Opportunities for improving regulations governing the seismic safety of large nuclear installations

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Improving the framework

- We design SSCs (structures and components) for NPPs and other large nuclear installations to withstand earthquakes
- **Observation:** The facilities are generally adequately safe, with plenty of additional margin above the earthquake design basis
- **Issue:** The framework for designing, analyzing, and regulating these facilities' seismic safety is far from optimal
- **Implications:**
  - The facilities may fail to take advantage of safety insights and improvements
  - The facilities may cost more than they should
  - The facilities may be more difficult to analyze than they should be
  - Regulation is uneven, and more challenging than it should be

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  - One seismic accident sequence dominates, and is controlled by one SSC
- **Unbalanced risk profiles exist for many existing large nuclear facilities**
  - Seismic failure of a single structure or component comprises half or more of the risk

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  - **A seemingly acceptable risk profile may be unacceptable if the risk analysis is performed correctly**

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Unbalanced risk profile

- Remedy
  - Infuse probabilistic risk assessment into design
    - Perform design using codes and materials standards
      - Need to be risk-informed
    - Perform a PRA and identify critical sequences
    - Identify any singleton SSCs

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    - Identify any singleton SSCs
    - **Implement design solutions that better balance the risk and reduce the dominance of the singleton(s)**
    - Confirm improvement by PRA

Unbalanced risk profile

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  - What are the criteria for *more balance*?
  - What are the critical consequences
    - Off-site risk to nearby populations?
    - Off-site risk to property?
    - On-site worker risk?
    - On-site risk (damage) property?

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- **DOE is uniquely positioned and staffed to lead**

Issue: SSC design process

- Currently, each SSC is designed individually
  - But risk is a function of *system response*
- Currently, design codes and materials standards are not coordinated
  - Within disciplines: reinforced concrete (ACI 349), prestressed concrete, structural steel (AISC N690)
  - Across disciplines: ASCE, ASME, IEEE

Issue: SSC design process

- Currently, each SSC is designed individually
  - But risk a function of *system response*
- Currently, almost none of the design codes considers the plant as a system
  - ASCE 43 is the exception
    - Articulated risk targets at the component level
    - Performance expectations are clearish
    - Limit states are fluffy and need better definition
      - What represents adequate confinement?

Issue: margins vary

- Seismic *margins* vary "all over the shop"
- Each seismic code and materials standard developed separately
  - Even within material type: ACI 349 and ACI 359
- Each code and standard using non-nuclear experience as a basis, often starting in the 70s
- No coordination across disciplines
- No coordination formally sought with the DOE and NRC regulatory frameworks

Issue: lack of knowledge

- Seismic performance expectations
  - Not clearly identified
- Seismic margins
  - Not understood
- Concrete safety-related nuclear structures (ACI 349)
  - Strength design for SSE (DBE, GMRS) shaking
  - Prescriptive details for shaking more intense than design basis
    - Too onerous with *special* details?
- Steel safety-related nuclear structures (AISC N690)
  - Strength design for SSE shaking
  - No discussion of beyond design basis performance
    - Non-ductile framing systems precluded by ASCE 43

Issue: lack of coordination

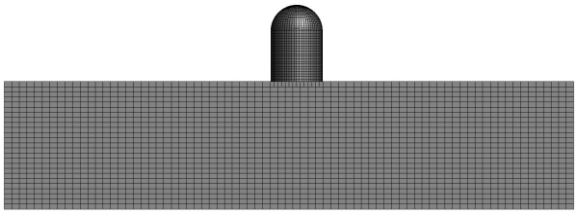
- Remedy
  - Coordinate across and within the disciplines
    - Performance expectations
    - Understanding of systems behavior
    - Methods for characterizing performance during design and at the end of the process
    - Coordination across the nuclear standards development community
  - DOE is uniquely positioned and staffed to lead
    - An *uber* version of the ASCE Nuclear Standards Committee
      - ANS, ASCE, ASME, and IEEE, among others

Closing remarks

- Risk profiles of our large nuclear facilities are highly unbalanced
  - Within a hazard by SSC, and across the hazards
  - No reason not to seek balance
  - Infuse PRA into the design process
- Lack of balance exposes a facility to a potentially great change in risk if one hazard is revised
  - Likely over the long lifespan of most nuclear facilities
- SSCs are designed component-by-component, discipline by discipline
  - System behavior is not (well) understood
  - Design processes are completely uncoupled and somewhat archaic
    - Efficient and cost-effective design and construction not possible
  - Seismic margins vary by component, material and discipline
    - Efficient and cost-effective design and construction not possible

Closing remarks

- Work of different codes and standards committees are uncoupled
  - Coordination needed
    - ASCE 4/43 and ACI 349, for example
  - Performance expectations to be identified
  - Common strategies to achieve performance goals
  - Common cycles for codes and standards
- DOE is uniquely positioned and staffed to lead
  - An overarching Nuclear Standards Committee
    - ANS, ASCE, ASME, and IEEE, among others
  - Deploy by 2035 with advanced reactor designs for testbeds



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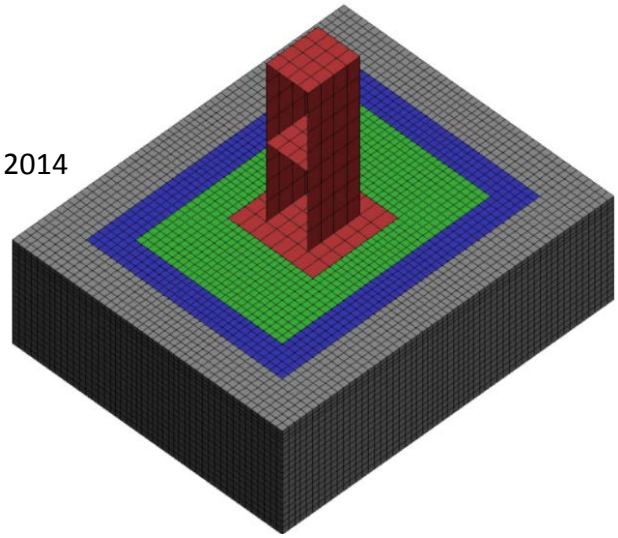

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