EPRI Activities for WGRISK Meeting

27th Meeting of the Working Group on Risk Assessment

Reports on Activities in the Area of PSA by Other International Organisations

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Risk and Safety Management
Nuclear Sector, EPRI

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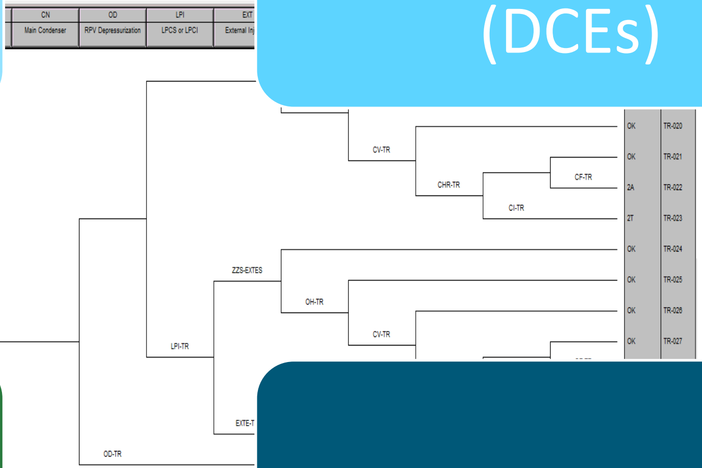
2025 EPRI Risk DELIVERABLES

TRAINING	3002030767	Causes of Human Error and Relationship to Human Reliability Analysis -Computer Based Training Module
	3002030768	Introduction to Building and Quantifying Fault Trees in CAFTA - Computer Based Training Module
	3002031633	Probabilistic Risk Assessment - Introduction to Initiating Events
	3002031635	Probabilistic Risk Assessment - Introduction to Accident Sequences and Success Criteria
SOFTWARE/OTHER	3002031688	Central and Eastern United States (CEUS) Seismic Source Characterization(SSC) v1.0
	3002031968	MAAP Wiki v1.0
	3002031966	GOTHIC 8.5 - gPIPE Add-on -Version 1.0
	3002031969	GOTHIC Wiki v1.0
	3002033073	Fault Tree Reliability Evaluation eXpert (FTREX) v2.1
	3002031967	GOTHIC 8.5 - CVAN Add-on v1.0
	3002031961	Phoenix Architect v2.2
TECHNICAL REPORT/UPDATE	3002032026	External Hazards: Information Compilation and Analysis-2024 New Information Report
	3002032020	Component-Based Fire Ignition Frequency Methodology
	3002032021	Alternative Treatment to Environmental Qualification for RISC-3 Applications
	3002033536	Enhanced Risk-Informed Categorization Methodology for Pressure Boundary Components (Revision 1-A)
	3002032025	BWR Dose Consequence Evaluation: Assessment of Proposed Source Terms for RG 1.183 Rev. 2
	3002032027	External Hazards: Information Compilation and Analysis - 2025 Catalog of Relevant Information Sources
	3002032022	Wildfire Vulnerability Assessment Guidance for Nuclear Power Plants
	3002032029	GOTHIC: Application Guide
	3002032028	The Kahramanmaras, Turkey Earthquake Sequence of February 6, 2023
	3002032023	EPRI Credible Dependent Failure Mechanisms: HRA Dependency Methodology and Guidance
	3002032030	Impact of Sea Level Rise on Coastal Flooding Hazard: Natural Hazards in a Changing Environment
WHITE PAPER	3002032032	PRA Model Maintenance: Cross-Cutting Challenges when Maintaining PRA Models
	3002032033	Multi-Module Risk Assessments
	3002032024	Seismic Penalty for Risk Informed Completion Times (RICT): Calculation Approaches
	3002032034	Best Practices and Expected Benefit Applying the MAAP5 Zonal Model to Plant-Specific Analyses
	3002032031	Risk-Informed Considerations for Rare Seismic Events in Advanced Reactors

Credible Dependent Failure Mechanism (CDFM) Method

Identify Event Tree Functions (ETFs)

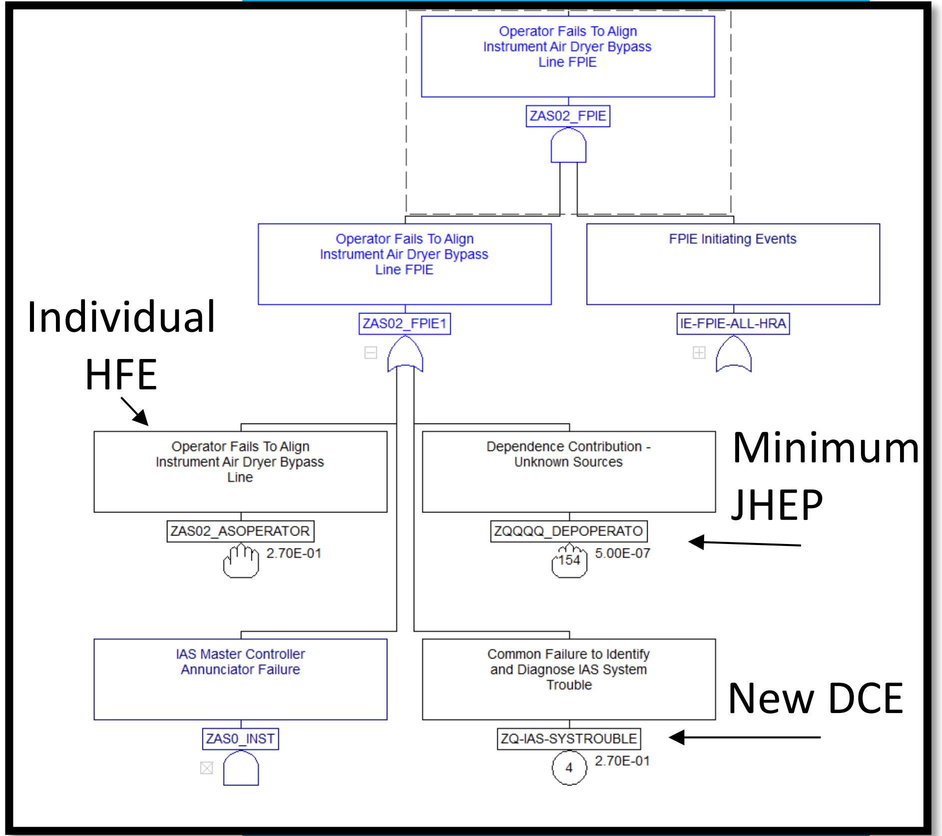
Define ETF Dependent Combination Events (DCEs)



Incorporate DCEs into the PRA Model

Like CCF!

Review, Finalize, & Document the Analysis



Comparing the HRA Dependency Framework (old vs. new)

HRA Dependency Steps	Old Process	New Process
1.Identify dependent HFE combinations	HFE combinations identified based on cutset review with artificially increased HFE failure probabilities	HRA dependencies are identified based on groups related to known mechanisms 1) Accident sequence logic and support system models are examined for credible dependent failure mechanisms 2) A general HFE combination is added for unknown failure mechanisms
2. Quantification of dependent HFE combinations	HRA Calculator dependency decision tree (rule based)	EPRI HRA Calculator quantification methods such as CBDTM and HCR/ORE
3. Model incorporation of HFE combinations	HFE combinations are implemented via post-processing recovery rules	HFE combinations are implemented into the PRA fault tree logic directly

<ins>Iterations:</ins>

Old process: Every time PRA cutsets change, the identification changes

New process: Update is only required when HFEs have been added or significantly changed

How Does CDFM help?

HRA Dependency Challenges	Old Process	New Process
HRA Technical Basis	🟡	🟢
PRA Model Runtime	🔴	🟢
Level of Effort for Updates	🔴	🟢
Transparency of Dependencies	🟡	🟢
Realism in Applications	🟡	🟢
Initial Modeling Investment	🟢	🟡

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CDFM Pilot Summary

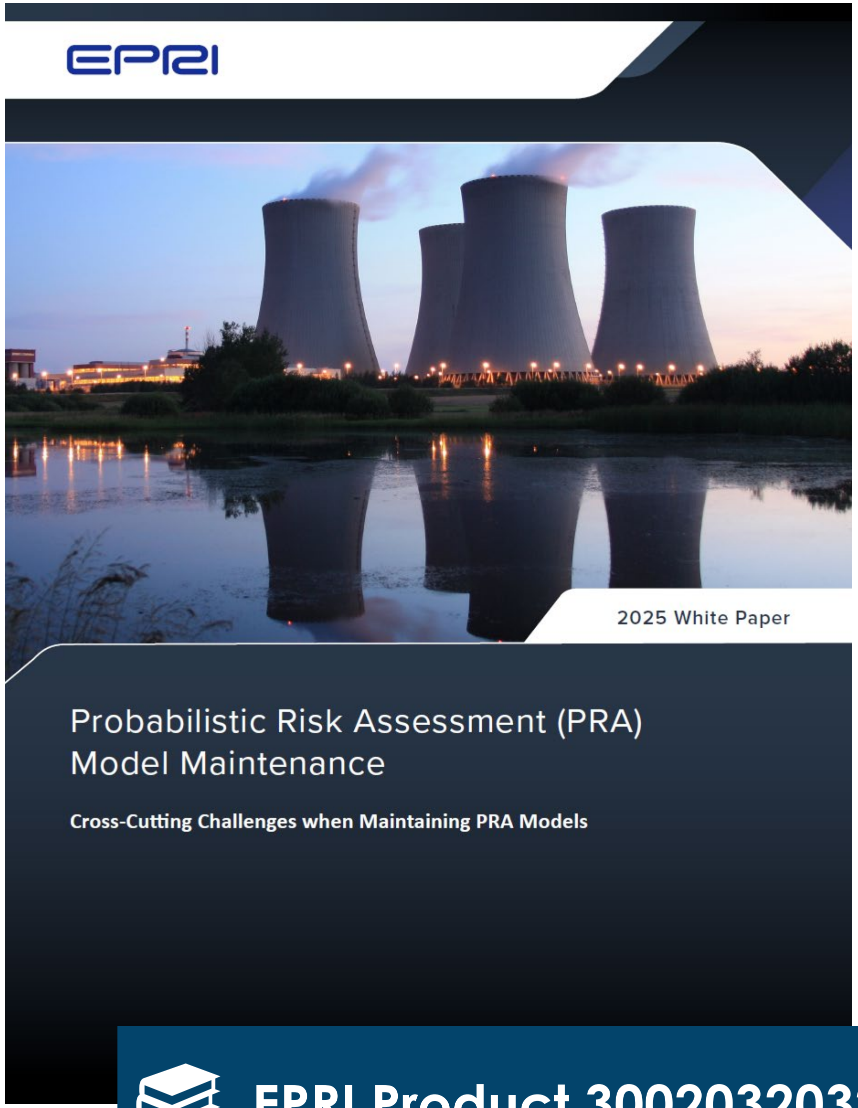
- Testing was conducted using a variety of analysts:
  - Model owners.
  - External consultant.
  - Analysts that were inexperienced and experienced in HRA.
- Stress testing of models.
  - 1 full model (internal events, internal fire, internal flood).
    - Seismic hazards follows the same approach, will describe in a KB article.
  - 1 fire model, and portions of 2 other models.
  - Configuration Risk Management sensitivity cases.
    - Front line component out of service.
    - Support system component out of service.

Method is AVAILABLE for USE/Under PRA Standard Review in US

PRA Model Maintenance White Paper (2025)

Overview

Investigates the complexities and challenges of maintaining PRAs for use by the nuclear power industry. This research aims to develop cross-cutting approaches to enhance and simplify the PRA model maintenance process, ensuring that PRA models remain accurate, reliable, and useful for risk-informed decision-making.



EPRI Product 3002032032

Challenges Identified based on Industry Feedback

PRA Model Update Project Planning

- Limited PRA resources, limited industry engagement, and limited awareness of updated methodologies.
- Complexity when incorporating the PRA model changes into a living model.
- The Nuclear industry lacks a standard definition of -PRA model update.ˇ
- The development of HRA dependencies falls at the end of the PRA model update project and requires significant resources to complete.
- Workforce attrition and maintaining the overall PRA skills/knowledge base.

Human Reliability Analysis and Dependency Analysis

- Quantifying and processing large numbers of HRA dependency combinations.
- The iterative nature of the HRA dependency process.
- HRA˛s non-transparent -black boxˇ nature.
- The performance of an HRA dependency analysis at the end of a PRA model update project.
- There is a need for a large influx of resources in a short amount of time to perform the HRA dependency analysis.

Plant Modification Review and Configuration Control

- The complexity associated with the review of plant modifications and procedural changes, specifically in the context of internal and external hazards.
- The review of plant modifications and maintaining configuration control of the PRA model.

Convergence and Truncation

- The increasing computational needs of the PRA quantification process.
- Lowered truncation for convergence values can be computationally challenging.

PRA Model Qualities

- Developing and maintaining PRA model documentation.
- The increasing age of PRA models and their documentation.

Data Update Process

- Lack of plant-specific information readily available to PRA practitioners.
- Lack of clear rules related to the incorporation of new data.

PRA Model Control and Verification

- Coordinating the use of multiple resources to perform concurrent PRA model changes.

Risk-Informed Applications

- Lack of understanding of the impact of risk-informed applications during a PRA model update.

PRA Model Propagation

- Ensuring that PRA model changes and their impacts are propagated correctly across all modeled hazards in a timely fashion.

Technical Element Specific Update

- Adopting an element-focused update may not be practical and lacks general guidance.

Uncertainty Analysis

- The performance of a PRA uncertainty analysis is seen to yield limited practical value.

Better define the scope of an "update?"

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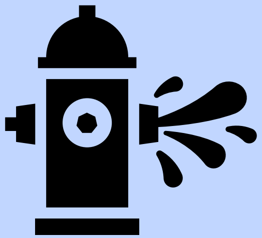
Continue to make the update process more efficient?

Revised EPRI Internal Flooding PRA Guidance – <u>Under Development</u>

- Example questions and requests from users
  - New flood frequencies for rubber expansion joints with steel sleeves
  - Clarification on system boundary conditions
  - Better guidance for estimating flood-induced initiating event frequencies
  - Better guidance for analyzing specific flood scenario(s) aspects:
    - Water sprays, flood door and barrier integrity
    - Modeling flood propagation via barriers, drains
    - Treatment of operator actions to mitigate flooding
    - Screening, grouping flood scenarios
    - How to refine analysis results
    - Examples and case studies implementing IFPRA best practices

- **Potential Topics:**



  - Pipe size refinements
  - Flow rate refinements
  - Integrity management factors
    - Including other utility solutions to aging
  - Aging factors
  - Use of software (EPRI FRANX) to optimize refinement process
  - Risk-informed application-related topics
    - Screening criteria for larger floods based on frequency and/or a low system pressure
    - Segment definition
    - How to treat standby systems and heat exchangers
  - When NOT to refine
  - How to refine flood timing and consequences using geometry from existing notebooks without doing full-blown new analysis.
  - Distinguishing spray vs. submergence vulnerability based on component elevations.
  - Consistent credit for drainage and leak detection
  - Common pitfalls and lessons learned, plus tips for writing strong justifications that hold up in peer reviews.

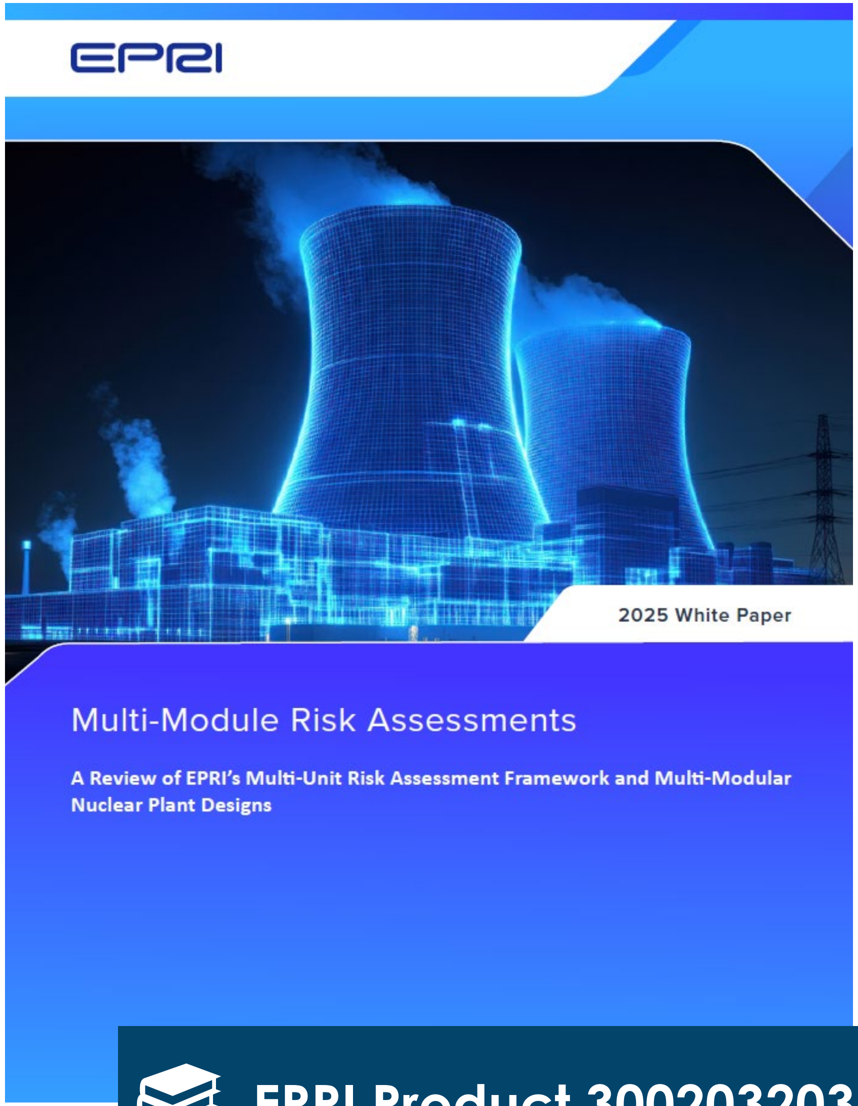
Internal Flooding PRA Path Forward

- Next step: publication of updated IFPRA guidelines
- Alignment of the guidance with US PRA Standards
- Future efforts for consideration include
  - developing data for HDPE piping
  - guidance for piping containing combustible fluids.
  - more detailed guidance on selection/justification of integrity management factors
  - Increasing scope of piping to selected systems inside the containment
- Literature search with categorization of reports
- Long-term sustainability of Pipe Rupture Frequency updates
  - Data pipeline
  - Calculation streamlining
  - Developing new talent / contractors

Multi-Module Risk Assessments White Paper (2025)

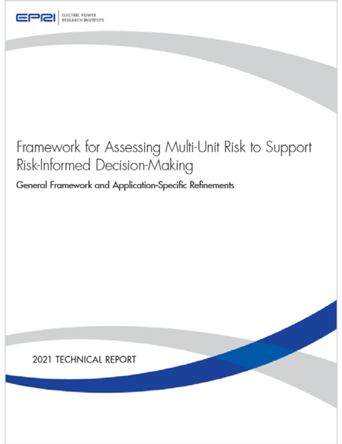
Overview

This white paper reviews advanced reactor concepts to identify insights related to EPRI's multi-unit risk assessment framework. It explores regulatory definitions, design characteristics, and operational considerations influencing tightly coupled reactor modules. The research finds that while unique configurations may need tailored risk assessment approaches, in general, EPRI's multi-unit framework remains broadly applicable.



EPRI Product 3002032033

EPRI's Multi-Unit Research



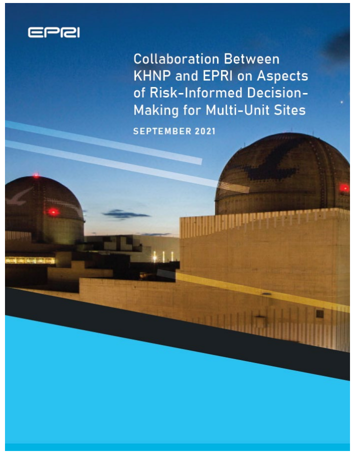
3002020765 (2021)

Framework for Assessing Multi-Unit Risk to Support Risk-Informed Decision-Making: General Framework and Application-Specific Refinements

3002029304 (2024)

Application of Multi-Unit Probabilistic Safety Assessment Strategies in Canada – Multi-Unit Risk for CANDU Nuclear Generating Stations Operating in Canada

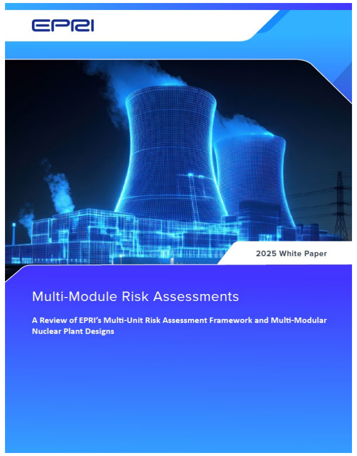
Technology Transfer Award



3002020756 (2021)

Collaboration Between KHNP and EPRI on Aspects of Risk-Informed Decision-Making for Multi-Unit Sites

Technology Transfer Award



3002032033 (2025)

Multi-Module Risk Assessments: A Review of EPRI's Multi-Unit Risk Assessment Framework and Multi-Modular Nuclear Plant Designs

Partial Correlation of Seismic Fragilities

- Seismic PRAs (SPRAs) traditionally use a binary approach to assessing correlation – zero (no correlation) or one (complete correlation).
- EPRI is develop guidance on how ***and when*** to consider partially correlated failures that are important to the development of seismic PRA insights.
- The goal is to develop an efficient method for estimating and modeling partially correlated seismic failures.

Apply additional detail where it yields the most benefit

Tail-Oriented Multi-Normal Model Method (TMM)

- Seismic ground motion capacity of an SSC is modeled as a lognormal random variable with a median (A_m) and a logarithmic standard deviation, which is split into randomness and uncertainty components (β_R and β_U).

- The TMM method partitions the SSC fragilities into the products of two random variables: common and independent.

- These variables are then used to develop a composite fragility for any success criterion (n_s out of N).

Full Report Under Review – soon to be published

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