Support Improving the Quality of Internal Event PRA Models

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CRIEPI Central Research Institute of Electric Power Industry

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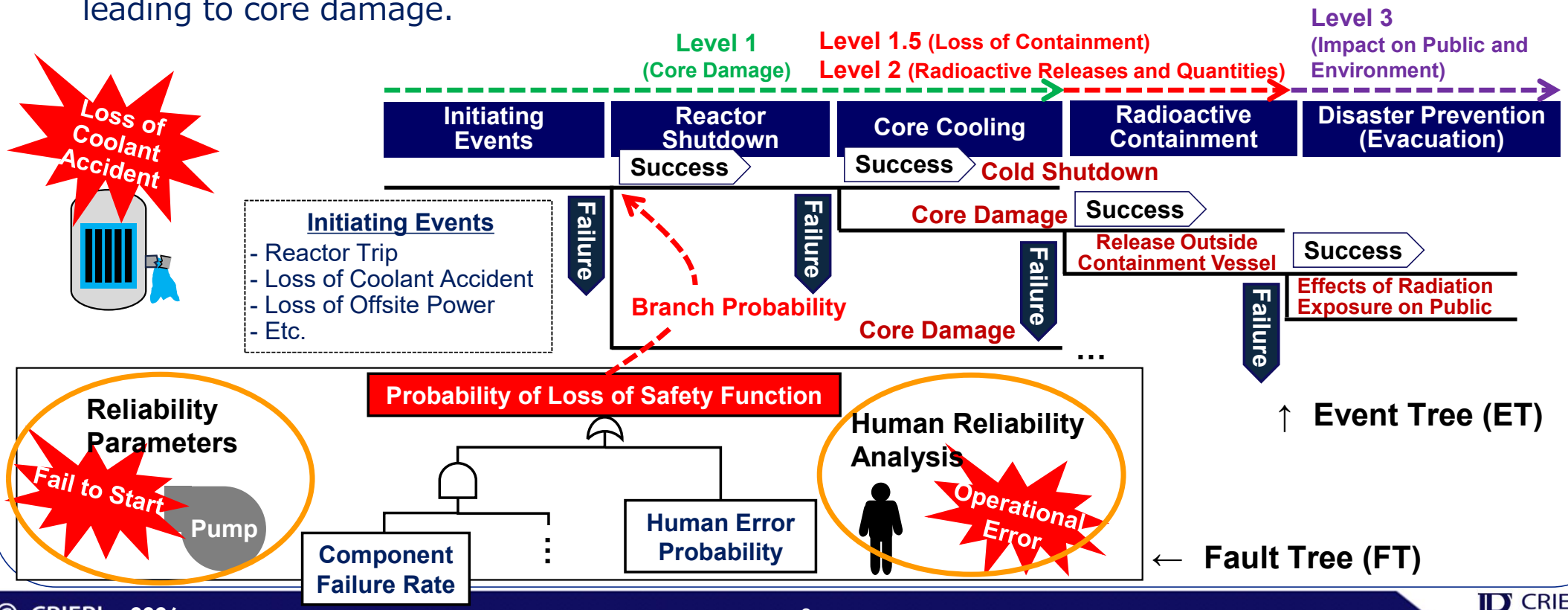
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1. Internal Event PRA Structure

■ **Internal Event PRA (basis for PRAs addressing seismic, tsunami, fire, flooding, and other hazards)**

Internal event PRA models realistically represent and analyze reactor response to loss of safety functions due to incidental failures inside the plant (e.g. component failures or human errors), leading to core damage.



2. Internal Event PRA Background & Gaps

■ Background

- PRA Models for Internal Events at Domestic Utilities

- Internal event PRA models for domestic utilities were developed around 1990. These are based on a PRA model used to assess vulnerabilities of individual power plants in the U.S. Since then, **PRA use has been limited to "reviewing severe accident countermeasures and performing effective assessments."**

- In the U.S. and other countries, the quality of PRA methods and models has improved, and regulations advanced on utilization of risk information.

■ Gaps to Overcome

- Improvements in the quality of PRA methods and models in Japan have lagged behind those in other countries.

- Insufficient analysis of initiating events at individual plants, lack of component reliability data, outdated human reliability assessment methods, etc.

- **Japan's PRAs have yet to reach the level of technical standards (international technical standards) attained overseas, which have broadly advanced the utilization of risk information.**

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3. Efforts to Overcome Gaps

Nuclear Risk Research Center (NRRC) is conducting the following research to establish PRA that meet international technical standards for the utilization of risk information in Japan.

■Upgrading PRA Models

- Internal Event PRA peer reviews by overseas experts ⇒【Research Result (1)】

■Reliability Parameters for PRAs (such as component failure rates)

- Improvements in methods for collecting and analyzing equipment failure rate data ⇒【Research Result (2)】
- Maintenance of other parameters: common-cause failures, unavailability, and frequency of Loss of offsite power, and the probability of recovery failure

■Human Reliability Analysis (HRA)

- Implementation of HRA quantification tools that meet international standards
- Development of HRA Qualitative Analysis Guide ⇒【Research Result (3)】
- Development of Human Reliability Data Collection Forms and Databases
- Development of HRA Methods for Complex Situations Where No Operating Procedures Exist (application to Tsunami PRA, Fire PRA, Internal flooding PRA, etc.)

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4. Research Results
(1) Overseas Experts Peer Review of Internal Event PRA (1/3)

■Overseas Experts Peer Review of Internal Event PRA

What are PRA Peer Reviews by Overseas Experts?

- Overseas Experts Peer Review allows third-party PRA practitioners to identify gaps between utilities' PRA models and PRA implementation technical requirements and practices as specified in ASME/ANS PRA standards*, and identify areas for improvement.
- Nuclear Risk Research Center (NRRC) has selected representative domestic plants (BWR: Kashiwazaki-Kariwa Unit 7; PWR: Ikata Unit 3) and invited overseas experts with extensive practical PRA experience in support of peer review activities for internal event PRA models (coordinating review plans, selecting reviewers, and providing support).
- Based on PRA peer review results, utilities have improved their PRA models.

*ASME : American Society of Mechanical Engineers
ANS : American Nuclear Society

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4. Research Results
(1) Overseas Experts' Peer Review of Internal Event PRA (2/3)

■ Compliance with International Technical Standards – Ex. of Internal Event-Level 1 PRA

- Overseas experts judge compliance with Capability Categories (CC) I and II as specified in the ASME/ANS PRA standard.
- If a PRA model satisfies the CC-II criteria, it is deemed to comply with the international technical standard in terms of model granularity, plant specificity, and realism of plant response.

■ Status of Compliance with International Technical Standards

- Since the initial review, PRA models have been upgraded to generally comply with the technical requirements of the ASME PRA standard.
- The technical gaps present at the start of the reviews have been resolved, ensuring the quality of PRA for utilizing risk information.

Ex.: Ikata Unit 3 -Changes in Conformity with International Technical Standards of the Level 1 PRA Model for Internal Events

	FY2018 After completion of initial overseas expert review	FY2025 After completion of 12th overseas expert review
Ratio of Compliance with International Technical Standard	65%	92%

4. Research Results
(1) Overseas Experts' Peer Review of Internal Event PRA (3/3)

■ Example of Improving Technical Gaps – Segmentation of Initiating Events

- Previous domestic PRA models only considered basic initiating events identified in earlier knowledge.
- Taking into consideration past operational experience both domestically and internationally, utilities performed a comprehensive analysis using Failure Modes and Effects Analysis (FMEA)※ and added plant-specific initiating events.

➡It is now possible to assess initiating events in a way that reflects the plant's unique characteristics.

※Method for identifying failure modes for each target component and deducing the effects of such failures in a bottom-up approach

■ Industry-Wide PRA Model Upgrades

- Peer reviews of representative domestic plants have provided utilities with recommendations and advice on technical improvements premised on internationally-recognized knowledge. These recommendations have enabled utilities to upgrade their PRA models.
- NRRC established a meticulous peer review process and reviewer requirements, referencing practical experience from peer reviews of representative domestic plants and the U.S. Peer Review Guide. [1] (PRA Peer Review Guide[2])
- Using the PRA Peer Review Guide as a basis, utilities have conducted peer reviews spearheaded primarily by domestic engineers since FY2025.

➡The technical infrastructure is being established for Good PRAs in Japan.

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4. Research Results
(2) Improvements in Methods for Collecting and Analyzing Data on Component Failure Rates (1/2)

■ Criticism of Conventional Domestic General Component Reliability Data[3]

- "Failure rate figures are so unrealistically low compared to those in the U.S. that they are not credible."
- "Some component failure data has likely not been collected."

■ Establishment of Transparent Data Collection and Analysis Methods in Accordance with ASME/ANS PRA Standard

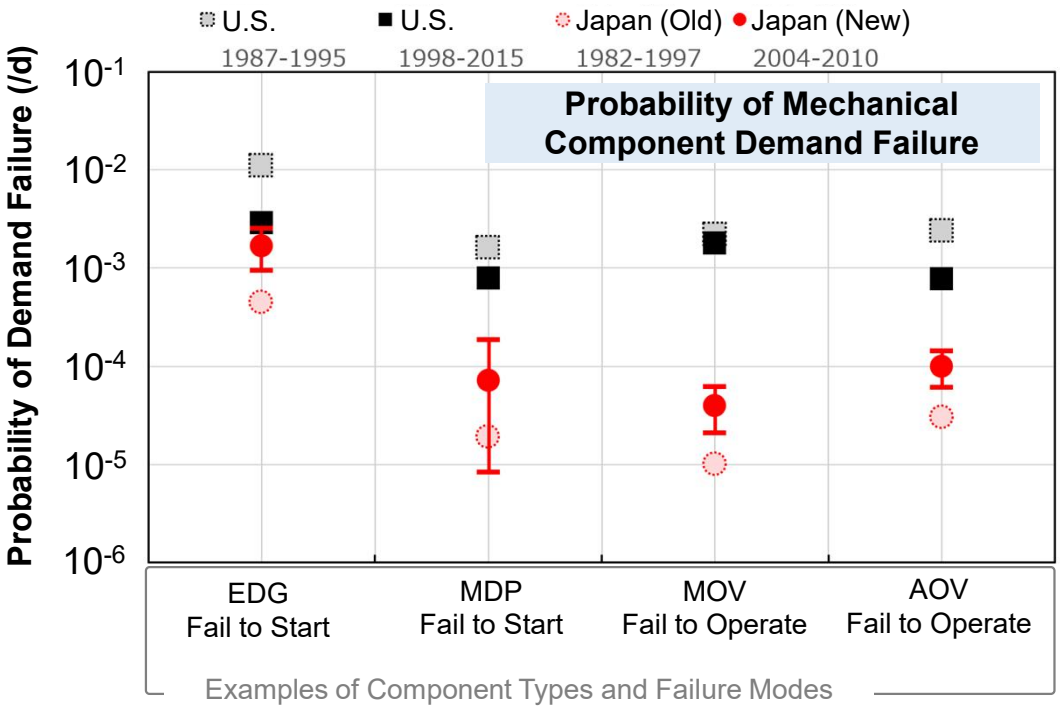
- **Component Reliability Data Collection Guide for Probabilistic Risk Assessments[4]**
  - ✓ Process for **directly and comprehensively collecting necessary information** from maintenance databases at individual plants
  - ✓ Mechanism for ascertaining the **exact number of components** by clearly defining the scope of components subject to PRA at individual plants
  - ✓ Component failure determination process for accurately determining **loss of safety functions** handled during PRA
- **Estimation of Generic Component Reliability Parameters[5]**
  - ✓ Adopted global standard statistical method that takes into account uncertainty in component failure rates (Bayesian statistical method)

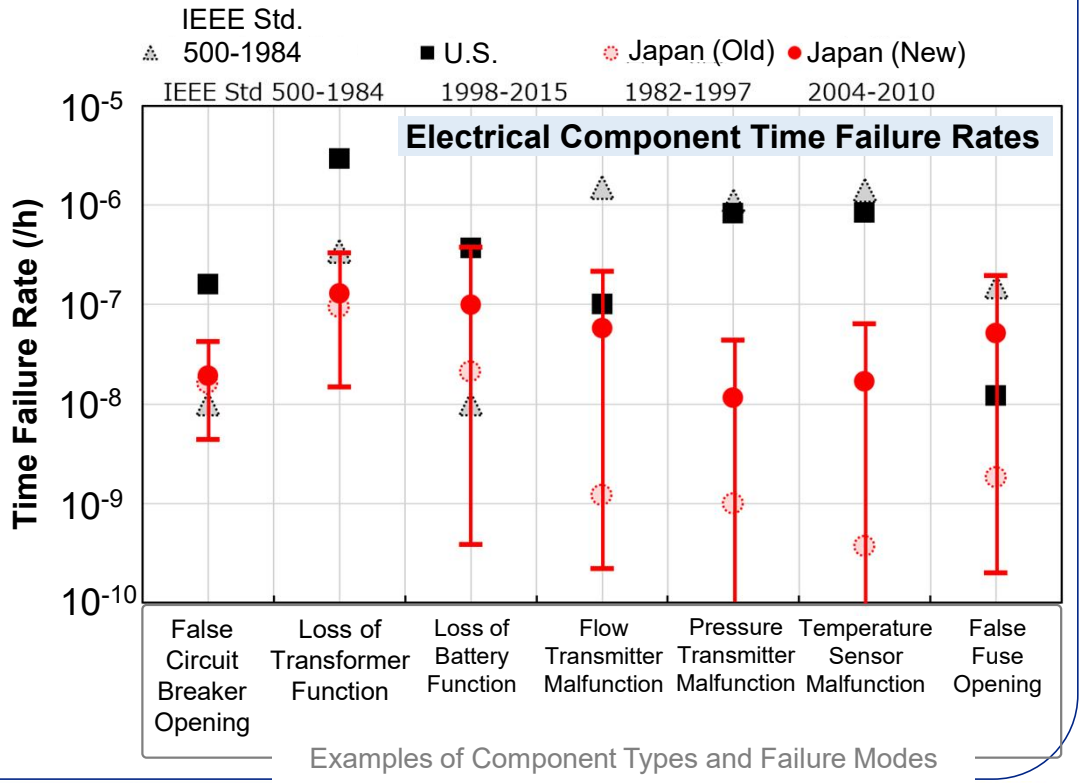
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4. Research Results
(2) Improvements in Methods for Collecting and Analyzing Data on Component Failure Rates (2/2)

■ Changes in General Component Failure Rates/Probabilities Due to Improvements and Comparison of These Rates/Probabilities to Performance Data in U.S.

- Improved data collection methods removed 'unrealistically low' values.
- New component failure rate used in domestic plant PRAs for NRA's New Regulatory Inspections (FY2020~).





4. Research Results
(3) Development of HRA Qualitative Analysis Guide

■ Improvements to HRA Method Meeting International Technical Standards

- Outdated assessment method previously used in domestic HRA was unable to properly assess “cognitive/diagnostic failures” so that the “contexts leading to human error” were not properly analyzed.
- Utilities adopted the HRA Calculator and updated their models for “recognition/diagnosis failures.”

■ Improving Variability in HRA Analysis Results

- Even when using the same tool, the results of human error probability (HEP) assessments generally tend to vary significantly from analyst to analyst depending on how the context is interpreted.
- Establishing analytical methods for human error context (task structure, situation and environment, timelines, etc.) reduces HEP variability.
- “HRA Qualitative Analysis Guide[6]” developed for HRA analysis.

➡Domestic HRA methods have been improved so they meet international technical standards.

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5. Current Achievements & Future Actions

■ Current Achievements

PRA models now meet international technical standards, enabling significant advances in the utilization of risk information.

■ Future Actions

➢ Upgrade PRA Models

- Conduct PRA peer reviews of all remaining plants

➢ Reliability Parameters for PRA

- Component failure rates/probabilities: Update parameters and improve their reliability by expanding the scope of target components and accumulating operational experience.
- Consolidate remaining undeveloped parameters as soon as practical

➢ Human Reliability Analysis (HRA)

- Estimate and update representative human error probabilities based on human reliability data obtained from domestic training programs
- Extend HRA methods to address external hazards and digital components

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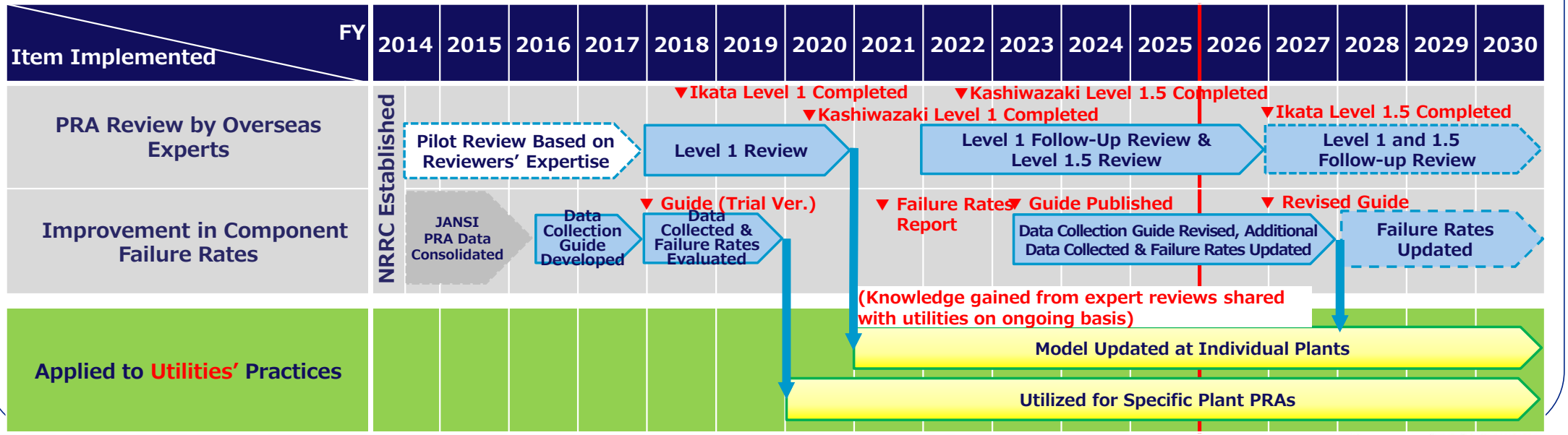
[Appendix] Progress in Overcoming Gaps (1/2)

■ Upgrading PRA Models

- Utilities' internal event PRA models have been upgraded to generally be on par with international standards

■ PRA Reliability Parameters (component failure rates, etc.)

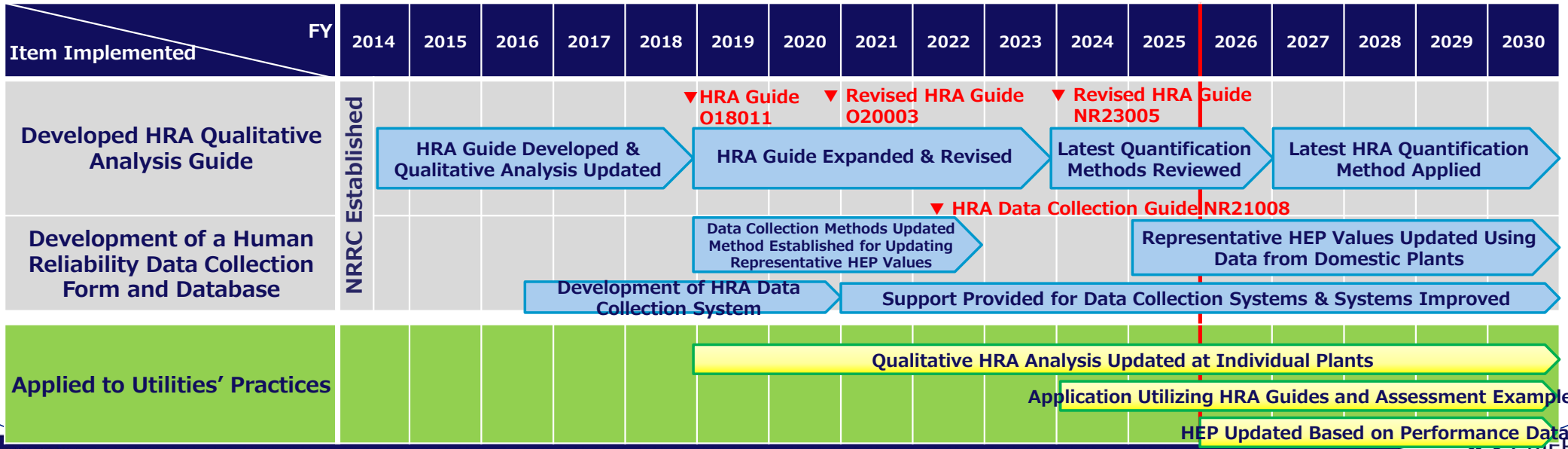
- Developed guide for collecting component failure data for PRA
- Improved domestic component failure parameters in accordance with guide



[Appendix] Progress in Overcoming Gaps (2/2)

■ Human Reliability Analysis (HRA)

- Developed HRA qualitative analysis guide and examples. Published two revised editions incorporating latest knowledge and expanded examples.
- Conducted HRA interviews at actual plants. Applied the HRA guide evaluation method to the HRA for a national project's Tsunami PRA.
- Developed HRA data collection system based on observations of domestic training simulators.



[Appendix] Status of Initiatives

Gaps to Overcome	Description	Progress
Gaps compared to international PRA methods and models	Internal event-Level 1 PRA peer review by overseas experts	Completed in FY2020
	Internal event-Level 1.5 PRA peer review by overseas experts	In progress
Unconsolidated component reliability data (equipment failure rates, etc.)	Improvement in component failure rates	Completed in FY2021
	Development of parameters related to common-cause failures, unavailability, and frequency of loss of offsite power/probability of recovery failure	In progress
Outdated human reliability assessment methods	Introduction of HRA quantification tool based on international standards	Each utility has introduced the HRA Calculator developed by U.S. EPRI in their HRAs
	Development of HRA Qualitative Analysis Guide	Completed in FY2018
	Development of Human Reliability Data Collection Forms and Database	Completed in FY2022

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[Appendix] References

[1] NEI, “Performance of PRA Peer Reviews Using the ASME/ANS PRA Standard,” NEI17-07, Revision 2, August 2019

[2] PRA Peer Review Guide, Research Report NR25001, July 2025

[3] Estimation of Component Failure Rates for PSA on Nuclear Power Plants 1982 – 1997, Research Report P00001, January 2001

[4] Component reliability data collection guide for probabilistic risk assessment, Research Report NR22006, May 2023

[5] Estimation of the generic component reliability parameters for probabilistic risk assessment of the Japanese nuclear power plants, Research Report NR21002, September 2021

[6] Guide for Qualitative Analysis in The Human Reliability Analysis (HRA) with Emphasis on Narratives (FY2023 Edition), Research Report NR23005, May 2024

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