Earthquake, Tsunami and Fukushima Daiichi NPP Accident
— Can Accidents Be Avoided ? —

March 7, 2012

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3.11 and myself

- I was in Tokyo, about 250km away from the Fukushima NPP on March 11, 2011. The train was stopped because of the earthquake, so I could not go home.

- During the night of the 11th to the 12th, I could hear the TV news reporting, “With the Fukushima Daiichi’s core cooling failure, the pressure of a reactor containment vessel (RCV) has risen to nearly twice as high as the design pressure.” I thought this would become an accident more serious than the TMI accident.

- I could predict the progress of the accident, because I had been working on the design of the reactor containment vessel for Toshiba since 1989.

3.11 and myself (suite)

- Until then, I had occasionally written about the risk of nuclear accidents, but under a pseudonym. From the night of March 12, I started to comment on the progress of the Fukushima accident using my real name on the internet video such as U-STREAM.
- Tokyo Electric Power Company (TEPCO) and the Nuclear and Industrial Safety Agency (NISA) were saying, ”There may be some core damage, but as there is water in the reactor, there is no meltdown.”

From TMI to Fukushima

- Three Mile Island nuclear accident (March 28, 1979)

  Hydrogen explosion, small Loss-Of-Coolant Accident (LOCA), failure in relief safety valve, error of operating personnel (stopped ECCS!)

- Chernobyl nuclear accident (April 26, 1986)

  Lack of stability in reactor and design flaws of control rods

  Reckless test management plan and mistakes in operation

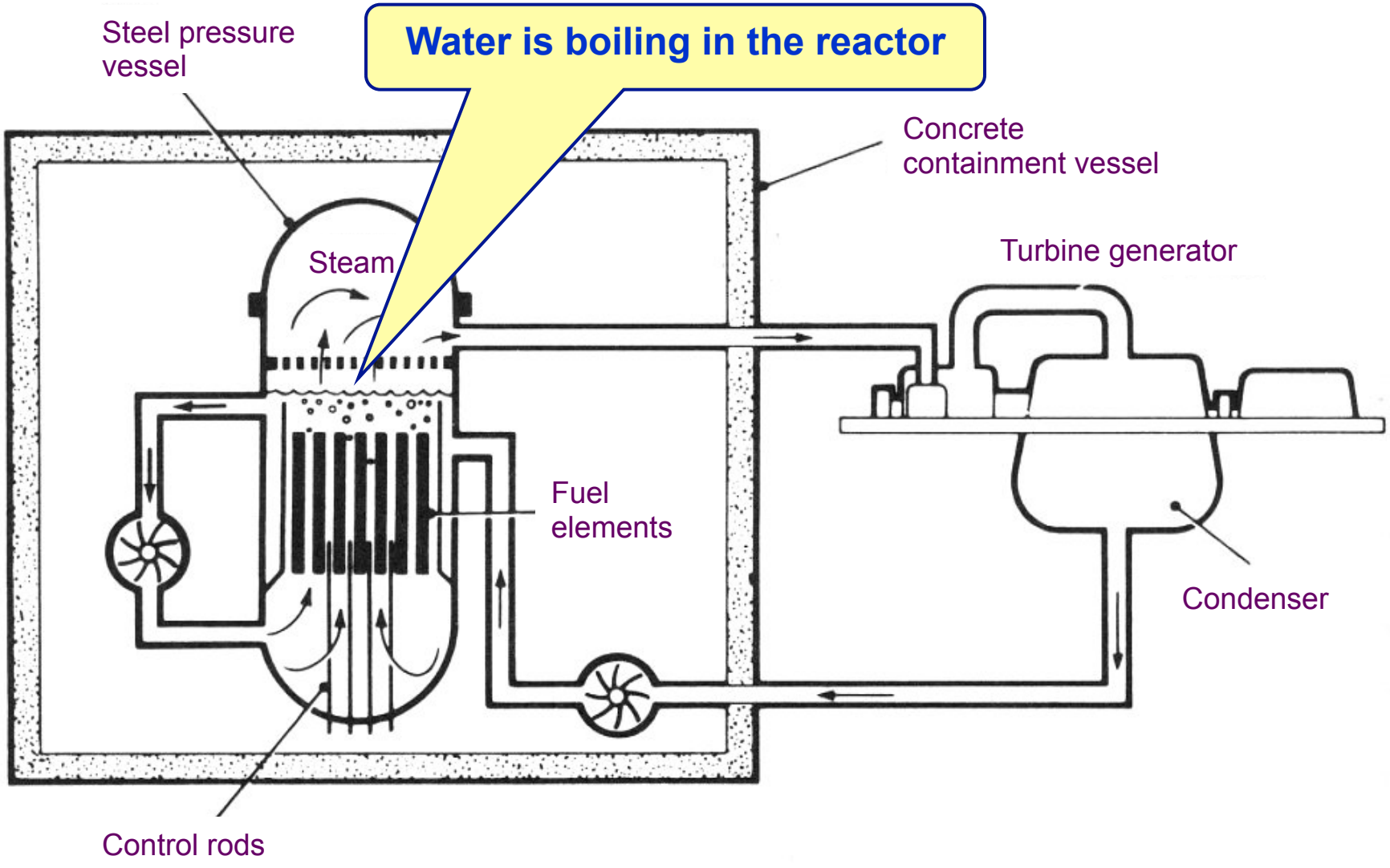
- Fukushima Daiichi nuclear accident (March 11, 2011)

  Earthquake and tsunami ⇒ core meltdown, hydrogen explosions, venting of containment vessels?

  ⇒ What were the impacts of the earthquake?

Where will the next accident take place?

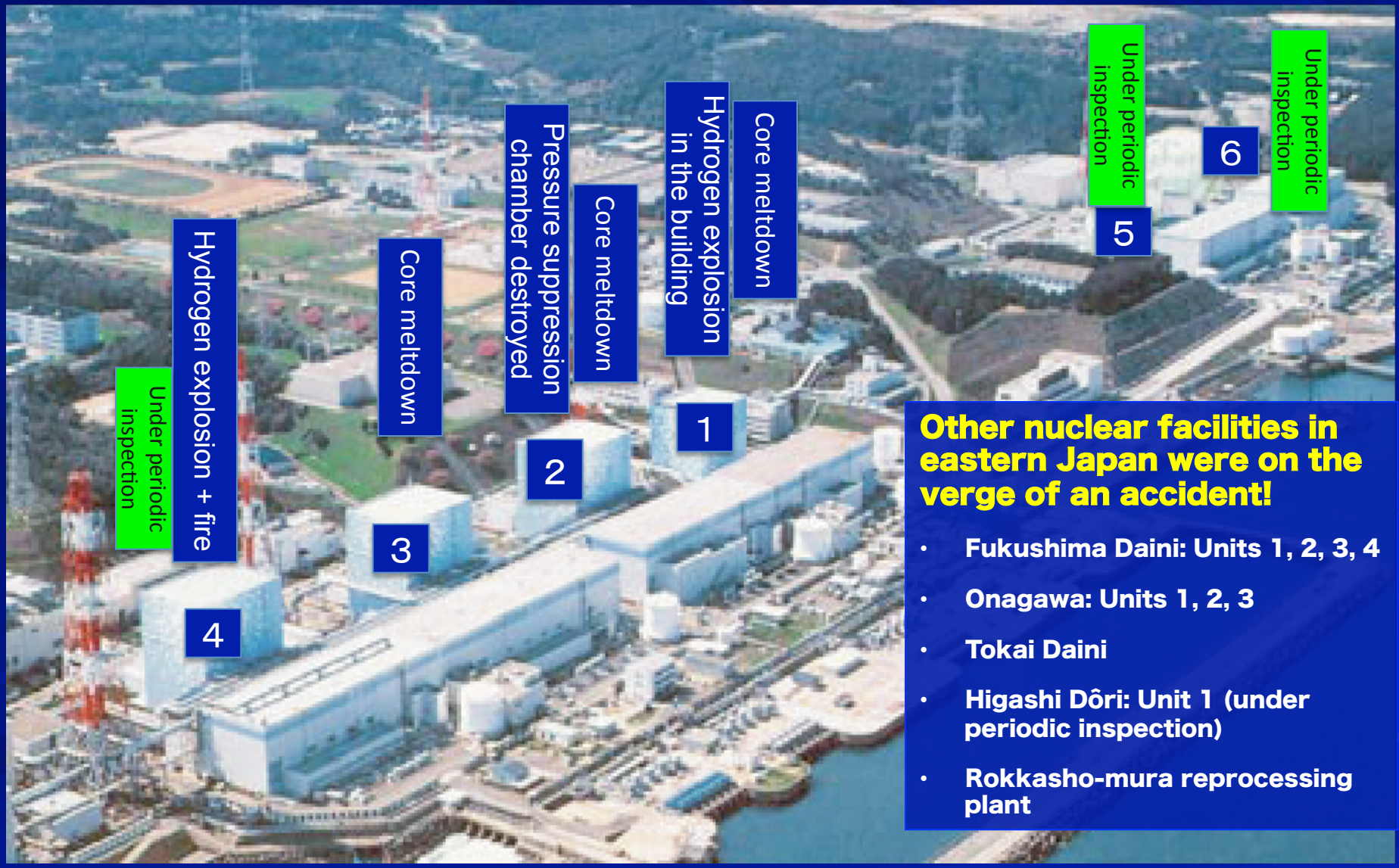
Conceptual diagram of BWR



Fukushima Daiichi NPP and 2011 earthquake of the Pacific coast of Tôhoku

- **Occurred on March 11, 2011**
- **Magnitude 9.0Mw**
- **The height of the tsunami that struck the Fukushima NPP is believed to be more than 14 meters.**

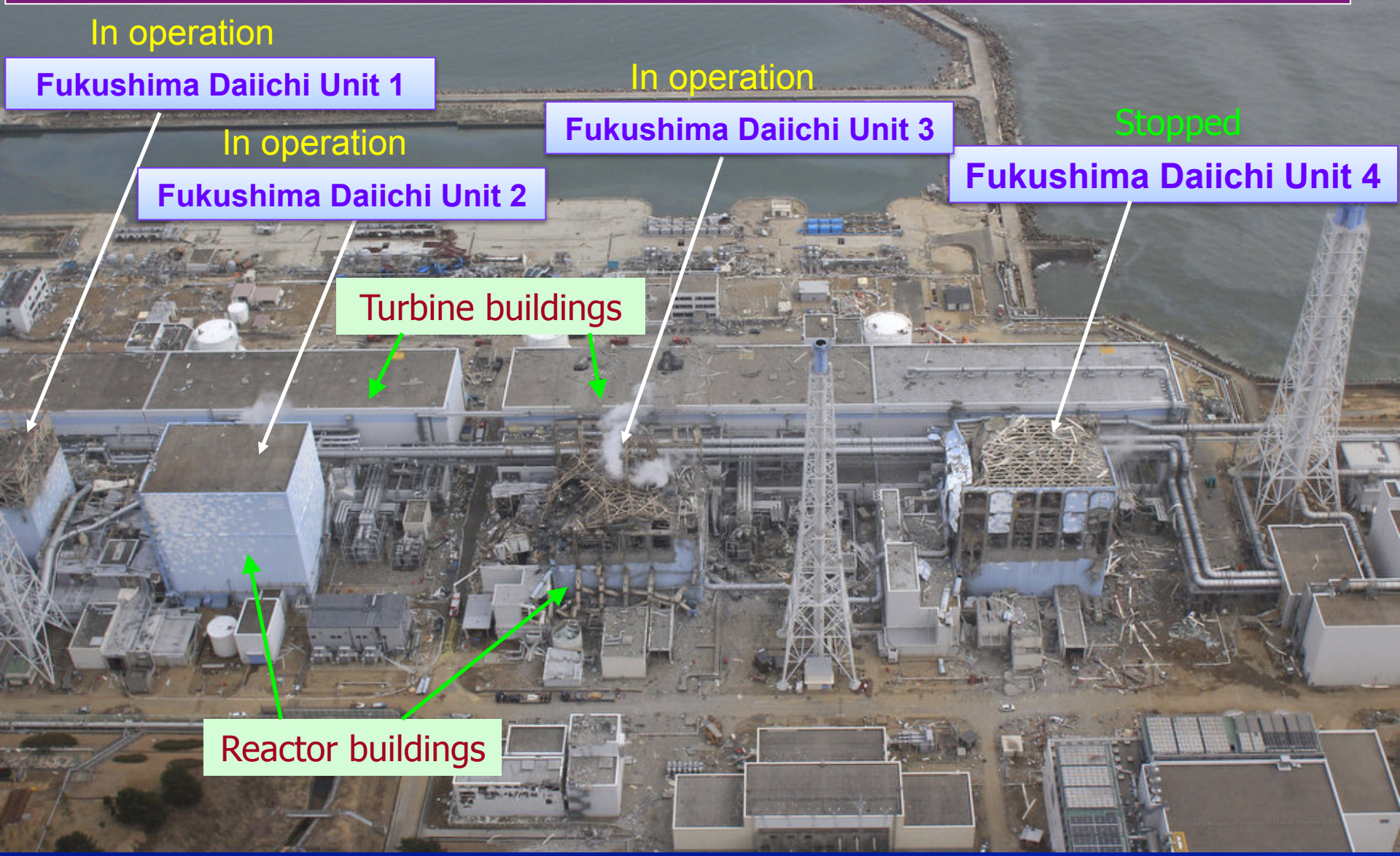
Fukushima Daiichi NPP



Other nuclear facilities in eastern Japan were on the verge of an accident!

- **Fukushima Daini: Units 1, 2, 3, 4**
- **Onagawa: Units 1, 2, 3**
- **Tokai Daini**
- **Higashi Dôri: Unit 1 (under periodic inspection)**
- **Rokkasho-mura reprocessing plant**

Destruction of the Fukushima Daiichi NPP



Fukushima Daiichi Nuclear Accident

◆**Stop ⇒ Control rods were inserted and successfully stopped the reactors!**

Power companies have had 15 incidents with control rods since 1978, and have hidden them. There is no guarantee of control rods being inserted in case of an earthquake.

⇒Incidents including criticality accidents at Fukushima Daiichi Unit 3 and Shiga Unit 3

◆**Cool ⇒ Failed due to failures caused by earthquake and tsunami.**

Core meltdowns and pressure vessels damaged.
Cooling still unstable

◆**Contain ⇒ Both pressure vessels and containment vessels are damaged.**

Radioactive materials (in smaller amount) are still discharged into the atmosphere and the sea water.

List of accidents with control rods (until 2007)

These accidents were hidden for more than 20 years!

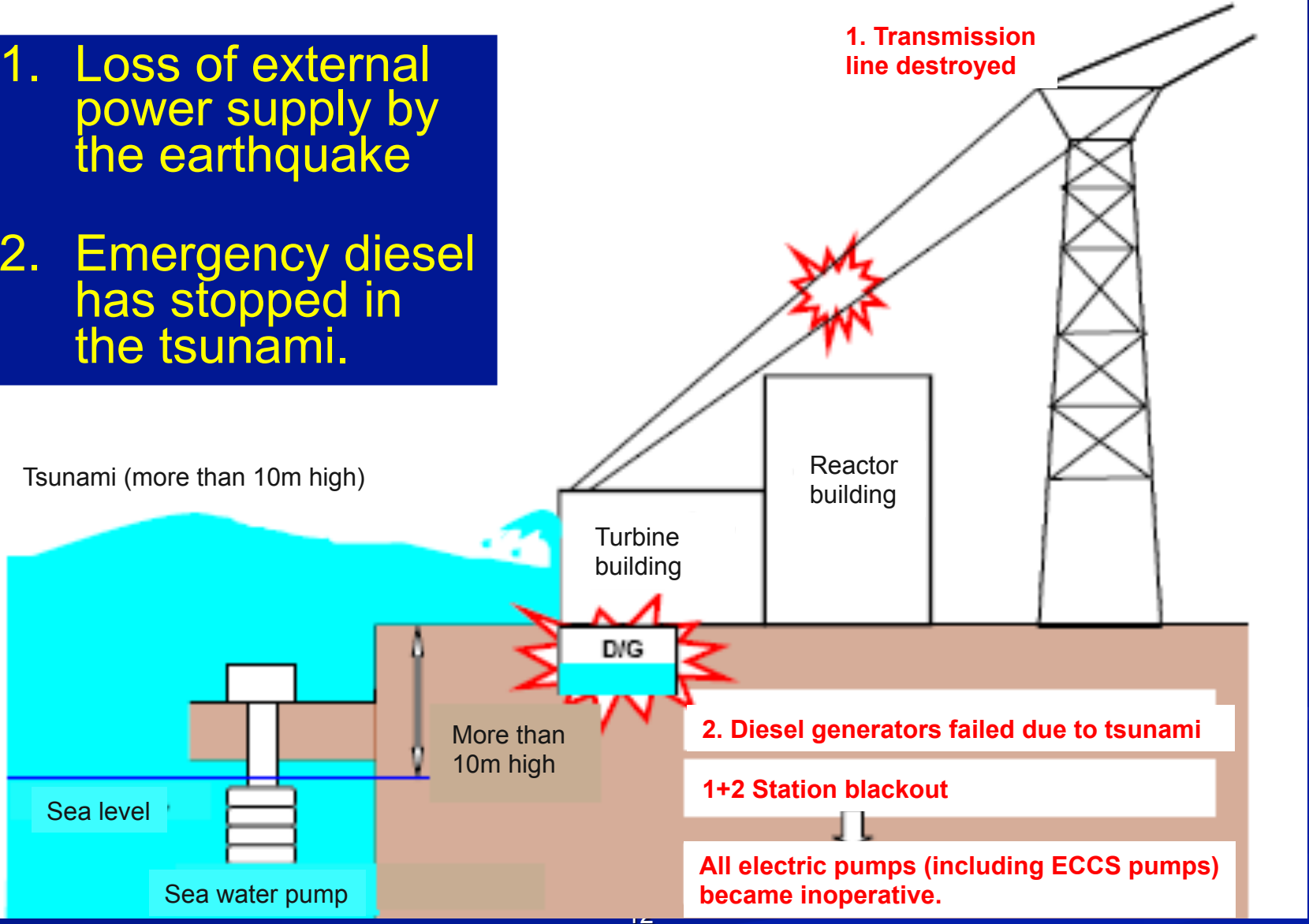
Date	NPP-Unit	accident
1978/11/02	Fukushima I-3	5 control rods fell-off. **Criticality**
1979/02/12	Fukushima I-5	1 control rod fell-off.
1980/09/10	Fukushima I-2	1 control rod fell-off.
1988/07/09	Onagawa-1	2 control rods fell-off.
1991/05/31	Hamaoka-3	3 control rods fell-off.
1991/11/18	Fukushima I-2	5 control rods mis-inserted.
1993/04/13	Onagawa-1	1 control rod mis-inserted.
1993/06/15	Fukushima II-3	2 control rods fell-off.
1996/06/10	Kashiwazaki-6	4 control rods fell-off.
1998/02/22	Fukushima I-4	34 control rods fell-off.
1999/06/18	Shiga-1	3 control rods fell-off. **Criticality**.
2000/04/07	Kashiwazaki-1	2 control rods fell-off.
2002/03/19	Onagawa-3	5 control rods mis-inserted.
2005/04/16	Kashiwazaki-3	17 control rods mis-inserted.
2005/05/24	Fukushima I-2	8 control rods mis-inserted.

Progress of Fukushima Nuclear Accident

- Huge M9 earthquake struck the Tohoku region at 14:46, March 11, 2011.
- Nuclear reaction at Unit 1 to 3 in operation of Fukushima Daiichi NPP was stopped with the control rods inserted into the reactor.
- However, due to the decay heat, the fuel must be cooled with water to prevent meltdown.
- External power supply was lost due to the fall of the transmission line steel tower and the failure of the power switchgear by the earthquake.
- Emergency diesel generator started, but station blackout (SBO) after the tsunami.
- Loss of cooling function.

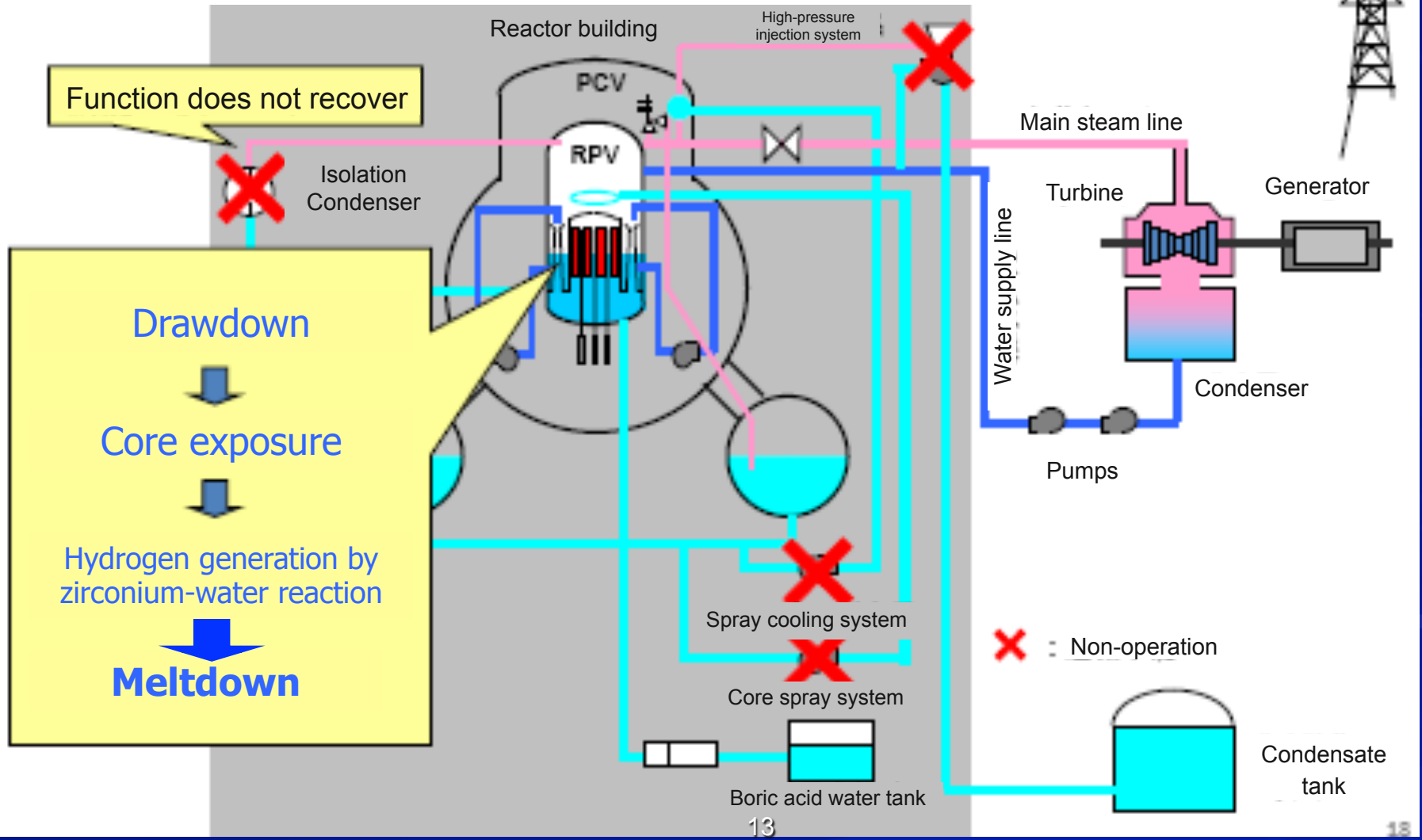
Genesis of the Fukushima accident

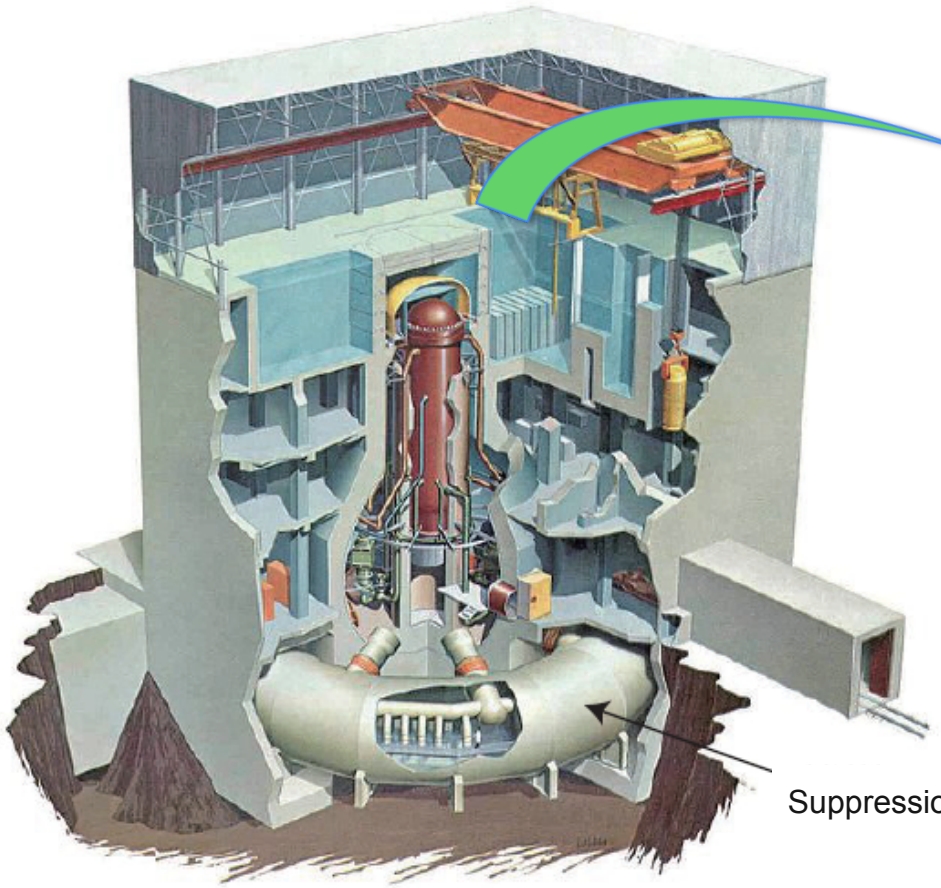
1. Loss of external power supply by the earthquake
2. Emergency diesel has stopped in the tsunami.



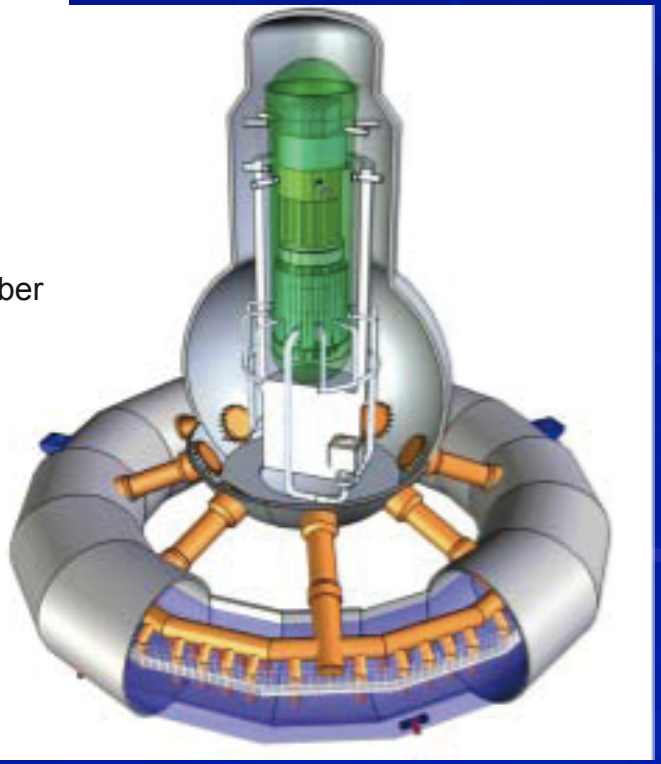
Progress at Fukushima Unit 1

Loss of cooling capacity for emergency condenser, the reactor water level falls, followed by exposure of the core.





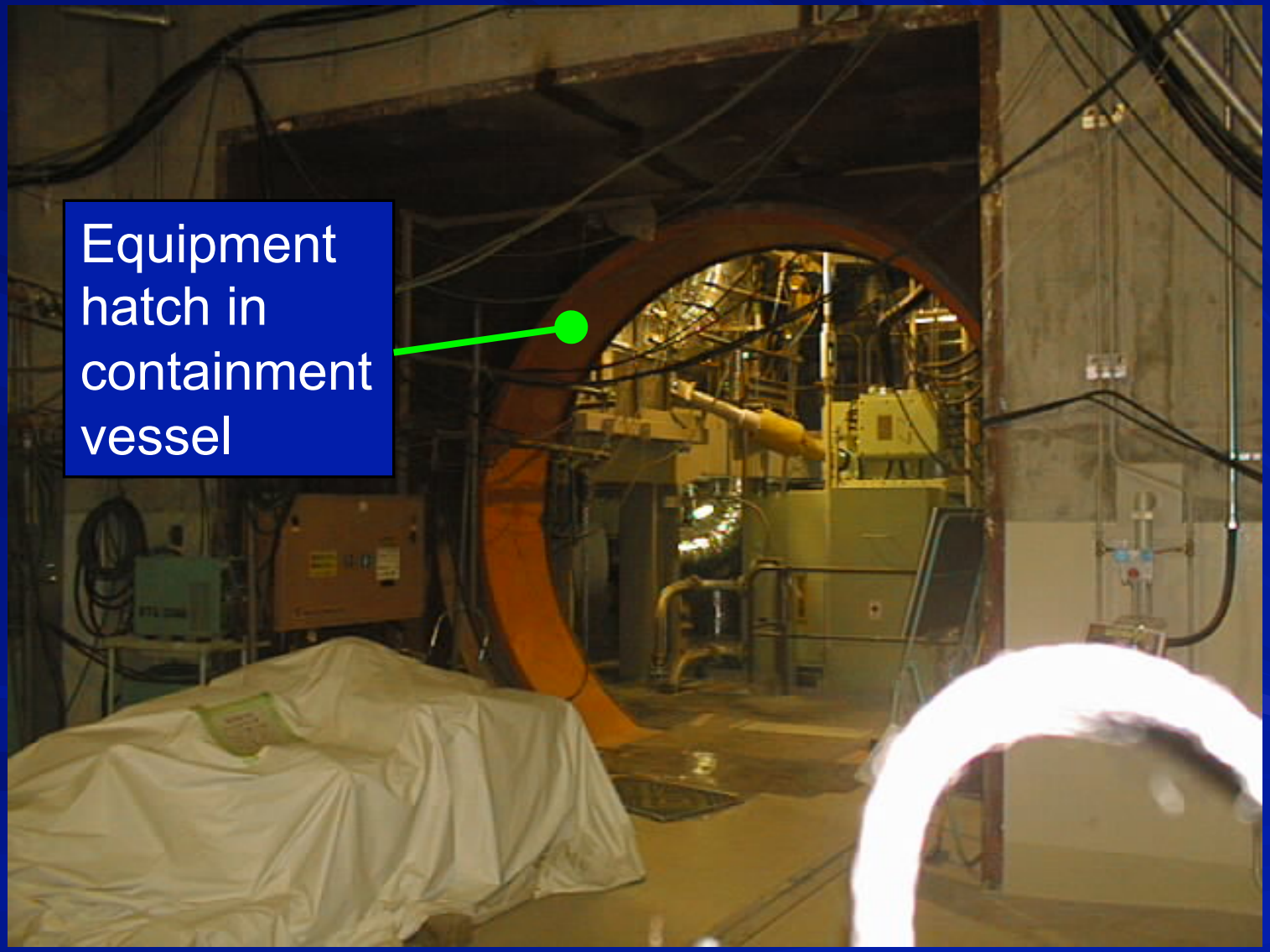
Reactor containment vessel (PCV) made of steel (Mark Ⅰ Type)



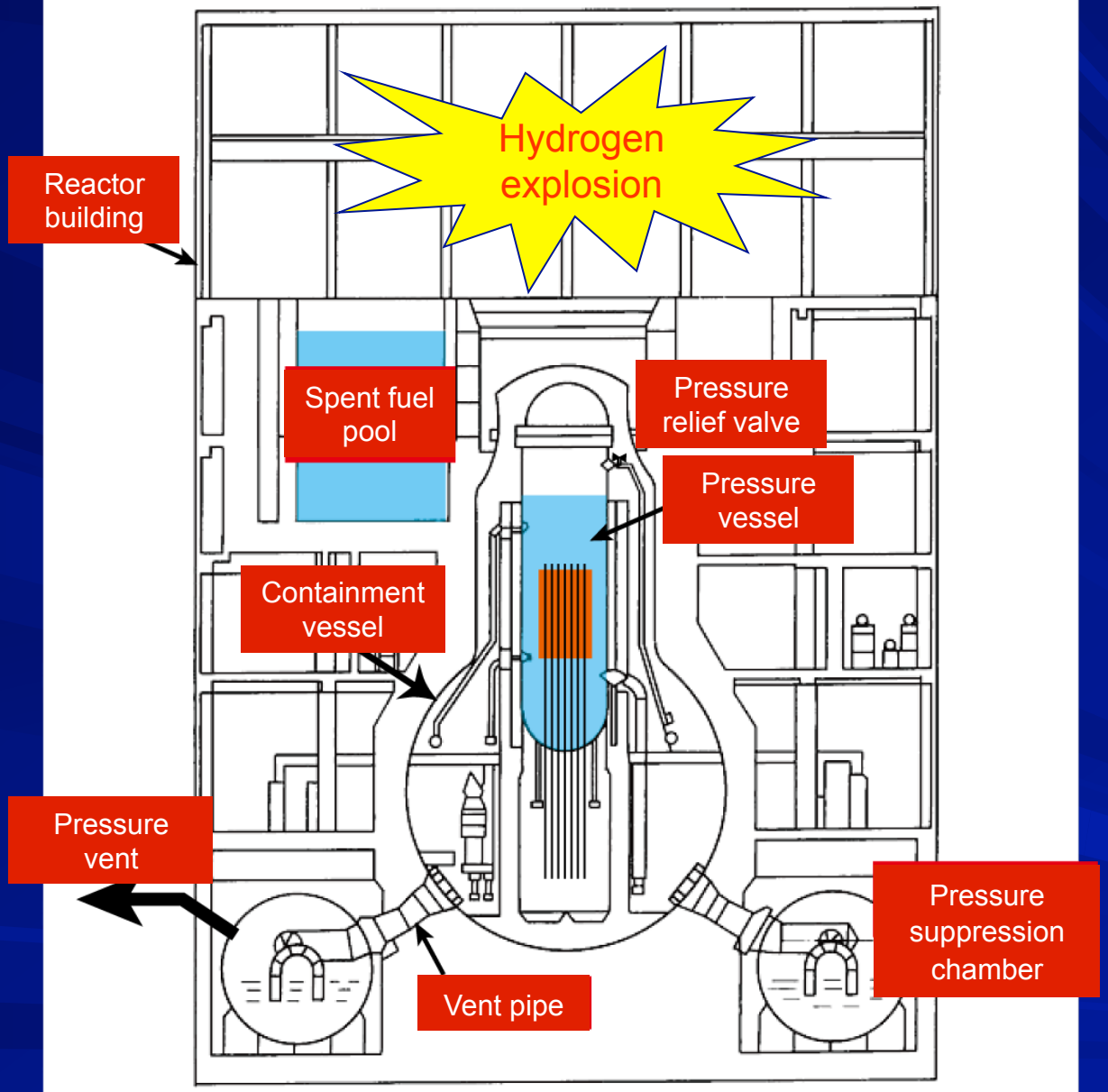
Reactor building（R/B）
made of reinforced concrete

Mark I type PCV under construction in the United States

Equipment hatch in containment vessel



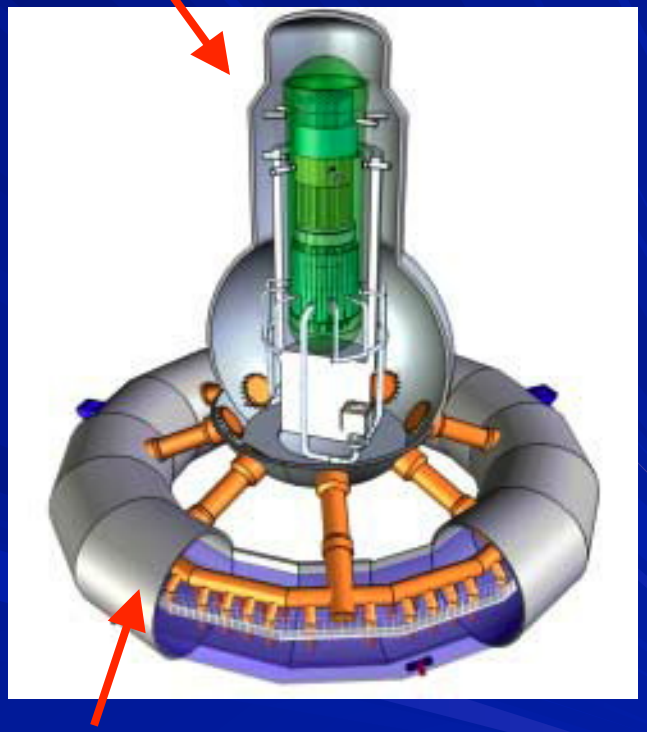
Fukushima Daiichi Units 1-3



Mark-I type containment vessel

Containment has high temperature-high pressure in the early stages!

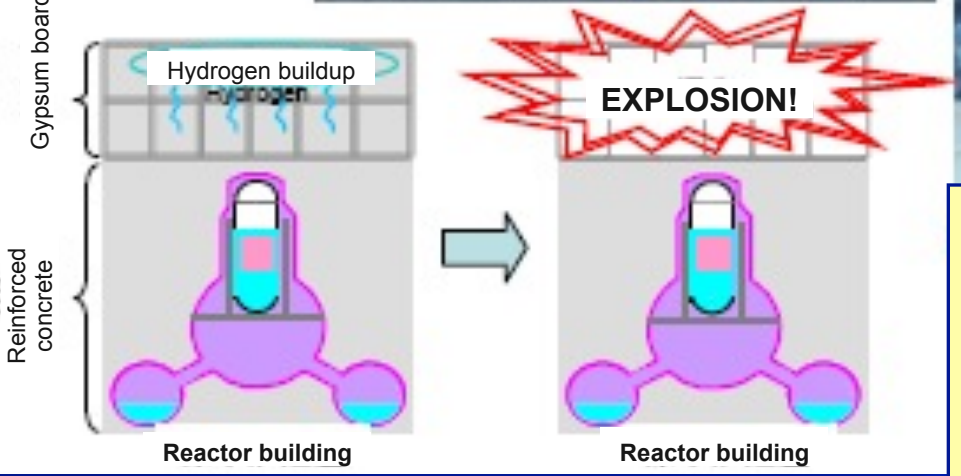
Reactor containment vessel (drywell)



Reactor containment vessel (wetwell)

Progress at Fukushima Unit 1

Hydrogen explosion in the operation floor

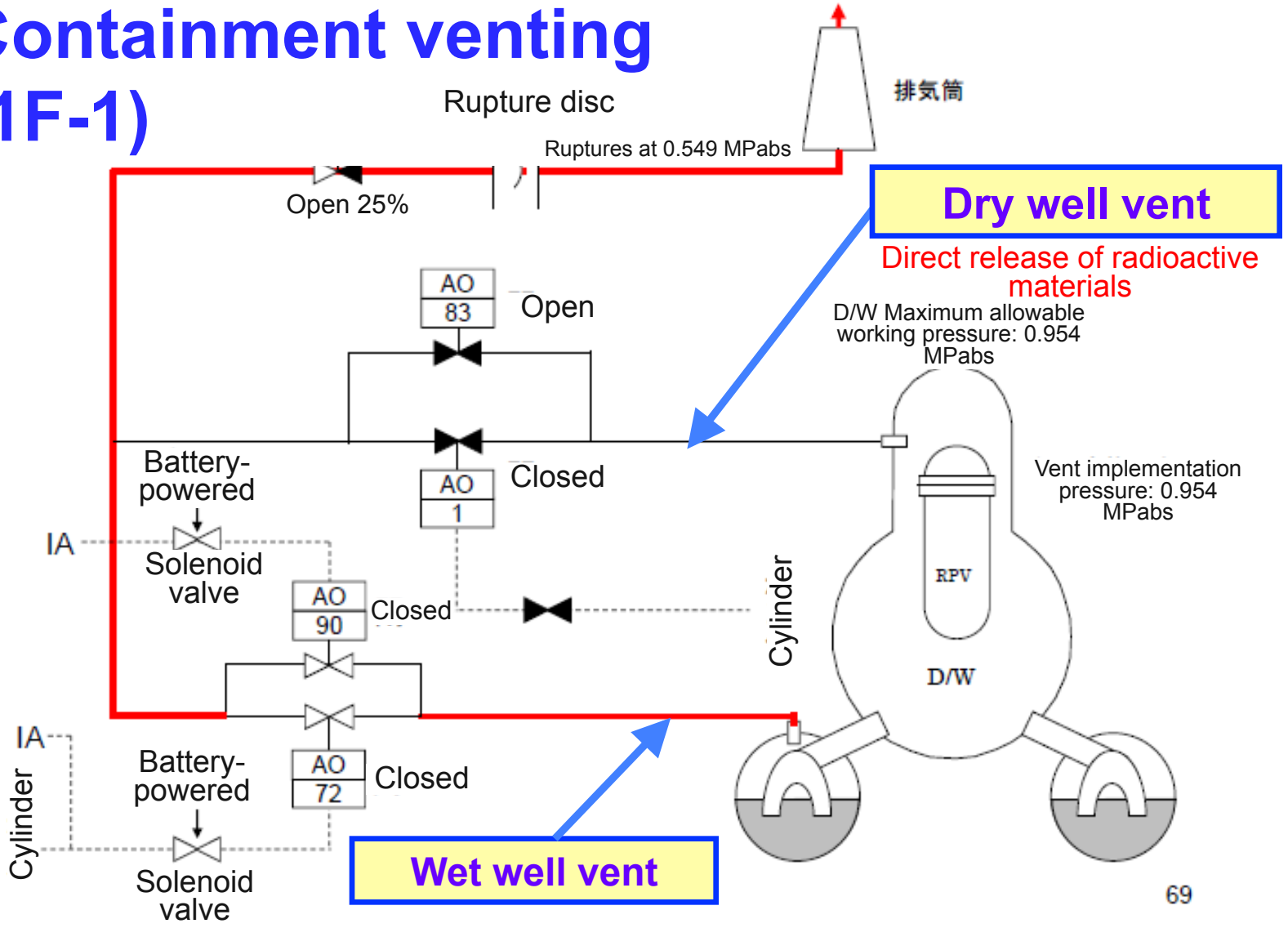


Supposed migration path of hydrogen:

Reactor core
⇒Pressure vessel
⇒Containment vessel
⇒Leakage to flange part of the containment vessel ?

Severe accident measures (accident management)

Containment venting (1F-1)



Containment venting as ultimate choice

- Containment vessel is the "last wall to confine radioactive material" at the time of the accident.
- In case of core damage, it releases (vents) radioactive steam and gas to prevent destruction of containment vessel with too much pressure and heat.

⇒ This means an intentional spread of radioactivity into the environment; **"Suicide of pressure vessel"**

- Should equip "filtered vent" as in EU

Failure modes of containment vessel (how it breaks)

＊Early failure mode: Energetic failure

- DCH（Direct Containment Heating）
- Reactivity control failure
- Hydrogen explosion （Detonation）
- Contact with debris（Mark-I type）
- Phreatic explosion（inside reactor/containment vessel）
- MCCI（Core-concrete reaction）

＊Quasi-static overpressure-overtemperature mode

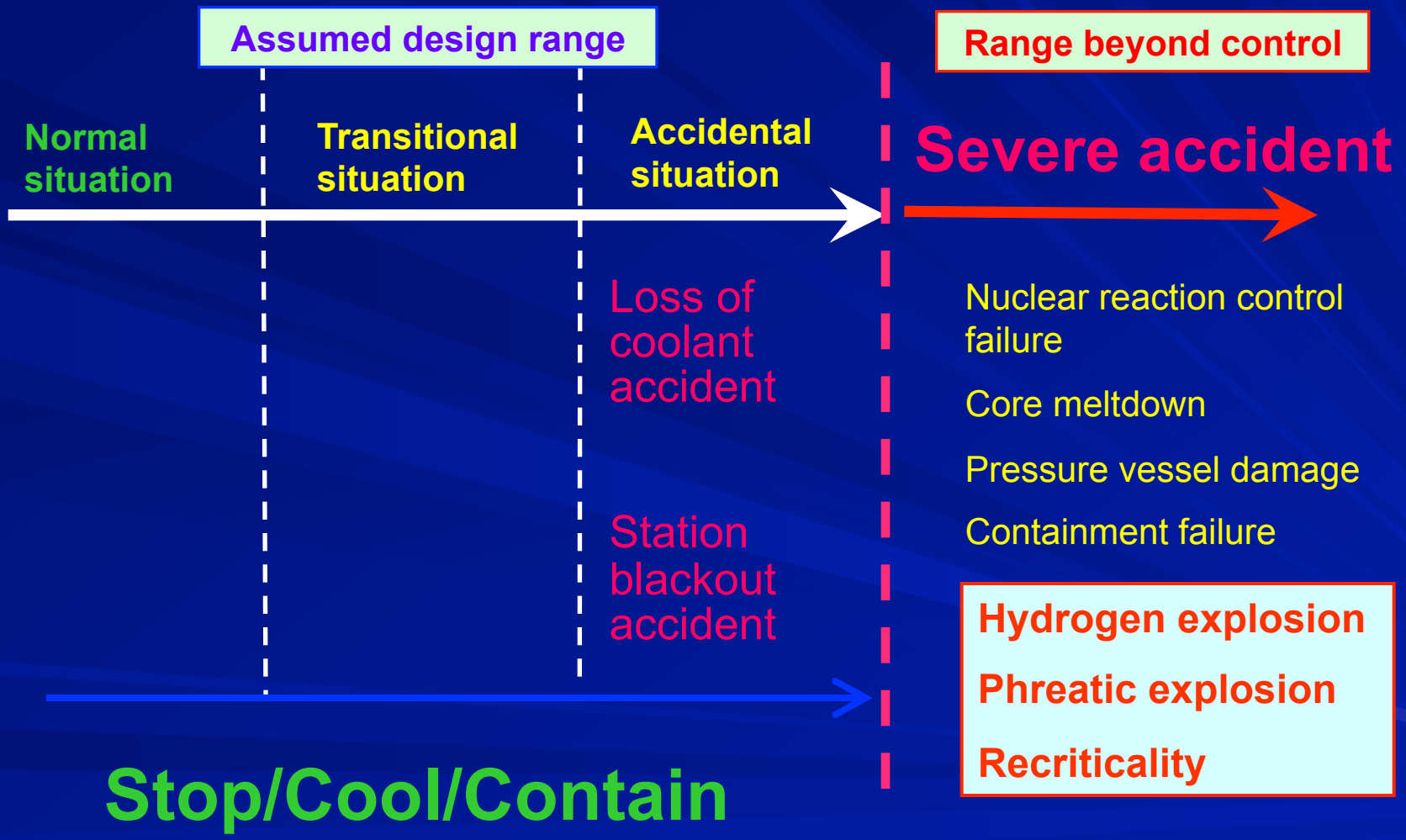
⇒ **containment venting**

Explosive destruction of containment vessel will result in damage far bigger than Fukushima case.

Conditions of nuclear power plant design

- Design conditions against earthquake and tsunami are too lax.
  ⇒Collusive liaison between “seismological findings” and their “application to plant design”; fundamental problem of science and its application.
  ⇒ “Silent pressure” to minimize design requirements for earthquakes and tsunamis.
- By selling the idea that nuclear plants are “safe,” they ended up inducing themselves to believe the myth : **“Containment vessel will never give way.”**

Severe accident



Is the newly introduced accident management effective?

Though claimed to be anti-severe accident measures,

- nothing but a patchwork made of anything seemingly usable like external power supply and fire engines, after all the existing safety systems have collapsed.

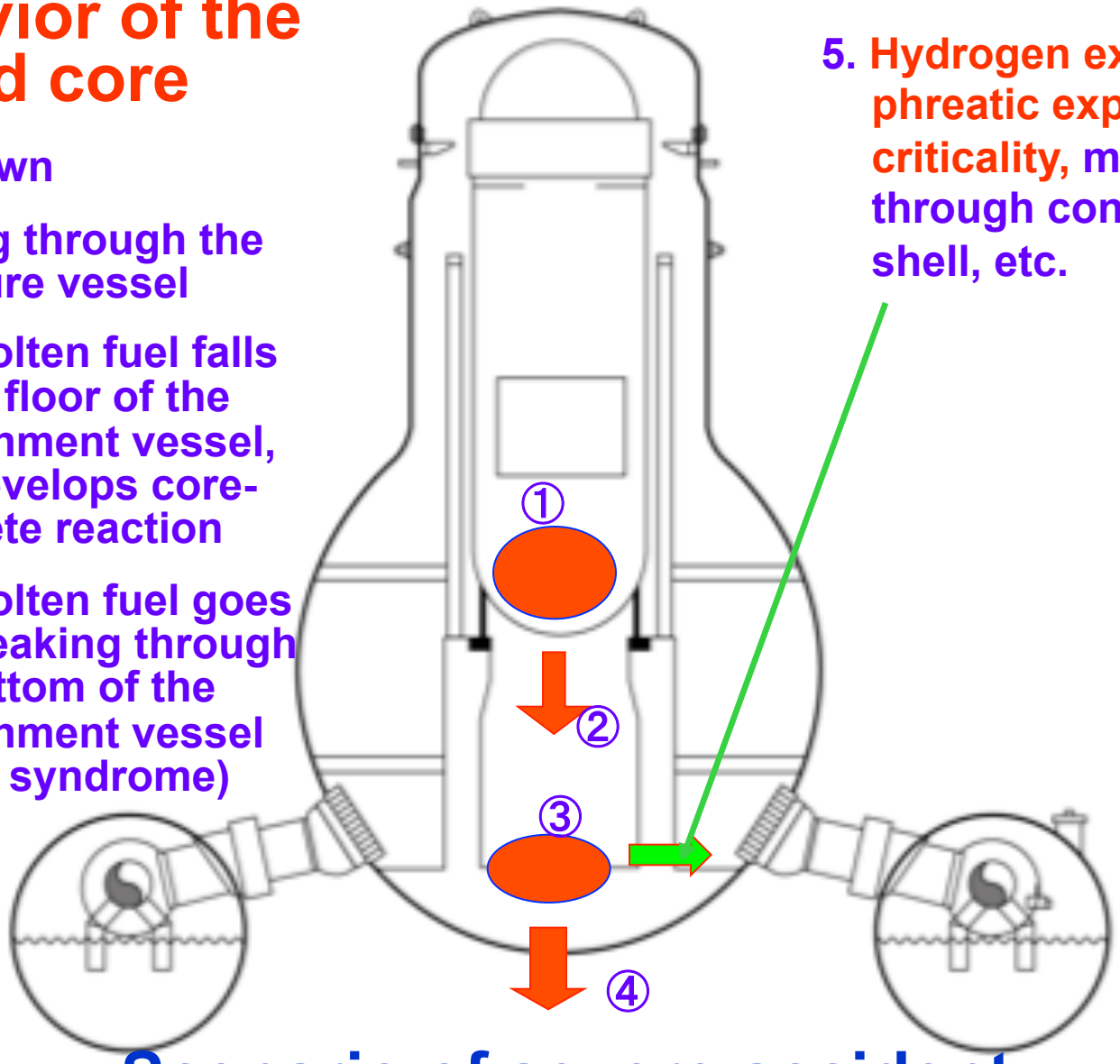
⇒ not reliable compared with the original plant equipment!

⇒ additional emergency equipment may not work under certain weather and environmental conditions

Patchwork of unreliable measures can never achieve safety!

Behavior of the melted core

1. Meltdown
2. Melting through the pressure vessel
3. The molten fuel falls on the floor of the containment vessel, and develops core-concrete reaction
4. The molten fuel goes out breaking through the bottom of the containment vessel (China syndrome)
5. Hydrogen explosion, phreatic explosion, re-criticality, melt through containment shell, etc.

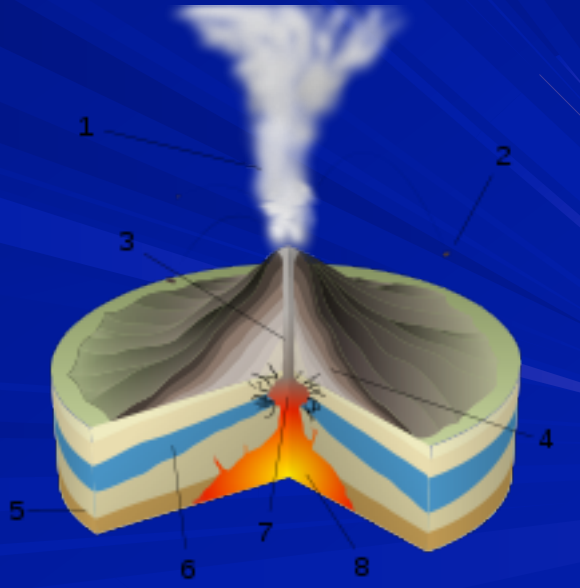


Scenario of severe accident

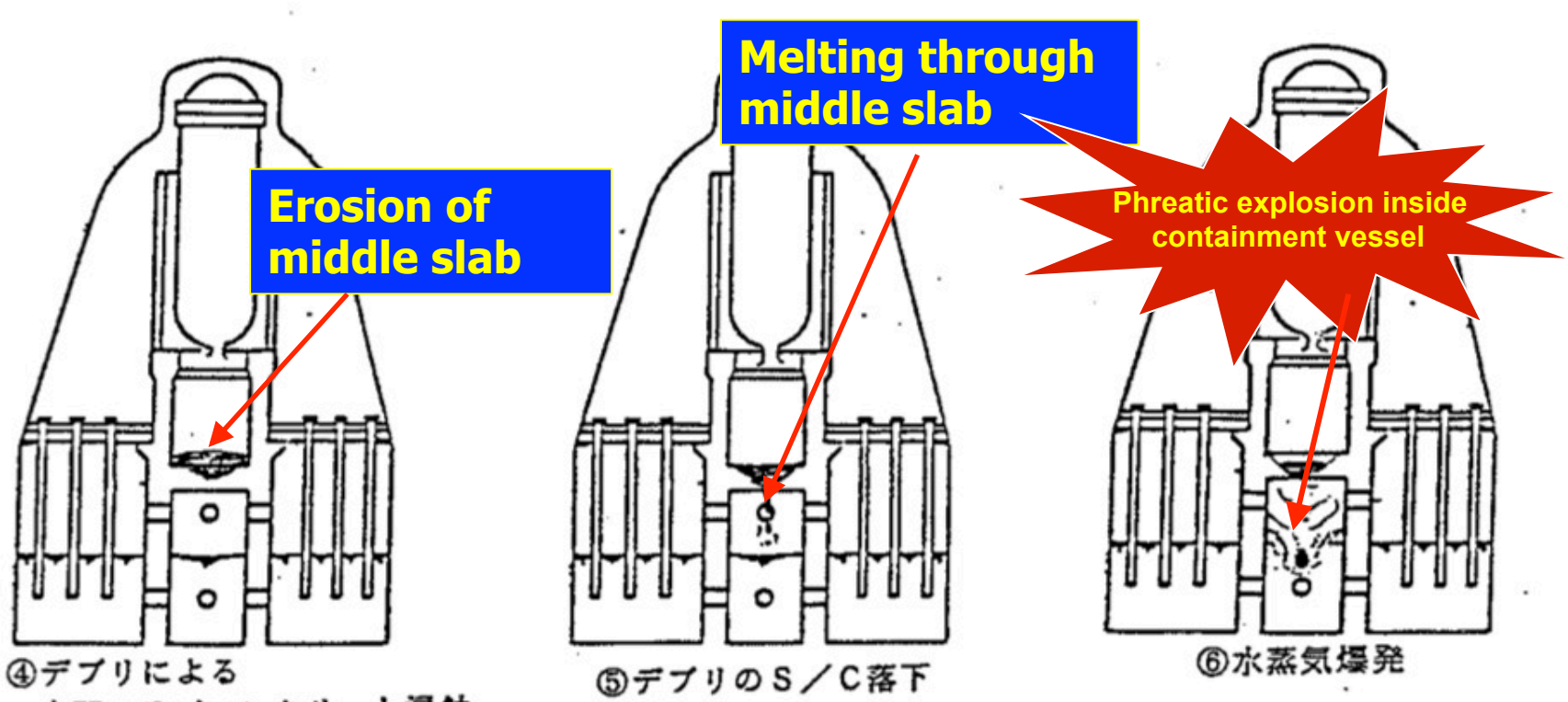
Phreatic explosion

High-temperature melt causes a massive explosion on contact with cold liquid (water).

⇒ Large uncertainty!



Erosion of middle slab (concrete) by melting of debris and its falling down to the pressure suppression pool

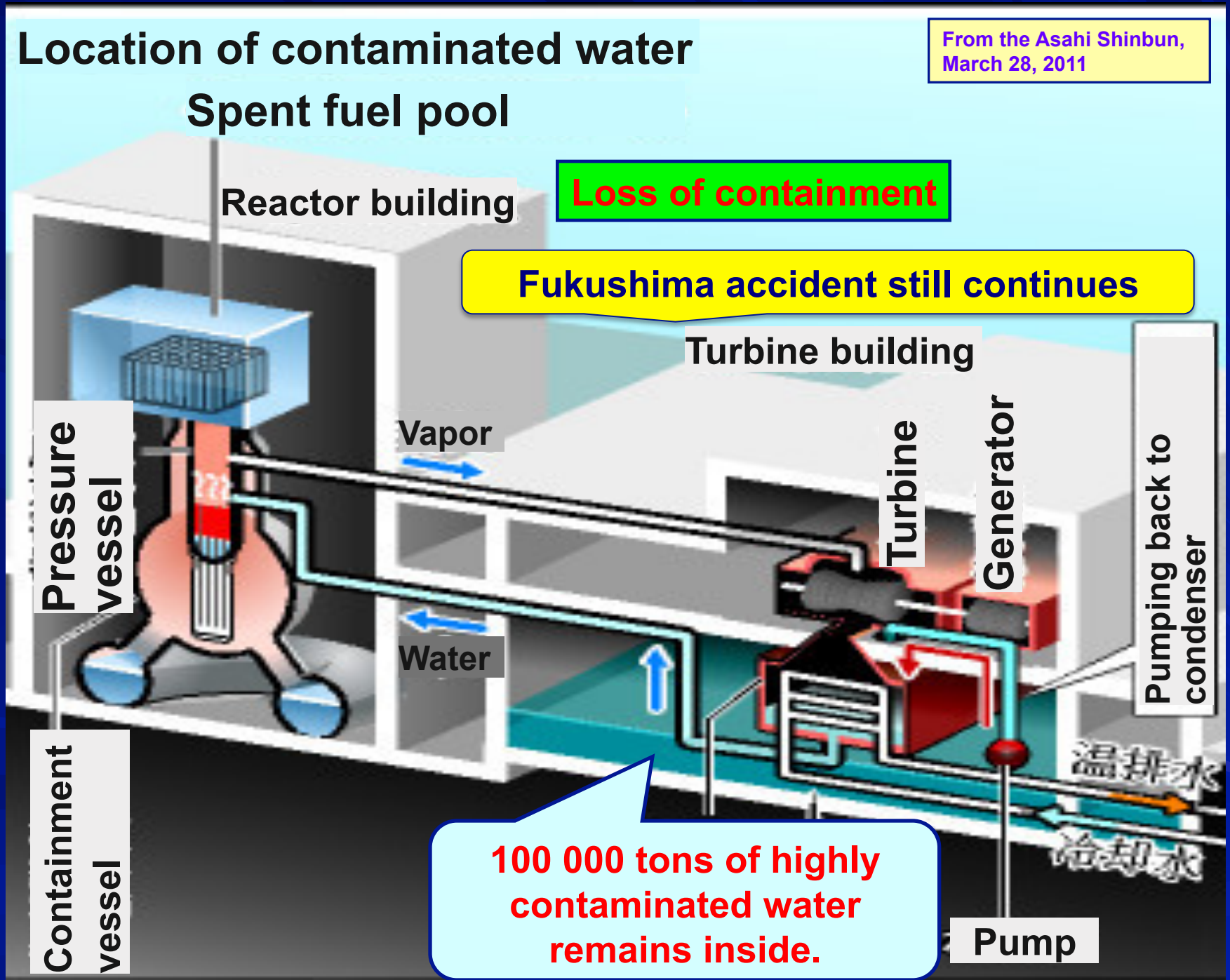


Nuclear power continuously requires ultimate choices

- After the meltdown, if you fail to cool the molten fuel with water, you have **"China Syndrome,"** but there is a risk of **phreatic explosion** if the fuel gets in contact with water.
- Hydrogen is generated after core damage, but if the hydrogen gets out, it will **explode** in contact with oxygen.
- With containment vessel breached, efforts of continuous cooling will produce **large amounts of radioactive vapor and contaminated water**.
- **Containment vessel venting** must be implemented to prevent containment vessel from exploding due to the internal pressure getting greater than the design limit. But the venting will **spread gas and vapor containing large amounts of radioactive materials**.

Location of contaminated water

From the Asahi Shinbun, March 28, 2011



Causes of Fukushima nuclear accident

- Direct causes were the earthquake and the tsunami, but they were suspectedly overlapped with troubles and damages to the valves, pipes and equipment.

  ⇒As the plants are inaccessible, the real damage is not known yet ! There is suspicion of pipe ruptures and the failure of containment vessels !

- The supposition of the conditions of natural environment was wrong ⇒ Stress Test?

- ⇒From how many meters should tsunami countermeasures be assumed to be sufficient? How big will be enough?

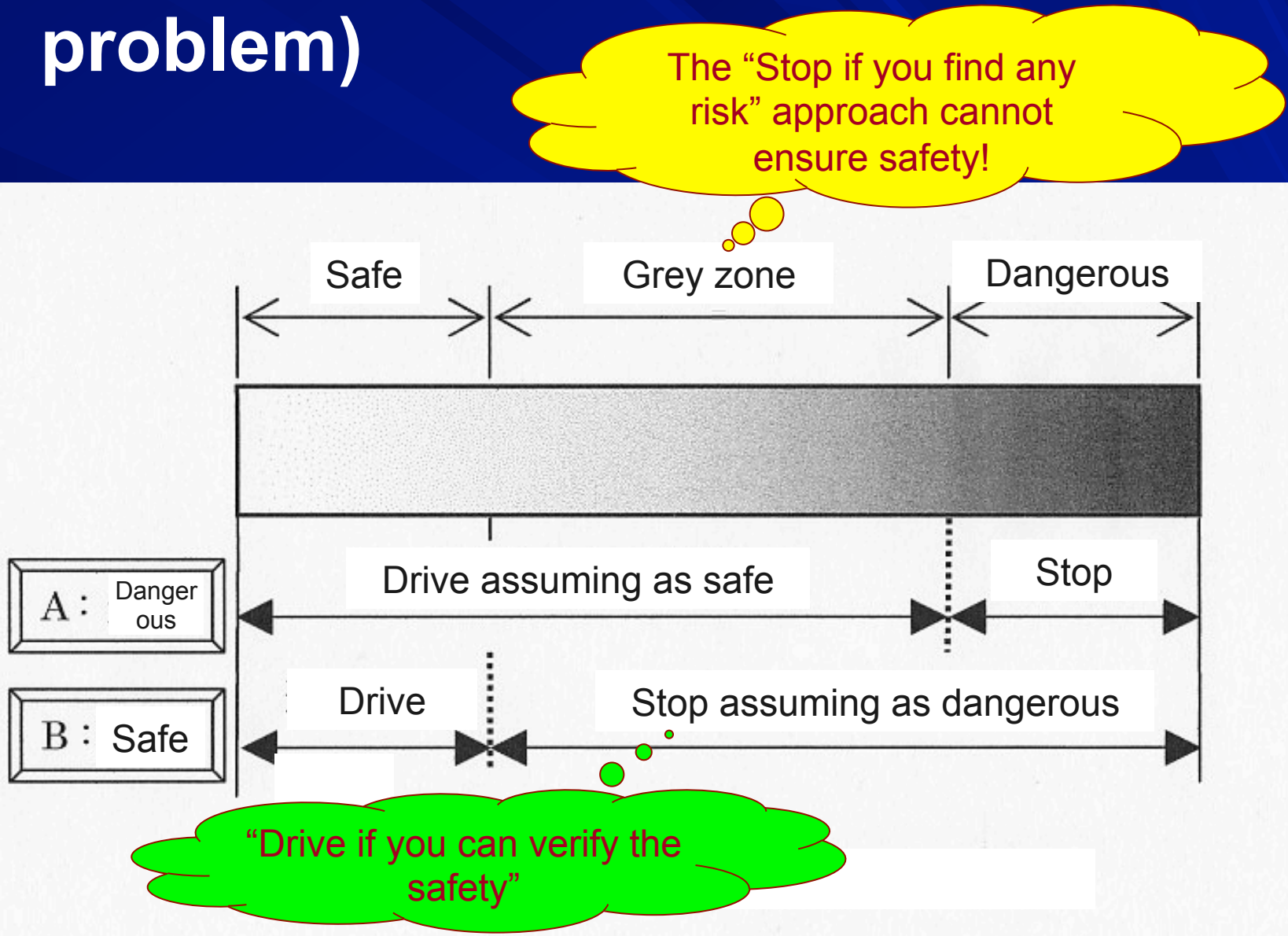
  ⇒Up to how many gals should we take into account? No figures could be considered enough!

- Even if we reinforce some of the anti-earthquake and anti-tsunami measures, we could never prevent severe accidents to occur! ⇒ lightning, hurricanes, tornadoes…

Nuclear community without safety philosophy

- *The biggest problem was that the nuclear community neglected the probability of a severe accident !*
  ⇒ a grave responsibility of the Nuclear Safety Commission
  ⇒ NISA also guilty
- *Academics and industry-society invented a "safety myth"*
- *Manipulated media by spending large amounts of money for publicity.*
- *Illusory Probabilistic Safety Assessment (PSA)!*
  - probability of core damage, probability of containment damage, …

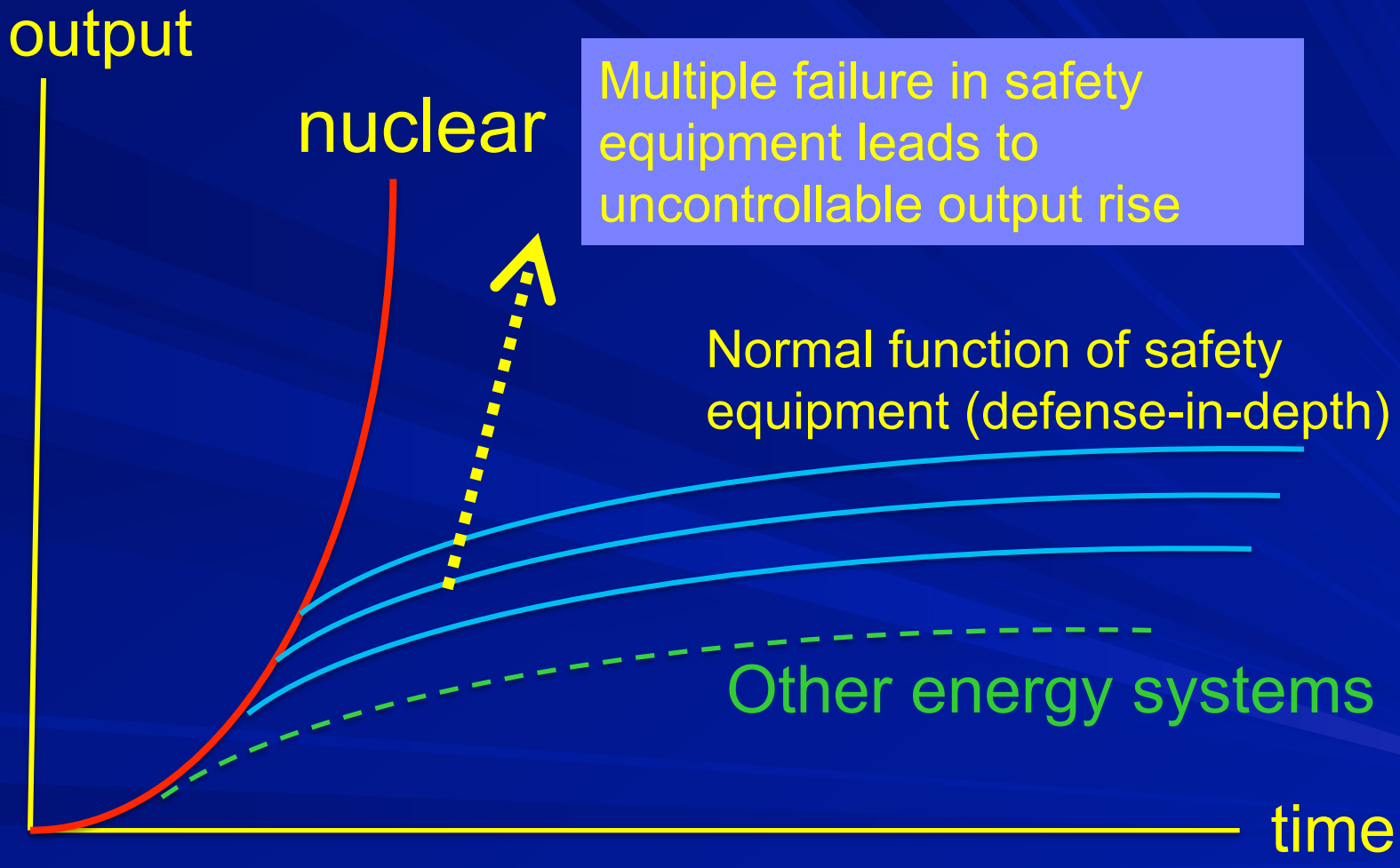
Concept of safety (gray zone problem)



Current situation at Fukushima Daiichi NPP

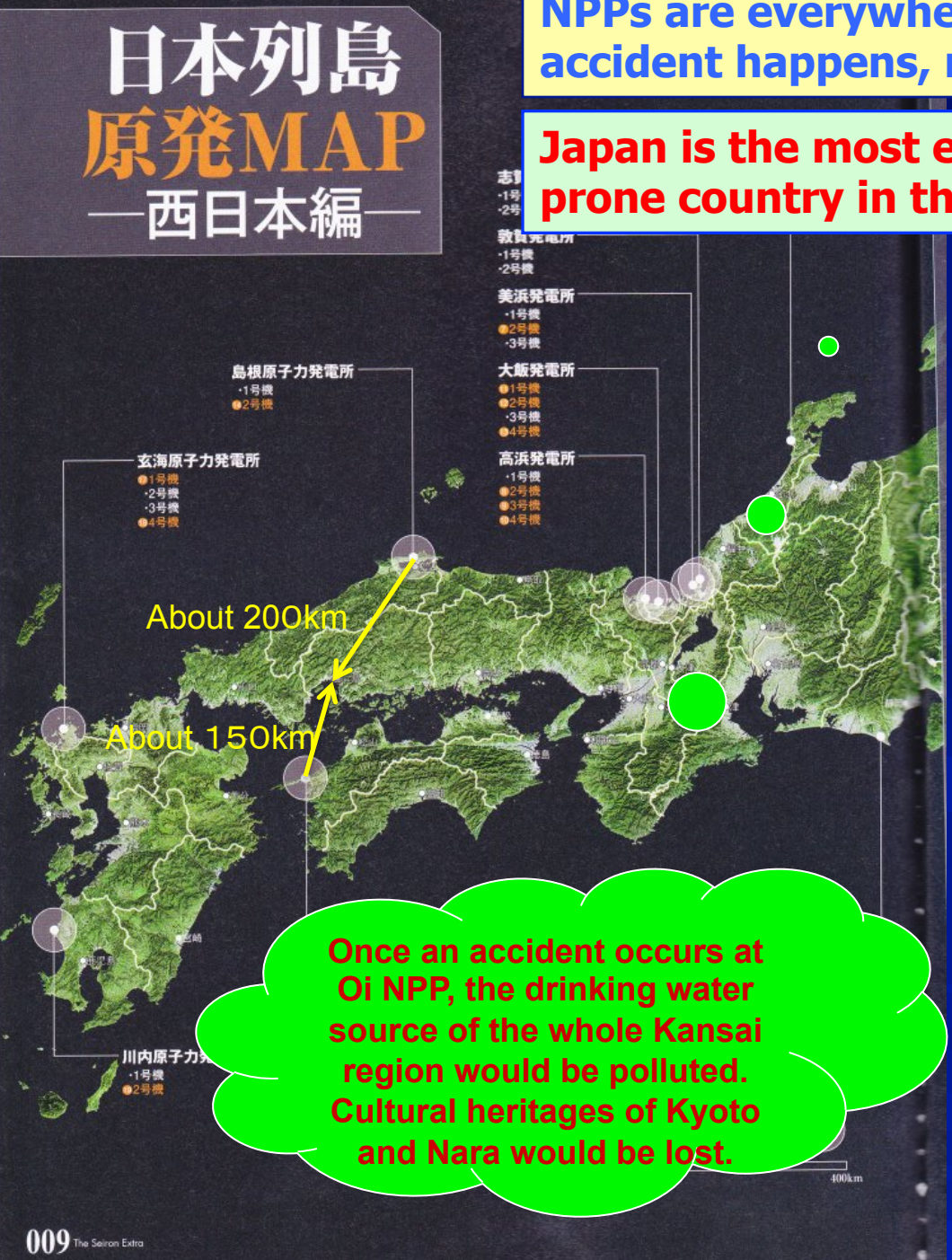
- Not even possible to verify meltdown
- Still not possible to know where the molten debris are
- Is cooling enough? ⇒ We do not know what is really going on.
- 200 thousand tons of contaminated water. Rapid increase with underground water pouring in. Storage tanks will be full in a few months!
- Safety requires a philosophy!
  - ⇨ No safety without certainty
  - ⇨ “May be safe” or “No signs of danger” is not safe enough (“Gray zone” situation)
  - ⇨ What can happen logically will surely happen someday.
  - ⇨ Nuclear safety technology is a “a house of cards.”

Nuclear power is uncontrollable



NPPs are everywhere in Japan. Once an accident happens, no place to live!

Japan is the most earthquake-prone country in the world!



Once an accident occurs at Oi NPP, the drinking water source of the whole Kansai region would be polluted. Cultural heritages of Kyoto and Nara would be lost.

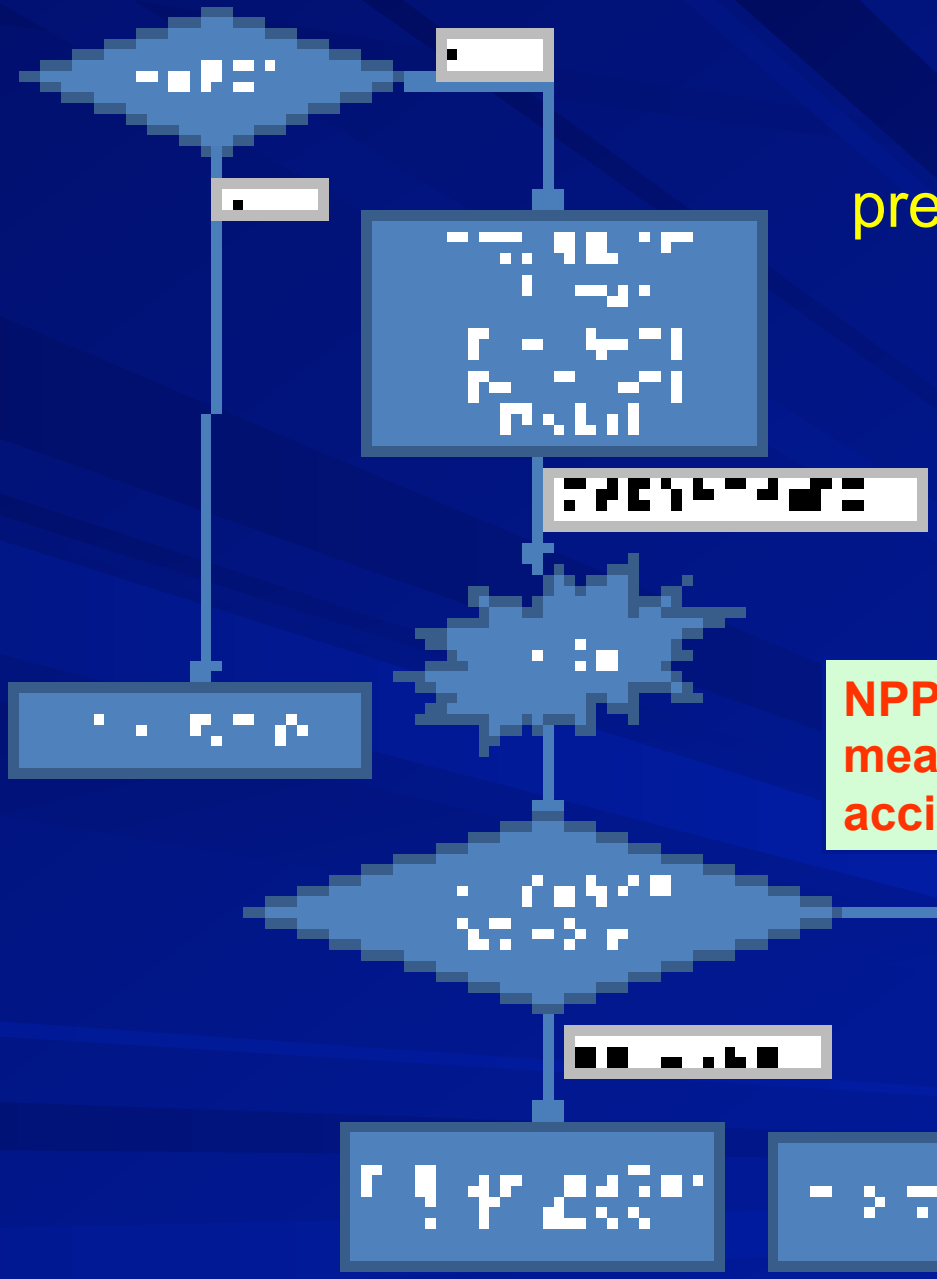
From *Seiron*, August 2011

No safe NPPs in earthquake-prone Japan

- Possibility of ocean-type earthquakes
  - At plate boundaries, earthquakes of more than M9 can happen anywhere
- Epicentral earthquake
  - Oversight of active faults / Integration of multiple active faults ignored
- Kashiwazaki-Kariwa NPP in the Chuetsu-oki Earthquake
  - Ground motion exceeded more than three times the design basis!
  - Ground motion design basis should have been the maximum imaginable.
  - ⇨ It should never be exceeded!
  - This is common to every NPP in Japan.

* ***There are 54 reactors, of which only two are in operation!***

Concept of accident prevention and acceptability of target technology



NPP does not have reliable means to avoid a severe accident!

NPP is unacceptable!

Problems of the Japanese version of "Stress Test"

- After the Fukushima accident, 52 out of the 54 nuclear reactors in Japan are out of operation. All of them will be stopped next month.
- Nuclear and Industrial Safety Agency (NISA), in the same organization and personnel as the pre-Fukushima period, and with no remorse at all, is trying to give the green light to the re-opening of the reactors, judging the reports of the stress tests undertaken by power companies as "appropriate."
- I give my opinions as member of the Hearing Committee for the "stress test", but my observations are ignored and not listed in the report of the Committee.

- **The Japanese "Stress Test" ignores the events associated with tsunami.**
  - Collision of vessels, rubble and flotsam

    ⇒ The pressure of tsunami is considered, but collision of objects is ignored.
  - Earthquake and tsunami caused large-scale and long-lasting fires.
  - ⇒ How resistant are reactor buildings against a large fire?
- **Combined incidents, as well as armed attacks are not taken into account.**

  * Aircraft crash, collision of drifting ships, fires…
- **Deformation and destruction of site ground caused by the earthquake**

  * Buildings, pipes and intake channels can be destroyed massively in the event of destruction of the ground or "cracks"

Our lives are incompatible with radioactivity

- Identification of the cause of the Fukushima accident is still under way ⇒ Was the real cause earthquake?
- Nuclear plants can develop meltdown not only by earthquakes and tsunamis, but also by equipment and/or human failures.
- Exports of nuclear plants to Southeast Asia and the United States should never be allowed!
- A nuclear accident can destroy the whole country, but also engulf other countries.
- **Communizing the experiences of Chernobyl and Fukushima to build a world without nuclear power plant is the only way for the humankind to survive!**