The Defense in Depth Concept

applied to the new regulatory requirements in Japan

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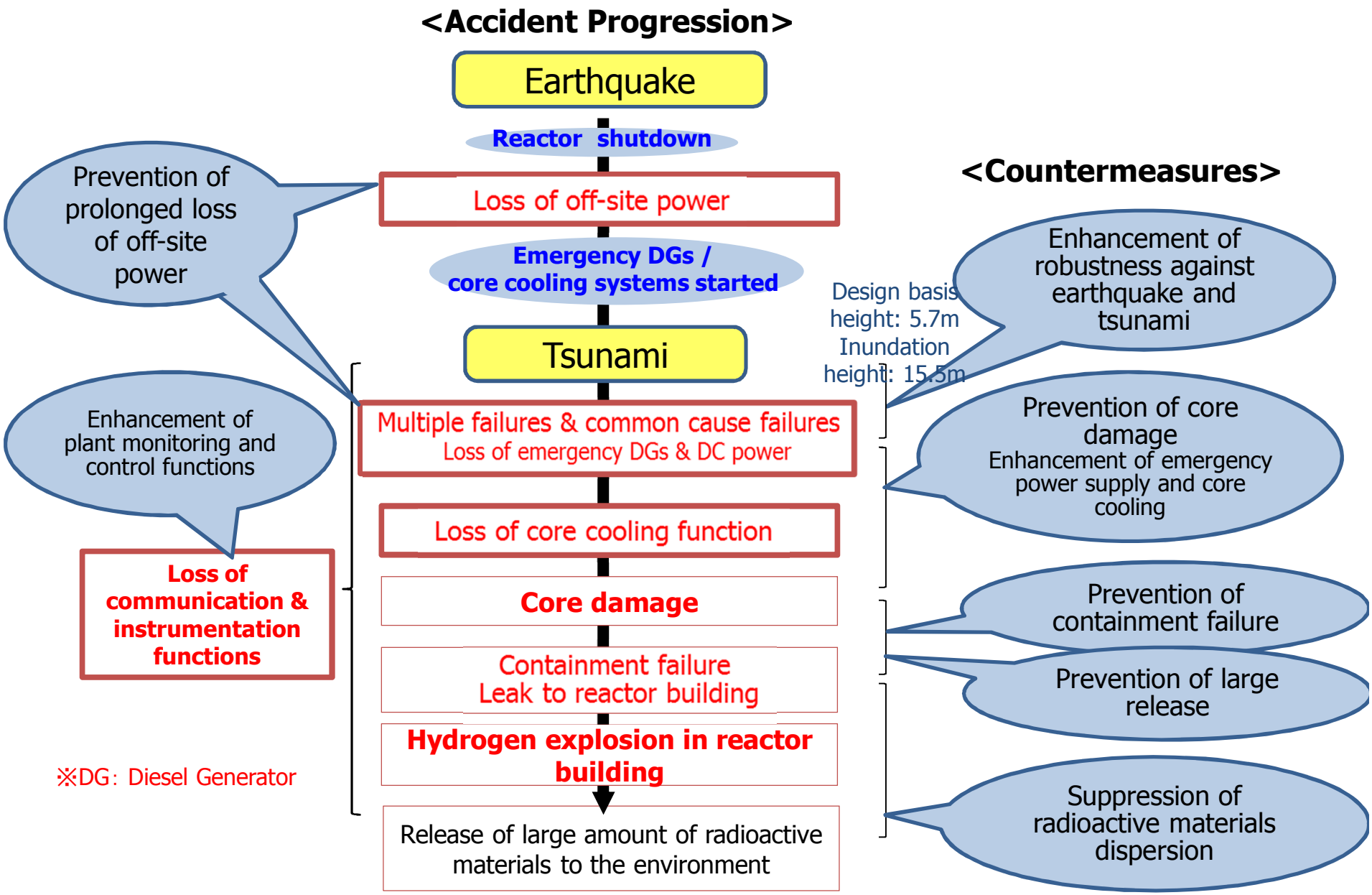
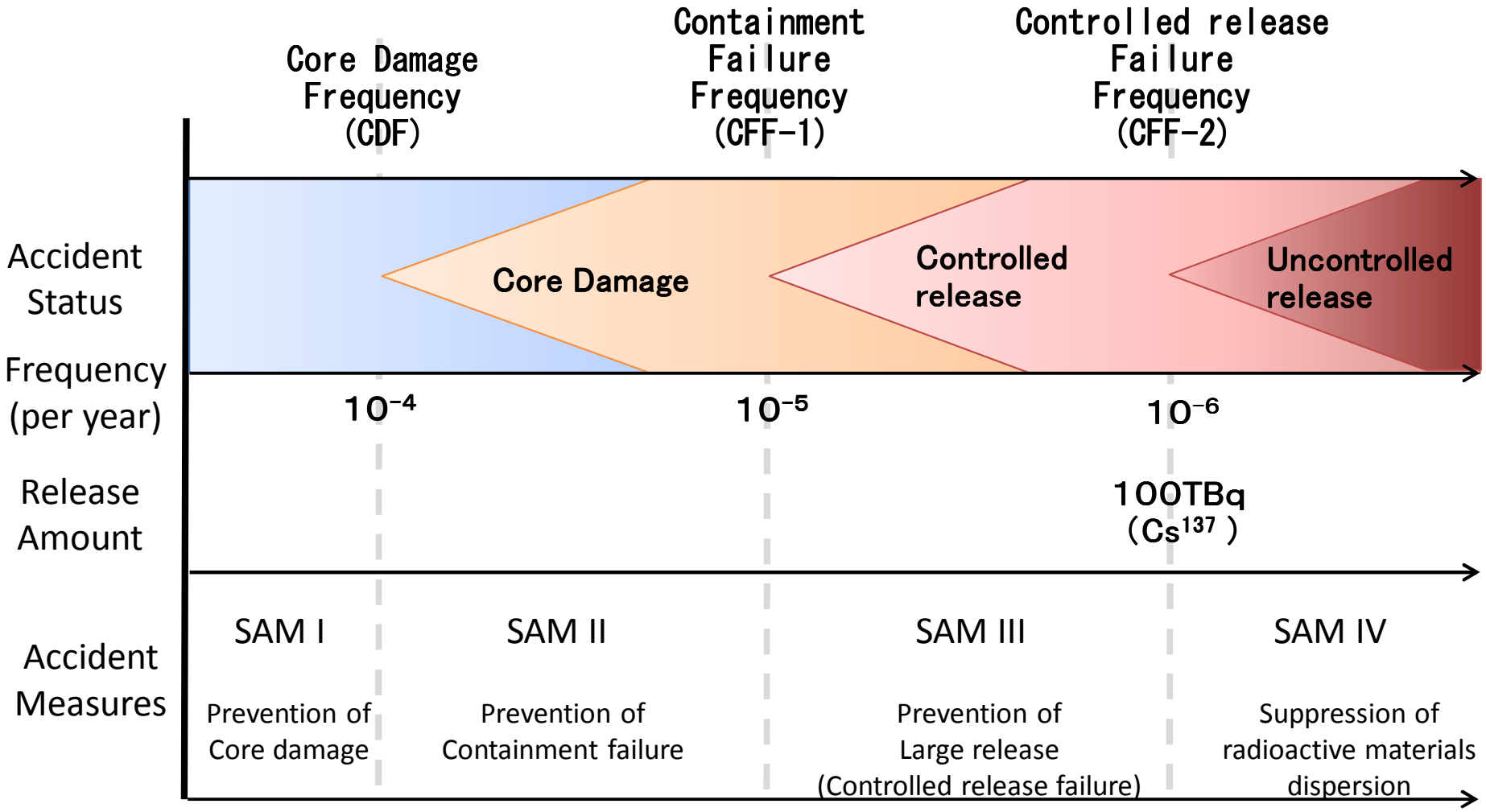
Progression of Fukushima-Daiichi Accident and Countermeasures



Safety Goals

- NRA agreed the safety goals in April 2013.
- Based on the ex-Nuclear Safety Commission report
  - ✓ Qualitative: “The possibility of health effects to the public caused by utilization of nuclear power should be limited to the level not to cause a significant increase in the public risk.”
  - ✓ Quantitative: CDF < 10^{-4}, CFF < 10^{-5}
- In addition, by taking the environmental protection point of view into consideration, NRA introduced limits of amount and frequency of radioactive materials release.
  - ✓ Cs-137 release of 100 TBq or larger < 10^{-6}

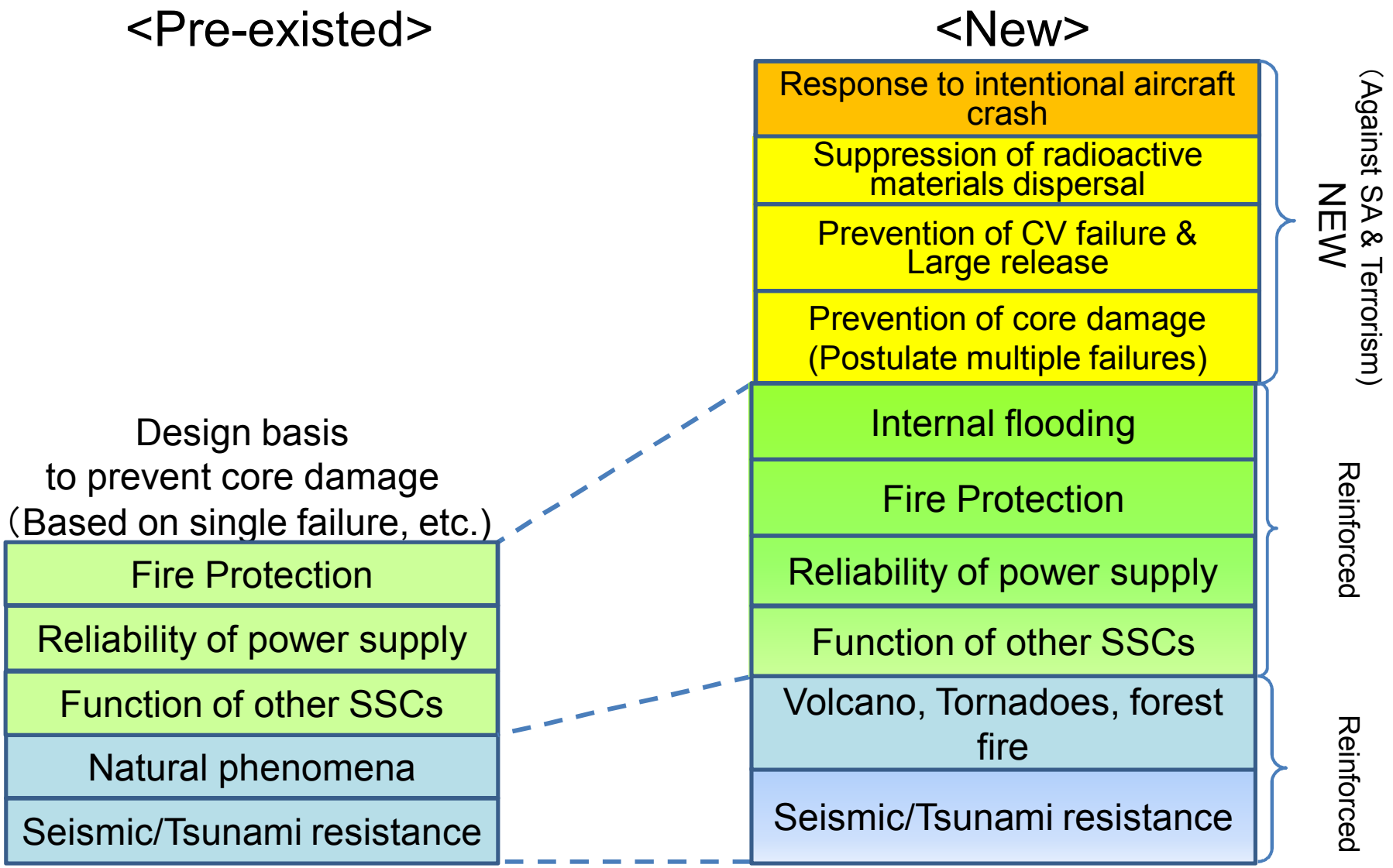
Safety Goals : Accident status and its frequency



Policy in New Requirements

- Place emphasis on Defense-in-Depth concept
  - Prepare multi-layered protective measures and, for each layer, achieve the objective only in that layer regardless of the measures in the other layers.
- ✓ Eliminate common cause failures
  - Introduce accurate approaches in assessment of earthquake and tsunami and measures against tsunami inundation.
  - Introduce assessment of volcano, tornado, & forest fire.
  - Enhance measures against fire, internal flooding, & loss of power.
  - Make much account of “diversity” and “independence”.
- ✓ Prepare multi-layered protection against severe accidents
- ✓ Introduce measures against terrorism

Structure of New Requirements



Stringent Standards & Multiple Protection on Tsunami

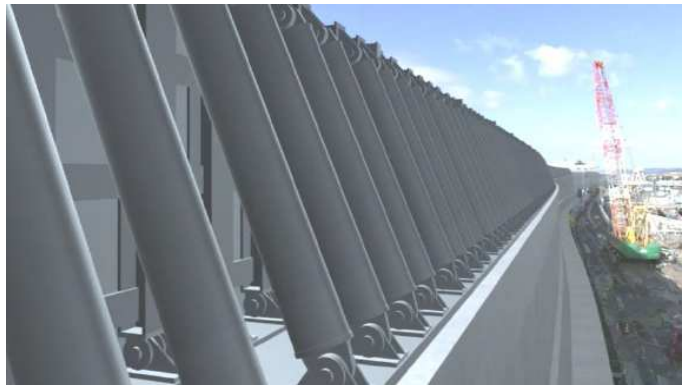
✓ More Stringent Standards on Tsunami

- Define "Design Basis tsunami" that exceeds the largest in the historical records and require to take protective measures such as breakwater wall based on the design basis tsunami.

✓ Multiple Protective Measures

＜Example of tsunami measures＞

◆ Breakwater Wall
(prevent inundation to site)



◆ Tsunami Gate
(prevent water penetration into the building)

Fire Protection

The nuclear reactor facilities shall be so designed that their safety will be protected against fire

<Ex-requirement>

✓ by an appropriate combination of three measures of fire prevention, fire detection and extinguishment, and mitigation of fire effects.

<New requirement>

✓ by considering individual protective measure of fire prevention, fire detection and extinguishment, and mitigation of fire effects.

Ex. Use of non-combustible cables for SSCs with safety functions, whose non-combustibility are confirmed by verification tests

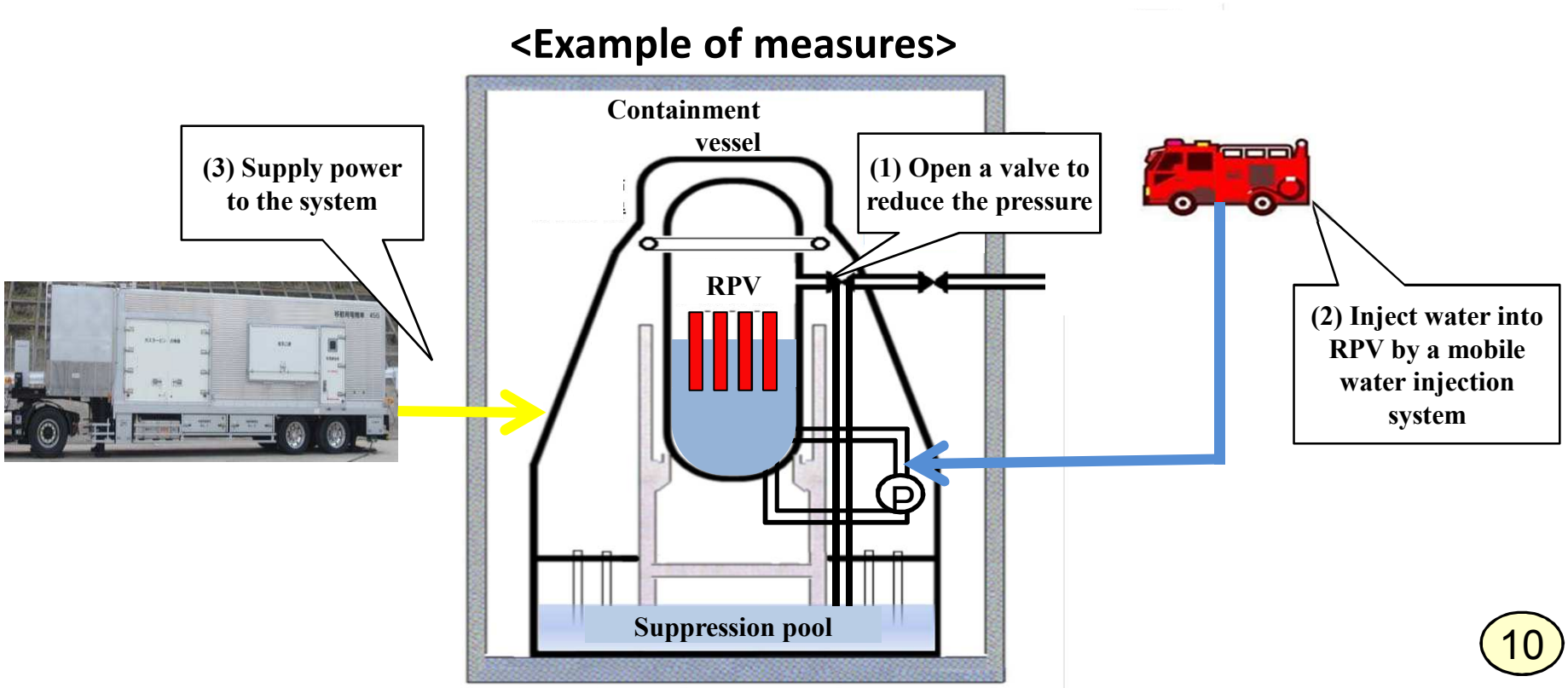
Against Severe Accident

- ✓ Prepare multi-layered protection for
  - prevention of core damage,
  - prevention of containment failure,
  - prevention of large release (controlled release by venting), and
  - suppression of radioactive materials dispersion.
- ✓ Use mobile equipment as a base, as in U.S., and enhance reliability with permanent systems/equipment.
- ✓ Enhance protective measures in spent fuel pool.
  - Water level measurement, alternative water supply, spray.
- ✓ Evaluate effectiveness of measures under the assumption that failure of equipment is not recovered.

Against SA

Prevention of Core Damage at Multiple Failures

- ✓ Assuming loss of safety functions due to common cause,
- ✓ Require measures to prevent core damage
  - Ex.1 Open a safety-relief valve by mobile battery
  - Ex.2 Inject water into the RPV by mobile pump
  - Ex.3 Supply power by power vehicle at SBO

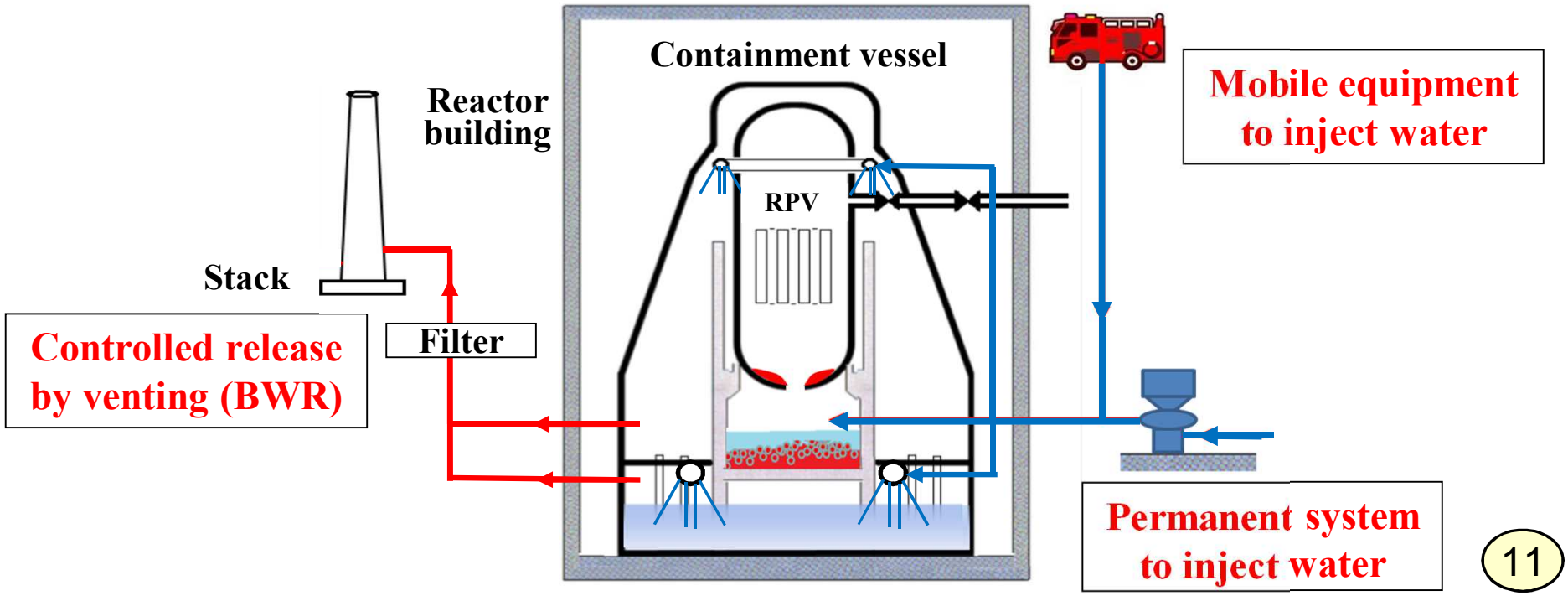


Against SA

Prevention of Containment Failure

- ✓ Assuming severe core damage,
- ✓ Require measures for
  - cooling, depressurization and radioactive material reduction in the atmosphere of the containment vessel
  - cooling molten core fallen to the bottom of the containment vessel
  - preventing hydrogen explosion, and etc.

<Example of measures>



Suppression of Radioactive Materials Dispersion

- ✓ Assuming CV failure,
- ✓ Require outdoor water spraying equipment, etc. to suppress radioactive materials dispersion by water spraying to reactor building and radioactive plume.

Water-spraying with a large scale bubble water cannon system

(Pictures cited) Fire fighting white paper, 2011 edition, http://www.fdma.go.jp/html/hakusho/h23/h23/html/2-1-3b-3_2.html

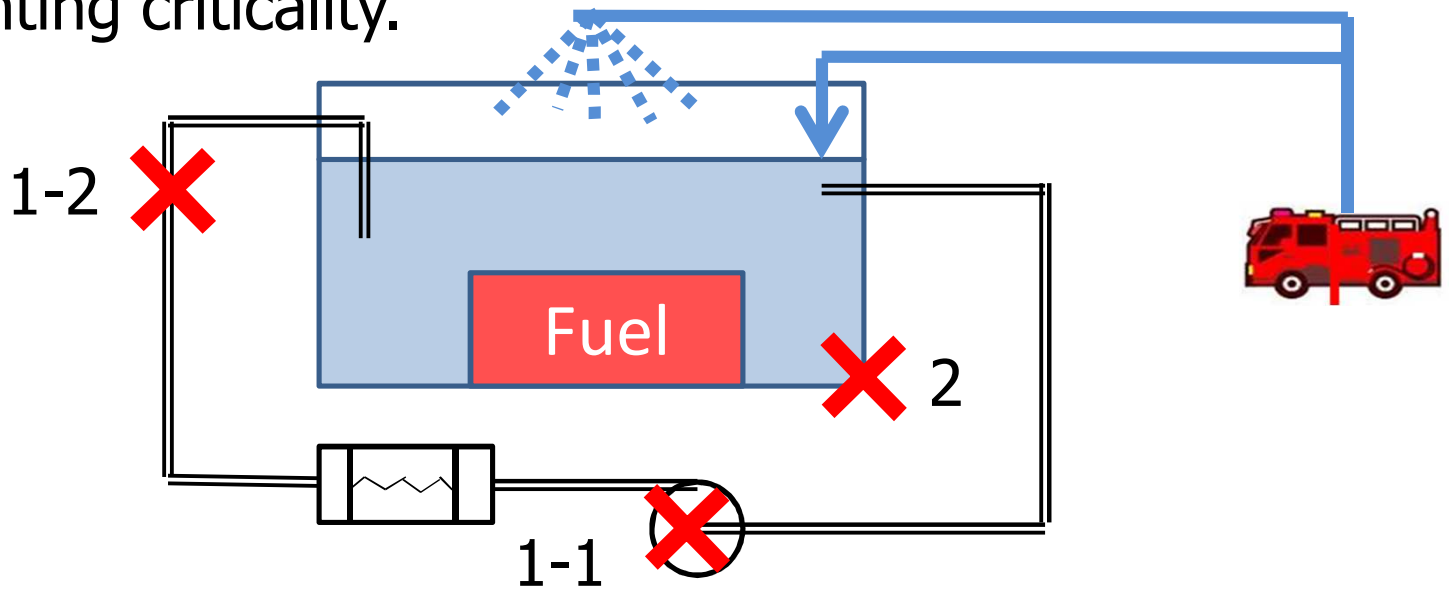
Spent Fuel Pool

1-1 Assuming loss of cooling or water injection function,
1-2 Assuming loss of water by siphon effect due to pipe break,

✓ Require water injection equipment, etc. to maintain enough water level and sub-criticality.

2 Assuming loss of large amount of water,

✓ Require equipment, etc. to mitigate fuel damage and preventing criticality.



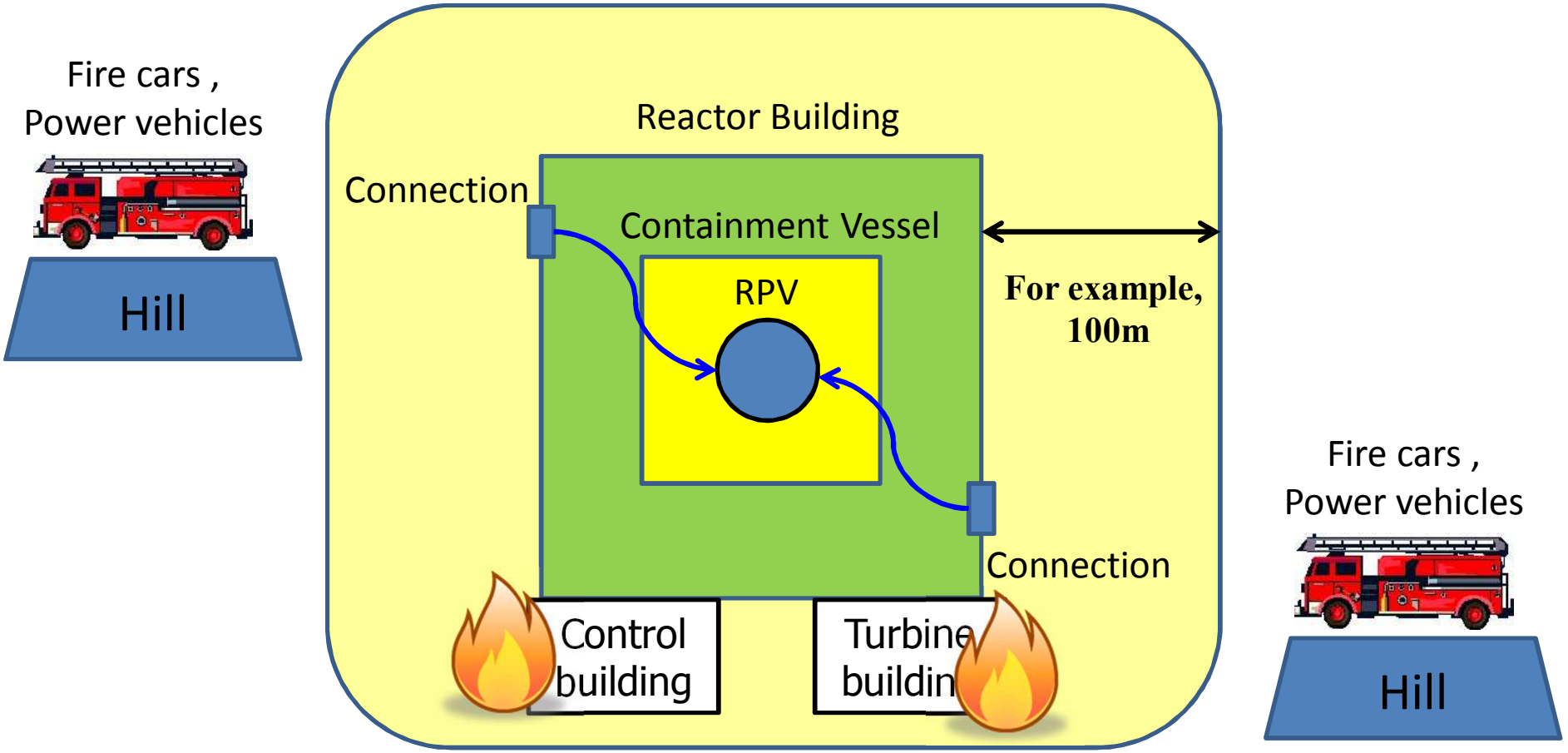
Response to Extreme Natural Hazards & Intentional Aircraft Crash

- ✓ Prepare mobile equipment and connections with spatial dispersion.

- ✓ Introduce “Specialized Safety Facility” against intentional aircraft crash within 5 years.

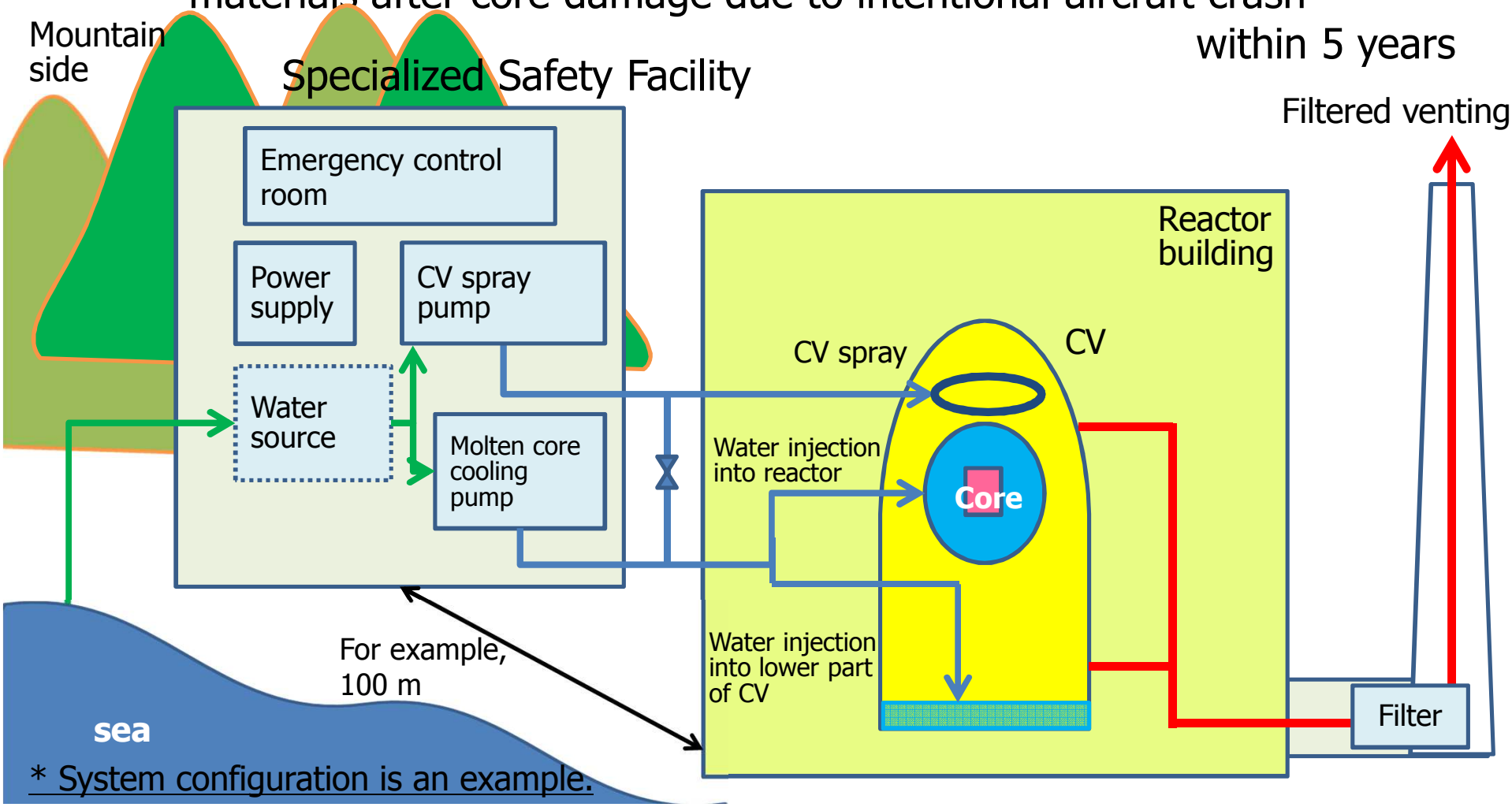
Mobile Equipment against Extreme Natural Hazards & Intentional Aircraft Crash

- ✓ Prepare mobile equipment and connections with spatial dispersion



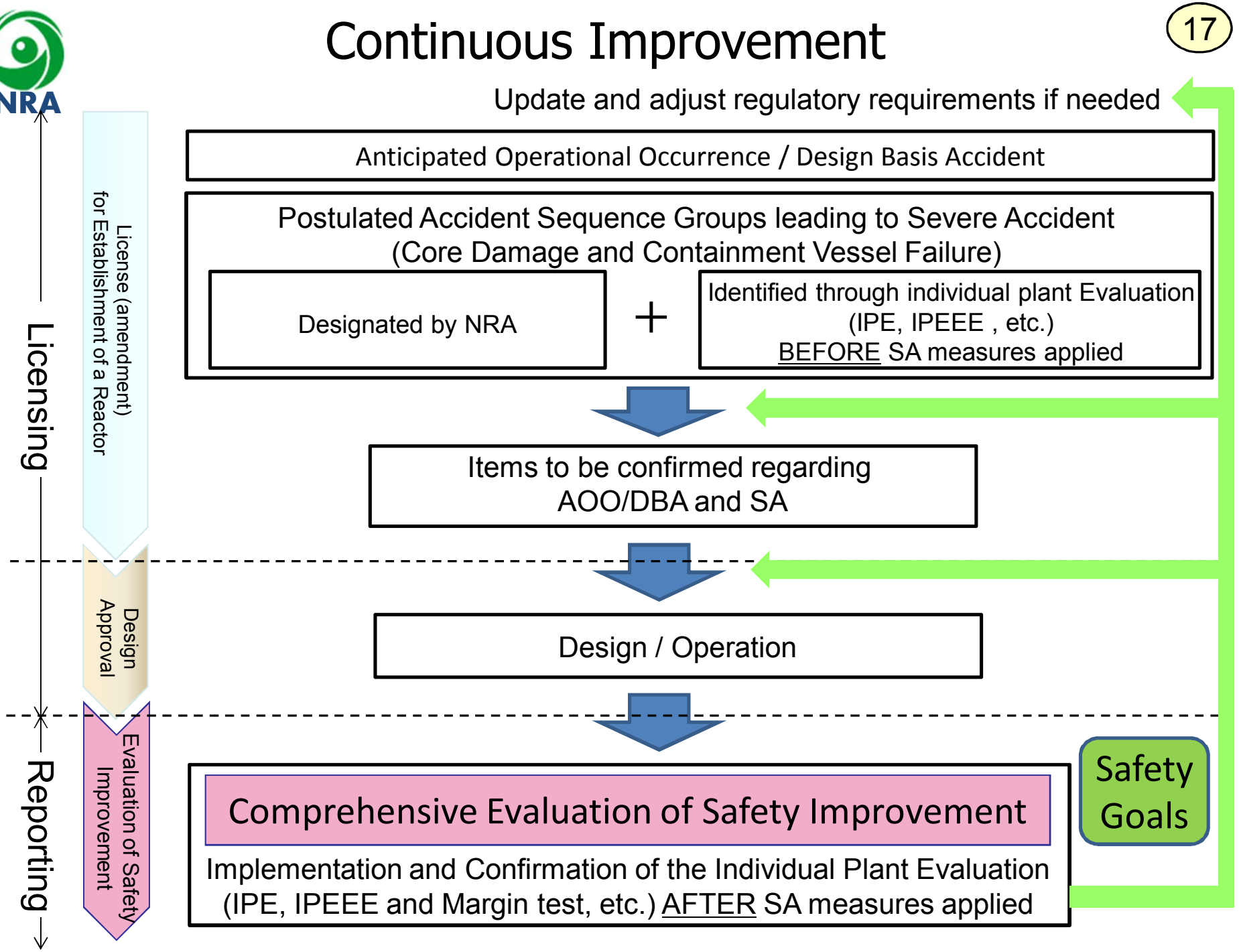
Facility against Intentional Aircraft Crash

✓ Require a "Specialized Safety Facility" to mitigate release of radioactive materials after core damage due to intentional aircraft crash within 5 years



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

Continuous Improvement



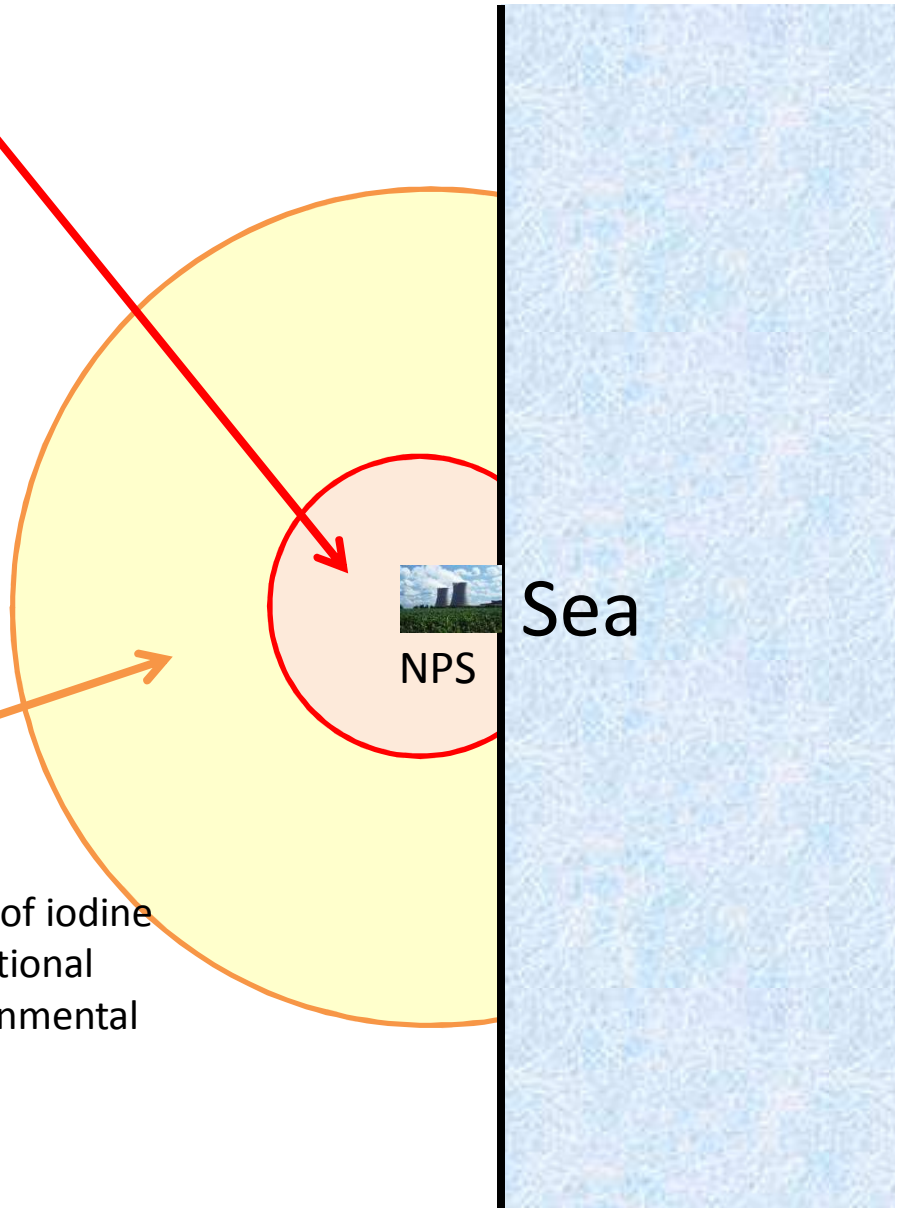
Nuclear Emergency Preparedness

PAZ (Precautionary Action Zone): ~ 5 km in radius

Residents take swift actions (e.g., evacuation, intake of iodine tablets) based on the emergency action level (EAL) before the potential release of radioactive material into the environment.

UPZ (Urgent Protective Action Planning Zone): ~30 km in radius

Residents take actions (e.g., evacuation, temporary relocation, sheltering, intake of iodine tablets) based on the EAL and the operational intervention level (OIL) based on environmental monitoring data.



Summary

Multi-Layered Protective Measures, for example;

- Design Basis: Elimination of common cause failures
  - ✓ Tsunami: Prevention of inundation to site / penetration to building
  - ✓ Fire: Prevention / Detection & extinguishment / Mitigation
- Severe Accidents:
  - ✓ Prevention of Core damage / Containment failure / Large release / Suppression of RM dispersion
  - ✓ SFP: loss of water / Large amount of water
  - ✓ Terrorism: Mobile equipment / Facility
- Emergency Preparedness: PAZ / UPZ

Thank you for your attention.

Outline of New Regulatory Requirements at NRA website:
http://www.nsr.go.jp/english/