

## Fukushima Accident : An overview



27 June 2011, Akira OMOTO, University of Tokyo and AEC of Japan

### OUTLINE

- Part I 3.11 Earthquake and Tsunami***
- Part II Response of the nuclear reactors***
- Part III Recovery actions***
- Part IV Offsite consequences***
- Part V Key Lessons Learned***

- ✓ **Part I 3.11 Earthquake and Tsunami**
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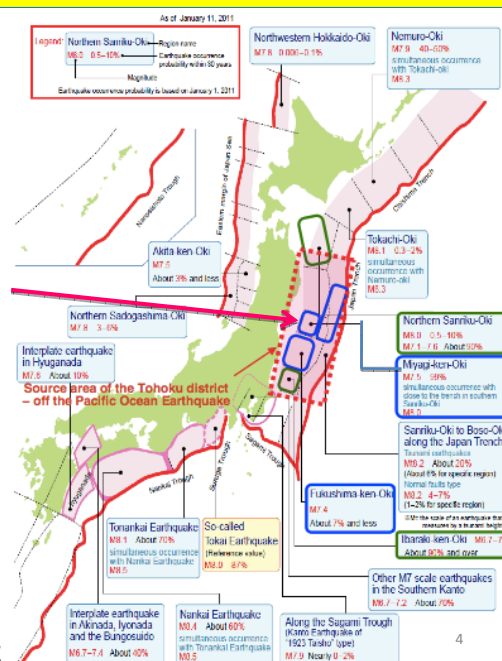
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## How the occurrence of this earthquake was estimated?

Estimated probability of occurrence by the Headquarter of Earthquake Research (2011 January 1<sup>st</sup>)

The Headquarter;

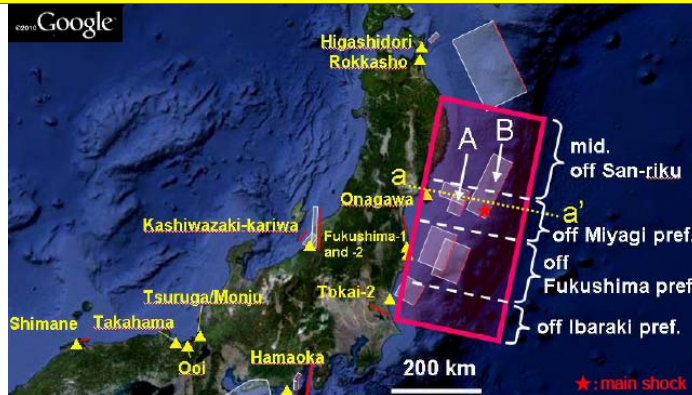
- a) Had alerted 99% probability of occurrence within 30 years for the **Miyagi-oki** region with a magnitude of M7.5
- b) Had not correctly estimated the size of the source area (400km x 200km) nor the magnitude (M9) nor the amount of slip



[SOURCE] Gov. Report to the IAEA, June 2011

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## Source area of the 3.11 earthquake (multi-segment rupture)



### Government Report to the IAEA, June 2011

Initiation from B, then propagated westwards to area A, and further to the North and South down to Ibaraki

[SOURCE] Gov. Report to the IAEA, June 2011

### Statement by the Headquarter for Earthquake Research, 11 March 2011

The Committee evaluated earthquake motion and tsunami for the individual region off-shore .....but occurrence of the earthquake that is linked to all of these regions is "out of hypothesis".

[SOURCE] <http://www.jishin.go.jp/main/index-e.html> The 2011 off the Pacific Coast of Tohoku Earthquake

## 3.11 Earthquake

At the Basement of Reactor Building

Nr.	MWe	3.11 Observed (max. gal)			Design (Ss) (max. gal)		
		N-S	E-W	Vertical	N-S	E-W	Vertical
1Fuku1	460	460	447	258	487	489	412
1Fuku2	784	348	550	302	441	438	420
1Fuku3	784	322	507	231	449	441	429
1Fuku4	784	281	319	200	447	445	422
1Fuku5	784	311	548	256	452	452	427
1Fuku6	1100	298	444	244	445	448	415

Note 1: **Damage by the earthquake:** Not fully inspected but maybe not significant to safety systems, considering the KK earthquake (2007) where no damage to safety functions even though the observed acceleration exceeded design basis by factor 2-3. However, all the 7 offsite power lines to 1F were lost due to failure of breaker, cable damage and collapse of transmission line tower. (In KK earthquake (2007), 3 out of the 4 offsite power lines remained intact.)

### Note 2: Reactor Scram by the earthquake

Set points by acceleration at the basement of Reactor Building

Horizontal=135 gal, Vertical=100 gal

## Earthquake: Renewed evaluation basis (2009)

### ◆ Renewed seismic design standard (2006)

### ◆ “Chuetsu-oki” earthquake hit KK NPS (2007)

### ◆ Design review of existing NPSs in the light of the above two

- ✓ Fukushima seismicity review by NISA/Advisers/TEPCO (2009)
- ✓ TEPCO document shows “Probability of exceedence”  $(10^{-4})$ - $(10^{-6})$ /year
- ✓ Tsunami review to come later after studies of year-869 Tsunaru

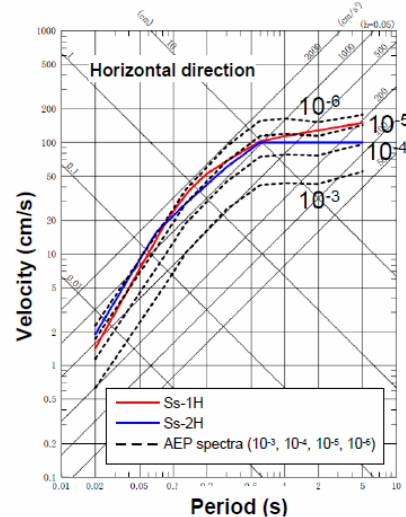


Fig. III-2-3 Annual exceedence probability (AEP) of DBGM Ss for Fukushima Dai-ichi NPS.

[SOURCE] Gov. Report to the IAEA, June 2011

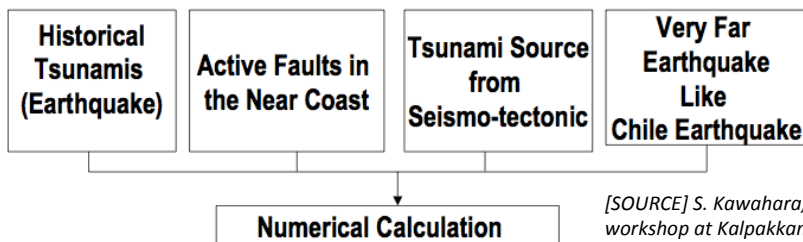
## Tsunami design basis

### ◆ Safety Design Guide (NSC) Nr. 2 [footnote]

- “....Anticipated natural hazard includes flood, Tsunami ....”

### ◆ JSCE (Japan Society of Civil Engineers) guideline on Tsunami (2002)

- From JSCE Nuclear Civil Engineering Committee  
[http://committees.jsce.or.jp/ceofnp/system/files/JSCE\\_Tsunami\\_060519.pdf](http://committees.jsce.or.jp/ceofnp/system/files/JSCE_Tsunami_060519.pdf)



[SOURCE] S. Kawahara, IAEA workshop at Kalpakkam, 2005

- Deterministic approach
- Need to exceed historical highest
- Probability of “combination of Tsunami source” not considered, if no historical evidence
- NPP modifications based on this guideline

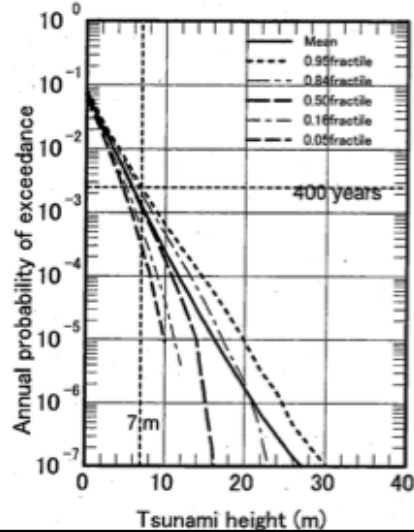
## Tsunami design guideline based on probabilistic study

### ◆ Tsunami Probabilistic Hazard study

- Probabilistic Tsunami hazard analysis (TEPCo, ICONE-14, 2006)
- Methodology guide from JSCE Nuclear Civil Engineering Com. (2009)

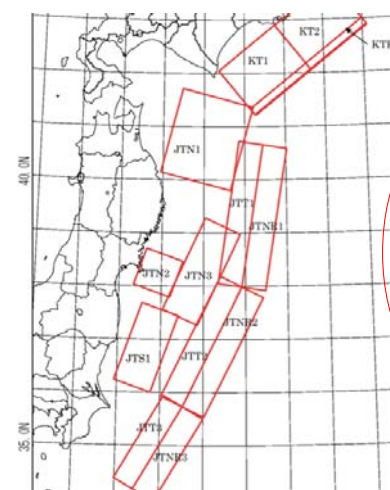
### ◆ IAEA DS417 (draft)

- Includes guide on Tsunami analysis



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## Tsunami design guideline based on probabilistic study



### Logic tree to represent epistemic uncertainty

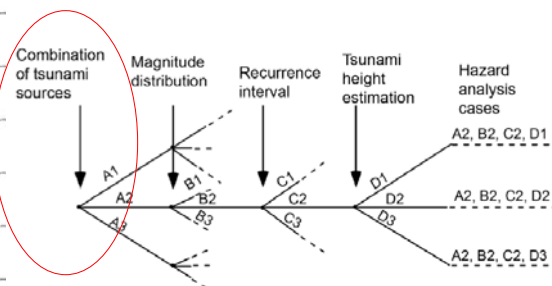


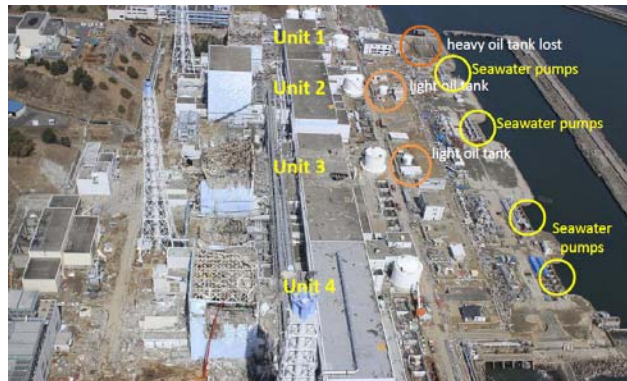
Fig. 1 Logic-tree representation of uncertain parameters

[SOURCE] T. Annaka, "A method of Probabilistic Tsunami Hazard analysis, 12<sup>th</sup> Civil Engineering Society, 2006

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### Fukushima Daiichi being struck by the tsunami

Taken from near the south side of Unit 5, looking east



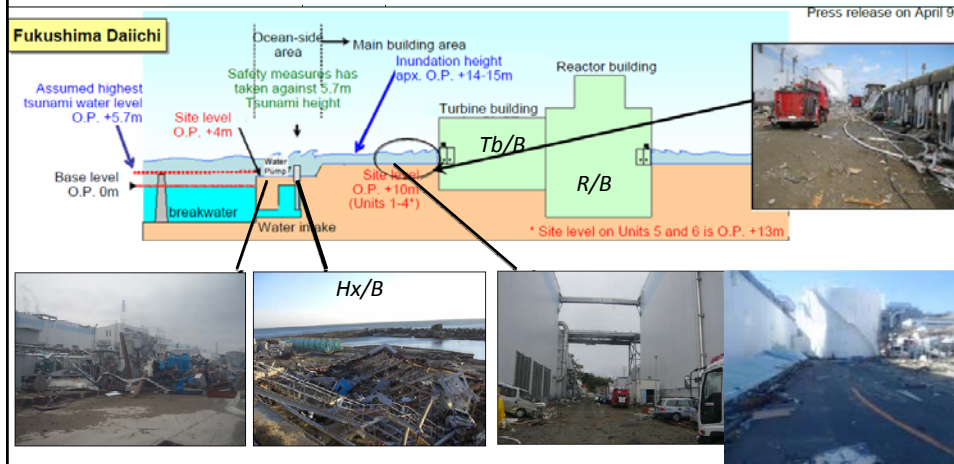
Taken from radwaste building 4<sup>th</sup> floor, looking north

Tank Height about 5.5m  
(height of ground : O.P. +10m)



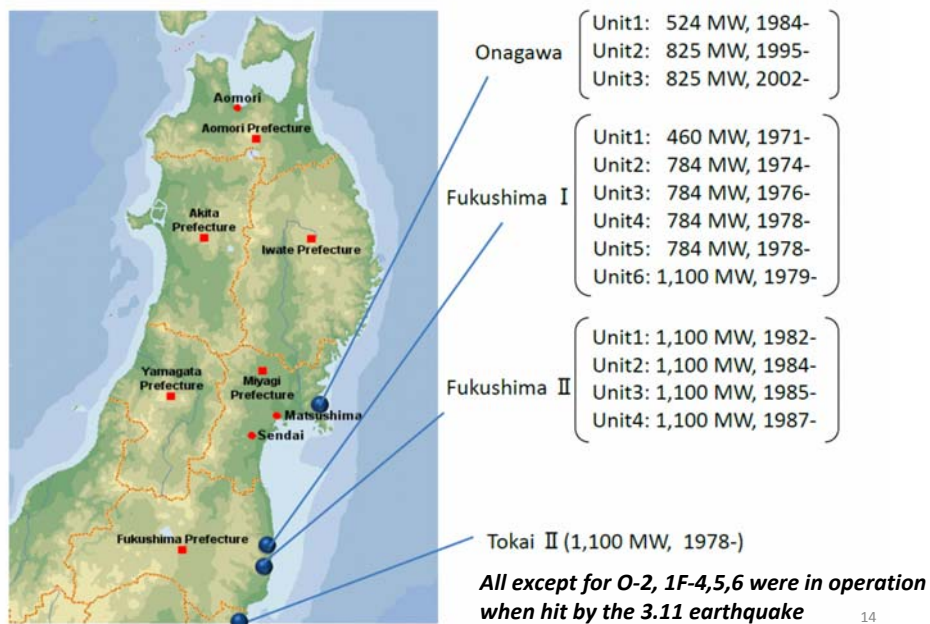
O.P. : Onahama bay construction base level

## Fukushima Dai-ichi Unit 1-4



[SOURCE] [http://www.tepco.co.jp/cc/press/betu11\\_j/images/110618l.pdf](http://www.tepco.co.jp/cc/press/betu11_j/images/110618l.pdf) and TEPCO May 23 report <sup>13</sup>

## 14 NPPs along the coastal line affected by Tsunami




### 3.11 Tsunami

Unit	Ground Level		Tsunami height [m]			Location of Electric Equipment Room (M/C, Battery)	Type & location of Emergency Diesel Generator SC: Seawater-cooled AC: Air-cooler
	R/B, Tb/B [m]	Intake str. [m]	DB	Mod (2002)	3.1 1		
1Fuku1,2,3,& 4	10.2	4	3.1	5.7	14-15		1F1.3: 2 SC-EDGs (design) 1F2,4: 1 SC-EDG (design) + 1 AC-EDG (SAM)
1Fuku5	13.2	4	3.1				2 SC-EDGs
1Fuku6							2 SC-EDGs (design) 1 AC-EDG (SAM)
2Fuku1,2,3 & 4	12	7	3.7	5.2			3 SC-EDGs
Onagawa1,2 & 3	14.8		9.1	-	13		3 SC-EDGs
Tokai 2	8.0	3	1.5	4.86	5.1-5.4		3 SC-EDGs

Location info not listed here.

**2F**

- Different Tsunami inundation path from 1F
- One of the offsite power lines stayed alive during & after the Earthquake/Tsunami



Tsunami flow path @2F

### Fuel damage or not ---- What made the difference?

Simply said,

(1) Elevation vs. Tsunami height

- Site ground level → saved Onagawa and Tokai
- Location of EDG/EE room/battery

(2) Availability of power

- Offsite power (together with SAM under loss of UHS) → saved 2F
- Air-cooled EDG coupled with the above location and SAM under loss of UHS) → saved 1F6
  - Air-cooled EDG was added for 1F2,4,6 respectively in the 1990's as a part of SAM modifications.

(3) Implementation of AMG by using then-available resources

- saved 1F5 (power supply from adjacent 1F6)
- saved SFPs (makeup water)



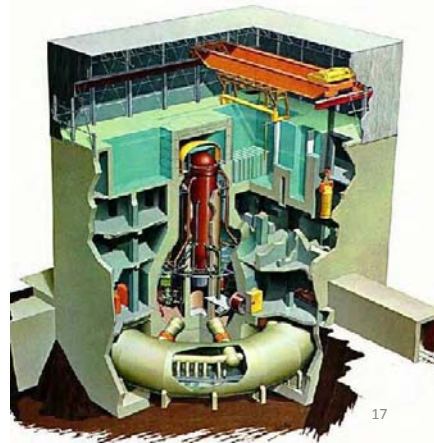
## BWR/3,4 generation plant

### BWR/3 (460MWe, 1Fuku1)

- Mark I Containment (Drywell + Suppression Pool, Pd=62psig)
- IC (Isolation condenser)
  - high pressure core makeup
  - No need for AC power
- Battery : 10 hrs

### BWR/4 (784MWe, 1Fuku 2,3,4 &5)

- Mark I Containment (Drywell + Suppression Pool, Pd=45psig)
- RCIC (Reactor Core Isolation Cooling) & HPCI (High Pressure Core Injection)
  - high pressure core makeup
  - No need for AC power
- Battery : 8 hrs



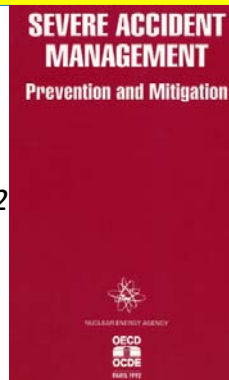
## What SAM (Severe Accident Management) was in place?

### (OECD/NEA)

In the aftermath of Chernobyl, OECD/NEA organized a series of meetings by SESAM (Senior Expert for Severe Accident Management)

*"Severe Accident Management": published in 1992*

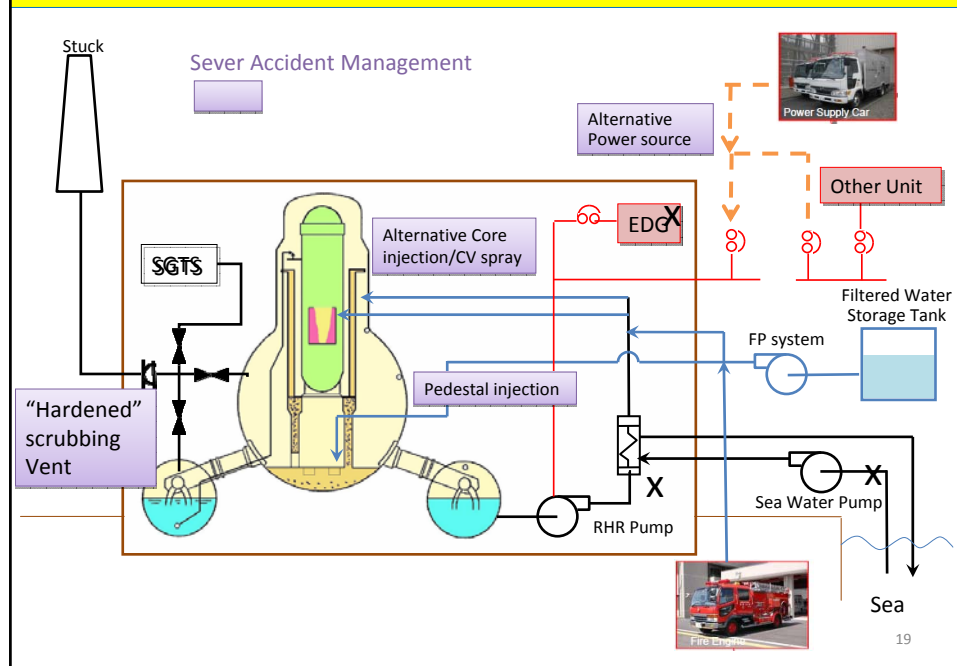
*"Implementing Severe Accident Management in Nuclear Power Plants", published in 1996*



### (Japan)

- NSC recommendation for SAM preparation (1992)
- SAM study followed by SAMG and modifications (hardened vent, injection to RPV and RPV-pedestal region etc)
- Technical basis for SAM by Utility/Industry/Academia (NSRI guideline, 1999, <http://www.nsra.or.jp/safe/cv/index.html>)
- Submittal of Utility report to NISA, followed by evaluation by NISA

## What SAM (Severe Accident Management) was in place?



## Continuous improvement of SAM through drill and information from other countries?

### 1. Not effective enough, give 3.11 situation

- Location of CV vent valve
- Sharing of vent line with adjacent units and connection with SGTS
- No reactor building venting provision
- No provisions for battery recharger etc
- SAM assuming working environment after Tsunami and Hydrogen explosion

### 2. Not learning SAM from outside of Japan

Small diesel-powered generators or small power-packs to SRV  
Air-cooled "blackout diesel generator"

### 3. Some improvements after KK earthquake (2007 July)

a) Emergency response center (ERC) : seismic isolation, shielding, communication etc

If not for this ERC, on-site actions would have been severely hampered

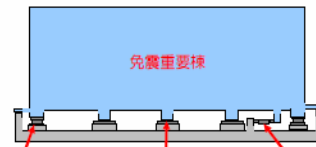
b) Underground water tank (16 units/site x 40m<sup>3</sup> /unit) and

Fire Engines (3/site) ( [source] [http://www.tepco.co.jp/cc/press/betu11\\_j/images/110618l.pdf](http://www.tepco.co.jp/cc/press/betu11_j/images/110618l.pdf))

Nevertheless,

- Prior RCS depressurization
- Limited amount of water for multiple units

## Onsite ERC



6プラグ入り積層ゴム(8台)  
(変形を元に戻し揺れを吸収する)



滑り支承(12台)  
(摩擦が少ない板上を滑る)



オイルダンパー(4台)  
(地震の揺れを吸収する)



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## Actions to avoid core damage

14.46 Earthquake, Loss of offsite power, Start of EDG, IC/RCIC  
15.38-41 Tsunami followed by Loss of AC/DC, Isolation from UHS

**Given this situation, operation to avoid core damage**

Short term

- Reactor water makeup by AC-independent IC/RCIC/HPCI
- Containment vent to avoid over-pressure failure

Then, while trying to restore AC/DC power and Heat Sink

- Depressurize RCS by Safety/Relief Valves (Need DC and gas pressure to cylinder and reduced back-pressure from the containment, If CV pressure is high)
- Activate LP injection systems (FP, MUWC etc)

Failure of RCIC/HPCI on the 3<sup>rd</sup> and 4<sup>th</sup> day  
Delayed de-pressurization and LP injection

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### Actions for core injection(1F2 as an example)

- 3.11.17:12 Initiated actions for alternative core injection by FP system, Fire Engine etc.
- 3.12. 2:55 Confirmed RCIC operation
- 3.13.8:10 Opening **containment vent** valve  
Given high temperature in the suppression chamber (S/C), difficulty of steam condensation expected even though SRV send steam to S/C
- 3.14.13:25 Suspected RCIC trip → **Core uncovered**  
16:30 Activate Fire Engine to inject water to RPV  
18:00 Reactor pressure started decrease because **SRV** was opened by utilizing temporary batteries  
19.54 Start **water injection** to reactor

Unavailability of power (AC/DC power and air) to vent and RCS depressurization

[SOURCE] [http://www.tepco.co.jp/cc/press/betu11\\_j/images/110618l.pdf](http://www.tepco.co.jp/cc/press/betu11_j/images/110618l.pdf)

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### Actions for AC/DC power

#### AC

LOOP(6+1)

EDG: only 1 air-cooled EDG functioned properly

(13 EDG on site, 3 air-cooled, except for 1F6 location problem)

Delayed arrival of mobile power units

Problems such as submerged M/C,P/C and cable connection after hydrogen explosion

#### DC

Loss of instrument reading & power to operate some valves→ Serial connection of batteries from automobile etc. to power essential instrumentations and valves



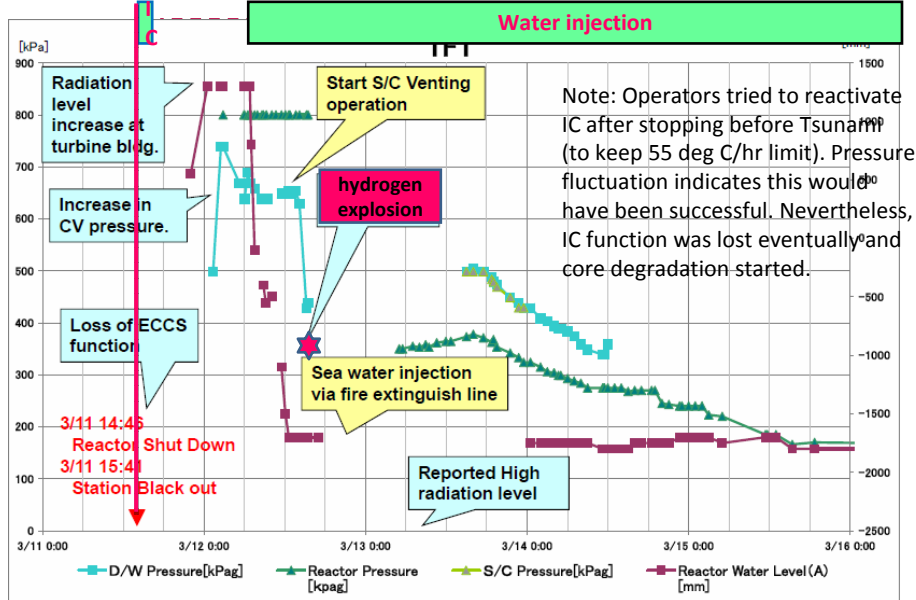
[SOURCE] [http://www.tepco.co.jp/cc/press/betu11\\_j/images/110618l.pdf](http://www.tepco.co.jp/cc/press/betu11_j/images/110618l.pdf)

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## 1Fuku1

IC trip (March 11.15.37)

Start of injection via FP line (March 12. 05.6)



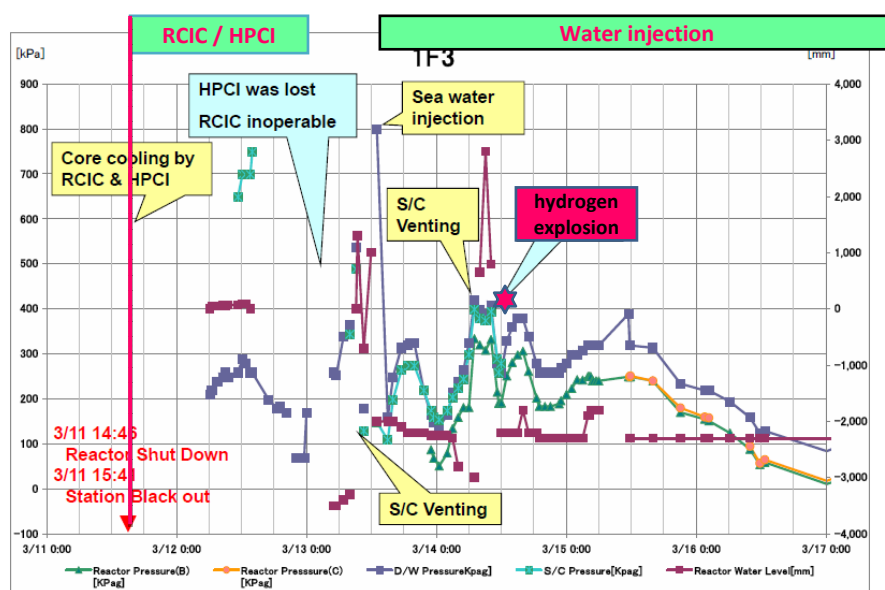
[Based on NISA slide, IAEA Safety Convention Meeting, 2011April4 and Gov report to IAEA, TEPCO report June18]

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## 1Fuku3

RCIC/HPCI trip (March 12.02.42)

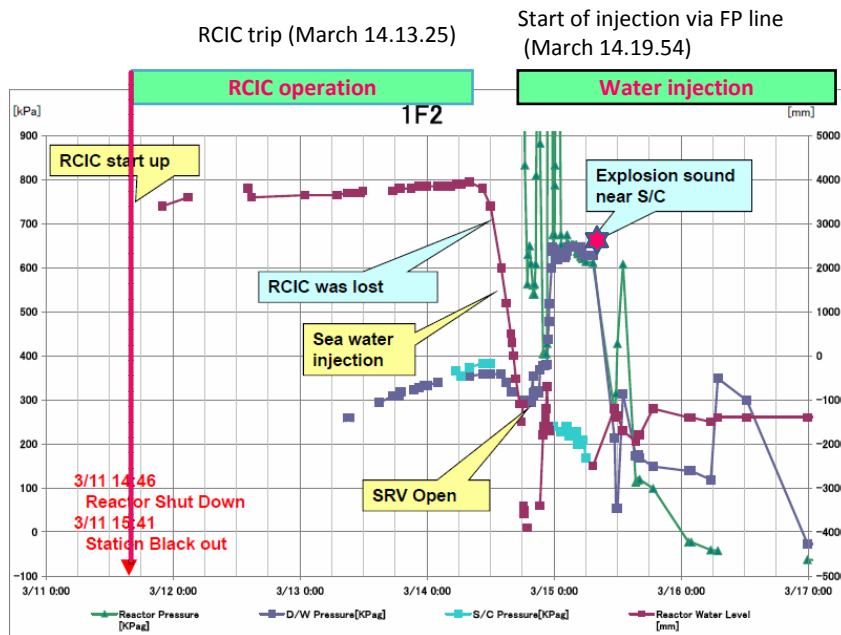
Start of injection via FP line (March 12.09.25)



[Based on NISA slide, IAEA Safety Convention Meeting, 2011April4 and Gov report to IAEA]



## 1Fuku2



[Based on NISA slide, IAEA Safety Convention Meeting, 2011 April 4 and Gov report to IAEA]

## TMI and Fukushima core uncover: estimation

	TMI	Fukushima
<b>Day 1</b>	00 Tb trip, Loss of FDW 03 sec SRV stuck open 3 min HPI stop 100 min Coolant circulation stop 174 min B pump start (fuel collapse) 113-174 min Core uncover 200 min HPI restart 224 min Slumping to RPV bottom	00 Earthquake LOOP, EDGs start, IC/RCIC operation 1 hr Tsunami Blackout & loss of UHS
		(1F1) (1F2) (1F3)
<b>Day 2</b>		4-15* hrs
		*Estimated time from start of core uncover to start of successful injection
<b>Day 3</b>		
<b>Day 4</b>		75-77* hrs
		40-43* hrs

[SOURCE] Based on Gov. report to the IAEA and TEPCO May 23 report

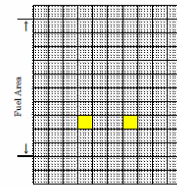
## What are the results of code assessment?

MAAP (TEPCO), MELCOR (JNES),  
SAMPSON (IAE/NUPEC)

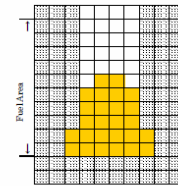
- MAAP calculation by TEPCO in the Gov. report to the IAEA (Ex.)1F1→
- MELCOR calculation by JNES

Time of RPV melt-through (M/T) after the earthquake

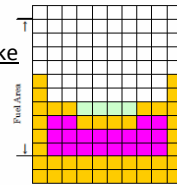
	MAAP(TEPCO)	MELCOR (JNES)
1F1	5-12 hrs	15 hrs
1F2	109 hrs or no M/T	80 hrs or no M/T
1F3	66 hrs or no M/T	79 hrs or no M/T



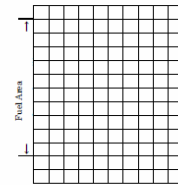
Approx. 4.7 hours after SCRAM



Approx. 5.3 hours after SCRAM



Approx. 14.3 hours after SCRAM



Approx. 15 hours after SCRAM

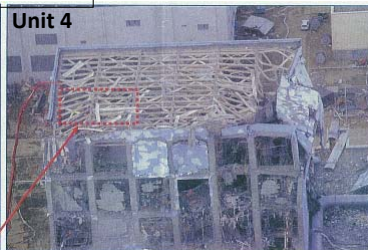
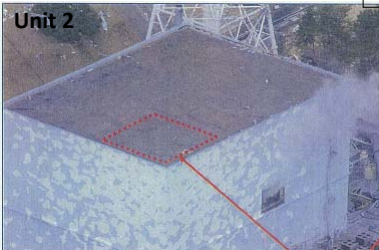
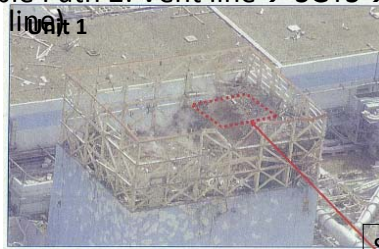
Model of Fuel Damage  
 : No Fuel (Slumped)  
 : Normal Fuel  
 : Accumulation of Slumped Fuel  
 : Accumulation of Melted Fuel  
 : Flow Channel Blockage with Melted Fuel  
 : Molten Core Pool

[SOURCE] Based on Gov. report to the IAEA and TEPCO May 23 report

## Hydrogen explosion

Possible Path 1 : Excessive leakage by over-pressure at CV flange/airlocks

Possible Path 2: Vent line → SGTS → R/B (vent line merge with adjacent unit's line)

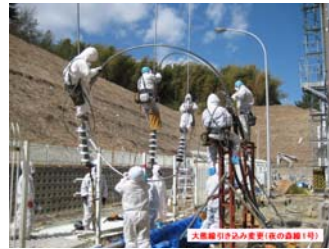


1F2 blowout panel opened by  
1F3 blast, which released H<sub>2</sub>

SFP zone

Water sample from SFP and photo indicate  
SFs in 1F4 most probably remain intact

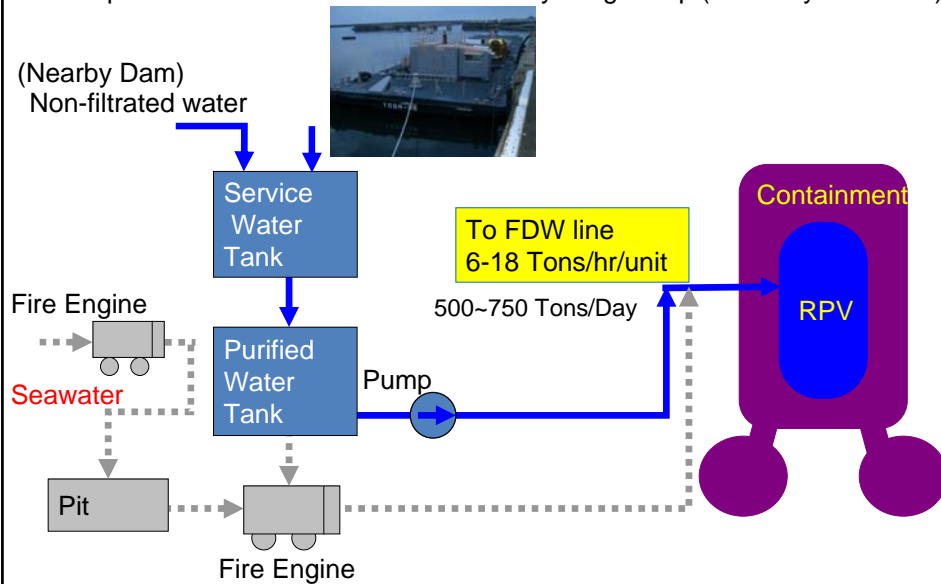
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## Water Injection to the reactor core

Backup water source: Freshwater carried by Barge Ship (Courtesy of the US)

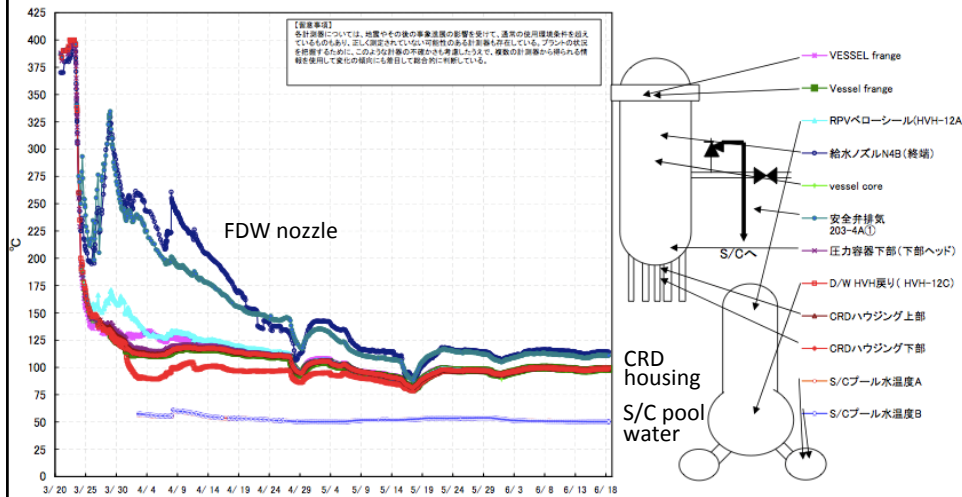


[SOURCE] Modified based on NISA, IAEA Safety Convention Meeting, 2011 April 4

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## Recent trend of 1F1 temperature

CAUTION: include questionable data

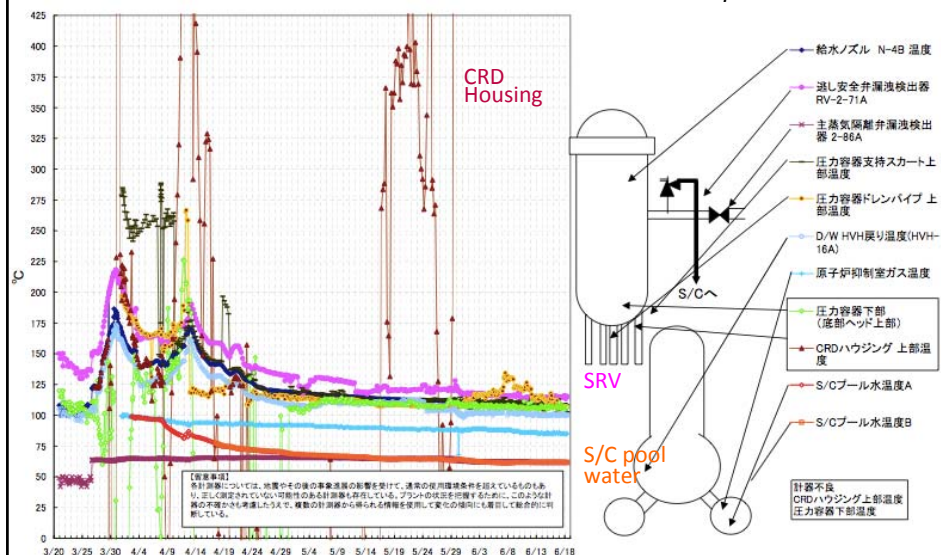


[SOURCE] [http://www.tepco.co.jp/nu/fukushima-np/f1/images/11061812\\_temp\\_data\\_1u-j.pdf](http://www.tepco.co.jp/nu/fukushima-np/f1/images/11061812_temp_data_1u-j.pdf)

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## Recent trend of 1F2 temperature

CAUTION: include questionable data



[SOURCE] [http://www.tepco.co.jp/nu/fukushima-np/f1/images/11061812\\_temp\\_data\\_2u-j.pdf](http://www.tepco.co.jp/nu/fukushima-np/f1/images/11061812_temp_data_2u-j.pdf)

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## Key near-term recovery actions

### 1. COOLING

- ◆ Flooding the containment to a certain level & installation of heat exchanger to remove heat, *[challenge] working environment & leakage of water from the containment*
- ◆ SFP cooling system (rather than spray and evaporation)

### 2. MINIMIZING AIRBORNE/LIQUID EFFLUENT

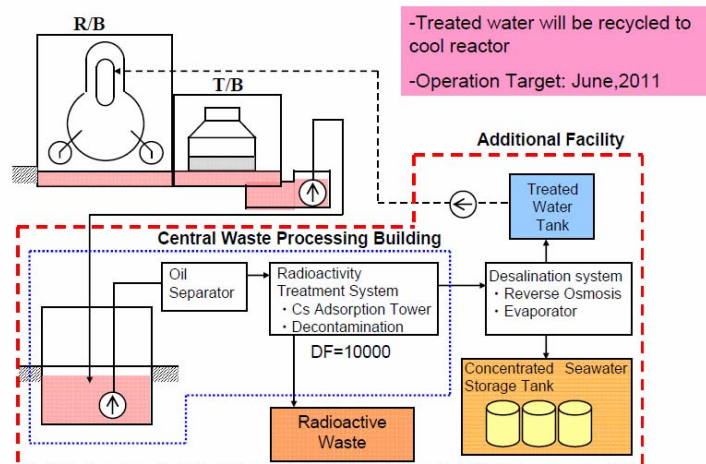
- ◆ Recycling of water recovered from Tb/B through removal of radioactivity (France/US/Japan) and RO (Japan)  
~1200 Tons/Day treatment  
500~750 Tons/Day treated water return to the reactors
- ◆ Storage of contaminated water
- ◆ Installation of R/B cover
- ◆ Corrosion control (Deaeration of supply water, hydrazine)

### 3. MINIMIZING RESIDUAL RISKS

- ◆ Aftershocks (Structural integrity of damaged R/B, Reliability of power/water supply)
- ◆ Hydrogen

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## Installation of Water Treatment Facility



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Water in the Tb/B is treated and recycled to the reactor for feed. Will balance by 2011/E.

✓ Capacity of Treatment facility : 1200 Ton/Day x 6month (7-12) =216,000 Ton

✓ Water to be treated : 1-4 Tb/B 87,500 Ton + (500-750) Ton/Daily feed x6month<sub>38</sub>  
=177,500~22,250 Ton

## Reactor building cover

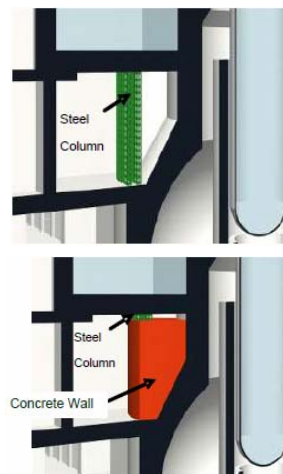
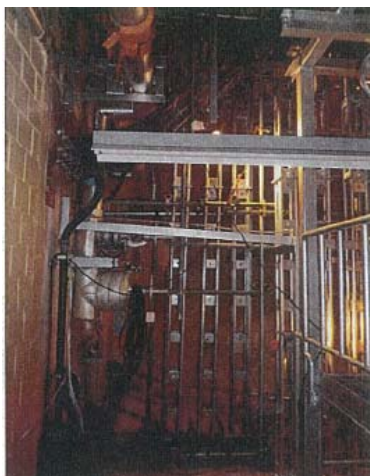


[SOURCE] [http://www.tepco.co.jp/en/press/corp-com/release/betu11\\_e/images/110614e17.pdf](http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110614e17.pdf)

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## Support 1F4 SFP from bottom

- ◆ Steel structure and concrete
- ◆ Steel structure: completed by June 18th
- ◆ Concrete filling : Ongoing to further take loads



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## Machines/Robotics in harsh radiation environment

Removal of debris  
Taking samples  
Remote camera  
Remote radiation monitoring



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## Beyond stabilization phase (ends early 2012)

### 1. Defueling

- Removal of intact SF in the SFPs
- Removal of debris
  - ✓ TMI-2 experience

### 2. Continued waste management

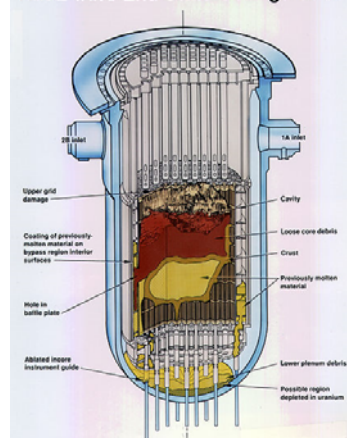
- contaminated water : 10-20 x TMI-2

### 3. Sarcophagus, Isolation of surrounding area by walls and dismantling

- No experience of dismantling seriously damaged reactor
  - ✓ A-1 (Slovakia, 1977)
  - ✓ TMI-2(USA, 1979)
  - ✓ Chernobyl (Ukr, 1986)

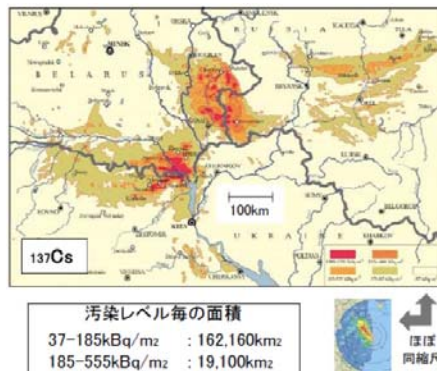
### 4. Final disposal of wastes

TMI-2 Core End-State Configuration



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- Part I 3.11 Earthquake and Tsunami**  
**Part II Response of the nuclear reactors**  
**Part III Recovery actions**  
✓ **Part IV Offsite consequences**  
**Part V Key Lessons Learned**



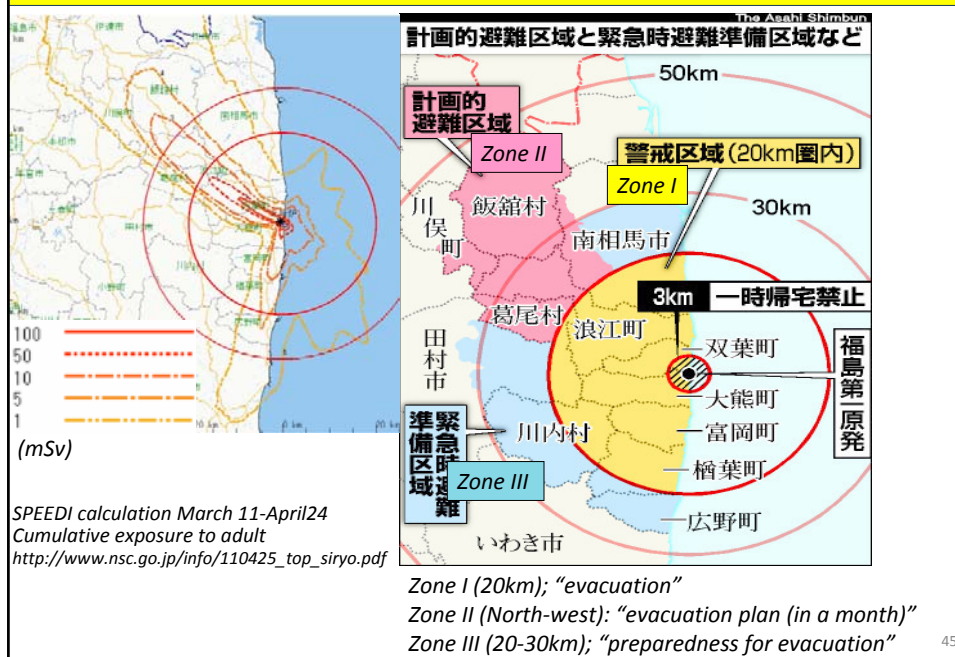
[Source] sunoyama, AEC hearing, 2011June14

## Emergency Response Center

- Established on Mar.15 (4 days after quake) to facilitate crisis management
- Located at TEPCO corporate office
- Chief: Prime Minister of Japan  
Deputy Chief: Minister of Trade, Economy and Industry (METI)  
Chairman of TEPCO
- Other member includes liaisons from related ministries and organization:  
Nuclear and Industrial Safety Agency (NISA), Ministry of Foreign Affairs (MOFA), Ministry of Defense, Prime Minister Office, Self Defense Force (SDF), Tokyo Fire Dept. etc



## What offsite emergency plan was enacted?



## What offsite Emergency Actions?

### March 11

- 16-18: Notification of no confirmation of water injection & increase of CV pressure (TEPCO)
- 19:03: Government declared nuclear emergency. (Setup of Government Nuclear Emergency Response Headquarter and Local Emergency Response Center)
- 21.23: PM directed evacuation (3km radius) and sheltering (10km radius) of 1F site

### March 12

- 5.44 : PM directed evacuation (10km radius) of 1F site
- 7.45: PM directed evacuation (3km radius) and sheltering (10km radius) of 2F site
- 17.39: PM directed evacuation (10km radius) of 2F site
- 18.25: PM directed evacuation (20km radius) of 1F site

### March 15

- 11.00: PM directed sheltering (20-30km radius) of 1F site
- Local Emergency Response Headquarter issued "direction to administer the stable Iodine during evacuation from the evacuation area (20 km radius)" to the Prefecture Governors and the heads of cities, towns and villages.

### March 25

- Chief Cabinet Secretary prompted voluntary evacuation (20-30km radius) of 1F site

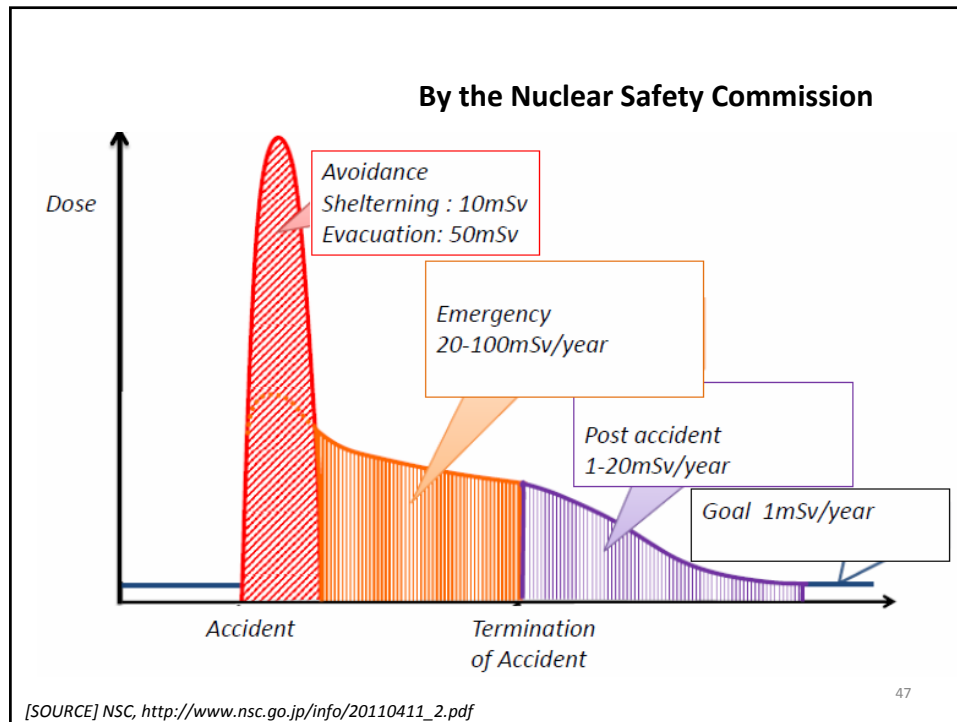
### April 11

- Chief Cabinet Secretary set up an area of planned evacuation within 1 month to avoid exposure beyond 20mSv/yr and prompted preparation for evacuation (20-30km) of 1F site (reason: just in case of large release)

### April 20

- Chief Cabinet Secretary set-up of de-fact exclusion zone for 20km radius of 1F (Nr. of residents: 7,8000) and reduction of EPZ to 8km around 2F





- Part I 3.11 Earthquake and Tsunami**
- Part II Response of the nuclear reactors**
- Part III Recovery actions**
- Part IV Offsite consequences**
- ✓ **Part V Key Lessons Learned**

## Key Lessons Learned

### 1. Design considerations against natural hazards

- CCF (such as of onsite/offsite power) by natural and man-made hazard
- Probabilistic approach using logic tree to represent epistemic uncertainty

### 2. Design considerations against TOTAL loss of power and Isolation from UHS

- Diversified power & water supply: Air-cooled DG, Water from dam
- Diversified Ultimate Heat Sink (UHS) of Residual Heat Removal and Emergency Equipment Cooling Systems

### 3. Multi-unit installation

### 4. Passive safety

- Heat removal from reactor core/containment/SFP by Isolation Condenser, PCCS, external CV cooling, wall cooling etc
- Preparations for “what if onsite recovery actions were disabled”

### 5. SFP design

- Location
- Early transfer to storage facilities

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## Key Lessons Learned

### 6. Accident Management

- a) Review and drill for the “use of all available resources (Apollo 13)”
  - Provisions of Onsite or National/Regional Nuclear Crisis Management Center (or WANO), under appropriate delineation of responsibility, transportation systems and storage of mobile equipments such as Fire Engines, portable sweater pumps, batteries, remote sensing devices, remote spray system, robotics etc & drill for use
- b) Implementation of recovery actions in harsh radiation environment
- c) Potential of detonation/deflagration of leaked hydrogen outside of the CV
  - Vent line pipe and SGTS line pipe
  - “hydrogen deflagration/detonation in a BWR R/B” (NE&D 211,27-50)
- d) Structure of Emergency Management organization

### 6. SAM Operational aids

Real-time simulation of plant behaviour as an aid to decision-making from options and assess the current/future risks potentials, backed by precise accident data tracking system by recoding every plant behaviour and remedial actions

### 7. Accident instrumentation

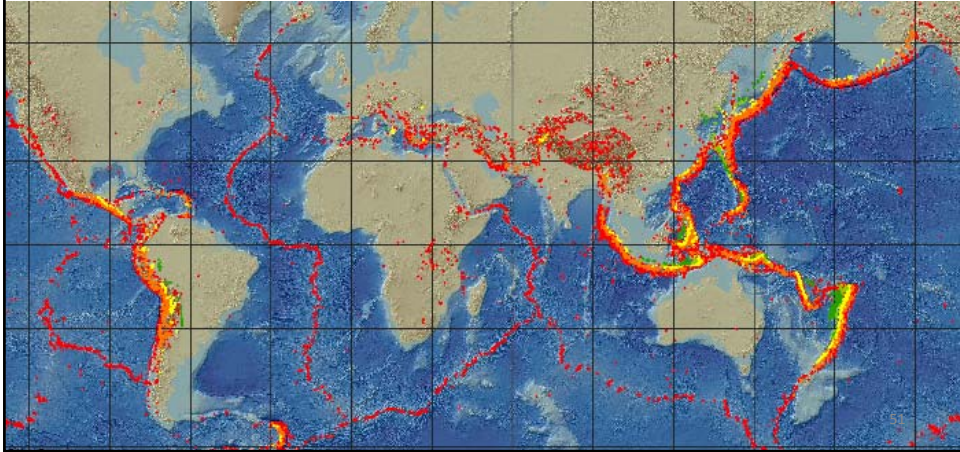
### 8. Management (Who is in charge?, Operation and Tech Support, SPEEDI etc)

## Key Lessons Learned

### 9. Regulatory system

### 10. International aspect

Peer review of design and SAM, CSC etc



***Last but not least***



## International supports

### < Governments > (Examples)

**[Canada]** 154 radioactivity survey meters, 5,005 personal dosimeters

**[Finland]** 50 Radioactivity measuring monitors

**[France]** protective suits and masks(approx. 20,000 sets), 250 radiation measurement equipment, 10pumps, 5 power generators, 5 compressors, boron(100tons)

**[Korea]** approx. 52 tons of boron

**[U.S.A] Technical support from DoE**, 10,000 radioactive-proof suits from USAID; 2 fire trucks, 5 pumps, 99 protective suits against nuclear, biological and chemical weapons, approx. 9 tons of boron, 1 large water spray pump unit, fresh-water transportation by a barge for carrying fresh water from the U.S. Forces. 31,000 Radiation dosimeters, NRC's experts support

### <Industries> (Examples)

**[Areva]** Protective suits (approx. 10,000), protective masks(3,000), 2 monitoring cars etc

**[iRobot in U.S.A]** Packbot by iRobot worked inside the reactor building of Unit 3 on April 17.

**[Rosatom in Russia]** 400 Radiation dosimeters, protective masks(5,000)

**[Sany Heavy Industry in China]** 62 truck mounted concrete pump

**[Putzmeister in Germany]** Several long pumps including a 70m long pump

**[Westinghouse/B&W/Shaw, GE]** Proposal of the mid-term & long term plan



Packbot in reactor of Fukushima Daiichi Unit3



Putzmeister pump



Sany Heavy Industry pump

## HEARTFUL THANKS!

- ❖ To technical support and equipments from USDOE & National Lab's, USNRC, INPO, EPRI, Nuclear Industry, Military Force etc.
- ❖ To \$175,000 dollars donation from ANS members to AESJ as Japan Earthquake Fund

Thanks to ANS



*Part of the funds spent for refrigerators to serve refreshments for emergency response workers at Fukushima site, working in harsh environment*

***Never, Ever Again  
anywhere in the world***



<http://www.asahi.com/photo/news/gallery/fukushima-genpatsu/>