PRA Reliability Data in Japan

Nuclear Risk Research Center Workshop 2024

Risk-Informed Decision-Making Benefits & Obstacles

3. Sessions for Obstacles

(1) Ensuring Good PRA

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Introduction

- Regarding introducing risk-informed regulation in the Japanese nuclear power industry, the reliability of Japanese PRA models and reliability data has been questioned.

  “The Japanese equipment failure rates and CDF values are too much lower than those overseas.”

- This presentation shows a brief history and improvements in the development of domestic PRA equipment failure rate data.

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A Brief History of the Development of Japanese PRA Equipment Reliability Data

Fiscal Year	1996-2001	2009-2016	2020-Present
Organization	Former Nuclear Information Center (**NIC**), **CRIEPI**	・2009-2011 The Japan Nuclear Technology Institute (**JANTI**) ・2012-2016 The Japan Nuclear Safety Institute (**JANSI**) *Technically supported by **CRIEPI***	**NRRC, CRIEPI**
Information Source	・Failure data: **NICS**[*1] ・Population: NICS has no data. **Set irrelevant to PRA model**	・Failure data: **NUCIA**[*2] ・Population: NUCIA has no data. **Set irrelevant to PRA model**	・Failure data: **Plant-specific maintenance records** ・Population: **Defined based on the basic events of plant PRA models**
Publication Year [Data Window]	1996: 10 yrs[1982-1991] 34 units (-> **Reviewed by NSRA**[*3] **in 1997**) 2001: 16 yrs[1982-1997] 49 units	2009: 21 yrs[1982-2002] 49 units 2014: 26 yrs[1982-2007] 55 units 2016: 29 yrs[1982-2010] 56 units	2020: 7yrs[2004-2010] 27 units
Estimation Methodology - Features	**Most Likelihood Method** ・Zero failures are treated as 0.5 failures. ・Chi-squared 90% confidence interval is regarded as 90% credible interval of uncertainty distribution.	**Hierarchical Bayes** (MCMC) ・An average of 40% of the actual number of failures is assumed to be collected. (Data collection probability)	**Hierarchical Bayes** (Empirical)
References for data collection and estimation	・NUERG/CR-1205 LER Data Summaries ・NUREG/CR-2815 NREP Guide ・IEEE Std. 500	・Same as the left ・NUREG/CR-6823 Parameter Handbook	・NUREG/CR-6823 Parameter Handbook ・NUREG/CR-6928 Industry-Average Performance ・EPRI Data Collection Guide

*1 NICS: Predecessor of NUCIA / *2 NUCIA: Nuclear Information Archives run by JANSI(JANTI)
*3 NSRA: The Nuclear Safety Research Association

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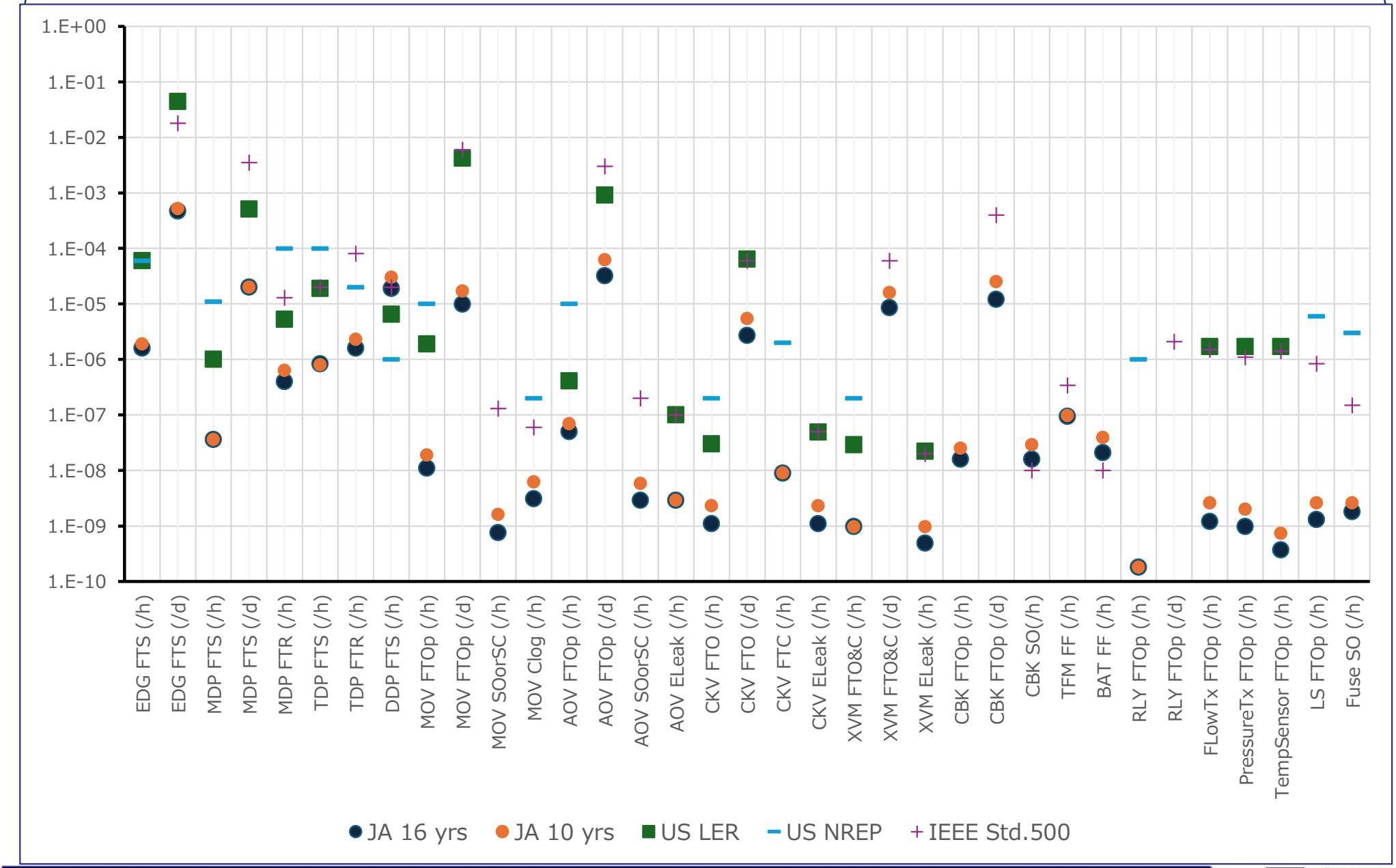
Comparison of generic component failure rates in the late 90s between Japan (10-year, 16-year) and the U.S.



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Generic component failure rate values in the late 90s were very low.

- **Many generic component failure rates in Japan were about two orders lower than those in the United States** (see the previous slide).
- The values of the Japanese failure rates became widely known in Japan through a published report by NRSA, which may have caused a strong impression remain that “the Japanese failure rates are significantly lower than those overseas.“
- **The Japanese method of component failure data collection was questioned.**
  Some doubted that NICS/NUCIA* captured the component failure information needed for PRA.
  * NICS/NUCIA: Database systems of failure events in nuclear facilities recorded by the utilities, which contain legal reporting events and maintenance information voluntarily shared among the utilities.
- CRIEPI, not being in charge of data registration to NUCIA, was not able to dispel the doubt.

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Introduction of Bayesian Estimation (2009-, JANTI/JANSI)

- Most Likelihood Method ⇒ **Bayesian Estimation** (MCMC Hierarchical Bayes)
  - Assuming a failure rate uncertainty distribution accounting for **plant-to-plant variability**
  - Assuming **uncertainty in the number of failures**
    ⇒ “60% of failures overlooked on average”
  - The Hierarchical model was too complex for a small number of failure data.
    ⇒ **Difficulty in MCMC convergence**
  - The data collection method was unchanged (**NUCIA failure data**).

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Improvement of data collection method (2020-, NRRC)

- The data collection method, a source of doubt, has been revised.
- **Plant-specific maintenance records have been used** as a source of equipment failure information instead of NUCIA.
  - To ensure the collection of equipment failure information necessary for PRA
  - Events not considered in PRA or as PRA equipment failure were screened out (see the next page).
- **Target equipment populations were clearly defined by basic events of plant-specific PRA models** (see the next page)
- Some equipment failure criteria were revised in line with those in the US.
- Empirical Bayes method was used to avoid the complexity and convergence problems with the computation model.

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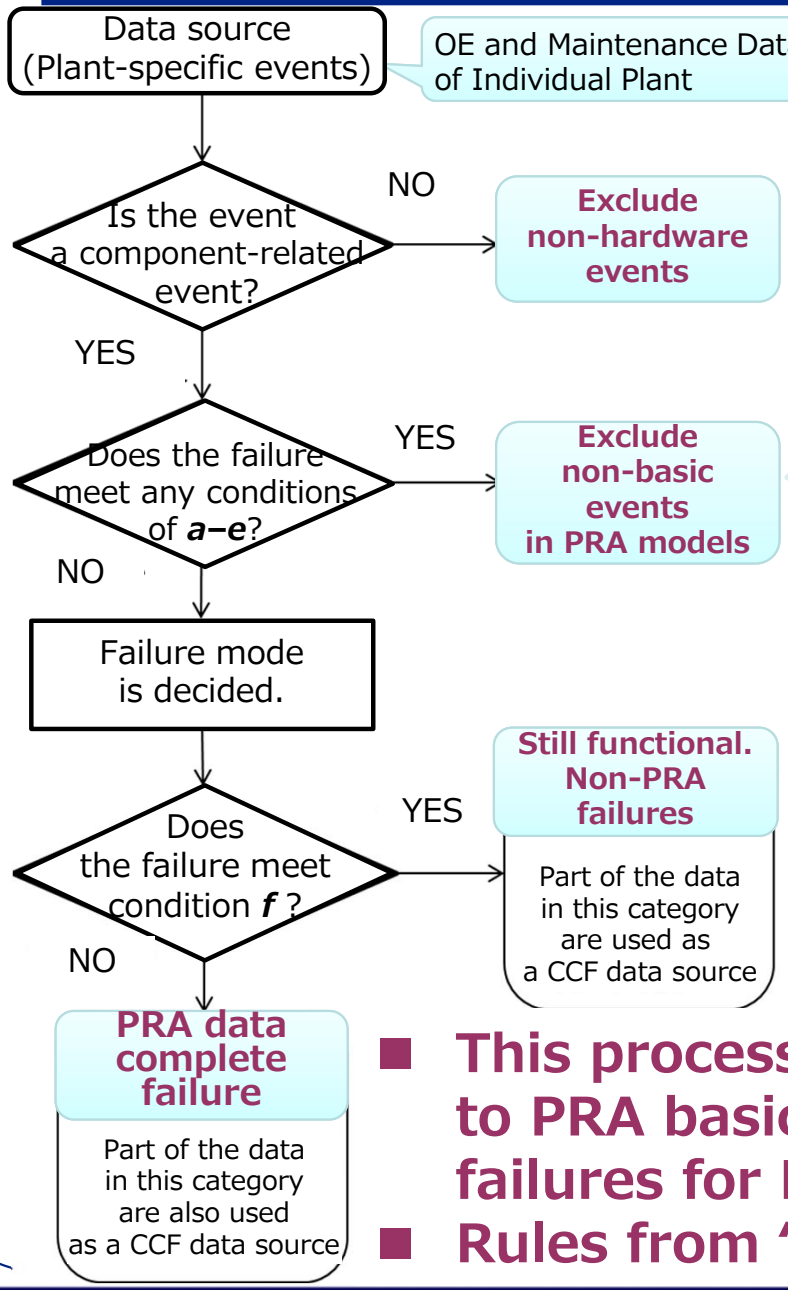
New Data Collection Process for PRA



Definition of target component types and failure modes

- ***a***: Exclude failures out of the PRA component boundaries. [These failures do not affect the plant risk.]
- ***b***: Exclude failures caused by miss operation [These events are treated in HRA.]
- ***c***: Exclude failures that occur when the functions are not required to be in service.
- ***d***: Exclude failures caused by external events [These failures are considered in the applicable external event PRA]
- ***e***: Exclude failures that are not relevant to the functions required for safety (PRA functions)
- ***f***: Exclude failures that are not complete failures of the target components [degradation, incipient, or non-repeatable transient]

- This process screens out events not applicable to PRA basic events to finally extract component failures for PRA reliability estimation.
- Rules from "*a*" to "*f*" are used for screening out.

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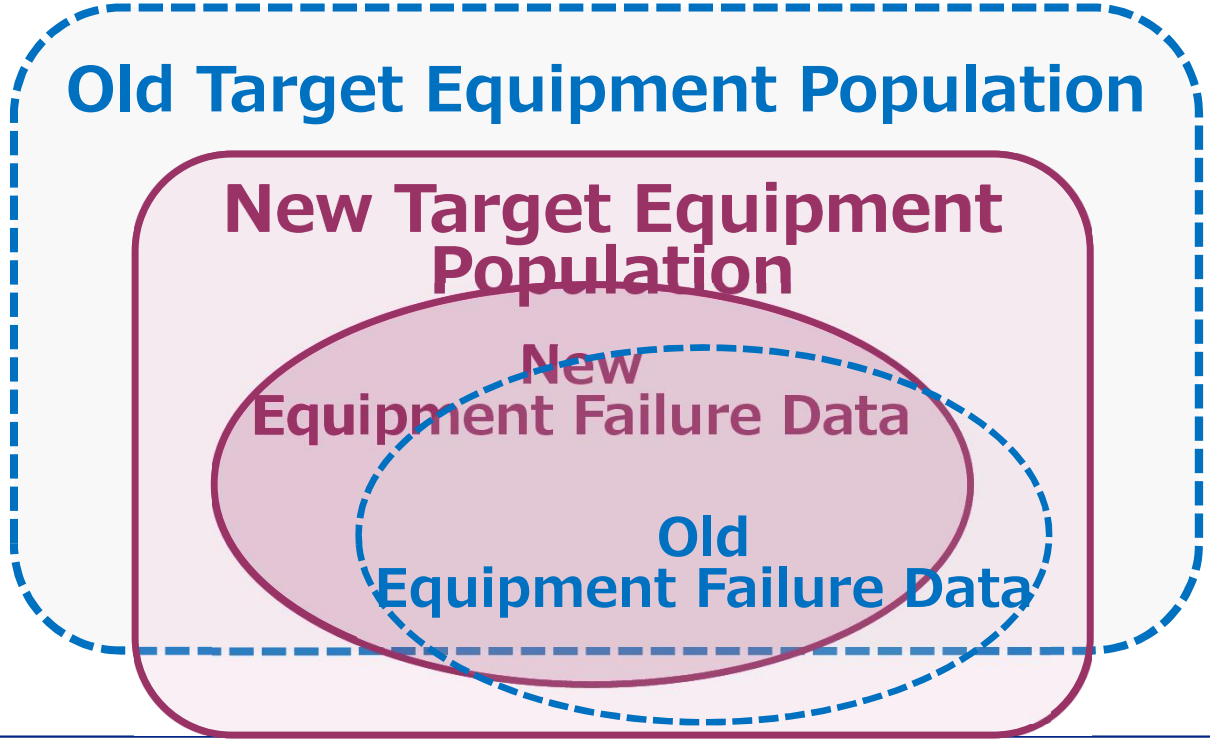
Clarification of target equipment population for data collection

- Unclear target equipment population in the old method in which NICS/NUCIA were used as information source.
  - Collection of all the necessary failure data in the target population was not guaranteed.
- The new method has a clearly defined population.



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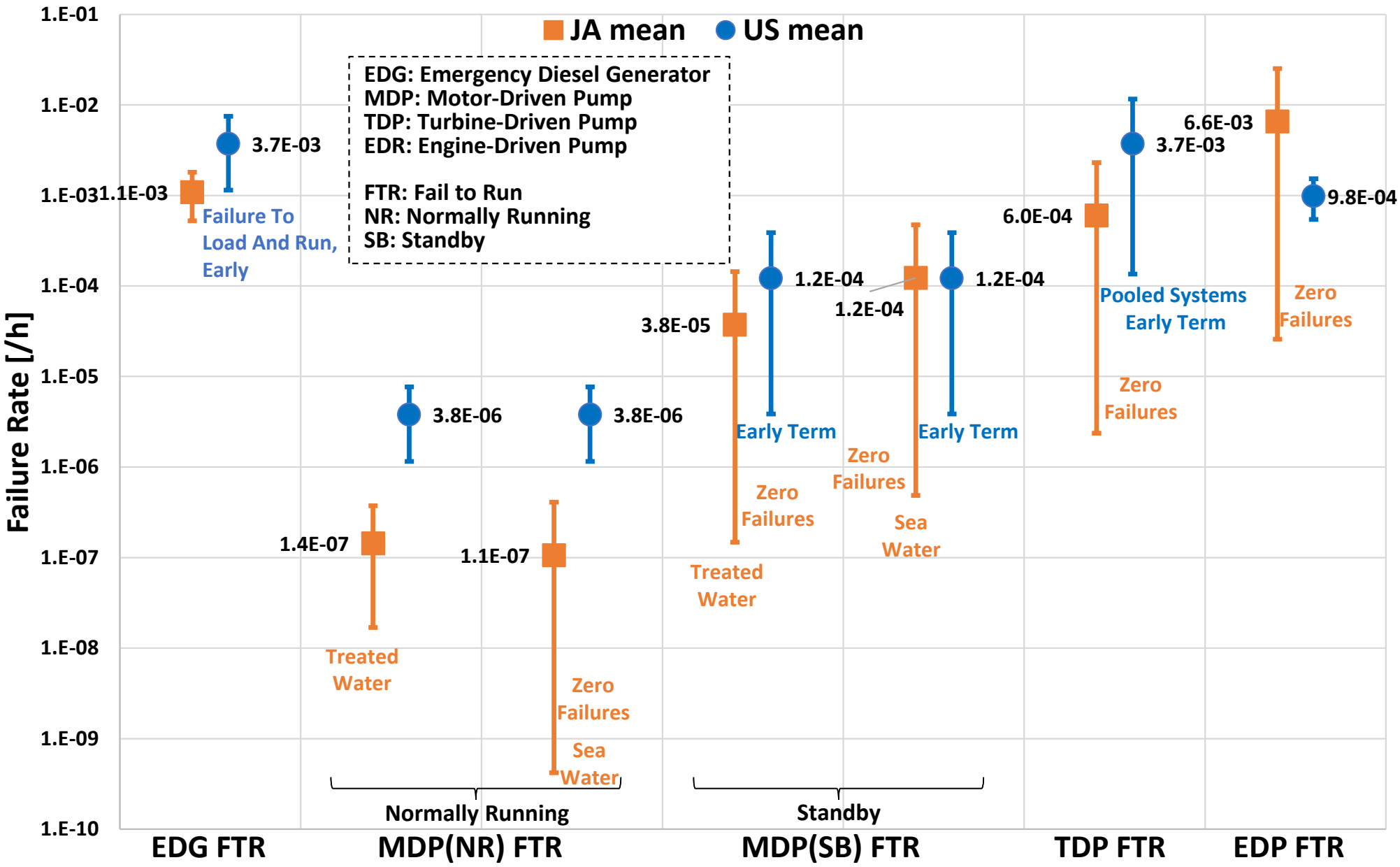
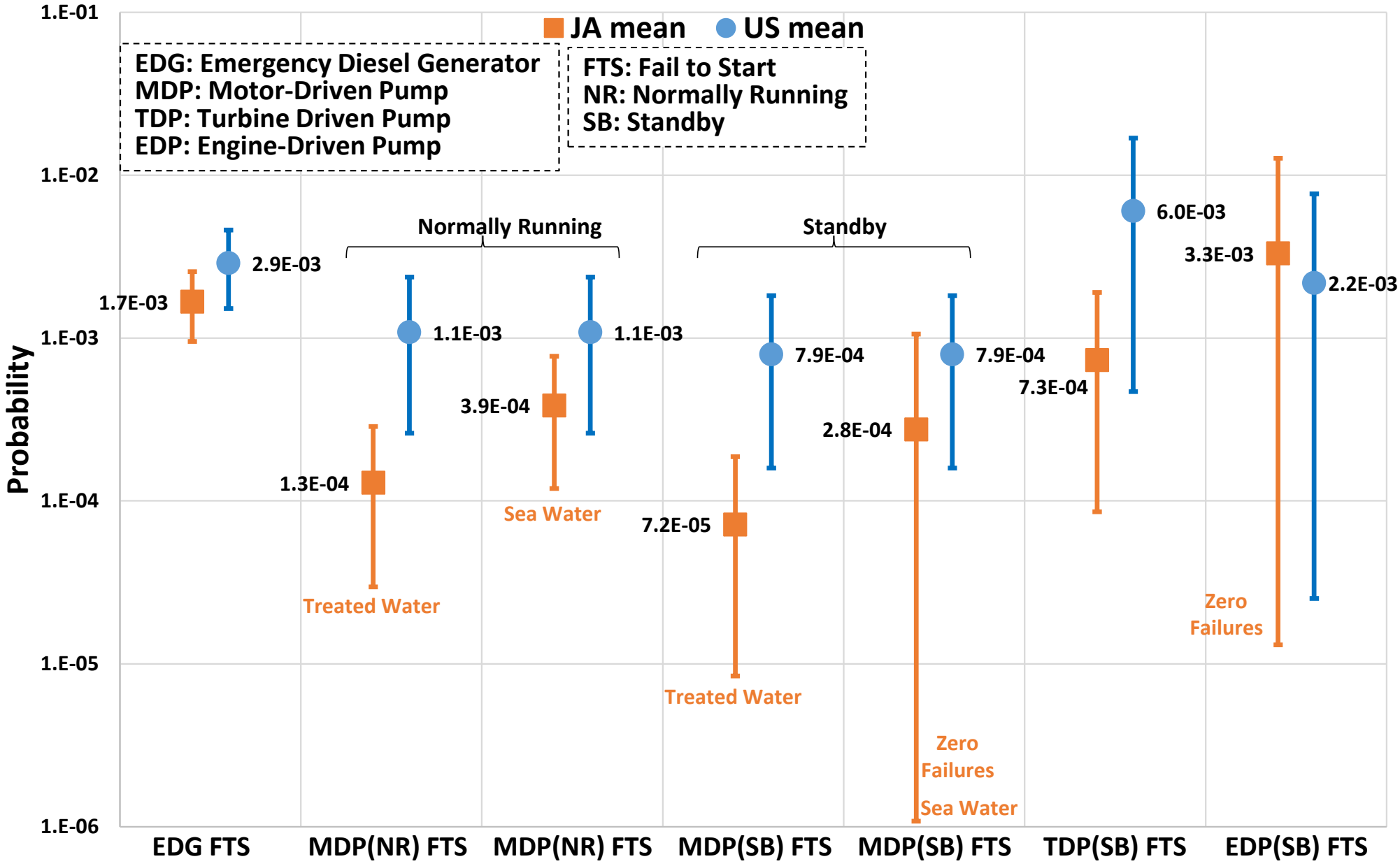
J-US Comparison of Failure Rates



J-US Comparison of Demand Failure Probabilities



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CRIEPI Central Research Institute of Electric Power Industry

Major Improvements in the Future

- **Enhancement of the scope of target components and failure modes**
  - Useful component types and failure modes from components other than those modeled in the PRA
  - Useful component types and failure modes to the other plants or the other reactor type
  - Additional component types and failure modes for enhanced PRA models in the future.
- **Reduction of variability in analysts' interpretation of failure criteria**
  - Check and correction (if necessary) of the utilities' component failure screening through the utilities' mutual review meetings hosted by NRRC
  - Clarification of descriptions of the technical requirements in the data collection guide based on the review results above.
- **Improvement in estimation methods of failure rates/probabilities**
  - "Demand failure model" should be used for estimating demand failure probability of a standby component instead of "standby failure model," which may cause underestimation.
  - Further analysis of plant-to-plant variability

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Summary

- **Process to collect all the necessary equipment-failure data for PRA has been developed.**
  - Information source: O&M records of individual plants
  - Technically adequate failure criteria
  - Clear definition of target equipment population necessary for PRA
- **Failure rates/probabilities in Japan are generally about an order of magnitude lower than in the U.S. Some are larger in Japan.**
  - ⇒ Difference of this magnitude are quite possible.
  - ⇒ It does not mean that the reliability values in Japan are "wrong" just because they are lower than in the U.S.
- Efforts are continued to improve data collection and evaluation according to what were pointed out in the NRA and overseas-expert reviews.

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