후쿠시마원전 사고 시사점 및 사고관리방향

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Fundamentals for Nuclear Safety

Levels of Defense-in-depth(INSAG-10)

Levels of DiD	Objective	Essential means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident Management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Additional Safety Measures (ANSI/ANS-58.9)

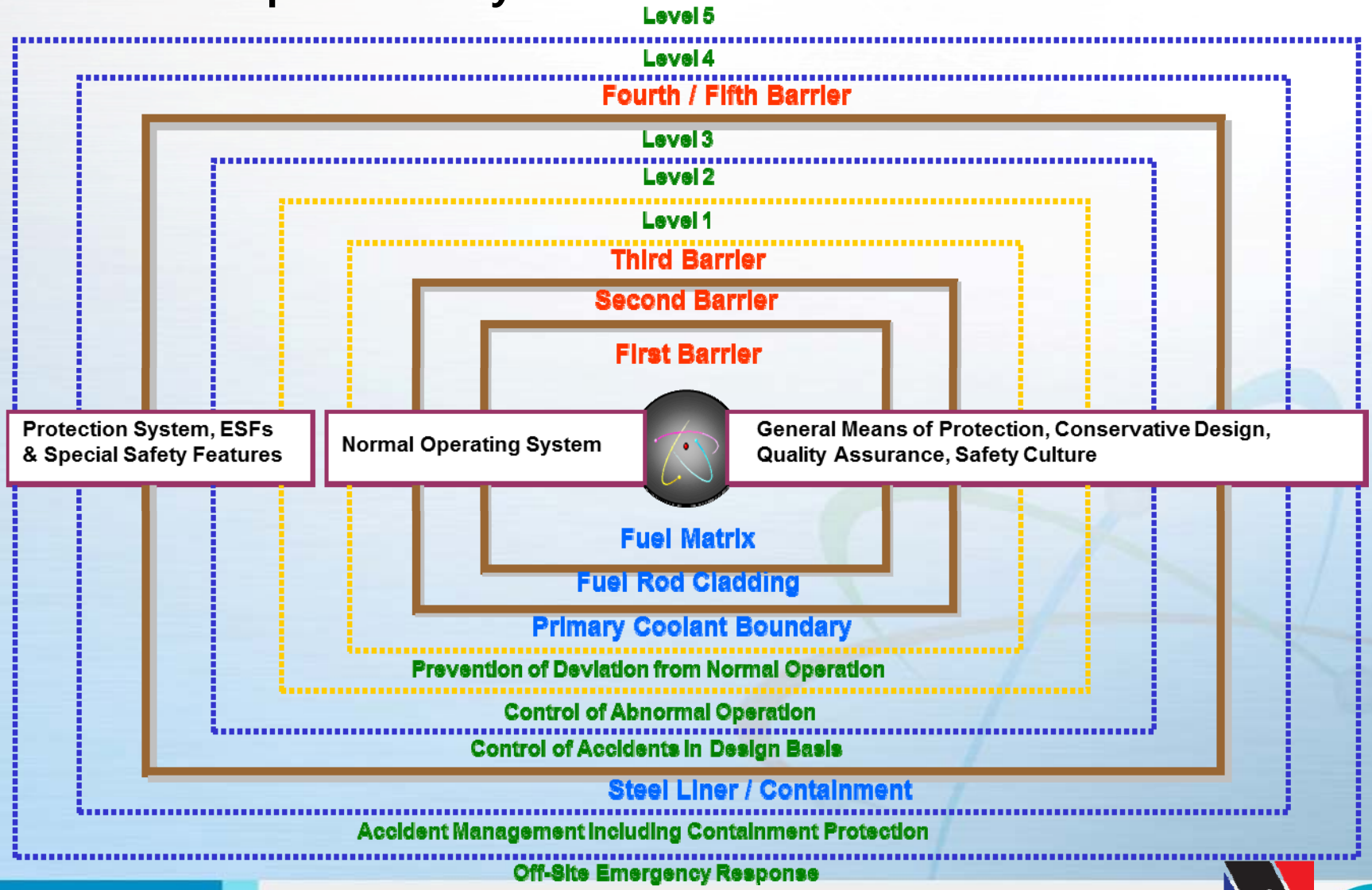
❖ **Single failure**

- **A random failure and its consequential effects assumed in addition to an initiating event and its consequential effects for the purpose of safety-related fluid system design and analysis**

Redundancy & Diversity

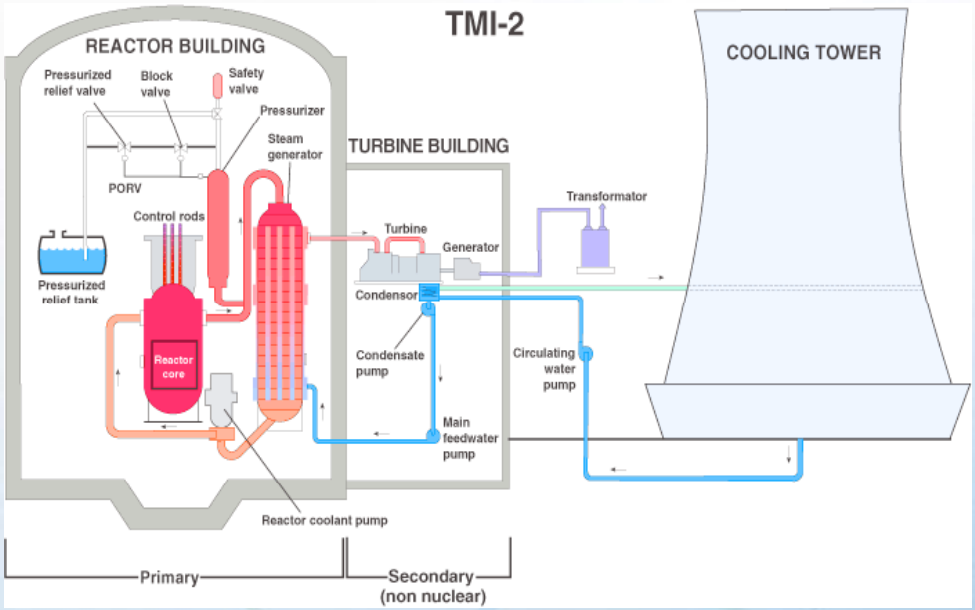
Fundamentals for Nuclear Safety

Defense-in-depth and Physical Barriers



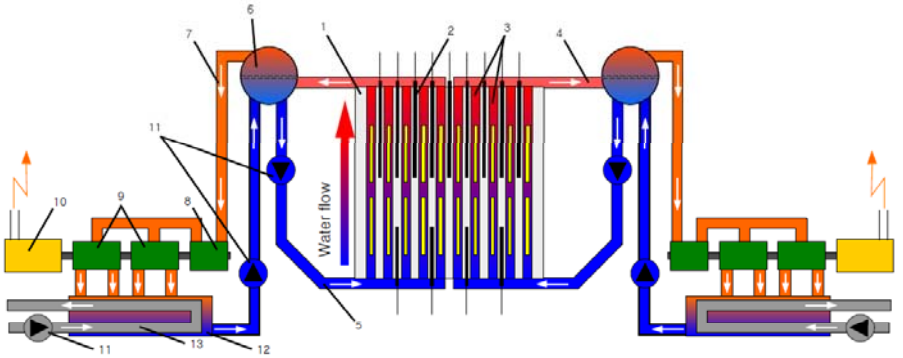
Overview of Nuclear Accident
- TMI Nuclear Accidents (1979)

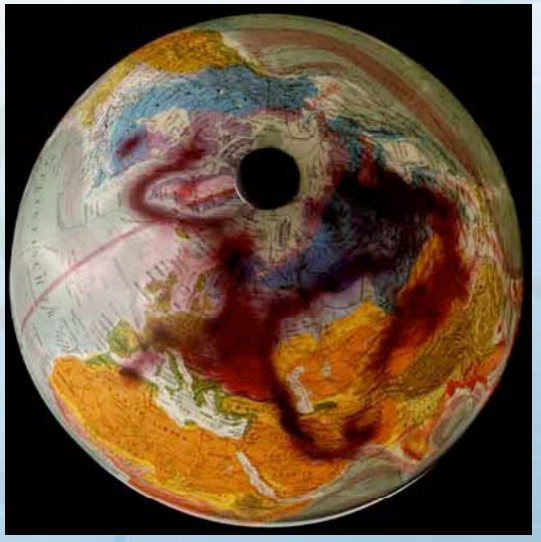
- Turbine trip and reactor trip
- Aux. feed water system was unavailable due to maintenance (TS violation)
- PORV open because of pressure buildup in RCS
- PORV did not reseat properly and remained stuck open (mechanical fault)
- PORV signal was in closed position (design fault)
- Operator did not grasp the situation
- Operator shut RCP down and isolated safety injection
- No cooling water injected and core melt down
- 16 hours after the start RCS temperature began to fall



Overview of Nuclear Accident
- Chernobyl Nuclear Accidents

- At loss of external power, DG took 1 min. to reach full power capacity. To use turbine spin down to generate electricity to fill the 1 min gap, test was tried with low Rx power and full turbine speed.
- Test was delayed and finally conducted by untrained night shift
- To reduce the Rx power control rods were inserted too far, xenon oscillation was occurred. Operator did not know.
- They pull out the control rod beyond safety limit and injected water,....
- They disabled auto-control system...
- Control rod insertion displaced water..
- Core overheated, cooling pipe ruptured, steam explosion, hydrogen explosion...





Overview of Nuclear Accident
- Fukushima Nuclear Accidents

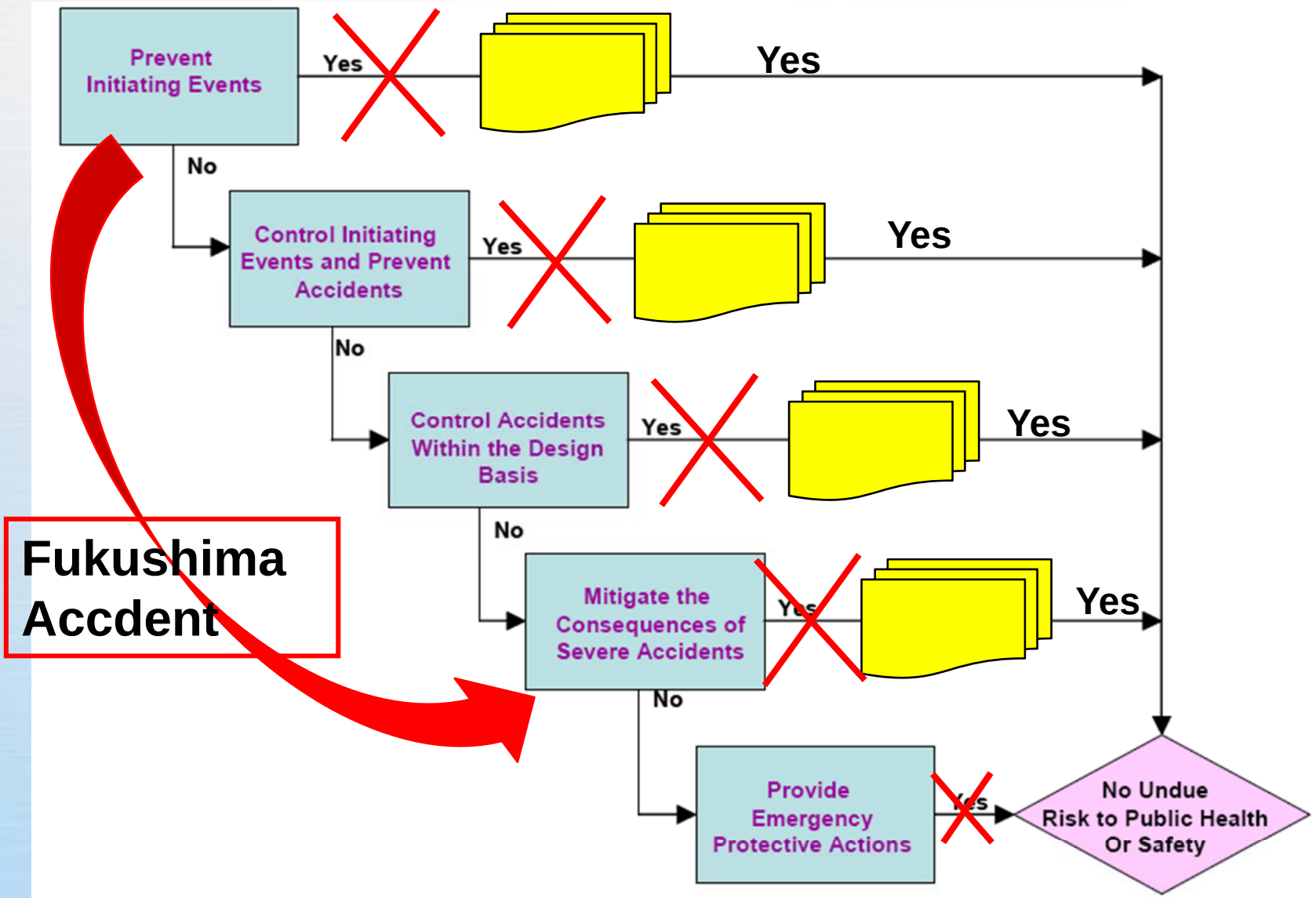
❖ Fukushima accident precursors;

- **2008: Tsunami study ignored (from Managing the Fukushima Challenges, Atsuyuki Suzuki)**
  - A 2008 in-house study identified an immediate need to better protect the facility from flooding by seawater. This study mentioned the possibility of tsunami-waves up to 16 metres.
  - TEPCO decided not disclose this to the public, entrusted JSCE to look into more and ordered in-house technical team further evaluation.
  - Headquarters officials insisted that such a risk was unrealistic and did not take the prediction seriously

❖ Diet Report concludes that Fukushima accident was clearly "manmade".

- **The official report of the Fukushima Nuclear Accident Independent Investigation Commission**

Fukushima unit 1 to 4

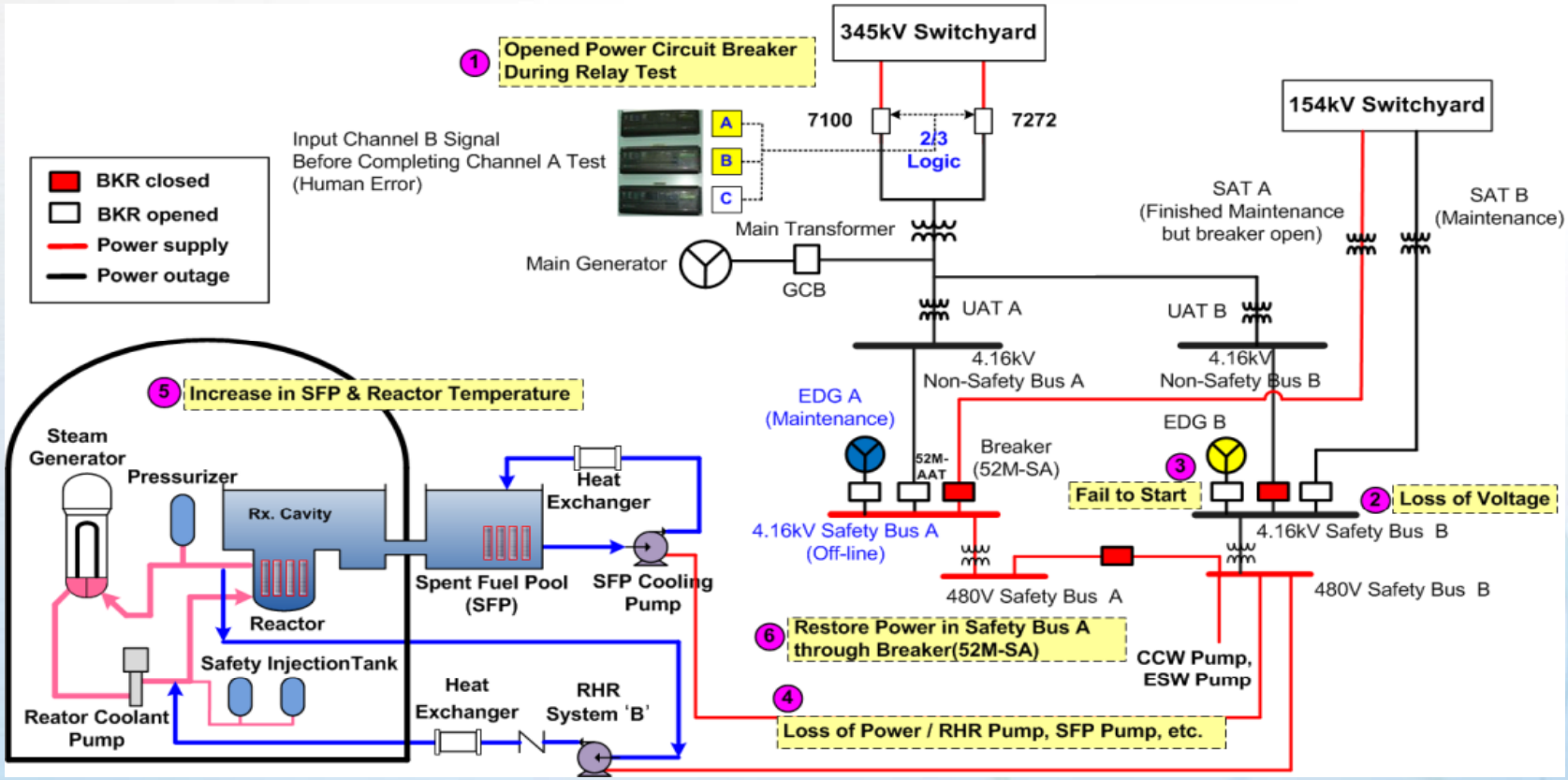


Comparison of Nuclear Disasters

Accident	Initiating Event	Major Safety Issue	Radioactive Material Release	Containment Integrity
TMI	Internal	Core Cooling	No Release	C/B intact
Chernobyl	Internal	Power Excursion	Large Release	C/B exploded
Fukushima	External	Core Cooling	Large Release	C/B failed

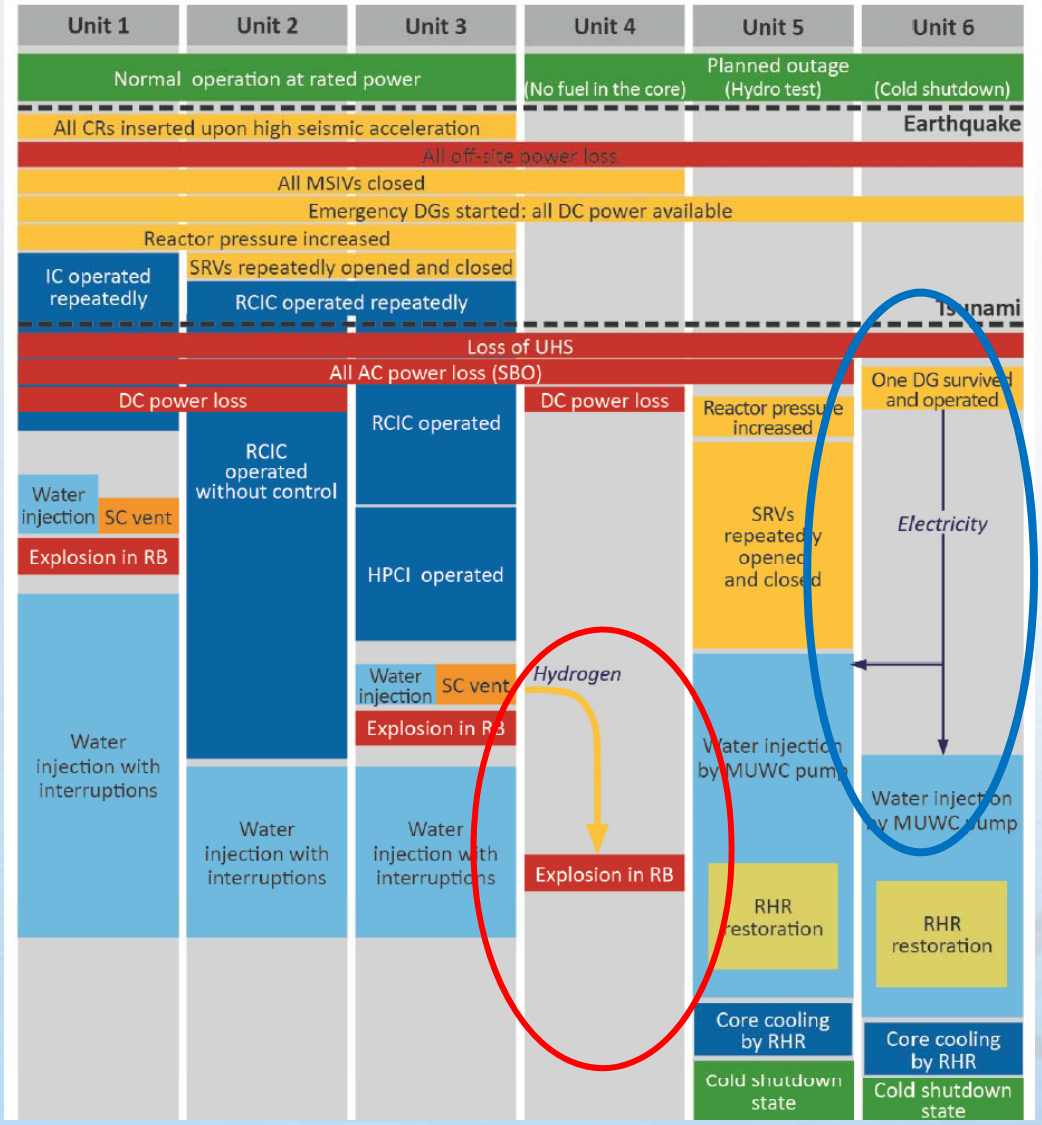
Which one more likely to occur in the future?

Our Experience : Kori 1 SBO Event



- Maintenance of SAT B was started although SAT A was not returned to operation
- During relay test of GCB, field test personnel started channel “B” before returning channel “A” to normal
- 345kV circuit breaker tripped opened
- EDG “B” failed to start due to failure of single solenoid valve for startup air for EDG
- Resulting in SBO, loss of RHR and spent fuel pool cooling
- In 12 min, 154kV power “A” was recovered
- Top manager decided not to report this SBO and cover up subsequent actions

Progress of Fukushima Accident



- Normal status
- Accident progression
- Expected/designed response
- Designed core cooling
- Alternate water injection
- Containment venting
- Recovery work

Abbreviations:
CR: Control rod
DG: Diesel generator
HPCI: High pressure coolant injection system
IC: Isolation condenser
MSIV: Main steam isolation valve
MUWC: Make-up water condensate system

RHR: Residual heat removal system
RB: Reactor building
RCIC: Reactor core isolation cooling system
SC: Suppression chamber
SRV: Safety relief valve
UHS: Ultimate heat sink

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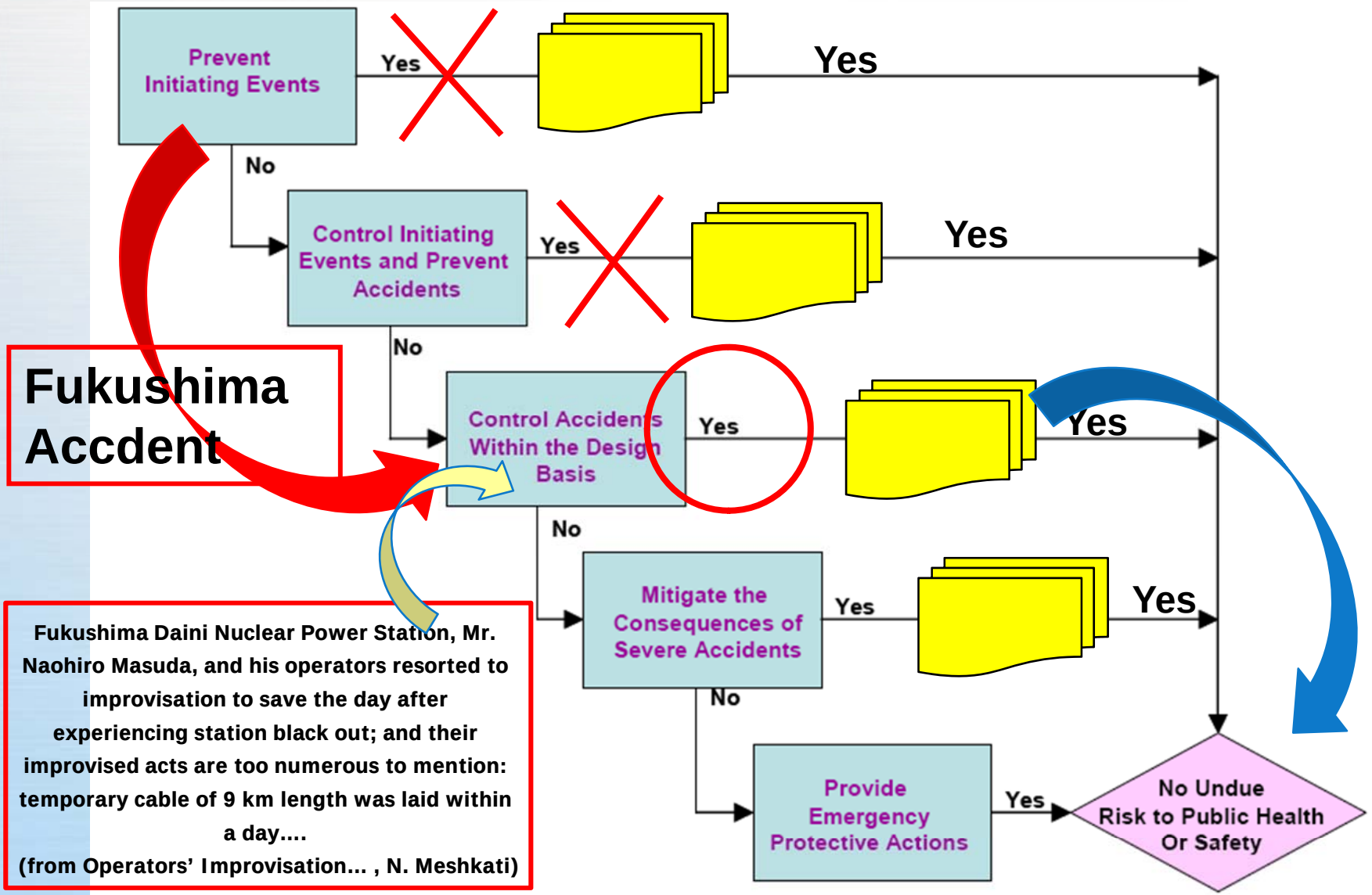
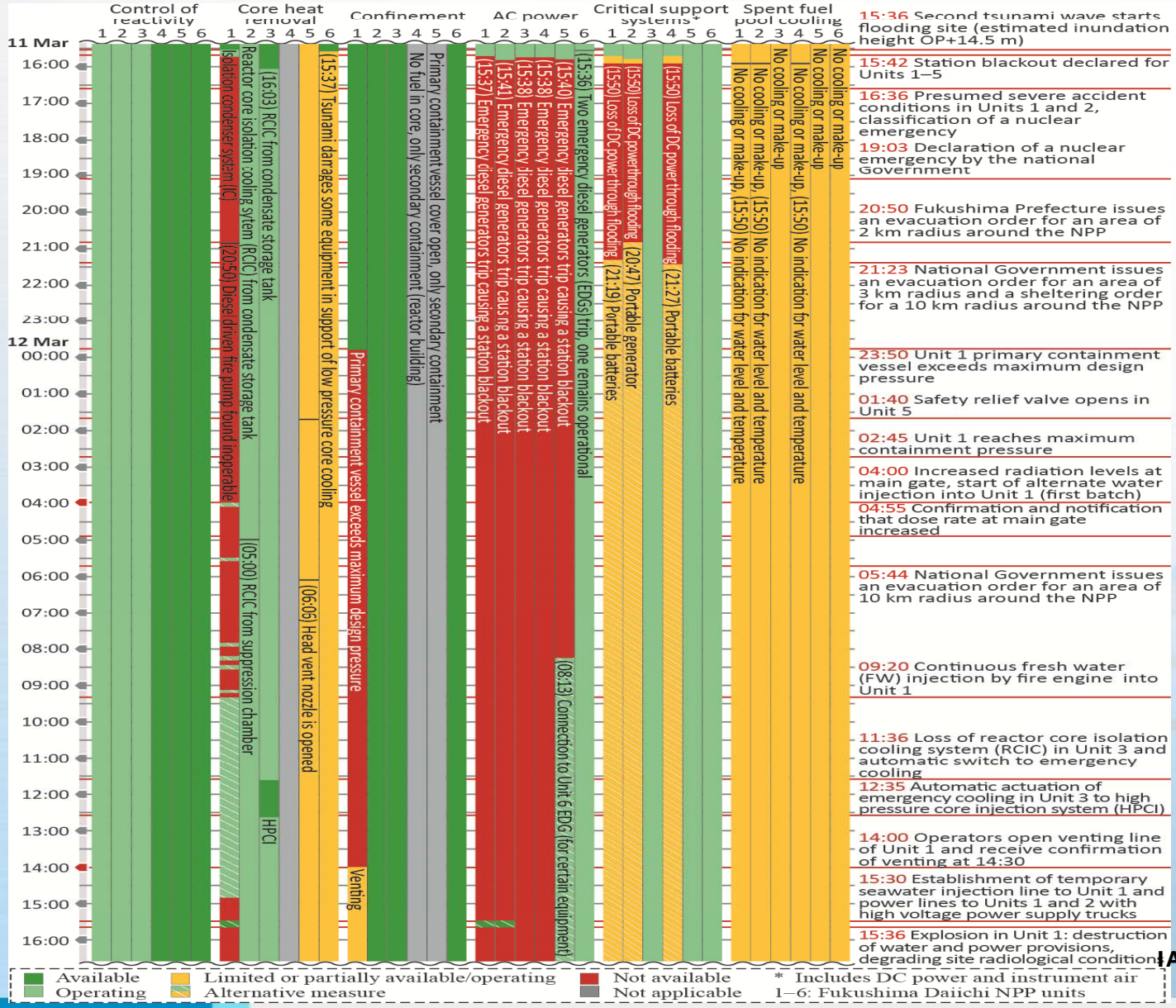
Fukushima unit 5 and 6





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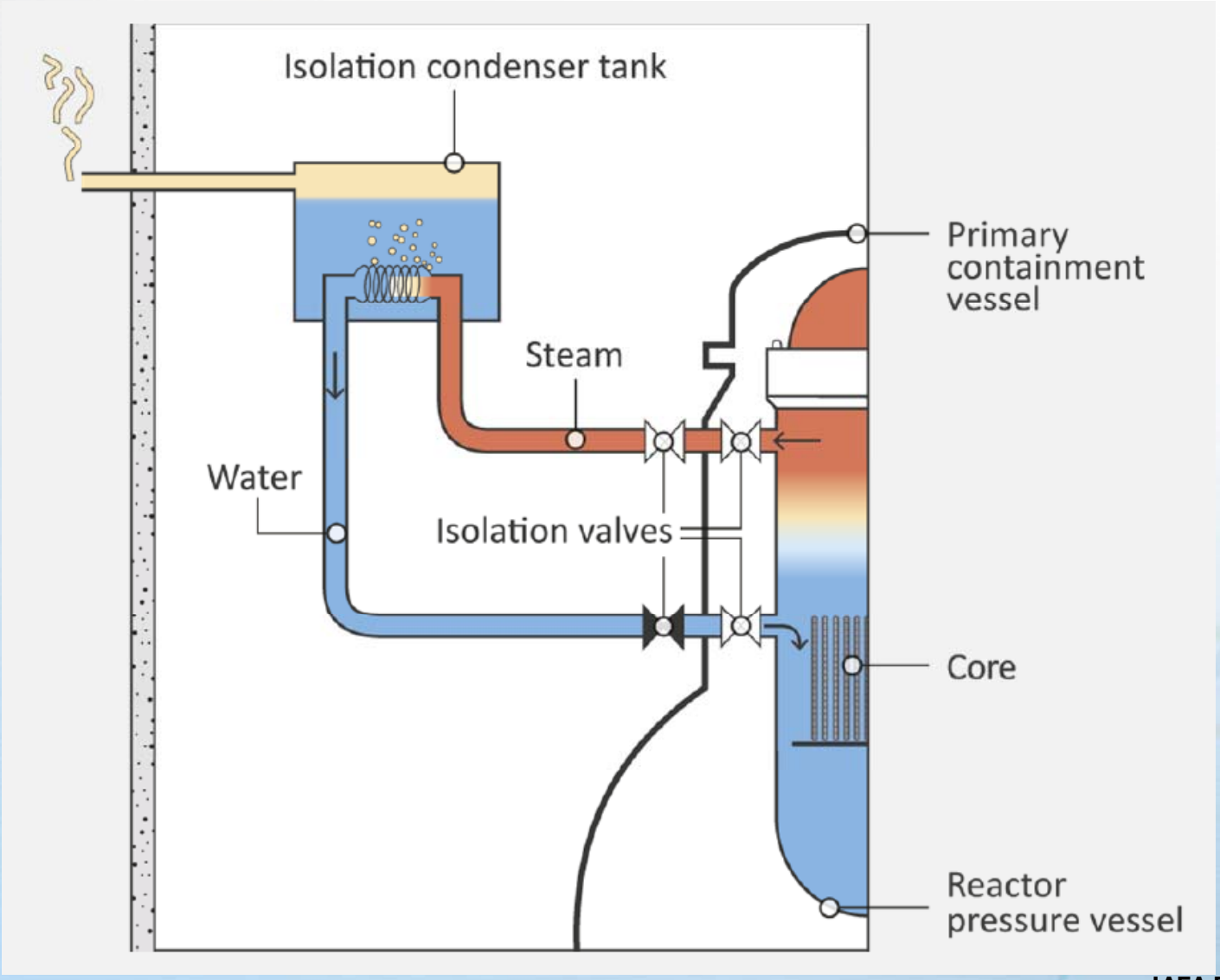
Fukushima Unit 1 Isolation Condenser



The IC was out of function at the time of SBO but the operators believed it operational.

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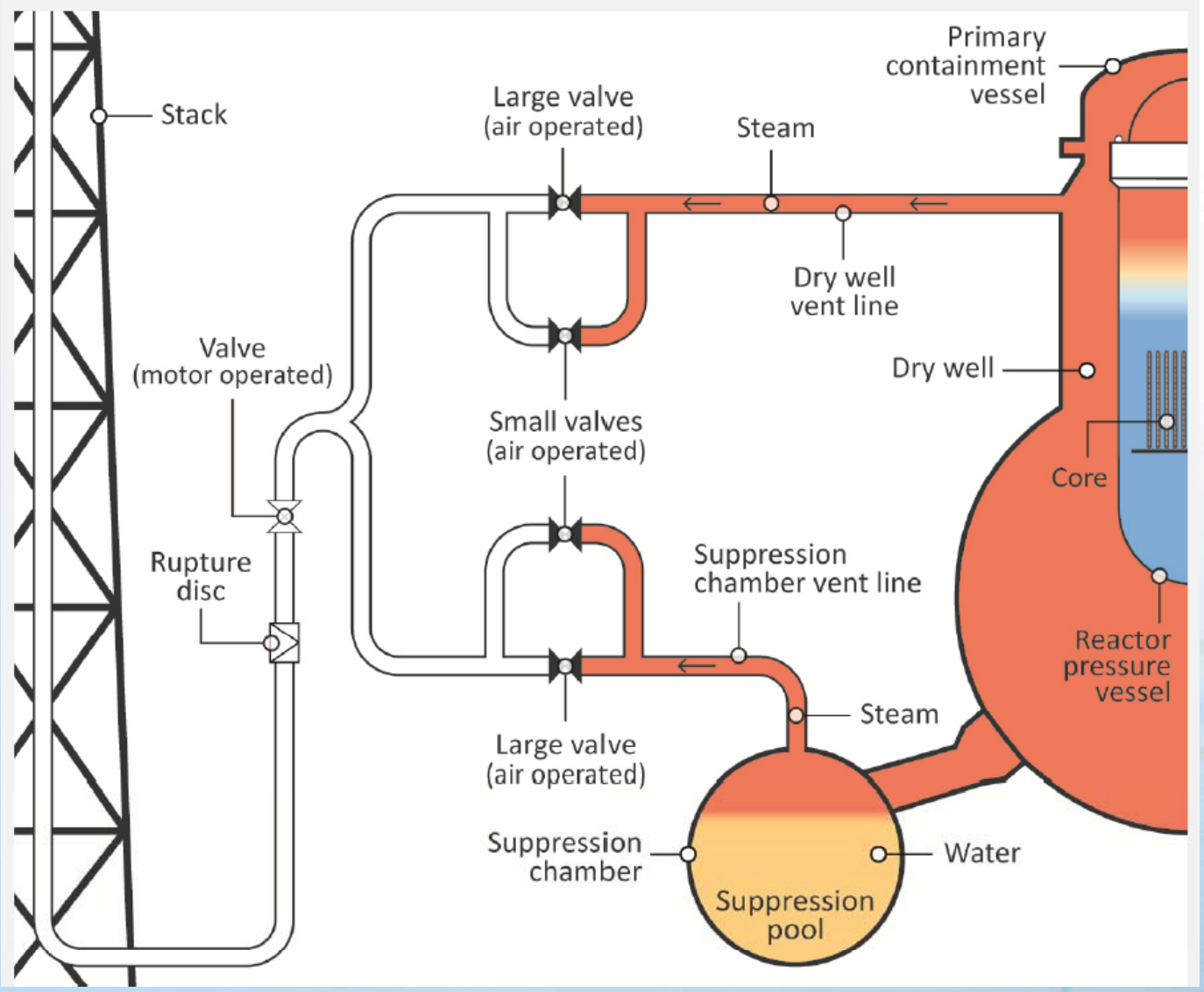
Vent system to protect reactor building integrity



Vent was installed in 1990 and shared between two units

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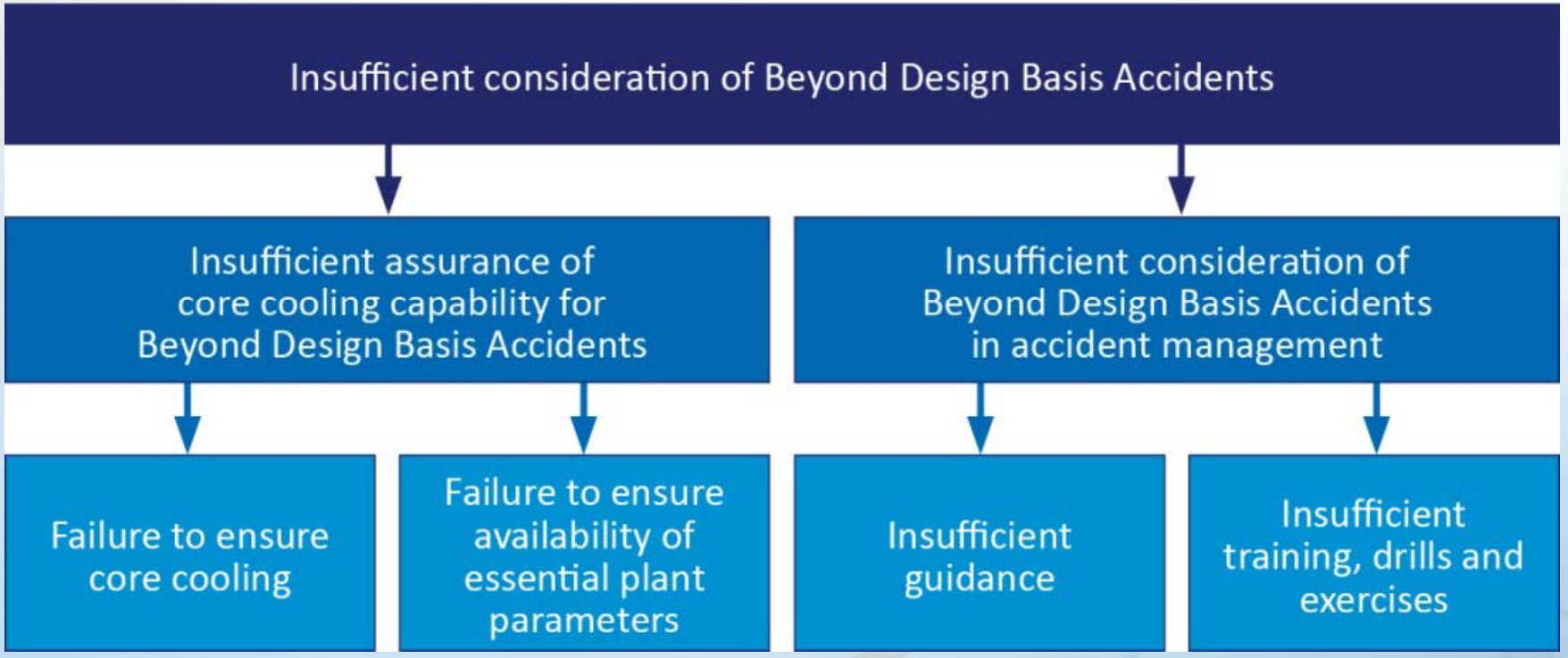
Typical BWR Design



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IAEA Recommendations for Fukushima Accident

1. Large uncertainties remain in the prediction of natural hazards and their assessment needs to be sufficiently conservative and consider:
   - prehistoric data;
   - hazards in combination, either simultaneously or sequentially, and their combined effects on an NPP; and
   - their effects on multiple NPP units.

2. NPP safety needs to be periodically re-evaluated, operating experience programmes need to include both national and international sources and necessary actions or compensatory measures need to be implemented promptly.

IAEA Recommendations for Fukushima Accident

3. The defence in depth concept remains valid, but implementation needs to be strengthened

4. For BDBAs robust and reliable I&C systems, cooling systems and a confinement function are necessary.

5. Comprehensive PSA/DSA are needed to confirm the capability to withstand applicable BDBAs and provide confidence in the robustness of the design.

IAEA Recommendations for Fukushima Accident

6. Accident management provisions need to be comprehensive, well designed and take account of accidents a multiple units.

7. Training, exercises and drills need to include postulated severe accident conditions to ensure that operators are well prepared.

8. A systemic approach to safety needs to consider the interactions between human, organizational and technical factors.

9. Individuals and organizations need to continuously challenge the prevailing assumptions to strengthen safety culture

IAEA Recommendations for Fukushima Accident

10. The emergency management system needs clearly defined roles and responsibilities and interactions between operators and regulators needs to be regularly tested in exercises.

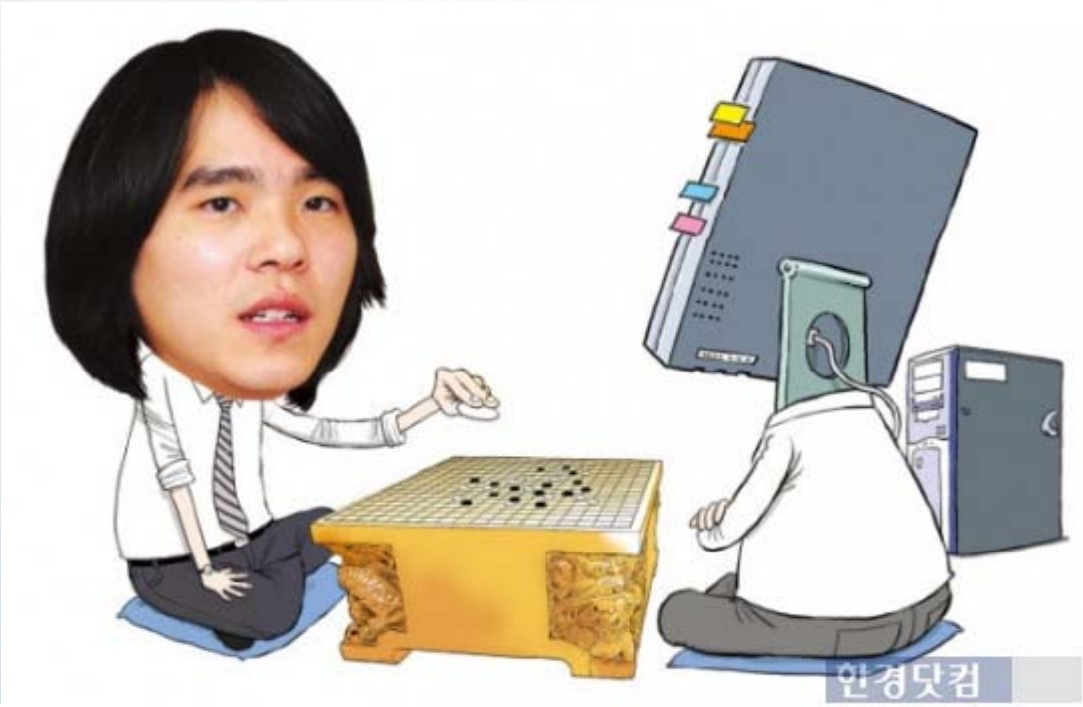
11. Need to consider emergencies involving multiple units also occurring at the same time as a natural disaster.

12. Emergency workers need to be designated, assigned clearly specified duties, adequately trained and properly protected.

13. Need to integrate into the response, workers not designated before the emergency and 'helpers' who may also assist.

14. Arrangements need to be in place to enable urgent protective actions to be extended or modified in response to developing plant conditions or monitoring results.

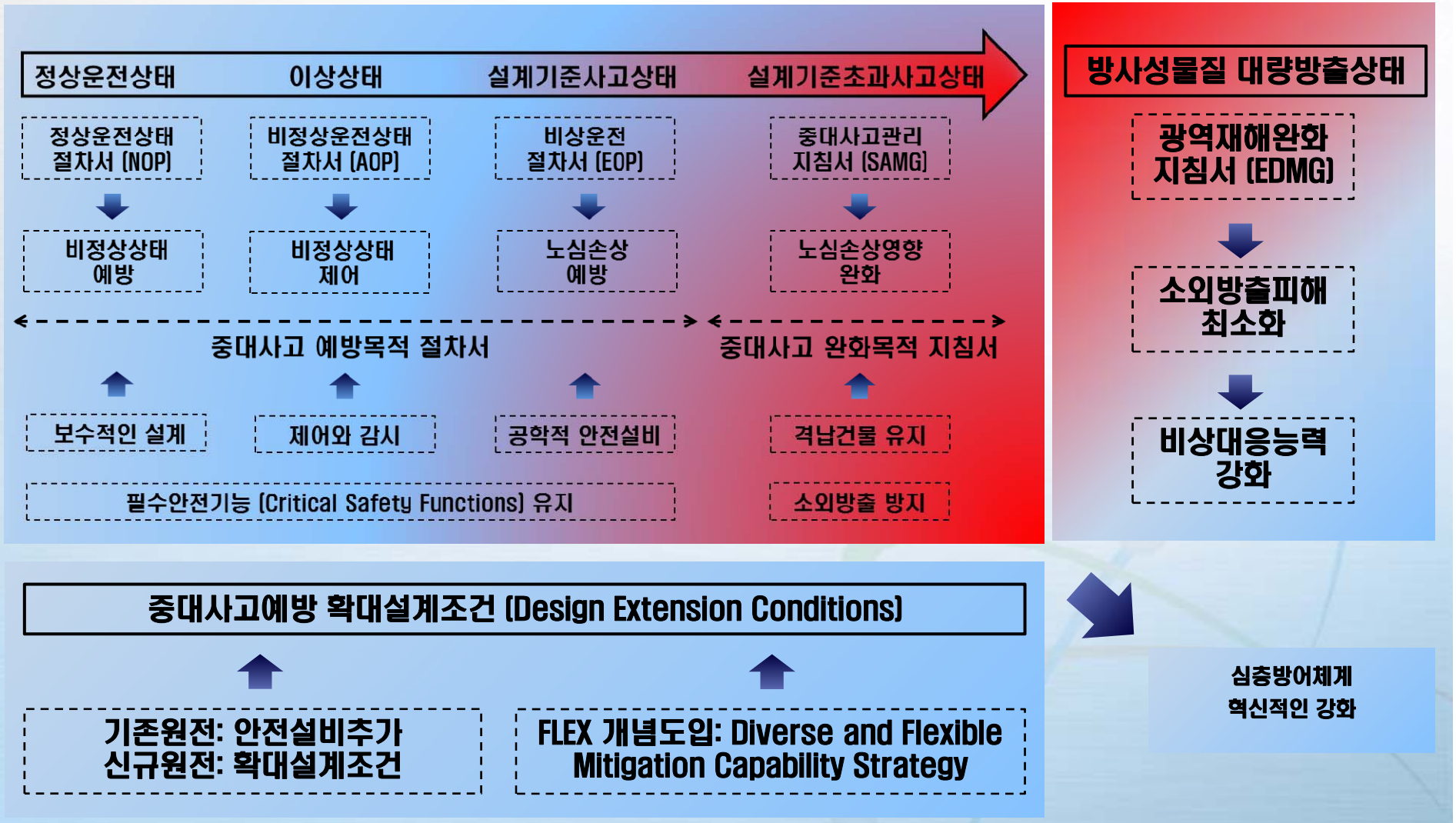
안전-사람의 문제



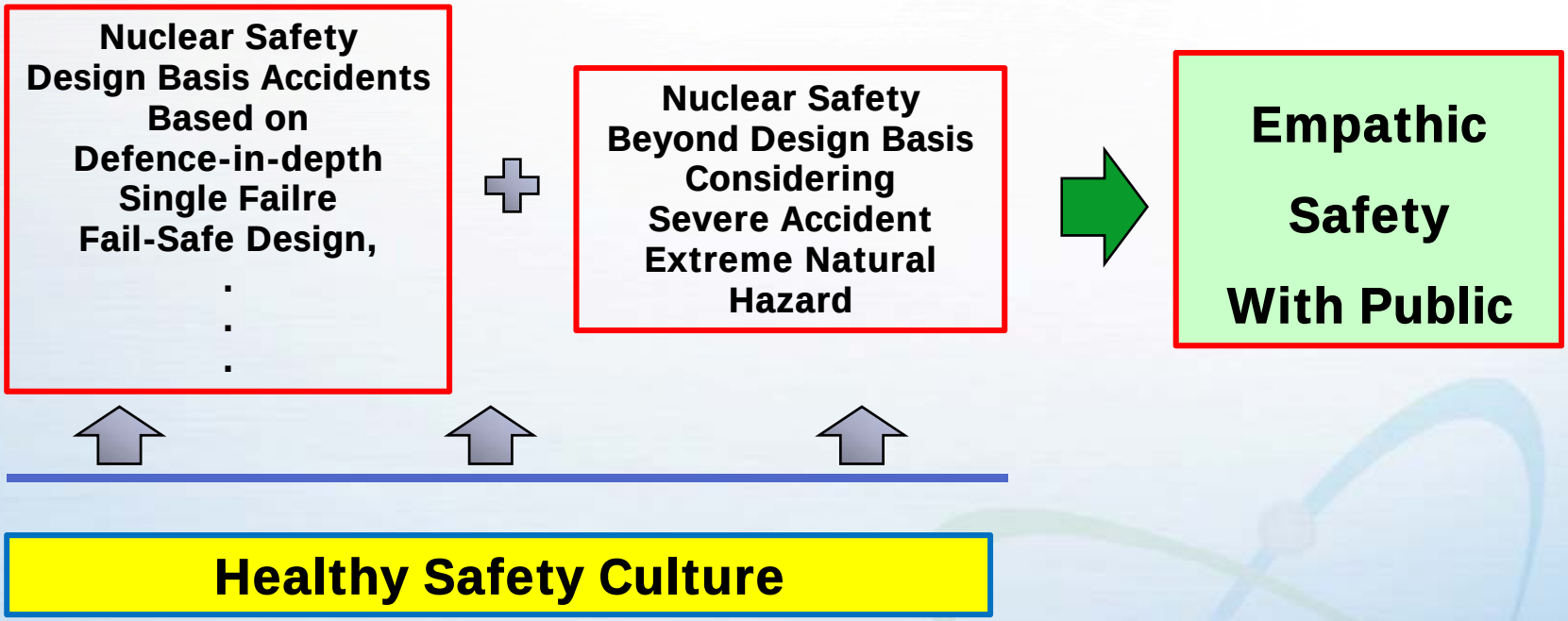
pattern-recognising abilities of deep-learning algorithms are impressive, but computers still lack many of the mental tools that humans take for granted. A big one is "transfer learning", which is what AI researchers call reasoning by analogy. This is the ability to take lessons learned in one domain and apply them to another. And machines like AlphaGo have no goals, and no more awareness of their own existence than does a word processor or a piece of accounting software.

From the Economist, 2016.3.11, " Artificial intelligence and Go, Showdown"

후쿠시마 사고이후 사고관리체계



The Way to go


Nuclear Safety
Design Basis Accidents
Based on
Defence-in-depth
Single Failre
Fail-Safe Design,
.
.
.
Nuclear Safety
Beyond Design Basis
Considering
Severe Accident
Extreme Natural
Hazard
Empathic
Safety
With Public
Healthy Safety Culture

Thank you

for your attention !!!

It’s not what you don’t know that get you into trouble
It’s what you know for sure that isn’t so.
-Mark Twain-