xLPR Modular Code
Status and Update

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Annual Industry/U.S. NRC Materials Programs Technical Information Exchange Meeting
Rockville, MD
Thursday, June 9, 2011

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Topics Discussed

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- Brief background – Problem and Motivation
- xLPR Pilot Study (Version 1.0) Description
- Pilot Study Problem Results
- Pilot Study Conclusions
- Path Forward

GDC-4 and LBB

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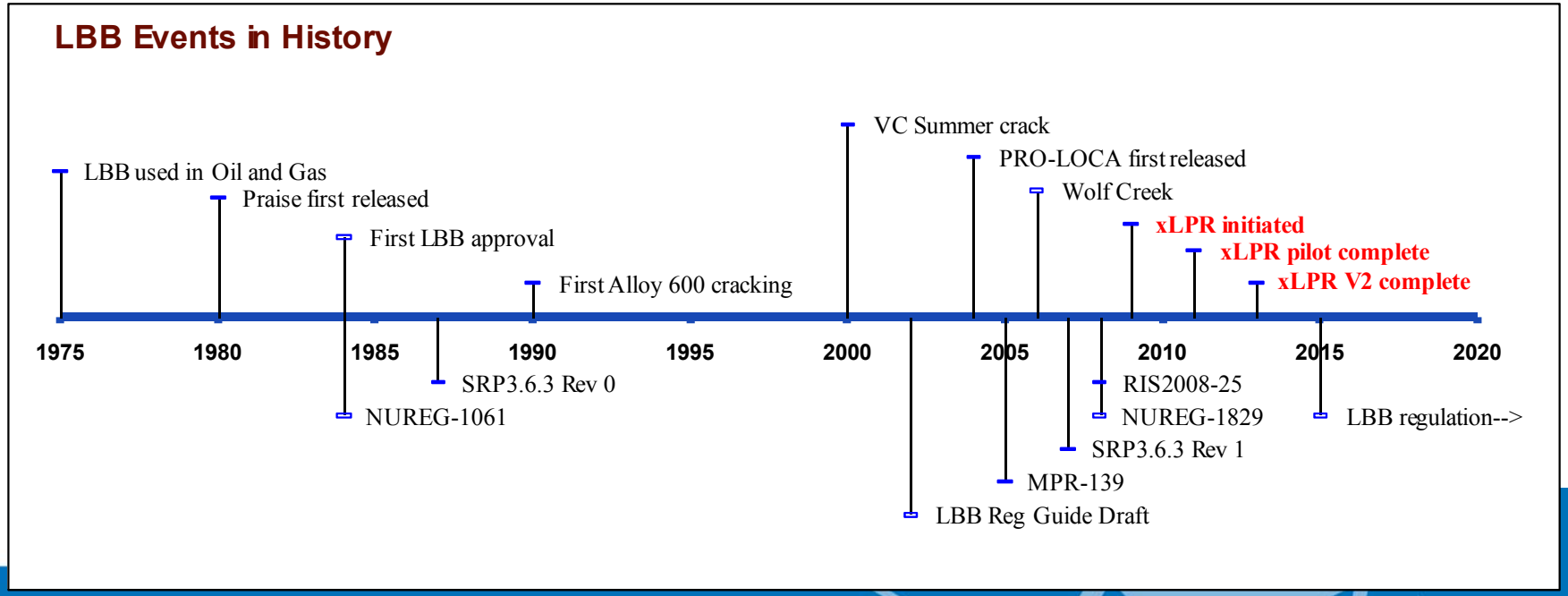
- 10CFR50 Appendix A GDC-4 allows local dynamic effects of pipe ruptures to be excluded from design basis if pipe ruptures have extremely low probability of occurrence
- Local dynamic effects include pipe whipping and discharging fluids
- Commission-approved conservative flaw tolerance analyses developed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

xLPR

Problem / Motivation

- 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



xLPR Development

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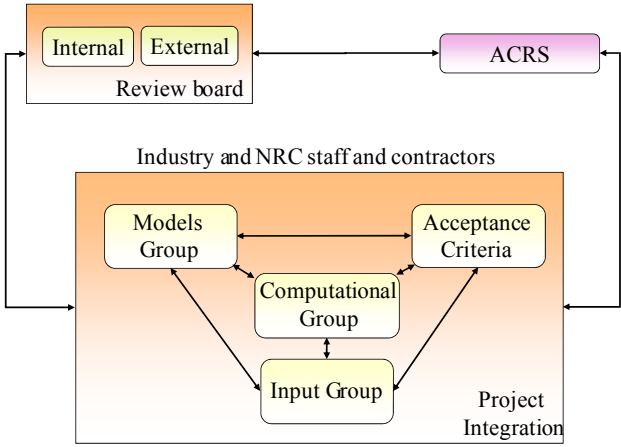
- NRC goal to develop "Modular" code for addressing issues related to Risk of Pressure Boundary Integrity Failure
- Currently focusing on piping issues (xLPR) to solve current LBB need. May be applicable to other needs
- Working cooperatively with EPRI through a Memorandum of Understanding Addendum



- NRC and Industry staff participation in all aspects of code development
- Initial pilot study to assess effectiveness of approach

Team Members

Computational Group
David Rudland – U.S. NRC
Bruce Bishop – Westinghouse
Nathan Palm – Westinghouse
Patrick Mattie – Sandia National Laboratories
Cedric Sallaberry – Sandia National Laboratories
Don Kalinich – Sandia National Laboratories
Jon Helton – Sandia National Laboratories
Hilda Klasky – Oak Ridge National Laboratory
Paul Williams – Oak Ridge National Laboratory
Robert Kurth – Emc^2
Scott Sanborn – Pacific Northwest National Laboratory
David Harris – Structural Integrity Associates
Dilip Dedhia – Structural Integrity Associates
Anitha Gubbi – Structural Integrity Associates

Inputs Group
Eric Focht – U.S. NRC
Mark Kirk – U.S. NRC
Guy DeBoo – Exelon
Paul Scott – Battelle
Ashok Nana – AREVA NP Inc.
John Broussard – Dominion Engineering
Nathan Palm – Westinghouse
Pat Heasler – Pacific Northwest National Laboratory
Gery Wilkowski – Emc^2

Acceptance Group
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Glenn White – Dominion Engineering Inc.
Aladar Csontos – U.S. NRC
Robert Hardies – U.S. NRC
David Rudland – U.S. NRC
Bruce Bishop – Westinghouse
Robert Tregoning – U.S. NRC

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Gary Stevens – U.S. NRC
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Darrell Paul – Battelle
Lee Fredette – Battelle
Craig Harrington – EPRI
Gabriel Ilevbare – EPRI
Frank Ammirato – EPRI
Patrick Heasler – Pacific Northwest National Laboratory
Bruce Bishop – Westinghouse

Program Integration Board
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Robert Hardies – U.S. NRC
Denny Weakland - Ironwood Consulting
David Rudland – U.S. NRC
Bruce Bishop – Westinghouse
Eric Focht – U.S. NRC
Guy DeBoo – Exelon
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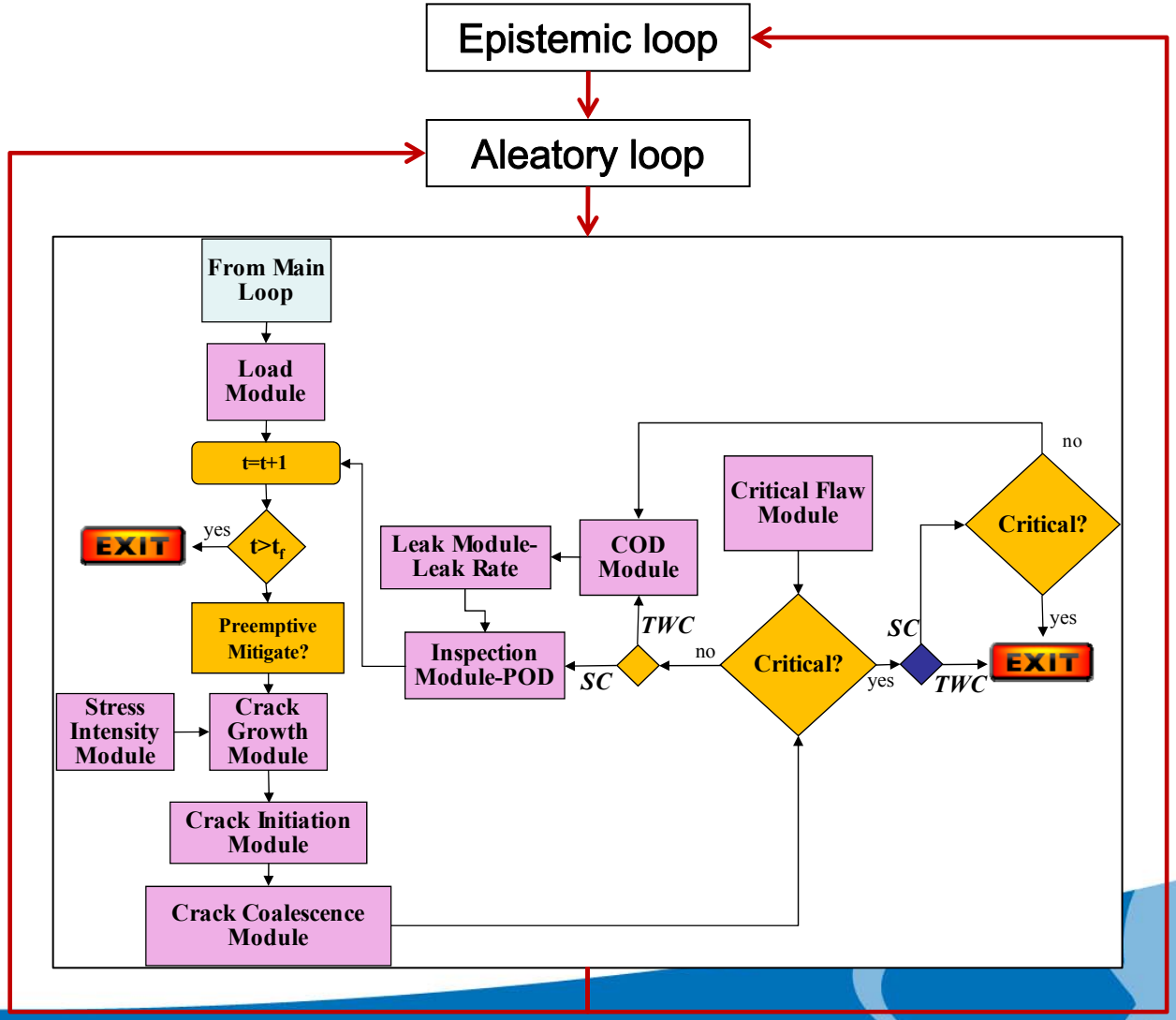
xLPR Process



Purple boxes represent self-contained, independent modules

Epistemic – Lack of Knowledge uncertainty

Aleatory – Irreducible uncertainty

Probability of leak/rupture

xLPR Framework

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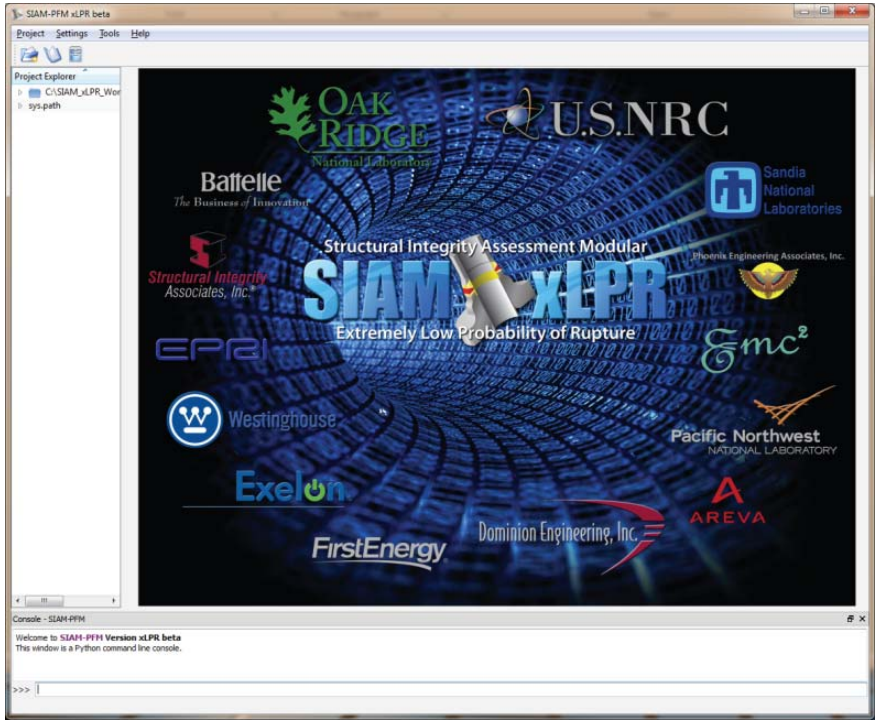

Fully Open Source

GoldSim Commercial Code

Pilot Study Problems

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Analysis	Description
Probabilistic Base Case	Probabilistic base case analysis using Monte Carlo sampling.
Sensitivity Study	
Stress Mitigation	Analyses evaluate different mitigation times, for the same stress-based mitigation.
Chemical Mitigation	Chemical effects of increasing the hydrogen concentration in the water on the crack growth module. Three hydrogen concentrations were evaluated.
Crack Initiation	Considers the crack initiation model uncertainty.
Safe End Evaluation	Considers stainless steel safe end weld, which causes a through-thickness bending stress that can reduce the tensile inner-diameter stress.

Uncertainty

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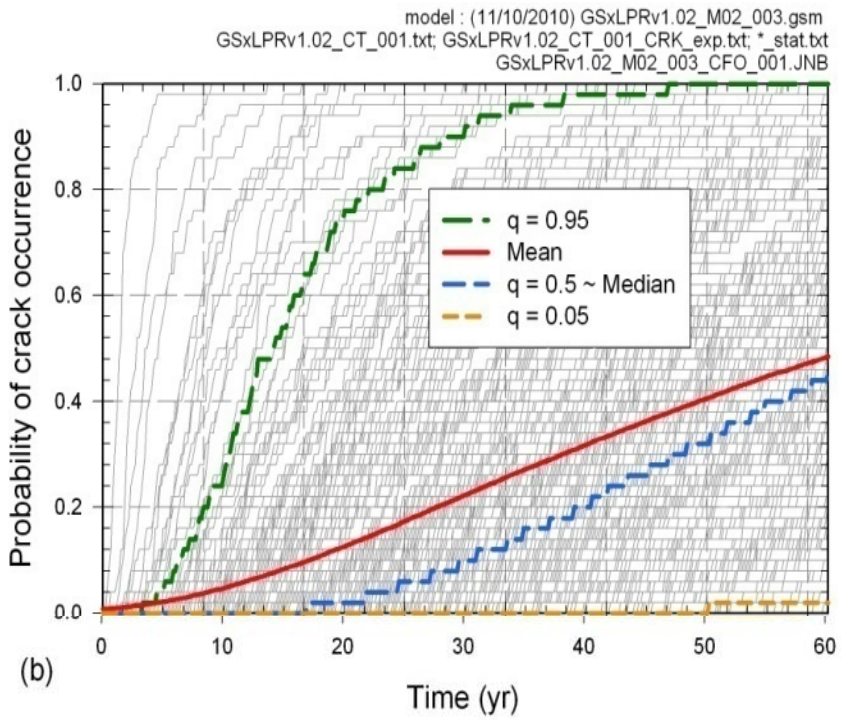
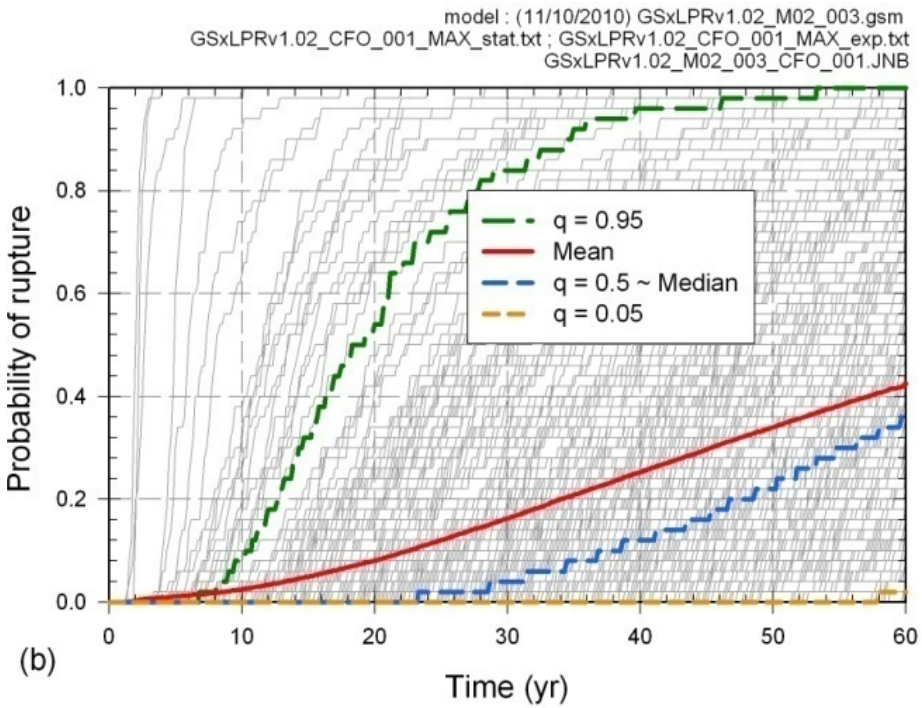
- Uncertainties were classified by models/inputs group
- More discussion needed, but satisfactory for pilot study

Epistemic (Lack of knowledge)	Aleatory (Irreducible)
• Loads • WRS • Crack growth (fweld) • Crack initiation parameters • POD parameters	• Crack size • POD detection • Material properties • Crack growth parameters (Q/R,c,P)

- Currently uses LHS (epistemic) and MC (aleatory)
- Importance sampling was demonstrated

Base Case Results





Problem is driven by crack initiation!!

Grey lines represent individual epistemic realizations

Base Case Results

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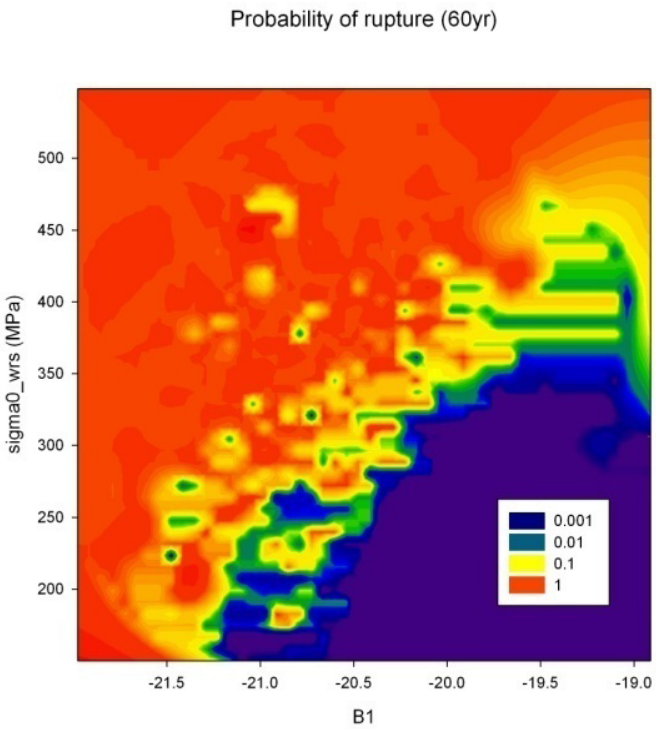
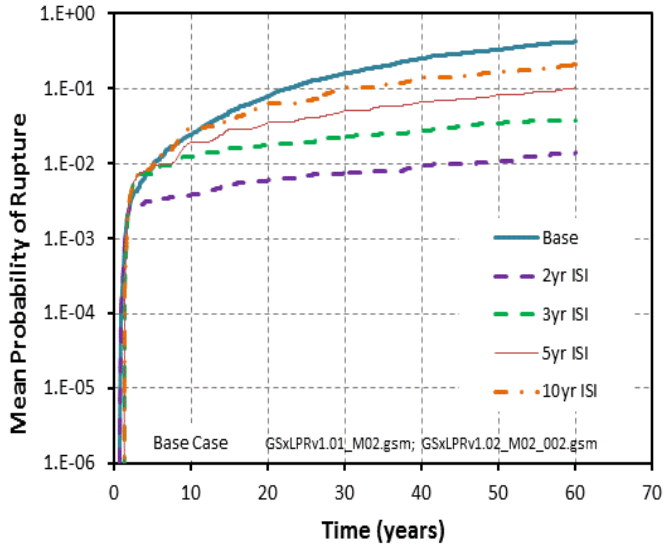
Sensitivity analyses were conducted to determine driving variables

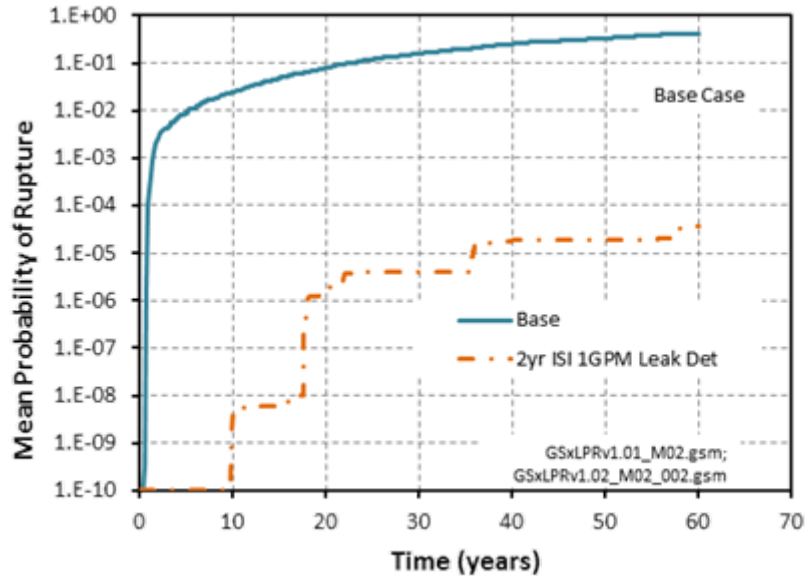
EXPCFO: 50 yr				EXPCFO: 60 yr			
var.	R^2	R^2 inc.	SRRC	var.	R^2	R^2 inc.	SRRC
SIG0WRS	41.80%	41.80%	0.5363	SIG0WRS	43.90%	43.90%	0.5764
B1	57.10%	15.30%	-0.3299	B1	60.70%	16.80%	-0.3568
FWELD	57.80%	0.70%	0.0701	FWELD	61.60%	0.90%	0.0853
RANDL17	58.00%	0.20%	0.0369	RANDP05	61.80%	0.20%	0.0391
				ODRAND	62.00%	0.20%	-0.0358

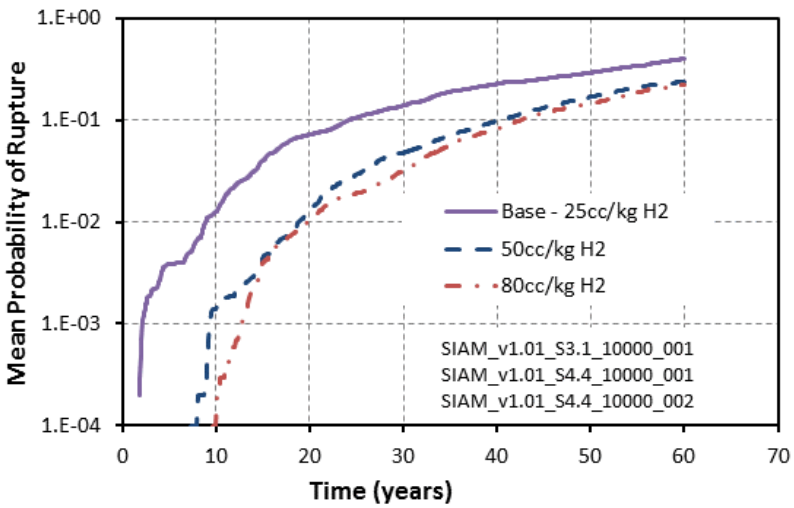


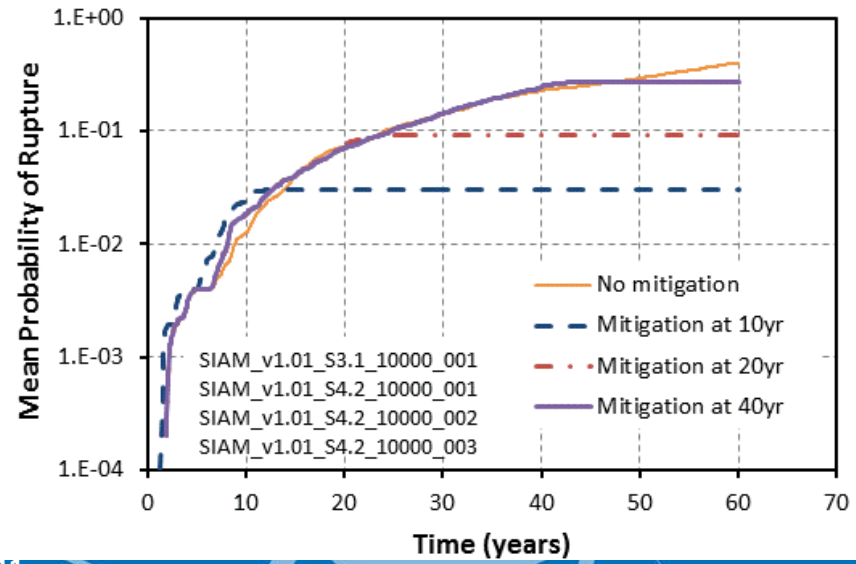
- R^2 - how much of the output variance is explained with the current input and all previous inputs
- The incremental R^2 - how much variance is explained by the addition of this input
- SIG0WRS – ID weld residual stress
- B1 – crack initiation parameter

Other Base Case Results









Safe End Sensitivity Case

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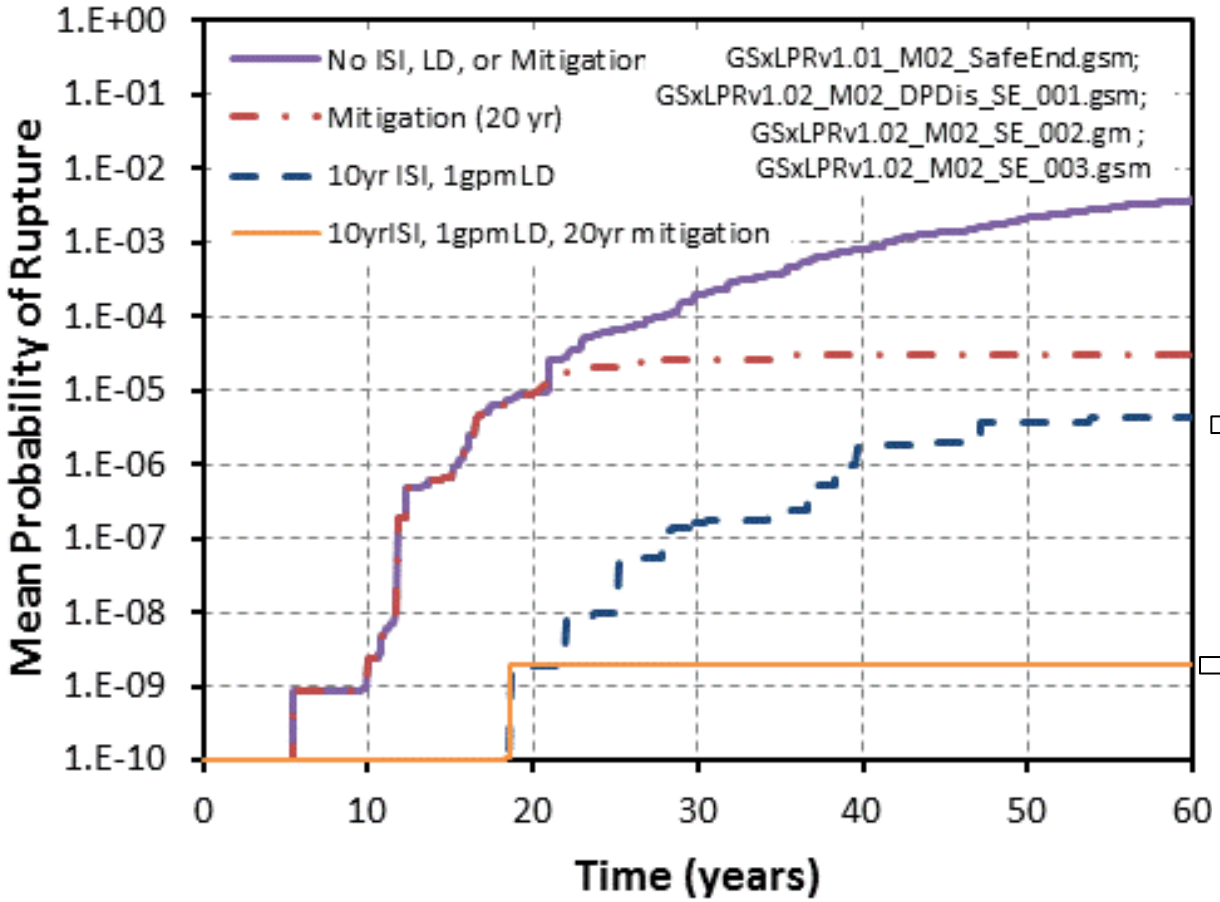

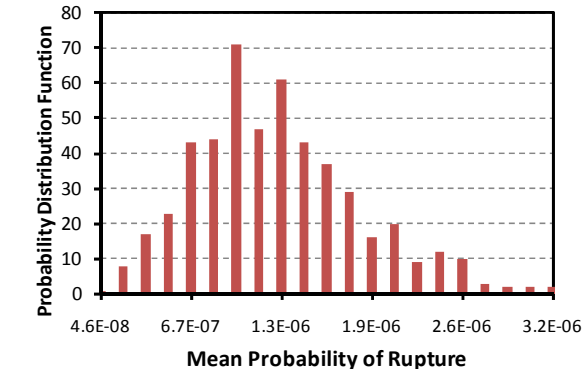

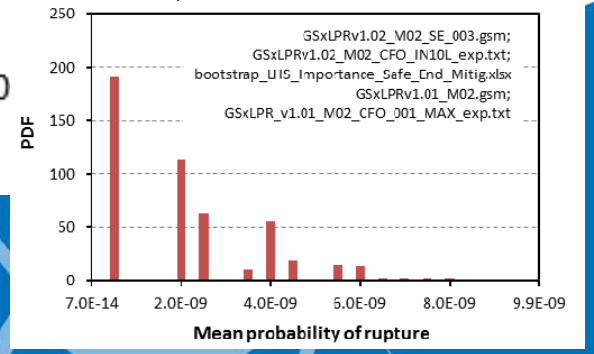

Pilot Study Results

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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 a code development leader be selected and the PIB be restructured as an advisory committee

Pilot Study Results

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- Based on the framework code comparison, a cost analysis, and long term prospects, the xLPR project team recommends that the future versions of xLPR be developed using the GoldSim commercial software as the computational framework

xLPR Pilot study Final Report

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- GSxLPR Users Manual ML110700017
- SIAMxLPR Users Manual ML110700023
- xLPR Version 1.0 Report ML110660292
  - xLPR Version 1.0 Goldsim Framework Report ML110700019
  - xLPR Version 1.0 SIAM Framework Report ML110700026
  - xLPR Version 1.0 Models/Inputs Report
    Being published as EPRI report
- Version 1.0 Comparison report ML111510924

Includes:
- Description of framework development
- QA and CM
- Pilot study problem and results
- Sensitivity analyses
- Code assessment and comparison with other
- Lessons learned
- Recommendations for further xLPR development

Written by SNL
Written by ORNL
Written by CNWRA
Written by Computational group
Written by Models/Inputs group
NUREG/EPRI Report

Path Forward

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- Project management restructuring - underway
- Version 2.0 QA program development – underway
- Version 2.0 Model and capability discussions – underway – Focus first on SCC initiation
- Version 2.0 Model development – Sept 2011
- Version 2.0 Framework implementation – April 2012
- Version 2.0 V&V – April 2013
- Version 2.0 release – End 2013