Industry xLPR Update

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xLPR V2.4 Release

- Technical refinements based on recent applications and benchmarking
- What's new:
  - Crack growth module for stainless steel stress corrosion cracking
  - Stability module corrections
  - Automated testing
- Maintains backward compatibility with existing inputs and workflows

xLPR

PROBABILISTIC FRACTURE MECHANICS CODE

https://www.epri.com/research/products/000000003002032195

Estimation of LOCA Frequencies (MRP-480)

- xLPR used to support alternative fuel licensing strategy (ALS) for high-burnup fuels
  - Evaluate probability of LOCAs as a function of line size
    - Demonstrating LOCAs/ruptures are sufficiently low frequency
  - Evaluate if leakage would be detected in sufficient time prior to piping rupture
    - Demonstrating further defense in depth
- <u>Safety Evaluation received and we are updating MRP-480 to “-A”</u>

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Reactor Vessel Outlet Nozzle (RVON – Hot leg) Inspection Schedule (MRP-505)

- Objective
  - Evaluate whether inspection intervals for unmitigated hot leg RVON dissimilar metal (DM) butt welds can be extended from 5 to 6 years
- Scope
  - Applies to Inspection Item A-2 hot leg RVON welds (< 625°F)
  - Covers seven Westinghouse PWR plants with remaining unmitigated RVON welds
  - Uses probabilistic fracture mechanics (PFM) with xLPR v2.3
- Regulatory Context
  - ASME Code Case N-770

Technical Approach (MRP-505)

- Methodology
  - Probabilistic Fracture Mechanics (PFM) using xLPR
  - Updated PWSCC crack growth rates from MRP-420 Rev. 1
- Key Modeling Features
  - Circumferential flaws only (bounding for rupture risk)
- Conservative assumptions:
  - Crack present at time zero
  - No credit for leak detection
  - Direct comparison to absolute acceptance limit (not Δ-risk) - Maximum annual rupture frequency used
- Acceptance Criterion
  - Annual rupture frequency $\leq 1\times10^{-6}$ /yr, consistent with GDC-4

Analyses Performed (MRP-505)

Fleet
- Conservative stresses and temperature
- Expected to have considerable conservatism (screening case)

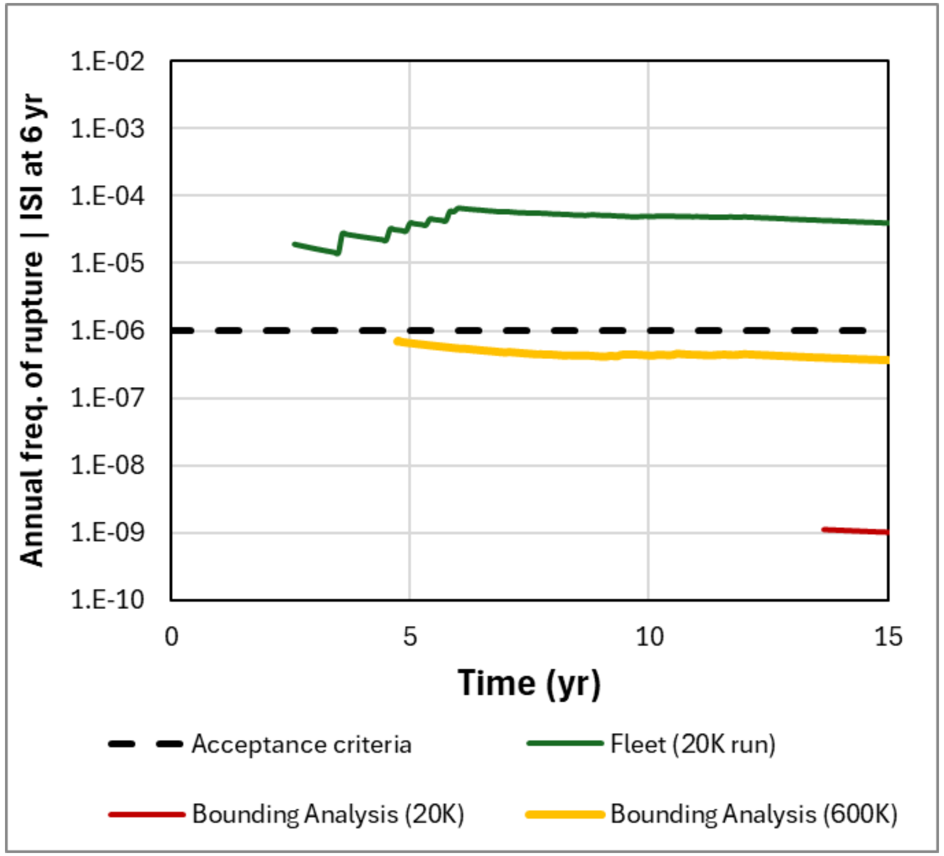
Affected Plants
- Maximum stresses across the seven plants
- Used to assess feasibility of 6-year interval

Plant Specific
- Most conservative plants (highest stresses)
- Median-stress plant for margin demonstration

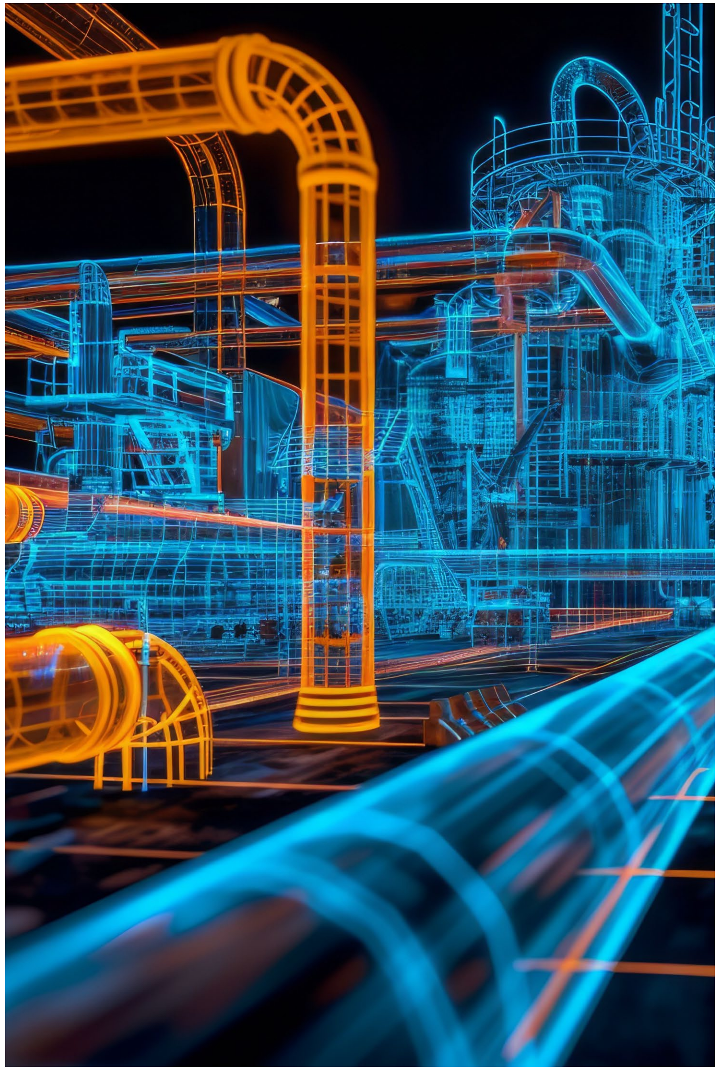
- Numerical Rigor
  - Initial screening: 20,000 realizations
  - Confirmation runs: 600,000 realizations (15 years) for convergence

Key Results (MRP-505)

- Fleet Bounding Case
  - Does not meet acceptance criterion
  - Confirms conservatism of fleet-wide assumptions
- Seven-Plant Bounding Case
  - Meets acceptance criterion for 6-year inspection interval
  - Max annual rupture frequency ≈ 7×10^{-7} /yr (acceptable margin)
- Plant-Specific Results
  - Most limiting plants: acceptable with margin
  - Median-stress plant: orders-of-magnitude margin below 10^{-6} /yr
  - Inclusion of crack initiation modeling further reduces rupture frequency



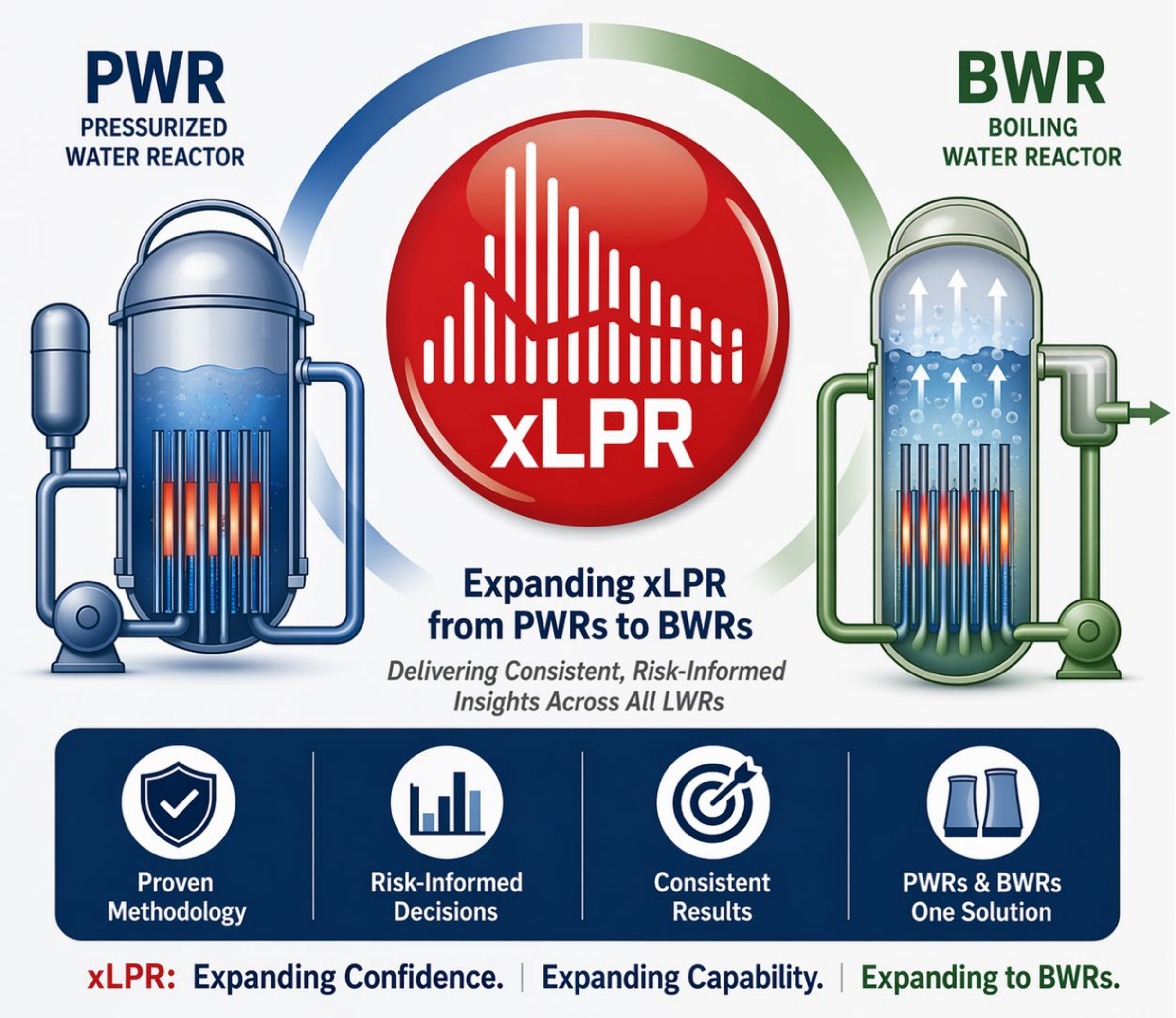
Conclusions and Recommendations (MRP-505)



- Conclusions
  - Generic Code change not supported (fleet bounding fails)
  - Plant-specific relief is technically justified for the seven applicable plants
  - 6-year inspection interval maintains extremely low rupture probability under conservative assumptions
- Recommendations
  - Proceed with plant-specific NRC relief requests for 6-year intervals
  - EPRI to develop a template relief submittal using this technical basis
  - Use plant-specific stresses to demonstrate additional margin where possible
- Value
  - Reduced inspection burden and dose
  - Maintains safety and regulatory alignment

xLPR Application for BWRs

- The BWRVIP is pursuing xLPR due to the following potential benefits:
  1) reduction of design basis loads on reactor internals and
  2) application of risk insights to refine reactor internals inspection guidance



Review of PFM Acceptance Criteria for Passive Components

- White paper reviews acceptance criteria for PFM analyses of passive nuclear components and their role in risk-informed decision-making (RIDM)
  - Acceptance criteria are a key methodological and regulatory review focus
- Regulatory Framework (U.S.)
  - NRC RG 1.174 defines acceptance in terms of CDF and LERF
  - PFM failure frequencies relate via conditional core damage probability (CCDP) / conditional large early release probability (CLERP)
- Current Practice
  - Most applications do not estimate CCDP explicitly
  - Assume component failure ⇒ direct CDF/LERF contribution
  - Conservative; blurs distinction between local failure probability (PFM) and global risk (PRA)
- International perspectives included as well

Review of PFM Acceptance Criteria for Passive Components

Better separation of PFM (local) vs PRA (global) metrics

More defensible conclusions

Reduced unnecessary conservatism and analytical burden

Improved risk understanding

https://www.epri.com/research/products/000000003002032193

v3 Planning Meeting

- The EPRI and NRC development teams met in March to discuss the future development needs for xLPR v3
- Primary objective: **define a realistic and defensible scope for v3 release**
- NRC team led initial development, brought EPRI team up to speed

xLPR v3: Replicate v2.4 with Improved QA and Usability

- Development Strategy
  - Replicate xLPR v2.4 functionality on the new Go-based framework
  - Retain existing Fortran physics modules
  - Prioritize documentation, QA pedigree, and usability

- Development Process
  - Standardized developer training
  - Updated Software Management Plan (SMP)
- User-Facing Enhancements
  - User control of parallel processing (improved run efficiency)
  - Updated GUI for improved usability
  - Improved error logging and diagnostics

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