Seismic Design of Japanese Nuclear Power Plants and Their Actual Response in the July 2007 Chuetsu-oki Earthquake

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Introduction

- Japan had 54 Nuclear Power Plant units before March 11, 2011. Now we have 50 units. U.S.A. has almost 100 NPP units and China has around 40.
- Japan, U.S.A and China are also earthquake prone countries. Seismologists and engineers have learned how to build safe NPPs against major earthquakes.

Introduction

- The earthquake engineering technologies used for the design of NPPs are some of the most advanced technologies in the field of earthquake engineering.
- These technologies are usually transferred to the seismic design of ordinary buildings.
- Earthquake design and construction technologies of NPPs are very important in Japan, U.S.A, China and many other earthquake prone countries.

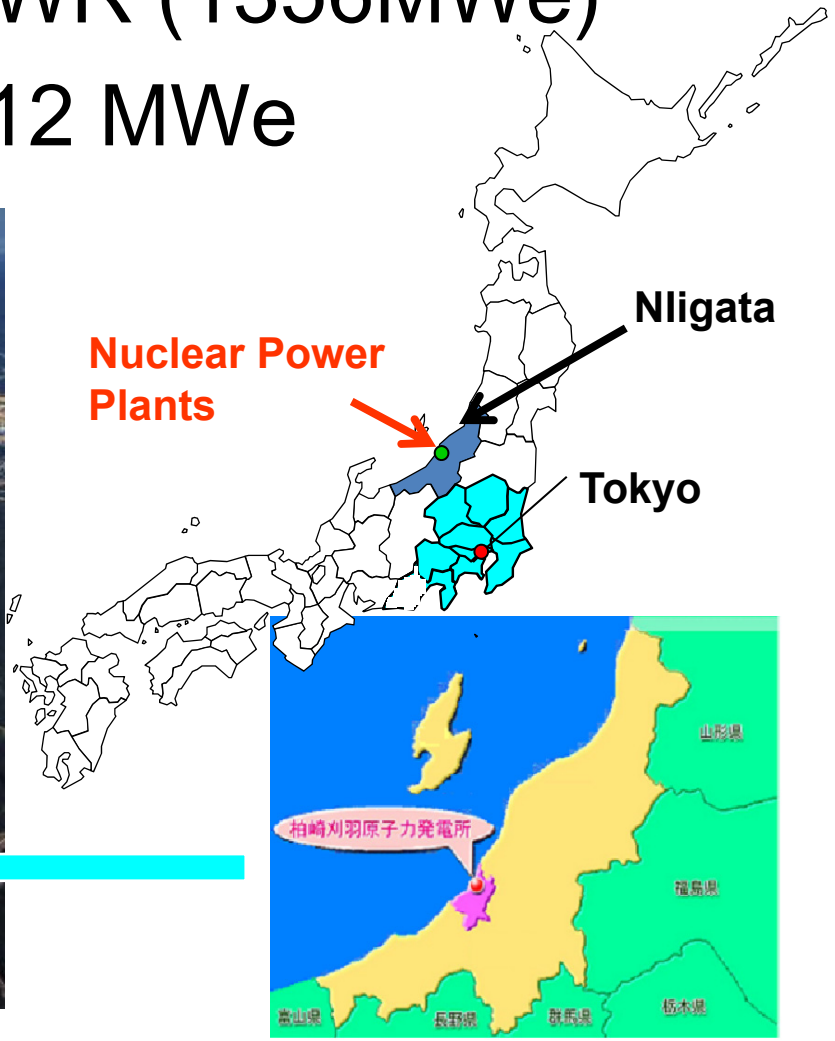
Earthquake Design and 2007 Earthquake

- The earthquake ground motions used for the design of NPPs are much stronger than those used for the design of ordinary buildings.
- As a result, a strong earthquake affecting an NPP will very rarely exceed the design criteria.
- But, in July of 2007 the Chuetsu-oki earthquake affected the Kashiwazaki-Kariba Nuclear Power Plant and the recorded earthquake ground motion exceeded the design ground motion.

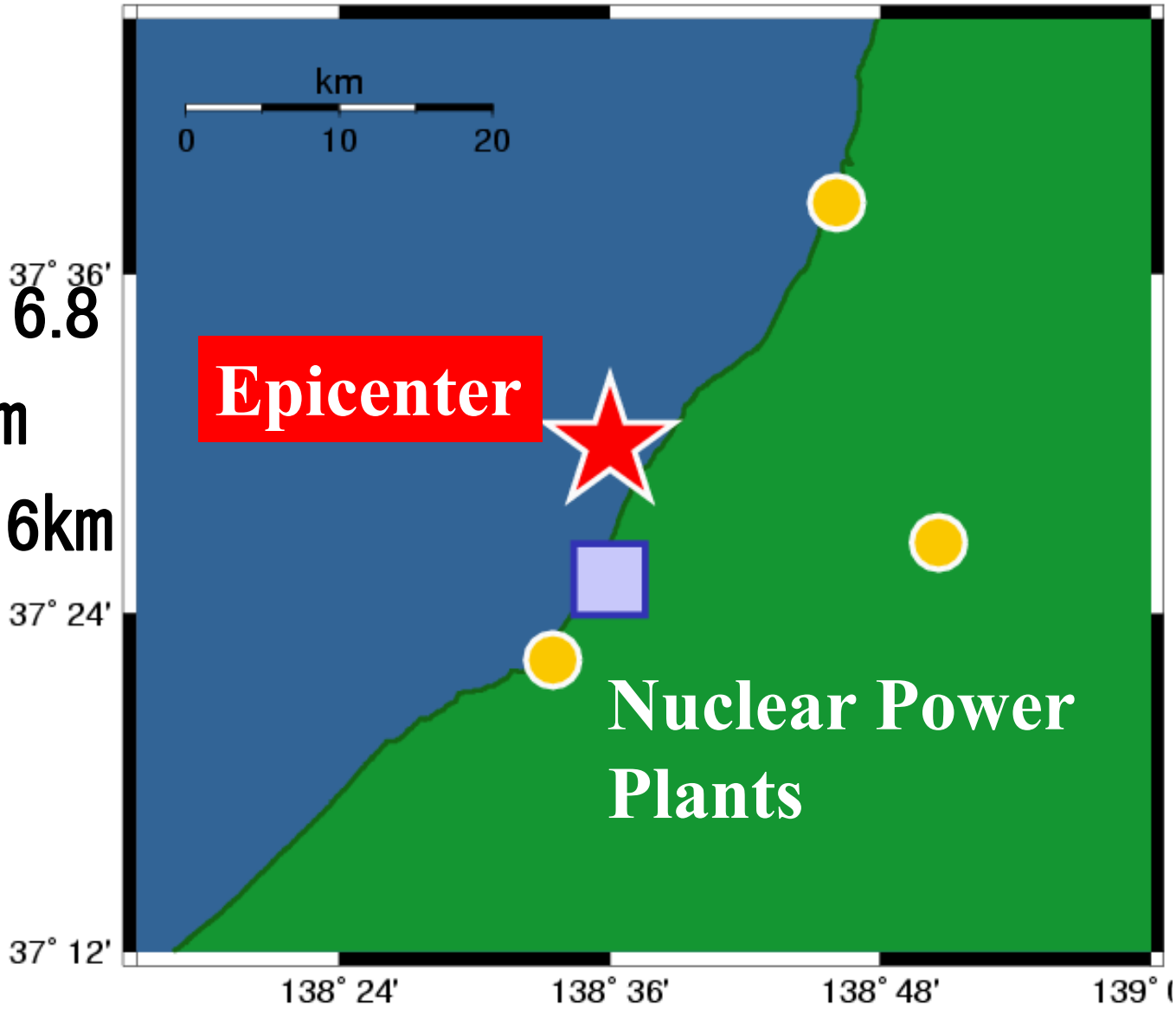
5units of BWR (1100MWe)

and 2 units of Advanced BWR (1356MWe)

⇒ Total capacity is 8,212 MWe



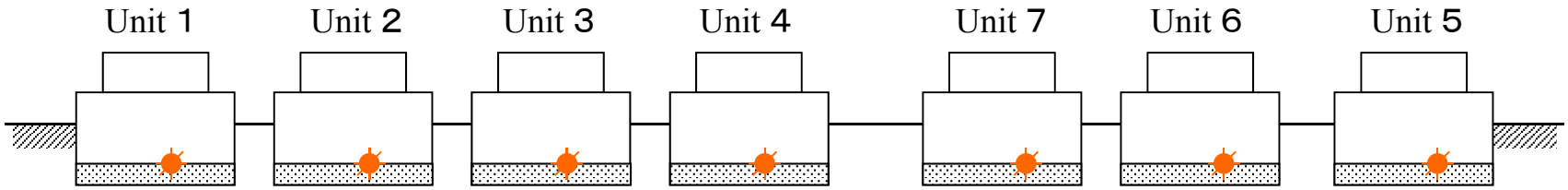
- 2007.7.16
- Magnitude 6.8
- Depth 17km
- Distance 16km



NPPs attacked by 2007 earthquake

- The earthquake did not significant damage at the plant;
- however much minor damage was observed.
- Engineers from the Tokyo Electric Power Company, several professors, and I formed a research committee to study the earthquake response of this plant to the Chuetsu-oki Earthquake.

Maximum acceleration (cm/sec^2) at the basements



Observed Values		NS	EW	UD
1	B5F	311	680	408
2	B5F	304	606	282
3	B5F	308	384	311
4	B5F	310	492	337
5	B4F	277	442	205
6	B3F	271	322	488
7	B3F	267	356	355

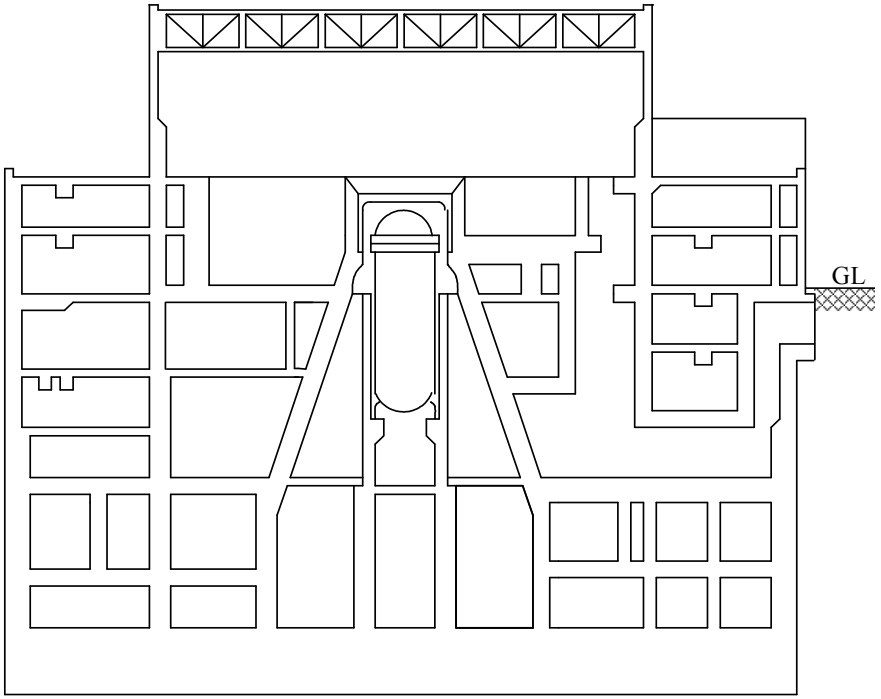
Design Values		NS	EW	UD
1	B5F	274	273	(235)
2	B5F	167	167	(235)
3	B5F	192	193	(235)
4	B5F	193	194	(235)
5	B4F	249	254	(235)
6	B3F	263	263	(235)
7	B3F	263	263	(235)

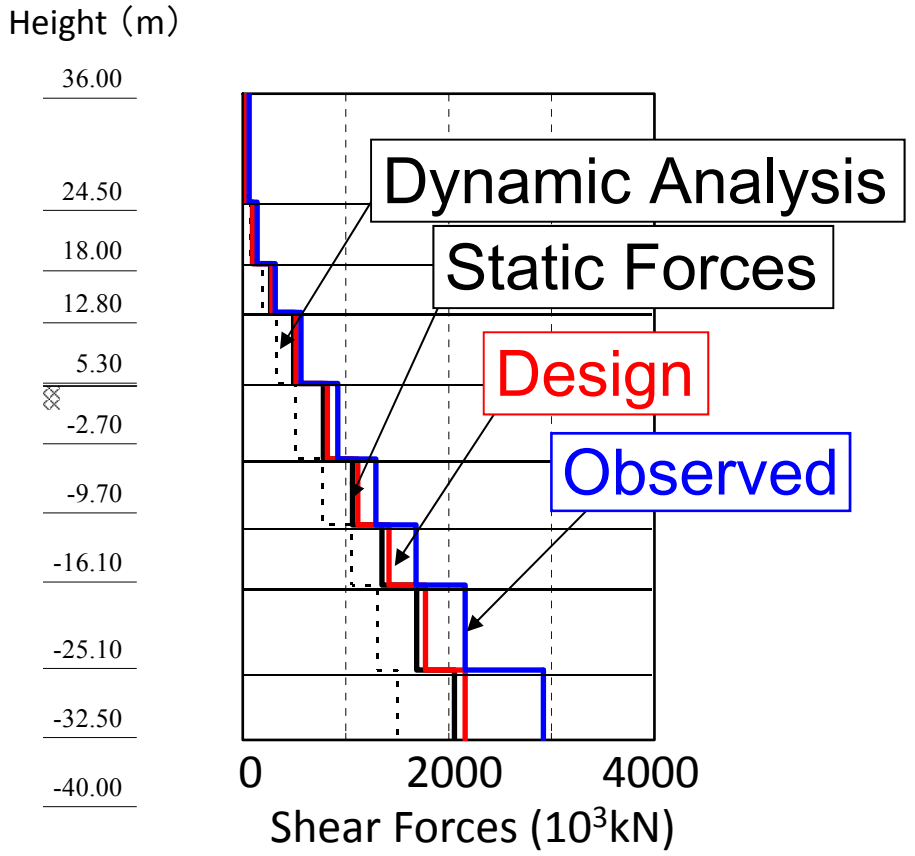
Damage due to the earthquake 2007

No Damage in the plants

Many Damages in other buildings

Responses in the Unit-1





Fire accident at the transformer of Unit-3

Subsidence

Subsidence

Large deformation of Exhaust duct at Unit 1 to Unit 5

Buckling of tanks

Broken to outdoor fire extinguishing piping

Screw joint

Coupling joint

Cracks in the tailrace tunnel

Liquefaction happened in the site

Old Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities

- **Basic idea was developed more than 40 years ago.**
- **Original version of the regulatory guide was published at 1981.**
- **Current version was revised at September 19, 2006.**

Contents: September 19, 2006

1. Introduction
2. Scope of Application
3. Basic Policy
4. Classification of Importance in Seismic Design
5. Determination of Design Basis Earthquake Ground Motion
6. Principle of Seismic Design
7. Load Combinations and Allowable Limits
8. Consideration of the Accompanying Events of Earthquake

session 4 and session 6 in OLD Guide

Classification of Importance in Seismic Design and Structural Design

S Class Most important --- 3 times stronger

B Class Important --- 1.5 times stronger

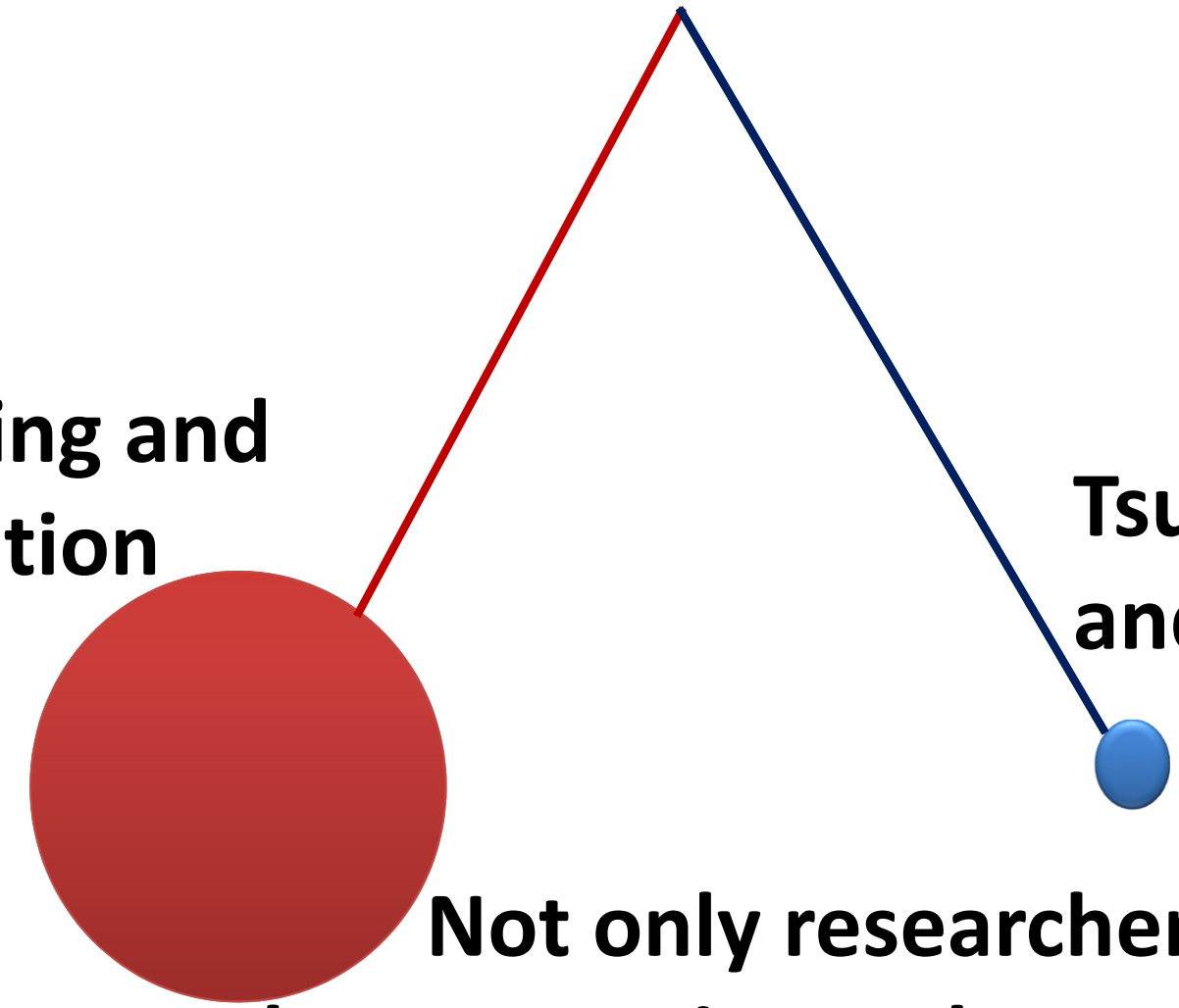
C Class ordinary --- same as ordinary

Session 8. of OLD Guide

Consideration of the accompanying events of earthquake

(2) Safety functions of Facilities shall not be significantly affected by the **tsunami** which could be postulated appropriately to attack but very scarcely in the operational period of Facilities.

Pendulum of worries and concerns

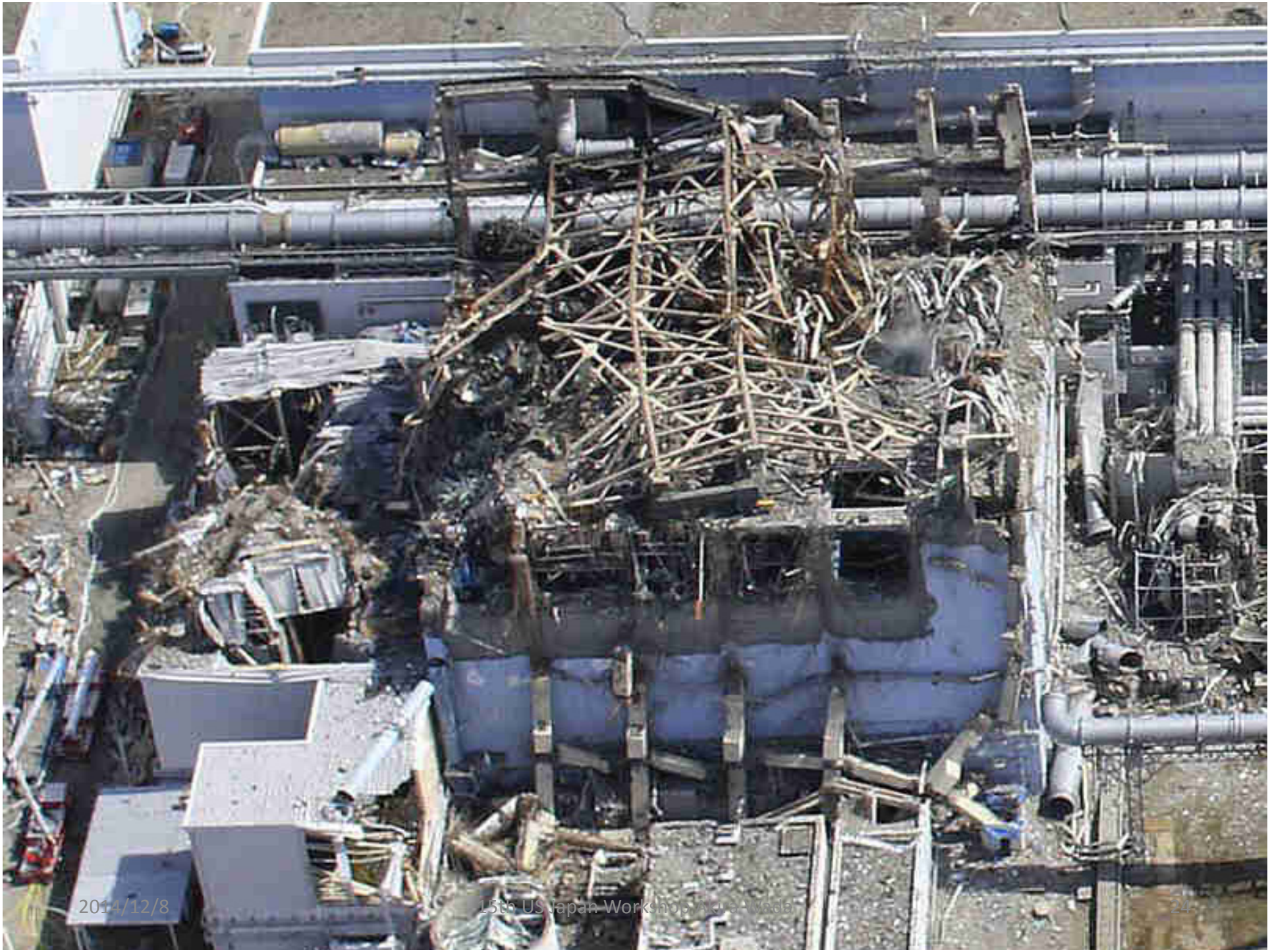


Not only researchers but also People, companies and Governments.

Severe tsunami attacks to a hospital that was retrofitted by steel braces

Effects of tsunami on NPPs

- Almost all researchers and engineers in earthquake engineering, including me, have traditionally focused their attention to the vibration aspects of earthquakes;
- Very few have focused on the effects of tsunami on NPPs.



What we have to reconsider

- Before March 11, 2011, we had not any experience that the tsunami hit nuclear power plant at all.
- Japanese seismic design guide wrote only one word of ‘tsunami’ at the final short sentence.
- Humankind is always optimist.
- We cannot take into consideration before an accident that we have not experienced.

New Regulatory Requirements For Light Water Nuclear Power Plants (Earthquakes and Tsunamis)

1. Basic Design Policy for Earthquakes and Tsunamis
2. Classification of Importance of Facilities
3. Formulation of Standard Seismic Motion
4. Seismic Design Policy
5. Considerations Regarding Ground Stability
6. Formulation of Design basis tsunami
7. Design Policy against Tsunami
8. Design Considerations Regarding the Stability of Surrounding Slope

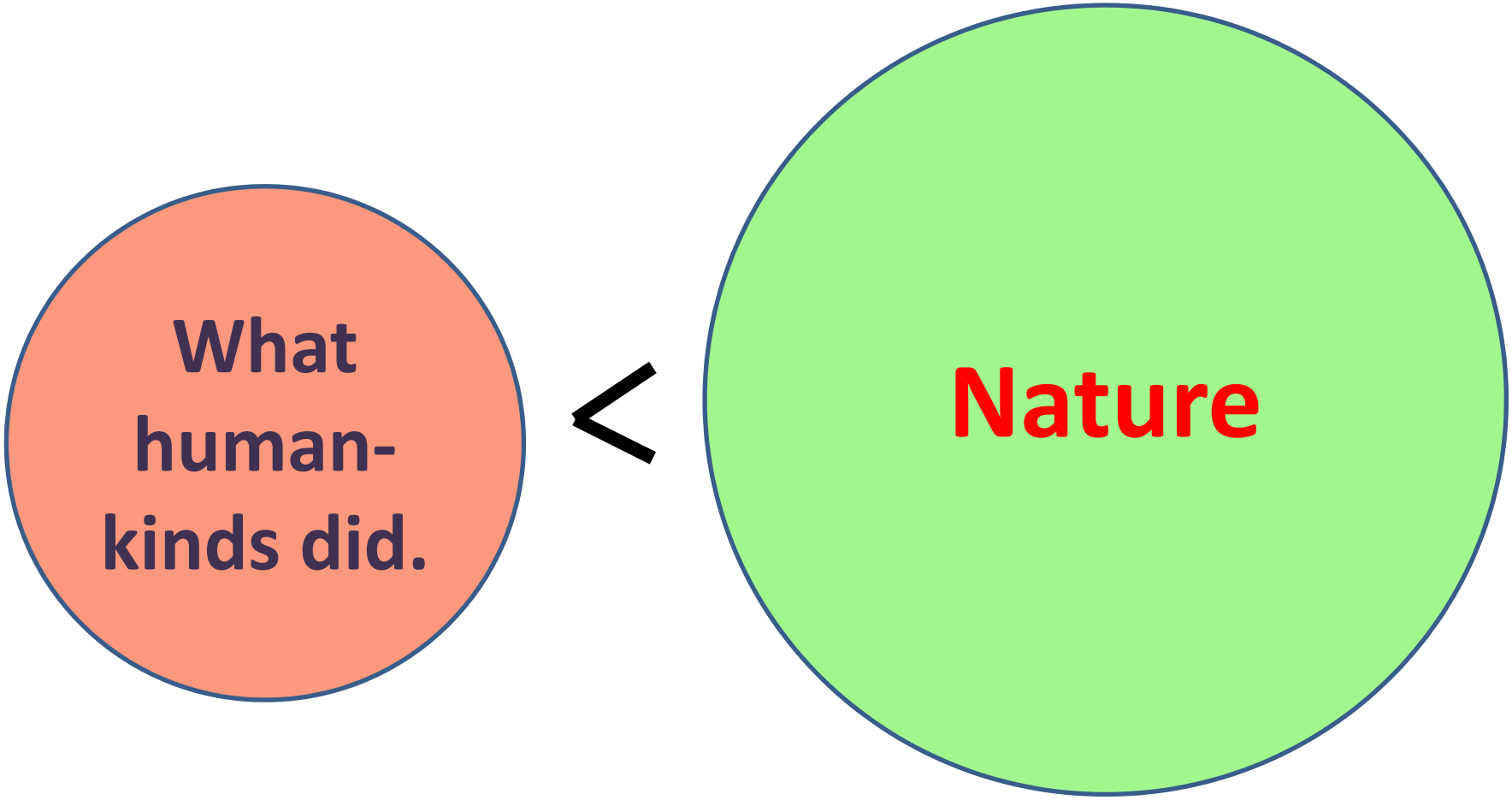
Different Thoughts

- When all engineers think or believe one common thought such as "earthquake is vibration", it will be very dangerous against next earthquake.
- Nature always thinks all.
- Other disaster such as Tsunami will be happened in the next earthquake.
- We have to think many things and different thoughts are always important.

Two approaches for earthquake engineering

- **Precise and complicated theories**
- **Comprehensive and simple methods**

Why natural disaster cannot be stopped



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