NA251

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Why Are Japanese Nuclear Power Plants "So Safe"?
— Insights from Safety Improvement Assessments

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Background and Motivation

- Since 2013, periodic PRA* required for Japanese utilities under the Periodic Safety Assessment of Continuous Improvement System.
- Reported internal-event CDFs** for Japanese Gen II PWRs: 10^{-6} to 10^{-5} /ry.

Why are Japanese CDF estimates so low?

*Probabilistic Risk Assessment
**Core Damage Frequency

This Study

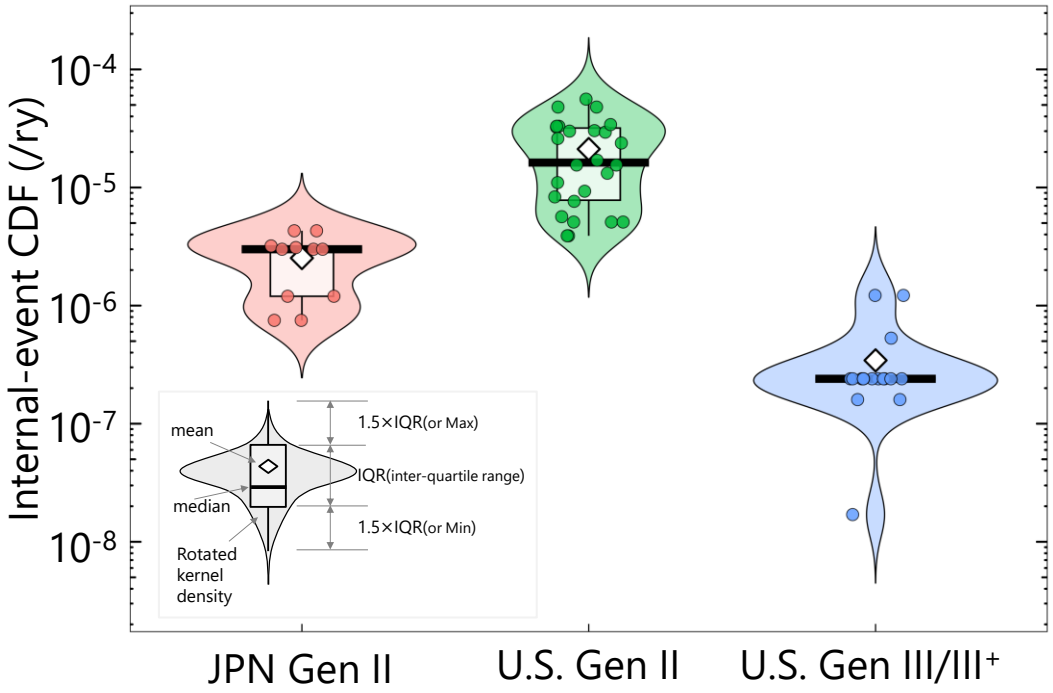
- Compare Japanese and U.S. reactor CDFs
- Examine: Reliability data; CDF profiles and accident sequences; Plant design and equipment credits
- Discuss implications for risk-informed applications in Japan

Data and Scope of Comparison

- **Metric**
  - At-power internal-event Level 1 CDF (Internal flooding excluded)
  - Point estimates from publicly available sources
- **Japan**
  - Gen II PWRs: Reported by 2025 in the Safety Improvement Assessment reports* *Taku Sato, The 8th Meeting of the Committee on Safety Goals, Material 1, Tokyo, Japan, July 24, 2025.
- **U.S.**
  - Gen II PWRs: SAMA** / license renewal documents***
  - Gen III/III+: design and licensing-stage PRAs****

**Severe Accident Mitigation Alternatives
***NUREG-1437, Vol. 3, Rev. 2 (2024).
****NUREG-2249 (2026).

Comparison Results



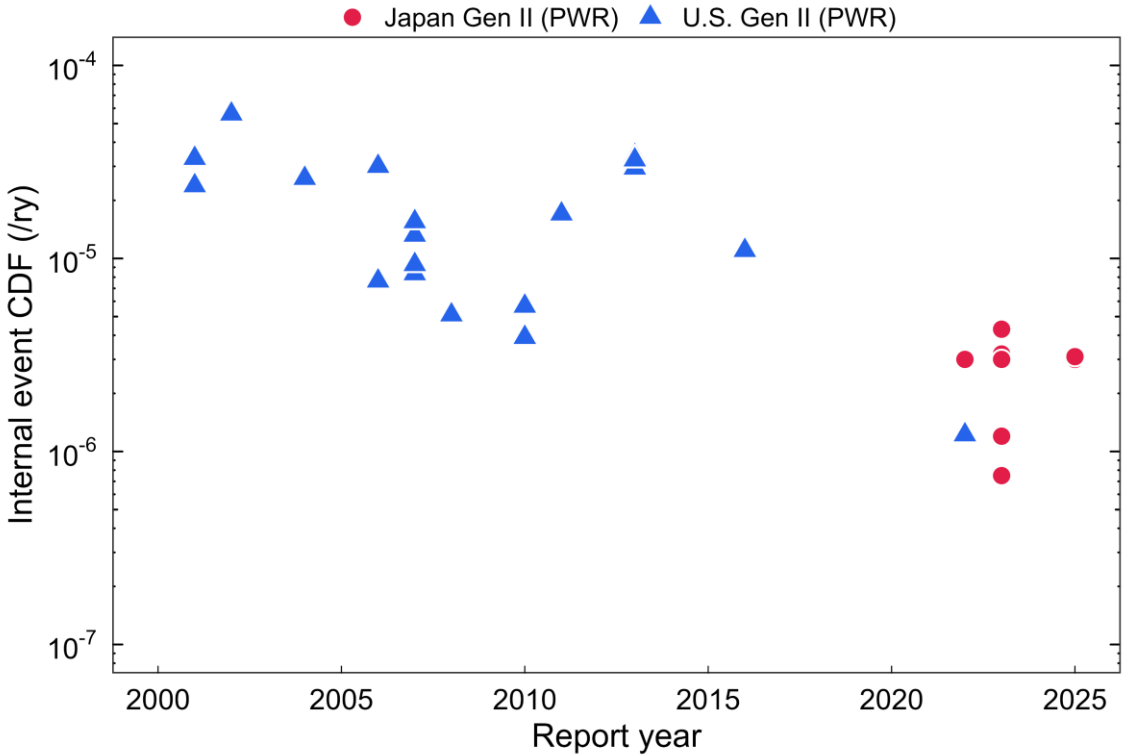
At-Power Internal-Event CDFs

Summary Stats

	n	Mean CDF (/ry)
JPN Gen II	11	2.5E-6
U.S. Gen II	26	3.8E-5
U.S. Gen III	18	2.4E-7

- ✓ **Japanese Gen II PWR CDFs** are approximately **one order of magnitude lower** than those of U.S. Gen II PWRs
- ✓ Some are comparable to U.S. Gen III/III+ reactors

Assessment Year



- No clear relationship between report year and CDF
- Assessment timing alone cannot explain the Japan–U.S. difference.

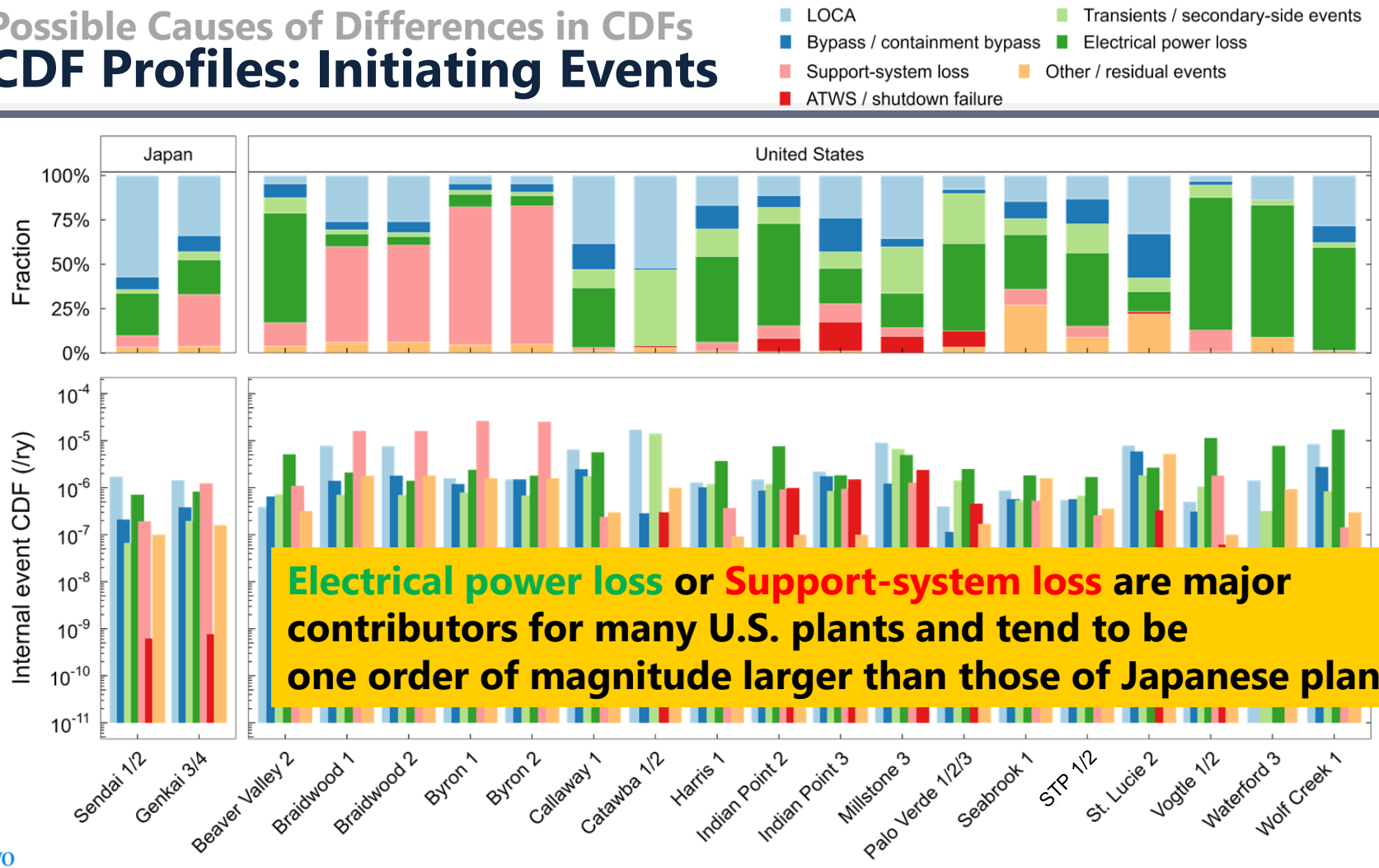
Reliability Data

- Previous study*
  - Japanese mean failure rates or failure probabilities tend to be lower than those of U.S.
    - Emergency diesel generators; Motor-driven Pumps: Turbine-driven pumps: Engine-driven pumps
  - Differences reach approximately one order of magnitude for some failure modes.

Plausible contributor, but not quantitatively evaluated its contribution in this study

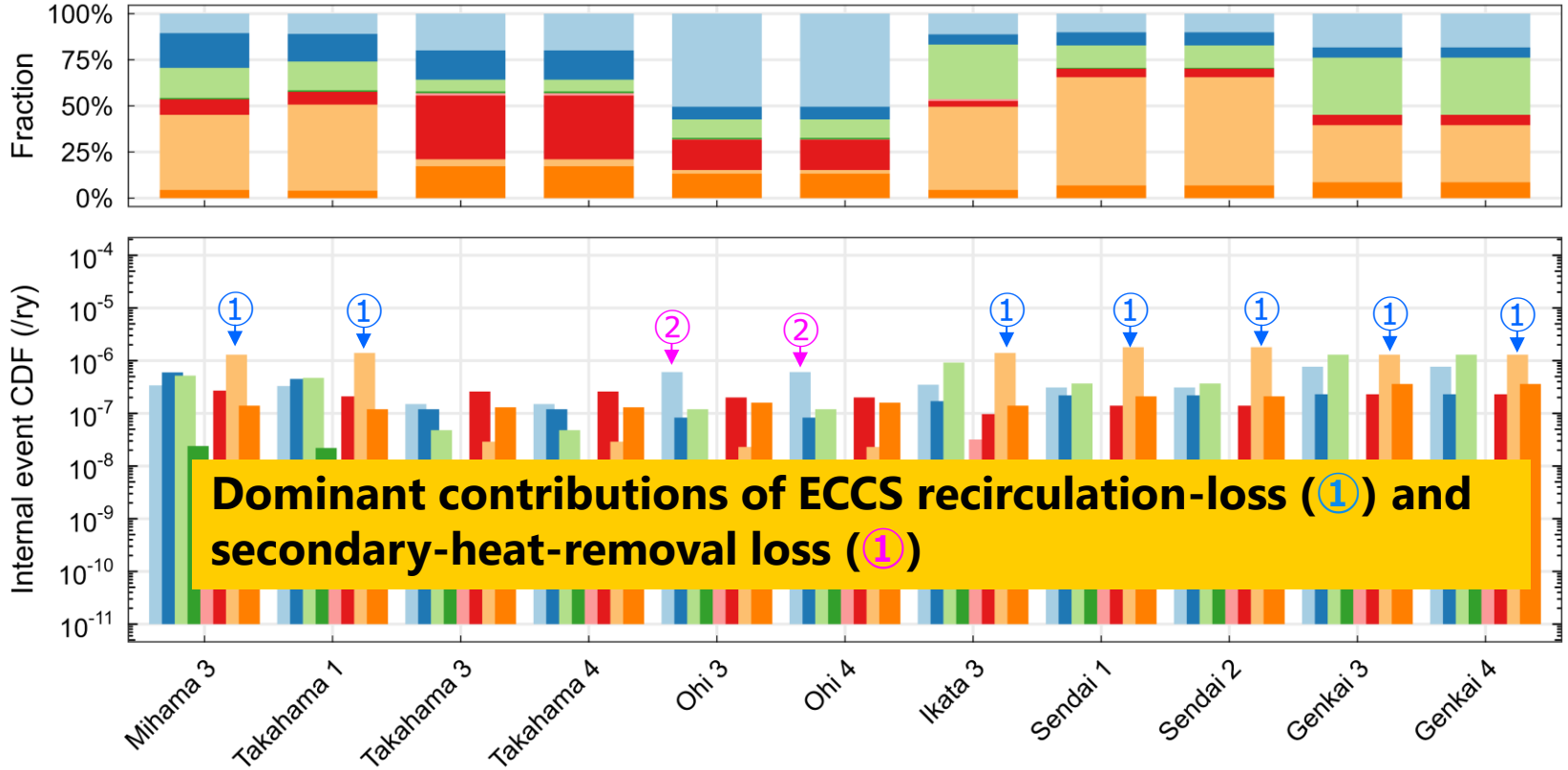
*Tomoaki Yoshida, "PRA Reliability Data in Japan," NRRC Workshop 2024, Abiko, Japan, November 12, 2024.

CDF Profiles: Initiating Events

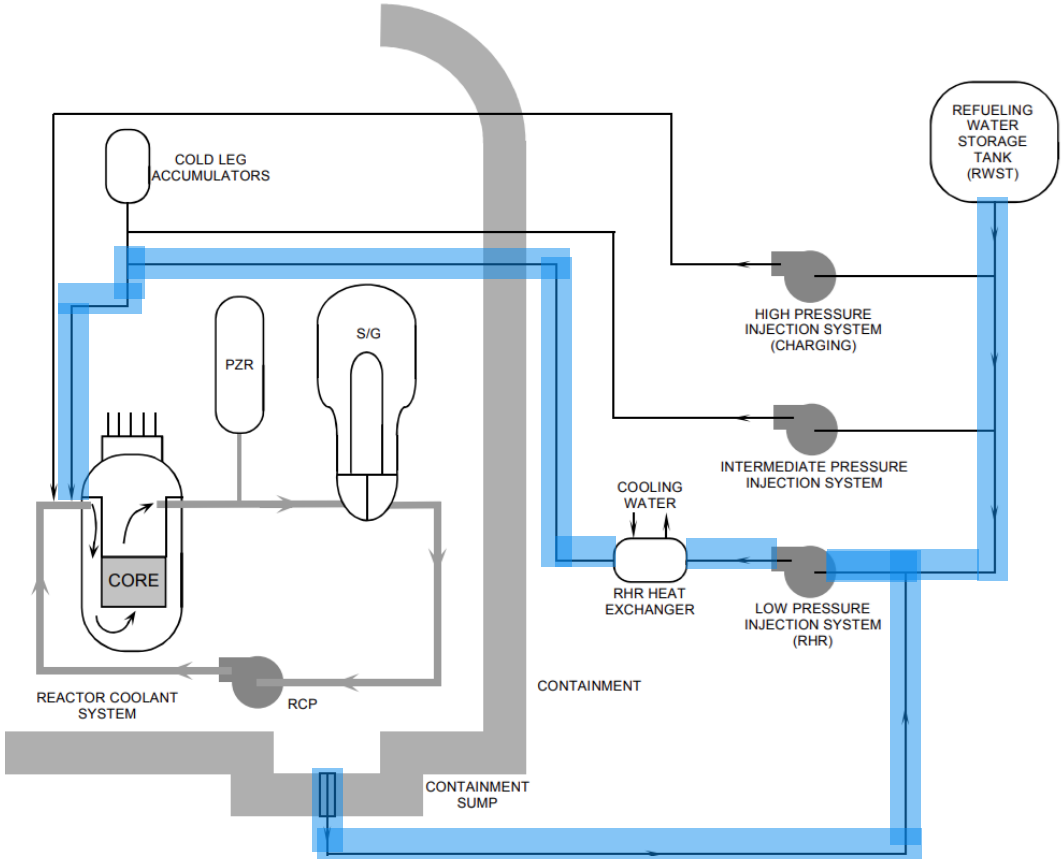


Electrical power loss or Support-system loss are major contributors for many U.S. plants and tend to be one order of magnitude larger than those of Japanese plants.

CDF Profiles: Accident Sequences (Japanese PWRs)



ECCS Recirculation-Loss Contribution (①)

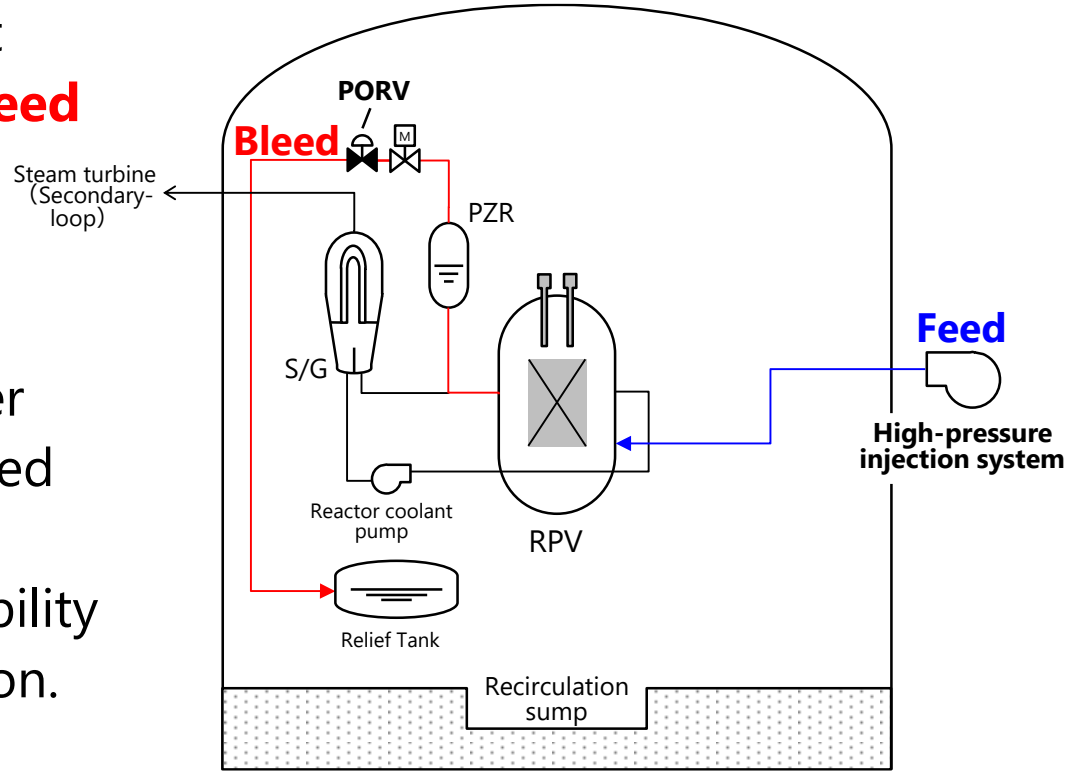


- Manual ECCS recirculation switchover introduces human error risk.
- Automation at Takahama 3/4 and Ohi 3/4 results in lower contributions.

UTokyo (adapted from U.S. NRC, Reactor Concepts Manual: Pressurized Water Reactor Systems)

Secondary-Heat-Removal loss Contribution (②)

- Loss of secondary-side heat removal requires **feed** & **bleed** cooling through depressurization and safety injection.
- Ohi 3/4 have two pressurizer (PZR) PORV* trains, compared with three at Takahama 3/4, resulting in lower F&B reliability and a larger CDF contribution.

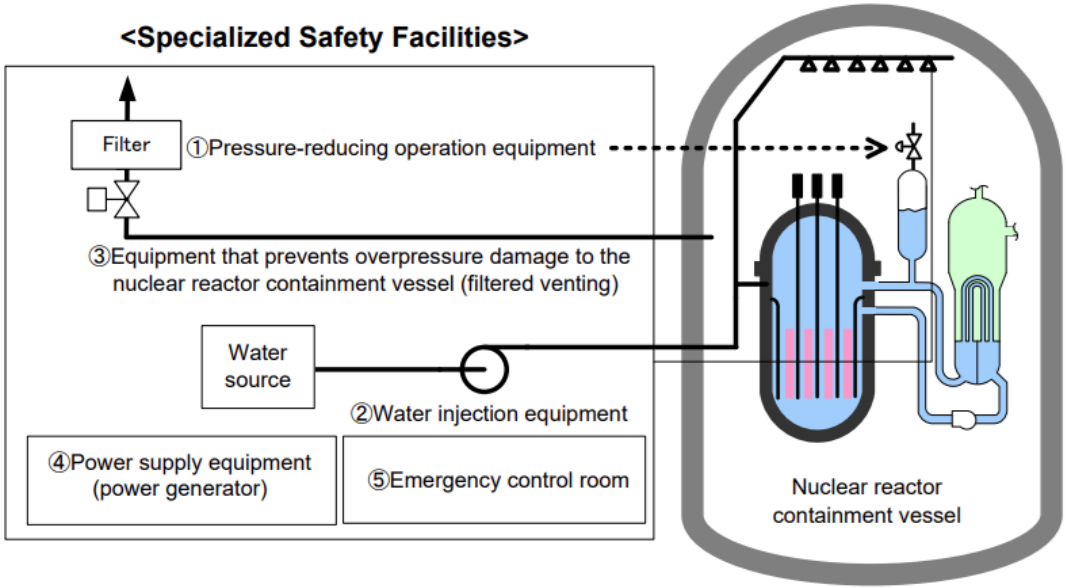


*Power-Operated Relief Valves

Plant Design and Equipment Differences

- **Automated ECCS recirculation switchover & more PORV trains**
  - Help explain differences of CDFs among Japanese PWRs, but not the overall Japan–U.S. CDF gap.

- **Specialized Safety Facility**
  - Reduces CDF by about a factor of two*, but cannot explain the overall Japan–U.S. CDF gap.



(Shikoku Electric Power Co., FY2015 Financial Results Outline, p. 36, "Outline of Specialized Safety Facilities at Ikata Unit No. 3" (2016).)

*Akihiko Kagawa, "Enhancement of PRA at Ikata Unit 3 –Enhancement of PRA and Transition of CDF–," NRRC Workshop 2024, Abiko, Japan, November 12, 2024.

Summary of Possible Causes

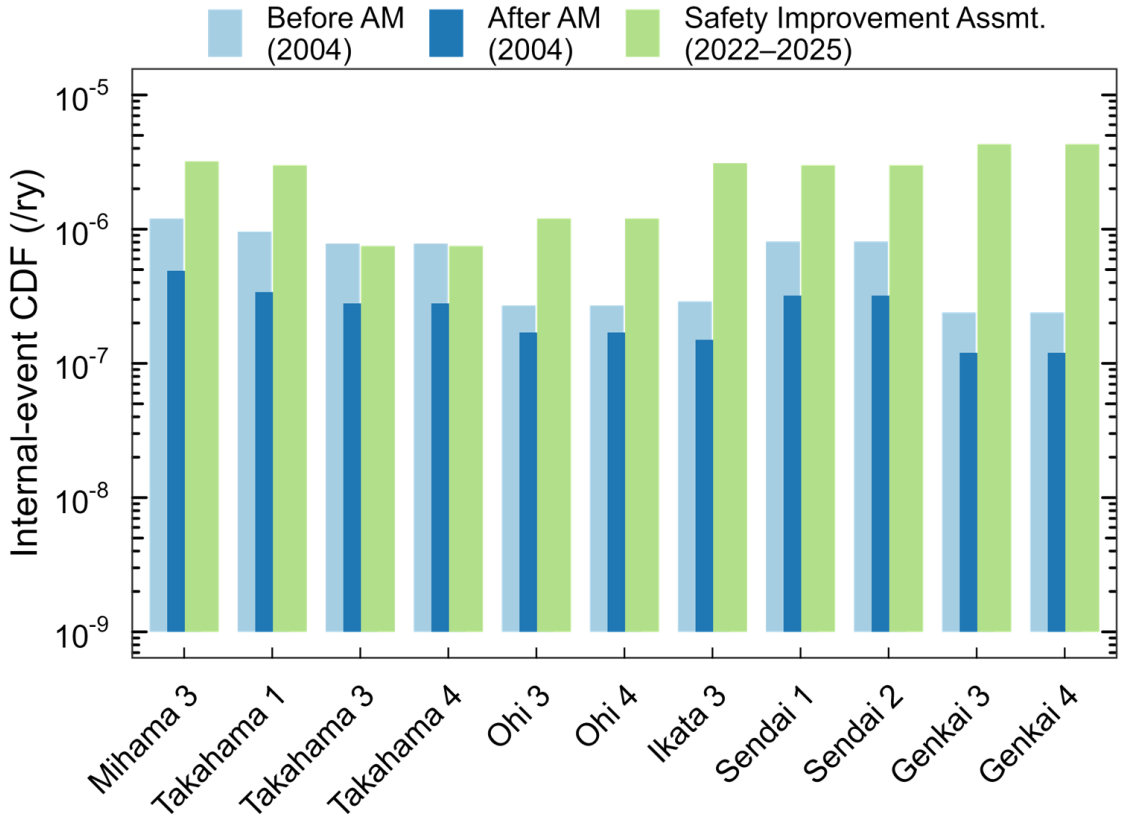
- **No single factor explains the one-order-of-magnitude CDF gap** btw Japanese and U.S. Gen II PWRs.
  - Lower reliability parameters in Japan
  - Different initiating-event profiles
  - Equipment features including the Specialized Safety Facility, automated ECCS recirculation switchover, and additional PORV trains
- The difference likely reflects **the combined effects** of data, accident-sequence structures, plant features, and modeling assumptions.
- Other influences may include **O&M practices, SAM equipment, procedures, and training, HRA*, and CCF** treatment**, which could not be fully assessed from public information.

*Human Reliability Analysis
**Common Cause Failure

Implications for Risk-Informed Applications in Japan

- Low CDFs are not direct evidence of high plant safety.
- They must be interpreted through the underlying:
  - Data and assumptions
  - Modeling choices
  - Equipment credits
  - Sensitivities and uncertainties
- The issue is not that Japanese CDFs are low, but **whether those low values are supported by transparent and defensible PRA** that is acceptable for use in risk-informed decision-making.
- If PRA underestimates risk, using it to demonstrate compliance with safety goals may **justify the status quo rather than drive continuous safety improvement**.

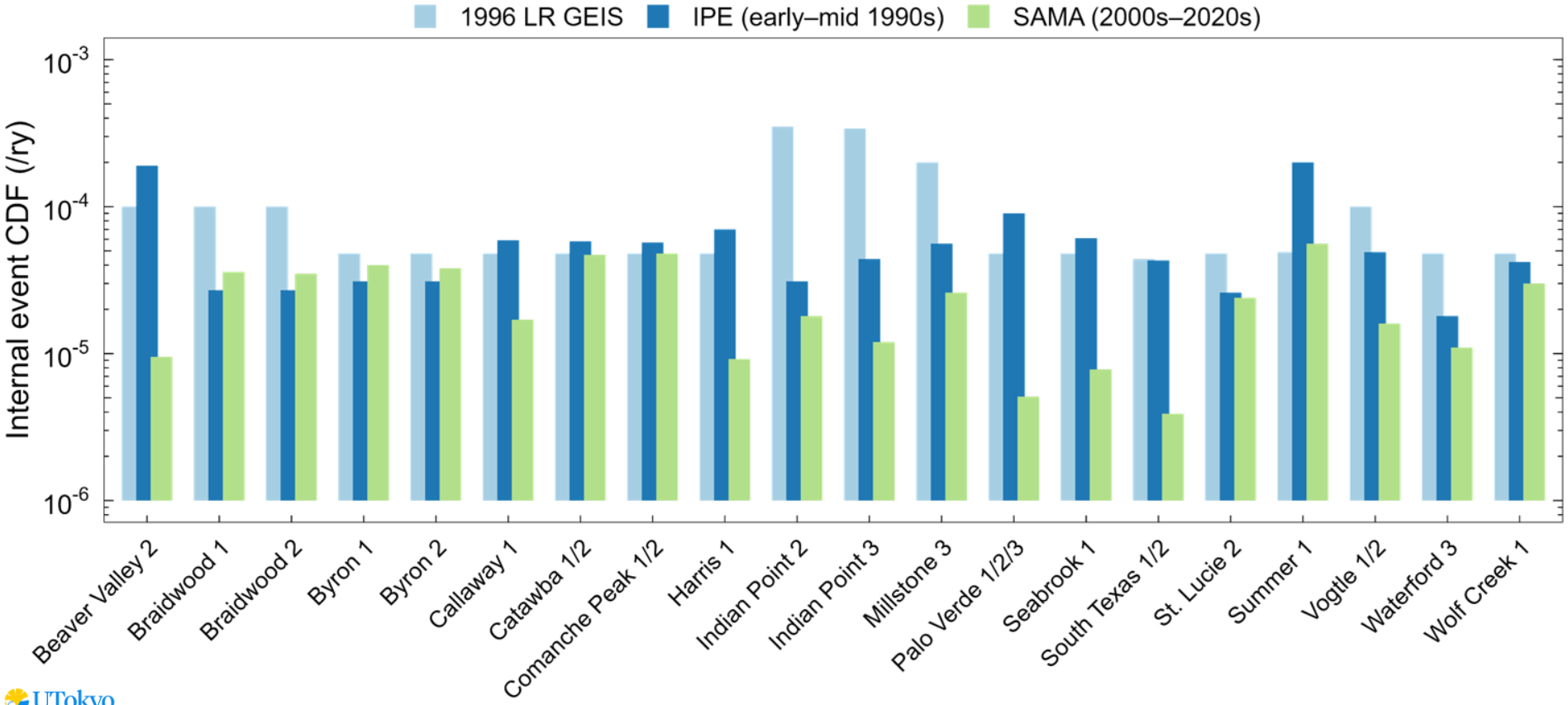
Evolution of Internal-Event CDF of Japanese Gen II PWRs



- In earlier Japanese PRAs, sufficiently defensible data, assumptions, and modeling choices may not have been adopted.
- This observation is consistent with **"10^{-6} culture"*** in Japan.

* George Apostolakis, Proc. PSAM17&ASRAM2024 (2024).

Evolution of Internal-Event CDF of U.S. Gen II PWRs



Toward Advancing Risk-Informed Applications in Japan

- Develop PRA using the **best available knowledge and technology**.
- Transparently document key risk contributors, data, assumptions, models, equipment credits, sensitivities, and uncertainties.
- Do not defer risk-informed applications until PRA is “complete”; use PRA that is fit for purpose.
- Continually **examine whether PRA is transparent and defensible** for decision-making, and improve it accordingly.

Conclusions

- Japanese Gen II PWR internal-event CDFs are, on average, about one order of magnitude lower than those of U.S. Gen II PWRs
- Low CDFs should not be interpreted as direct evidence of plant safety.
  - They strongly reflect the combination of underlying data, assumptions, models, and equipment credits.
  - Important factors including O&M practices, SAM, HRA, and CCF treatment remain insufficiently transparent in publicly available sources examined in this study.
- To advance risk-informed applications in Japan, **PRA must be transparent and defensible** and be continually improved using the best available knowledge and technology.