OPPORTUNITIES FOR ADVANCING TECHNOLOGY-NEUTRAL AND PERFORMANCE-BASED DESIGN METHODS FOR THE SEISMIC DESIGN AND REGULATION OF SSCs AT NUCLEAR POWER PLANTS

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LBNL now has 5 NRC-sponsored research projects

- “An advanced framework for risk-informed seismic regulation of NPPs”
- “Advanced SSI modeling and simulation”
- “Correlations in the seismic response of NPP structures and equipment”
- Advances in base isolation technology for NPPs”
- “Evaluation of NRC seismic regulation of SMRs (small modular reactors)”

Plus another NRC project that is not research

- Each operating NPP has been asked by the NRC to do a re-evaluation of its seismic safety.
- The NRC and the industry are cooperating on writing the guidance that will govern this reevaluation.
- I (Budnitz) am the NRC staff's principal consultant on writing a major part of this guidance.
- The guidance will be out in late November.

A new framework: What is the issue?

- **We design SSCs (structures and components) to withstand earthquakes.**
- **What are the design requirements or guidance?**
- **What analysis is required to confirm acceptability?**
- **What acceptance criterion is used?**
- **Is this process “risk-informed”? “performance-based”?**

Basic framework for seismic-structural regulations (from ASCE 43-05)

- **Target performance goal: 10^{-5} per year**
- **"Success" vs. "failure" --- "onset of significant inelastic deformation" (OSID)**
- **Applies to one individual structure or component**
- **Level of confidence --- requirements seek mean confidence, which is typically between 80% and 90% confidence for these design problems**
- **Analysis --- determination of OSID: combination of realistic analysis and imposition of conservative assumptions**

Design approach -- seismic-structural design

- **Applies to one individual structure or component**
- **Begin with "design basis earthquake": 10^{-4} per year**
  (site-specific probabilistic seismic hazard analysis)
- **Design rules: deterministic design rules with some conservative assumptions (prescribed in ASCE 43-05)**
- **Based on experience from existing NPP structures and components – using above design rules, an individual SSC will generally have:**
  - **≤ about 1% prob. of failure at DBE**
  - **≤ about 10 % prob. of failure at 150% DBE**
- **NRC objective is that:**
  Conditional prob. of core damage < about 1% at 1.67 DBE
  (if DBE is 0.30g, then 1.67 times DBE means 0.50g)

Observations

- **Approach seems to be adequately conservative:**
  - **Target performance goal 10^{-5} per year**
  - **Applies to one individual structure or component**
  - **Each SSC designed starting with DBE (10^{-4}/year) has ≤ 1% prob. of "failure" at DBE**
  - **Each SSC has ≤ 10% prob. of "failure" at 150% DBE, recurrence say ~ 3 x10^{-5} per year**
  - **"Failure" is defined as "OSID"**
- **Specific design rules constrain innovation, even for SSCs similar to those already in our plants.**
- **"New" types of SSCs may or may not fit into this scheme.**
- **New design solutions for "old" SSCs may or may not fit.**

Limitations

- **Not fully "performance-based" – specific deterministic design rules**
- **One SSC at a time – as if each SSC is a "singleton" for Core Damage**
- **"Failure" = "onset of significant inelastic deformation"**
  a long way from actual "failure to perform the safety function"
  for most SSCs
- **Choosing a certain DBE (10^{-4}/year) plus specified design rules may not be optimum.**

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  Allow more realistic definition of "failure", case-by-case
- **Choosing a certain DBE (10^{-4}/year) plus specified design rules may not be optimum.**
  Allow designers to select whatever DBE they wish -- burden on analysis of actual performance

Full Use of PRA ("risk-based")

- **Still not ready for this.**
  - ***Seismic PRAs have large numerical uncertainties.***
  - ***The structure of a Seismic PRA is more robust than the numbers. [True of PRA generally!]***
  - ***Designers at-the-bench cannot now be trusted with too much flexibility as they execute their designs.***

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  - ***Designers at-the-bench cannot now be trusted with too much flexibility as they execute their designs.***
- **Possible path forward: Introduction of Seismic PRA into the design process with a very high burden of proof for the analyst**
- **First inroads could be in defining "failure" more realistically than "OSID", based on probabilistic fragility curves.**
- **Use of seismic PRA for relaxations for some SSCs, especially perhaps for some structures**

Broader insights

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- **The structure of the PRA may be a more reliable basis for changes in design approaches than the numbers themselves.**