RIPB Community of Practice Webinar

Recent Developments in RIPB Methods for Seismic Design

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Views expressed during this presentation are personal views and do not represent views of any organization

Most of the following slides are adapted from a presentation given at SMiRT-25, August 2019

Introduction

- LMP Framework
- Availability of Standards and Practices

A unique opportunity to move forward with the implementation of RIPB based seismic design

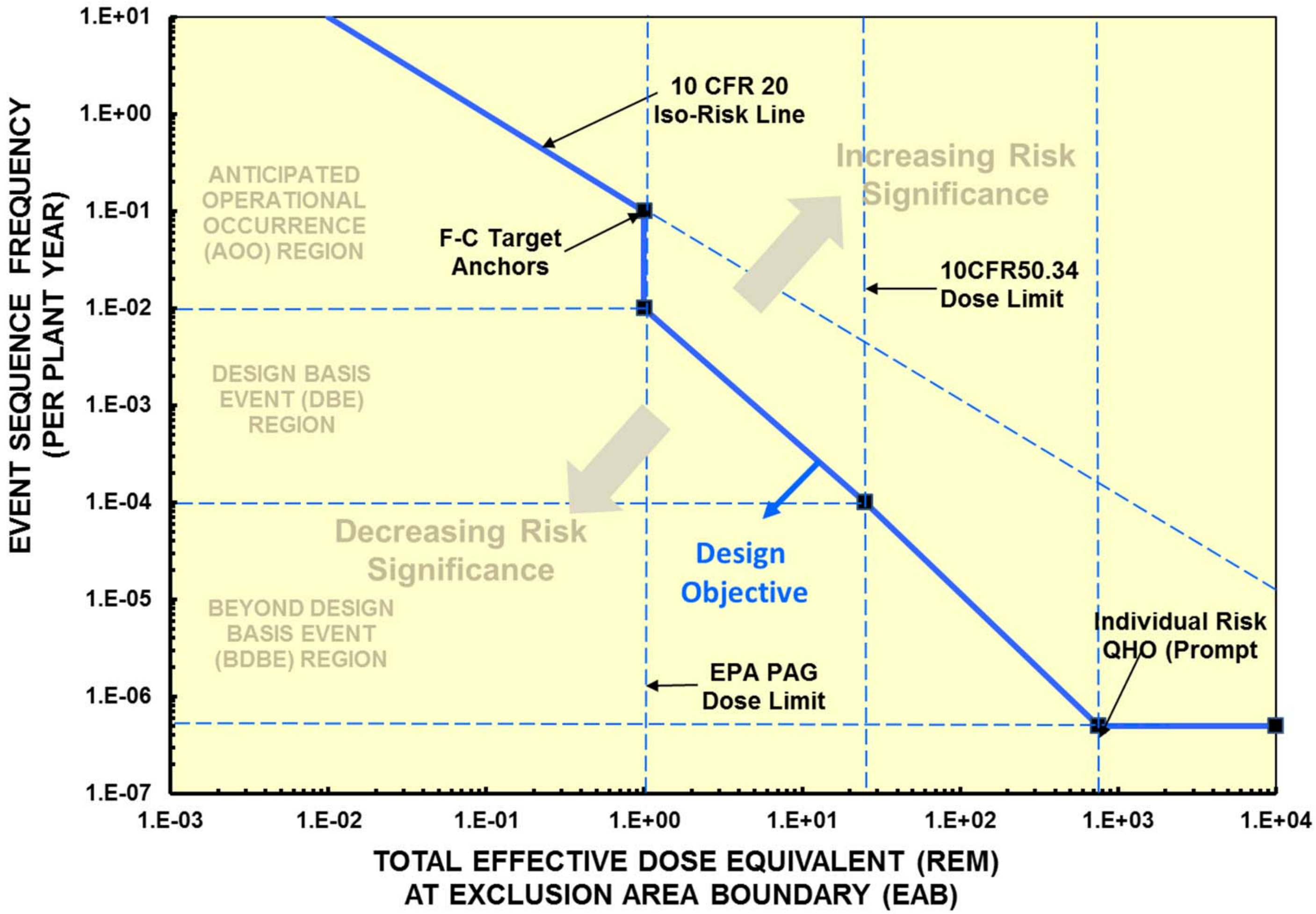
Cornerstones of LMP Framework

- Selection and evaluation of licensing basis events (LBEs)
- Frequency - Consequence (F-C) target and LBE risk-significance criteria
- Structures, systems, and components (SSC) classification and performance requirements
- Defense in depth adequacy evaluations

A PRA for non-LWRs is an essential element of the proposed RIPB LMP framework.

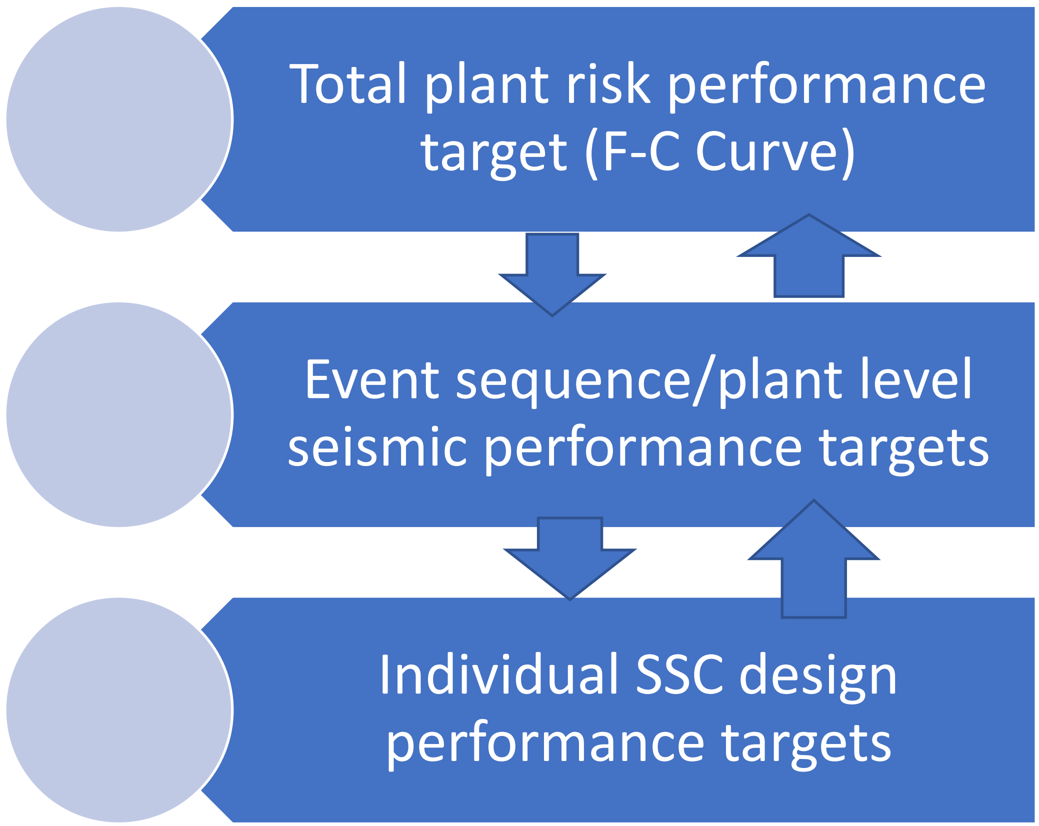
SPRA technology is mature and well-practiced

F-C Target



10 CFR 20
Iso-Risk Line
Increasing Risk Significance
ANTICIPATED OPERATIONAL OCCURRENCE (AOO) REGION
F-C Target Anchors
10CFR50.34 Dose Limit
DESIGN BASIS EVENT (DBE) REGION
Decreasing Risk Significance
Design Objective
BEYOND DESIGN BASIS EVENT (BDBE) REGION
Individual Risk QHO (Prompt
EPA PAG Dose Limit
EVENT SEQUENCE FREQUENCY (PER PLANT YEAR)
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
TOTAL EFFECTIVE DOSE EQUIVALENT (REM) AT EXCLUSION AREA BOUNDARY (EAB)

LMP Framework and Application to Structural Analysis and Design (Concepts)



Guiding Principles

- Integrate with the broader RIPB framework
- Build on existing RIPB approaches in structural/seismic engineering
- Utilize existing codes and standards to a maximum extent possible
- Update regulatory framework and guidance as necessary

Design process still basically familiar “deterministic” process

Evolution to Performance-Based and Risk-Informed Seismic Design

DOE and consensus standards

DOE 1020-2002 Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities (updated in 2012)

ASCE 43-05 Establishes criteria for risk-informed performance-based seismic design (Reviewed in NUREG/CR-6926)

ASCE 43 Update (2018)

ASCE 4 Update (2016) Seismic and structural analysis (consistent with ASCE 43)

ASCE 1 (Update) (2018) Geotechnical analysis and design

1971 – **GDCs**

1973 – **RG 1.60** Standardized seismic design response spectra

1996 – **10CFR100.23** Requires addressing uncertainties in SSE estimates and permits use of PSHA

10CFR50 App. S Relocated seismic engineering design criteria in Part 50

RG 1.165 PSHA guidance

2002

2005

2007 – **RG 1.208** Performance-based approach for selecting site-specific earthquake ground motion

2016-2021 – **RG 1.208 Update**

New RGs Performance-based seismic design criteria and analysis

SRP Revisions

Advanced Reactors Performance-based guidance

Other hazards

> 2021

ASCE 43
Seismic design criteria for structures, systems, and components in nuclear facilities

- A standard for the design of a new nuclear facility using performance targets for individual SSCs.
- The goal of the standard is to achieve the specified target levels at the component levels:
  - Less than about a 1% probability of unacceptable performance for design basis earthquake (DBE) ground motion; and
  - Less than about a 10% probability of unacceptable performance for ground motions equal to 150% of the design basis ground motion.

ASCE 43
Seismic design criteria for structures, systems, and components in nuclear facilities

- The acceptable performance level (the target performance goal) is achieved by selecting the return period of the DBE shaking in accordance with the seismic design category (SDC)
- Limit state (LS) defines the required performance in terms of the limiting acceptable condition of the SSC.
- The limit state (or the design performance) is adjusted based on the ultimate safety function and risk significance of the component.

This approach allows to control conservatisms and safety margins in accordance with the risk significance of SSCs. In the current approach, all safety-related SSCs are designed to same DBE and prescribed conservative limit states. For example, the level of ground motion for SDC4 is approximately half of SDC5 ground motion level for some sites. SDC 5 is currently considered applicable to NPPs.

ASCE 43 – Concept of Seismic Design Categories (SDC) and DBE

- ANS 2.26 provides guidance to assign categories for DOE facilities - SDC 5 is considered applicable to NPPs

	SDC Categories		
	3	4	5
Target Performance Goal (P_F)	1 x 10^{-4}	4 x10^{-4}	1 x10^{-5}
Probability Ratio (R_P)	4	10	10
Hazard exceedance probability (H_D) ($H_D = R_P \times P_F$)	1 x10^{-4}	4 x10^{-4}	1 x10^{-4}
DBE Response spectra or time history	DF (or SF) x UHRS		

ASCE 43 – Limit States

Limit State	Structural Deformation Limits
A	Large permanent distortion, short of collapse
	Significant damage
B	Moderate permanent distortion
	Generally repairable damage
C	Limited permanent distortion
	Minimal damage
D	Essentially elastic behavior
	Negligible damage

Limit state D is used currently for safety related SSCs

Use of ASCE 43 for Advanced Reactors

- Explore assigning alternate DBEs and limit states to SSCs according to their risk significance
- An example of a potential process
  - **Perform the design selecting initial SDC and LS categories**
  - **Perform a seismic PRA**
  - **Identify the major <u>accident sequences (similar to the concept of design basis sequence in addition to postulated design basis accidents)</u>**
  - **Identify the <u>actual "importance"</u> of each SSC, (if different than the original classification)**
  - **Revise SDC and LS categories, to identify design solutions that use a risk categorization approach to provide more margin where needed, but that backs off where appropriate. Maintain defense-in-depth and other qualitative factors, such as balance between prevention and mitigation, over reliance on human actions, etc.**
  - **Revise the seismic PRA to assure that the final design meets all of the criteria..**

Summary and Future Steps

- The biggest benefit of the RIPB seismic design is **flexibility** – flexibility to select design basis and design limits according to risk and safety significance
- Efforts are underway to establish links among the performance targets for the overall plant risk, seismic accident sequence and plant level, and individual SSCs according to the risk significance
- Adopt ASCE 43 approach to the proposed framework
- Develop guidance as necessary

NRC Public Meeting

September 2 and 3, 2020

ML20106F033 - Enhancing Risk-informed and Performance-based Seismic Safety for Advanced Non-light Water Reactors

ML20106F035 - A Proposed Alternative Risk-informed and Performance-based Regulatory Framework for Seismic Safety at NRC Regulated Facilities

ML20106F034 - White Paper on RIPB Approach to Seismic Safety

ML20115E533 - Workshop on Enhancing Risk-informed and Performance-based Seismic Safety for Advanced Non-light Water Reactors Agenda