ISSUE STATEMENT

Earthquakes have the potential to cause significant damage to nuclear power plants, and therefore can constitute a significant contributor to the risk of a severe accident. Effective decision-making related to managing risk and addressing safety in the regulatory arena relies on a proper characterization of the risks associated with seismic events. Data refinements and analytical improvements are needed to obtain a more realistic understanding of the risk associated with seismic events.

DRIVERS

Several factors drive the need for more comprehensive and improved methods for seismic probabilistic risk assessments (PRAs).

Regulatory Pressures

Safety authorities in many countries require seismic PRAs to be conducted as part of the process to understand the risks posed by operating nuclear power plants (e.g., as part of periodic safety reviews). In the United States, there are also formal programs in place to apply risk information in a regulatory environment. Based in part on observations from a pilot seismic PRA completed by EPRI, however, current methods appear to fall short of being able to meet requirements of PRA standards in some areas. Also in the United States, regulators have focused on seismic risk evaluations as the tool for evaluating the impact of updated seismic hazards on operating nuclear plants.

More Effective Risk Management

Utilities must make effective use of available resources to address risks. Seismic-related risks are subject to significant uncertainty, and utilities need to have a proper understanding of this uncertainty. An improved capability to evaluate the risk associated with seismic events is important to ensure that available resources are applied in a manner that results in proper decisions regarding operational activities and cost-effective improvements in safety.

Public Perception

Risk assessments performed using data and methods that are not adequately realistic can lead to incorrect public perceptions. Seismic risk estimates that do not reflect the most appropriate characterization have the potential to lead to public misperceptions that can divert resources from more important issues.

RESULTS IMPLEMENTATION

EPRI will, in conjunction with other stakeholders, refine the data, tools, methods, and guidelines needed to support adequately realistic assessments of the risk associated with seismic events. These efforts will produce a more coherent framework for seismic PRA, and a better and more coordinated set of technical methods. In the short term many of these methods have been or will be used to resolve Fukushima-related issues. In the longer term, owners of nuclear power plants will employ these methods and tools to develop an appropriate understanding of the contribution of seismic events to risk necessary for risk management and effective risk-informed interactions with regulators. At the same time, the results of this research will aid regulators in developing a better understanding of the risk associated with seismic events to support future risk-informed decisions.

PROJECT PLAN

More effective and realistic assessments of the risk associated with earthquakes require research activities that are coordinated with regulatory agencies and other organizations. Some of these activities have been ongoing for several years. Others are being highlighted or redefined as a result of the pilot seismic PRA completed in 2010 and by the issuance of the NRC NTTF Recommendation 2.1. The research activities are organized into four areas:

Reassessment of the Seismic Hazard

EPRI is engaged in significant research to better characterize the level of earthquake ground motions as a function of their frequencies of occurrence. These include an overall assessment of the seismic hazard for the Central and Eastern United States, and participation in the updating of models for the attenuation of ground motion. EPRI is also working with NRC and the Department of Energy to develop a maintenance process for the Central and Eastern Seismic Source Characterization model.
**Improved Characterization of Fragilities**

Fragility analysis is the assessment of the conditional probability of failure as a function of the intensity of the hazard. Necessary areas of improvement with respect to fragility analysis for seismic PRA include better coordination of the failure characterization with the response spectra for the site; refinement in fragility estimates to reflect more recent data from tests and actual experience; the use of individual “scenario” earthquakes to reduce the conservatism intrinsic in the use of uniform hazard spectra which assume equal probability of exceedances at all frequencies; and better treatment of the impact on plant structures and equipment for soil sites. Additionally, EPRI completed a project to address the high frequency capacity of potentially sensitive equipment involving shake table testing and is completing a project with analytical techniques to reflect limited displacement at high frequencies. A separate project to summarize component capacity data from 20 years of EPRI SQRUTS program seismic testing is also underway.

**Seismic Risk Modeling and Quantification**

Efforts are underway or are being initiated to improve the integration of the seismic hazard, fragility, and plant model to obtain better risk estimates. These improvements include how best to treat the correlation among seismic failure of similar equipment; adaptation of methods for human reliability analysis to reflect the conditions and context of earthquakes; and better methods for quantifying seismic risk. These improvements will be tested through additional pilot studies.

**Implementation Activities**

To make the most effective use of these research efforts, specific activities must be undertaken to ensure that they are incorporated into various programs. These activities include supporting the revision and refinement of the PRA Standard; interacting with regulators; and providing training to utilities in the performance of seismic PRAs. Intensive efforts are underway to develop guidance to allow effective and timely resolution of seismic issues arising from the Fukushima accident. Ongoing efforts continue to focus on efficient use of resources and information sharing among utilities.

**RISKS**

The primary impact of not completing the development of a more comprehensive and realistic approach to seismic PRA will be that important safety issues are not identified and addressed. There is also a risk that if improvements are not made in certain elements of seismic PRA methods, the resources to complete seismic PRAs may be greater than should be needed. There are no clear risks posed by activities to pursue these research efforts.

**RECORD OF REVISION**

This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

<table>
<thead>
<tr>
<th>REVISION</th>
<th>DESCRIPTION OF CHANGE</th>
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| 0 | Original Issue: August 2011  
Roadmap Owner: Bob Kassawara |
| 1 | Revision Issued: August 2012  
Roadmap Owner: Bob Kassawara  
Changes: Addition of detail on projects for resolution of post Fukushima seismic related issues |
| 2 | Revision Issued: August 2013  
Roadmap Owner: Bob Kassawara  
Changes: Addition of detail on the flow chart on projects for resolution of post Fukushima seismic related issues including the following.  
- Funded task to update the Ground Motion Model (GMM)  
- Funded task to perform High Frequency research  
- Funded task to calculate site-specific seismic hazards and Ground Motion Response Spectra (GMRS)  
Extended the end date for the DOE led New Ground motion Attenuation (NGA) East Project consistent with current expectations. |
| 3 | Revision Issued: January 2014  
Roadmap Owner: Bob Kassawara  
Changes: Rearranged RSM activities into two primary groupings; EPRI Seismic PRA Research Program and Implementation Activities for SPRA. Added specific activities for the following funded tasks:  
- SPRA Structural Modeling Techniques  
- Fragilities from Scenario Earthquakes  
- Fragilities from EQ data  
- Resolution of Walkdown Questions  
- Interactions on ESEP and SPRA Implementation  
- Interaction with NRC and ANS on Regulatory Guides and Standards for restart following an earthquake |
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| 4        | Revision Issued: August 2014  
Roadmap Owner: Bob Kassawara  
Changes:  
Minor updates as follows.  
- Deleted activities associated with NTTF 2.3 seismic walkdowns and OBE exceedance criteria. These are not associated with PRAs for seismic risk, which is the scope of this Roadmap.  
- Extended the final date on the Fragilities from EQ Data task to include 2 additional trial equipment classes.  
- Extended the final date on the HF Program task to facilitate interactions with NRC on the application guidance. The report summarizing the test results is to be issues as previously scheduled.  
- Updated CEUS Site-Specific Seismic Hazard and GMRS Estimate milestone to show as complete |
| 5        | Revision Issued: December 2014  
Roadmap Owner: Bob Kassawara  
Changes:  
Minor updates as follows:  
- Added a Phase 2 project for determining equipment capacities from experience data.  
- Extended the project on fragilities from scenario earthquakes.  
- Noted completion of the structural modeling project.  
- Updated connections between projects (arrows).  
- Added a project to develop a maintenance plan for the CEUS SSC.  
- Added a project to consolidate SMA and fragility guidance. |
| 6        | Revision Issued: August 2015  
Roadmap Owner: Bob Kassawara  
Changes:  
Minor updates as follows:  
- Consolidated collaboration activities with government agencies and EPRI ANT into one area of the Road Map diagram.  
- Consolidated several Post Fukushima activities into one activity.  
- Added new project on high frequency component capacity.  
- Added new project on NUREG 2117 Update. |
| 7        | Revision Issued: December 2015  
Roadmap Owner: Bob Kassawara  
Changes:  
Minor updates as follows:  
- Marked High Frequency Phase 3 report as complete on the diagram. |
| 8        | Revision Issued: August 2016  
Roadmap Owner: Bob Kassawara  
Changes:  
Updated as follows:  
- Updated to reflect current progress through August, 2016 on the roadmap graphic.  
- Following this revision, this roadmap is being retired. Seismic events encompass a broad scope of research activities. The EPRI Nuclear Sector’s more recent prioritization process, which is organized by research focus areas (RFAs), is a more useful tool for presenting broad research areas. Together with the project overview forms and new, more consistent project plans, the RFAs provide sufficient detail and the needed perspective on the strategic horizon to inform advisors and obtain effective feedback. In the future, a separate roadmap may be initiated to track more specific areas within Seismic PRA, based on the need to reflect cross-organizational collaboration in a given technical area, as roadmaps are a particularly effective tool for displaying and communicating these interrelationships. |