

Status and Path Forward on Near-Term Task Force Recommendation 2.1 - Seismic

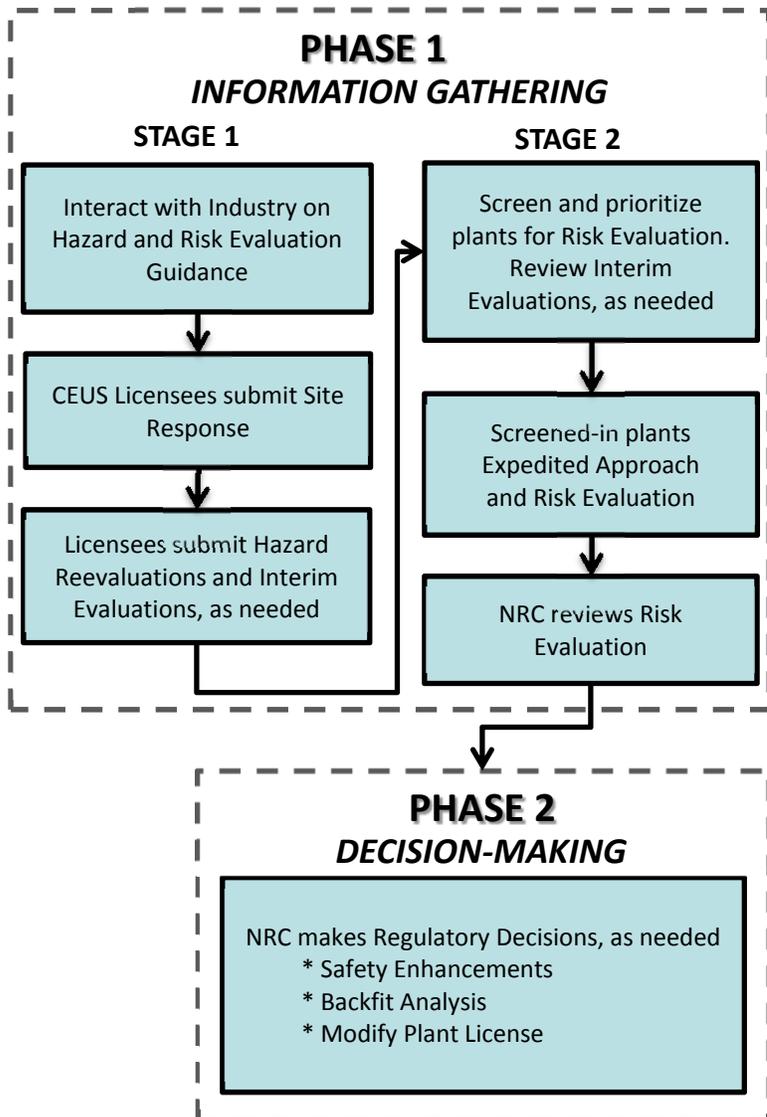
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Following the March 2011 accident at Fukushima Dai-ichi a task force was formed at the Nuclear Regulatory Commission (NRC) to review relevant regulatory requirements, programs, and processes, and their implementation, to recommend whether the agency should make improvements to the regulatory system. One recommendation (NTTF R2.1)¹ of the task force involves re-evaluating the seismic and flooding hazards at operating reactor sites. This paper will describe the seismic-related activities being pursued to address NTTF R2.1.

PHASED APPROACH

As illustrated in the figure below, a phased approach has been established by the NRC to address NTTF R2.1 for seismic events.



Phase 1 is focused on gathering and reviewing information from the licensees and Phase 2 is focused on regulatory decision-making. The following sections will provide more detail regarding each of the major steps of the phased approach for the seismic evaluation.

Site Response and Hazard Reevaluations

As part of Phase 1, the NRC issued 10 CFR 50.54(f) letters² to all licensees to request information concerning, in part, the seismic hazards at operating reactor sites. The request established the need for each licensee to provide a Seismic Hazard Evaluation and Screening Report, which includes a reevaluation of the site seismic hazard based on the latest seismic information and methods. The NRC requested that the information be provided within 1.5 years for Central and Eastern United States (CEUS) plants and within 3 years for Western United States (WUS) plants. The date for CEUS plants was subsequently extended to March 31, 2014.

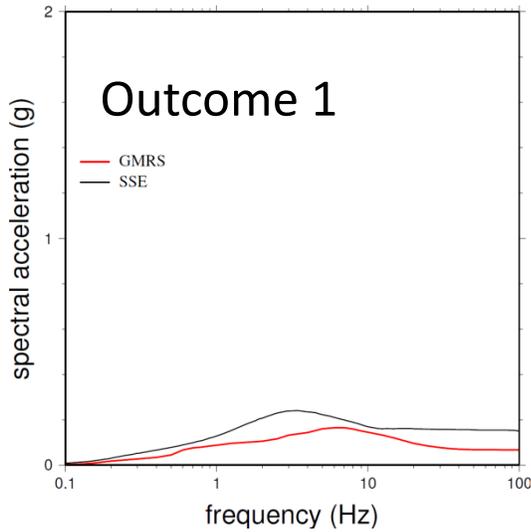
Each of the licensees performed a probabilistic seismic hazard analysis to develop a ground motion response spectra (GMRS) for their plant site. Licensees whose plants are located in the CEUS developed a GMRS using a regional source model called the CEUS Seismic Source Characterization (CEUS-SSC). The CEUS-SSC was developed over a five-year period, beginning in 2007, jointly by the Electric Power Research Institute (EPRI), the Department of Energy (DOE), and the NRC. This regional source model was published in six volumes as NUREG-2115³ in 2012. The CEUS licensees also used a set of regional CEUS ground motion models published by EPRI⁴ in 2013 and then performed a site response analysis to develop a GMRS for their specific sites. This work was submitted to the NRC in March 2014.

Licensees whose plants are located in the western United States (WUS) do not have the advantage of previously developed seismic source and ground motion models. As such, the three WUS licensees were given more time by the NRC and have been developing their own regional source and ground motion models using the same NRC-endorsed process as that used for the development of the CEUS models. The WUS NTTF R2.1 hazard reevaluations are due to the NRC in 2015.

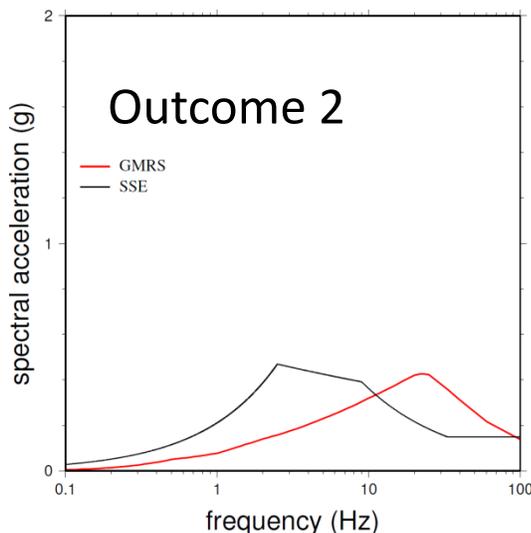
One of the first steps following development of the plant-specific GMRS is to compare it to the licensee's plant-specific safe shutdown earthquake (SSE). Based on

this comparison of the GMRS with the SSE, there are three potential outcomes:

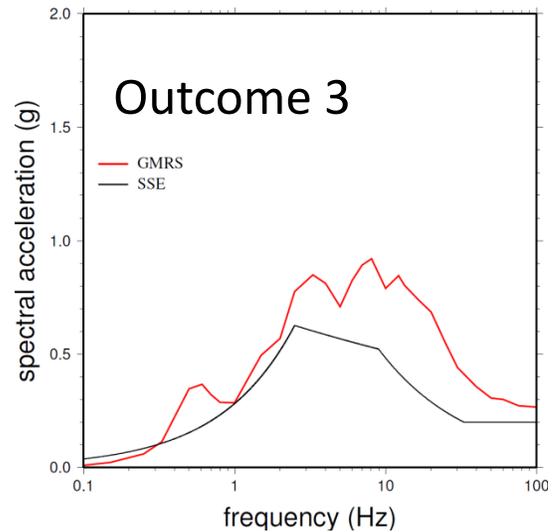
The first possible outcome is that the SSE is greater than the GMRS for the entire frequency range. For this case, the licensee does not need to do any further analysis and has completed the NTF R2.1 process.



The second possible outcome is that the GMRS exceeds the SSE, but only for frequencies above 10 hertz (Hz). For this case, the licensee will need to evaluate the high-frequency sensitive components in the plant, such as electrical relays to determine if they have sufficient capacity to handle the GMRS accelerations. To support this evaluation, EPRI has established a testing program for high frequency sensitive components.



The third possible outcome is that the GMRS exceeds the SSE in the important frequency range of 1 to 10 Hz. The 1 to 10 Hz frequency range covers the natural frequencies for a majority of the systems, structures, and components in nuclear power plants. For exceedances in the 1 to 10 Hz range, licensees “screen-in” for further, more detailed, plant evaluations.

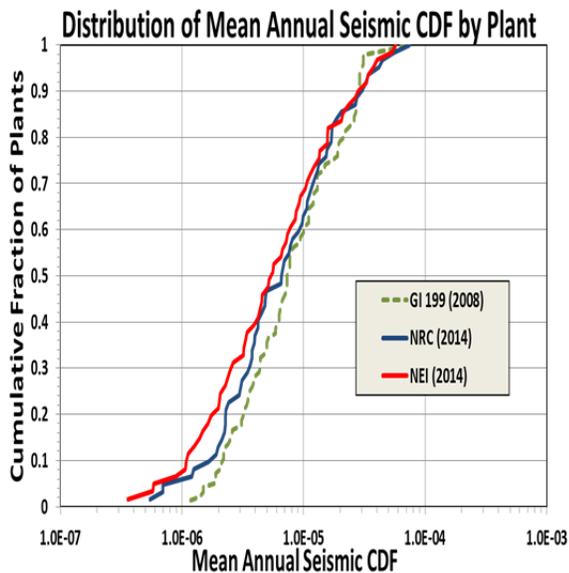


Many licensees were able to demonstrate that the current plant design has adequate margin without needing to do any significant analyses beyond addressing specific seismic issues, such as the potential for relay chatter or to address the seismic capacity of their spent fuel pool. Other licensees need to perform more refined, detailed analyses, including probabilistic risk assessments (PRAs), to demonstrate additional capacity for beyond design basis seismic events.

Interim Evaluations

On March 12, 2014 industry submitted a fleet-wide study⁵ that combined the new seismic hazard curves with the plant seismic capacities, previously developed from the 1990s individual plant examination for external events (IPEEE) results, to calculate an estimate of the seismic core damage frequency (CDF) for each of the CEUS plants. The interim evaluations were necessary to determine whether there was a need for immediate action and to provide confidence that plants can cope with a higher seismic hazard while any seismic risk assessments are being conducted. The submitted information was reviewed by the NRC and considered in determining what next actions were needed and the priority for specific plants.

The results of the interim evaluations are shown as a cumulative distribution plot with the industry's calculated values as the red curve and the staff's confirmatory calculations as the blue curve. Also shown as the green dashed curve are the results from the Generic Issue (GI-199) report from 2008.



What these plots show are that the estimated seismic CDF values for CEUS plants are all below 10^{-4} /year; confirming that the plants can continue to operate safely while the longer term plant risk assessments are being completed. Comparing the 2014 results (the blue and red curves) to the earlier GI-199 from 2008 results shows that there has not been an overall increase in seismic risk for the fleet of U.S. plants. Although the industry fleet-wide study provides an important measure of the overall safety of the nuclear power plants in the CEUS with respect to the reevaluated seismic hazards, the seismic CDF values for any given plant should be considered a preliminary estimate due to the use of the IPEEE seismic capacity information. The NRC gained valuable insights from the IPEEE program; however, the IPEEE program did not establish a new regulatory or licensing basis for the nuclear plant. Rather, the primary purpose of the IPEEE program was to identify plant-specific vulnerabilities to severe accidents caused by seismic and other hazards and to gain a qualitative understanding of the overall likelihood of core damage.

Screening and Prioritization

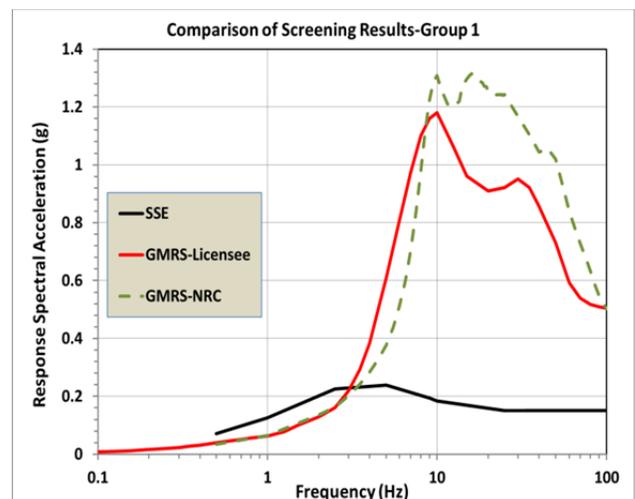
The screening and prioritization process identified the plants that need to proceed with the expedited seismic evaluation and the priority for the seismic risk assessment. Each of the CEUS plants submitted a hazard and screening evaluation report in March 2014. In the

request for information sent out via the 10 CFR 50.54(f) letters, the staff outlined a 30-day screening and prioritization process to evaluate which plants screened-in for further review and to prioritize the screened-in plants. In order to perform this rapid 30-day review of the hazard submittals from the 60 CEUS plants, the NRC staff formed, prior to the March submittals, a team of geoscientists and engineers from the offices of New Reactors (NRO), Nuclear Regulatory Research (RES), Nuclear Reactor Regulation (NRR), Nuclear Material Safety and Safeguards (NMSS), and the Regions to develop independent GMRS curves for each site. As soon as the CEUS hazard evaluations arrived, the staff was able to review each report to evaluate the licensee's screening determination.

Based on the NRC prioritization, licensee plants that may need to perform additional detailed analyses were placed into one of three groups. Groups were based on certain key parameters, such as:

- (1) the maximum ratio of the new re-evaluated hazard (GMRS) to the SSE in the 1-10Hz range;
- (2) the maximum ground motion in the 1-10 Hz range; and
- (3) insights from previous seismic risk evaluations.

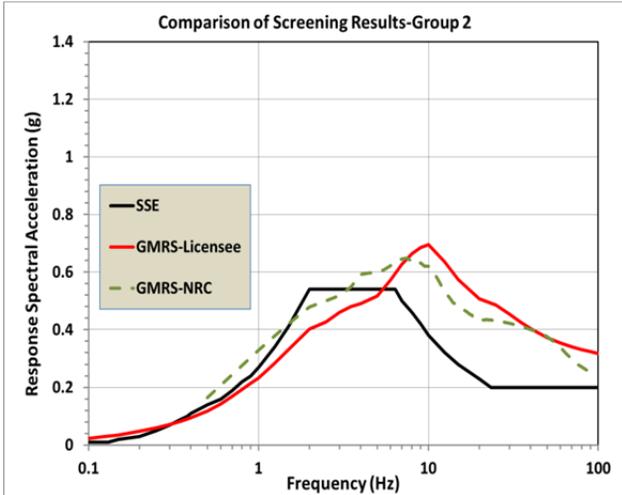
The figure below is an example of a plant GMRS and SSE for Priority Group 1 plants. Shown on the plot is the plant SSE as the black line, the GMRS calculated by the licensee in red and the NRC GMRS as the dashed green curve. The plants screened-in to Group 1 have the largest difference between the GMRS and SSE response spectra over the 1 to 10 Hz range.



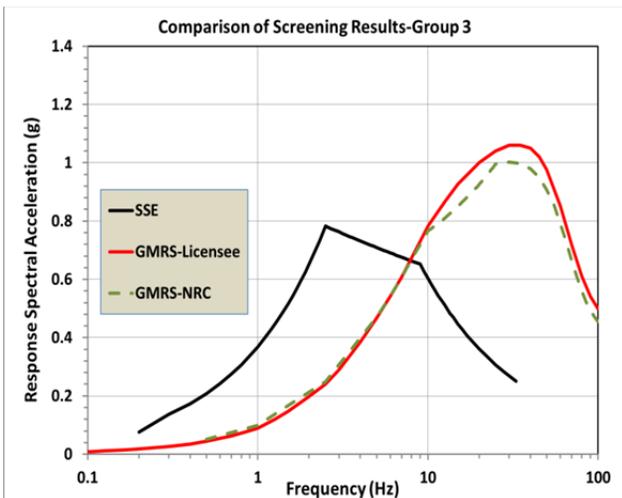
Although the GMRS relative to the SSE is higher for Group 1 plants, it is important to remember that nuclear power plants are very rugged structures that have been designed and built to withstand ground shaking beyond

their SSE ground motion levels. The risk evaluations for Group 1 plants are due in 2017.

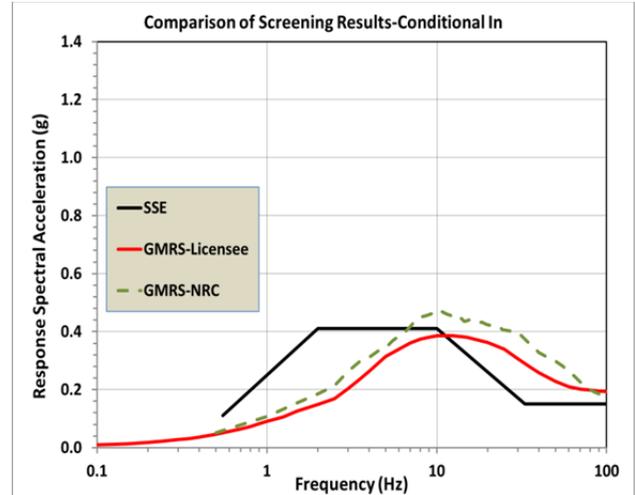
As shown in the figure below, the Group 2 plants have a GMRS to SSE ratio that is greater than 1, but the amount of exceedance in the 1-10 Hz range is moderate and less than that of the Group 1 plants. The risk evaluations for Group 2 plants are due in 2019.



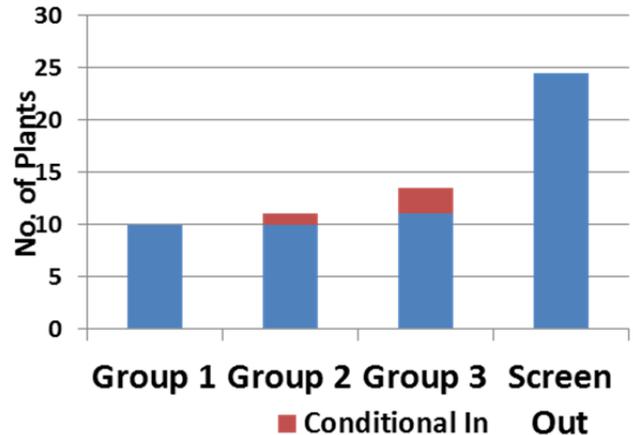
The following figure illustrates plants that fall into Priority Group 3. Group 3 plants have a GMRS to SSE ratio that is greater than 1, but the amount of exceedance in the 1-10 Hz range is relatively small. Given the limited level of exceedance of the Group 3 plants, the staff is evaluating the need for these licensees to conduct a seismic risk evaluation in order for the staff to complete its regulatory decision making. If a risk evaluation is needed, it will be due by the end of 2020.



For some plants the NRC staff and licensee reached different screening conclusions based on the GMRS to SSE comparison in the 1 to 10 Hz range. The NRC staff conditionally screened-in these plants while additional evaluations are performed. An example of a conditionally screened-in plant is shown in the figure below.



During the prioritization review, the staff considered each licensee's re-evaluated hazard submittals, seismic risk insights from GI-199⁶ and the staff's confirmatory analysis of the seismic hazard. The following graph shows the screening and prioritization results after completion of the NRC's 30-day review and subsequent interactions with licensees to address questions regarding information provided in their submittals. The number of plants assigned to each Group reflects the relative priority for conducting a seismic risk evaluation and accounts for the appropriate allocation of limited staff resources and the available expertise for reviewing and conducting seismic risk evaluations. The graph also shows the plants screened out of performing seismic PRAs.



Expedited Evaluation

To support the allowance for the time needed to perform the detailed analyses for the screened-in plants, the affected licensees will submit “expedited evaluations.” The purpose of the expedited evaluation is to focus on short term evaluations of critical plant equipment to determine if prompt modifications are necessary to improve plant seismic safety for beyond design basis earthquakes while the more detailed seismic plant risk evaluations are being conducted. The expedited evaluation begins with the development of a list of equipment identified in the plant-specific FLEX implementation strategy for scenarios involving a loss of ac power, which is an important contributor to seismic risk. Specifically, the scope of the expedited evaluation is focused on installed plant equipment, identified as FLEX Phase 1 equipment. The expedited evaluation involves the determination of the seismic capacity of the equipment up to twice the plant SSE, depending on the ratio of the plant-specific GMRS to the plant-specific SSE between the 1 to 10 Hz range. If the equipment capacity does not exceed this review level ground motion, then the equipment will be modified within 2 years of completion of the expedited evaluation program unless a plant outage is required to implement the modification. The expedited evaluations were submitted at the end of December 2014 and are currently under NRC review. Any identified modifications or enhancements need to be implemented by 2016. This supports the Group 1 PRA submittals that are due by 2017. After the review of these submittals, the staff will also decide which, if any, of the Group 3 and conditionally screened-in plants need to perform a risk evaluation.

Risk Assessments

Finally, plants that screen-in for further evaluation may also need to perform detailed seismic risk evaluations using seismic PRA methodologies. The key elements of the seismic probabilistic risk assessment are (1) the modeling of various combinations of structural and equipment and operator failures that could initiate and propagate a seismic core damage sequence, (2) a fragility analysis of key plant equipment and structures, and (3) a seismic risk quantification for the plant.

Phase 2

The results of the information gathering process is intended to inform the Phase 2 decision making process such that any necessary regulatory actions would be based on a good understanding of the risk posed by the reevaluated risk hazard and the most effective actions to meaningfully reduce the risk. The seismic risk evaluations will provide the most comprehensive information to make

regulatory decisions, such as whether to amend the design or licensing basis or to make additional safety enhancements. The staff will use the information from the risk evaluations in conjunction with the existing regulatory tools to decide on further regulatory actions.

REFERENCES

1. US NRC, Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,” Recommendation 2.1, July 12, 2011.
2. US NRC, “Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,” March 12, 2012.
3. US DOE, EPRI, and US NRC, “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities,” US DOE Report # DOE/NE-0140, EPRI 1021097, Volume 6, NUREG-2115, January 2012.
4. EPRI, “EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project,” 3002000717. June 13, 2013.
5. Letter from NEI to US NRC transmitting March 11, 2014 letter from EPRI to NEI, “Fleet Seismic Core Damage Frequency Estimates for Central and Eastern U.S. Nuclear Power Plants Using New Site-Specific Seismic Hazard Estimates,” March 12, 2014.
6. US NRC, “Resolution of Generic Safety Issues,” NUREG-0933, “Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants,” GI-199, December 2011.

ACRONYMS

CDF	Core Damage Frequency
CEUS	Central and Eastern United States
CEUS-SSC	CEUS Seismic Source Characterization
CFR	Code of Federal Regulations
DOE	Department of Energy
EPRI	Electric Power Research Institute
GI-199	Generic Issue 199
GMRS	Ground Motion Response Spectrum
Hz	hertz
IPEEE	Individual Plant Examination of External Events
NMSS	Office of Nuclear Material Safety and Safeguards
NRC	Nuclear Regulatory Commission
NRO	Office of New Reactors
NRR	Office of Nuclear Reactor Regulation
NTTF	Fear-Term Task Force

PRA	Probabilistic Risk Assessment
R2.1	Recommendation 2.1
RES	Office of Nuclear Regulatory Research
SPID	Screening, Prioritization, and Implementation Details
SSE	Safe Shutdown Earthquake
WUS	Western United States