Lessons Learned for Space Safety from the Fukushima Nuclear Power Plant Accident

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The information about Fukushima Dai-ichi Nuclear Power Station (NPS) accident in this paper were mainly referred to the following reports. Please visit their website for more detailed information.

(1) "Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety - The Accident at TEPCO's Fukushima Nuclear Power Stations -".

**TEPCO: Tokyo Electrical Power Company*

http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html

(2) Additional Report of Japanese Government to the IAEA (Second Report)

http://www.meti.go.jp/english/earthquake/nuclear/iaea/iaea_110911.html

(3) The official report of the Fukushima NuclearAccident Independent Investigation Commission http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/report/

(4) Final Report, published by Committee on the Accident at Fukushima Nuclear Power Stations on July 23 2012. http://www.cas.go.jp/jp/seisaku/icanps/eng/

Contents

1. Purpose

- ✓ This paper will introduce lessons learned from Fukushima nuclear accident described in the reports published by the several investigation boards.

  (Please refer to the slide #2)

- ✓ Space safety can learn a lot of things from these lessons learned bacause space system safey is similar to NPS safety from many kinds of perspective. Therefore, this paper will also provide discussion to establish more robust safety in the space systems.

2.1. Overview of Great Eastern Japan Earthquake

The Japan Meteorological Agency
http://www.jma.go.jp/jma/en/2011_Earthquake.html

◆The Great Eastern Japan Earthquake

The earthquake brought crustal movement to the Japan Islands.

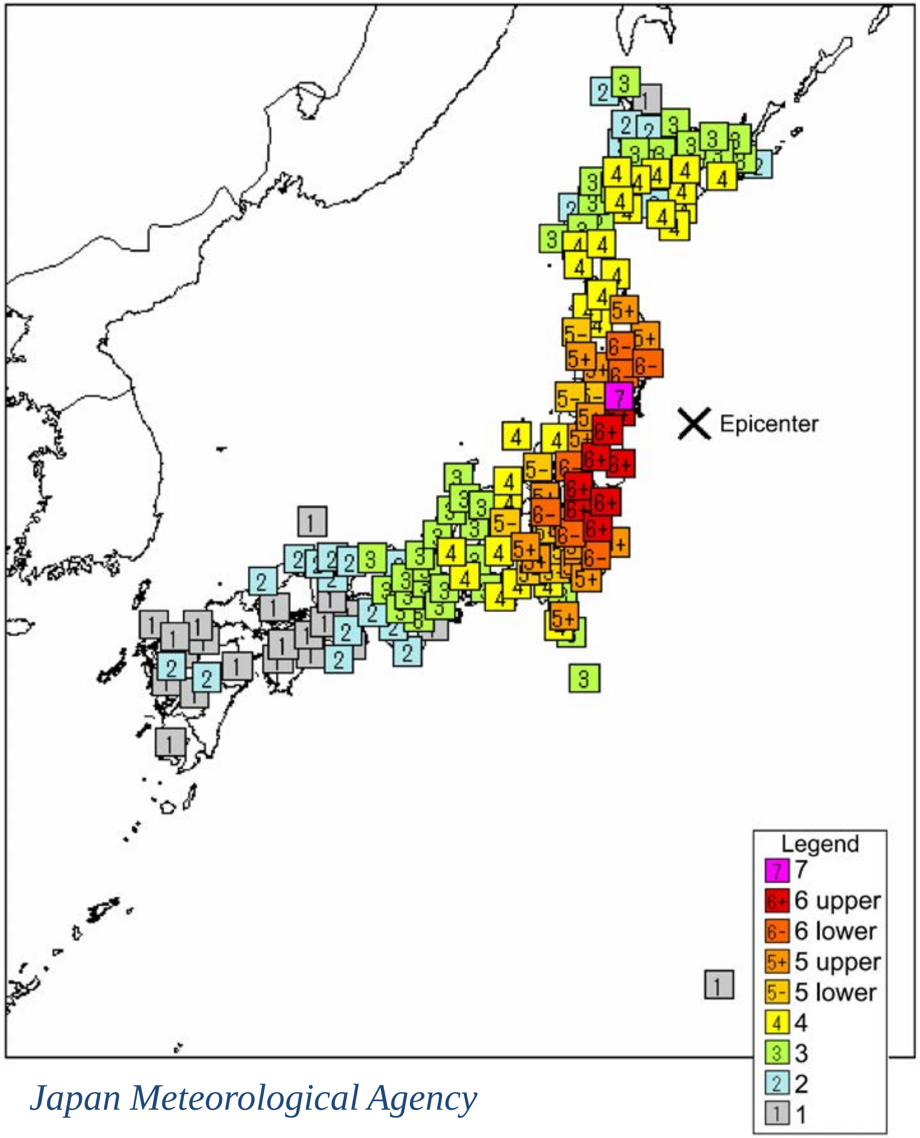
Information	Data	
Date and Time	11 March 2011 14:46 JST (05:46 UTC)	
Magnitude	9.0 (The largest earthquake recorded in Japan)	
JMA Seismic Intensity	7 (Max)	Kurihara City of Miyagi Prefecture
	6+	28 cities and towns in Miyagi, Fukushima, Ibaraki, and Tochigi Prefectures
	6- or weaker	Observed nationwide from Hokkaido to Kyushu (5+ at Tokyo)

◆ Tsunami

– Tsunami hit Northern Main Island and Metropolitan area for 7 times.
  - Submerged area: more than 561 km^2
  - The height of Tsunami: 40m (maximum)

2.1.   Overview of Great Eastern Japan Earthquake

Distribution of seismic intensity



Japan Meteorological Agency

Ministry of Defense
http://www.mod.go.jp/e/d_act/disaster/photo.html

2.2. Overview of Fukushima Dai-ichi NPS accident

[Loss of Electrical Power]

- ✓ Immediately after the earthquake struck, the emergency shutdown of reactors was occurred due to the excessive earthquake acceleration (at 14:16 on March 11).

  => Nuclear reaction was stopped successfully.

- ✓ The earthquake damaged the power system and lead to loss of power. Two emergency diesel generators automatically started up.
- ✓ These emergency generators were submerged simultaneously due to flooding of tsunami, leading to the loss of all electrical power (At 15:37).

2.2. Overview of Fukushima Dai-ichi NPS accident

Tsunami attacks the nuclear power plant

2.2. Overview of Fukushima Dai-ichi NPS accident

Nuclear reactor had to continue cooling down in order to remove the heat ...

[Loss of cooling system of reactors]

- ✓ Loss of all electrical power led to loss of cooling system of reactors.
- ✓ Many countermeasures were taken to maintain cooling function.
  - Backup cooling system, water spray using helicopter/fire extinguish hose were tried.

=> However, Reactor meltdown was occurred

[Effect to public]

- ✓ Radioactive materials were released into the atmosphere by the hydrogen explosion occurred in the buildings.
- ✓ The contaminated water with radioactive material was discharged into the sea.

2.2. Overview of Fukushima Dai-ichi NPS accident

- Explosion, Spraying of water -

[Left] After the hydrogen explosion.

[Right] Sea water was injected into buildings using fire extinguishing hoses.

At present, the situation has been settled to some extent , and the cooling of reactor is currently working.

3. Lessons learned from nuclear power station accident

- Through Fukushima Dai-ichi NPSs accident, the following lessons learned were mainly identified in the reports.
  - (1) Lessons learned from a point of safety design/operation
    - Practical assumption of the worst case /requirement
    - Elimination of common cause failures
    - Preparation for countermeasures in case of contingency
  - (2) Lessons learned from a point of organization
  - (3) Lessons learned from a point of risk communication
- This section will introduce the lessons learned picked up from these reports, and discuss the considerations in the space system safety.
  1. <u>Practical assumption of the worst case /requirement</u>
  2. <u>Preparation for proper response for contingency</u>

3.1 Practical assumption of the worst case /requirement

The hazard, runaway of nuclear reactor, was planned to be controlled by "Deactivating the reactor" in case of anomalies, followed by "Cooling the reactor." In the Fukushima Dai-ichi accident, "Cooling the reactor" was failed while "Deactivating the reactor" was succeeded due to <u>insufficient tsunami height expectation.</u>

At the later investigation, the history and background of tsunami requirement was revealed. The initial requirement 3.1m was a criteria based on criteria observed in 1960. After the initial requirement set, several modifications for the tsunami requirement were discussed with progress of knowledge and analysis approach, however, the discussion had not reached to conclude to prepare for the 15m high tsunami.

3.1 Practical assumption of the worst case /requirement

In order to assess a hazard, appropriate requirements are necessary.
A safety review panel, reviews compliance with safety requirements. However, this accident indicates that the requirements themselves should be updated as knowledge progresses. It also suggests that the controversial assumption including worst case condition and credibility should be carefully determined.

3.1 Practical assumption of the worst case /requirement

- *Spacecraft development generally apply rigorous safety requirements. And the requirements themselves are discussed and sometimes updated mainly triggered by such events as on-orbit anomalies and non compliance discussion to prevent the recurrence of anomalies or to judge the acceptability of non compliance. In addition, in a safety review, worst case assumption as baselines and/or credibility sometimes are discussed when they are controversial.*
- *It is required to understand the rationale and background of them and incorporate the latest knowledge to conclude whether they are acceptable with acceptance of specialists.*
- *When they the worst case condition cannot be agreed, it should be considered to prepare the countermeasures in case that the anticipated condition occurs.*

3.2 Preparation for proper response for contingency

Fukushima NPSs had pressure relief function in the case of excessive pressure.

However, in the Fukushima NPSs accident, it is reported several difficulties have identified to relief the excessive pressure in the system because the vent valve as a safety device has to be manually operated under the condition of loss of power.

One of the reports states the following lessons learned.

<u>The vent system should have been remotely controllable even when AC power source was lost. The vent system should have been equipped with a filter with sufficient radiation decontamination capability.</u>

3.2 Preparation for proper response for contingency

- *<u>This lessons learned indicates that it should be considered what situation the countermeasures for contingency needed in. In case of time critical or severe situation, safety control or contingency procedure should work.</u>*
- *<u>That shoulld be reviewed and confirmed at the safety review in advance. For that purpose, the safety review panel needs appropriate reviewers who can understand the system, operation scenario and have technical specialties to judge such details as independency of the controls and elimination of common cause failure. Because spacecraft take various implementation to the safety requirements, end-to-end and details for the respective cases must be confirmed.</u>*

4. Summary

At first, it had been insisted that safety assessment were performed appropriately for Japanese NPSs and reported that the Fukushima Dai-ichi NPS accident resulted from “unanticipated” events. However, the subsequent investigation revealed that there were several designs, operations, trainings with lack of appropriate assumption and so on. It should be reconsidered whether the same potential issues as NPSs exist or not in the space system safety by looking at lessons learned from NPSs.