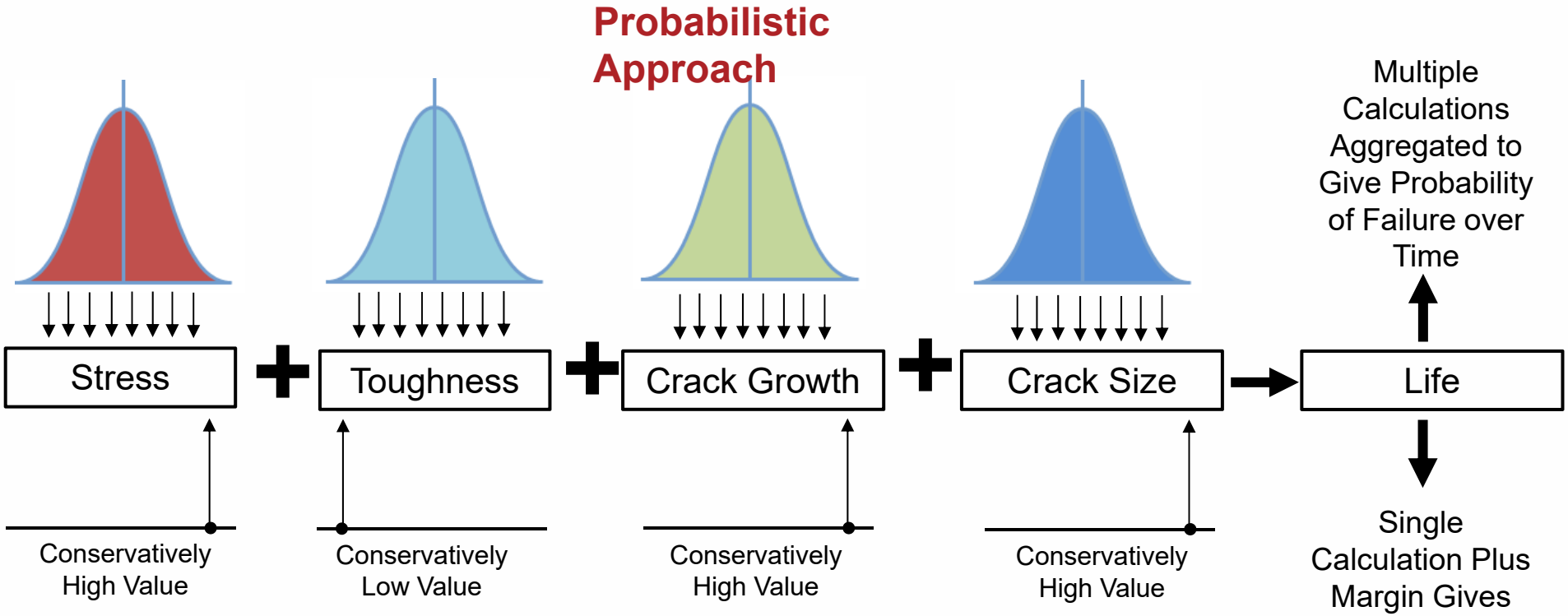
xLPR Version 2 Code Overview and Features

OVERVIEW

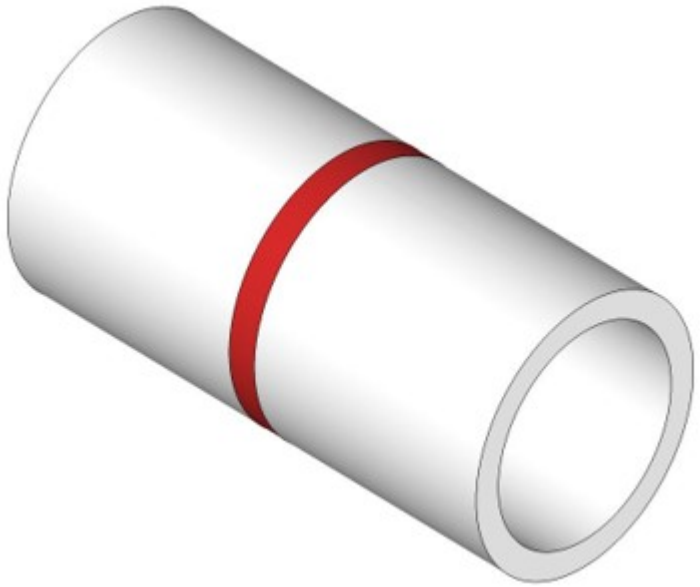
- Probabilistic fracture mechanics software tool for nuclear power plant piping integrity risk analysis
- Joint effort by the NRC's Office of Nuclear Regulatory Research and the Electric Power Research Institute (EPRI), now in second version
- Capable of modeling the effects of stress-corrosion cracking (SCC), fatigue, crack initiation, residual stresses, mechanical and chemical mitigation, and more
- Used by NRC and EPRI staff and contractors to risk-inform industrywide emerging piping integrity issues via probabilistic approaches

PROBABILISTIC VS. DETERMINISTIC



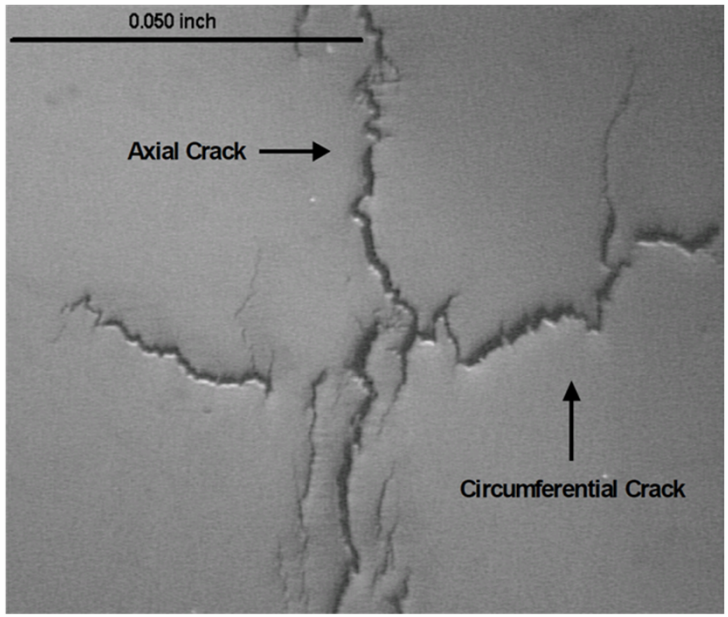
PIPE MODEL

- Geometry
  - Piping butt-weld
- Materials
  - Dissimilar metal weld
  - Similar metal weld



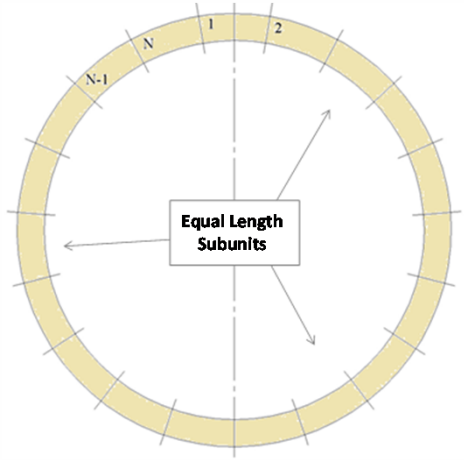
DEGRADATION MECHANISMS

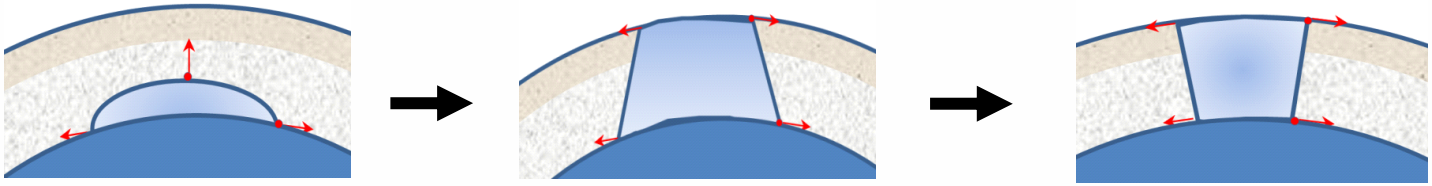
- Crack initiation
  - Initial flaws
  - SCC
  - Fatigue
  - Both SCC and fatigue
- Crack growth
  - SCC
  - Fatigue
  - Both SCC and fatigue



CRACK MODEL

- Crack orientations
  - Circumferential
  - Axial
- Multiple cracks
- Crack lifecycle





Surface Crack

Transitioning Through-Wall Crack

Idealized Through-Wall Crack

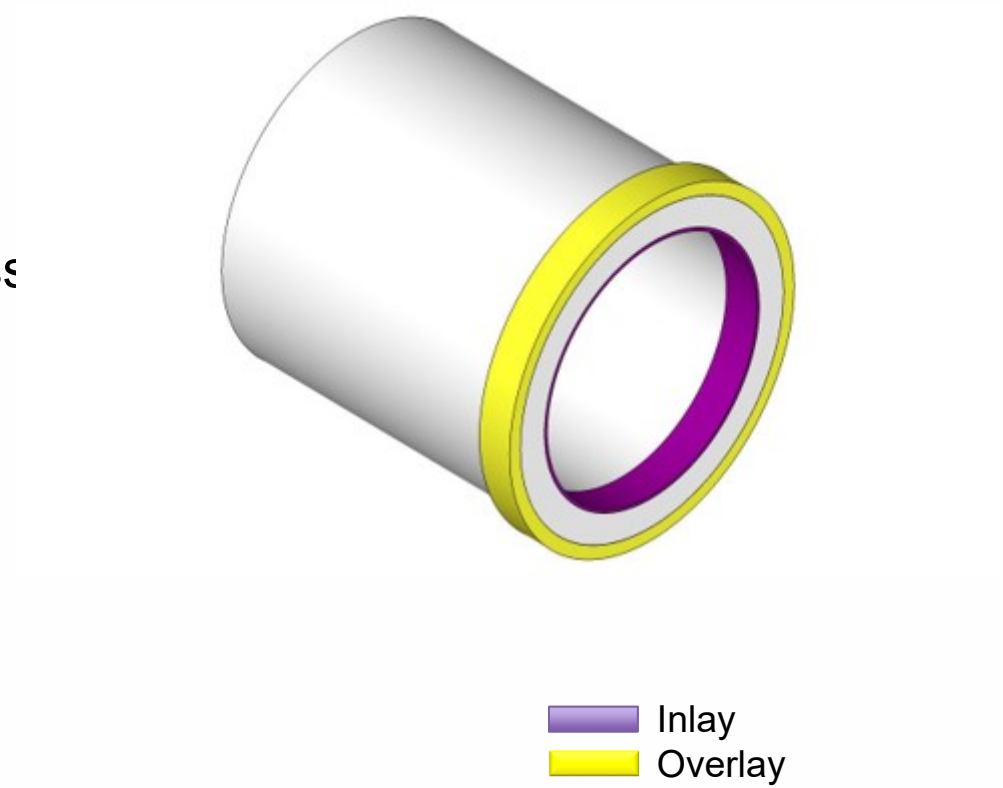
PLANT OPERATION MODELING

- Operating Conditions
  - Pressures
  - Temperatures
  - Stresses
  - Water Chemistry
- Mitigation

Refueling Outage	1	2	3	4	5	6	7	8	9	10
Operating Temperature	T=T1	T=T1	T=T1	T=T1	T=T2	T=T2	T=T2	T=T2	T=T3	T=T3
Operating Pressure	P=P1	P=P1	P=P1	P=P1	P=P2	P=P2	P=P2	P=P2	P=P3	P=P3
Zinc Concentration	Zn = Zn1			Zn = Zn2						
Mitigation Status	Unmitigated						Mitigated			
Time Interval	1			2	3		4		5	

MITIGATION

- Physical
  - Inlay
  - Overlay
  - Mechanical Stress Improvement Process (MSIP®)
- Chemical
  - Hydrogen
  - Zinc
  - Both

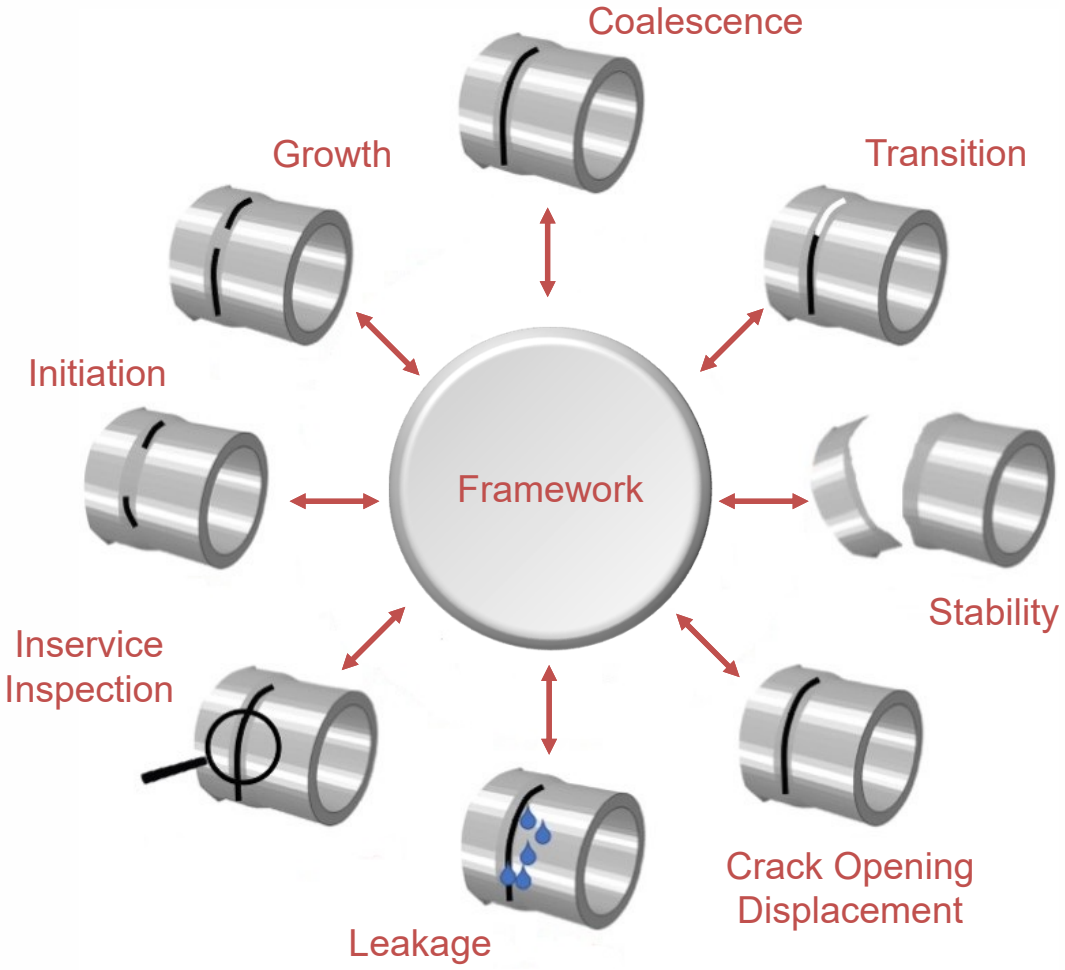


CRACK DETECTION

- Inservice inspection (ultrasonic testing)
- Leakage detection

CODE STRUCTURE

- Framework
  - User inputs
  - GoldSim Monte Carlo simulation engine
  - Time-stepping
  - Results
- Modules
  - Perform deterministic calculations
  - Fortran code

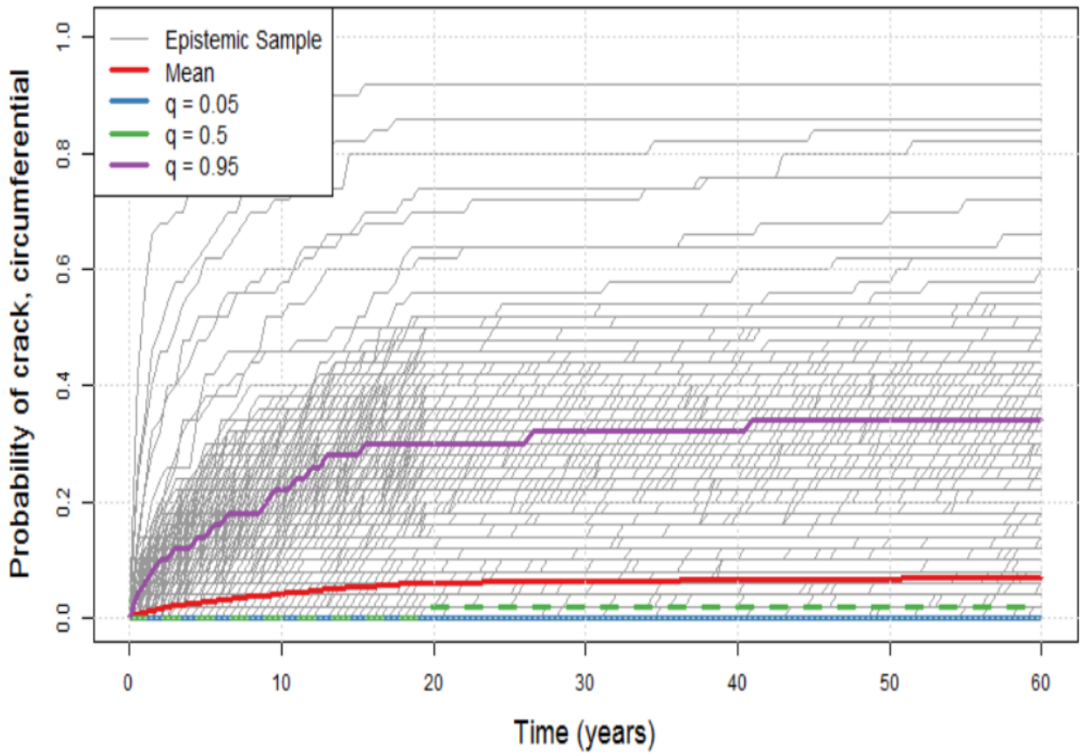


UNCERTAINTY HANDLING

- Dual loop structure
  - Aleatory (uncertainty due to natural variation)
  - Epistemic (uncertainty due to lack of knowledge)
- Supported probability distributions
  - Normal, log-normal, uniform, discrete, Weibull, triangular, etc.
- Sampling algorithms
  - Simple random
  - Latin hypercube
  - Discrete probability distribution
  - Importance sampling

CODE OUTPUT

- Probability of _____ vs. time
  - Crack
  - Leak
  - Rupture
  - Etc.



OTHER FEATURES

- Built under rigorous quality assurance program
  - Selected elements of ASME NQA-1-2008 and NQA-1a-2009 Addenda, which are endorsed for meeting NRC's 10 CFR Part 50, Appendix B, quality assurance requirements
  - Extensive technical documentation
- Verification and validation
  - 4,000+ verification tests
  - Validation of each physical model and of complete software against operating experience, finite element analysis simulations, and other probabilistic fracture mechanics codes
- Externally reviewed

SUMMARY OF CAPABILITIES

- xLPR V2 brings a breadth of modeling capabilities for the analysis of nuclear power plant piping integrity
  - SCC
  - Thermal and Mechanical Fatigue
  - Crack Initiation
  - Aleatory and Epistemic Uncertainties
  - Leakage Rate Calculations
  - Residual Stress Effects
  - Water Chemistry
  - Ultrasonic Inspections
  - Seismic Effects
  - Stress and Material Mitigation

Meeting Agenda

Introduction and Opening Remarks

Program History and Perspectives

xLPR Version 2 Code Overview and Features

Code Demonstration

Code Applications

Process for Requesting a Copy of the Code

Future Training Series

Questions and Answers

Closing Remarks