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Alternative Licensing Strategy

Risk Informed Analysis of Loss of Coolant Accident Induced Fuel Fragmentation, Relocation, and Dispersal

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NRC High Burnup Workshop
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Issue Statement

- Enhancements to fuel safety, reliability, efficiency and economics are critical to the industry, now and into the future
- Evolutionary fuel designs and materials (both cladding and pellets) have enabled increases in discharge burnup limits and uranium enrichments over the past several decades
  - Burnup limit currently at 62 GWd/MTU (rod average)
  - Enrichment limit currently at 5 weight percent U-235
- One generic issue for increasing burnup limit has been identified by the U.S. NRC as Fuel Fragmentation, Relocation, and Dispersal (FFRD) with fuel rod burst/rupture during design basis accidents (Ref: SECY-15-0148)
- Risk-informed methodologies are an effective method of identifying and addressing safety significant issues associated with design changes.

Challenges to Fuel Fragmentation, Relocation, and Dispersal (FFRD) Project Plans

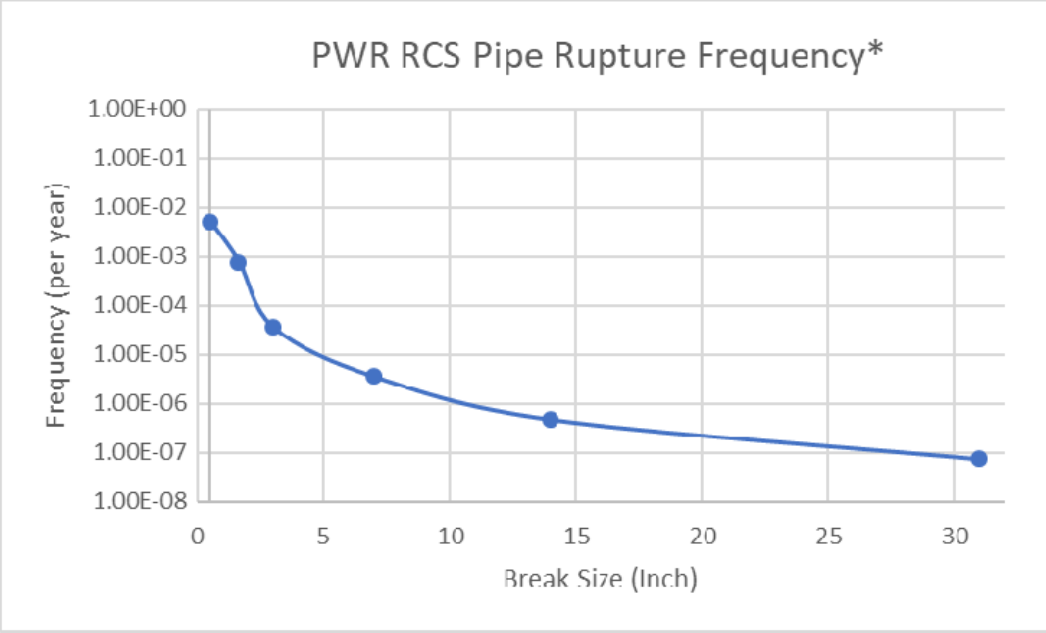
- Challenges to FFRD and Loss of Coolant Accident (LOCA) Testing Plans
  - Irradiated fuel shipments to INL delayed – Waste Treatment Operation
  - Other Schedule Uncertainties
    - LOCA/FFRD test execution
    - Data Analysis and Modeling
    - Topical development and approval
- Are there alternative licensing strategies with lower risk?
- Alternative Licensing Strategy Evaluation Project (Phase I)
  - Public Document
  - Publication Date July 31, 2020

Alternative Licensing Strategy Evaluation Project

- Collaboration Team Members
  - Utilities
  - Fuel Vendors
  - EPRI
  - MPR Associates (consultants)

LOCA Reactor Coolant System (RCS) Pipe Rupture Frequency and Impact on FFRD

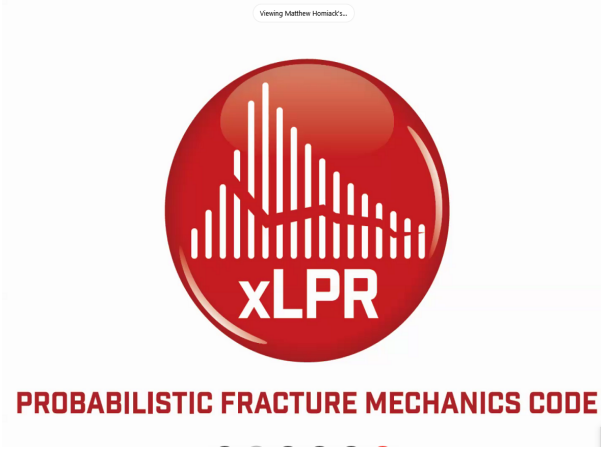
- Large Break LOCA (LB-LOCA) Events
  - Low Probability Event
    - Cladding Burst likely for high burnup interior fuel
    - Not Likely for peripheral fuel
- Small Break LOCA (SB-LOCA) Events
  - Higher Probability Events
  - Cladding Burst
    - Lower peak cladding temperatures
    - Burst not likely for high burnup pins
- Intermediate – Similar to small break events



* NUREG-1829, Vol. 2, Table 1

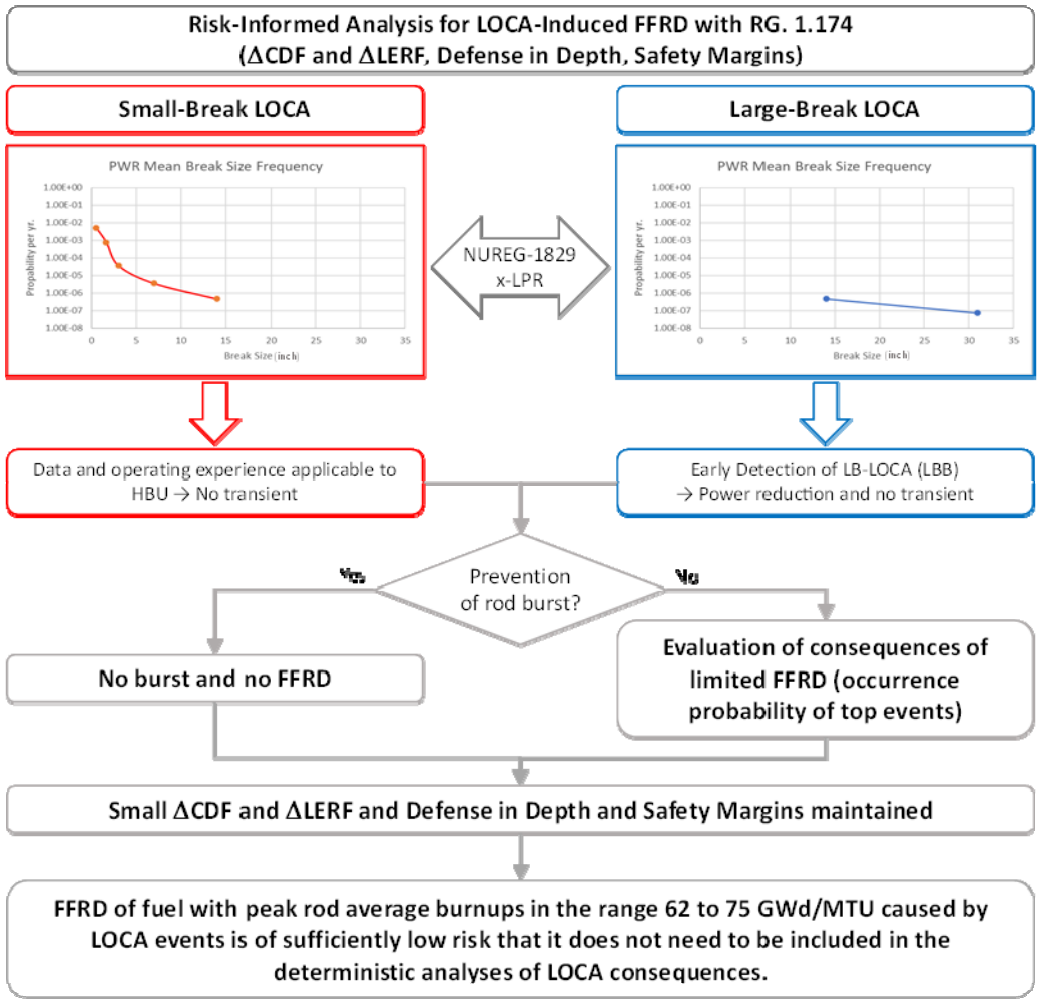
Leak Before Break (LBB)

- EPRI/NRC are finalizing xLPR (extremely low probability of rupture) models which supports risk evaluations of pipe rupture events
- Probabilistic Fracture Mechanics – Predicts probability of pipe rupture for defined leakage rate
  - Well characterized treatment of uncertainties
  - Active degradation mechanisms
  - Seismic Considerations
  - Inspection and mitigation activities
- All PWR Technical Specifications have 1 GPM unidentified leakage Limited Condition of Operations (LCO)
  - Mode 3 (Hot Standby) in 6 hours
  - Mode 5 (Cold Shutdown) in 36 hours
  - 24 hours after shutdown decay heat ~0.6 % of full power – LOCA non-event
  - xLPR Applications
    - Time to detect flaws leading to pipe rupture depends on pipe size
      - Large breaks detected well in advance
      - Small breaks more difficult to detect in short time frame
        - Estimate that timely detections are limited to ~10”
    - Validate NUREG-1829 conclusions



Risk Informed Analysis of LOCA induced FFRD

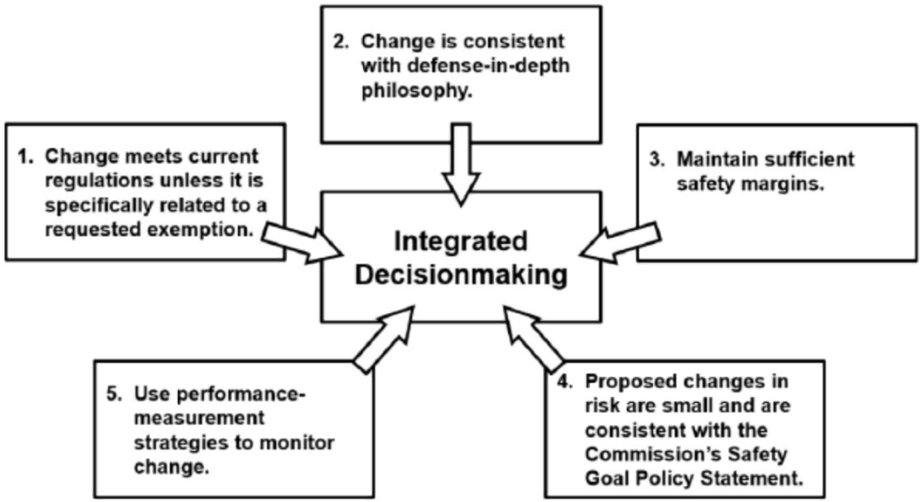
- Based on existing process – RG-1.174
- Small increase in Core Damage Frequency (<10^{-6}) and Large Early Release Fraction (<10^{-7})
  - Large Break – Credit Plant Shutdown (Leak Before Break) prior to LOCA
  - Small Break – No cladding rupture for high burnup fuel
  - Ensure overlap addresses Intermediate Break
  - Feasibility evaluations show lower risk than the target criteria by factor of 10 (regulatory margin)
- Defense in Depth/Safety Margins
  - Seven Principles for Defense in Depth addressed
  - Maintained with combination of SB-LOCA analysis results and Leak Before Break mitigation for LB-LOCA
  - Evaluation of fuel dispersal impacts provides a backup strategy



Risk Informed Process Based on RG 1.174 Process

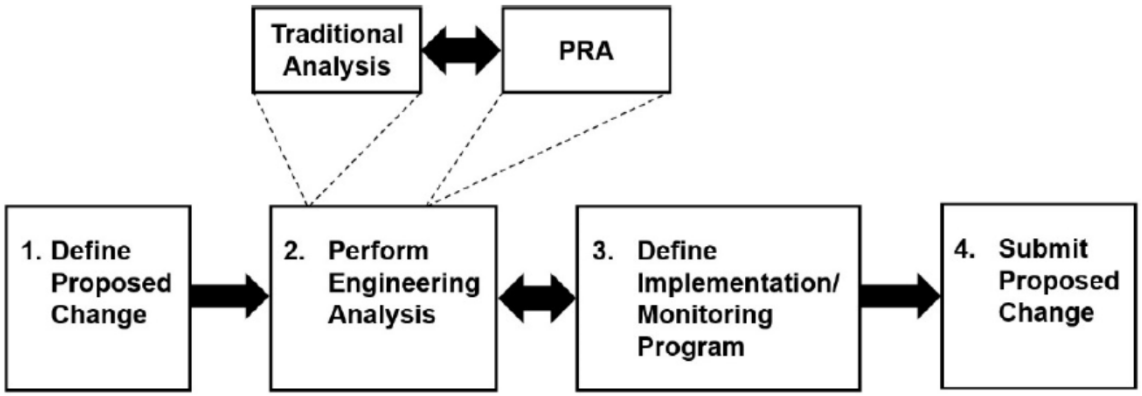
Licensing basis changes must:

1. Meet current regulations unless related to exemption request
2. Be consistent with defense in depth
3. Maintain sufficient safety margins
4. Result in no more than a small increase in risk
5. Be monitored using performance management strategies



Other Expectations within RG 1.174 Process

- Benefits commensurate with risk increases
- Analyses based on as-built and operated plant
- Plant specific PRA acceptable



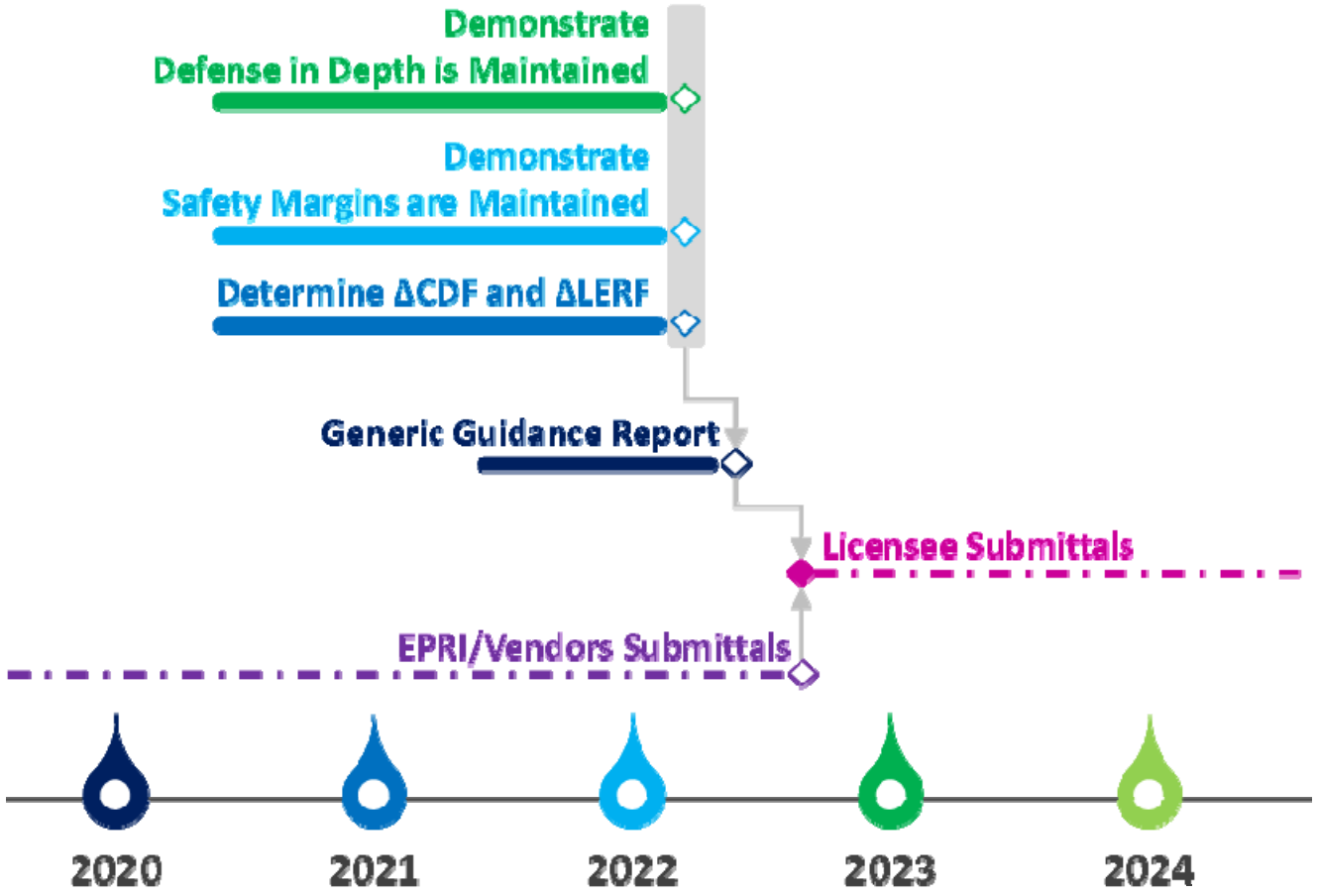
- Appropriate consideration of uncertainty
- Increases in CDF and LERF limited to small increments
- Evaluated in integrated fashion
- Data, methods, and assessment criteria well documented

Phase II – Identified Gaps for Phase II

- Validate LOCA rupture frequencies for 80-year operating life (xLPR)
- Determine fleet conditional containment failure probability
- Establish bases for FFRD probability inputs to PRA analysis
- Generic Small/Intermediate break size LOCA (no clad rupture)
- Demonstrate leak before break for Large and Intermediate break sizes
- Impacts of fuel fragmentation relocation into balloon region w/o rupture
- Demonstrate acceptable impact on Safety Margins
- Fuel dispersal model as backup to Defense-in-Depth arguments

Phase II – Gap Closure and Implementation (cont'd)

Roadmap to Inform Industry Submittals and Regulatory Reviews



Questions?

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