Development of a Performance-Based Approach in Seismic Siting and Design

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Presenting for

Seismic Issues Technical Advisory Group

Office of Nuclear Regulatory Research, USNRC

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Division K

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NRC Seismic Issues Technical Advisory Group

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Outline of the Presentation

- Background
- Seismic Issues Technical Advisory Group
- 1997 Regulatory Guidance – R.G. 1.165
  - Reference Probability – Hazard-Consistent Approach
  - Based on 29 Operating Nuclear Power Plants - newest units
- 2007 Regulatory Guidance – R.G. 1.208
  - High Frequency Exceedances in PSHA
    - New Ground Motion Attenuation Models
  - Risk Consistent Approach – Performance-Based
- Technical Basis/Content
- Additional Discussion of Topics

Background

R.G. 1.208

- Intended to provide guidance to applicants for ESPs or COLs
  - RG 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion", remains as an acceptable alternative
- Utilizes a performance-based method for developing a site-specific safe shutdown earthquake ground motion (SSE)
- Technical basis informed by:
  - SITAG knowledge and expertise
  - ASCE 43-05
  - Industry research

Regulatory Guide 1.165 – Identification & Characterization of Seismic Sources & Determination of SSE Ground Motion

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- Describes geological and seismological investigation for a site
- Provides a Hazard-Consistent approach to siting
- Establish a Reference Probability (RP) Method to determine SSE
- RP is a Hazard-Consistent measure, based on the annual probability of exceedance of SSE at 29 operating reactor
- Since RP depends on specific hazard curves being used, periodic update is needed
- Published in 1997, and used in two ESP applications
- New studies need to be incorporated

New Regulatory Guide 1.208 – A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion – Published Final March 2007

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- Uses a Risk-Consistent approach
- Describes a Performance-Based approach to determine SSE and PB approach is a risk consistent method
- Achieves both high and consistent level of seismic safety in the design of future NPPs
- Uses a Mean Performance Target of 10-5/year
- Has been used in DOE practice for 10 years
- Reflects recent improvements in PSHA methodology, such as applying Cumulative Absolute Velocity (CAV) method to eliminate non-damaging earthquakes
- Provides probabilistic site response guidance

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Performance-Based Approach to Determine SSE

$$PB\ SSE = DF \times UHRS_{10^{-4}}$$

$$DF = \text{Max}\ (0.6 A_R^{\ 0.8}, 1.0)$$

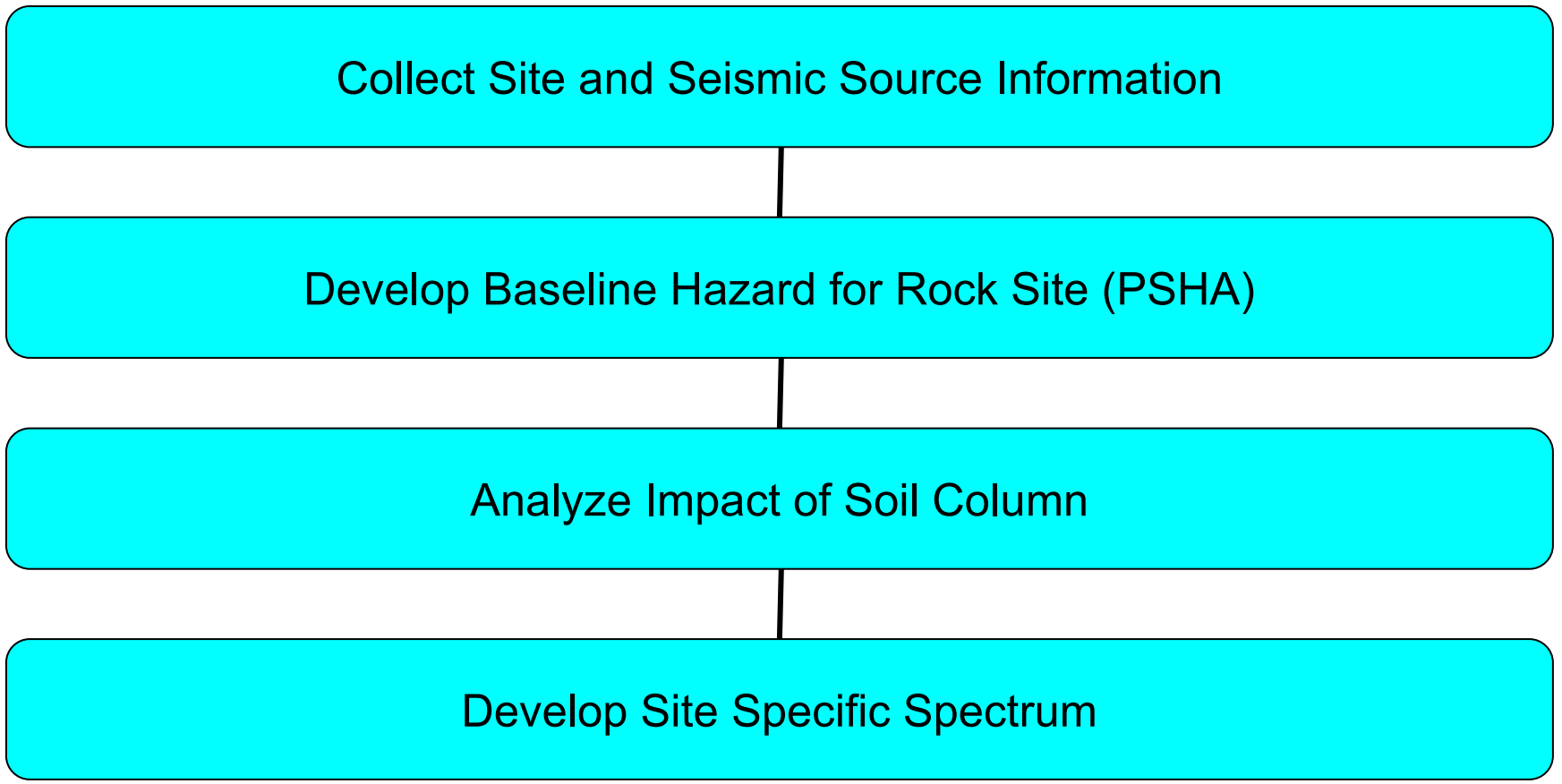
$$A_R = \frac{UHRS_{10^{-5}}}{UHRS_{10^{-4}}}$$

DF: Design Factor
AR: Hazard curve slope
$UHRS_{10\text{-}5}$ and $UHRS_{10\text{-}4}$: mean Uniform hazard response spectra with annual probability of exceedance of 10^{-5} and 10^{-4}

Performance Target

- Performance Target (P_{FT}) is $1x10^{-5}$ per year
  - Median SCDF is $1.2x10^{-5}$/yr
  - IPEEE seismic PRAs conducted for 25 NPPs during mid/late 1990s determined annual SCDF values
- Implies a Mean Seismic Hazard of 10^{-4}/year – Empirical
- Performance is measured in terms of Frequency of Onset of Significant Inelastic Deformation (FOSID), essentially elastic behavior
- Therefore, P_{FT} corresponds to a damage state which is more conservative than the SCDF

What does Reg Guide 1.208 do?



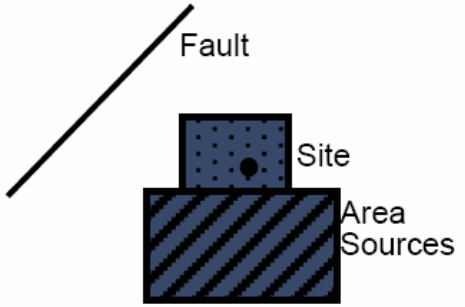
Collect Information

- Site Specific Investigations
  - Geological
  - Geophysical
  - Seismological
  - Geotechnical
  - Regulatory Position 1
  - Appendix C
- Regional Seismic Sources
  - Shaking
  - Surface rupture
  - Latest models incorporated
  - Regulatory Position 2
  - Appendix C

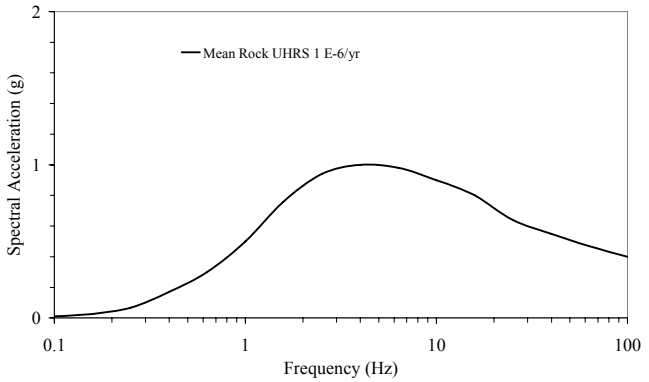
New Issue: CAV Filtering

- Cumulative Absolute Velocity
- Small close quakes = short high-f motions

  Current methods over-predict damage for sites in area sources
- Better predictor of damage than peak acceleration
- Removes quakes too short to cause damage



Regulatory Position 3



Cumulative Absolute Velocity vs. Minimum Magnitude Truncation

- Current PSHA uses minimum magnitude (step function) as a threshold for hazard input
- Recommend the use of Cumulative Absolute Velocity (CAV) to determine ground motion cut-off

Cumulative Absolute Velocity vs. Minimum Magnitude Truncation

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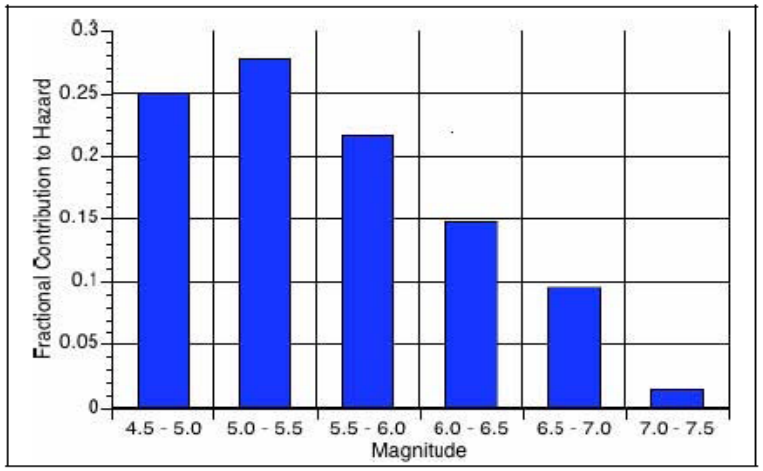
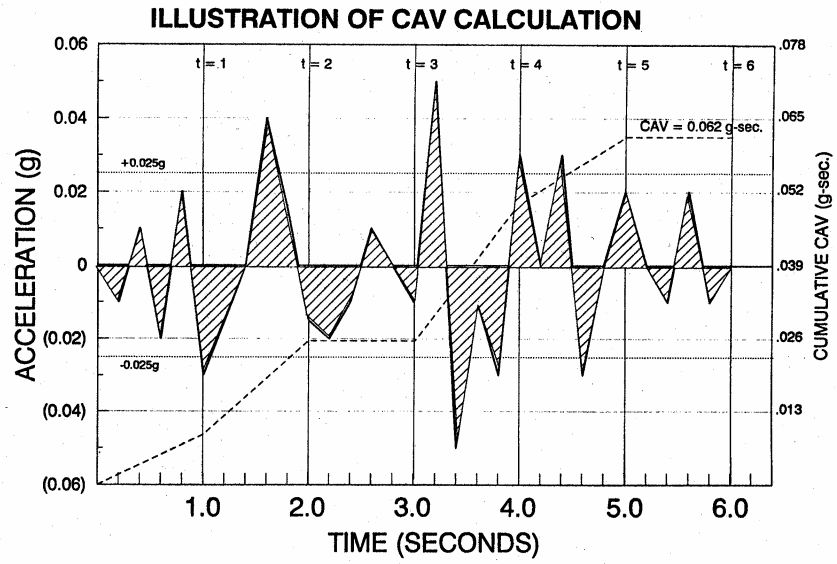
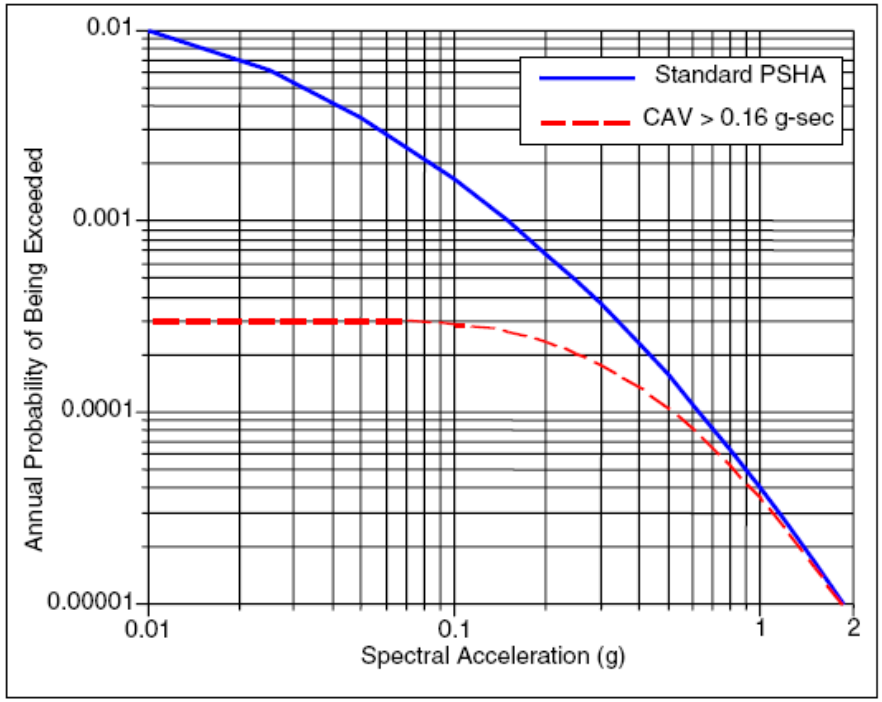
Magnitude Truncation

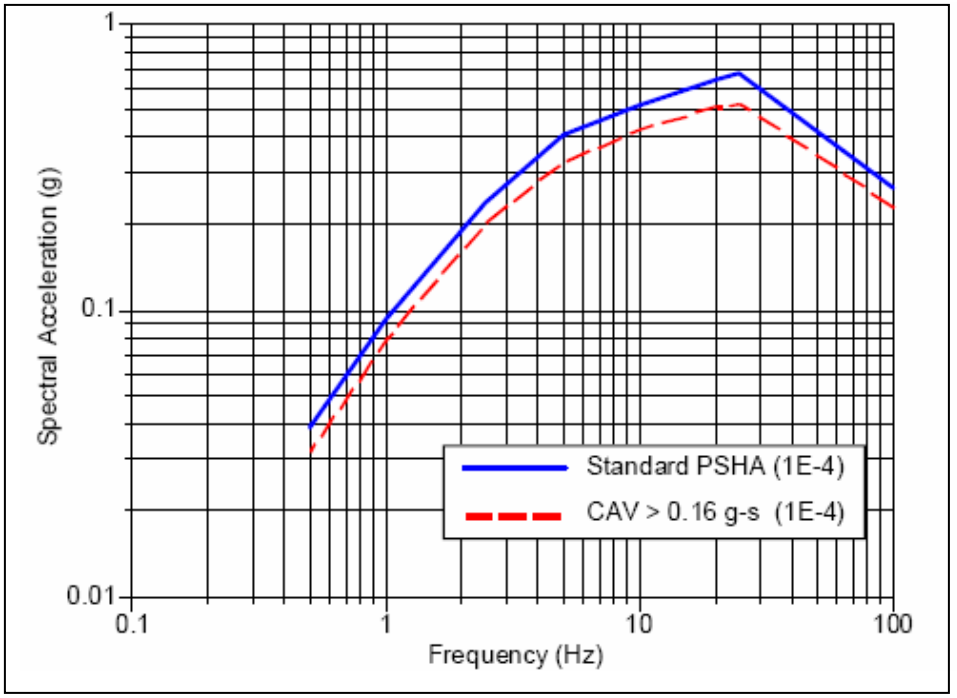


Cumulative Absolute Velocity



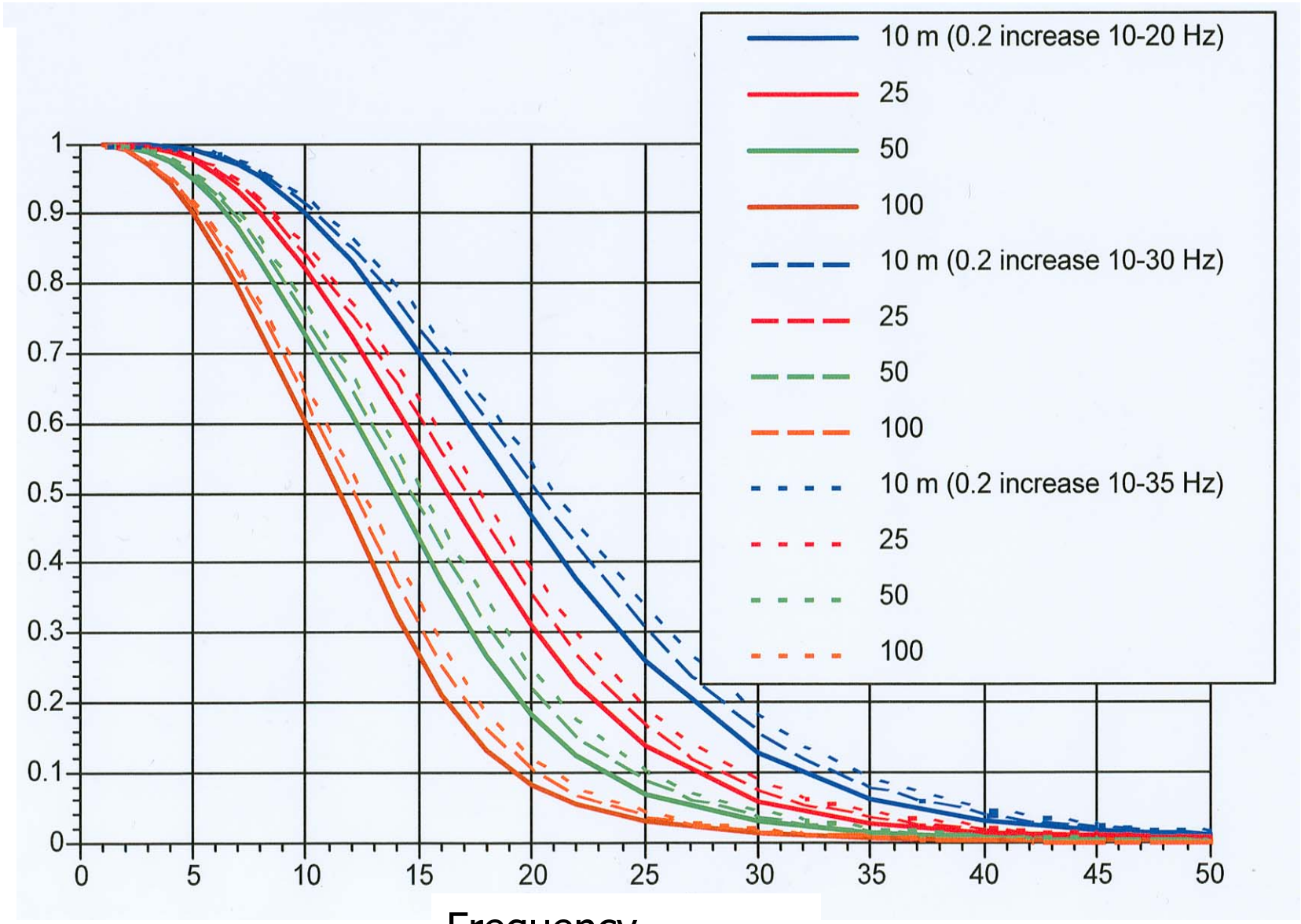
CAV Effects

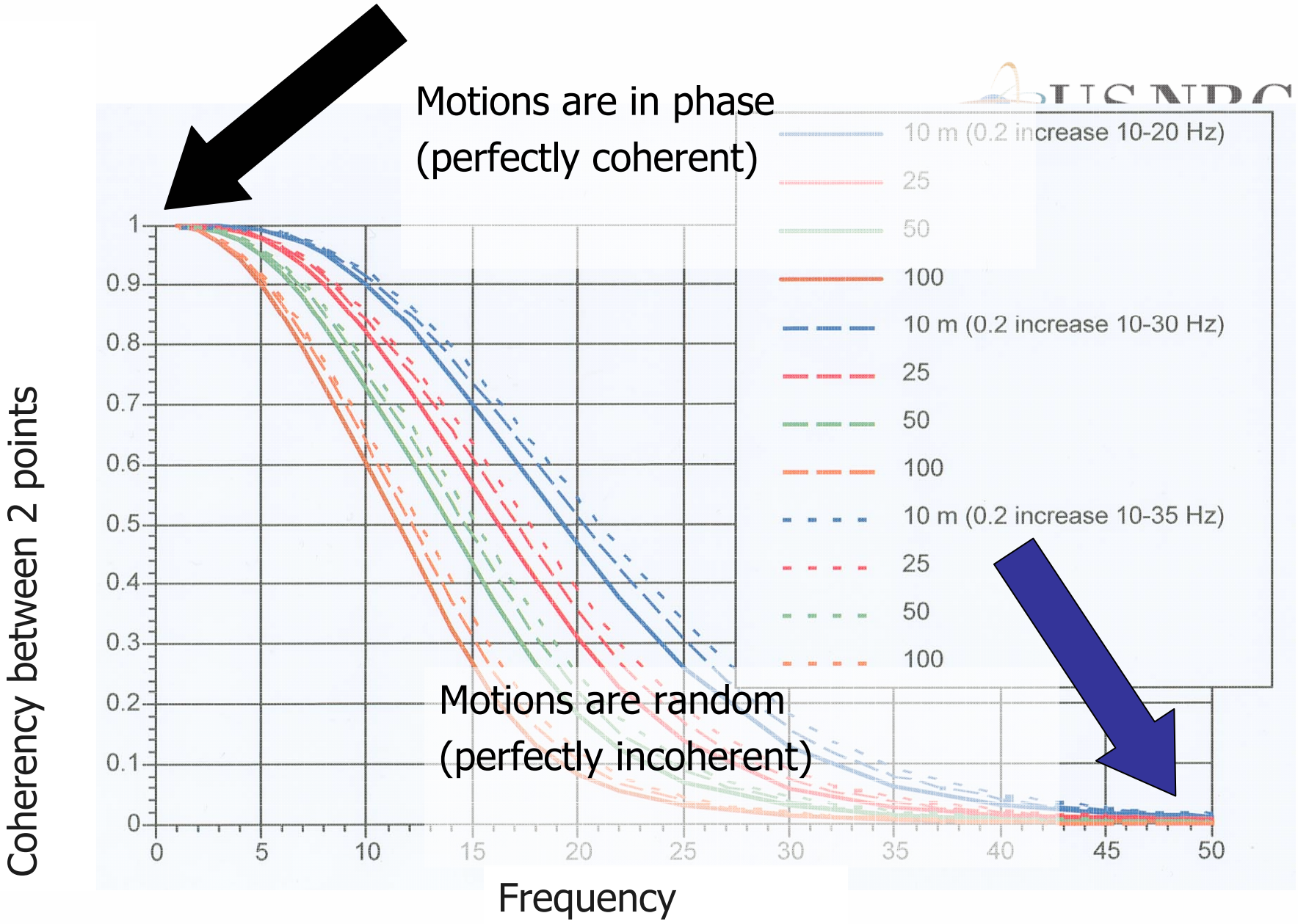

0.01
0.001
0.0001
0.00001
Annual Probability of Being Exceeded
0.01
0.1
1
2
Spectral Acceleration (g)
Standard PSHA
CAV > 0.16 g-sec

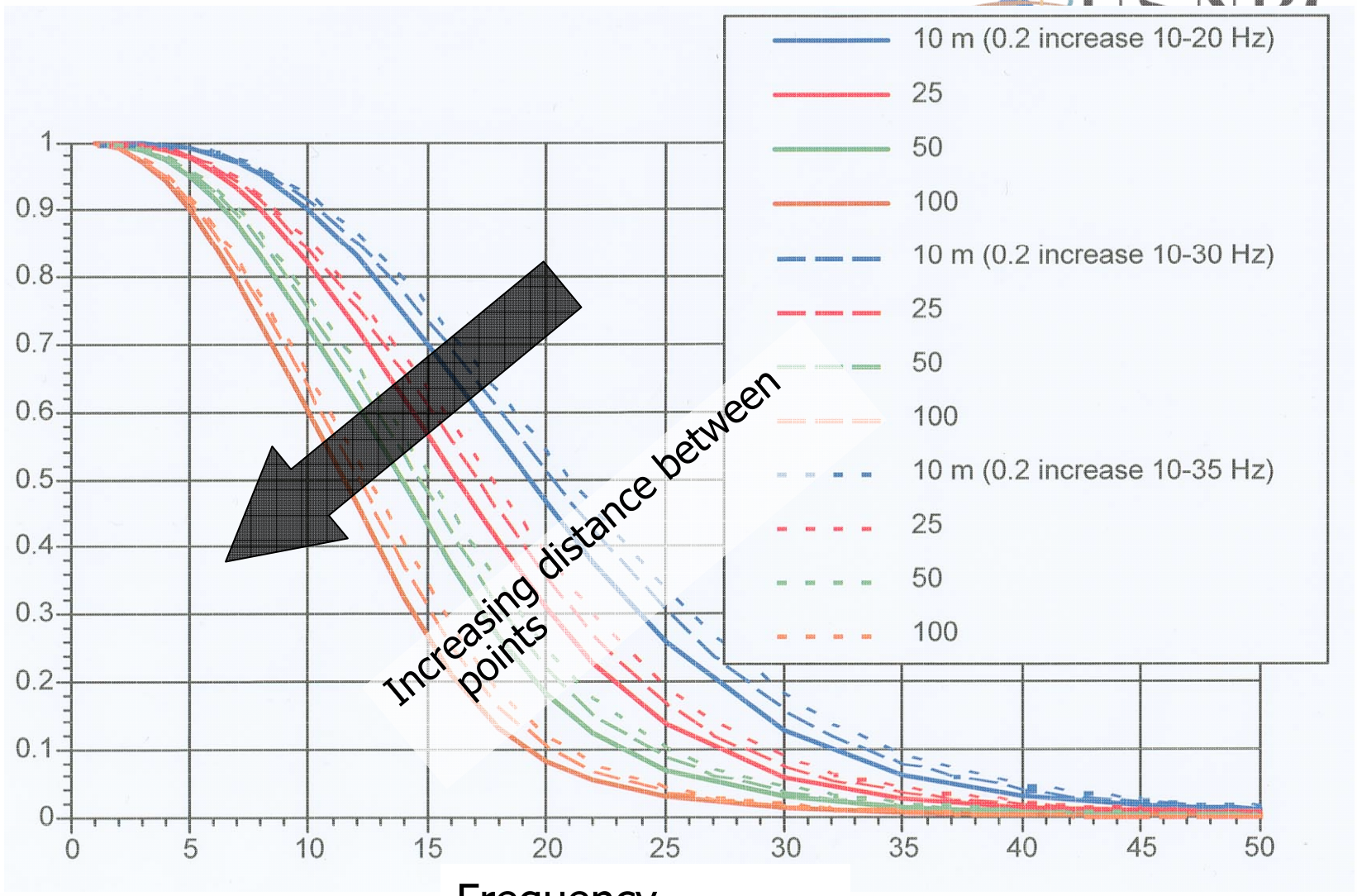

1
0.1
0.01
Spectral Acceleration (g)
0.1
1
10
100
Frequency (Hz)
Standard PSHA (1E-4)
CAV > 0.16 g-s (1E-4)

Pending/Potential Issues

- Potential Use of an Incoherency Function to Reduce Effects of High Frequency Ground Motions
  - Topic to be addressed in Standard Review Plan (SRP)
- SSE is not a Design Response Spectrum for all cases (DRS)
  - Current document does not address the development of a site-specific DRS
  - Assumed that the DRS will be included in the NRC SRP


10 m (0.2 increase 10-20 Hz)
25
50
100
10 m (0.2 increase 10-30 Hz)
25
50
100
10 m (0.2 increase 10-35 Hz)
25
50
100
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
40
45
50
Coherency between 2 points
Frequency


Motions are in phase
(perfectly coherent)
Motions are random
(perfectly incoherent)
Coherency between 2 points
Frequency
10 m (0.2 increase 10-20 Hz)
25
50
100
10 m (0.2 increase 10-30 Hz)
25
50
100
10 m (0.2 increase 10-35 Hz)
25
50
100
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
40
45
50


Coherency between 2 points
Frequency
Increasing distance between points
10 m (0.2 increase 10-20 Hz)
25
50
100
10 m (0.2 increase 10-30 Hz)
25
50
100
10 m (0.2 increase 10-35 Hz)
25
50
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35
40
45
50

Conforming Standard Review Plan Changes

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- Standard Review Plan (NUREG – 0800)
  - Chapter 3 – Design of Structures, Components, Equipment, and Systems
    - Section 3.2.1 – Seismic Classification - reviews the seismic classification of SSCs important to safety & designed for the effects of the SSE
    - Section 3.7.1 – Seismic Design Parameters – review of OBE & SSE as three components of the design ground motion
    - Section 3.7.2 – Seismic System Analysis – reviews dynamic analysis methods (response spectra, time history, equivalent static load, etc.) for all Seismic Category I SSCs
    - Section 3.7.3 – Seismic Subsystem Analysis – reviews dynamic analysis methods for all Seismic Category I subsystems