



# Application of New Seismic Ground Motion Approach

3<sup>rd</sup> Steering Committee Meeting of IAEA EBP on Seismic  
Safety of Existing Nuclear Power Plants

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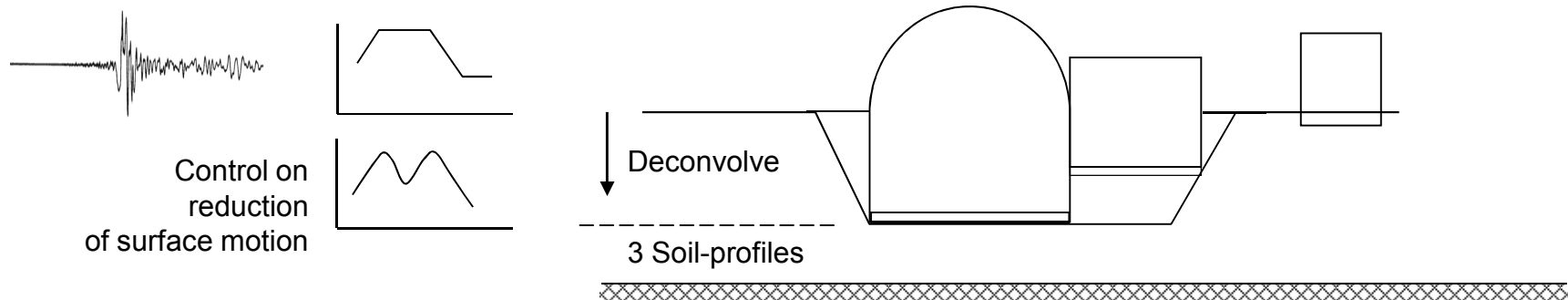
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# Current Status

- 18 Combined License Applications received
- 3 Design Certification (DC) Applications
  - General Electric Economic and Simplified Boiling Water Reactor (ESBWR)
  - AREVA Evolutionary Power Reactor (EPR)
  - Mitsubishi U.S. Advanced Pressurized Water Reactor (US APWR)
- 1 Amended DC Application
  - Westinghouse AP1000 Certification Amendment
- 4 Early Site Permit/Limited Work Authorization granted.
- 6 Letters of Intent for ESP/LWA/COL Applications over next 2 to 3 years
- 2 Letters of Intent to renew ABWR DC
- Interest in several Advanced Reactor DCs and GenIV

# Past Approach

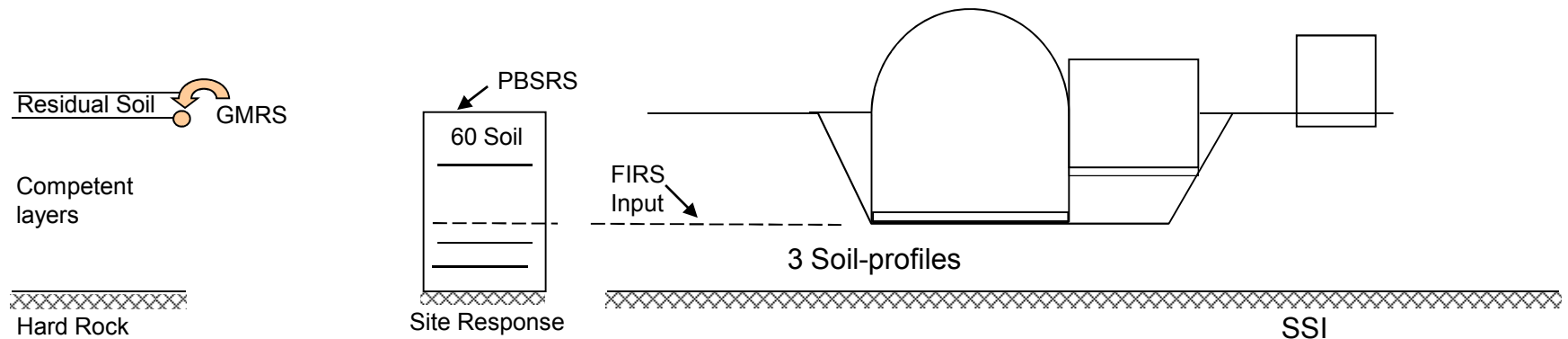
- Deterministic
- Steps to Determine SSE
  - Identify max. PGA level based on earth-science review (SRP 2.5)
  - Anchor a fixed shape (RG 1.60 for most cases) to max PGA (SRP 3.7.1)
    - This is SSE
  - SSE is defined at Free Surface
- Application in Subsequent Analysis



- SSE applied at surface in all subsequent analysis
- Deconvolved surface motion
- Deterministic procedure using 3 soil-profiles

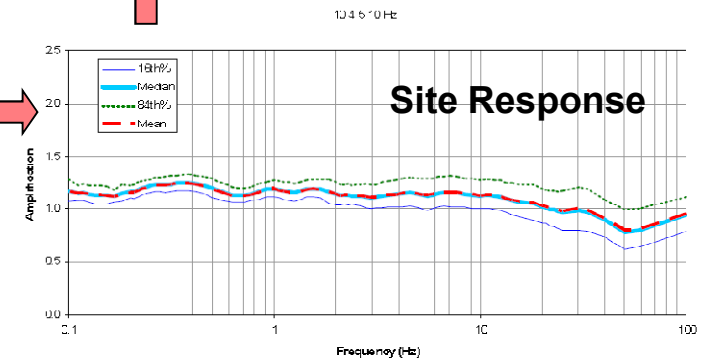
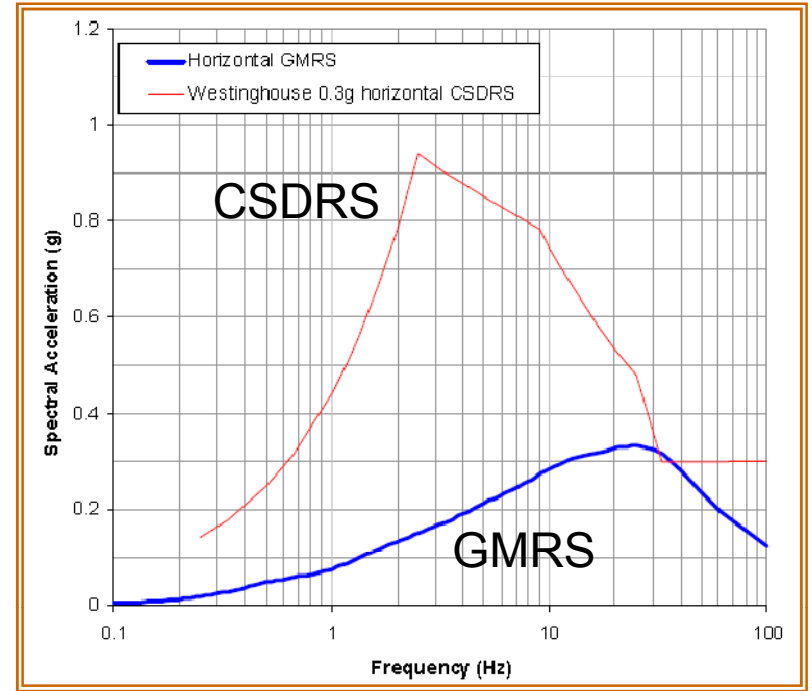
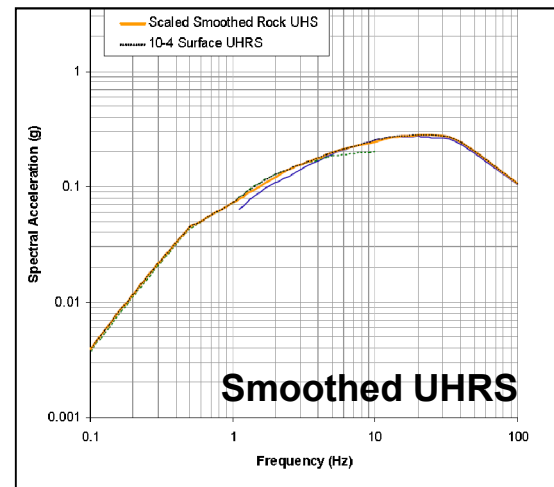
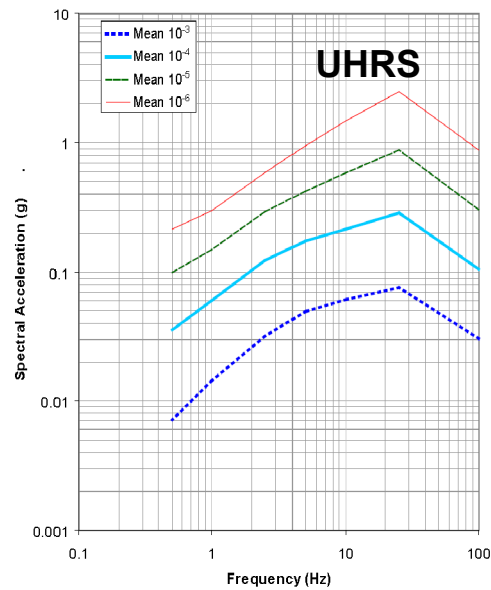
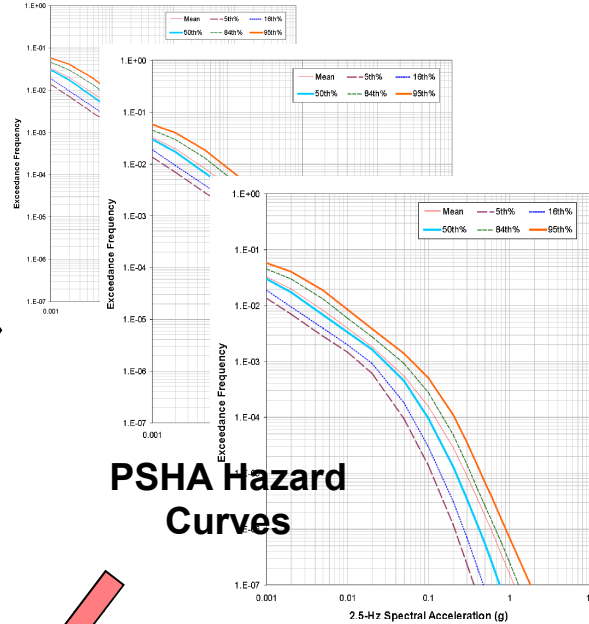
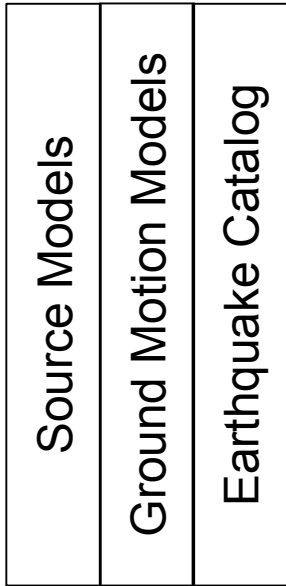
# Current Approach

- Probabilistic, performance-based to determine ground motions
- Steps to determine ground motion
  - Compute hazard curves (including uniform hazard spectra (UHS)) at hard rock (9200 ft/s)
  - Use 60 site-profiles to perform site-response analysis
  - Develop  $10^{-4}$  and  $10^{-5}$  non exceedance UHS at free surface
  - Determine performance-based ground response spectra from two UHS ( $10^{-4}$  and  $10^{-5}$ )
- Application in subsequent analysis



- In principle starting point for all subsequent analysis – UHS at rock
- Preserve performance-based approach for the surface motion for actual conditions
- Use input at the foundation level in free-field (that is compatible with the above) to perform deterministic SSI analysis

# Pathway to Performance- Based GMRS



Local Structure



# Comparison of Approaches

## Past Approach

- No ambiguity in defining SSE
- Surface motion is starting point for all subsequent analysis
- SSE same as design motion
- SSE response spectra are not site-specific
- SSE/OBE relationship straight-forward

## Current Approach

Unique and invariant site ground motion is UHS at hard rock - not at surface

UHS at hard rock starting point for analysis

No single surface motion applicable as design motion under varying site conditions. Site specific motion used for two major purposes

- To compare with the DC design

- To design site-specific structures

GMRS is a site-specific spectrum

CSDRS is not a site-specific spectrum

SSE/OBE relationship more complex (e.g., OBE for CSDRS designed items is tied to the CSDRS)

## Current Approach – Other Factors

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- ESP – Ground motion for site characterization. Design details of actual foundation conditions not available
- COLA – May have to generate new performance-based motions to account for site-profiles and design conditions (e.g., embedment, backfill, etc)
- Varying approaches used in DCs in the analysis and input location for the CSDRS

# Insights on Technical Issues

- Probabilistic Seismic Hazard Analysis – seismic source and ground motion update
- High frequency ground motion
- Comparison of site-specific motion with certified design motion
- Consistency between probabilistic site-response and deterministic SSI analysis



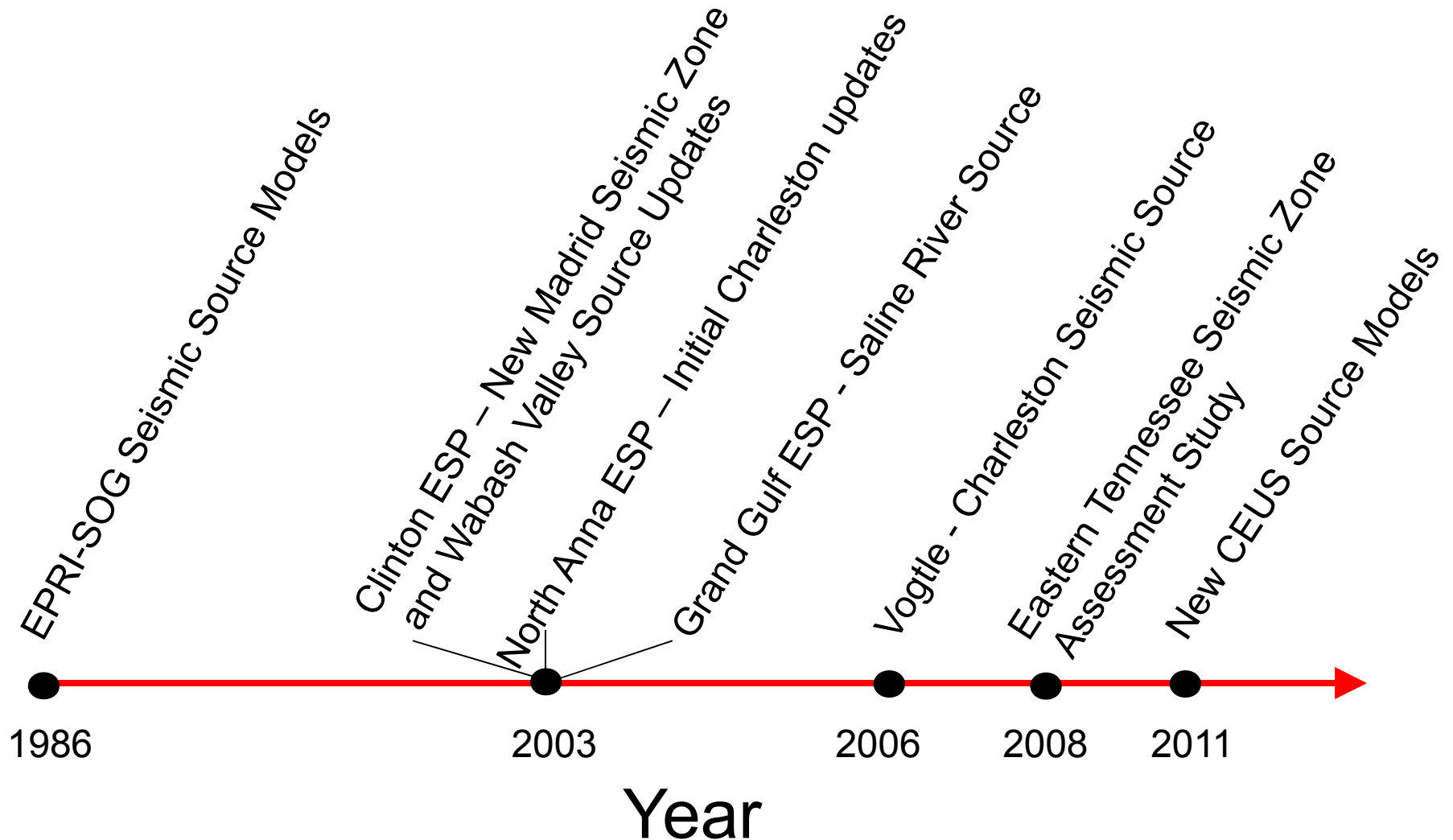
# Insights: Seismic Hazard



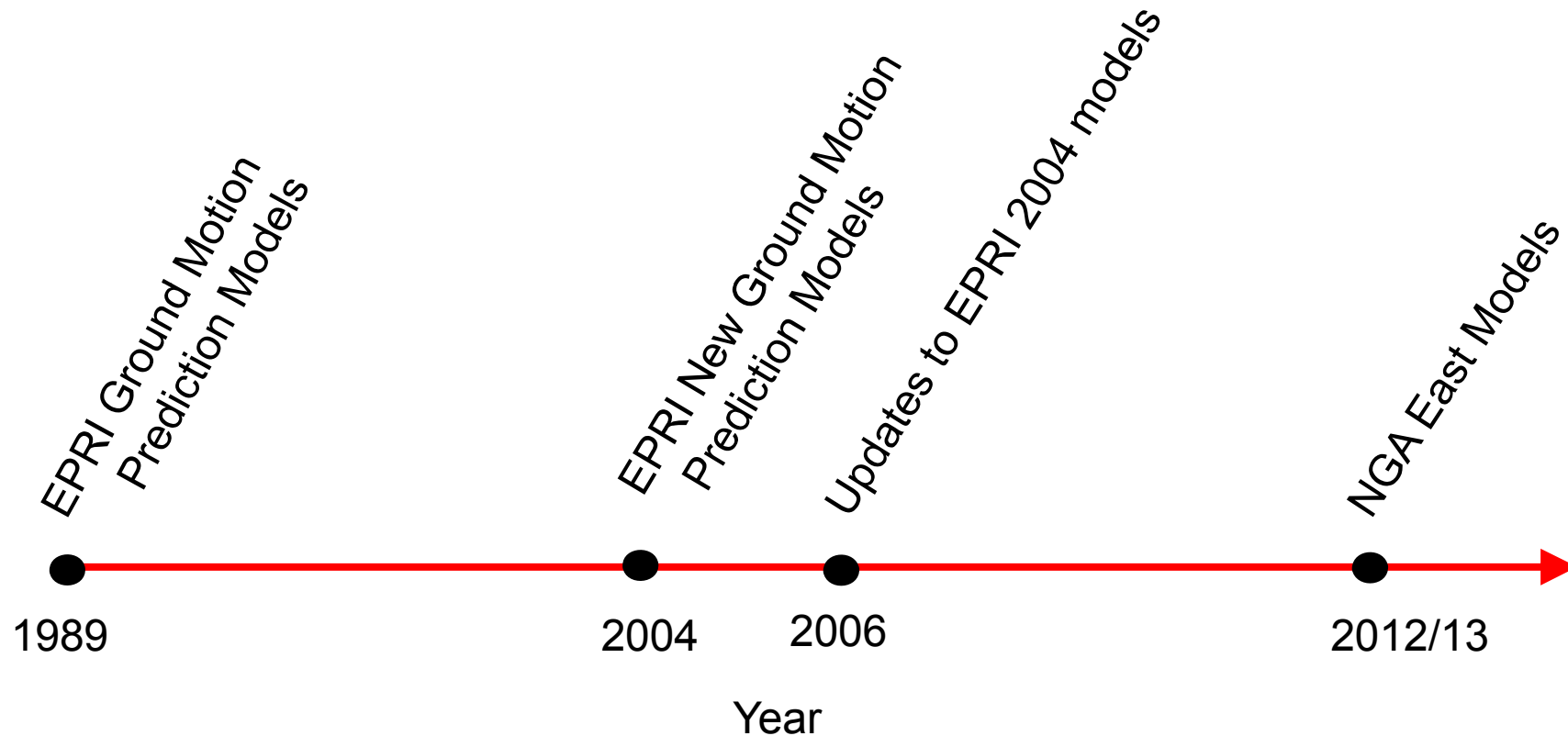
- Seismic Source Zone Updates
  - 1980's seismic hazard models for Central/Eastern U.S. approved for use as a starting point
  - NRC collaborating with Electric Power Research Institute & US Department of Energy to update old models
  - Worked with the industry on an approach to conduct sensitivity analyses for zones affecting site seismic hazard analysis
  - SSHAC lessons learned program

# Updates to EPRI-SOG Source Models

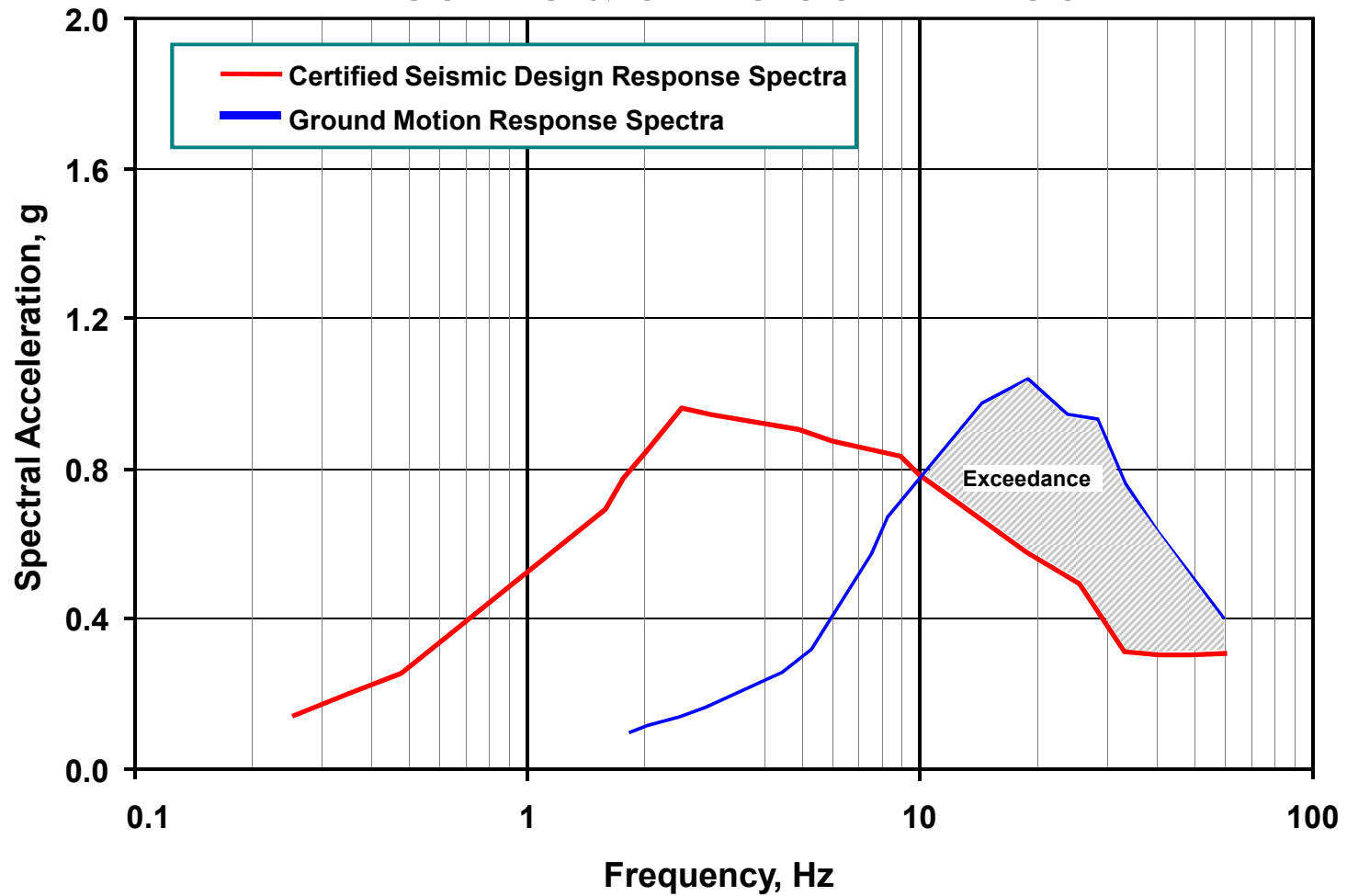
Source models are not static, they require updates as our understanding of the geology/tectonics of these sources improves



# Updates to Ground Motion Prediction Models



# HIGH-FREQUENCY GROUND MOTION ISSUE CSDRS & GMRS COMPARISON



# High Frequency Ground Motion - Resolution

- Updated SRP Section 3.7.1 “Seismic Design Parameter”
  - Provides a framework for review
  - Uses a graded approach
  - Recognizes the non-damaging effect of high frequency
  - Allows for the use of advanced analytical techniques

# High Frequency Ground Motion - Resolution

- Interim Staff Guidance (ISG –DC/COL-ISG-1) issued based on technical studies carried out by the industry
- Evaluation – not a design basis
- Acceptance criteria to implement new SSI analysis incorporating ground motion incoherency – identified acceptable incoherency functions
- Approved computer codes
- Equipment screening criteria
- Evaluation of selected structures and components

# Comparison Of Site-specific Motion With Certified Design Motion - Issue

- CSDRS – certified seismic design response spectra - generic response spectra used for certified design (CD)
  - At free grade surface or at the foundation elevation at an outcrop
- FIRS – foundation level input response spectrum
  - horizontal and vertical response spectra at foundation elevation at an outcrop
- How do we compare?
  - Comparison method driven by seismic design approach approved for certified design (CD)
- What do we compare?
  - Foundation input motion
    - Generic foundation input motion used in CD and corresponding hazard consistent site-specific input

# Comparison Of Site-specific Motion With Certified Design Motion - Resolution

- ISG under preparation based on industry white paper
- Acceptable procedures for different situations
  - Surface founded structures with no embedment
    - Site-specific FIRS, the surface response of soil column, with CSDRS
  - Embedded structure analyzed as surface structure
    - Compare horizontal and vertical FIRS with corresponding CSDRS
  - Embedded structure analyzed as embedded structure
    - Envelope of CSDRS-based FIRS for all the generic soil properties with the corresponding site-specific FIRS, provided that the CD was approved using enveloped responses, as well



# Minimum Input Check

- Only for horizontal excitation the peak ground acceleration (PGA) value of FIRS should be at least 0.1g
  - CDs based on 0.3g PGA broad band spectrum this check is redundant
  - For site-specific SSI analysis for Seismic Category I structures not covered by CD, the envelope of FIRS and the minimum input spectrum should be used.
  - Alternatively, separate analyses using site-specific FIRS and minimum spectrum can be conducted; but design should be based on envelope of responses.

# Summary

- Comprehensive seismic reviews
- Major achievements to date – 3 ESPs completed and ISGs issued
- Site-specific nature of issues
- Generic approach to the resolution of issues
- Maintain cognizance of advances in knowledge
- Internal & external coordination