Initial Development of the Extremely Low Probability of Rupture (xLPR) Version 2.0 Code

by

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Introductory Note

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- This work is a continuation of the results presented at last year's PVP conference (PVP2012-57531)

- Final Pilot Study NRC/EPRI document has been published
  - xLPR Pilot Study Report. U.S. NRC-RES, Washington, DC, and EPRI, Palo Alto, CA: NUREG-2110 and EPRI 1022860. 2012.

GDC-4 and LBB

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- 10CFR50 Appendix A GDC-4 allows local dynamic effects of pipe ruptures to be excluded from design basis if pipe ruptures have extremely low probability of occurrence
- Local dynamic effects include pipe whipping and discharging fluids
- Commission-approved conservative flaw tolerance analyses developed and incorporated in SRP3.6.3 to demonstrate leak-before-break (LBB) and satisfy GDC-4
- One screening criterion in SRP3.6.3 requires no active degradation mechanism

xLPR

Problem / Motivation

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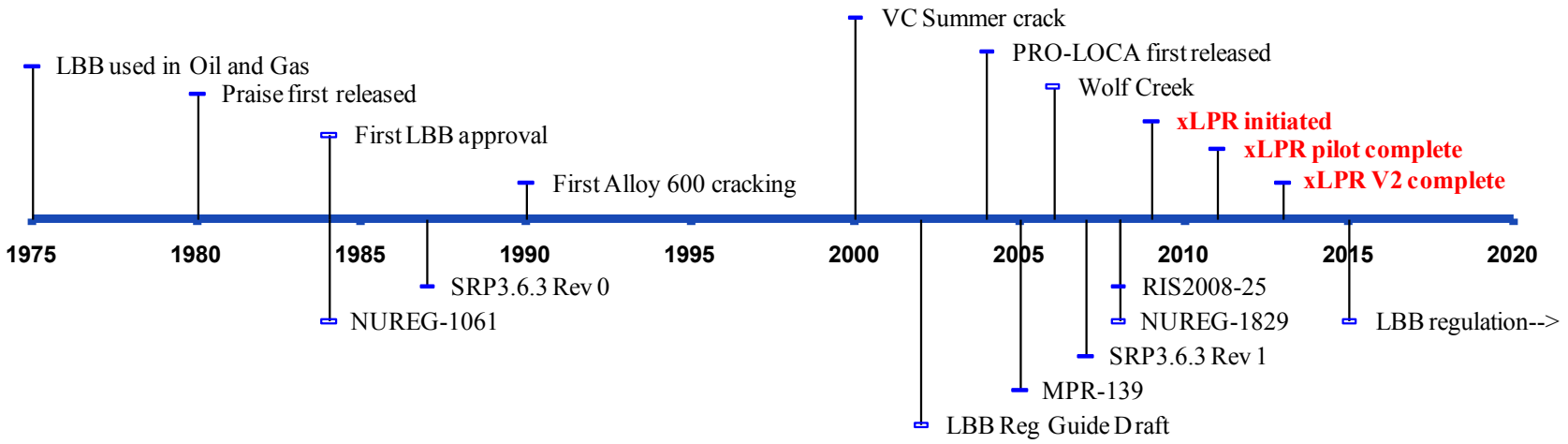
- LBB approved for piping systems prior to PWSCC operational experience
- LBB systems still in compliance with regulations
- Qualitative: mitigations and inspections
- Quantitative: probabilistic evaluation to assess compliance

LBB Events in History



xLPR Development

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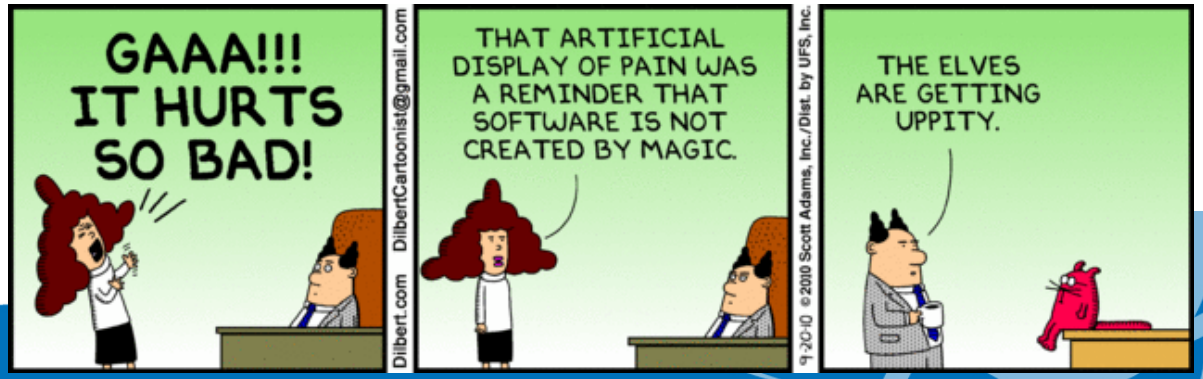
- NRC goal to develop "modular" code for evaluating the risk of pressure boundary integrity failure
- Currently focusing on piping issues
  - LBB
  - May be applicable to other needs
- Working cooperatively with EPRI through Memorandum of Understanding addendum
- Initial pilot study to assess effectiveness of approach



Code Development
Team Members

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Bruce Bishop – Westinghouse
Mark Dennis - EPRI
George Connolly - EPRI

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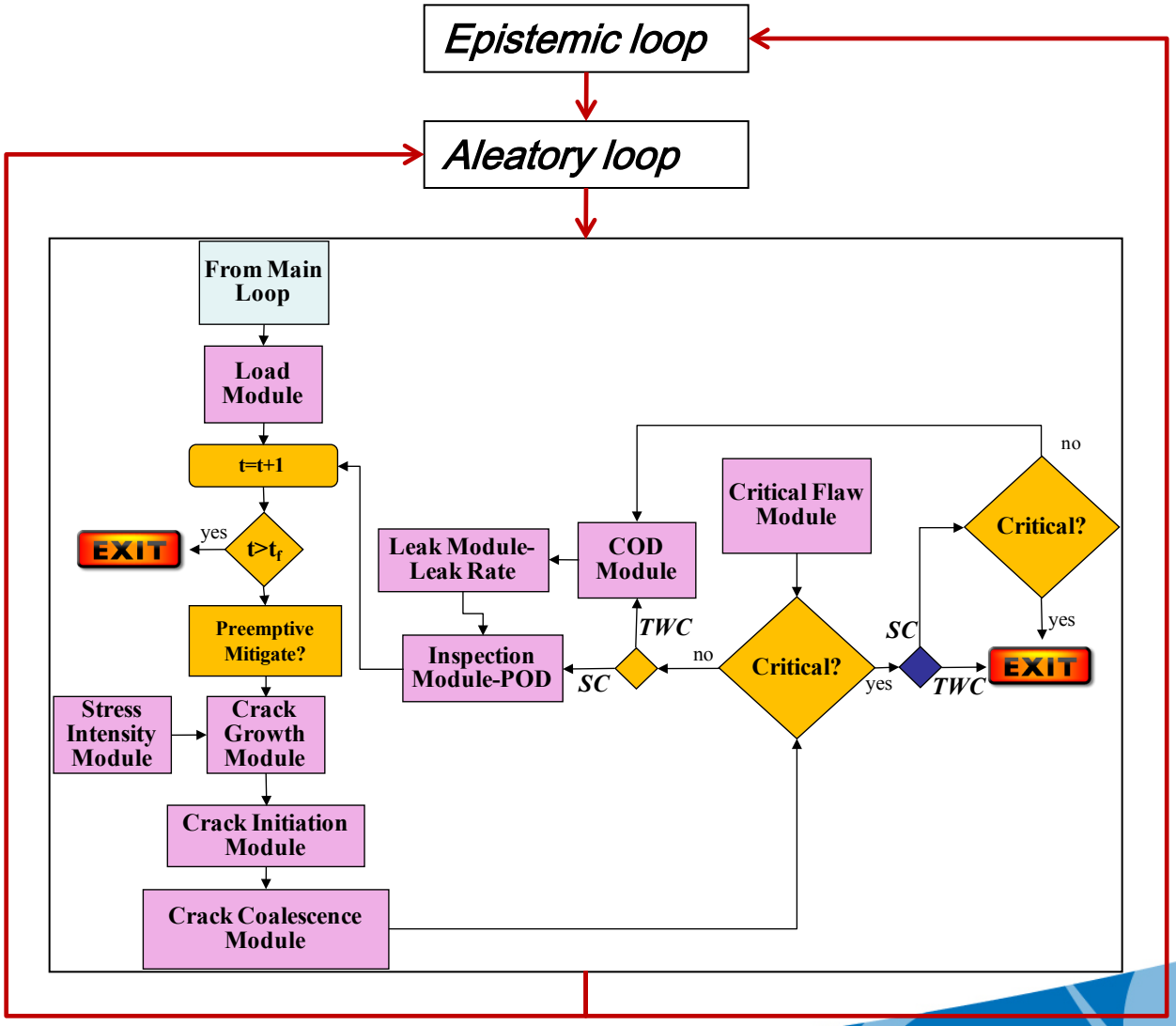
EPRI ELECTRIC POWER RESEARCH INSTITUTE
OAK RIDGE NATIONAL LABORATORY MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY
Sandia National Laboratories
PEAI
Structural Integrity Associates, Inc.
Exelon
Battelle *The Business of Innovation*
Emc²
AREVA
Dominion Engineering, Inc.
Pacific Northwest NATIONAL LABORATORY
Westinghouse

Cooperative effort between NRC and EPRI through Memorandum of Understanding

xLPR Process



Purple boxes represent self-contained, independent modules

Epistemic – Lack of Knowledge uncertainty

Aleatory – Irreducible uncertainty

Probability of leak/rupture

Models described in detail in PVP2010-25681

xLPR Framework

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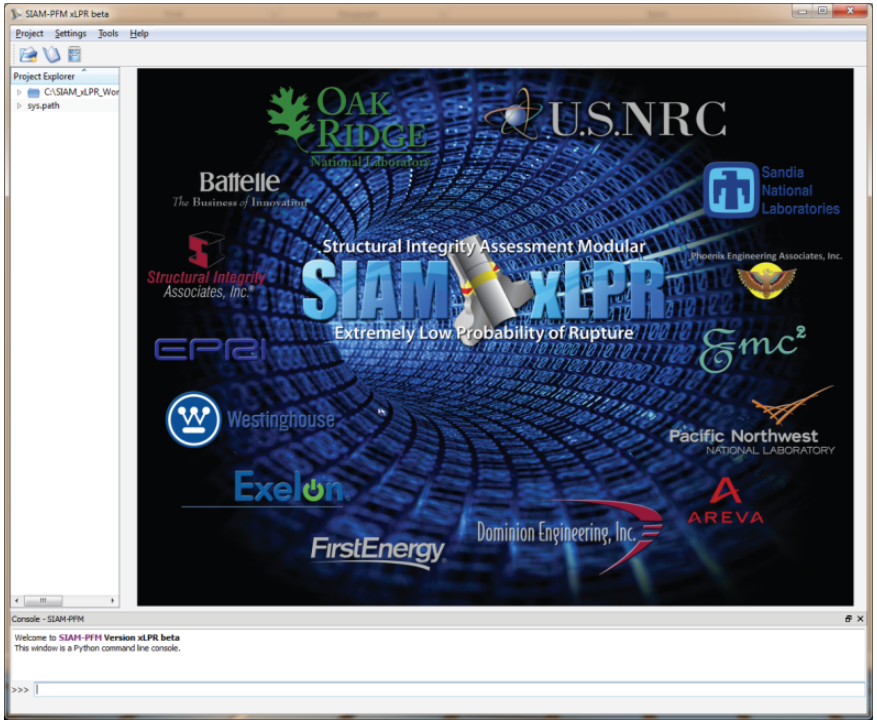

Fully Open Source

GoldSim Commercial Code

Two framework structures considered in pilot study
Framework code discussed in PVP2010-25963

Pilot Study Results

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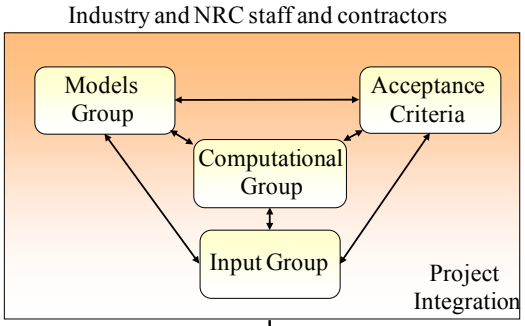
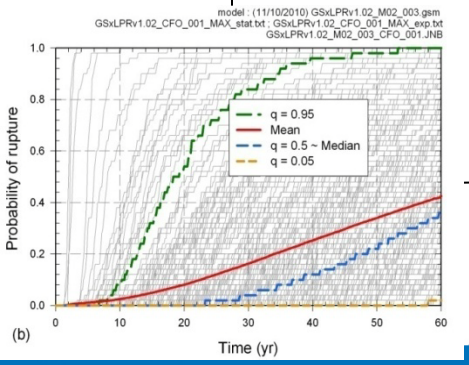
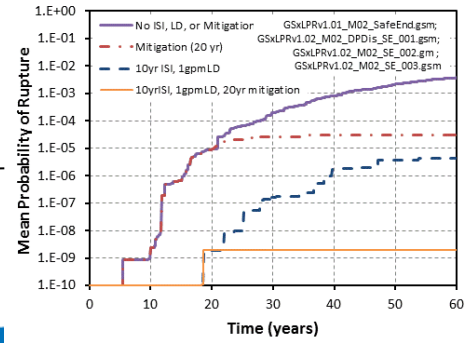
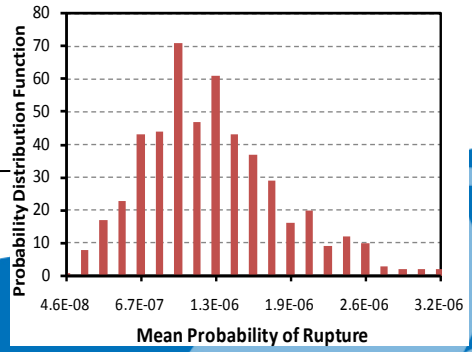
Process is FEASIBLE









Lessons:

- Management structure needs some work
- CM only a small portion of QA
- Best-estimate models are required
- Classification of uncertainty very important

Pilot Study Results

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- The project team demonstrated that **it is feasible** to develop a modular-based probabilistic fracture mechanics code within a cooperative agreement while properly accounting for the problem uncertainties.

- The project team demonstrated that the cooperative management structure was promising, but recommends slight restructuring.

- The GoldSim commercial software will be used for future xLPR versions.

xLPR Version 2.0 Scope

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- xLPR Version 1.0 was developed as part of a feasibility study and focuses on PWSCC in a Westinghouse-style pressurizer surge nozzle DM weld
- Version 2.0 is being expanded to handle welds within piping systems approved for LBB
- Capabilities of Version 2.0 will meet requirements for LBB lines, but must stay within available cost and schedule limitations
- Model inclusion in xLPR Version 2.0 does not guarantee regulatory approval. Process for obtaining approval of xLPR models is under discussion

Version 2.0 Scope "Modifications"

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- Framework
  - Investigate advanced methodologies to improve sampling efficiency and solution accuracy
    - Adaptive Sampling
  - Revisit uncertainty propagation methodology
  - Modify GoldSim for additional user capability
- Models
  - Revisit PWSCC initiation – Expert panel
  - Update WRS model – more generic, better uncertainty
    - Piece-wise linear representation
  - Update K-solution to be consistent with updated WRS model
    - Universal weight function method

Red font represents high priority items

Version 2.0 Scope "Modifications"

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- Models
  - Update mitigation to include FSWOL,OWOL, Inlay, surface treatment, and other chemistry
  - Update ISI model – sizing, POD, simplified model
  - Update crack stability – Surface crack EPFM
  - Update leak rate model – Look-up table, SQuIRT,
  - Update COD tension and bending blended solution.
- Inputs
  - Update load definition to include transients
  - Retrieve all relevant data for
    - One reactor coolant loop - Westinghouse PWR
    - One reactor coolant loop - Babcock & Wilcox (B&W) PWR
    - Others may be considered

Version 2.0 Scope "Additions"

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- Framework
  - Microsoft Access dB for inputs
  - Pre-processor to condition inputs
- Models
  - Environmental fatigue
  - Axial cracks
  - IGSCC
  - Surface crack-to-through wall crack transition
  - Manufacturing defects

xLPR QA

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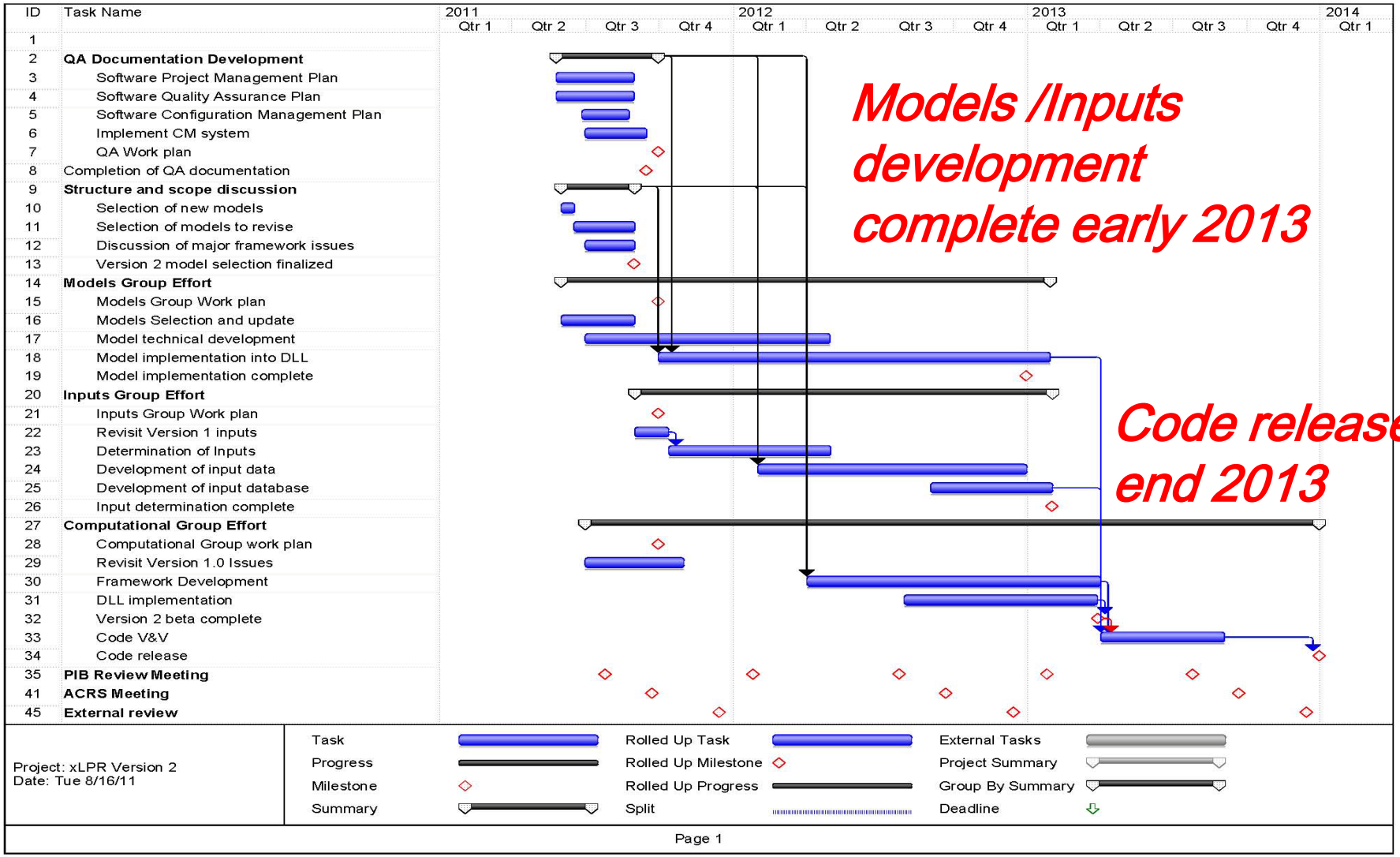
- Version 1.0 development was controlled by a Configuration Management plan but not associated with a detailed QA structure
- Conducted QA workshop with diverse group of Regulatory/Industry QA experts
- Consensus agreement that the top level requirements in ASME NQA-1 are sufficient to meet xLPR program, NRC, Industry, and DOE requirements for software development and regulatory use
- QA audits will occur and be aligned with key milestones

Version 2.0 Schedule

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