Outline of the Fukushima Daiichi Accident. Lessons Learned and Safety Enhancements

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Abstract. On March 11, 2011, an earthquake and subsequent tsunamis off the Pacific coastline of Japan's Tohoku region caused widespread devastation in Japan. As of June 10, 2016, it is reported that a total of 15,894 people lost their lives and 2,558 people are still unaccounted for. In Fukushima Prefecture, approximately 100,000 people are still obliged to live away from their homes due to the earthquake and tsunami as well as the Fukushima Daiichi accident.

On the day, the earthquake and tsunami caused severe damages to the Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Station (NPS). All the units in operation, namely Units 1 to 3, were automatically shut down on seismic reactor protection system trips but the earthquake led to the loss of all off-site electrical power supplies to that site. The subsequent tsunami inundated the site up to 4 to 5 m above its ground level and caused, in the end, the loss of core cooling function in Units 1 to 3, resulting in severe core damages and containment vessel failures in these three units. Hydrogen was released from the containment vessels, leading to explosions in the reactor buildings of Units 1, 3 and 4. Radioactive materials were released to the atmosphere and were deposited on the land and in the ocean.

One of the most important lessons learned is an importance to prevent such large scale common cause failures due to extreme natural events. This leads to a conclusion that application of the defense-in-depth philosophy be enhanced because the defense-in-depth philosophy has been and continues to be an effective way to account for uncertainties associated with risks. From the human and organizational viewpoints, the final report from the Investigation Committee of the Government pointed out so-called "safety myth" that existed among nuclear operators including TEPCO as well as the government, that serious severe accidents could never occur in nuclear power plants in Japan.

After the accident, the Nuclear Regulation Authority (NRA) was established on September 19, 2012. The NRA very urgently developed and issued the new regulatory requirements on July 8, 2014, taking into the account the lessons learned from the accident. It is noted that the NRA issued the Statement of Nuclear Safety Culture on May 27, 2015 which clearly expressed the NRA's commitment to break with the safety myth.

This paper briefly presents the outline of the Fukushima Daiichi accident and summarizes the major lessons learned having been drawn and safety enhancements having been done in Japan for the purpose of giving inputs to the discussions to be taken place in the Special Invited Session "Fukushima, 5 years after".

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NRA, Japan
Nuclear Regulation Authority

Fukushima Special Session
"Fukushima, 5 years after"

Outline of the Fukushima Daiichi Accident, Lessons Learned and Safety Enhancements

Masashi HIRANO and **Harutaka HOSHI**

Nuclear Regulation Authority (NRA)

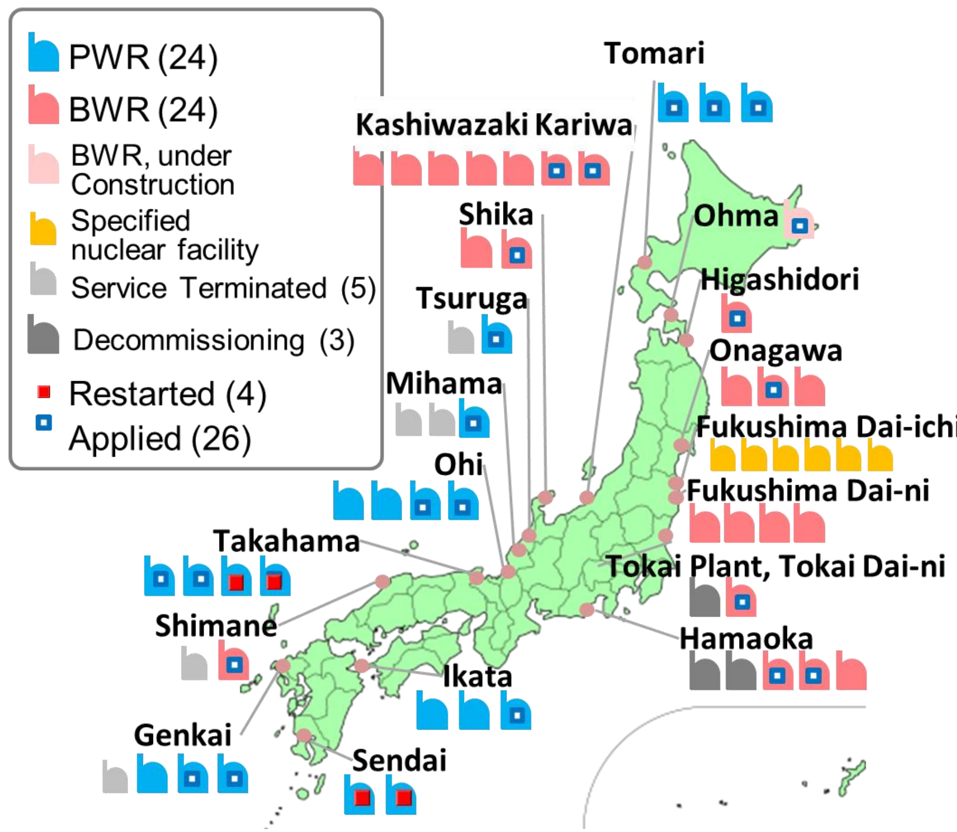
The joint conference of
the 13th Int. Conf. on Radiation Shielding (**ICRS-13**), and
19th Topical Meeting of the Radiation Protection and Shielding Division of ANS - 2016 (**RPSD-2016**)

October 3 - 6, 2016, Paris, France

Contents

Current Status of Nuclear Regulation in Japan

- NRA was established in **Sep. 2012** and developed the **new regulatory requirements** for NPPs which came into force in **July 2013**.
  - **All the 48 units** had been shut down **since Sep. 2013**.
  - So far, a total of **26 units** (**17 PWRs** and **9 BWRs**) have applied for **conformance review**.
  - In **Sep. 2014**, NRA first approved the applications from **Sendai Units 1 and 2**.
  - As of Aug. 2016, NRA has granted permission to **7 PWRs** of which **four units have restarted** (**Sendai Units 1,2 and Takahama Units 3, 4**)
- The **IAEA IRRS mission's review** was taken place in **Jan. 2016**.

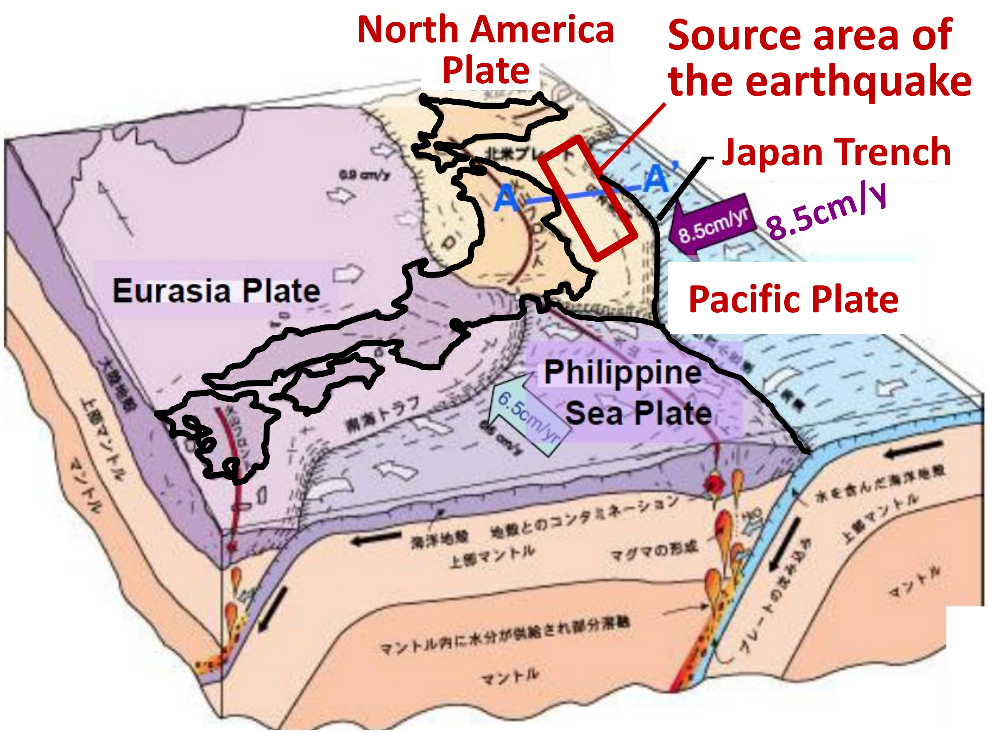


Y. Shimizu, IAEA Effective Nuclear Regulatory Systems (April 2016)

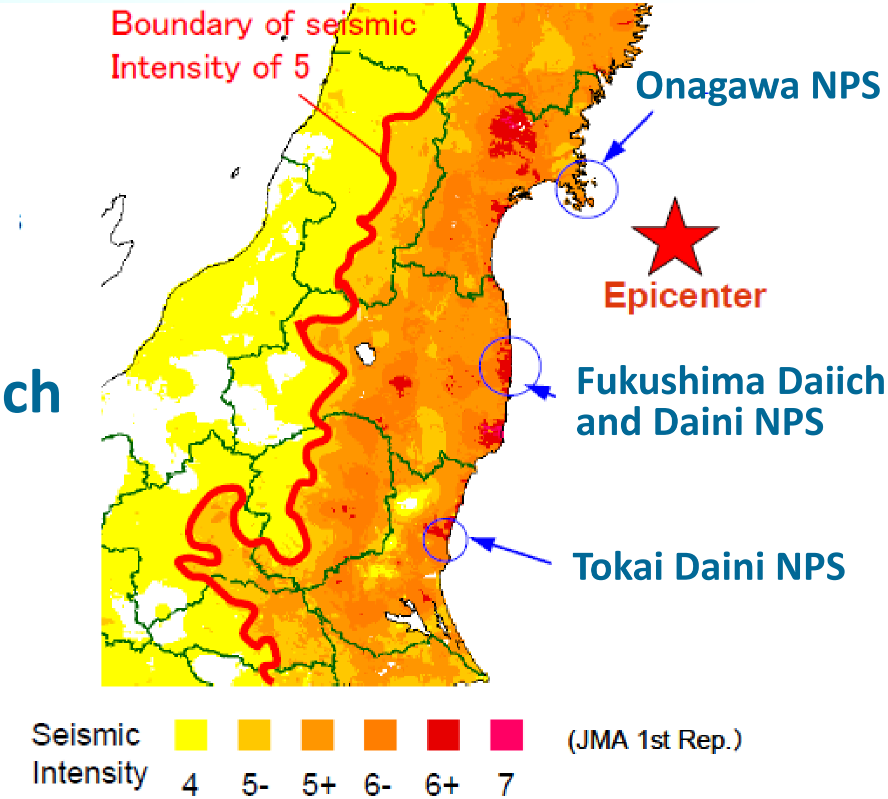
Outline of the Accident

Tohoku-District off the Pacific Ocean Earthquake

- Occurred at **14:46** on **March 11, 2011**
- **9.0 Mw**: largest ever recorded in Japan
- Rupture duration: **170 sec**
- Epicenter: 38º 10’’N and 142º 86’’E, 23.7km in depth
- **Reverse fault type near the Japan Trench**



Edited to figure in “1st Government Report (June) 2011)”

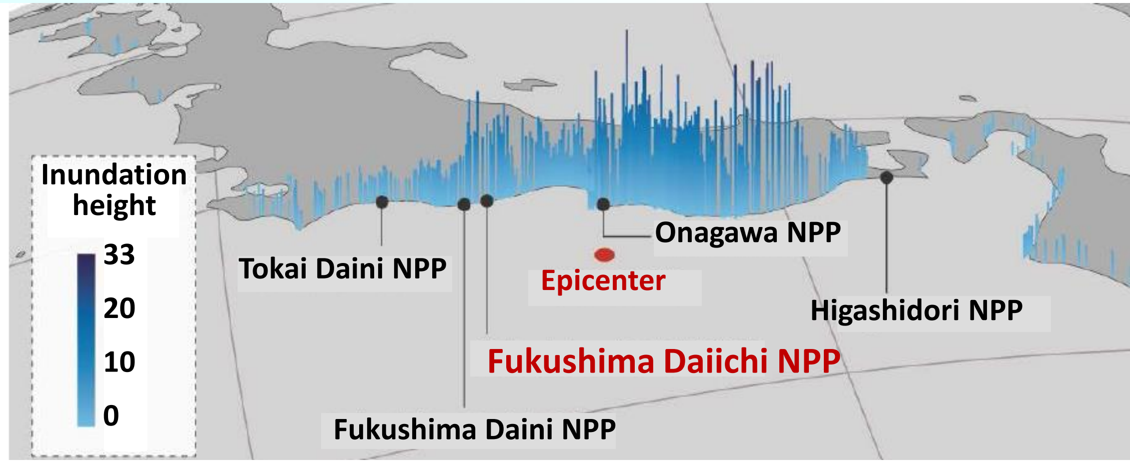


Reference: JMA Release [Online]. http://www.jma.go.jp/jma/index.html
Partially modified by JNES.

- Observed **max. acceleration** of seismic ground motion at **Fukushima-Daiichi** exceeded that of the **design basis by 26%.**

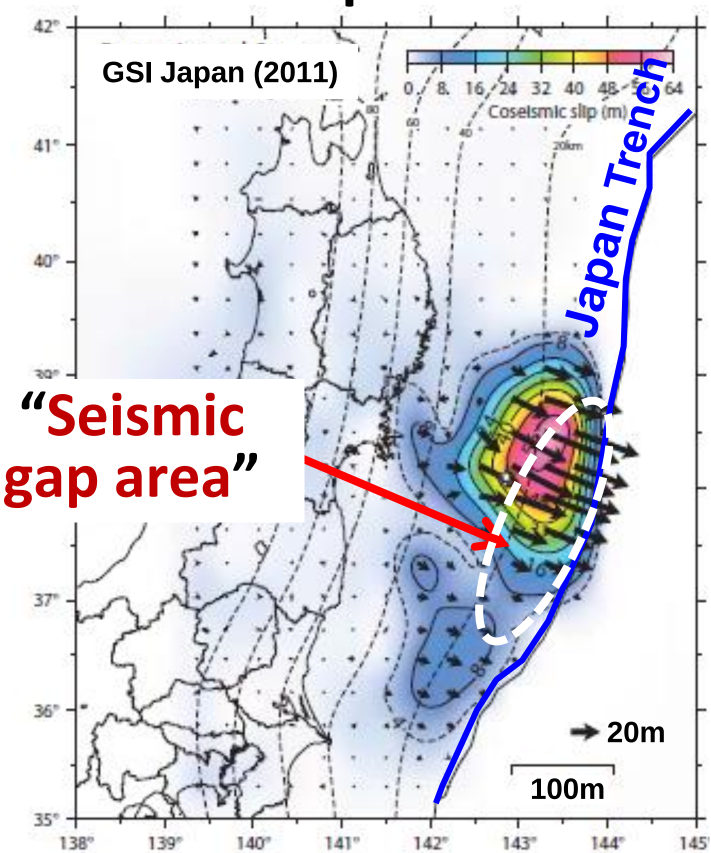
Accompanied Tsunami

- A **huge tsunami** was generated due to **a large slip**, more than 56m, **near the Japan Trench**.



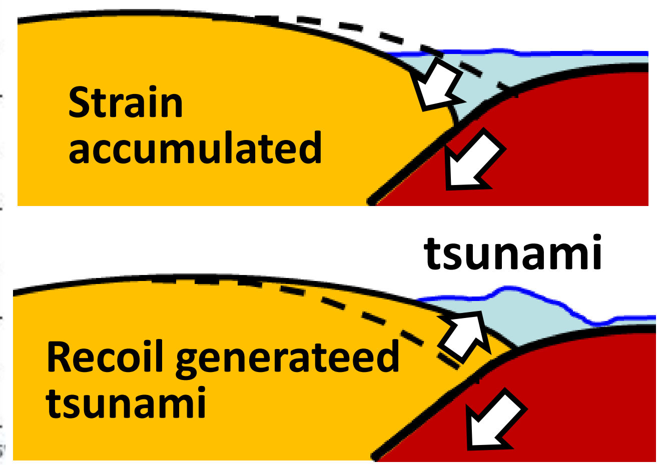
IAEA Fukushima report, Technical Volume 1/5 (2015)

Estimated slip distribution



Sugino, et al., NRA, 24 Feb, 2016

- **Multi-segment rupture** including "**seismic gap area (no seismic record)** "



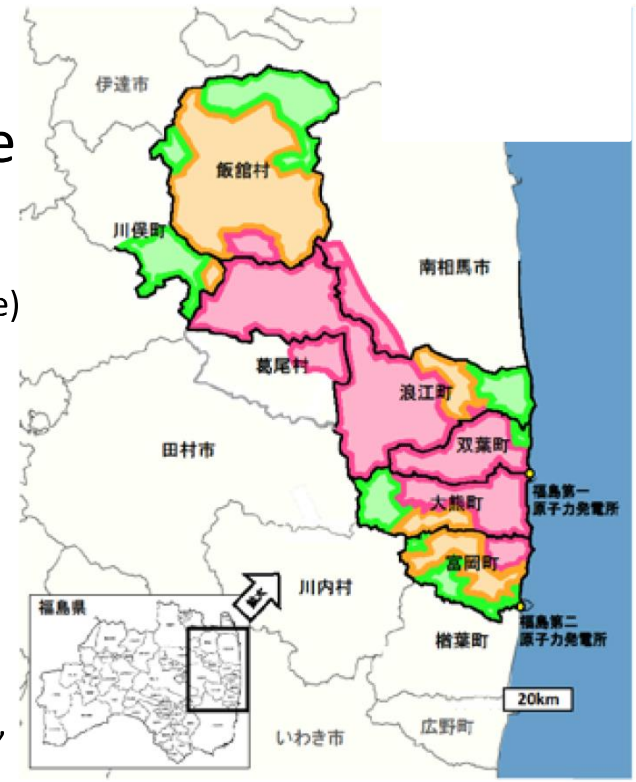
- Due to rupture of the **bonded interface**, the **North America Plate recoiled** and the strain energy was released, which generated the huge tsunami.

Consequences of Natural Hazards and the Accident

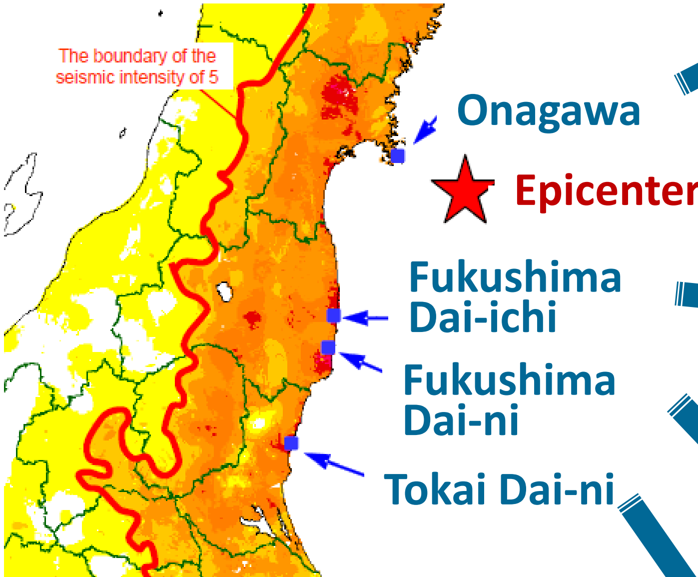
- **Casualties due to earthquake/tsunami** (as of Dec.1, 2011)
  - **Deceased**: **15,840**
  - **Injured**: **5,951**
  - **Unaccounted for**: **3,547**
  - **Damaged buildings**: **1,009,074**

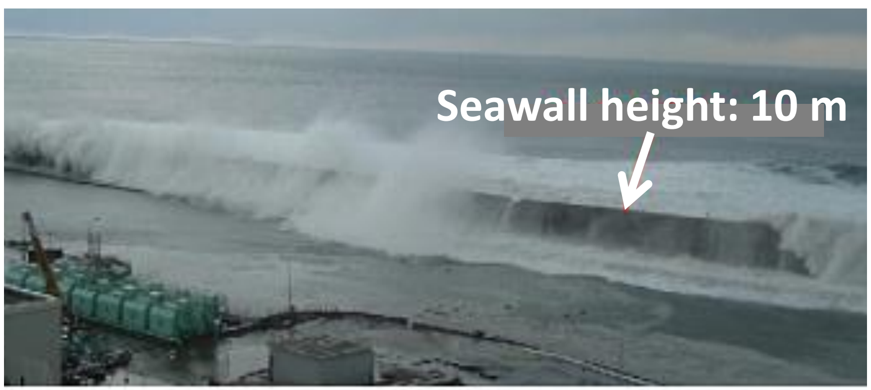
Interim Report from Government's Investigation Committee (Dec. 2011)

- As of June 2016, the number of evacuees has been reduced from **470,000** to **155,000**. Still **51,000 people** live in **temporary housing**.
- In **Fukushima Prefecture**, approx. **100,000** people are still **obliged to live away from their homes** due to the earthquake/tsunami as well as the Fukushima Daiichi accident. (website of the Fukushima Prefecture)
- **Evacuation order**: (1) Return is difficult **(red)**, (2) Habitation is restricted **(yellow)**, (3) Preparing for lifting orders **(Green)**
  - **Yellow and Green areas** will be lifted no later than March 2017. Current Status of Reconstruction and Challenges, June 2016, Reconstruction Agency



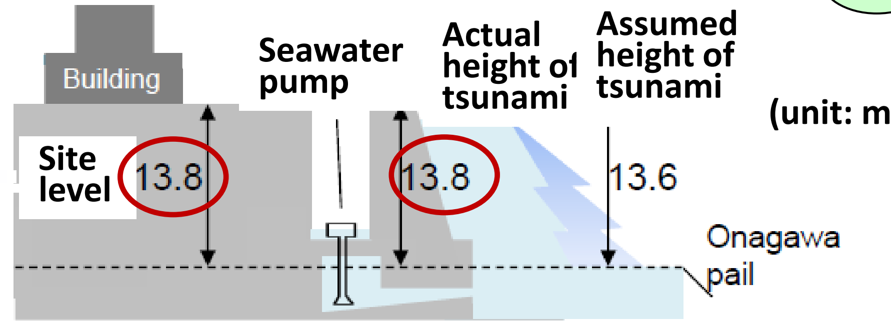
Tsunami Heights at four Different Sites



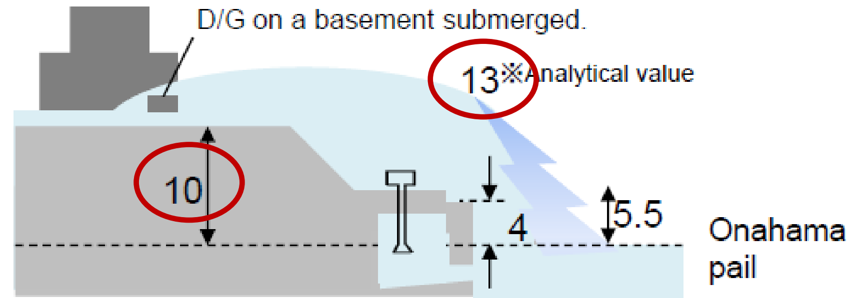


Tsunami at Fukushima Daiichi NPS

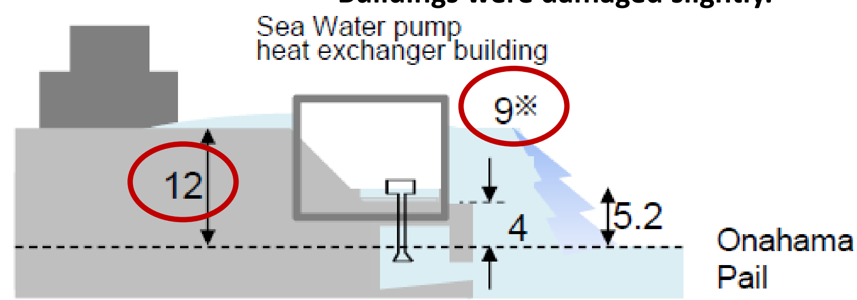
Onagawa: Not flooded



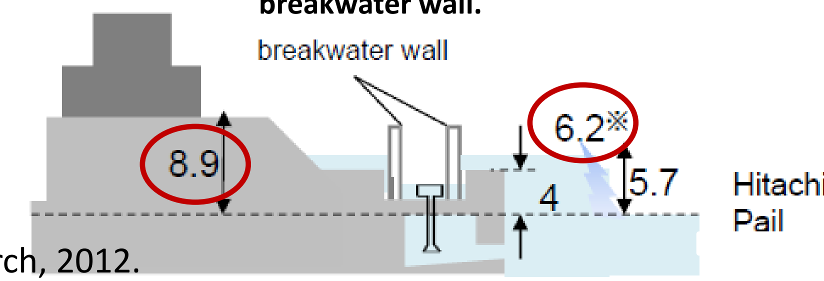
Fukushima Daiichi: Flooded destructively



Fukushima Daini: Seawater pumps were flooded. Buildings were damaged slightly.



Tokai Daini: Seawater pumps were not flooded due to breakwater wall.



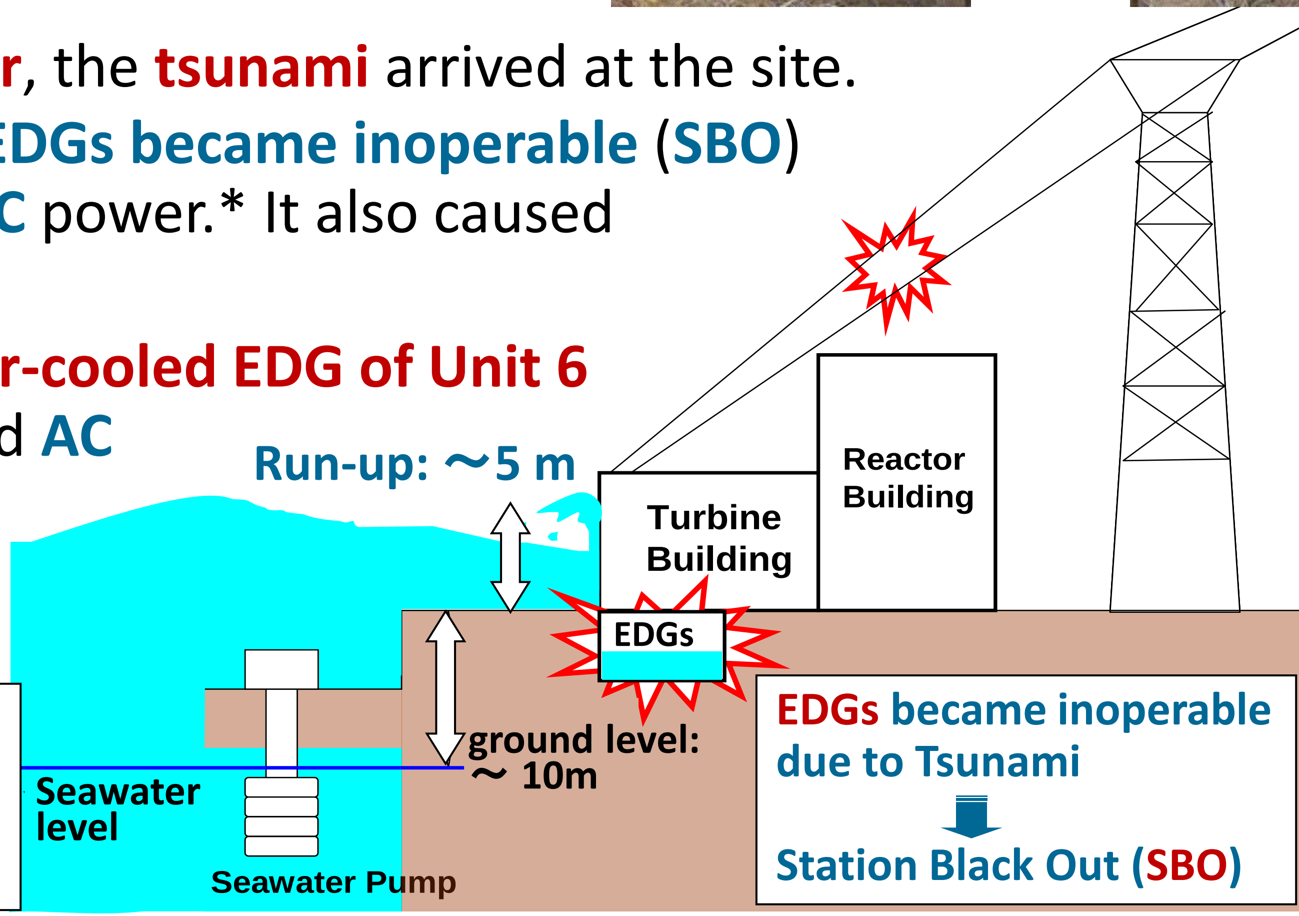
Yasui, METI, “Causes and Countermeasures”, March, 2012.

Loss of Offsite Power by Earthquake and Common-Cause Failures by Tsunami

- Units 1 to 3 automatically scrammed on seismic reactor protection trips. The **earthquake** led to **loss of offsite power**. All the **emergency diesel generators** (**EDGs**) automatically started.

- Then, **about 40 min. later**, the **tsunami** arrived at the site.
  - In Units **1 to 4, all the EDGs became inoperable** (**SBO**) together with loss of **DC** power.* It also caused **LUHS** as well.
  - In Unites **5 and 6**, an **air-cooled EDG of Unit 6 survived** and it supplied **AC power** to both units.

*DC power was available in Unit 3.



Seawater pumps for residual heat removal became inoperable

⬇

Loss of Ultimate Heat Sink (LUHS)

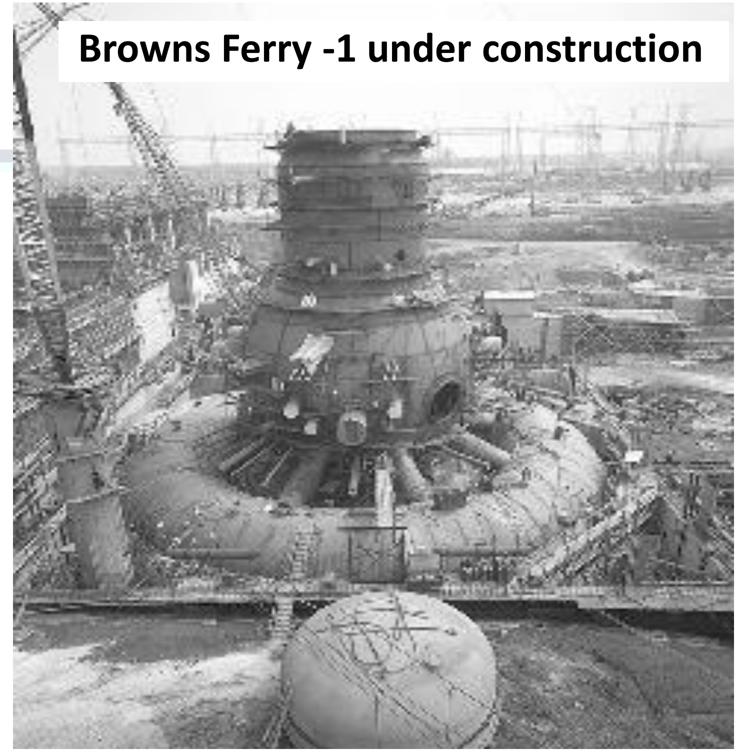
Major Chronology of Events

Source: IAEA DG Report and Technical Volumes 1 (2015):

<table>
<tr><th>Unit 1</th><th>Unit 2</th><th>Unit 3</th></tr>
<tr><td colspan="3">14:46 on Mar. 11: Shutdown due to earthquake</td></tr>
<tr><td colspan="3">LOOP: Loss of off-site power → EDGs started automatically</td></tr>
<tr><td>ICs (Isolation Condensers) operated manually</td><td>RCIC (Reactor Core Isolation Cooling System) started manually</td><td>RCIC started manually</td></tr>
<tr><td colspan="3">15:27 on Mar. 11: Tsunami arrived</td></tr>
<tr><td colspan="2">Loss of AC and DC power</td><td>Loss of AC power (DC power available)</td></tr>
<tr><td>ICs and HPCI were not operable
March 12
• PCV venting at about 14:30
• Hydrogen explosion at 15:36
• Seawater injection at 19:04</td><td>RCIC operated for about 70 hours without DC power
March 14
• RCIC stopped until ~12: 30
• Operators opened SRV at 18:02
• Seawater injection at 19:54
March 15
• Possible PCV failure</td><td>March 12
• RCIC stopped (11:36) and HPCI started (12:35)
March 13
• HPCI was shut down remote-manually from MCR at 2:42
• SRVs opened at 9:08 (ADS conditions met).
• Fresh water injection at 9:25
March 14
• Hydrogen explosion at 11:01</td></tr>
</table>

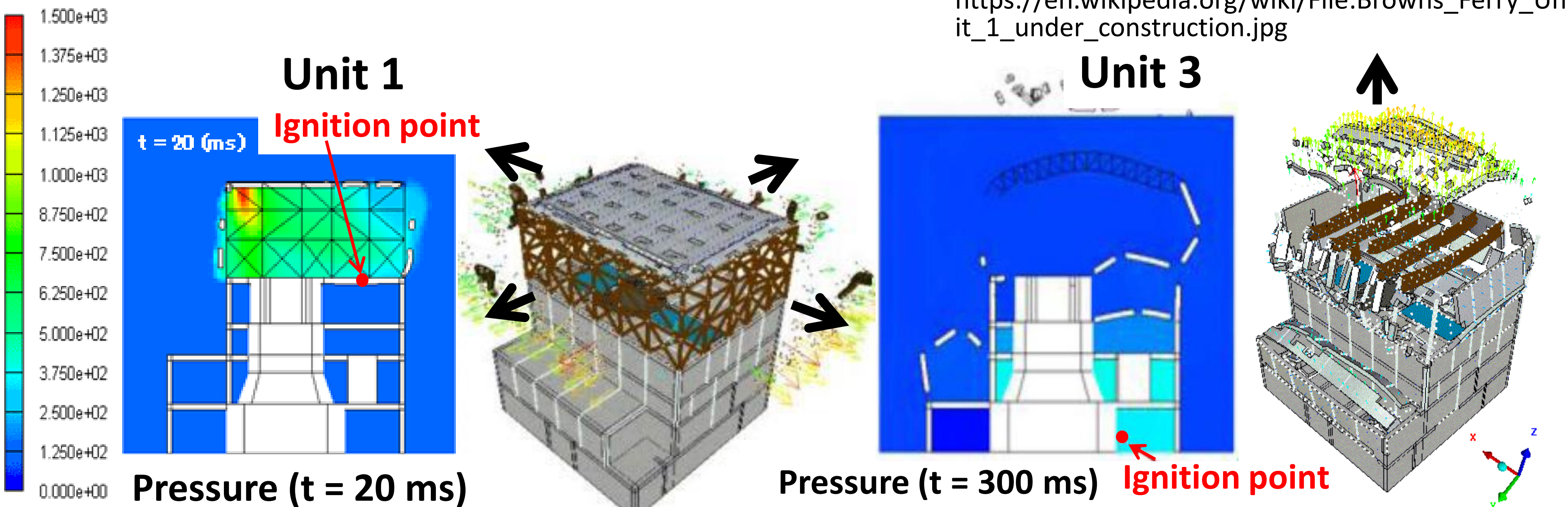
Hydrogen Explosion at Units 1, 3

- Hydrogen leaked from RPV to PCV and then to the RB, and exploded there.
- Analyses were done by the former JNES with **FLUENT** and **AUTODYN**.
- It was assumed that hydrogen leaked at:
  - **Top flange gasket at Unit 1**
  - **Sealing of hatch or penetrations at 1st floor at Unit 3**



https://en.wikipedia.org/wiki/File:Browns_Ferry_Unit_1_under_construction.jpg

[kPa]

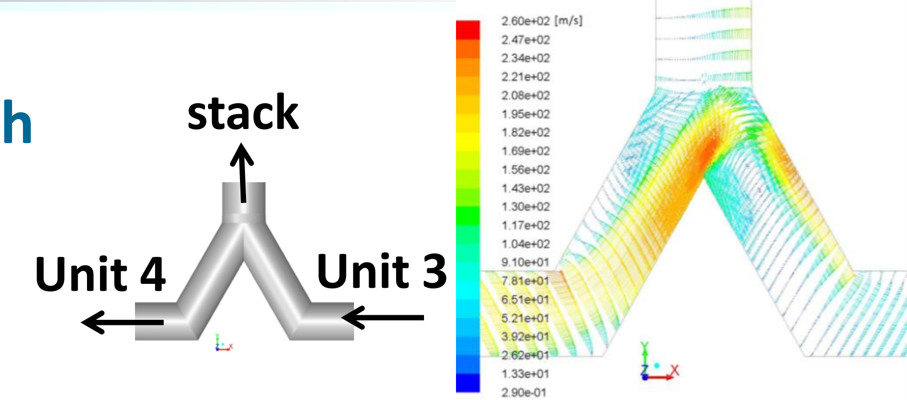


Pressure (t = 20 ms)

Pressure (t = 300 ms)

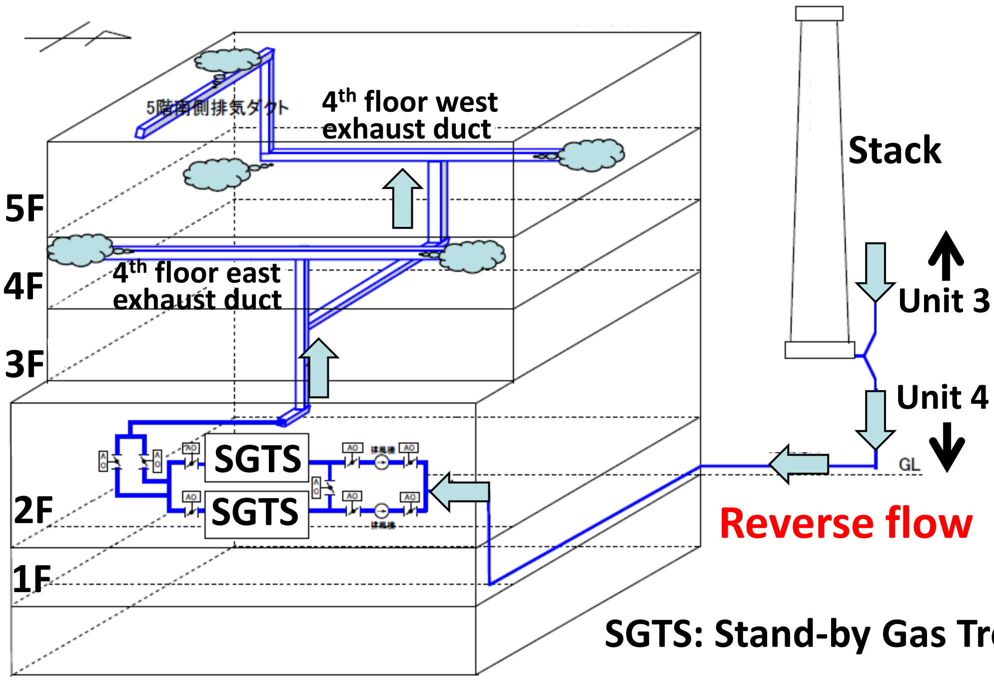
Hydrogen Explosion at Unit 4

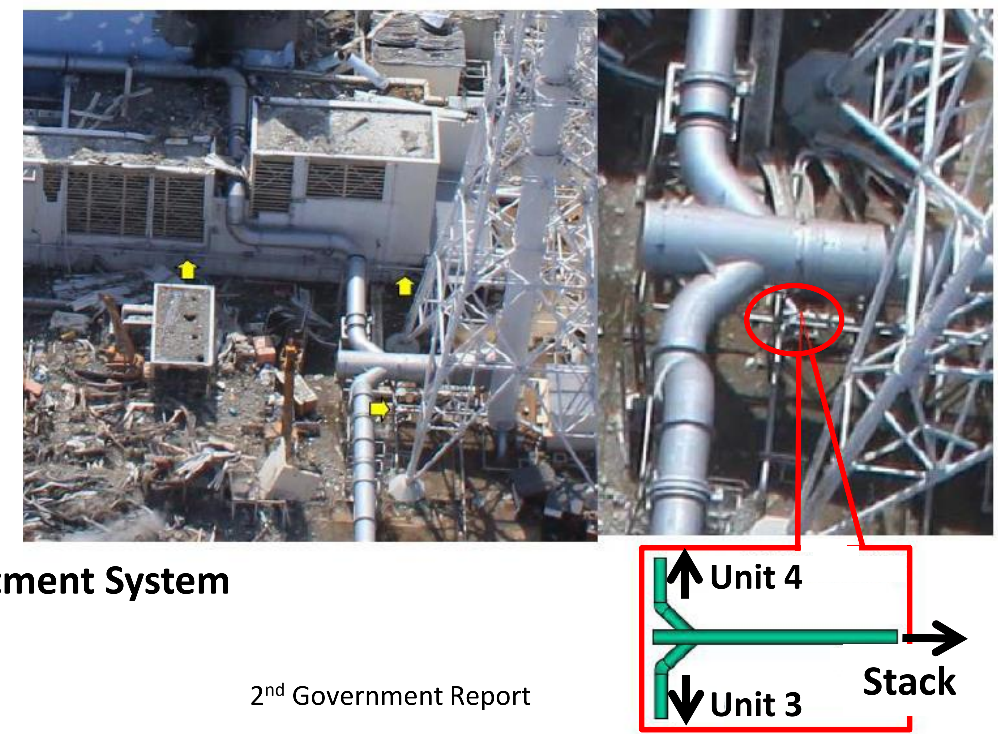
- **Hydrogen generated at Unit 3** might have been transported to Unit 4 **through SGTS piping and exhaust ducts**.
- The **exhaust stack was shared**. The valves of unit4 SGTS were open.



Analysis done by former JNES
WWW.nsr.go.jp/archive/jnes/content/000125907.pdf

Reactor Building of Unit 4





SGTS: Stand-by Gas Treatment System

Source: Added to "The impact of Tohoku-Chihou Taiheiyo-Oki Earthquake to Nuclear Reactor Facilities at Fukushima Daiichi Nuclear Power Station" (Sep. 9 2011, revised Sept. 28, 2011, Tokyo Electric Power Co., Inc.)

2nd Government Report

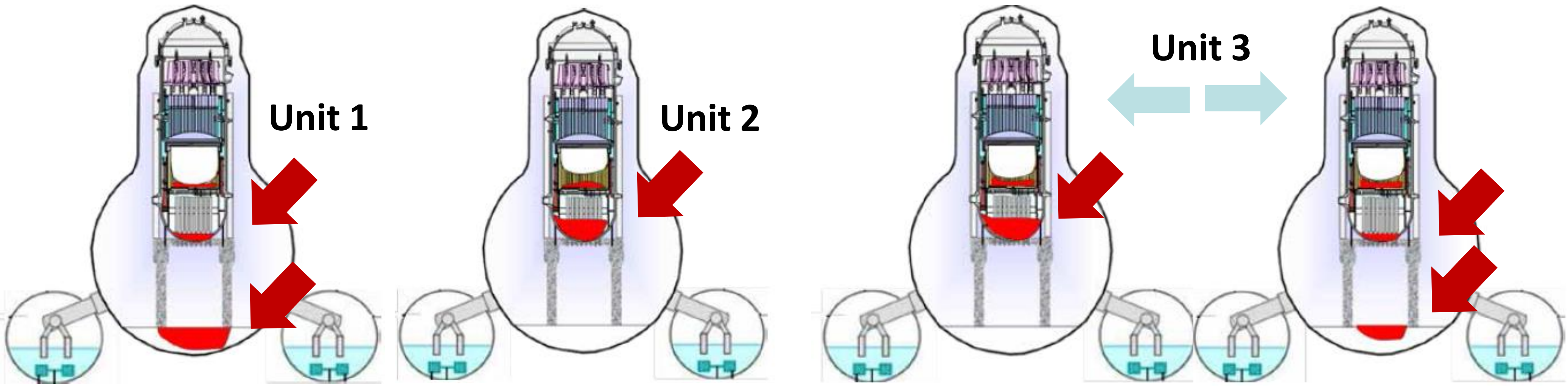
End States of Units 1 to 3:
OECD/NEA BSAF Project Phase I

OECD/NEA CSNI launched the **BSAF** (**Benchmark Study of the Accident at the Fukushima Daiichi NPP**) Project in **Nov. 2012**.

- **16 organizations** from **8 countries** (**France, Germany, Korea, Russia, Spain, Switzerland, the United States,** and **Japan**) participated.

Phase I Summary Report (March 2015)

- **Qualitative description of the plausible end states** after comparison of **the best estimate case analyses**



RPV failure
Every calculation predicted that extensive damage occurred.

No RPV failure
The majority of calculations do not predict RPV failure

Split into two groups:
a) No RPV failure
b) RPV failure and temporary MCCI scenario

Source Term Evaluation

- The IAEA collected / compared the source terms evaluated by various organizations with different methods and assumptions.
- **Technical Volume 1 of the IAEA Fukushima report**: "**The total amount of aerosol based fission product releases** from all of the Fukushima Daiichi units was **about one order of magnitude smaller than that from the Chernobyl accident.**"

IAEA Fukushima report, Technical Volume 1/5 (2015)

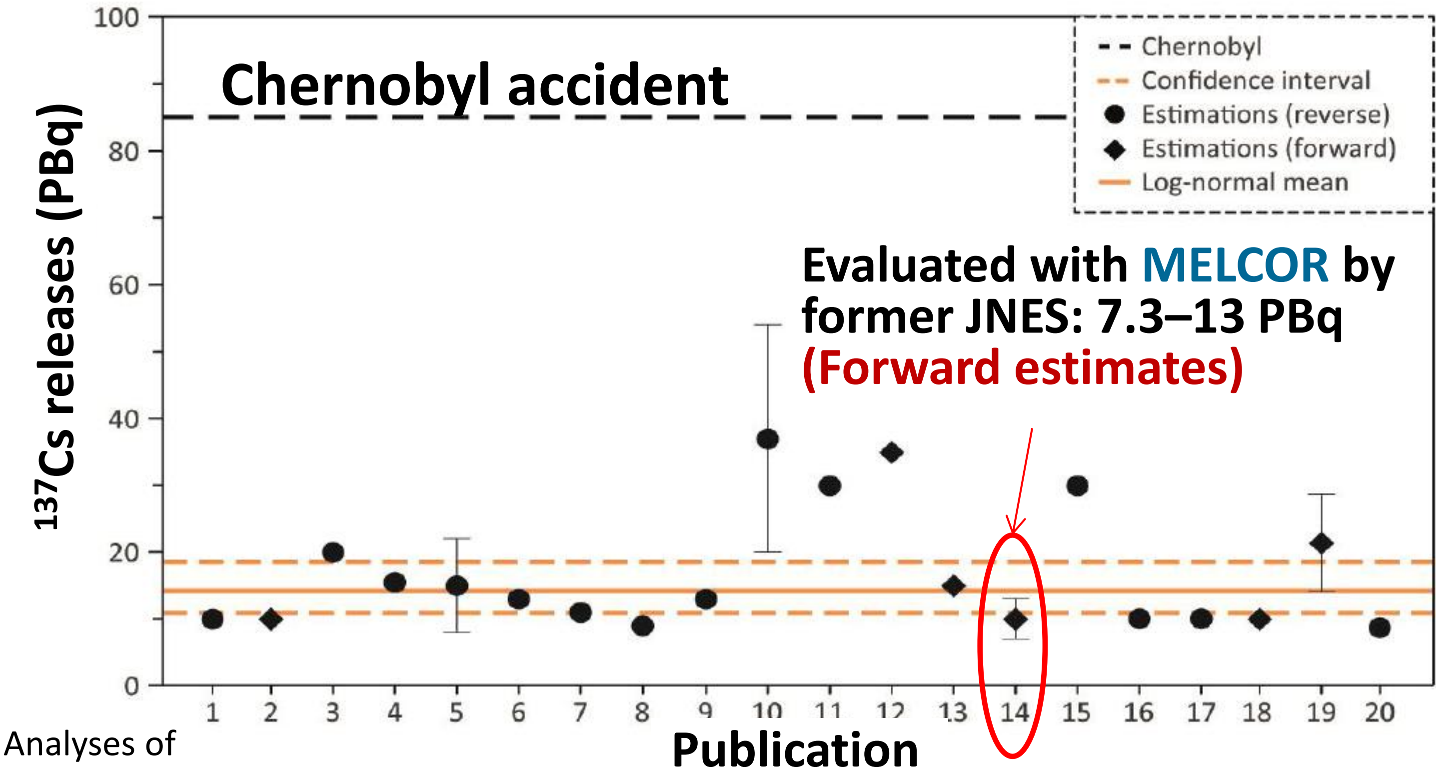


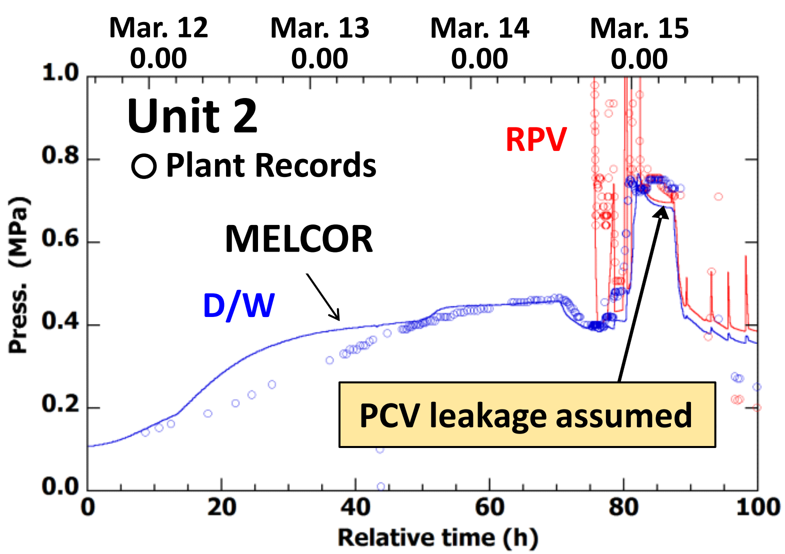
FIG. 1.4–4. Estimated atmospheric releases of 137Cs

Publication [14]:
HOSHI, H., HIRANO, M., Severe Accident Analyses of Fukushima - Daiichi Units 1 to 3, Side event by Government of Japan at 56th IAEA General Conference, Vienna, 2012, JNES (2012),

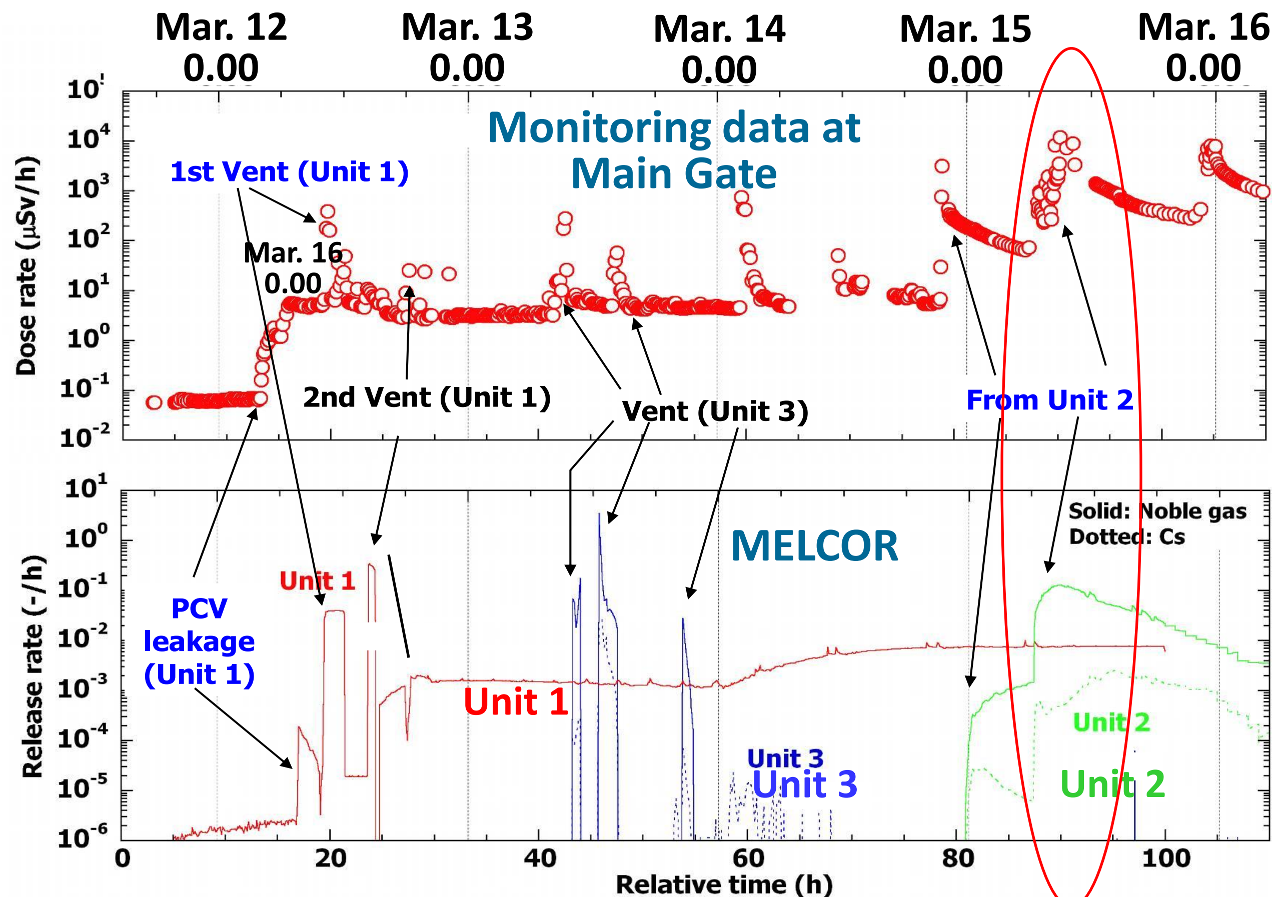
SA Progression and Source Terms

Hirano, Hoshi and Homma, Presented at U.S.NRC RIC, March 2013.

- The former JNES has conducted a SA progression analysis with **MELCOR** developed by U.S.NRC. The NRA continues to do it.
  - **Release timings** are in good agreement with the monitoring data.
  - **The largest peak in the morning on March 15** was probably caused by **PCV failure at Unit 2**



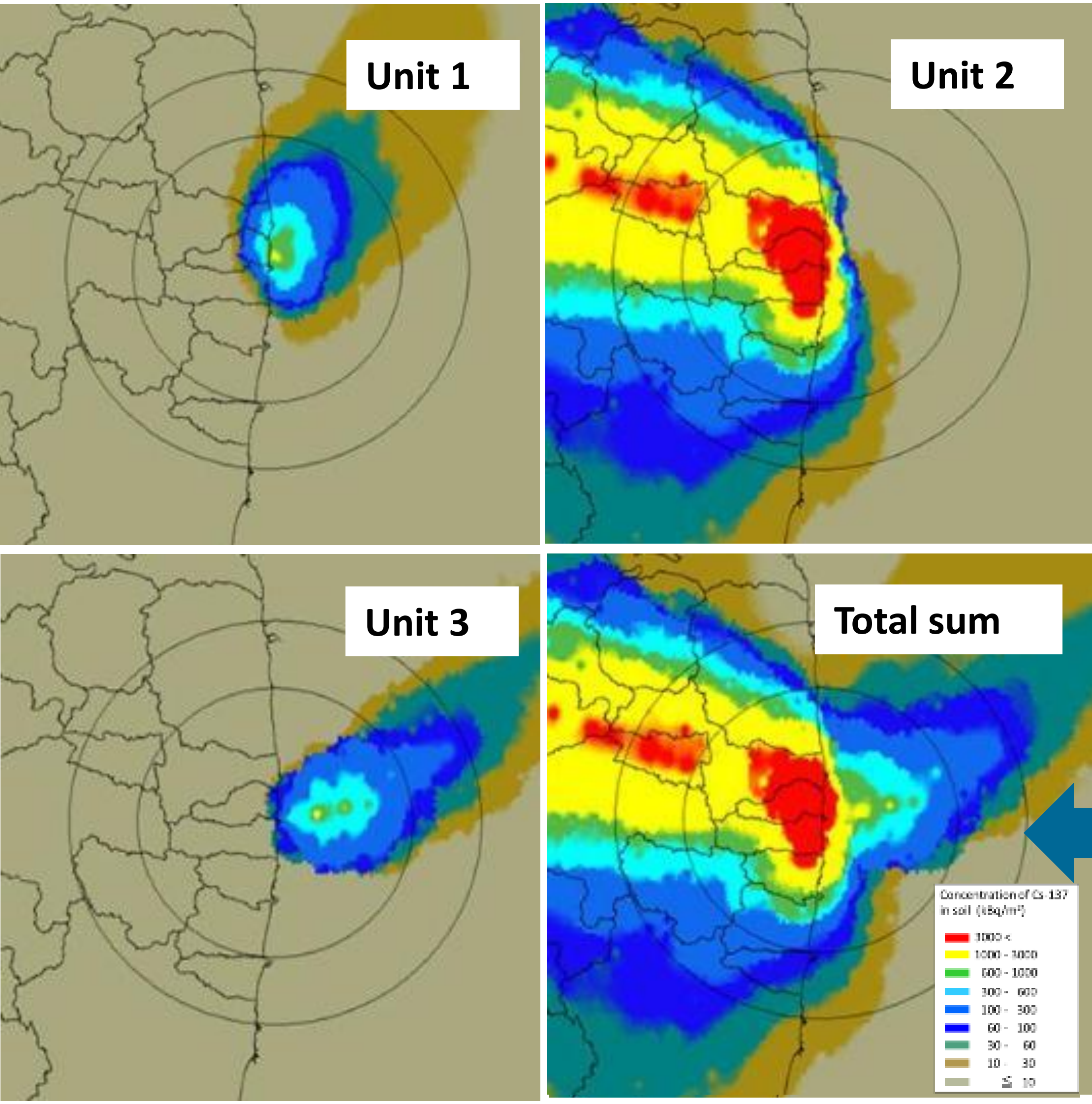
Comparison between the source terms by MELCOR and monitoring data



Environmental Consequence Analysis

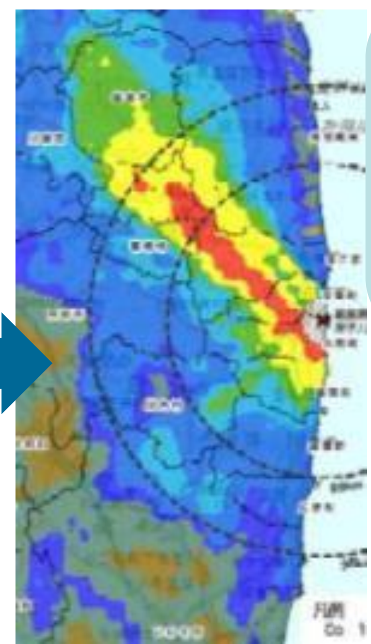
Hirano, Hoshi and Homma, Presented at U.S.NRC RIC, March 2013.

- By using the **source terms with MELCOR**, an **environmental consequence analysis** was done in JAEA with **OSCAAR** developed there.



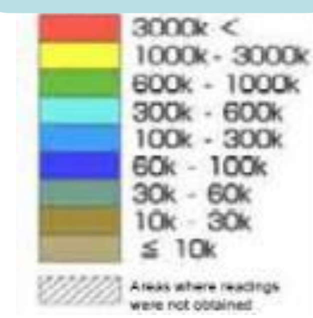
Major findings:

- The **release from Unit 2** on **March 15** had dominant contribution to the inland contamination.
- The release from **Units 1 and 3** mostly spread **to the ocean**.
- Sum of the release well reproduced the characteristics of the measured distribution of contamination.



Cs-137 Concentration measured by MEXT
(Nov. 5, 2011)

(Bq/m²)

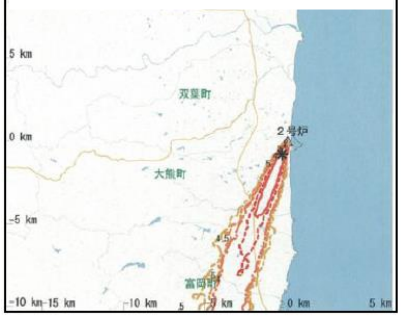


Wind was whirling clockwise on March 15, 2011.

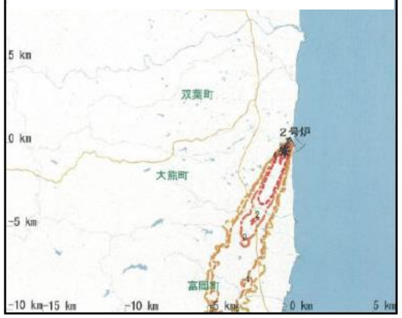
Ref.: Hirano, Presented at IAEA IEM9, 20–24 April 2015

- During the accident, the **SPEEDI** simulation had been done every hour assuming a **unit release (1 Bq/hour)** since the source terms were not available. ➡ The results were equivalent to the **meteorological data**.

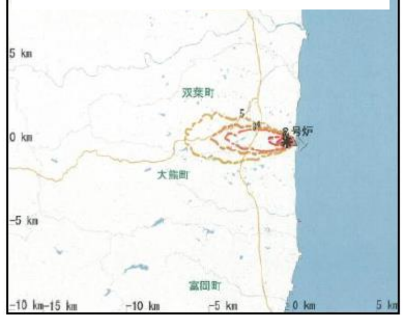
9:00 – 10:00



11:00 – 12:00

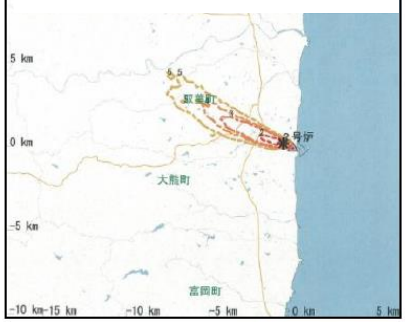


13:00 – 14:00



SPEEDI calculations
Mar. 15, 2011

15:00 – 16:00



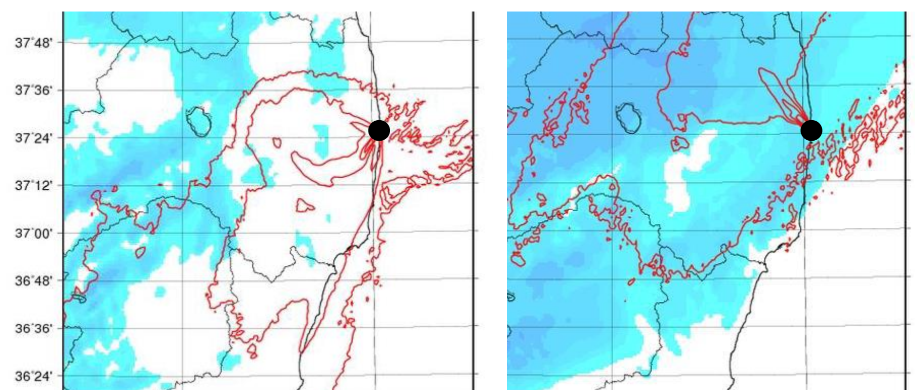
17:00 – 18:00

Final Report from Government's Investigation Committee (July 2012)

Source: M. Chino, JAEA, May 2013

Precipitation (Rainfall)

6:00 – 15:00 **15:00 – 21:00**



http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2013/siryo18/siryo1.pdf

Some Lessons Learned

Lack of "Defense-in-Depth" against external hazards

- Large scale "**common cause failures (CCFs)**" by **external hazards** should have been prevented/mitigated.
  - We should have been prepared for **"Low frequency, high consequence events" beyond design basis.**
- **Actually, the Defense-in-Depth (DiD) had not been taken into consideration for external events.**
  - **Watertight doors** were not implemented, **Seawater pumps** were not protected. **AM measures** were not effective, …
  - **Training** / **drills** assuming external events had not been conducted.
- **DiD has been and will continue to be an effective way to account for uncertainties.**
  - **Effective independence between different layers** of defense
  - More "**diversity**" and "**independence**" rather than "redundancy"

"Tsunami risk had been recognized": Lack of Agility

Diet`s Report: NAIIC : The National Diet's Fukushima Nuclear Accident Independent Investigation Commission, Reported to the Diet in July 2012

- The **Seismic Design Review Guide** was revised in **2006** and a requirement was newly introduced against **tsunami.** So-called "**back-check**" was in progress, but its progress was **very slow**.
  - "**Uncertainty allows for wishful thinking**" + "**Safety myth**"
  - **Lack of agility, lack of safety culture**

Diet Report

- As the regulatory agency **was aware of TEPCO's delaying of countermeasures**, but did not follow up with any specific instructions. Nor did they properly supervise the back-check progress.
- When **new findings indicate the possibility of a tsunami exceeding previous assumptions**, the operator is required to **quickly implement countermeasures**, rather than taking time to **clarify the scientific basis for that possibility through studies of sediment** ....

TEPCP's "Trial Calculations" of Tsunami

IAEA Fukushima report, Technical Volume 2/5 (2015)

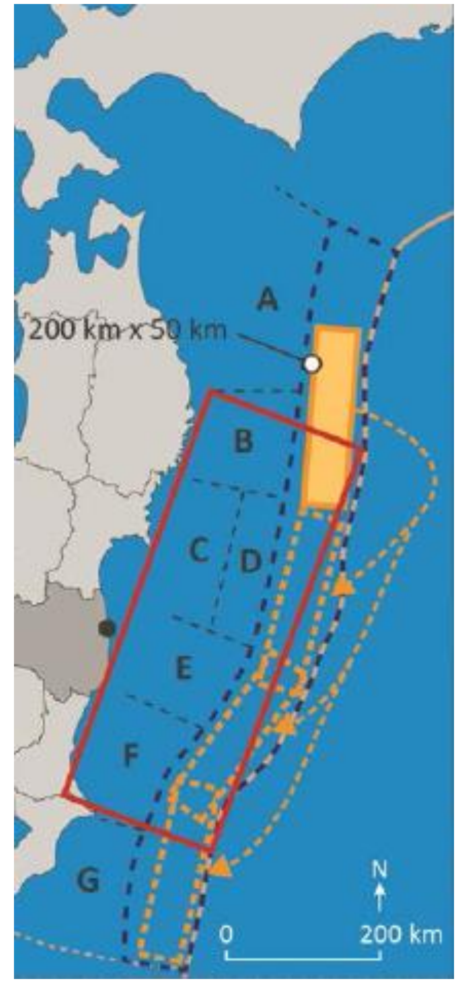
Seismicity Gap Area (no record of large earthquake):

- **Major opinion**: Majority of scientists believed the shallow plate boundary **along the Japan trench** was **not able to store a large amount of strain** (**coupling is weak**).

New findings / **minor opinion**

*Headquarters for Earthquake Research Promotion

- In **2002, HERP*** pointed out the **possibility of a tsunami earthquake occurring anywhere along the Japan Trench including the gap area could not be ruled out.**
- **In 2008, TEPCO** did hypothetical calculation assuming a **M 8.2 earthquake** occurring **off the coast of Fukushima Pref.** ➡ **Max. ~15.7 m**
- TEPCO also conducted a **Jogan** (869)-**type tsunami** simulation ➡ **Max. ~9.2 m**
- However, **TEPCO** decided only on a plan to ask JSCE* for investigation such as **tsunami deposit survey**, **rather than take any immediate measures.**



*JSCE : Japan Society of Civil Engineers

Regulatory Aspects: "Regulatory Capture" Pointed out in the Diet's Report

Diet's Report (July 2012)

Message from Chairman

- … this was a disaster "**Made in Japan**." Its fundamental causes are to be found in the … **Japanese culture**: our **reflexive obedience**; our **reluctance to question authority**; … and our **insularity**.

Organizational issues …

- … actual relationship **lacked independence** and **transparency**, … In fact, it was a typical example of "**regulatory capture**," …

Lack of expertise

- … the two incorporated technical agencies advising NISA, namely, **JNES and JAEA**, have been **too rigidly tied to NISA** ….

Conclusions

- … ***The lack of expertise*** resulted in "**regulatory capture**,"… They **avoided their direct responsibilities** by **letting operators apply regulations on a voluntary basis.**

Human / Organizational Aspects: "Myth of Safety" Pointed Out in the Government's Report

Final Report from Government's Investigation Committee (July 2012)

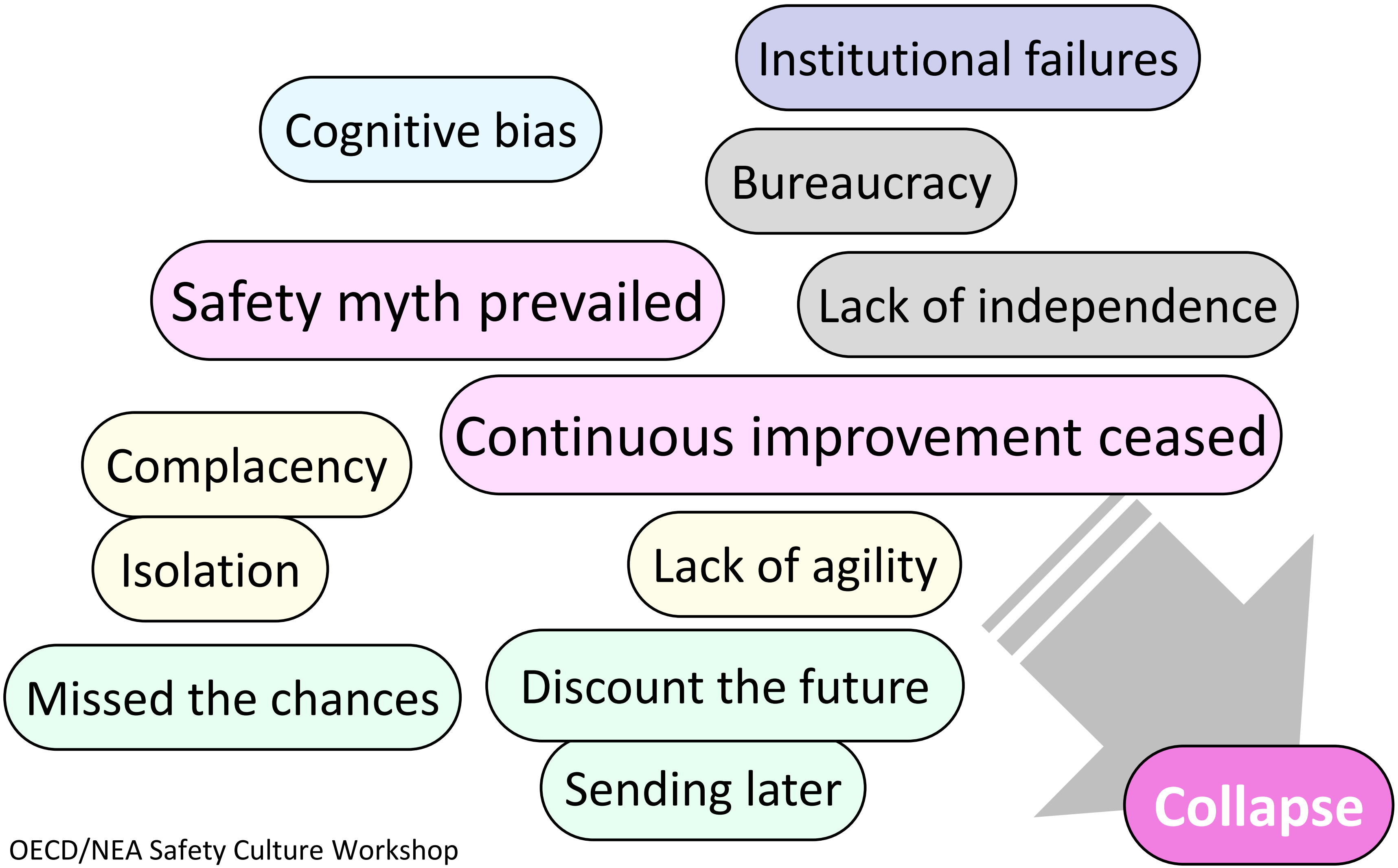
"Myth of Safety"

- … a fundamental problem of the inability to capture such crises as a reality that could happen in our lives; this, in turn, is the result of a **myth of safety** that existed among **nuclear operators including TEPCO** as well as **the government**, that **serious severe accidents could never occur** in NPPs in Japan.

"Basic Assumption" in the **IAEA DG Report**

- Because of the **basic assumption** that **NPPs in Japan were safe**, there was a tendency for organizations and their staff **not to challenge the level of safety**.
- The reinforced **basic assumption** among the stakeholders about the robustness of the technical design of NPPs **resulted in a situation where safety improvements were not introduced promptly**.

"**Complacency**" together with "**Bureaucracy**" allowed "**Safety myth**" to prevail, having let **"Continuous improvement" cease**.



T. Fuketa, OECD/NEA Safety Culture Workshop (June 2015)

Safety Enhancements

NRA: Nuclear Regulation Authority

Established in Sept. 2012

■ Independence

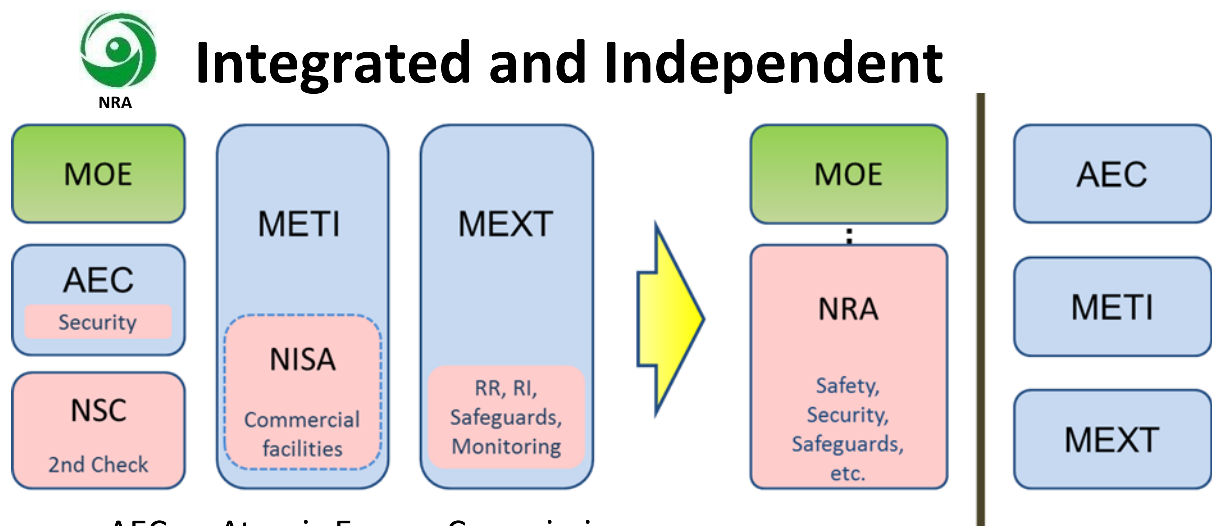
Nuclear regulation and nuclear promotion were clearly separated, and the NRA was established as **an independent commission body** defined by law* affiliated with MOE (Minister of Environment).

* a council-system organization based on Article 3 of the National Government Organization Act, ensuring its independence without any control or supervision by other organizations.

■ Integrated

Nuclear regulation functions regarding safety, security, safeguards, radiation monitoring and radioisotopes were integrated into the NRA.

Integrated and Independent



AEC : Atomic Energy Commission
METI : Ministry of Economy, Trade and Industry
MEXT : Ministry of Education, Culture, Sports, Science and Technology
MOE : Ministry of the Environment
NISA : Nuclear and Industrial Safety Agency (abolished)
NSC : Nuclear Safety Commission (abolished)

T. Fuketa, NRA, presented at U.S.NRC RIC2013, March 13, 2013: http://www.nsr.go.jp/data/000067048.pdf

New Regulatory Requirements: Structure

http://www.nsr.go.jp/data/000067048.pdf

Requirements for B-DBA

- **DEC**: Design extension conditions defined in IAEA SSR-2/1

<New>

4th Layer of DiD

- Suppression of radioactive materials dispersal
- Specialized Safety Facility
- Prevention of CV failure
- Prevention of core damage

NEW (Severe Accident Measures)

3rd Layer of DiD

- Natural phenomena
- Fire
- Reliability
- Reliability of power supply
- Ultimate heat sink
- Function of other SCCs

Reinforced

- Seismic/Tsunami resistance

Reinforced

<Pre-existed>

- Natural phenomena
- Fire
- Reliability
- Reliability of power supply
- Ultimate heat sink
- Function of other SCCs
- Seismic/Tsunami resistance

New Regulatory Requirements:
Enhanced Measures against Tsunami

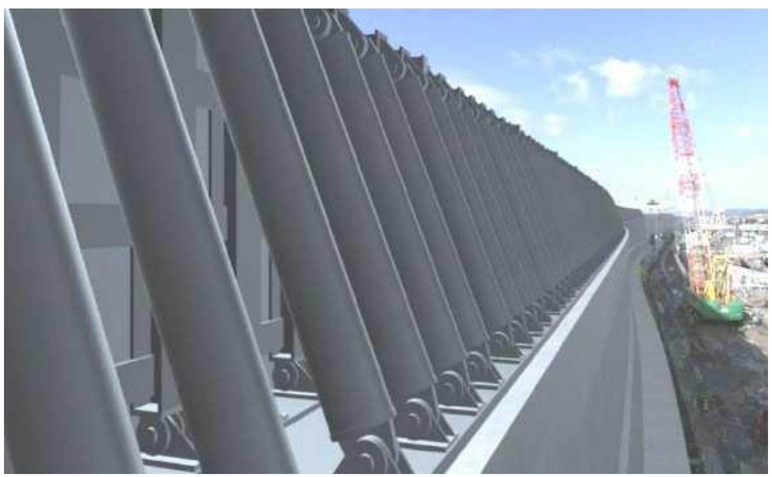
http://www.nsr.go.jp/data/000067048.pdf

More Stringent Standards on Tsunami → It is required to define "design basis tsunami" that **exceeds the largest in the historical records** and to take **protective measures** such as **breakwater wall** based on it.

Enlarged Application of Higher Seismic Resistance → SSCs for tsunami protective measures are **classified as Class S** equivalent to RPV etc. of **seismic design importance classification**.

Example of protective measures against tsunami (multiple measures)

- **Breakwater wall** for prevention of inundation to the site



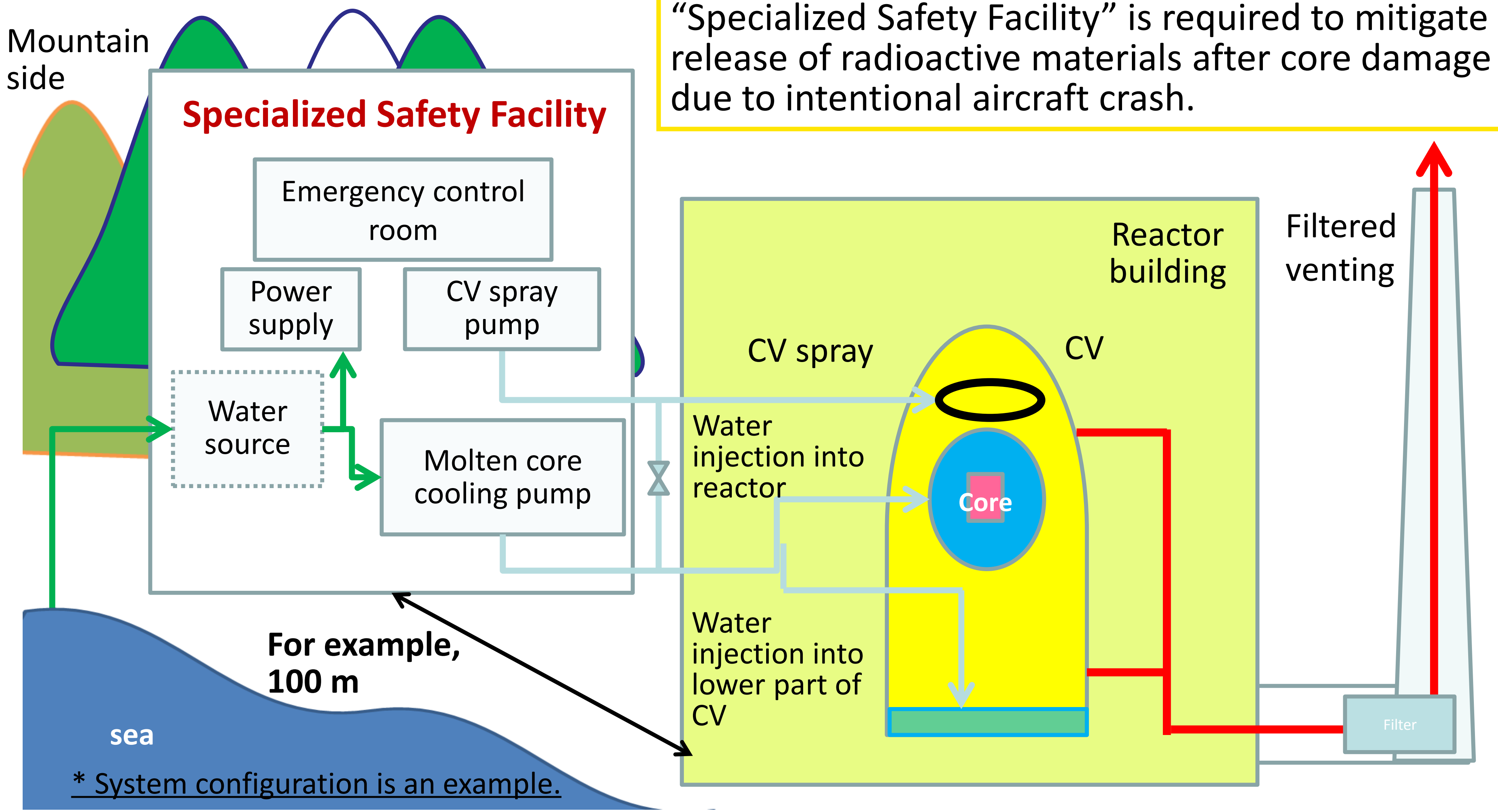
- **Tsunami gate** for prevention of water penetration into the building

NRA, Japan
Nuclear Regulation Authority

New Regulatory Requirements:
Measures against Intentional Aircraft Crash, etc.

http://www.nsr.go.jp/data/000067048.pdf

"Specialized Safety Facility" is required to mitigate release of radioactive materials after core damage due to intentional aircraft crash.



For BWR, one filtered venting for prevention of containment failure and another filtered venting of Specialized Safety Facility are acceptable solution.

NRA's Statement of Nuclear Safety Culture

Issued on May 27, 2015

T. Fuketa, OECD/NEA Safety Culture Workshop (June 2015)

- NRA's Mission Statements

The NRA's Core Values and Principles

The Statement of Nuclear **Safety Culture**

The Code of Conduct on **Nuclear Security**

- **Eight Traits** of Nuclear Safety Culture in NRA's Statement

1. Priority to Safety ➡ Break with "**safety myth**"
2. Decision-making prioritized by safety
3. Fostering, sustaining and strengthening safety culture
4. Learning organization ➡ Seek out "**opportunities for improvement**"
5. Communication ➡ Get rid of "**isolation**"/"**self-righteousness**"
6. Questioning attitude ➡ Avoid "**complacency**"
7. Rigorous and prudent judgment and action with agility
8. Harmonization with nuclear security

Summary

- One of the most important lessons learned is "**Lack of Defense-in-Depth against external hazards**". We need to continuously enhance DiD since **DiD has been and will continue to be an effective way to account for uncertainties.**
- We need to keep reminding that "**Complacency**" together with "**Bureaucracy**" allowed "**Safety myth**" to prevail, having let **"Continuous improvement" cease**.
- Commissioner Fuketa of NRA stated in the OECD/NEA SC Workshop*:
  - We, however, acknowledge we are oblivious. Numerous **sprouts of safety myth** reappear already.
  - We must incorporate lessons-learned into the "institutional memory" of the NRA. We must create an environment where **a gene letting us think "safety first" can survive**.

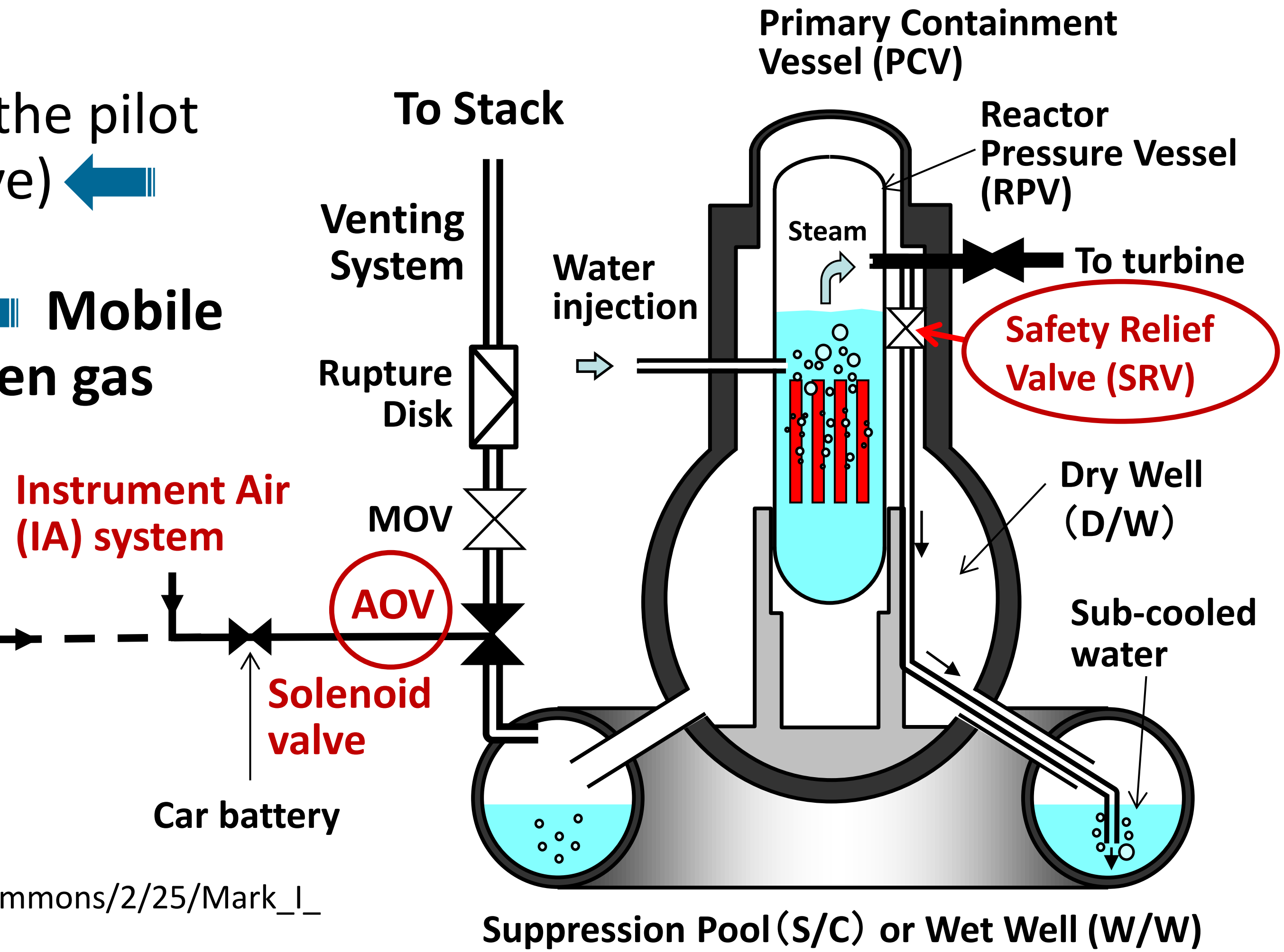
* T. Fuketa, OECD/NEA Safety Culture Workshop (June 2015)

References

- **1st Government Report (June 2011):** Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety, Nuclear Emergency Response Headquarters, Government of Japan, June 2011
- **2nd Government Report (September 2011):** Additional Report of the Japanese Government to the IAEA (Second Report), Nuclear Emergency Response Headquarters, Government of Japan, September 2011
- **Diet's Report (July 2012)**: The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), the National Diet of Japan, 2012
- **Interim Report from Government's Investigation Committee (Dec. 2011)**: Interim Report, Investigation Committee on the Accident at Fukushima NPS of TEPCO, Dec. 26, 2011
- **Final Report from Government's Investigation Committee (July 2012)**: Final report, Investigation Committee on the Accident at Fukushima NPS of TEPCO, July 23, 2012
- **IAEA DG Report and Technical Volumes 1 to 5 (2015)**: The Fukushima Daiichi Accident, Report by the Director General and Technical Volumes 1 to 5 (2015)
- **T. Fuketa, OECD/NEA Safety Culture Workshop (June 2015)**: OECD NEA/CNRA/ CSNI/CRPPH Joint Workshop on Challenges and Enhancements to Safety Culture of the Regulatory Body, Paris, June 3, 2015
- **Y. Shimizu, IAEA Effective Nuclear Regulatory Systems (April 2016)**: Y. Shimizu, "Lessons Learned from the Fukushima Daiichi Accident, Actions Taken and Challenges Ahead," presented at IAEA International Conference on Effective Nuclear Regulatory Systems, Vienna, Austria, April 11-15, 2016

Key: It was difficult to open Air-Operated Valves (AOVs)

- For **seawater injection by fire engines**, it was necessary to **depressurize RPV** by **opening SRVs**. It was needed to **open AOVs** in the **venting system** to **prevent PCV failure**.
- AOVs need:
  - **DC power** to open the pilot valve (solenoid valve) ⬅ **Car batteries**
  - Compressed air ⬅ **Mobile compressor, nitrogen gas cylinders**



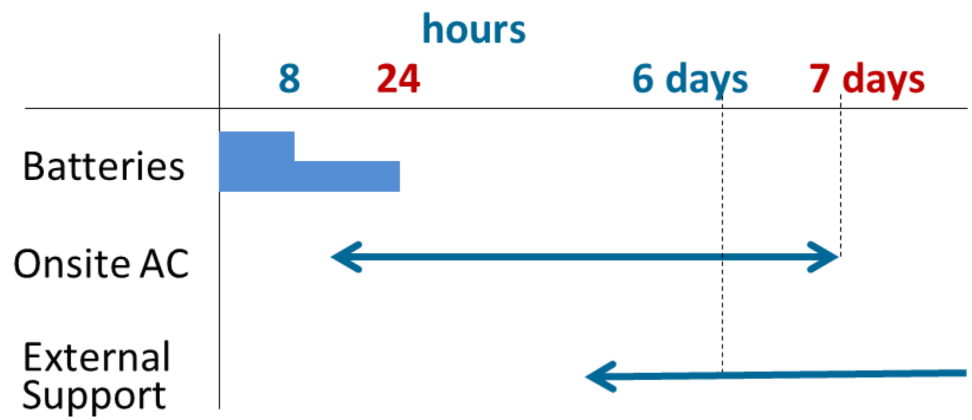
- Mobile compressors
- Nitrogen gas cylinders

https://upload.wikimedia.org/wikipedia/commons/2/25/Mark_I_Containment.jpg

Example of Use of Mobile Equipment: **Measures against Station Blackout (SBO)**

✓ Install both **mobile alternate power sources** (power vehicle, batteries, etc.) and **permanent alternate AC power sources**.

- **Batteries for 8 hours** without load shedding + **16 hours** with load shedding
- **Alternate onsite AC power supply** for **7 days**
- **External support** from offsite **by the 6th day**
- Alternative **MC, PC, MCC**



Alternative onsite AC power (Power Vehicle)

✓ It is also required to install the **third station battery system**.