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Safety Enhancement of Nuclear Power Plant Post Fukushima

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1. Outline of 3.11 Disaster

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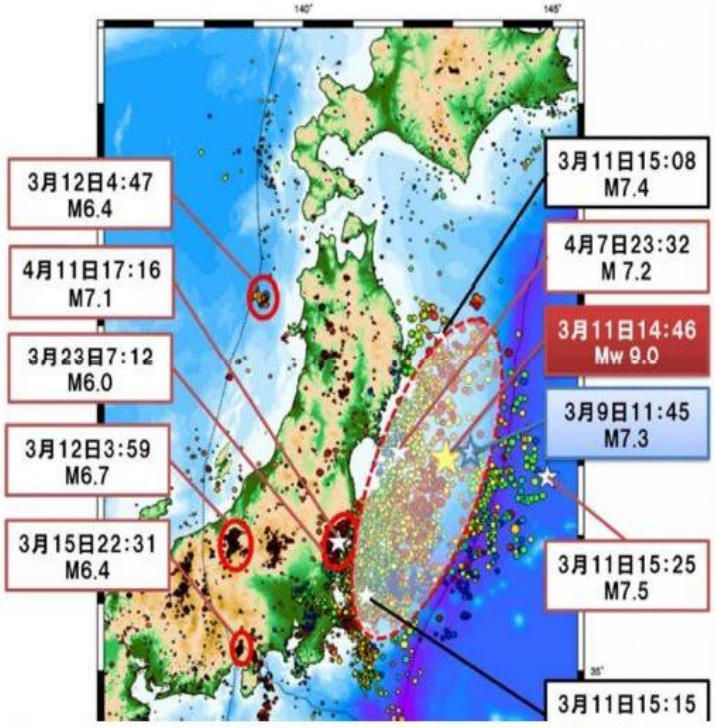
One of the largest magnitude Earthquake (M9.0 Richter) on record happened

Grade	Year	Name	Magnitude
1	1960	Chile	9.5
2	1964	Alaska	9.2
3	2004	Sumatra	9.1
4	**2011**	**Tohoku Pacific Ocean**	**9.0**
5	1952	Kamchatka	9.0

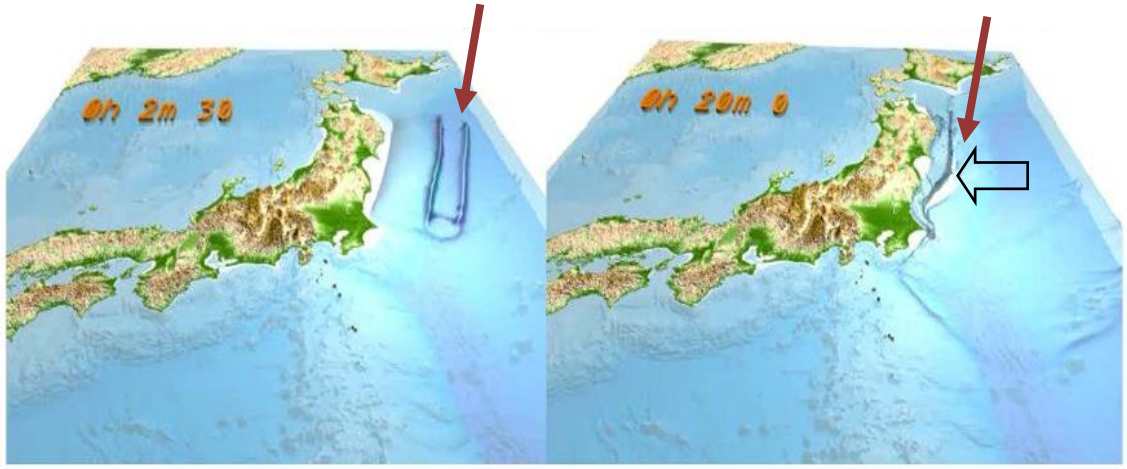
2:46 pm, March 11

Wide area Earthquakes including so many aftershocks



Earthquake Epicenter and Tsunami (image)

Tsunami Propagation

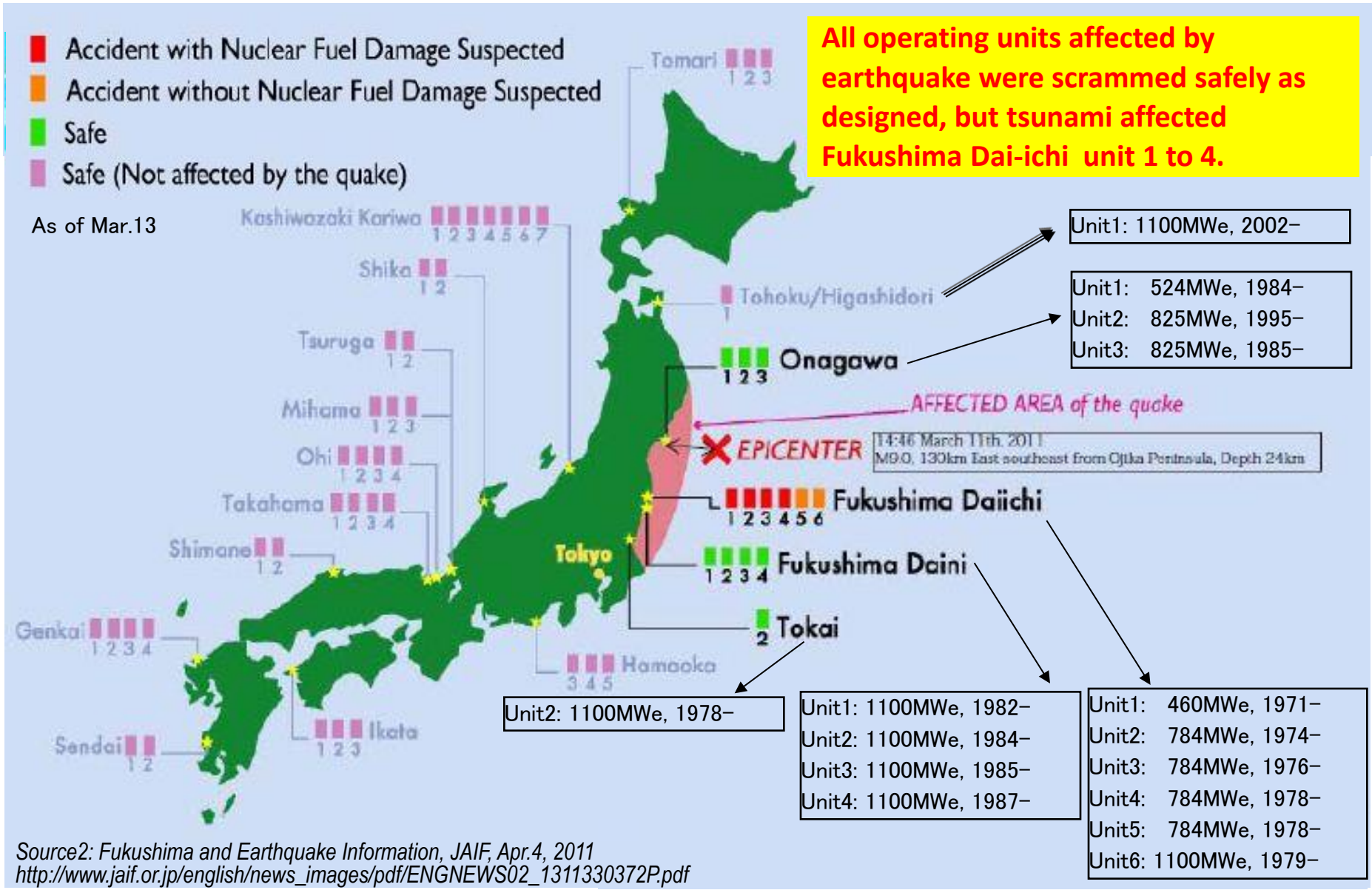


Source1: Earthquake Research Institute, University of Tokyo, Prof.Furumura & Researcher Maeda, Mar., 2011
; http://outreach.eri.u-tokyo.ac.jp/eqeqvolc/201103tohoku/eng/#mesonet

Source2: Fukushima Accident; an overview, Dr.Omoto, University of Tokyo, ICAPP, May 3, 2011

Source3: Effect of the Earthquake and Tsunami on the Fukushima Daiichi and Daini NPPs, TEPCO, Jul.26, 2011
; http://www.tepco.co.jp/en/nu/fukushima-np/handouts/index-e.html

2. Outline of Fukushima Accident



Source2: Fukushima and Earthquake Information, JAIF, Apr.4, 2011
http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS02_1311330372P.pdf

2.1 Effect of Seismic in Fukushima Dai-ichi site

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All units were shut down safely and kept safety functions after the Earthquake

Table: Acceleration of the earthquake

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	346	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

Some actual acceleration exceeded design condition but the safety-related equipment withstood the earthquake because of the large design margin.

[Reference] ICAPP 2011, 3 May 2011 Akira OMOTO, University of Tokyo, JAPAN

2.2 Effect of Tsunami in Fukushima Dai-ichi

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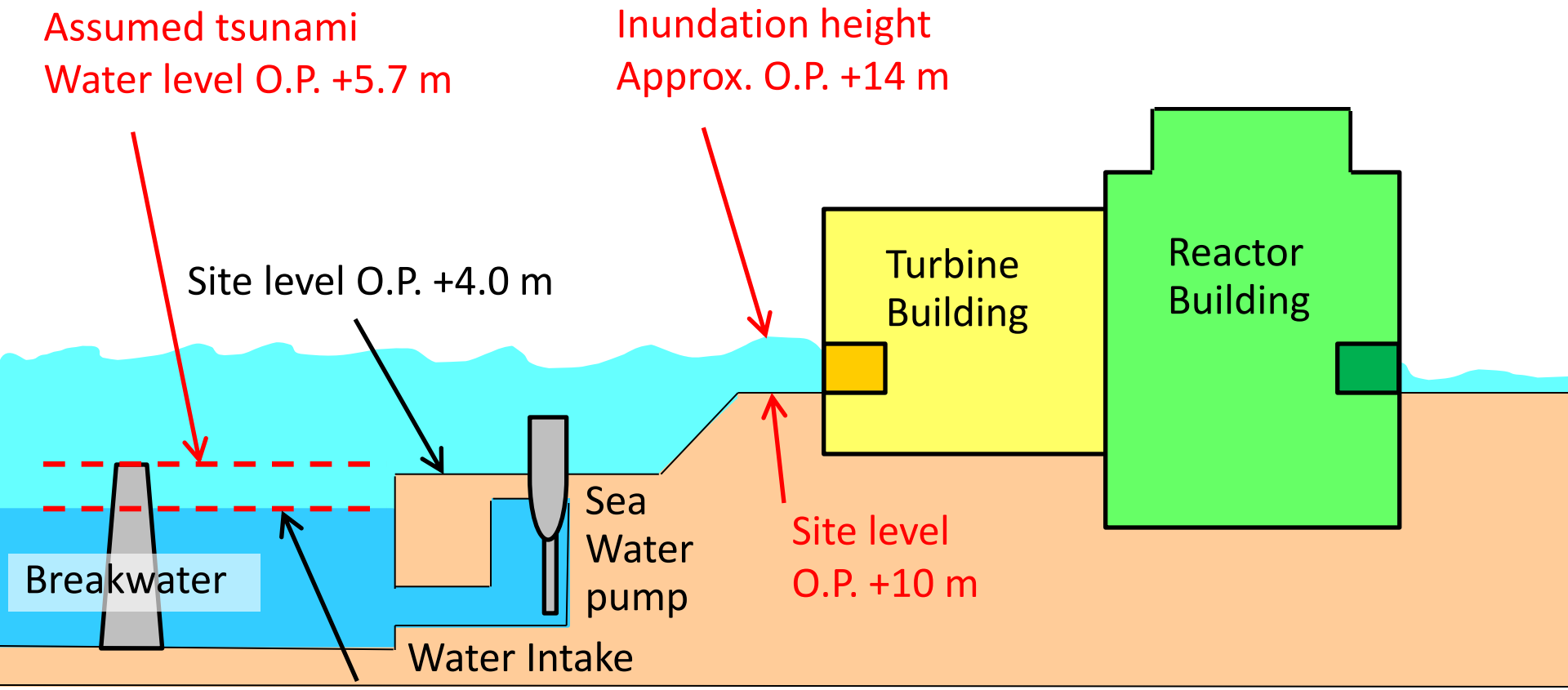
Inundation height was fatally higher than assumed tsunami water level



*O.P. :Onahama bay construction level as standard point

2.3 Damages caused by Tsunami in Fukushima Dai-ichi

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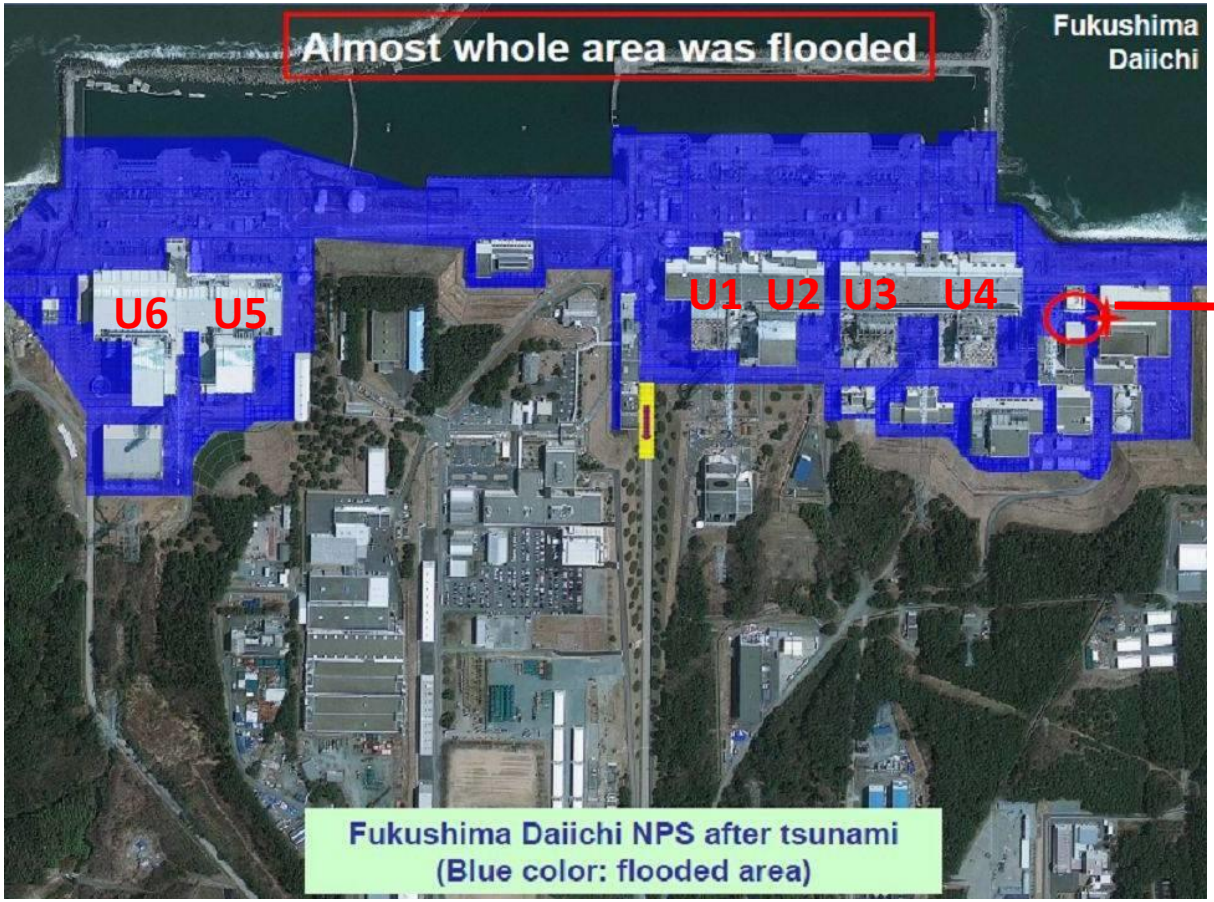

The sea water flooded into buildings through louver of ventilation, broken shutters and so on.

The whole area of Fukushima Dai-ichi site was inundated by sea water at a height of around 5m.

[Reference] The Great Japan Earthquake and Current status of Nuclear Power Station, TEPCO

2.4 Damages of Fukushima Dai-ichi Site

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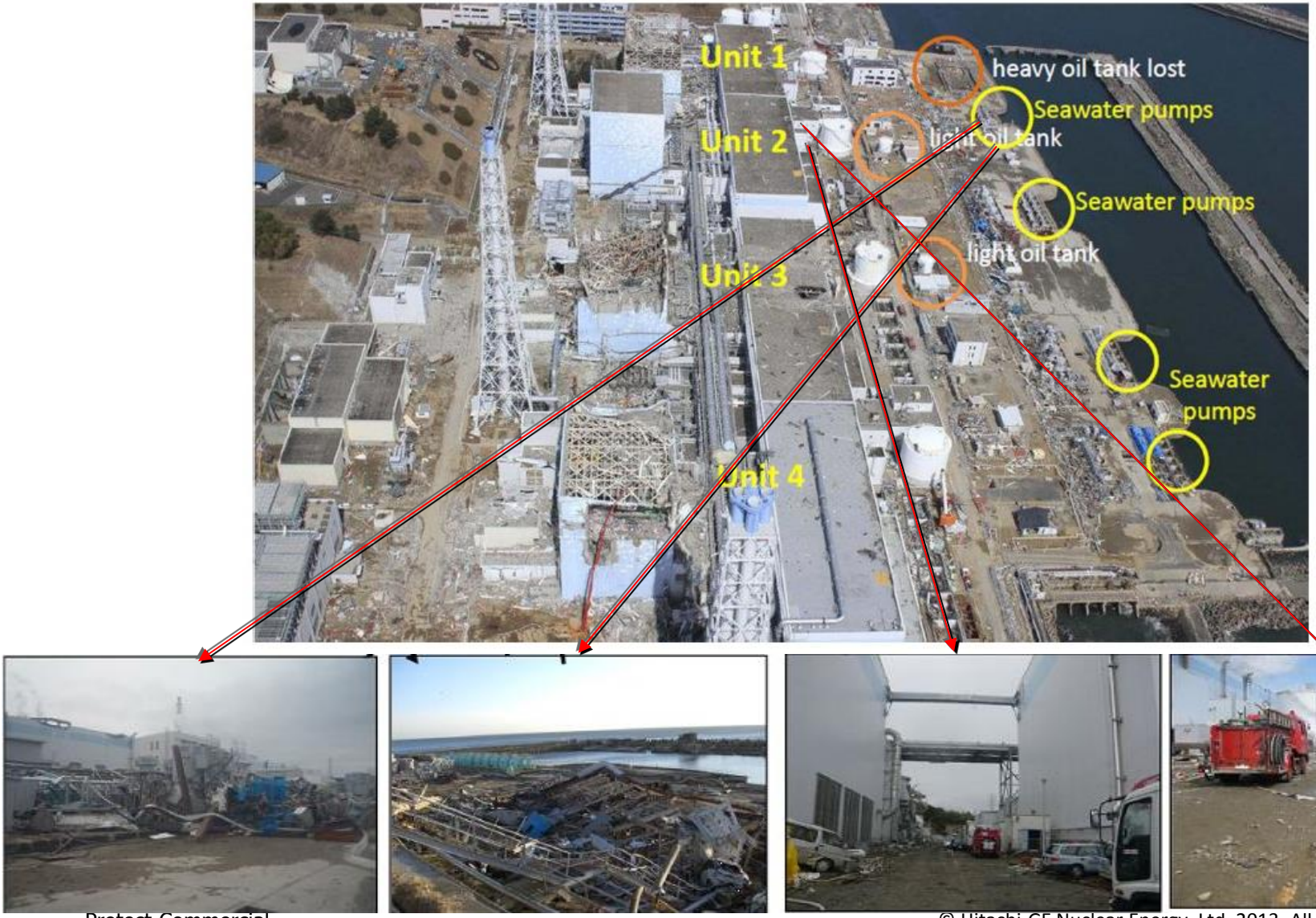
Tsunami destroyed many facilities outside plants



2.5 Damage of Electric Network of Fukushima Dai-ichi

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Unit 1 to Unit 4

【福島第一の電源：津波被災直後】

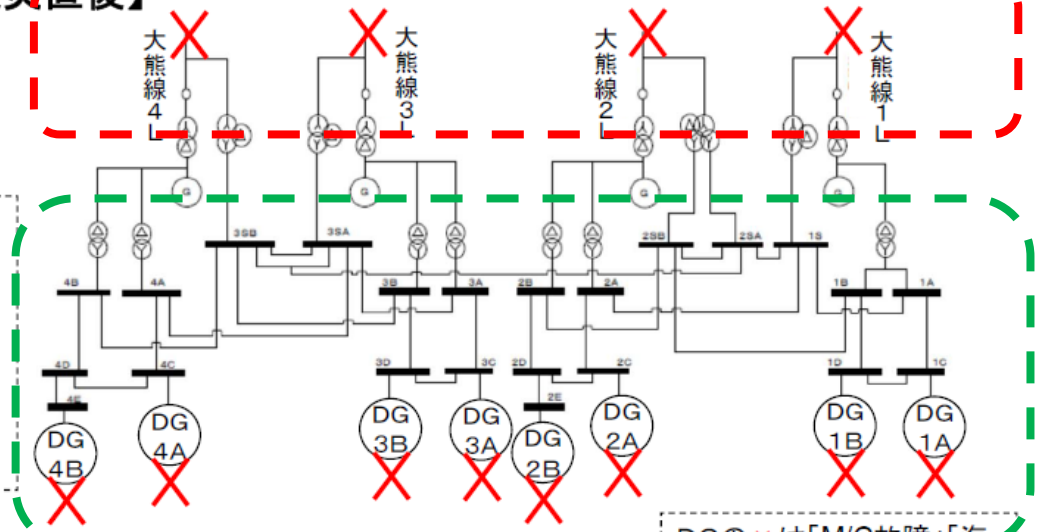
福島第一1～4号機

生き残った電源なし

大熊線1L、2L
　地震時に受電遮断器損傷
大熊線3L
　改造工事中
大熊線4L
　停止した原因を調査中

Damage by Earthquake

Damage by Tsunami



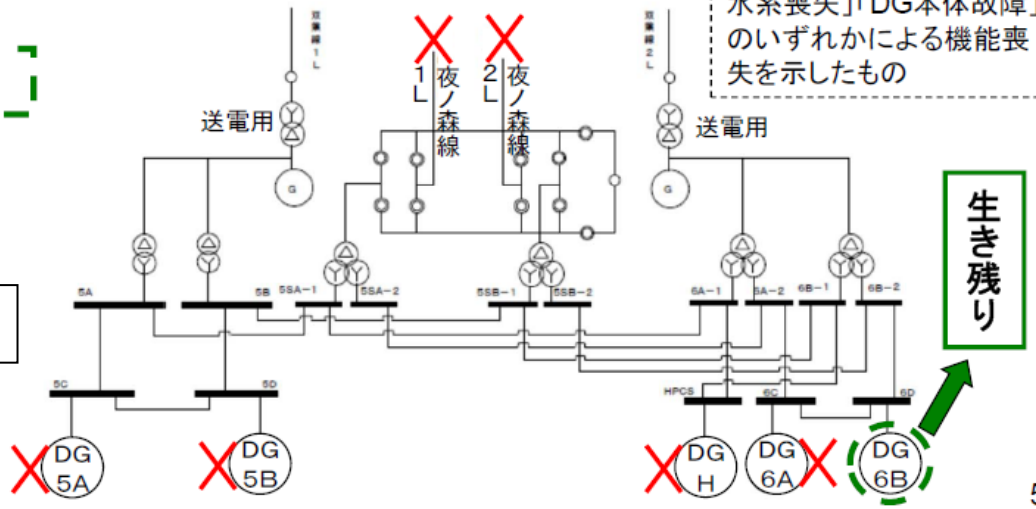
DGの×は「M/C故障」「海水系喪失」「DG本体故障」のいずれかによる機能喪失を示したもの

福島第一5～6号機

生き残りはDG6Bのみ

夜ノ森線1L，2L
　鉄塔が一部倒壊

Unit 5 and 6



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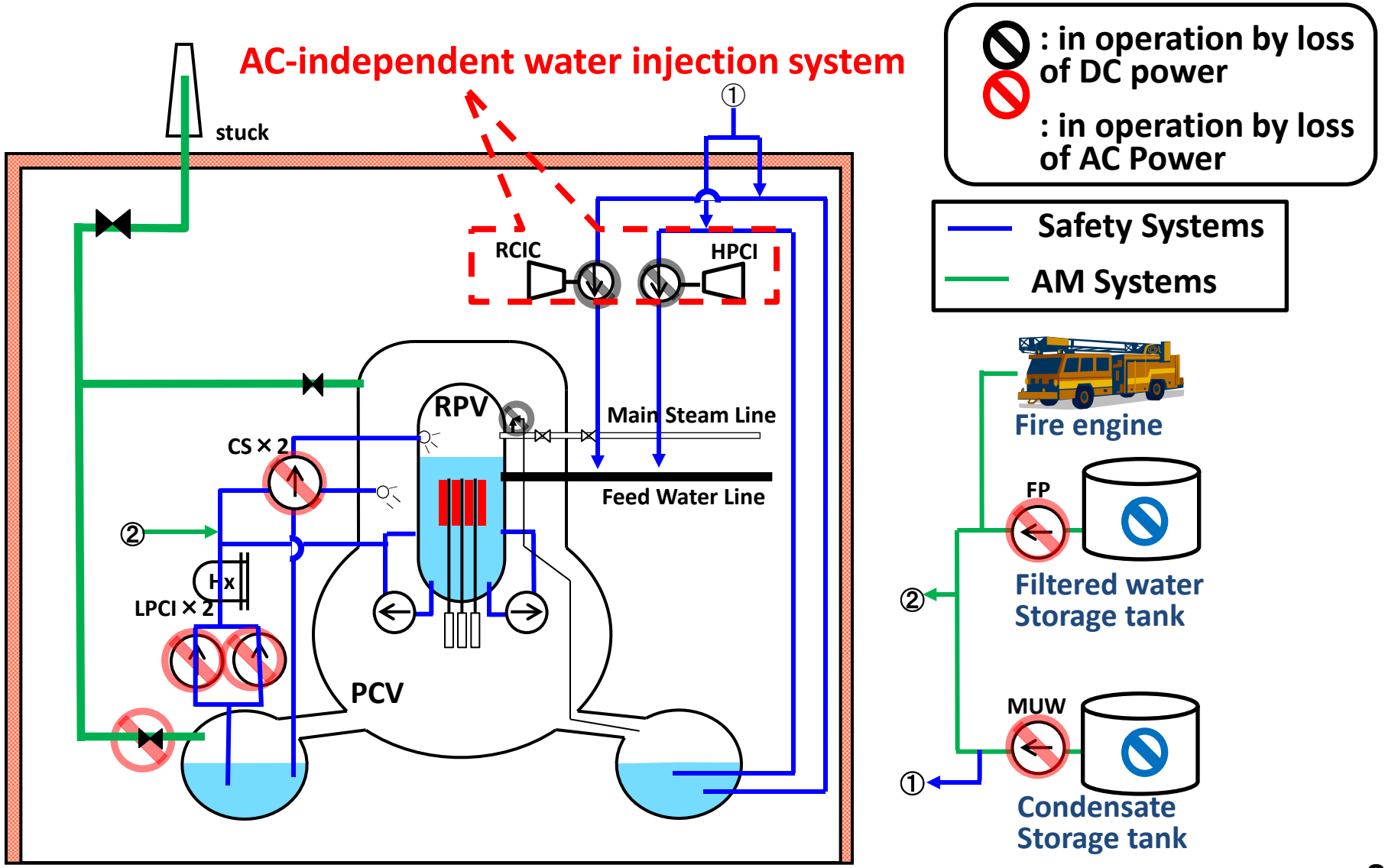
Finally, Sea Water Was Injected by Fire Engines.



2.7 Why FP discharge and H2 explosion occurred?

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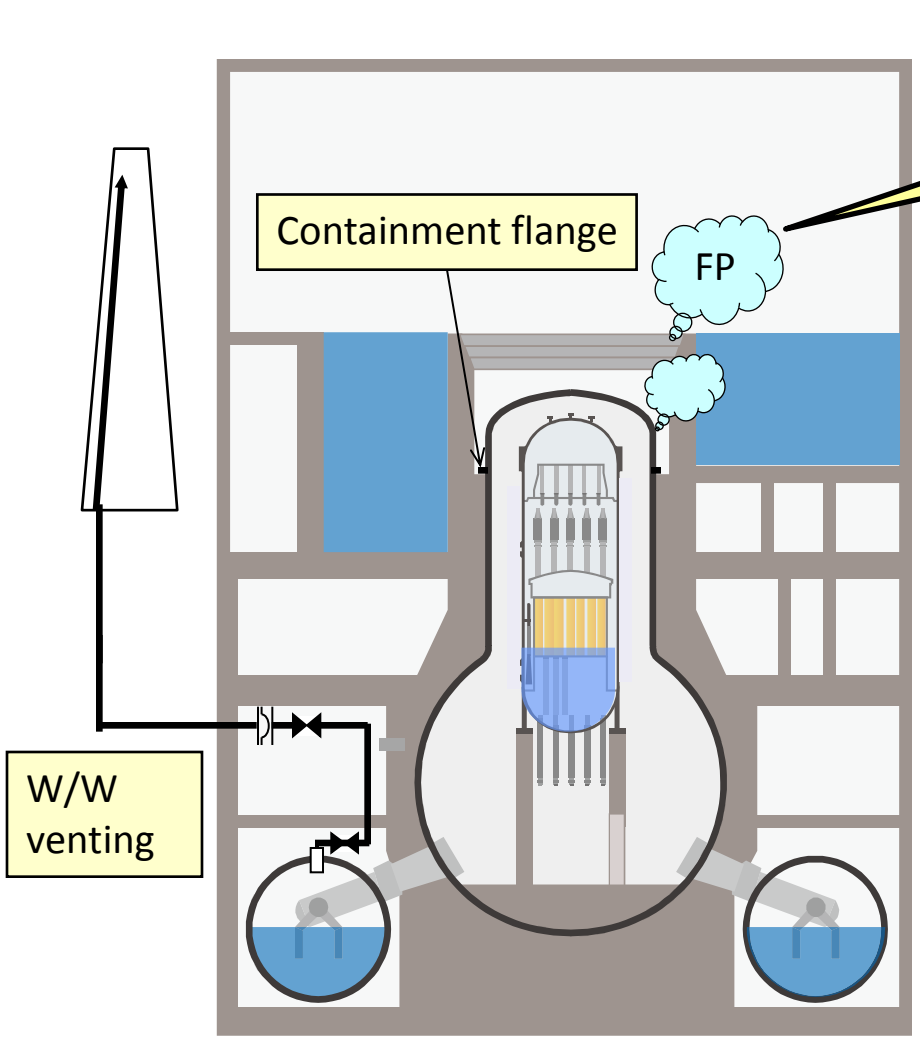

Over temperature of PCV flange led to leakage of Fission Products

Event sequence

Coolant injection delay

- Core damage
- RPV leakage
- Gas temperature in PCV rise

PCV venting delay

- PCV leakage by over heat
- Fission Products discharge outside of PCV

※W/W (Wet Well; filtering by water) prevent FP from discharging to the environment.

2.8 Effect of Tsunami in Fukushima Dai-ni

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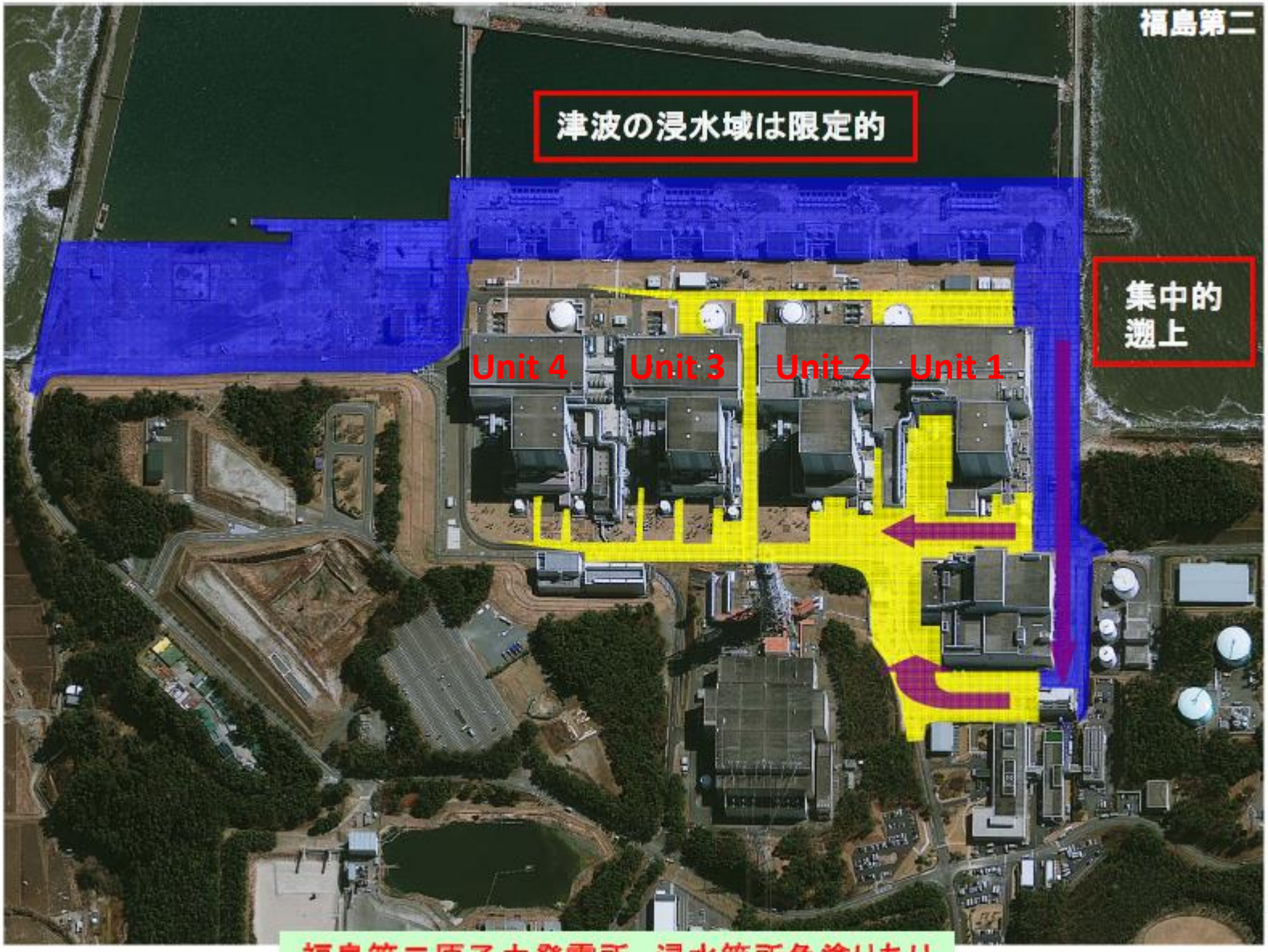

福島第二原子力発電所　浸水箇所色塗りあり

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2.9 Damage of Electric Network in Fukushima Dai-ni

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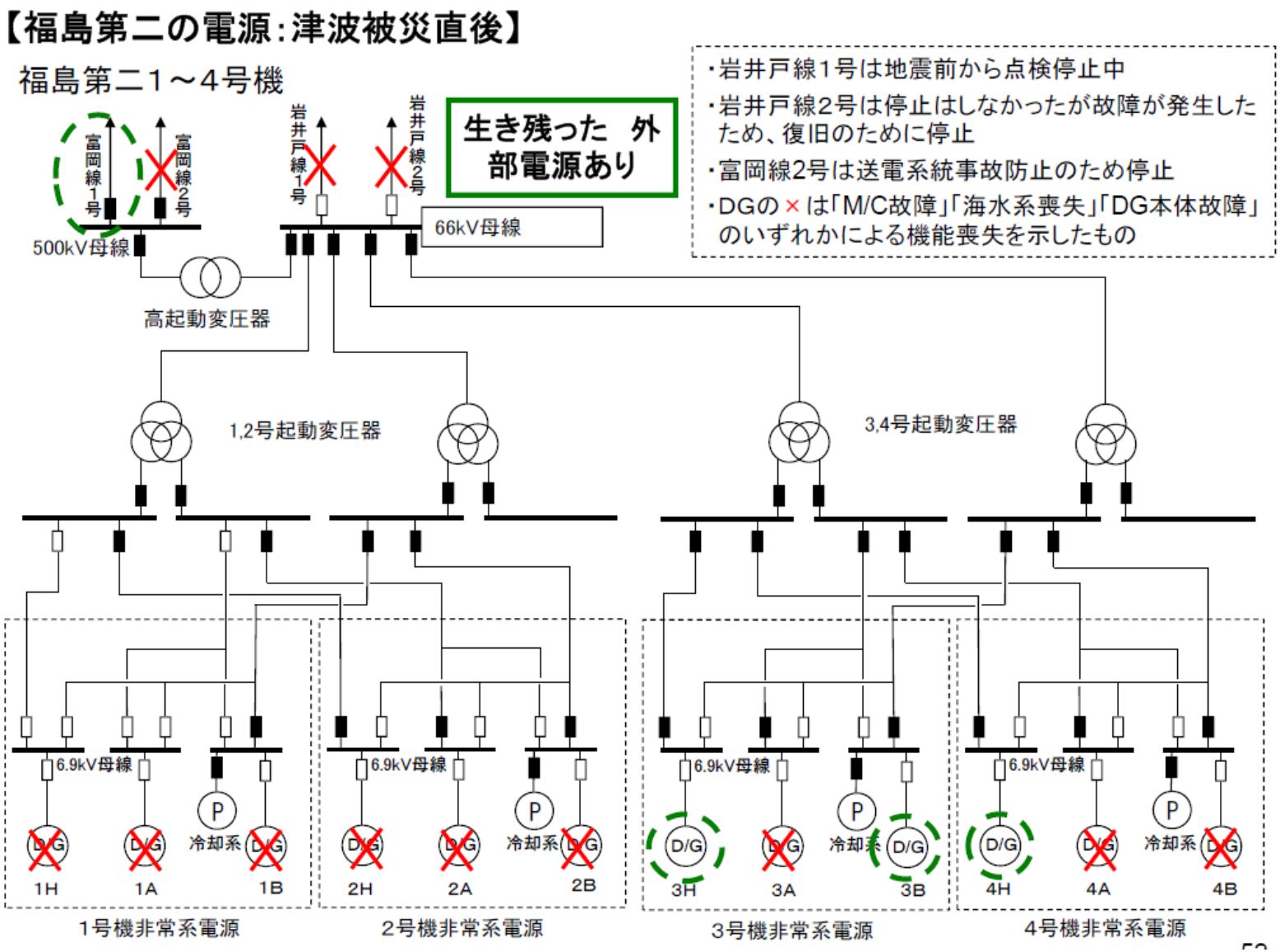

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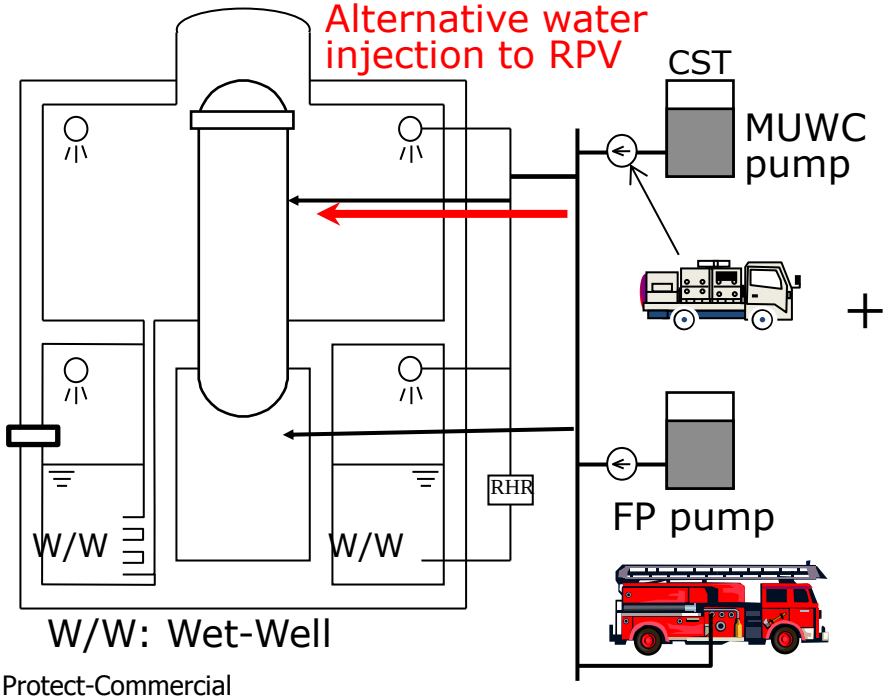
3.1. Finding Issues in Safety Design

- External events having different hazard from internal events
  - Internal events mainly dominated by random failures of system and equipment
  - External events inducing fatal common cause failure potential in case of beyond design condition
- Large uncertainties in external events
  - Difficulty to define design condition based on historical data
  - Complicated and complex damage
- Difficulty in AM operation by widespread damage over whole site
  - Difficulty to access, transport and communicate

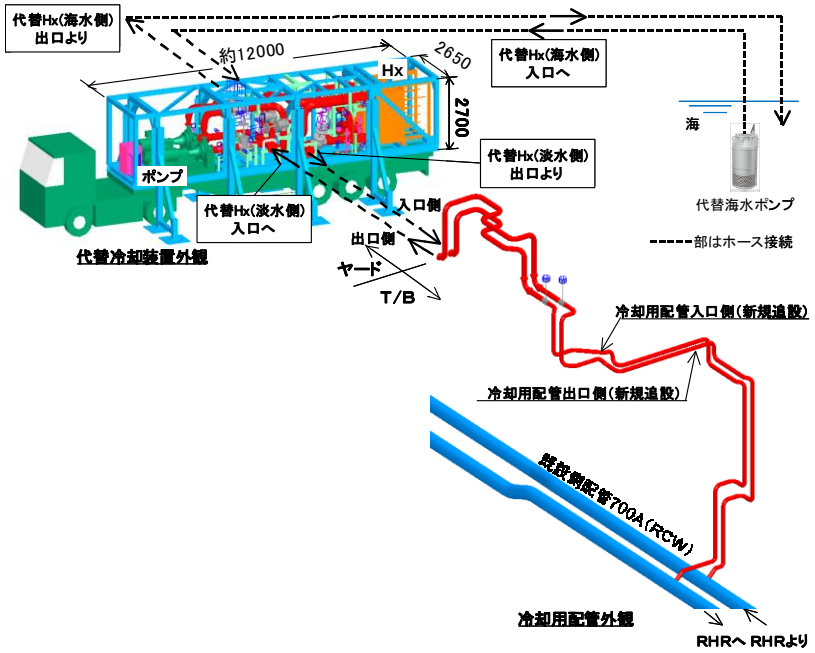
3.2. New Countermeasure for External Hazard

- Strengthening of plant facility by physical separation, redundancy diversity etc. is effective for external hazard.
- But mobile countermeasures located apart from plant facility should be prepared as the hedge of the common cause failure risk in the plant facility.

1) Existing accident management enhancement



2)Recovery management from on-site and off-site



3.3 Back-up Building Concept

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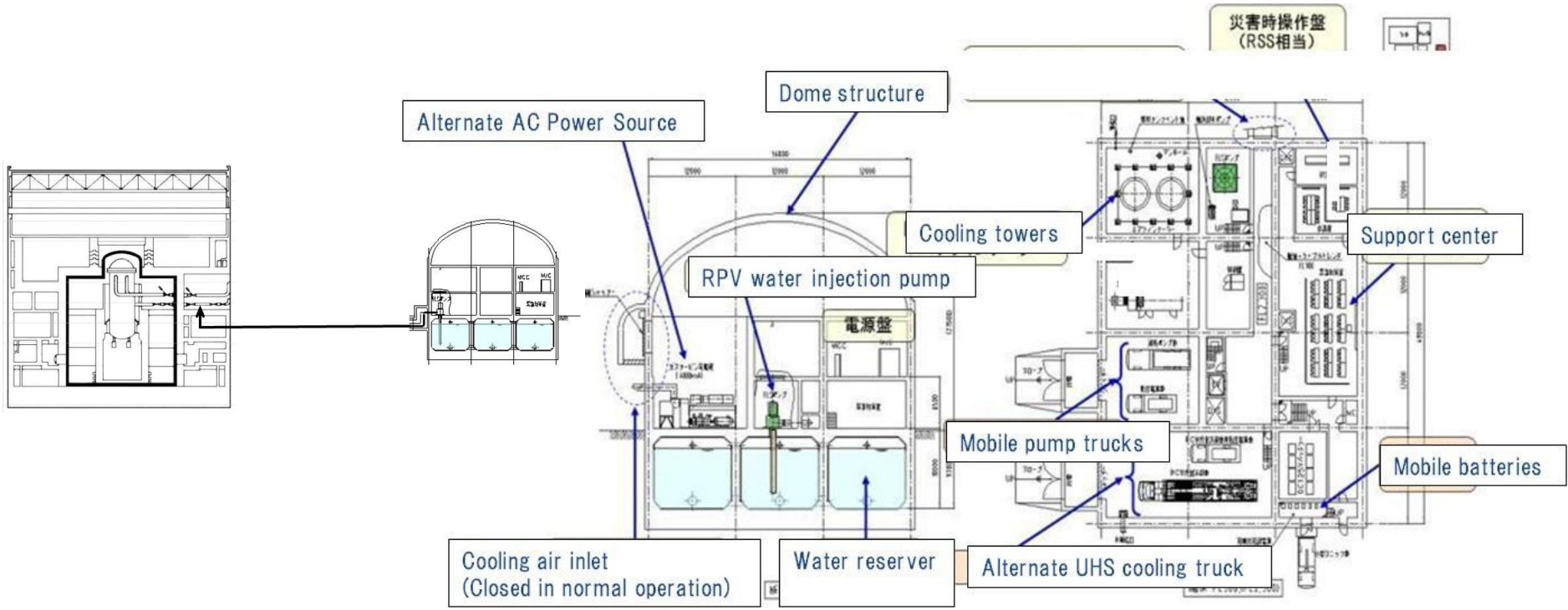
Backup Building located apart from a plant facility to recover the safety function of the plant.

- **Alternate AC power supply and mobile DC batteries**
- **Alternate water injection and cooling system**
- **Spare parts of pump, valve and electric panel etc.**
- **Advanced base instead of damaged main control room**



General Concept on B/B

3.4 Operation Procedure and Responsibility in Emergency

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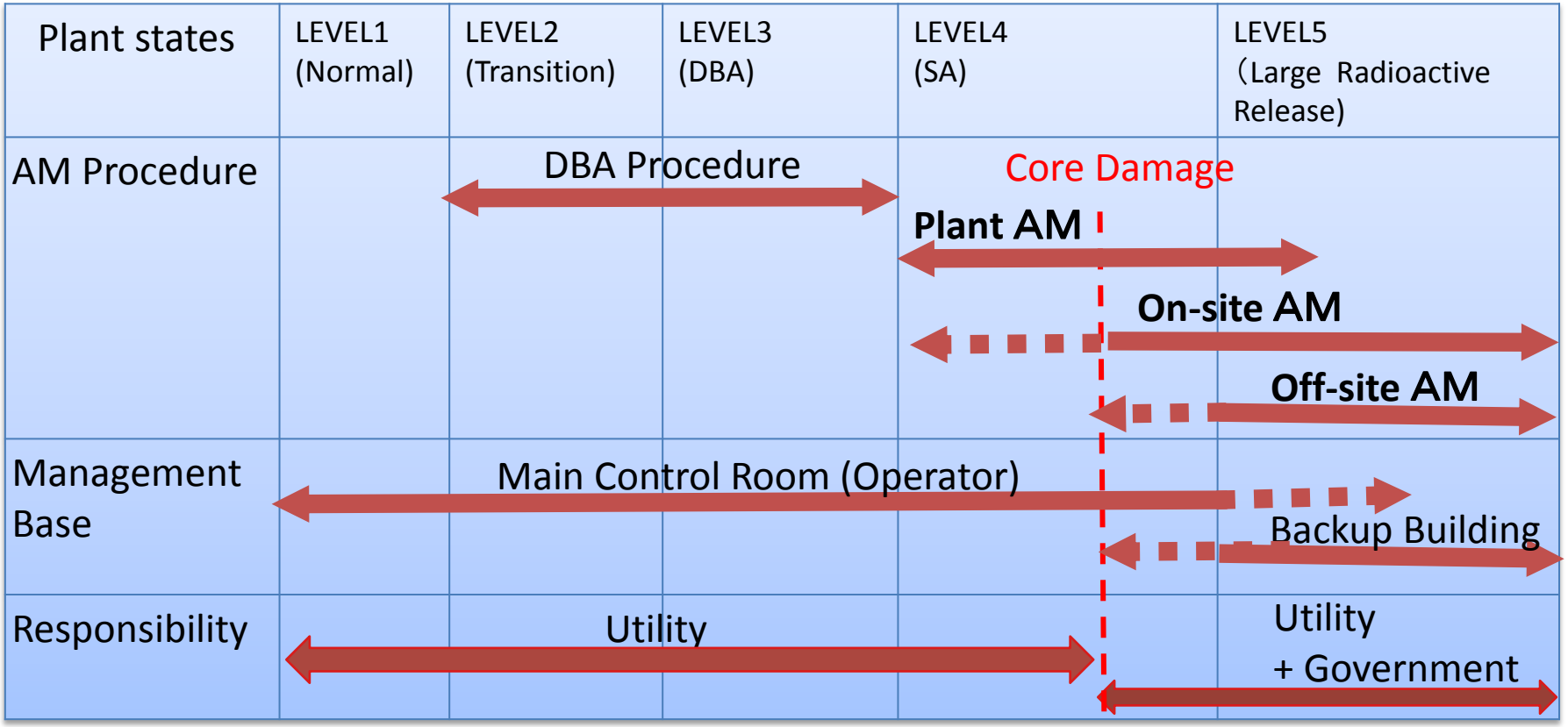
- Emergency procedures should be prepared for the proposed countermeasure.
- Appropriate changeover of management base and responsibility should be executed according to accident stage.



4. Deployment of Safety Enhanced ABWR

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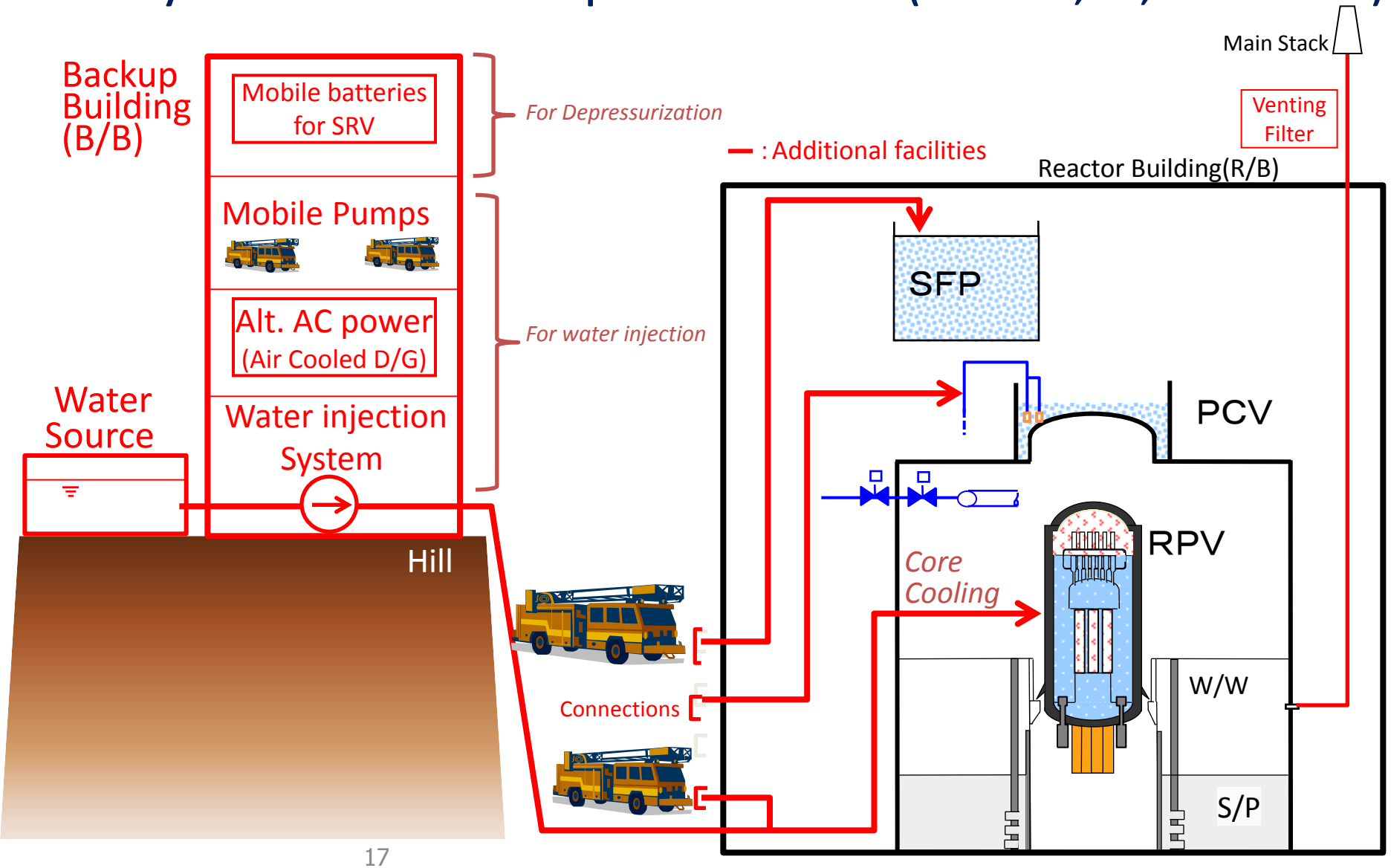
☐Safety Enhanced ABWR Developed for New Plants (Domestic, UK, Lithuania etc)



5. Conclusion

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- Fukushima accident is not only a conventional SBO but also a severe disaster derived from the loss of all safety-related system such as electric power, injection system and heat removal system. As result, all lessons learned from Fukushima accident should be reflected for all nuclear reactor types.

- Mobile system and backup building concept located apart from plant facility are effective for the protection and mitigation of external hazard.

- The measures against Fukushima accidents introduced here will be optimized and applied for the new nuclear power plants(UK, Lithuania etc.).