Importance of Risk-Informed, Performance Based Regulations

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Workshop on Probabilistic Flood Hazard Assessment

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The Pre-PRA Era

- **Management of uncertainty (unquantified at the time) was always a concern.**
- **Defense in depth became embedded in the regulations.**
- ***Design Basis Accidents* (DBAs) are postulated accidents that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to assure public health and safety.**

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Some Problems with Design Basis Accidents

- **DBAs use qualitative approaches for ensuring system reliability (the single-failure criterion) when more modern quantitative approaches exist**
- **DBAs use stylized considerations of human performance (e.g., operators are assumed to take no action within, for example, 30 minutes of an accident's initiation)**
- **DBAs do not reflect operating experience and modern understanding**

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Technological Risk Assessment (Reactors)

- **Study the system as an integrated *socio-technical* system**

- **Probabilistic Risk Assessment (PRA) answers the questions:**
  - **What can go wrong? (thousands of accident sequences are studied as opposed to the limited number of design basis accidents**
  - **How likely are these scenarios?**
  - **What are their consequences?**

- **The significance of external events was first identified by PRAs**

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Probabilistic Risk Assessment for Reactors

- **What is the core damage frequency (CDF)?**
  - **CDF = $\sum f(IE_i) \times P(CD/IE_i)$, where**
    - ✓ **$f(IE_i)$: frequency of initiating event i**
    - ✓ **$P(CD/IE_i)$: probability of core damage given initiating event i**

- **We need to consider the full range of potentially significant initiating events**
  - **This range includes very unlikely (and perhaps not-yet-observed) events**
  - **The uncertainties may be significant**

"It Cannot Be Done"

- In the early days of PRA, many engineers said that estimating core damage frequency for reactors "cannot be done"
  - Yet, it was done
- When practitioners were first trying to analyze human errors of commission, many said it "cannot be done"
  - Yet, it was done
- For certain external events, some experts say that estimating the frequencies of rare events "cannot be done"
  - ?

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Initiating Event Classification

PLANT CONDITION	IE FREQUENCY, $R\text{-}y^{-1}$
1	Normal Operation
2	$f > 10^{-1}$
3	$10^{-1} > f > 10^{-2}$
4	$10^{-2} > f > 10^{-4}$
5	$10^{-4} > f > 10^{-6}$

NRC Reviews of Initiating Event Frequencies

- **Risk-informing the large loss-of-coolant-accident (LLOCA) rule**
  - **The Commission stated: "a frequency of 1 occurrence in 100,000 reactor years is an appropriate mean value for the LOCA frequency guideline for selecting the maximum design-basis LOCA since it is complemented by the requirement that appropriate mitigation capabilities, including effective severe accident mitigation strategies, must be retained for the beyond design-basis LOCA category."** (US Nuclear Regulatory Commission, US Code of Federal Regulations, 2004)
  - **This statement indicates that the Commission considers the frequency of 10^{-5} per reactor year as an appropriate lower bound for the initiating events that should be included in the design basis**

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Risk-informed Regulation

"A risk-informed approach to regulatory decision-making represents a philosophy whereby risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety."

[Commission's White Paper, USNRC, 1999]

Risk-Informed Framework

Traditional "Deterministic" Approach

- Unquantified probabilities
- Design-basis accidents
- Defense in depth and safety margins
- Can impose unnecessary regulatory burden
- Incomplete

Risk-Informed Approach

- Combination of traditional and risk-based approaches through a deliberative process

Risk-Based Approach

- Quantified probabilities
- Thousands of accident sequences
- Realistic
- Incomplete

Risk-Informed Decision Making in Regulation

- **Improves Safety**
  - New requirements (SBO, ATWS)
  - Design of new reactors
  - Focus on important systems and locations
- **Makes regulatory system more rational**
  - Reduction of unnecessary burden
  - Operating experience accounted for in regulations
  - Consistency in regulations
- **Encourages performance-based regulation**
  - Maintenance rule
  - Fire protection
  - Determination of seismic design basis motion

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Challenges

- Overcoming the deterministic mindset
- Developing new decision guidelines
- Developing new or revised codes and standards
- Shortage of experts

Risk Management Task Force (RMTF)

"To develop a strategic vision and options for adopting a more comprehensive and holistic risk-informed, performance-based regulatory approach for reactors, materials, waste, fuel cycle, and transportation that would continue to ensure the safe and secure use of nuclear material."

NUREG-2150, April 2012

RMTF Findings: External Events

- The processes for establishing the external hazard design bases do not use consistent event frequency and magnitude methods
- New information that would provide the basis for external hazard frequency updates is not systematically collected, evaluated, and communicated
- PRA methods for assessing external hazard risks are available, but expertise in performing such studies is very limited

Conclusions

- **What is "worst case" is a matter of perception and is, therefore, notoriously subjective**
- **A risk-informed approach has many advantages**
- **A process is needed to systematically address new data and insights from experience and analyses, including:**
  - **Lessons learned from past events**
  - **Lessons learned from other agencies and the broader technical community**