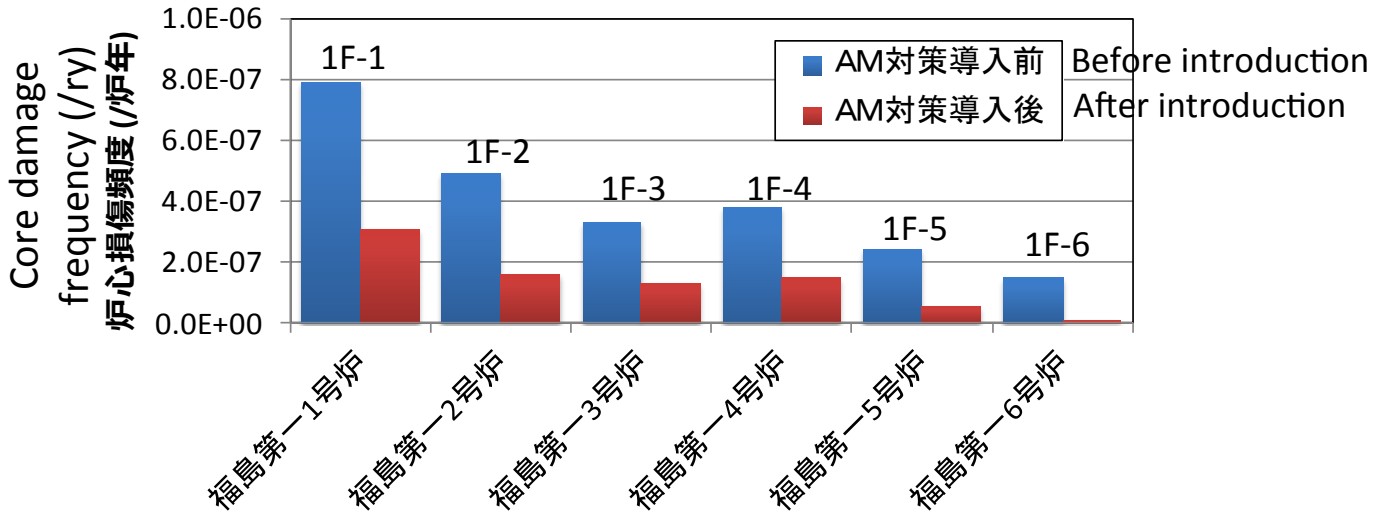
  ➢ What is within/out of scope?

  ➢ How much uncertain the result of risk assessment is?

  ✓ For use of appropriate decision-making by enhancing communication among experts as well as stakeholders

Inappropriate Use of Risk Assessment

- For Japanese NPPs, accident management was planned and introduced as countermeasures for severe accidents around 2000
  - ✓By operators as voluntary basis without regulatory requirements
  - ✓ Internal PRA (probabilistic risk assessment) to confirm the effectiveness of introduction of the countermeasures



http://warp.ndl.go.jp/info:ndljp/pid/286890/www.meti.go.jp/press/0005696/0/041018accident.pdf

Inappropriate Use of Risk Assessment (cont.)

- For Japanese NPPs, accident management was planned and introduced as countermeasures for severe accidents around 2000
  - ✓By operators as voluntary basis without regulatory requirements
  - ✓ Internal PRA (probabilistic risk assessment) to confirm the effectiveness of introduction of the countermeasures
  - ✓The main source of risk had been recognized not from internal events but from external events like earthquake
    - Accident management was not yet reinforced for external events by continuous efforts
    - A standardized method was prepared and published as AESJ standard for seismic PRA by 2007
    - Natural hazard risk assessment was not published for each specific plant in Japan before the Fukushima Daiichi NPP Accident in 2011.

Defense in Depth

Level of DiD	Objective	Achieved mainly by
Level 1	Prevention of abnormal operation and failures	Plant design
Level 2	Control of abnormal operation and detection of failure	
Level 3	Control of accident within the design basis	
Level 4	Control of severe plant conditions including prevention of accident progression and mitigation of severe accident consequences	Severe Accident Management
Level 5	Mitigation of radiological consequences of significant off-site releases of radioactive materials	Emergency response

- "Independent effectiveness" is considered to be an essential element of DiD

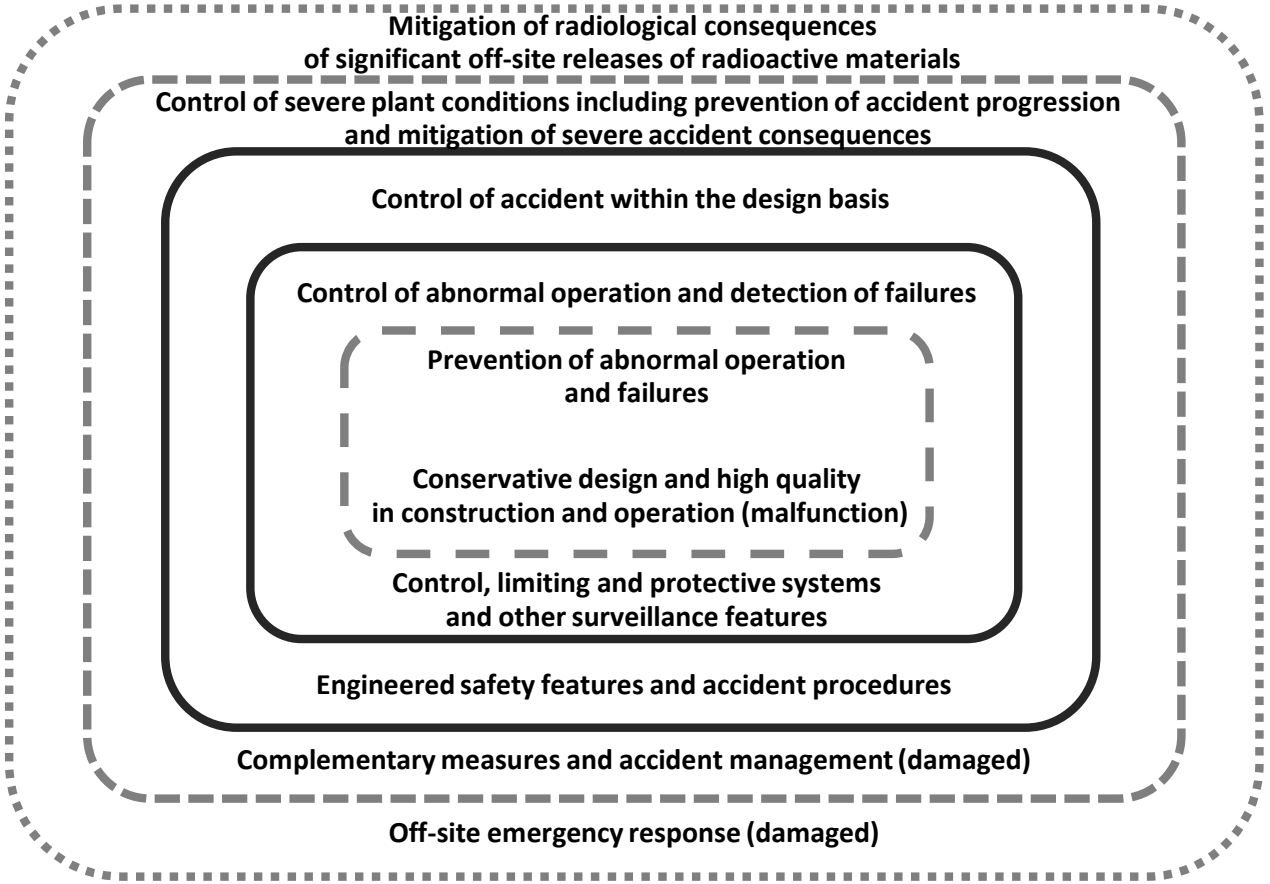
Defense in Depth (cont.)

- Conventionally, it had been considered that natural hazard risks can be avoided
  - ✓Through appropriate siting criteria and
  - ✓Through conservative design
  - ✓Without any consideration of higher levels of defense in depth

- Accident management introduced at NPPs in Japan around 2000
  - ✓Mainly for accidents from internal event
  - ✓Based on an implicit (ideal) assumption of above-mentioned ideal condition
  - ✓No effective mechanism to evaluate and reduce the risk from both internal and external events continuously

Defense in Depth (cont.)

- Levels 4 and 5 activities are not hardware-oriented but management-based
- Hardware related to Levels 4 and 5 DiDs may suffer damage prior to levels 2 and 3 DiDs



Modified based on IAEA INSAG-10

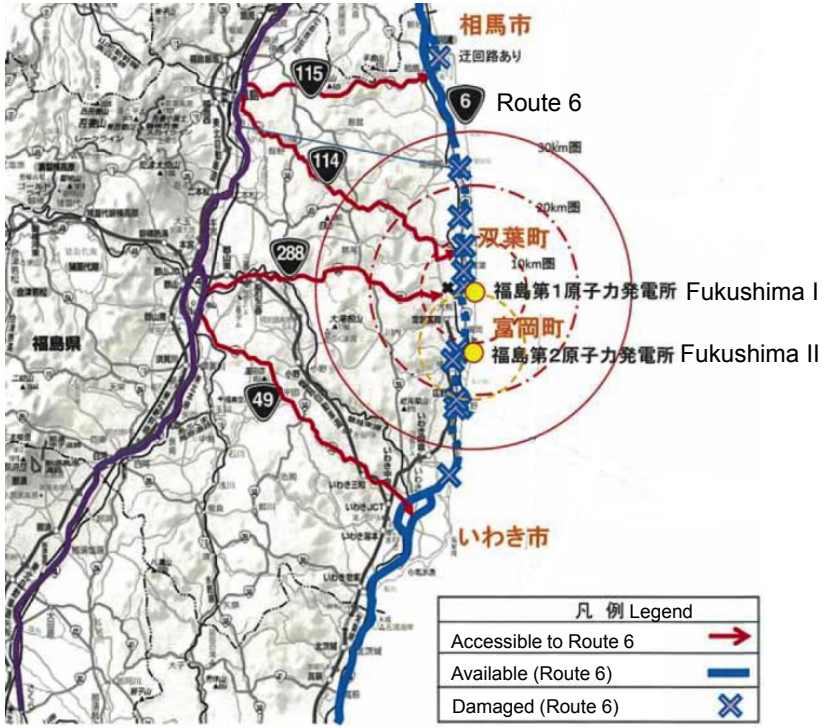
Earthquake- and Tsunami-Resistant Design

- Reference probability for NPP design basis is equal to or smaller than that of regional disaster prevention & mitigation
- On-site and off-site facilities other than reactor building are designed to resist a smaller natural event than a reactor building

		Annual probability of exceedance for design basis hazard	Cf. Exceedance probability in 50 years
Design ground motion for NPP	Level 1	10^{-2} (mean) (IAEA)	40% (mean) (IAEA)
	Level 2	10^{-4}-10^{-3} (mean) (IAEA) 10^{-5}-10^{-4} (median) (IAEA)	0.5%-5% (mean) (IAEA) 0.05%-0.5% (median) (IAEA)
Design ground motion for civil structure	Serviceability limit state	1/500-1/25 (AS/NZ) 1/50-1/20 (Japan)	5%-86%(AS/NZ) 63%-92% (Japan)
	Ultimate limit state	1/2500 (US) 1/2500-1/250 (AS/NZ) 1/500-1/1000 (Japan)	2% (US) 2%-20% (AS/NZ) 5%-10% (Japan)
Cf. Regional disaster prevention & mitigation		<10^{-3} (Japan)	<5% (Japan)

Regional Disaster Prevention/Mitigation

- It is of significant public concern that people can successfully evacuate from the nuclear accident (and can return home after accident).
- For the off-site emergency response, it is critically important that we recognize that off-site facilities suffer nuclear disaster after damage due to natural events.



Possible Interaction

- The difficulty for the local residents in evacuation and also the difficulty for the nuclear site to receive supports from external organization, due to spatial distribution of damage of infrastructure.
- The rescue activity for people suffered by severe natural event is disturbed, because of the forced evacuation due to nuclear accident, i.e., a rescue team is forced to leave the site.
- People are discouraged twice both by natural event as well as by nuclear disaster.

Summary

- Challenges for nuclear safety with respect to natural hazard risk management are summarized from the viewpoint of
  - ✓Risk-informed framework
  - ✓Defense in depth
  - ✓Design
  - ✓Regional disaster prevention/mitigation

- Total system view, not only NPP itself but also the site region, is important, when safety of NPP is discussed