THE INL SEISMIC RISK ASSESSMENT PROJECT: REQUIREMENTS FOR ADDRESSING DOE ORDER 420.1C & A PROPOSED GENERIC METHODOLOGY

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INL Seismic Risk-Informed Methodology Independent Review Panel

Eighth Meeting of CNS Seismic Lessons Learned Panel
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Outline of Talk

• Motivation for risk-informed methodology
• DOE Order 420.1C and guidance regarding the need for updating existing NPH-Seismic assessments
• Proposed *preliminary* generic risk-informed approach to address Order and other updating requirements
• Suzette Payne will follow with discussion of SL1 PSHA for INL
• Justin Coleman will follow with the risk-informed approach being implemented for INL
Motivation for INL Seismic Risk-Informed Methodology

- DOE nuclear facilities must comply with DOE Order 420.1C *Facility Safety*
- Requires a review their natural phenomena hazards (NPH) assessments no less than every ten years to evaluate the need for an update based on current knowledge
- Order points to DOE-STD-1020-2012 for criteria to be considered in the 10-year evaluation, also ANSI/ANS-2.29-2008 and NUREG-2117.
- DOE Order aimed at assuring the *safety of nuclear facilities*—function of both seismic hazard as well as the facility capacity—the inclusion of risk information appears to be in line with the spirit and objectives of the Order
- Purpose of this risk-informed methodology is to provide a systematic approach for evaluating the need for an update of an existing PSHA that will meet the Order and provide a documented basis for the decision.
- Focus on INL facilities, but may be applicable to other facilities and sites.
- Comments are welcome on this preliminary methodology
d. **Review and Upgrade Requirements for Existing DOE Facilities.**

(1) Existing facility or site NPH assessments must be reviewed at least every 10 years for any significant changes in data, criteria, and assessment methods that would warrant updating the assessments. Section 9.2 of DOE-STD-1020-2012 contains criteria and guidance for performing these reviews. The review results, along with any recommended update actions, must be submitted to the head of the field element. If no update is necessary, this result must be documented following the review.

(2) If a new assessment of NPH demands indicates deficiencies in existing SSC design, a plan for upgrades must be developed and implemented on a prioritized schedule, based on the safety significance of the upgrades, time or funding constraints, and mission requirements. Section 9.3 of DOE-STD-1020-2012 contains guidance on performing upgrade evaluations.
9.2. Periodic Review and Update of NPH Assessments

9.2.1 At a frequency not to exceed ten years, the following aspects of NPH assessments shall be reviewed for changes that would warrant updating the assessments:

- NPH data and data collection methods;
- NPH modeling techniques, either generic or specific to the region of interest; and
- NPH assessment methods.

9.2.2 Consistent with DOE 420.1C, a preliminary estimate of whether changes to data, models, or methods are “significant” and warrant updating the assessments should be performed and consider the following criteria:

- Are the changes to data, models, or methods likely to cause a change in the estimates of the major inputs to hazard calculations?
- Given potential changes to the hazard inputs, by what magnitude might the calculated hazard results change, and how might the results impact current site design standards?

9.2.3 The preliminary estimate of how hazard results might change from new inputs will likely be imprecise. An expected significant increase in the hazard results would clearly favor completion of a new assessment. However, even if hazard results are not expected to change significantly, large changes to the input parameters may warrant a new assessment to ensure the NPH assessment continues to have a viable technical basis.

9.2.4 In the case of seismic hazard assessments, a determination of whether an existing assessment remains adequate for future use should consider the criteria in Section 4.1 of ANSI/ANS-2.29-2008 for the suitability of existing studies. Additional guidance on the bases for updating existing seismic assessments can be obtained from NUREG-2117, Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies.

9.2.5 A decision on updating an NPH assessment should consider the intended application of the assessment results.
ANSI/ANS- 2.29-2008 on Updating Existing PSHA

• 4.1 High Level Requirements

• “…the PSHA analyst may have the option to use an existing seismic study as a starting point for a site-specific assessment.”

• HLR-A: Scope

  • “The assessment of the frequency of earthquake ground motions at a site shall be based on a PSHA that considers the epistemic uncertainty in the analysis inputs and that reflects the composite distribution of the informed technical community. The level of the analysis shall be determined based on the intended application of the PSHA results and on site-specific complexity (see Sec. 4.3). For PSHA levels 3 and 4, the analysis shall include a site-specific detailed analysis.”

• HLR-B: Data collection

  • [develop a comprehensive up-to-date database per ANSI/ANS-2.27-2008]
ANSI/ANS- 2.29-2008 on Updating Existing study (cont’d.)

- HLR-C: Seismic source characterization
- HLR-D: Ground motion characterization
- HLR-E: Local site effects
- HLR-F: Quantification
  - [Epistemic and aleatory uncertainties included in each element of PSHA]
- HLR-G: Use of existing studies
  - “When use is made of an existing study for PSHA purposes, it shall be confirmed that the basic data and scientific interpretations in the original analysis are still valid in light of current information, the study meets the requirements outlined in HLR-A through HLR-F above, and the study is suitable for the intended application.”
Chapter 6 *Updating: Replacing and Refining Probabilistic Hazard Assessments* is devoted to the updating issue.

Key parts of the updating process are:

- Identification of new data, models, or methods that have become available
- Evaluation of the impact of those new findings relative to hazard significance and to the center, body, and range of technically defensible interpretations (CBR of the TDI)
- If needed, designing the scope and SSHAC Level for the update
<table>
<thead>
<tr>
<th>Existing Study</th>
<th>Condition of Existing Study</th>
<th>Hazard Assessment Needed</th>
<th>Recommendation</th>
<th>SSHAC Level for New Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>No study, or previous studies conducted at lower SSHAC Levels (2 or 1), or non-SSHAC studies</td>
<td>Not adequate for nuclear/critical facilities</td>
<td>Regional and/or site-specific</td>
<td>Conduct new study</td>
<td>3 or 4</td>
</tr>
<tr>
<td>Regional or site-specific</td>
<td>Not viable**</td>
<td>Regional and/or site-specific</td>
<td>Replace existing study</td>
<td>3 or 4</td>
</tr>
<tr>
<td>Regional or site-specific</td>
<td>Viable</td>
<td>Site-specific</td>
<td>Refine regional study locally consistent with RG 1.208 and ANSI/ANS-2.27 / 2.29 2008</td>
<td>2, 3, or 4</td>
</tr>
<tr>
<td>Site-specific (one or more sites), no regional</td>
<td>Viable</td>
<td>Regional</td>
<td>Use site-specific studies to assist development of regional models</td>
<td>3 or 4</td>
</tr>
<tr>
<td>Site-specific (one or more sites), no regional</td>
<td>Not Viable</td>
<td>Regional</td>
<td>Conduct new study</td>
<td>3 or 4</td>
</tr>
</tbody>
</table>

**“Viable” is defined as: (1) based on a consideration of data, models, and methods in the larger technical community, and (2) representative of the center, body, and range of technically defensible interpretations.**
RECOMMENDATIONS FOR ENHANCING REACTOR SAFETY IN THE 21ST CENTURY

THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT

U.S. NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment
NTTF Recommendations

**Recommendation 2**

The Task Force recommends that the NRC require licensees to reevaluate and upgrade as necessary the design-basis seismic and flooding protection of SSCs for each operating reactor.

The Task Force recommends that the Commission direct the following actions to ensure adequate protection from natural phenomena, consistent with the current state of knowledge and analytical methods. These should be undertaken to prevent fuel damage and to ensure containment and spent fuel pool integrity:

1. **Order licensees to reevaluate the seismic and flooding hazards at their sites against current NRC requirements and guidance, and if necessary, update the design basis and SSCs important to safety to protect against the updated hazards.**

2. **Initiate rulemaking to require licensees to confirm seismic hazards and flooding hazards every 10 years and address any new and significant information. If necessary, update the design basis for SSCs important to safety to protect against the updated hazards.**

3. **Order licensees to perform seismic and flood protection walkdowns to identify and address plant-specific vulnerabilities and verify the adequacy of monitoring and maintenance for protection features such as watertight barriers and seals in the interim period until longer term actions are completed to update the design basis for external events.**
The CEUS SSC model and EPRI 2013, from regional SSHAC Level 3 studies, to be used for PSHA at plants east of the Rockies.
Recommendation 2.1: Seismic

Risk-informed screening using GMRS

Updated seismic hazard estimates

1. Develop new seismic hazard curves and GMRS

2. Submit new seismic hazard curves, GMRS, and interim actions

3. GMRS > SSE?
   - No
   - Yes

4. No further action

5. NRC Screening/Prioritization

6a. Develop SPRA

6b. Develop SMA

7a. Submit SPRA results and SFP evaluation

7b. Submit SMA results and SFP evaluation

8. Submit proposed actions, if any, to evaluate seismic risk contributors

9. Phase 2
Criteria for Evaluating the Need for an Update of an Existing PSHA

• Criterion #1: New data, models, and methods developed since the existing PSHA

• Criterion #2: New inputs to the PSHA model, including the SSC, GMC, and site response models
  
  • Includes the treatment of aleatory and epistemic uncertainties
  
  • Termed “viable” in NUREG-2117: captures center, body, and range of technically-defensible interpretations

• Criterion #3: Changes in the technical bases
  
  • Technical arguments and justifications for the hazard inputs and the associated treatment of uncertainties

• Criterion #4: Significant changes in mean hazard
  
  • Need to consider the precision or “noise” levels of hazard calculations
Goal of a SSHAC Process

“The fundamental goal of a SSHAC process is to properly carry out and completely document the activities of evaluation and integration, defined as:

- **Evaluation**: The consideration of the complete set of data, models, and methods proposed by the larger technical community that are relevant to the hazard analysis.
- **Integration**: Representing the center, body, and range of technically defensible interpretations in light of the evaluation process (i.e., informed by the assessment of existing data, models, and methods).”
Proposed Criteria for Evaluating Need for Update

1. New data, models, or methods
2. Changes in inputs to hazard
3. Changes in technical bases
4. Significant changes in hazard
5. Compare SDC-3,4,5 ground motion with design basis ground motion (DBGM)
6. GMRS vs. DBGM comparison
7. Risk vs. objectives and performance goals

Hazard-Related Comparisons

INL SSHAC Level 1 PSHA

Risk-Related Comparisons

Actions and Products to Address Proposed Updating Criteria
ASCE/SEI 43-05

- Performance-based approach to ensure facility achieves desired performance
- Tells us where to enter the mean hazard curve to achieve a desired performance objective and, in turn, to mitigate defined dose consequence
### Earthquake Design Parameters

<table>
<thead>
<tr>
<th></th>
<th>SDC 3</th>
<th>SDC 4</th>
<th>SDC 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target Performance Goal ((P_F))</strong></td>
<td>(1 \times 10^{-4})</td>
<td>(4 \times 10^{-5})</td>
<td>(1 \times 10^{-5})</td>
</tr>
<tr>
<td><strong>Probability Ratio ((R_P))</strong></td>
<td>4</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Hazard Exceedance Probability ((H_D))</strong></td>
<td>(4 \times 10^{-4})</td>
<td>(4 \times 10^{-4})</td>
<td>(1 \times 10^{-4})</td>
</tr>
</tbody>
</table>

Note: \(H_D = R_P \times P_F\)

Table 1.1-2, ASCE/SEI 43-05
U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 1.208
(Draft was issued as DG-1146, dated October 2006)

A PERFORMANCE-BASED APPROACH TO DEFINE
THE SITE-SPECIFIC EARTHQUAKE GROUND MOTION

MARCH 2007
One of the objectives in developing the performance-based GMRS is to achieve approximately consistent performance for SSCs, across a range of seismic environments, annual probabilities, and structural frequencies. The intent is to develop a site-specific GMRS that achieves the $P_F$ that ensures that the performance of the SSCs related to safety and radiological protection is acceptable.

The performance-based approach combines a conservative characterization of ground motion hazard with equipment/structure performance (fragility characteristics) to establish risk-consistent GMRS, rather than only hazard-consistent ground shaking, as occurs using the hazard reference probability approach in Appendix B to Regulatory Guide 1.165 (Ref. 5). The performance target (the mean annual probability of SSCs reaching the limit state of inelastic response) results from the modification of the UHRS at the free-field ground surface by a design factor to obtain the performance based site-specific GMRS. The design factor achieves a relatively consistent annual probability of plant component failure across the range of plant locations and structural frequencies. It does this by accounting for the slope of the seismic hazard curve, which changes with structural frequency and site location. The design factor ensures that the site-specific response spectrum is equal to or greater than the mean 1 E-04 UHRS.
RG 1.208 Performance-Based GMRS

Figure 2. Comparison of the Mean 1E-04 and 1E-05 Uniform Hazard Response Spectra and the Performance-Based Ground Motion Response Spectrum (GMRS)
Criteria for Evaluating the Need for an Update of an Existing PSHA (continued)

• Criterion #5: Compare mean hazard at AFE for specific SDC level with design basis ground motions (DBGM)
• Criterion #6: Compare mean hazard at AFE for specific SDC level with GMRS
  • Intended to ensure meeting target performance goals
  • GMRS includes a factor to account for slope of hazard curve
  • RG 1.208 defines GMRS for SDC-5; being developed for ASCE 43
• Criterion #7: Risk insights: Compare mean risk with target performance goals for SDC level; compare GMRS with HCLPF capacity
Seismic Design Category (SDC): A category assigned to an SSC, which is a function of the severity of adverse radiological and toxicological effects of the hazards that may result from the seismic failure of the SSC on workers, the public, and the environment. SSCs may be assigned to Seismic Design Categories that range from 1 to 5.
Decision Methodology for Evaluating the Need for an Update of Existing PSHA SDC-3 Facility

Any new facility or major modification will require that a SSHAC Level 3 study be conducted.

Perform a SSHAC Level 1 or 2 Study

Criterion 1

Change in data, models or methods?

Yes

Criterion 2

Change in hazard input models?

Yes

Criterion 4

Change in mean hazard?

Yes

Criterion 5

DBGM>SDC-3 ground motion

Yes

Criterion 6

DBGM>GMRS

Yes

Criterion 7

Risk objectives met?

Yes

Immediate safety concern identified or the risk value >> target performance goals?

Yes

Determine immediate actions to be taken based on estimated hazard (plus appropriate margin)

No

Recommend update to PSHA using SSHAC Level 3 to provide basis for new licensing or design level ground motion, for design modification and any associated engineering changes

Use updated hazard values to reevaluate risk in order to confirm earlier finding and/or to determine what additional actions, if any, are appropriate. Make modifications, engineering changes, or procedural changes, as necessary. Update design or regulatory basis, as necessary.

Documents assessment. No further actions required.

Process for SDC-3 Facilities
Any new facility or major modification will require that a SSHAC Level 3 study be conducted.

1. Perform a SSHAC Level 1 or 2 Study

2. Criterion 1: Change in data, models or methods?
   - Yes
   - Criterion 2: Change in hazard input models?
     - Yes
     - Criterion 4: Change in mean hazard?
       - Yes
       - DBGM > SDC-3 ground motion
         - Yes
         - Criterion 6: DBGM > GMRS
           - Yes
           - Criterion 7: Risk objectives met?
             - Yes
             - Process for SDC-3 Facilities
               - Immediate safety concern identified or the risk value >> target performance goals?
                 - Yes
                 - Document assessment. No further actions required.
                   - No
                   - Perform additional risk and/or safety evaluations using estimated hazard, evaluate need for interim safety improvements
Process for SDC-3 Facilities

Notes:
1. The SSHAC level 1 or 2 study must include a documented in-process peer review. The resulting estimated hazard should be compared with the existing studies used to develop design or regulatory bases for the facility.
2. The estimated hazard and any risk-informed findings apply to this facility only and cannot be used for other facilities.
3. See the report for discussion of the appropriate risk-related information to be considered.
4. A "no" determination here indicates that the risk objectives were not shown to be met, but that no immediate safety concern was identified and the risk did not exceed the target by a large amount.
5. Currently design factors needed for developing the GMRS have only been published for SDC-5 Facilities (ASCE 43-05). The next revision of the engineering rules and regulations will include new risk parameters for SDC-3.
Decision Methodology for Evaluating the Need for an Update of Existing PSHA SDC-4 Facility

Any new facility or major modification will require that a SSHAC Level 3 study be conducted.

- Perform a SSHAC Level 1 or 2 Study (1)
  - Change in data, models, or methods?
    - Yes
      - Change in hazard input models?
        - Yes
          - Change in mean hazard?
            - Yes
              - DBGM > SDC-4 ground motion
            - No
              - DBGM > GMRS
          - No
        - No
      - No
    - No
  - Criterion 2
  - Criterion 3
  - Criterion 4
  - Criterion 5
  - Criterion 6

- Evaluate need for interim safety improvements
- Recommend update to PSHA using SSHAC Level 3 to provide updated ground motions
- Perform additional risk and/or safety evaluations using updated hazard
- Risk objectives met? (2)
- Immediate safety concern identified or the risk value >> target performance goals?
- Determine new design or licensing basis ground motions and determine what additional actions, if any, are appropriate. Make modifications, engineering changes, or procedural changes, as necessary. Update design or regulatory basis, as necessary.

Notes:
1. The SSHAC level 1 or 2 study must include a documented in-process peer review. The resulting estimated hazard should be reasonable.
Decision Methodology for Evaluating the Need for an Update of Existing PSHA SDC-5 Facility

Any new facility or major modification will require that a SSHAC Level 3 study be conducted.

- **Performs SSHAC Level 1 or 2 Study**
  - **Change in data, models, or methods?**
    - **Yes**
      - **Change in hazard input models?**
        - **Yes**
          - **Change in mean hazard?**
            - **Yes**
              - **Recommend update to PSHA using SSHAC Level 3 to provide updated ground motions**
            - **No**
              - **Change in technical basis?**
                - **Yes**
                  - **Document assessment. No further actions required.**
                - **No**
            - **No**
        - **No**
      - **No**
    - **No**
  - **DBGM > SDC-4 ground motion**
    - **Yes**
    - **No**
  - **DBGM > GMRS**
    - **Yes**
    - **No**

- **Perform additional risk and/or safety evaluations using updated hazard. Evaluate need for interim safety improvements**
  - **Risk objectives met?**
    - **Yes**
    - **No**

- **Immediate safety concern identified or the risk value >> target performance goals?**

- **Determine immediate actions to be taken based on estimated hazard (plus appropriate margin)**
  - **Determine new design or licensing basis ground motions and determine what additional actions, if any, are appropriate. Make modifications, engineering changes, or procedural changes, as necessary. Update design or regulatory basis, as necessary.**

Notes:
- SSHAC: Site Specific Hazard Analysis Criteria
- SDC-5: Seismic Design Category 5
- GMRS: Generalized Motion Response Spectra

Process for SDC-5 Facilities
Additional Considerations by Panel

• Approach for sites that have recent, defensible SL3 studies and the possibility of site-specific refinements
• Encourage site-wide PSHAs that will benefit multiple facility sites
  • Hanford Site example
  • SL3 PSHA for all sites, with site-specific studies for site response
• Applicability of risk indices (e.g., HCLPF) for SDC-3, and -4 facilities
Conclusions

- DOE Order 420.1C *Facility Safety* requires evaluation of need for NPH update every ten years
- Generic methodology to address should be consistent with existing guidance, plus consider risk information
- Graded approach considers SDC level; higher SDC level having more rigorous actions conducted earlier in decision process
- Seven criteria are identified for evaluating the viability and defensibility of existing PSHA
- All decision methodologies require thorough documentation to support either decision to update or to not update
- Comments welcome on this preliminary methodology