Probabilistic Fracture Mechanics (PFM) Background

• New way of looking at engineering problems
  – PFM and DFM both address uncertainty, but differently
  – No longer 1 deterministic conservative analysis
  – Many deterministic analyses with randomly sampled inputs
  – Statistics performed on collection of outputs to determine probability of an event
Probabilistic Fracture Mechanics (PFM) Regulatory Issues

- Difficult for NRC staff to reproduce or verify PFM calculations
  - Complex regulatory review
  - ‘Black Box’ codes with insufficient vetting of inputs and code: low confidence in outputs

- Challenges where PFM was proposed as regulatory basis for long term inspection programs under NRC rulemaking
Need for PFM Guidance

• With advent of xLPR, increased number of industry PFM submittals expected
  – Proposed alternatives to ASME BPVC and ASME Code Cases
  – PFM calculations with new or modified PFM codes
  – Relief requests and topical reports

• Need to develop a regulatory guide to better inform applicants using PFM as a technical basis to support relief requests, license amendment requests, and topical reports

• Project main steps / deliverables
  – Technical Letter Report (short term, high level)
  – NUREG (longer term, in-depth technical basis)
  – Regulatory Guide (in parallel with NUREG)
  – Staff review guidance
  – Pilot study to test draft guidance
• GOAL: highlight important concepts that are relevant for PFM quality and confidence

• Topics covered:
  – Definition of PFM, including similarities and differences with deterministic analyses
  – Analysis models
    • Selection, definition
    • Verification & validation
    • Uncertainty
    • How to gain confidence in models used in PFM analysis?
  – Analysis inputs
    • Construction of input distributions
    • Input bounds
    • Quantification of assumptions and conservatisms
• Topics covered (cont’d)
  – Uncertainty framework
    • Identification and classification of uncertainty (epistemic/aleatory)
    • Probabilistic framework development, verification, and validation
    • Uncertainty propagation, sampling techniques
  – Analysis outputs
    • Convergence and stability
    • Output uncertainty analysis
    • Sensitivity analyses and studies
    • Problem drivers and confidence demonstration
  – Assessment of PFM quality
    • Displayed vs. required quality
    • Performance metrics
PFM Draft Regulatory Guide (DG) and Technical Basis NUREG (1/2)

- Draft guidance will outline a path for generating an acceptable PFM analysis
  - Process chart
  - PFM analysis tools
  - PFM analysis methodology
  - Reporting guidelines

- NUREG will follow DG outline and provide technical bases and other necessary details

- PFM analysis tool
  - Quality requirements and standards
  - Different paths to show acceptable quality based on ‘pedigree’ of tool
• PFM analysis methodology
  – Inputs
  – Analysis parameters, initial analysis, advanced analyses
  – Output uncertainty analysis
  – Convergence and stability
  – Sensitivity analyses and studies
  – Results assessment
  – Decision-making

• Reporting requirements
  – Software Quality Assurance (SQA)
  – Detailed documentation of analyses
Pilot Study: Testing the Draft PFM Guidance

• Define pilot study to test draft guidance
  – Use xLPR but do not treat as NRC code
  – Reference xLPR V&V to satisfy SQA requirements
  – Fictitious piping failure analysis problem that can test various aspects of guidance

• Follow draft guidance as best as possible

• Identify deficiencies in guidance

• Correct deficiencies in guidance

• Update draft guidance
Project Schedule and Milestones

• Final TLR available ~June 2017

• Draft Guidance and supporting NUREG technical basis:
  – Round #1
    • Initial Draft Guide (internal to NRC): September 2017
    • Initial supporting NUREG (internal to NRC): November 2017
  – Subsequent drafts through FY18
    • To be informed by pilot study lessons-learned, NRR review, and feedback from public meetings

• Pilot study:
  – Round #1:
    • Initial definition of pilot study in FY17
    • Initial study completed by March 2018
  – Subsequent rounds: April to September 2018
    • As needed based on changes to draft guidance
Public Involvement

- Public meetings:
  - Today
  - ACRS and public meeting after 1st round pilot study: May 2018 target
  - ACRS after final draft guidance is completed: September-December 2018 target
PFM Education and Training

• Work on PFM consistent with NRC’s risk-informed goals, however it is not as familiar as it might be to all practitioners & reviewers.

• Familiarization with PFM, and it’s many commonalities with deterministic approaches, enable more efficient review of PFM applications in the future.