Code Demonstration and Code Applications

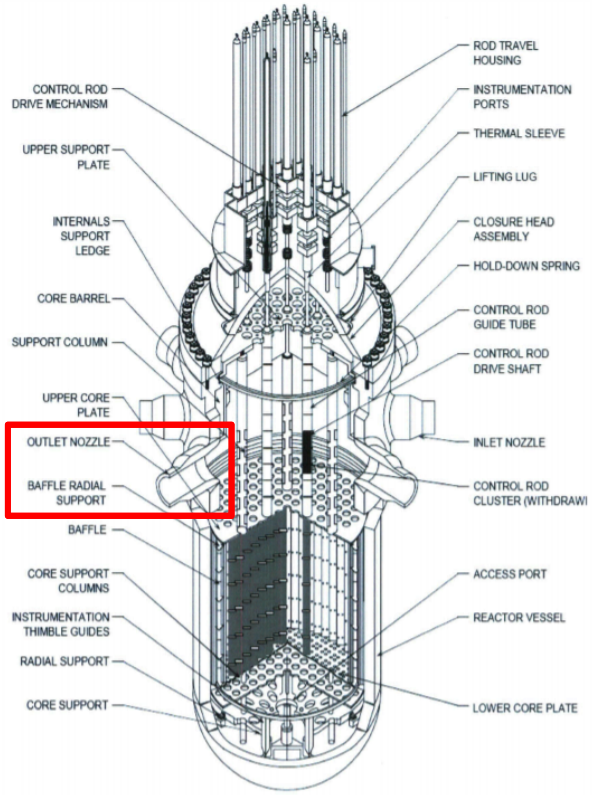
Running xLPR

Demonstration to show

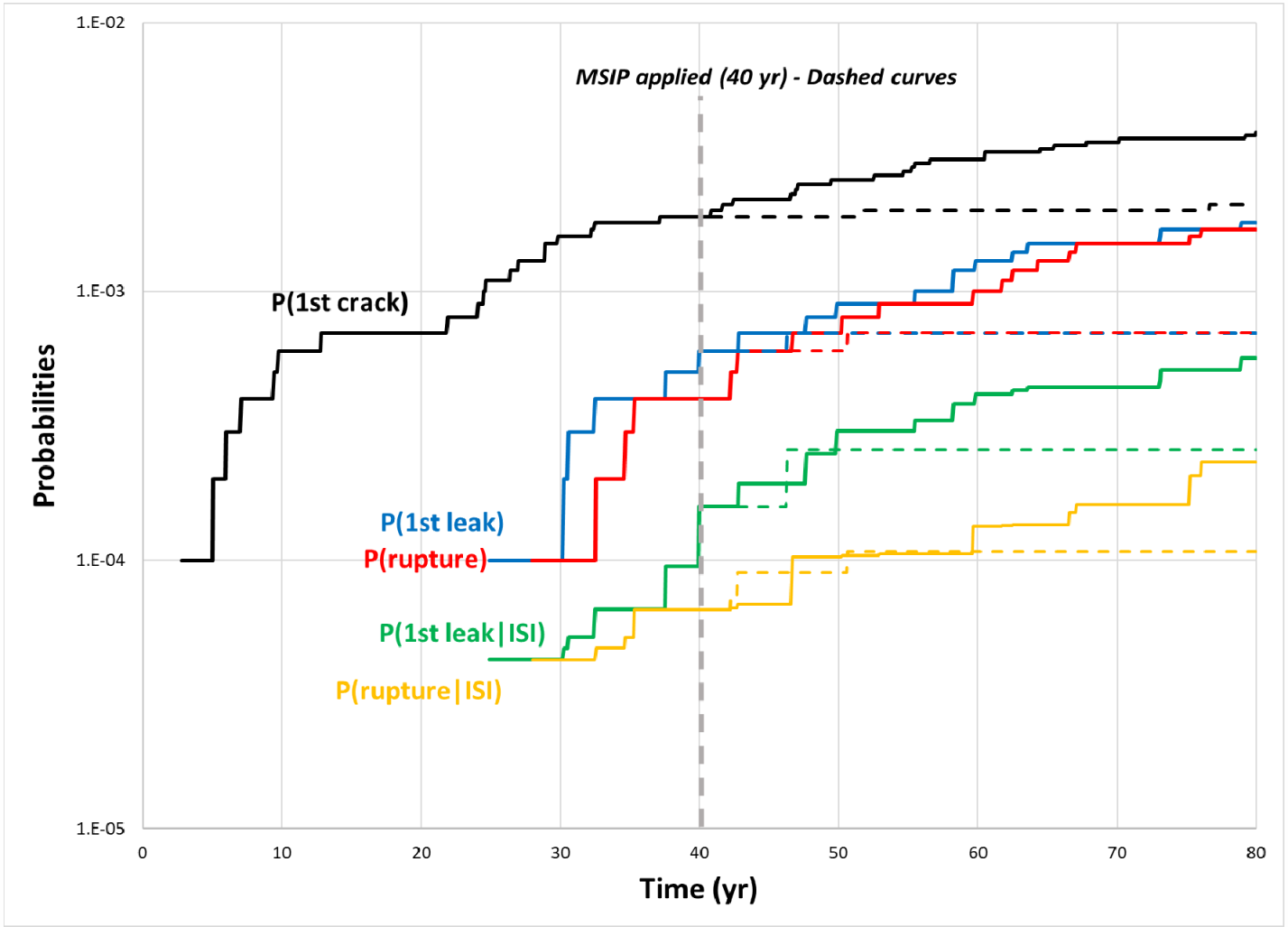
- Inputs setup and changes via the Excel file *(more direct when familiar with the code)* or the Sim Editor *(more user friendly)*
- How to use GoldSim to run the code
- xLPR run using the player *(free)* version of GoldSim
- Results from already run cases to focus on available outputs and data extraction
- The purpose is to illustrate some of the features. More in-depth training will follow in the future.
- Example application for leak-before-break (LBB) problem

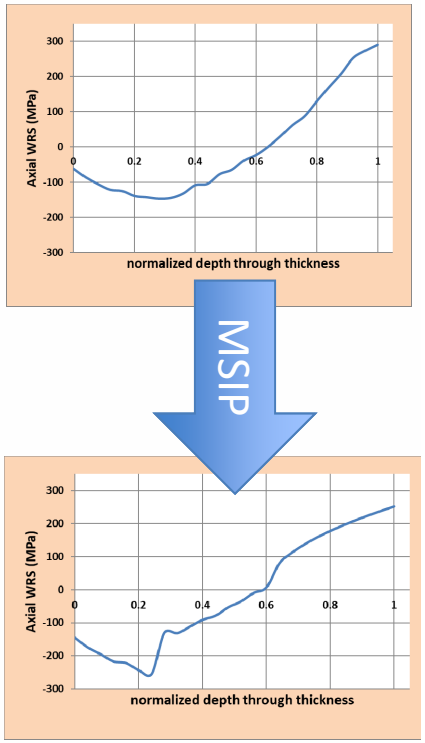
Example Problem: Primary Water Stress-Corrosion Cracking (PWSCC) Risk

- Reactor vessel outlet nozzle for a generic Westinghouse 4-loop pressurized water reactor
  - 34 inches outside diameter (0.869 m)
  - 2.6 inches thickness (0.0663 m)
  - Temperature: 320.5°C
  - Pressure: 15.41 MPa
  - Simulation time: 80 years (1-month timestep)
  - Impact of In-Service-Inspection (ISI) and Mechanical Stress Improvement Process (MSIP) presented



Direct Results from xLPR





Example LBB Application

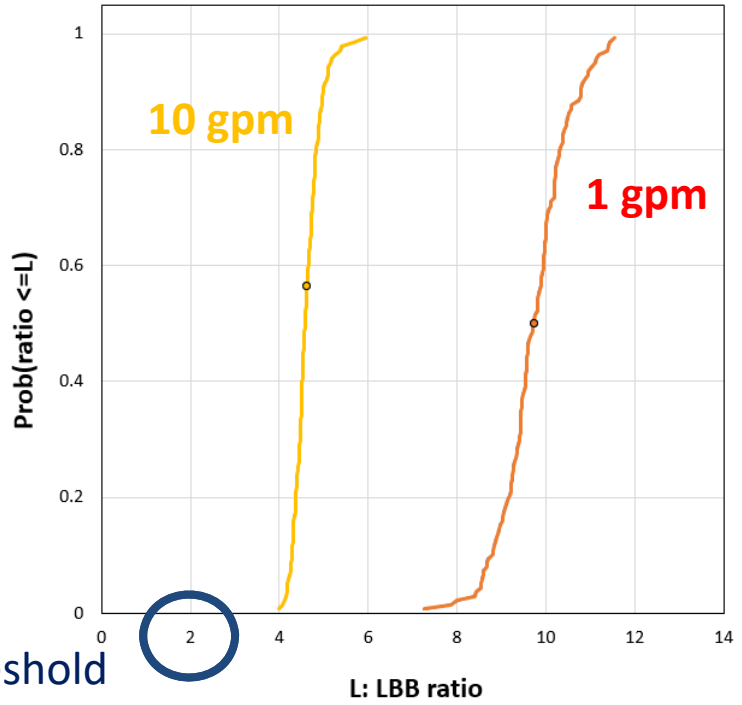
- Current LBB procedures follow NRC Standard Review Plan Section 3.6.3
  - Estimate crack size (c_l) required to have a 10 gallon per minute (gpm) leak rate (10 times the expected detectable leak rate)
  - Estimate critical crack size (c_c) leading to pipe rupture
  - Estimate LBB ratio (ρ) between critical crack size and leakage crack size: $\rho = \frac{c_c}{c_l}$
  - Acceptance criteria set at $\rho = 2$. Any ratio greater than 2 is acceptable.
- Procedure is **deterministic** and **static**
- Uncertainty is captured using **conservatism**

Probabilistic LBB

- NRC Standard Review Plan Section 3.6.3 is not applicable if there is an active degradation mechanism, such as PWSCC. Thus, there is need to address PWSCC in a risk-based framework.
- Increases in knowledge and computer capabilities have led to improvements over the years
  - Dynamic Codes (time-dependent simulation)
  - Probabilistic Fracture Mechanics (PFM) codes
  - Inclusion of additional mechanisms (surface crack rupture, impact of axial cracks, effect of mitigation/inspection, etc.)
- Conservatism can be reduced using a probabilistic approach (more realistic analysis)
- Dynamic calculations offer new types of evaluation criteria that are more informative

Example

- Probabilistic LBB ratio
  - Similar to one in NRC Standard Review Plan Section 3.6.3
  - Estimated for each realization leading to a distribution of the LBB ratio
- Based on larger Sample Size (100K total)
- Results quantify how conservatism can affect the answer



Motivation for Post-Processing/Extraction of Data

- NRC-EPRI piping system analyses considered results not directly calculated within xLPR
  - Included LBB ratio as well as time from detectable leakage to rupture
  - Rather than modifying the xLPR source code, the group decided to perform post-processing outside of xLPR
- In some cases, results from multiple runs were also desired
  - Memory limitations in the current xLPR version limit the number of realizations that can be evaluated in a given “run”
  - Consideration of increased realization counts allowed for evaluation of lower probability events

Post-Processing/Extraction of Data

- Third-party software can be developed to automate the extraction of data from xLPR and to expand the post-processing for additional applications
- A Python script with package PyAutoGUI was developed to automate extraction of millions of data points to plain text files for later post-processing
- A second script is then used to compute additional information for specific analysis including:
  - Mean and median time from leak to break across multiple xLPR runs
  - Mean and median time to rupture across multiple xLPR runs
  - Cumulative distribution function for LBB ratio across multiple xLPR runs

Conclusion of the Demonstration

- xLPR developed to be flexible and applicable to different problems
  - Large number of outputs directly available (probabilities of first crack, first leak, rupture, etc.)
  - Additional outputs available via intermediate results or with some simple changes in the code

Prospective Areas of Application for xLPR

- Further apply PFM approaches to optimize inspection and repair/replacement strategies
- Redefining design-basis break size
  - Could the manner in which large break loss-of-coolant accident (LOCA) is evaluated as a double-ended guillotine break be reduced to something more reasonable?
    - Possibility of xLPR demonstrating that the frequency of large-break LOCA is extremely low combined with the consequences of large-break LOCA proven to be not significant in probabilistic risk assessment
  - Environmental qualification impacts
  - Containment structural margins
  - Safety system response times

Prospective Areas of Application for xLPR Continued

- Licensing of High Burnup/High Enrichment Core Designs
- High Energy Line Break postulation
- Could a better understanding of LOCA frequencies change how Balance of Plant Systems are maintained or inspected?

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