1 April 2015

MEMORANDUM

From: Dave Rudland (david.rudland@nrc.gov)
Nuclear Regulatory Commission

Craig Harrington (charrington@epri.com)
Electric Power Research Institute

To: xLPR External Review Board
David Steininger, EPRI (Chair)
Bjorn Brickstad, Swedish Radiation Safety Authority
Robert Dodds, Consultant
Edwin Hackett, NRC
Mohommad Modarres, University of Maryland

cc: Mark Kirk, NRC
Richard Bass, ORNL

Subj: xLPR team response to comments made in your report dated 3 December 2014

Thank you for the comments you have raised in the subject report. Attached you will find the xLPR team's responses to these comments. For each comment we have provided a response, a point of contact, and a resolution status. On question ID 3.1 we would value your feedback, and there are several other questions in which we have committed to providing you with documentation (e.g., the uncertainty report) when it becomes available in the future. Many of your comments and questions we feel have been resolved, at least as much as is possible within the context of the Version 2 or the xLPR Code.

The xLPR team expects a final meeting of the external review board to be held upon completion and release of Version 2.0. It is likely this meeting will be held near the end of 2015.

Please allow us to thank you once again for all of the time you have spent and insights you have provided; all of these provide a valuable addition to the project.

Detailed Responses to xLPR ERB Questions – 30 March 2015

ID	Category	Resolution Status	xLPR Owner
3.1	Highest	Feedback from ERB sought	Rob Tregoning, Robert.Tregoning@nrc.gov

Short Label: Synergistic effects of vibratory fatigue and corrosion for complex cracks

ERB Comment

An evaluation should be made of K changes for a circumferential, stress corrosion crack that propagates through-wall due to corrosion alone and then experiences a vibratory stress load (e.g., frequency of 10-20 Hz). The resultant delta-K for this through-wall, circumferential crack can cause rapid growth of the crack (in the circumferential direction), leading to an undetected leak rate and possible pipe rupture. This is particularly significant for complex crack front shapes and should be evaluated for a range of pipe sizes — including large diameter pipes such as the main primary loop. Various, potential crack front shapes should be evaluated for this condition. The xLPR team should identify the level of vibratory stress that can cause this situation to develop and determine if large diameter pipes in plants can experience this vibratory stress during operation, leading to pipe leakage and possibly pipe rupture. See also next related comment.

xLPR Response

This is a scenario that can be addressed using xLPR, either deterministically or probabilistically. In the US, high-cycle vibratory loading has primarily affected smaller diameter piping (diameter < 100mm). Several failures have occurred as these pipes are obviously more susceptible to break-before-leak. However, there is no US operating experience with vibratory fatigue contributing to degradation in larger bore piping. Additionally, a suitable vibratory loading source is not currently known for such piping. The most likely loading sources that would cause load oscillation in larger bore piping result from earthquakes and water hammers. These are scenarios that should be evaluated through sensitivity study, and such study should consider realistically conservative plant loading scenarios. Assessing higher cycle loading is contingent on developing a supporting technical basis. The xLPR team would appreciate if the ERB has knowledge of relevant operating experience or other information that would provide a basis for an appropriate sensitivity study.

ID	Category	Resolution Status	xLPR Owner
3.2	Highest	Sensitivity study in progress	Dave Rudland, David.Rudland@nrc.gov

Short Label: Possibility of break before leak

ERB Comment

An evaluation should be made on the possibility that a surface crack grows to have a very long circumferential length (or even to a fully circumferential crack) before it penetrates the pipe wall. After wall penetration, the crack length and COD along the OD may be so small that it is not discovered by leak-rate detection before the continuing crack growth leads to pipe rupture. This non-LBB situation, which is not generally covered by xLPR, can occur for a weld residual stress field (WRS) that has compressive stresses in the middle of the pipe wall in combination with very small operating stresses from global bending. Based on preliminary calculations performed by the ERB, the following parameter combination is proposed for study using advanced finite element analysis (AFEA):

(a) A typical surge nozzle geometry (D0 = 381 mm, t = 40.1 mm) with a WRS taken from supplement Q25 (slide 3) in the Replies to xLPR ERB comments from February 2013, “Effects of WRS on TWC Growth – Results from limited case studies” by Do-Jun Shim. This WRS should

be combined with global bending stresses of the range 0 – 20 MPa. Internal pressure is 15.4 MPa. A proposed initial crack size with subsequent crack growth is a depth = 1 mm, and length = 5-10 % of the pipe circumference.

(b) A typical hot-leg nozzle geometry (D0 = 862 mm, t = 60.2 mm) with a WRS taken from supplement Q25 (slide 7). This WRS should be combined with global bending stresses in the range 0 – 20 MPa. Internal pressure is 15.4 MPa. A proposed initial crack size for subsequent crack growth is a depth = 1 mm, length = 5-10 % of the pipe circumference.

(c) If the existence of such non-LBB situations is verified by AFEA, the xLPR team should identify the level of global bending stresses in combination with typical WRS that can cause this situation and determine if pipes in plants subjected to PWSCC can experience this during operation.

xLPR Response

The xLPR team will be conducting the appropriate analyses using AFEA to address this concern. It is expected that the results from this study will be completed by May 2015. These results will be provided to the ERB once they are documented.

ID	Category	Resolution Status	xLPR Owner
3.3	Highest	Sensitivity study in progress	Dave Rudland, David.Rudland@nrc.gov

Short Label: Can WRS be ignored if global bending stress is low?

ERB Comment

The xLPR code ignores WRS for PWSCC growth of a through-wall crack (TWC) and also for COD and leak-rate evaluation. This is probably a justified assumption in most cases. However, for a combination of WRS and small operating stresses from global bending that cause very long circumferential cracks before wall penetration, the effect of WRS on TWC can be important. The WRS may cause crack growth on the OD to propagate relatively slowly up to the point of pipe rupture. A non-idealized crack shape will thus be present at rupture causing a smaller leak rate compared to the situation if WRS is ignored. In analogy with item 3.2, this effect is seen only when the operating stresses from global bending are low. In contrast, a large global bending stress will (almost) totally extinguish the effect of WRS causing a straight crack front (parallel to the pipe radius) before rupture is predicted.

The ERB recommends that the xLPR team employ advanced finite element analysis (AFEA) to study the effect of WRS on TWC (regarding crack growth, COD and leak rate) using the same parameter combination of WRS and global bending stresses as in item 3.2. Note: for a particular TWC geometry (also for a non-idealized crack shape), the effect of WRS on leak rate is not significant. But since WRS will affect crack growth for a TWC if the global bending stress is small, WRS will also indirectly influence the COD and leak rate just before rupture. The problem is also related to the stability criterion used. The effect of WRS on TWC growth becomes more pronounced when the stability is controlled by J (which accounts for the secondary WRS stresses) compared to application of net section collapse criterion.

If the influence of WRS on TWC behavior is verified by AFEA, the xLPR team should identify the level of global bending stresses in combination with typical WRS that can cause this situation to develop and determine if pipes in plants subjected to PWSCC can experience this during operation.

xLPR Response

The xLPR team will be conducting the appropriate analyses using AFEA to address this concern. It is

expected that the results from this study will be completed by May 2015. These results will be provided to the ERB once they are documented.

ID	Category	Resolution Status	xLPR Owner
3.4	Highest	Information permitting, this may be addressed qualitatively using xLPR V2. Will consider formal Bayesian approach in xLPR V3.	Marj Erickson, Erickson@peaiconsulting.com
Short Label: Formal (Bayesian) mechanism to incorporate fleet experience			
ERB Comment The ERB recommends that the xLPR code include an option to incorporate formally fleet or plant operational experiences (e.g., leakage events, no event, age of the plant, etc.). Such experiences can be used to update the xLPR calculated leakage and rupture probabilities, possibly by using Bayesian Analysis. Additionally, it seems desirable to compare xLPR simulations with plant experiences and to assess any apparent bias in the xLPR prediction. Professor Modarres of the ERB has provided journal papers and other references to the appropriate xLPR team member that describe mathematical approaches to address a bias in xLPR predictions. (See related item 3.6).			
xLPR Response xLPR simulations will be compared to any available plant experience. This information will be used to assess any bias in the predictions. The use of formal Bayesian methods to incorporate fleet experience or to account for any bias will be assessed but likely is beyond the scope of the current V2.0 project.			

ID	Category	Resolution Status	xLPR Owner
3.5	Highest	Resolved	Remi Dingreville, rdingre@sandia.gov
Short Label: Users should not bear primary responsibility to establish correlation coefficients			
ERB Comment The parameters used in some sub-models of the xLPR code appear to be correlated. How xLPR develops, computationally treats, and handles such dependencies remains unclear after this ERB meeting. It appears that users are largely responsible to provide estimates for the dependencies. The correlation coefficient representing such dependencies should be estimated from the regression fit of the sub-models to the relevant underlying data that support the sub-models. The user should not have primary responsibility for setting the correlation coefficients. Available data should be used to establish the sub-models and the correlation coefficients.			
xLPR Response A set of pre-defined parameters are correlated based on recommendations from the sub-model groups. Only pairwise correlations are allowed avoiding the manipulation of correlation matrices. Recommended correlations will be provided with the release of the code and justification for the use of such correlation factor will be detailed in the User Manual.			

ID	Category	Resolution Status	xLPR Owner
3.6	Highest	Resolved	Marj Erickson, Erickson@peaiconsulting.com

Short Label: Can the assumption of free rotation of pipe ends lead to a non-conservative result

ERB Comment

The ERB recommends that plant piping conditions, such as pipe restraint locations, be reviewed to determine if a non-conservative condition can exist that produces non-detectable (low) pipe leakage leading to rupture — and is not bounded by the free rotation condition for pipe ends presently used in the xLPR code. Example: even though the assumption of pipe free ends for boundary conditions produces a conservative result for pipe rupture probability, it will overestimate the leakage produced prior to rupture. An overestimation of pipe leakage is considered non-conservative because of the higher probability that the leakage would be detected for a given COD. The ERB would like to see a discussion on how the xLPR team balances non-conservative and conservative results in such a scenario as the one just described.

xLPR Response: The xLPR team has no current plans and is not aware of formal plans (either industry or regulatory) to assess and review actual plant piping conditions to determine whether such non-conservative conditions CAN exist. However, the effects of all model conservatism/non-conservatism will be assessed on downstream models and overall xLPR code predictions. This is one of many topics that will be addressed in the forthcoming "Uncertainty Report." This report will be sent to the ERB upon its completion, which is expected to occur in the Fall of 2015.

ID	Category	Resolution Status	xLPR Owner
3.7	Highest	Resolved	Marj Erickson, Erickson@peaiconsulting.com

Short Label: Explain the representation of some parameters as constants while others are modeled as uncertain.

ERB Comment

It is not clear why some sub-model parameters are constant and others variable for an applied uncertainty distribution. This approach should be explained in the xLPR documentation for those sub-models where this occurs. An example of the xLPR approach is provided by the Weibull distribution for leak rate. For a two-parameter Weibull model, it is our understanding that the Weibull slope (i.e., shape parameter) is kept constant and the scale parameter treated as uncertain. This approach requires justification — it seems that both parameters should be uncertain. This comment applies to all other sub-models where constant values of parameters are used.

xLPR Response

This is one of many topics that will be addressed in the forthcoming "Uncertainty Report." This report will be sent to the ERB upon its completion, which is expected to occur in the Fall of 2015. The information in the Uncertainty report will come from the Module Subgroup reports in which uncertainty characterization justification is required. See the following outline regarding discussions of parameter uncertainty:

Module parameter inputs

1. *Physical description of*
2. *Values*
3. *Source of values (laboratory data, field data, theoretical)*
4. *Uncertainty characterization (with justification) of values/distributions*
    a. *Constant/aleatory/epistemic*
    b. *Distribution, range, scatter characterization (std dev)*
    c. *Sampling recommended*

ID	Category	Resolution Status	xLPR Owner
3.8	Highest	Resolved	Gary Stevens, Gary.Stevens@nrc.gov

Short Label: Input error trapping

ERB Comment

The xLPR code should incorporate "alerts" in the user interface when an input value is not consistent with recommended values used in xLPR.

xLPR Response

Data range validity checks will be incorporated into the new xLPR Simulation editor interface that will alert the user on inputs that are outside of the valid range defined by the models. Development of this new interface is still on-going, scheduled for release in the May timeframe. Note, however, that, if the user elects to edit the Excel inputs spreadsheet directly, instead of entering inputs through the user interface, they will bypass this feature (there isn't a way to work around this alternative, should the user elect to do this).

ID	Category	Resolution Status	xLPR Owner
3.9	Highest	Resolved	Marj Erickson, Erickson@peaiconsulting.com

Short Label: Experimental measurement uncertainty will be accounted for explicitly.

ERB Comment

Experimental or measurement uncertainty (i.e., measurement errors) should be taken into account when developing correlations and sub-models.

xLPR Response

Measurement uncertainty was taken into account in the development of most models and is accounted for in the definition of distributions to be used for model parameters and inputs. This uncertainty is discussed in technical support documents and is being summarized in module validation reports and Subgroup reports. How the uncertainties are accounted for, both within the modules and as the modules are implemented in the framework, will be discussed in the Uncertainty Report.

ID	Category	Resolution Status	xLPR Owner
3.10	Highest	Resolved	Marj Erickson, Erickson@peaiconsulting.com

Short Label: Correct for COD Bias

ERB Comment

The bias apparent in the COD validation (i.e., used in leak-rate correlation) should be corrected using formal procedures. Formal approaches suggested as part of item 3.4 and item 3.5 would also be appropriate for validation of sub-models.

xLPR Response

For the current version of the code, model bias will be characterized and, if possible, quantified. Discussion of individual module bias and uncertainty, and how these flow through the code, will be contained in the Uncertainty Report along with any methods used to account for module uncertainty. Sensitivity studies may be performed to assess the effect of any module bias on the predictions made by the xLPR code, but there are currently no plans to correct the bias of individual modules for Version 2.0.

ID	Category	Resolution Status	xLPR Owner
3.11	Highest	Resolved	Remi Dingreville, rdingre@sandia.gov

Short Label: User responsibility with respect to selection of sampling scheme

ERB Comment

Construction of the DPD sampling scheme should not be a user responsibility. A correct construction requires expert involvement to arrive at the appropriate sampling scheme. Therefore, guidance should be provided in the xLPR documentation that defines when and how the users should choose this approach.

xLPR Response

We are currently performing a scoping analysis on 11 scenarios exercising various options of the code representative of diverse plant operations with low, medium and high level of probability of leakage and/or rupture. The intent of this scoping analysis is to identify the most appropriate sampling scheme for these specific scenarios and use those results to develop guidance for the user based on the expected output. These 11 scenarios will be documented in the user manual as templates for various simulations. The rationale and explanation of the recommended sampling scheme to be used will be provided as well. It is expected that the recommendation developed from these scenarios can be used to set initial values of the sampling type and inputs based on the users expected results.

ID	Category	Resolution Status	xLPR Owner
3.12	Highest	Resolved	Marj Erickson, Erickson@peaiconsulting.com and Gary Stevens, Gary.Stevens@nrc.gov

Short Label: Distribution truncation

ERB Comment

For cases where the tails of an uncertainty distribution go beyond reasonable or physically plausible limits, the distribution should be truncated and the distribution renormalized. The xLPR team should review all distributions to ensure that tails do not drive the results, and if so they should be appropriately truncated with justification provided in the documentation.

xLPR Response

The xLPR team agrees that distribution truncation to prevent simulation of non-physical results is important. When appropriate the documentation that is being developed for each model and/or input discusses (a) if truncation is used and, if so, the basis for the recommended truncation protocol. Sensitivity studies are planned to ensure that the tails of the distributions do not exert an undue influence on the result.

ID	Category	Resolution Status	xLPR Owner
3.13	Highest	Resolved	Marj Erickson, Erickson@peaiconsulting.com and Remi Dingreville, rdingre@sandia.gov

Short Label: Identification of aleatory *vs*. epistemic uncertainties

ERB Comment

For consistency and better accuracy, the xLPR documentation should provide recommendations for parameters whose uncertainties should be treated as aleatory and those to be treated as epistemic - along with clear supporting discussions and rationale for such choices. One possible approach treats

questionable uncertainties as epistemic, and then determines the ones that dominate the epistemic output uncertainty. Only for those that are dominant, additional evaluation becomes necessary to justify their treatment as epistemic. All other uncertainties can then be allocated to the aleatory category. This allocation should not be the (primary) responsibility of the users.

xLPR Response

The xLPR team agrees that how uncertainties are identified (i.e., as being aleatory or epistemic) should be consistent and well documented. The documentation that is being developed for each model and/or input discusses the basis for identification as being aleatory or epistemic. The xLPR team further agrees with the ERB recommendation that questionable uncertainties should be identified as being epistemic. A principal consideration of the sensitivity analysis will be to understand the effect of uncertainty classification on the results. See also the response to 3.7.

The documentation being developed summarizes the views of the xLPR team concerning uncertainty type identification. This information is available to all users of the xLPR code. While we expect most users to accept these recommendations it is nevertheless the responsibility of the user to both make the final determination and to be responsible for defense of this determination.

ID	Category	Resolution Status	xLPR Owner
3.14	Highest	Resolved	Remi Dingreville, rdingre@sandia.gov

Short Label: Automation of subroutine validation

ERB Comment

The ERB recommends that the code for each sub-model be exercised for a range of input values that can be anticipated from GoldSim and the output checked to determine if the module is producing anticipated results. This process should be automated to support future code verification studies.

xLPR Response

As an integral part of the module development, verification, and validation process, each module is tested over the full range of expected operation to ensure stable functionality and valid results. Typically, errors will be logged if the module receives inputs outside known valid ranges. The inputs associated with these tests are captured within the required QA documentation of the program and thus are readily available for subsequent testing needs.

The team acknowledges that automating these functional and output validity tests may be beneficial. However, given the complexity of the inputs required by some of the modules, the suite of test cases fully exercising the range of inputs becomes extensive. Furthermore, adding in effect a test "layer" within the GoldSim framework of xLPR to exercise the modules in this manner constitutes a significant addition of complexity within the code. While it is unlikely to be incorporated into V2.0, the team will continue to evaluate the practicality and potential benefits of adding this feature in the future.

ID	Category	Resolution Status	xLPR Owner
3.15	Highest	Resolved	Rob Tregoning, Robert.Tregoning@nrc.gov

Short Label: Alternative initiation model

ERB Comment

The ERB would like a discussion about the potential option to assign an initial crack with a small size (e.g., 0.2mm) in each subunit that then grows — thus eliminating the need for the code to incorporate

crack initiation models for PWSCC. This comment is motivated by the apparent greater (relative) confidence in the PWSCC growth models than in the initiation models. Probabilistic codes used in Sweden for stress corrosion cracking issues adopt the approach of prescribing initial crack sizes in view of the physical complexities of initiation and the current state of knowledge. Damage tolerance frameworks employed in other industries often prescribe initial flaw sizes (or flaw size distributions).

xLPR Response

xLPR already has an option that allows an initial starter crack(s) to be seeded at the onset of the analysis.

ID	Category	Resolution Status	xLPR Owner
4.1	Ongoing	Resolved	Mark Kirk, Mark.Kirk@nrc.gov

Short Label: Timeliness of communication

ERB Comment

Managers of the xLPR team are encouraged to provide the ERB with a proposed plan to address the key technical recommendations/suggestions contained in this 2nd review. This process will likely prove more effective than the prior procedure of providing the ERB with responses to the 1st review just before the 2nd review meeting. If necessary, members of the ERB with extensive expertise on these matters likely would provide valuable, early feedback to xLPR team in the coming months.

xLPR Response

The xLPR team agrees with the ERB's comment. The team's goal is to communicate our responses to the ERB's questions to the ERB by 1 April 2015 at the latest. Additionally, the xLPR team may engage individual members of the ERB in the future to seek guidance on specific matters within their specialized areas of expertise.

ID	Category	Resolution Status	xLPR Owner
4.2	Ongoing	Resolved	Rob Tregoning, Robert.Tregoning@nrc.gov

Short Label: Use of Bayes Filter

ERB Comment

The xLPR team should consider implementing a recursive algorithm (e.g., through a Bayes filter) to update xLPR code output to incorporate sequential inspection data and incoming information (such as ISI data).

xLPR Response

Currently, xLPR considers sequential inspections independently using a single relationship to address all welds. However, it is certainly expected that some welds will be more difficult to inspect and that missing a flaw in the weld during one inspection may be due to factors that would also make the flaw more likely to be missed in subsequent inspections. Therefore, one could envision weld-dependent POD curves and correlation between sequential inspection results. While the prior discussion is somewhat distinct from the ERB comment, it points out one possibility for consideration of more advanced inspection models. The xLPR team would like to learn more about the algorithm suggested by the ERB to determine if this is also a candidate for a more advanced inspection model. Unfortunately, the schedule and resource constraints associated with the development of xLPR V2, preclude consideration of adopting more advanced inspection models. However, this will be added to the list of modifications that are being considered for V3 of the code and beyond. This list of modifications will be further developed and prioritized based on sensitivity analyses using V2. Those

models/portions of xLPR that most significantly impact the results will be the ones with the highest priority for future modifications.

ID	Category	Resolution Status	xLPR Owner
4.3	Ongoing	Resolved	Dave Rudland, David.Rudland@nrc.gov

Short Label: Treatment of secondary stresses

ERB Comment

The ERB suggests that guidance be provided in the xLPR documentation describing a recommended approach to handle secondary piping stresses and the degree of conservatism involved in the recommendation. The scaling factor approach now incorporated in the xLPR code, which requires setting the value by the code user, is not an ideal solution. The setting of a recommended value for the scaling factor with supporting discussion in the xLPR documentation is the correct approach.

xLPR Response

Over the years, researchers conducted experiments and analyses (MPR-216 for example) that suggest that secondary stresses can be relieved by the presence of a through-wall crack. However, complete relief of these stresses may not occur and is a function of the compliance of the system and the constraints around the crack. In order to account for this effect properly, a detailed, location specific model is required. The subject matter experts within xLPR were not able to come to consensus on an appropriate model for this behavior since the behavior has not been generalized. Therefore, the experts decided that the best way to handle this relief is by a user input scale factor. The xLPR documentation will recommend that a scaling factor of one be used as a conservative approximation, and the use of any other scaling factor will require a detailed justification. As part of the first application of xLPR, to address LBB piping systems, sensitivity studies will be conducted to investigate the impact of the secondary loads on the leakage probabilities. These sensitivity studies will be used to justify if further model development for secondary stresses is required.

ID	Category	Resolution Status	xLPR Owner
4.4	Ongoing	Resolved	Marj Erickson, Erickson@peaiconsulting.com

Short Label: Use of model averaging

ERB Comment

If multiple models of equal credibility are developed for a particular subject (e.g., crack initiation), consideration should be given to apply a formal, model averaging approach. If there are conditions that justify the preference of one model over the others under some known conditions, then such conditions should be clearly spelled out in the xLPR documentation to help the user in their choice of the appropriate sub-model.

xLPR Response

There are several instances where multiple models are available and used in various modules (stability, initiation). Model averaging is beyond the scope of the current project and will not be applied in V2.0. For stability, two model predictions are compared and the more conservative result used. Consequences of this bias will be discussed in the uncertainty report. If framework V&V suggests that corrections for model bias should be implemented, a method will be developed to do so.

For PWSCC crack initiation, three models are provided for flexibility and generality. Due to the inherent uncertainty in models predicting initiation, it was felt that leaving model selection to the user was appropriate to enable comparisons, sensitivity studies, and to account for available material and condition information. The selection and use of multiple models for the various modules will be discussed in greater detail in the SubGroup reports and the implication of these decisions will be discussed in the Uncertainty report.

ID	Category	Resolution Status	xLPR Owner
4.5	Ongoing	Resolved	Mark Kirk, Mark.Kirk@nrc.gov

Short Label: Reports provided to ERB

ERB Comment

The ERB requests that the committee members receive in timely fashion the module validation reports for information.

xLPR Response

The xLPR team agrees. These reports are being provided to the ERB through the ERB dropbox site as they are finalized. (Four posted there to date).

ID	Category	Resolution Status	xLPR Owner
4.6	Ongoing	Resolved	Mark Kirk, Mark.Kirk@nrc.gov

Short Label: Uncertainty report provided to ERB

ERB Comment

The ERB requests that the uncertainty report be sent to the committee members when the first draft is completed.

xLPR Response

This report will be provided to the ERB when it is completed, which is expected to occur in the Fall of 2015. Given the complexity of the subject matter for this report and the detailed characterization of the "inner workings" of essentially every aspect of the xLPR code that it is intended to convey, the xLPR team will complete our normal review and approval process to ensure all internal stakeholders have concurred in its representations prior to releasing it for external review.

ID	Category	Resolution Status	xLPR Owner
4.7	Ongoing	Resolved	Remi Dingreville, rdingre@sandia.gov

Short Label: Sampling scheme selection

ERB Comment

Latin Hypercube Sampling (LHS) should be used to reduce computation time. This approach can be adopted for all epistemic distributions rather than random sampling.

xLPR Response

As mentioned in response to item 3.11, we are currently performing a scoping analysis on eleven scenarios in which we are exercising various options of the code. This will enable us to provide recommendations on which sampling scheme to use. One of the key features of the xLPR Framework is that it offers the user the flexibility to select the sampling method that is used, including LHS.

ID	Category	Resolution Status	xLPR Owner
4.8	Ongoing	Resolved	Remi Dingreville, rdingre@sandia.gov

Short Label: Monte Carlo Sampling errors

ERB Comment

Standard errors in the Monte Carlo algorithm used by GoldSim should be estimated, and if significant in comparison to the output uncertainty, they should be accounted for in the xLPR.

xLPR Response

The xLPR project team is aware of the standard errors induced from the MC algorithms. Such errors were investigated in the pilot study (see section 8.2.7 of the Technical Basis and Pilot Study Problem Results, Feb. 2011). The accuracy of the MC technique won't be studied directly using GoldSim but will be considered in a post-processing manner in the V&V phase.

ID	Category	Resolution Status	xLPR Owner
4.9	Ongoing	Resolved	Remi Dingreville, rdingre@sandia.gov

Short Label: Automated code verification process

ERB Comment

A similar, automated verification process as in item 4.8 should also be implemented for the Framework code, perhaps by including "dummy" versions of the sub-model codes that return simple look-up values for a limited range of parameters rather than those from detailed computations.

xLPR Response

Similar to the response to Comment 3.14, the team recognizes the convenience and potential value of incorporating an automated method for running basic framework verification tests. However, integrating this test "layer" into the xLPR framework constitutes a significant addition of complexity within the code. While it is unlikely to be incorporated into V2.0, the team will continue to evaluate the practicality and potential benefits of adding this feature in the future.

ID	Category	Resolution Status	xLPR Owner
4.10	Ongoing	Resolved	Craig Harrington, charrington@epri.com

Short Label: Multiple Cracks

ERB Comment

A review should be performed to verify that the formation of multiple cracks in one discretized, subunit of the pipe circumference has an extremely low probability of occurrence for the largest subunit size a user may request. It is the ERB's understanding that multiple crack formation at a given time step is not allowed to occur in the current version of the xLPR code.

xLPR Response

Actually there is no constraint on the number of subunits that may initiate cracks during a given time step. However, given the importance of initiation within xLPR, the following additional detail should provide a more nuanced understanding of the issues associated with initiation and subunit size.

Initiation Modeling: For xLPR Version 2.0, initiation refers to the occurrence of singly dominating flaws of engineering significance (as is reflected in the initial depth distributions that have been developed), in contrast with micro-scale cracking which is governed by distinct physical mechanisms. Therefore, each subunit reflects the site of a singly dominating flaw of engineering significance, i.e.,

after earlier stages of initiation including incubation, micro-flaw formation, and micro-flaw coalescence.

To accommodate initiation of multiple cracks, each weldment is discretized into multiple subunits of equal size. Initiation is simulated within each subunit using the within-weld material susceptibility and stress conditions specific to the subunit. While only one circumferential and one axial flaw can initiate within a given subunit; across the set of subunits, multiple flaws can initiate, even in the same time step. The initiation times of the different subunits are implicitly correlated by sampled values that apply to the weldment as a whole (e.g., heat-to-heat material susceptibility).

Selecting an appropriate discretization: As suggested by the ERB comment, spatial discretization should be sufficiently granular to accommodate multiple crack initiation with a reasonable number of unique, independent crack initiation sites to accurately capture spatial gradients of the stress profile (e.g., caused by bending loads). However, spatial discretization should not be so granular that subunits have lengths smaller than the characteristic length of a singly dominating flaw of engineering significance, estimated as ranging from a few millimeters to a few inches. There are also run time implications associated with more subunits, so the recommended number of subunits is the minimum number of subunits that satisfies all of the above guidance. Additionally, the two direct initiation models do not include normalization for the subunit length. Therefore, the number of subunits input to xLPR should be regarded the same way as any other PWSCC Crack Initiation (CI) regression model parameter—it should only be modified concurrently with other model parameters such that the model remains representative of available data.

ID	Category	Resolution Status	xLPR Owner
4.11	Ongoing	Resolved	Dave Rudland, David.Rudland@nrc.gov
Short Label: Benchmarking			
ERB Comment The xLPR code should be benchmarked against previous, similar calculations that used the PC-Praise computer code (see NUREG/CR-6674, PNNL-13227) with explanations developed for any significant differences.			
xLPR Response The xLPR team agrees. This will occur as part of the acceptance study, which is expected to be completed as part of the official Verification and Validation efforts. The xLPR team plans to conclude these efforts by August 2015.			

ID	Category	Resolution Status	xLPR Owner
4.12	Ongoing	Resolved	Dave Rudland, David.Rudland@nrc.gov
Short Label: NRR attendance at meetings			
ERB Comment The ERB recommends that the xLPR team have an NRR representative attend future review meetings of the ERB committee. This person should be someone who will likely be involved in licensing activities associated with the leak-before-break issue which motivated development of the xLPR program. This request has been made previously by the ERB.			
xLPR Response			

The xLPR team will attempt to include an NRR representative to the next ERB meeting. However, the purpose of the ERB meetings is to review the technical, organizational and managerial aspects of the code development efforts and not to determine or discuss regulatory acceptance of the code or procedures.