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Japanese Implementation of Seismic Probabilistic Risk Assessment

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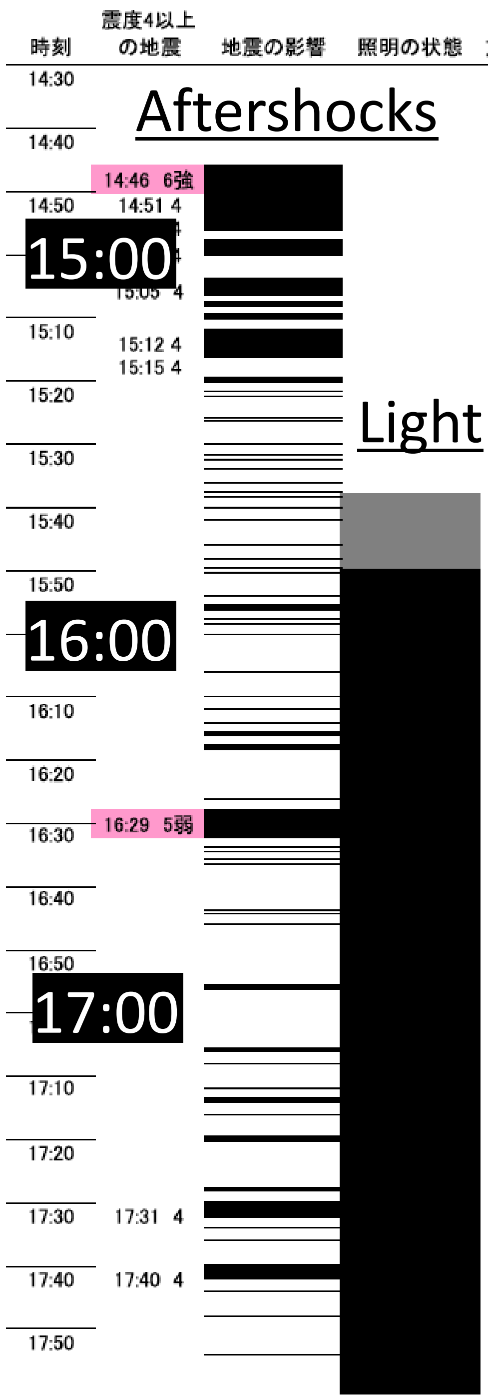
- **Lessons-Leaned from Fukushima Daiichi Accident**



14:46 Earthquake

Loss of offsite power

Many aftershocks

15:27 Tsunami

Station blackout
Loss of ultimate heat sink

Frequent tsunami alarms

Darkness in buildings
No communication tool

Complete darkness

Difficulty in habitability/accessibility

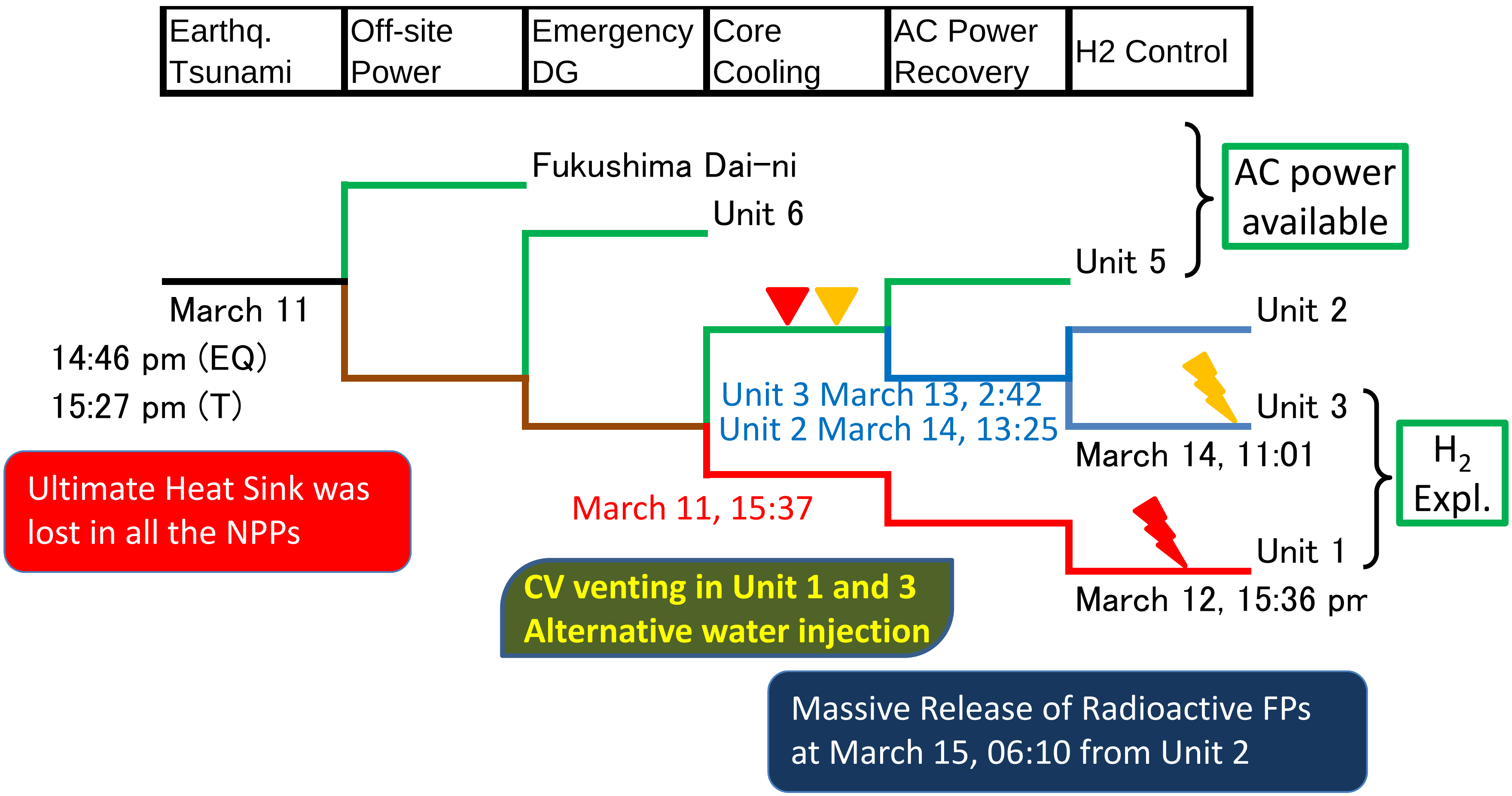
17:41 Sunset

High radioactivity level

17：50 Increased in RB
21：51 High in RB

22:00 Power Vehicle

Accident Progression at Fukushima Dai-ichi NPS



Major Events

- March 11, 14:46pm Earthquake, LOSP
- March 11, 15:27pm~ Tsunami, SBO
- Unit 1
  - March 11, 15:37pm IC stopped operation
  - March 12, 15:36pm H_2 explosion
- Unit 2
  - March 14, 13:25pm RCIC stopped operation
  - March 15, 6:10am FP large release
- Unit 3
  - March 13, 2:42am HPCI intentionally stopped
  - March 14, 11:01am H_2 explosion

- **Looking Back: Since 1995 to Present**
  - **NRA Regulatory Requirement**
  - **AESJ Standards for Seismic PRA**

Recent Earthquake Occurrence in Japan No Loss of Safety Function

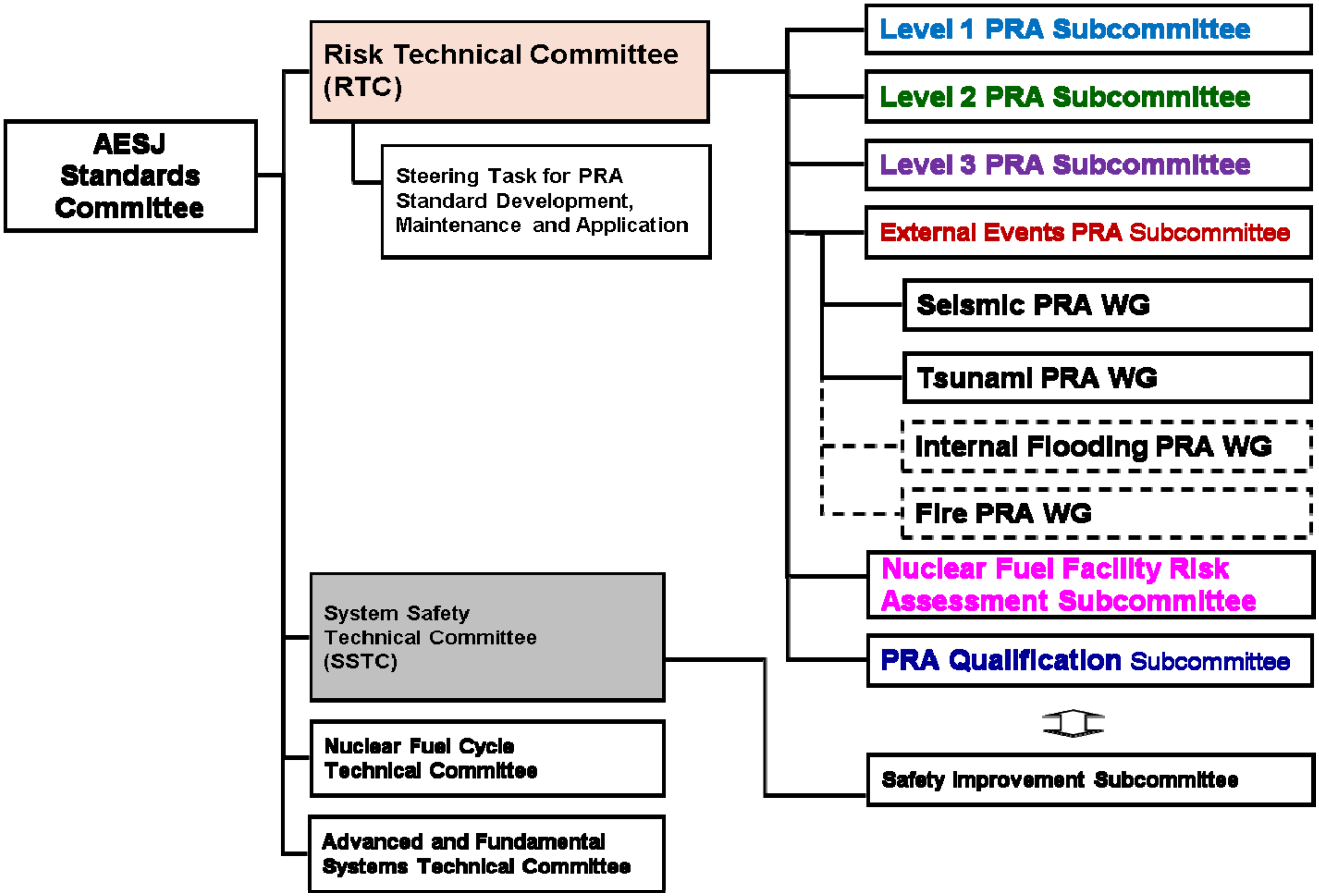
- Hyogo-Ken Nammbu Earthquake
  - (January 17, 1995, Magnitude 7.3)
- Miyagi-Oki Earthquake Onagawa NPP
  - (August 16, 2005, Magnitude 7.2)
- Noto Peninsula Earthquake Shika NPP
  - (March 25, 2007, Magnitude 6.9)
- Niigata-Ken Tyuetsu-Oki Earthquake K-K NPP
  - (July 16, 2007, Magnitude 6.8)
- Suruga-Bay Oki Earthquake Hamaoka NPP
  - (August 11, 2009, Magnitude 6.5)
- The Great East Japan Earthquake Fukushima NPP
  - (March 11, 2011, Magnitude 9.0)

Regulatory Requirement

- Level 1 and level 2 PRAs for internal and external events (seismic and tsunami)
- State-of practice methodology and data
- Step-by-step extension of the PRA scope
  - Internal flooding and fire
  - Couples seismic and tsunami event
  - Other external events
  - Spent fuel pool
  - Multi-unit events

Nuclear Regulatory Agency, Guideline for Safety Evaluation Report (in Japanese), https://www.nsr.go.jp/data/000085457.pdf

Organization of AESJ/Risk Technology Committee

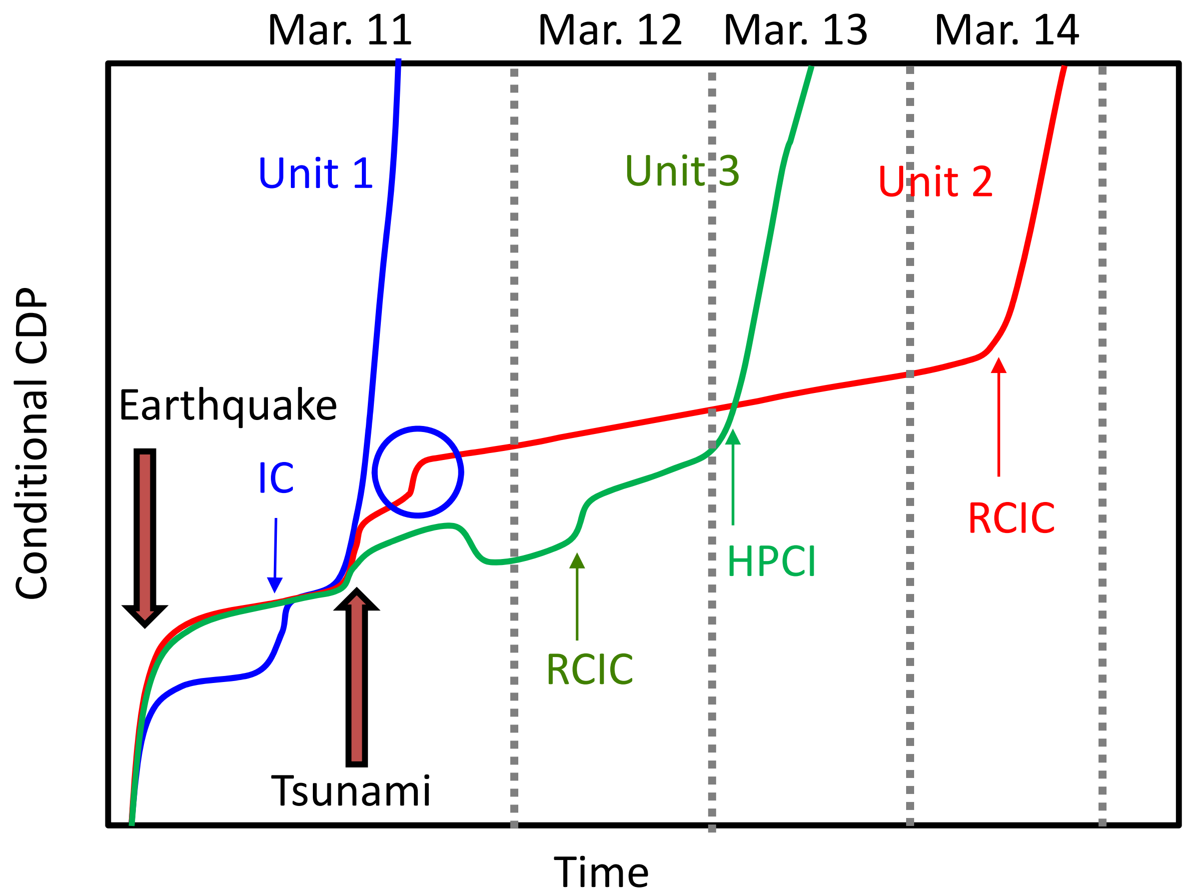


Current status of AESJ PRA Standards

Subcommittee	Standard (Current Edit.)	Scope
External Events PRA Subcommittee	Seismic PRA Standard:2015	at-power, Level 1 (including CV failure analysis)
	Tsunami PRA Standard: 2011 (Under revision)	at-power, Level 1, focused on tsunami effects only
	Case Studies for Tsunami PRA Standard: 2012	-
	Internal Flooding PRA Standard: 2012	at-power, Level 1
	Internal Fire PRA Standard: 2014	at-power, Level 1
	Standard for Risk Analysis Methodology Selection of External Hazards: 2014	Selection of an appropriate risk analysis methodology in terms of a character of individual external hazard

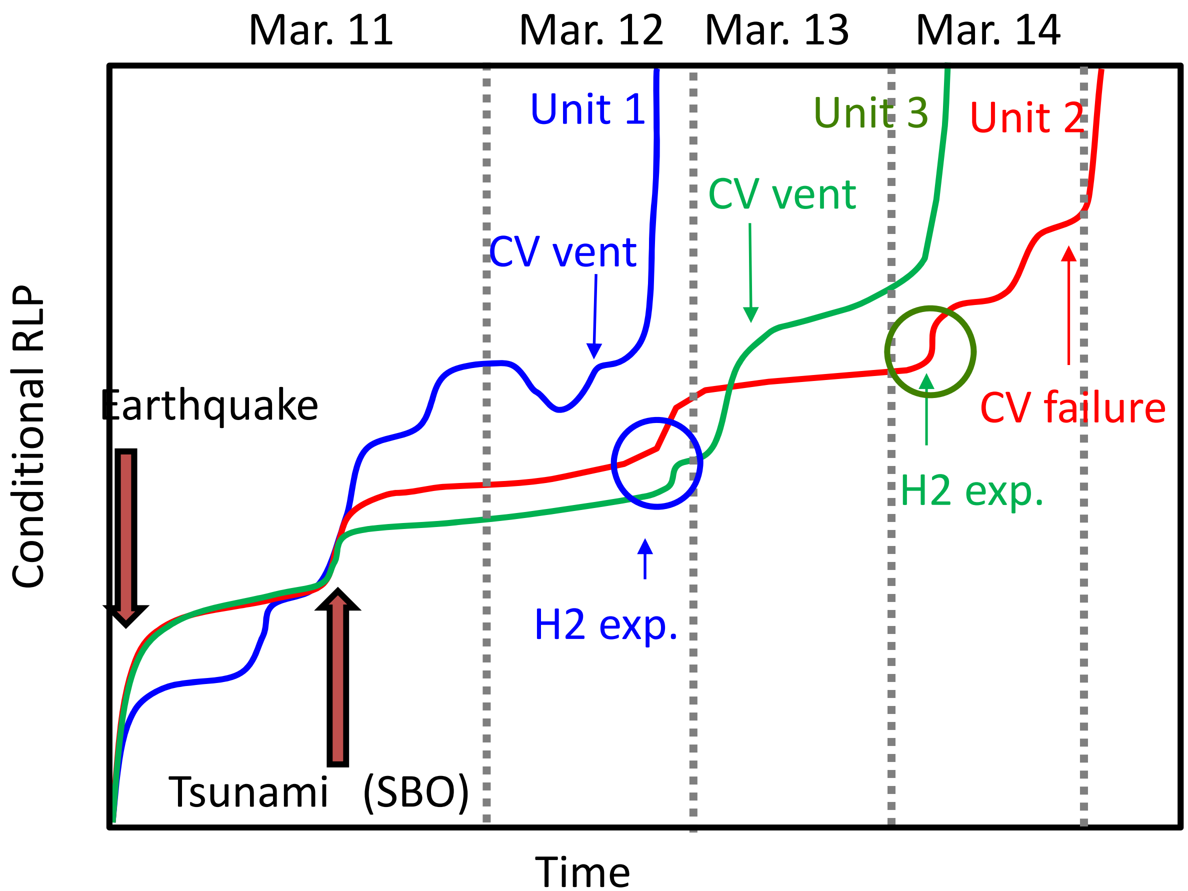
- **Integrated Quantitative Seismic Risk Assessment and AESJ PRA Standards Development**

Dynamic and Multi-Unit Risk Profile
Core Damage Probability



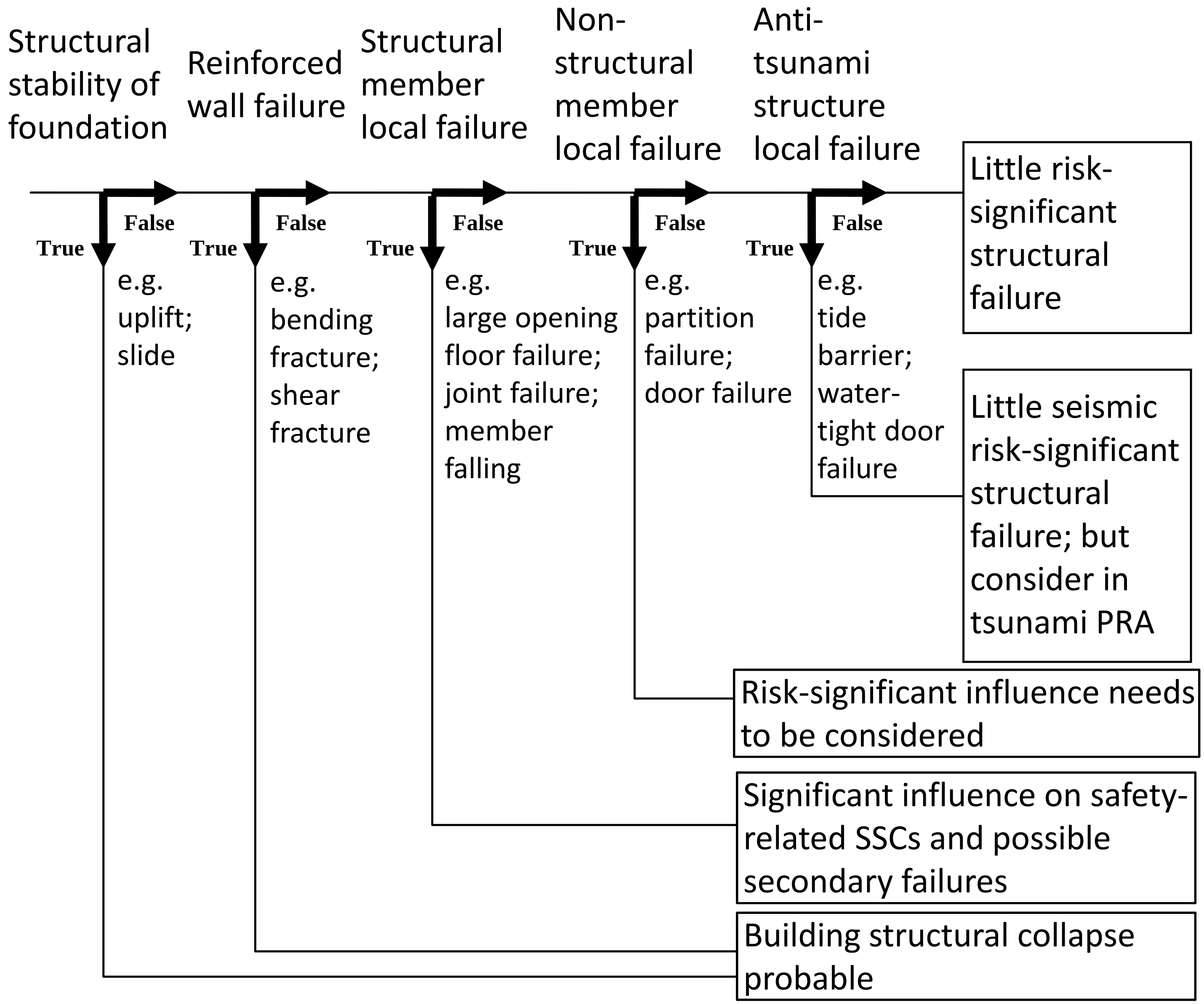
SBO: Station Blackout,   PCV: Primary Containment Vessel

Dynamic and Multi-Unit Risk Profile Large Release Probability

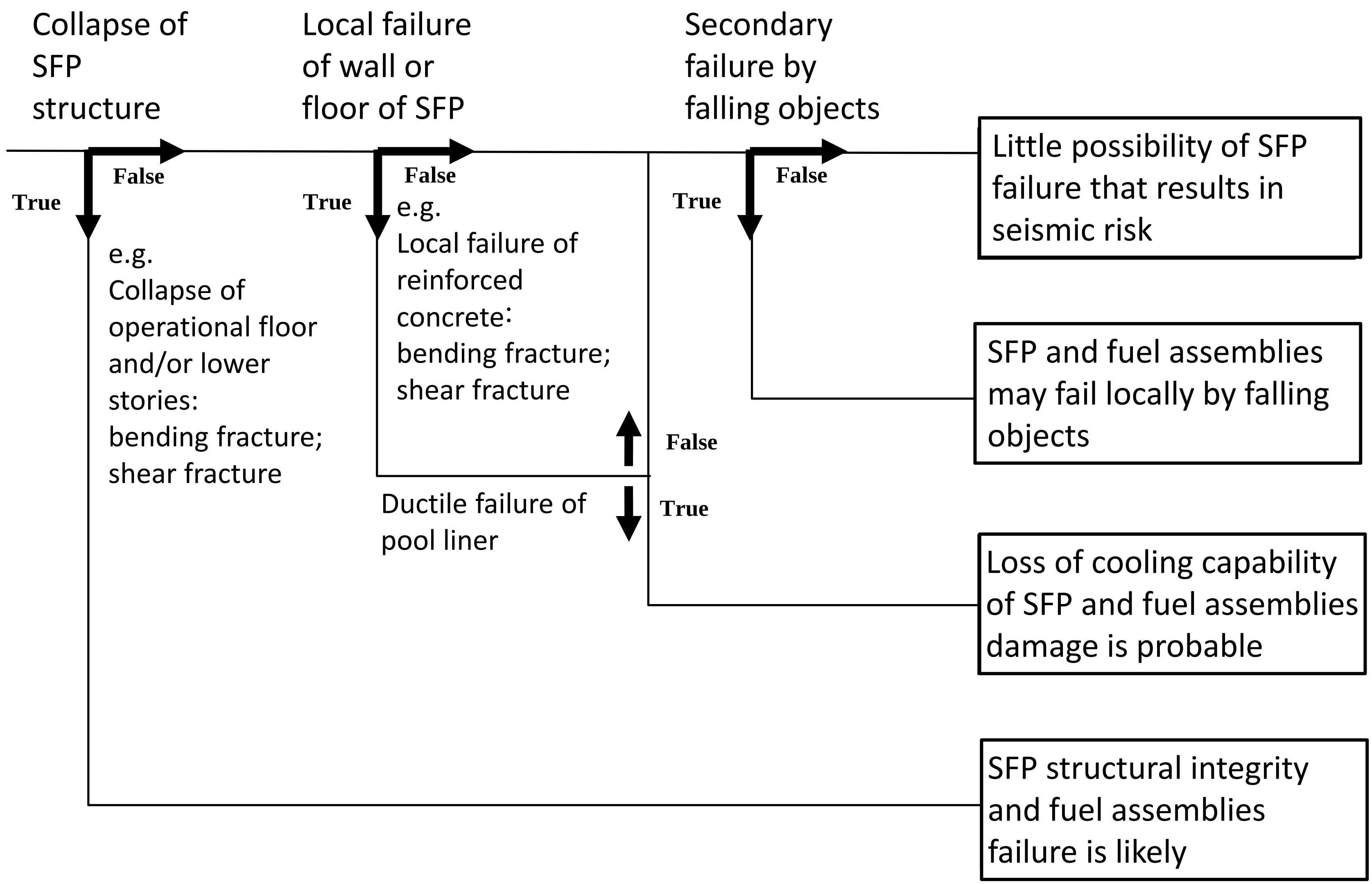


SBO: Station Blackout, PCV: Primary Containment Vessel

Reactor Building Failure Mode



Spent Fuel Pool



Prioritization of PRA Standard Development

- High necessity A+ A B(A) B C Low
- Large workload a b c(b) c d Small
- High priority standards
  - Priority 1, Priority 2

		Internal event	External event						
			Internal flooding	Internal fire	Tsunami	Seismic	Seismic-induced/caused		
							Internal flooding	Internal fire	Tsunami
At Power	L1	*	*	*	*	*	A^+b	A^+b	A^+b
	L2	*	Ac	Ac	A^+c	A^+c	B(A) c	B(A) c	B(A) c
	L3	*	Ad	Ad	A^+b	A^+b	B(A) d	B(A) d	B(A)d
LPSD	L1	*	Ab	Ab	A^+a	A^+a	Ac(b)	Ac(b)	Ac(b)
	L2	Bc	Bc	Bc	Bc	Bc	Bc	Bc	Bc
	L3	*	Bd	Bd	Bd	Bd	Bd	Bd	Bd

Developed Priority 1 Priority 2

Quantitative Risk Assessment Approach

QRA Approach	Note	Hazard Analysis	Sequence Analysis	
			Load (Capacity)	Response
Hazard frequency Analysis	Quantify based on hazard frequency	Conservative Simplified	None	None
Consequence Analysis	Quantify risk based on plant level capacity	None	Plant level capacity (conservative)	None
Safety margin Analysis	Quantify risk based on accident scenario analysis and safety margin analysis	None	Deterministic	Deterministic
Deterministic CDF Analysis	Quantify risk based on hazard frequency and accident scenario analysis	Conservative	Deterministic	Deterministic
Probabilistic Risk Assessment	Investigate Risk Triplet: Scenario; Frequency; Consequence	Realistic hazard curve + uncertainties	Realistic load + Uncertainties	Realistic response + uncertainties

Conclusions - Future Perspectives

- Seismic-induced combined hazard
- Multi-unit and dynamic seismic risk
  - LPSD seismic risk (e.g. Unit 3 and Unit 4)
- Seismic level 2 and level 3 PRAs
- Flexible and various quantification approaches
- Plant risk, site risk and regional risk