NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Risk-targeted Ground Motions for Bridge Design

May 17, 2023

12:00 – 1:00 PM

PDH Certification Information

1.0 Professional Development Hour (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

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Purpose Statement

This webinar will share the development and basis for the recently adopted risk-targeted approach. Presenters will share the differences between uniform hazard and risk-targeted ground motions and how to apply the new risk-targeted ground motions within the AASHTO specifications.

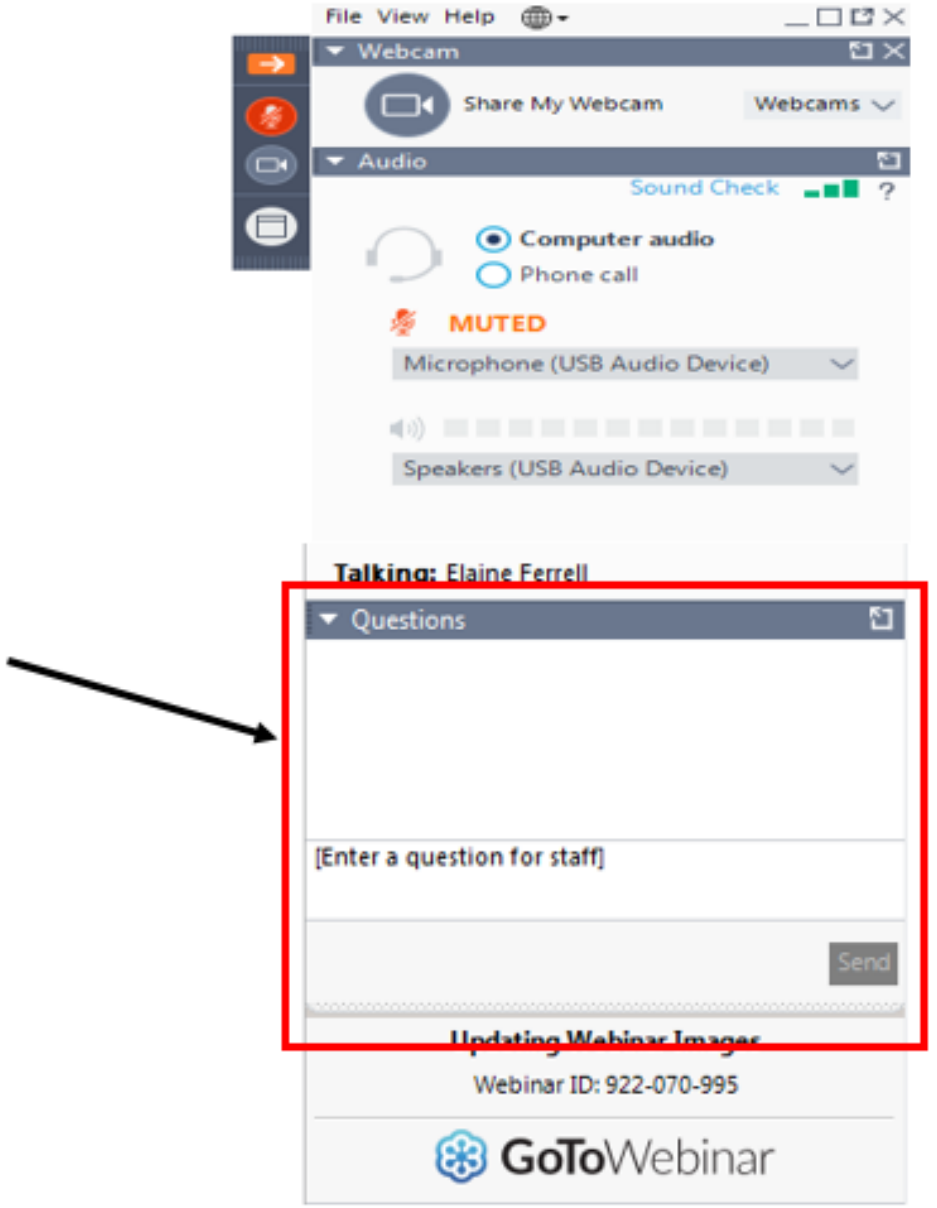
Learning Objectives

At the end of this webinar, you will be able to:

- Differentiate between risk-targets and uniform hazards ground motions
- Apply the risk-targets ground motions within the AASHTO specifications

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

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Risk-targeted Ground Motions for Bridge Design

Transportation Research Board

AKB 50

May 17, 2023

Project Team

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Jerry Shen, Jeffrey Ger, Derek Soden	FHWA - Advisory

Outline

- Motivation
- Improvements in Hazard Estimation
- Shortcomings of Uniform Hazard Ground Motions
- Introduction to Risk Targeted Ground Motions
- Effects on Geotech Design
- Comparison of New vs. Previous Ground Motions
- Q/A

Motivation

- AASHTO seismic design maps based on 2002 Hazard Model
- Significant changes in seismic hazard estimation
  - Seismic sources
  - Site factors/Soil effects
  - Multi-period accelerations
  - Next Generation Attenuation relationships
  - Basin effects
- Some states abandoning AASHTO maps due to age
- Move back toward a national standard for ground motions

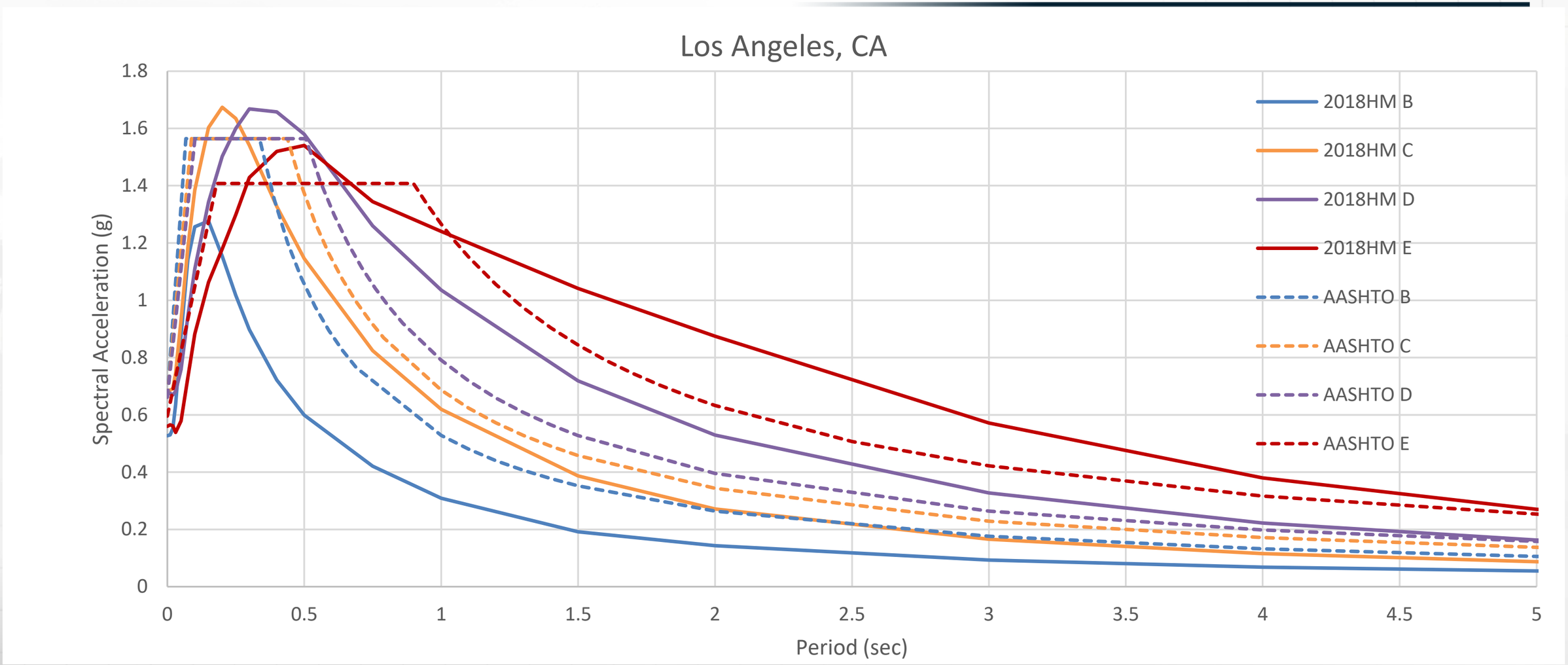
Changes in USGS Hazard Model

- Seismic sources/faults
- Next Generation Attenuation relationships
  - Soil effects
  - Multi-period accelerations
  - Basin effects
- No longer provided in maps – now database available online

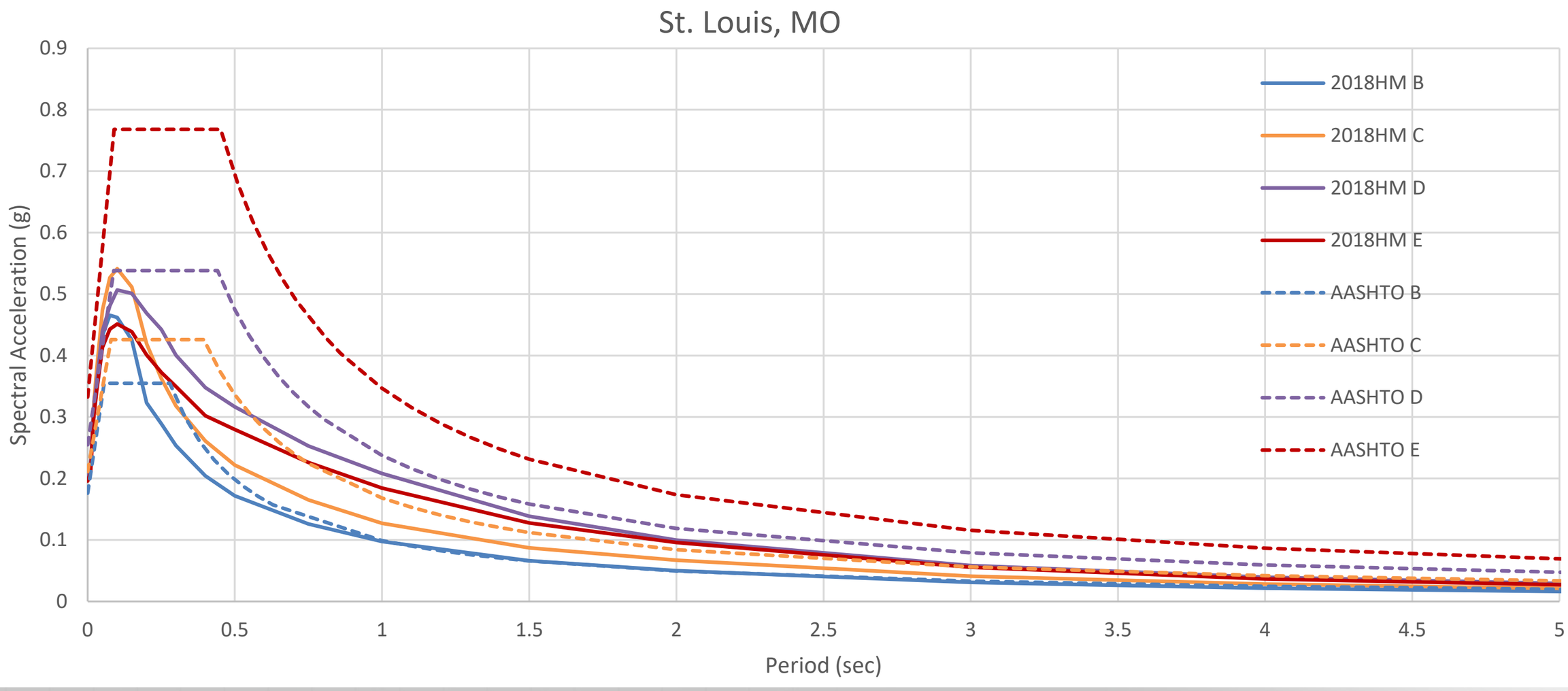
Changes Affecting Design Procedure

- Site Factors
  - Were the same everywhere
  - Provided at 0, 0.2, and 1.0 seconds
  - Now known to be inaccurate, with exceptions
  - Site factor method can underestimate hazard (even with updated factors)
  - New approach includes them directly in design spectra (no need to modify results)
  - New site classes BC, CD, DE
- 22-point spectrum vs. 2 point
  - Full curve provided (with straight line interpolation)
  - No “canned” curve fitted to the 2 points

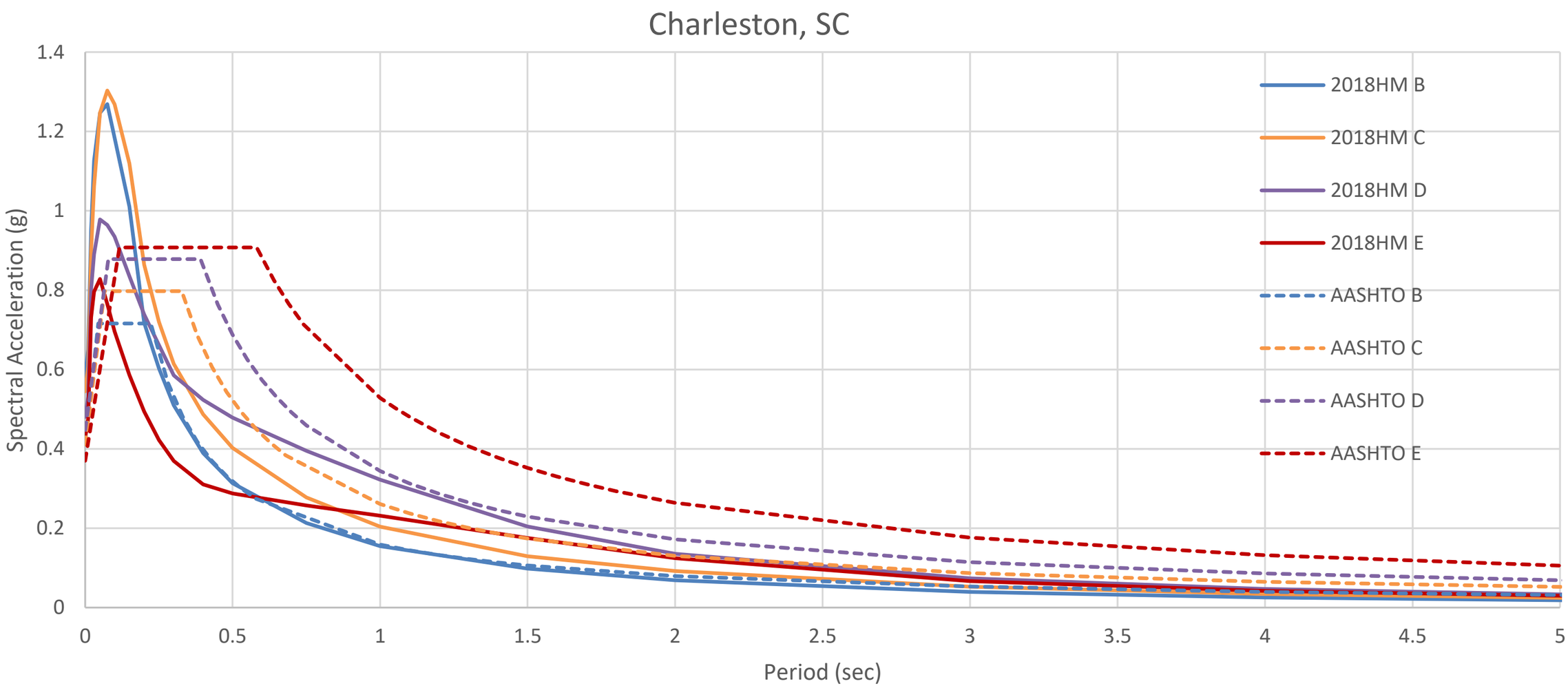
2018 USGS Uniform Hazard vs. Current AASHTO Uniform Hazard



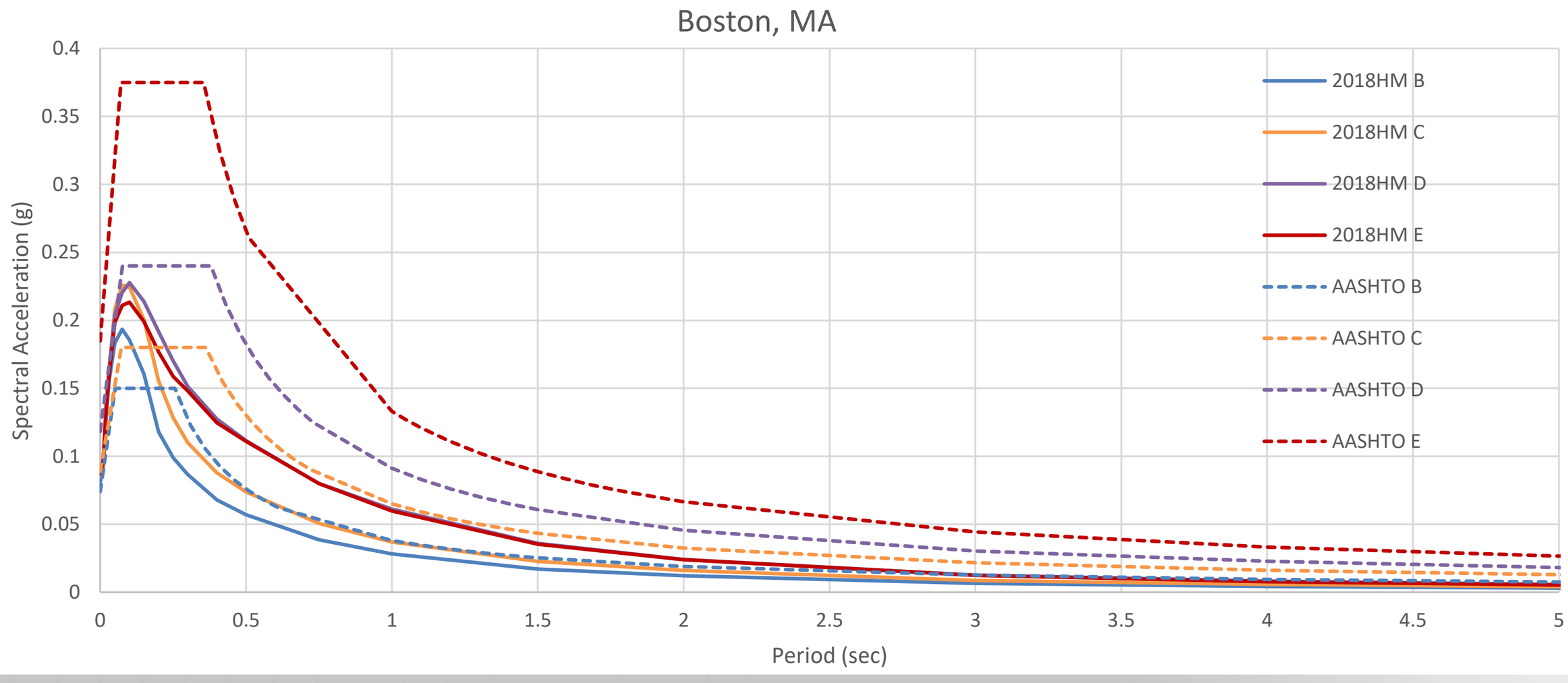
2018 USGS Uniform Hazard vs. Current AASHTO Uniform Hazard



2018 USGS Uniform Hazard vs. Current AASHTO Uniform Hazard

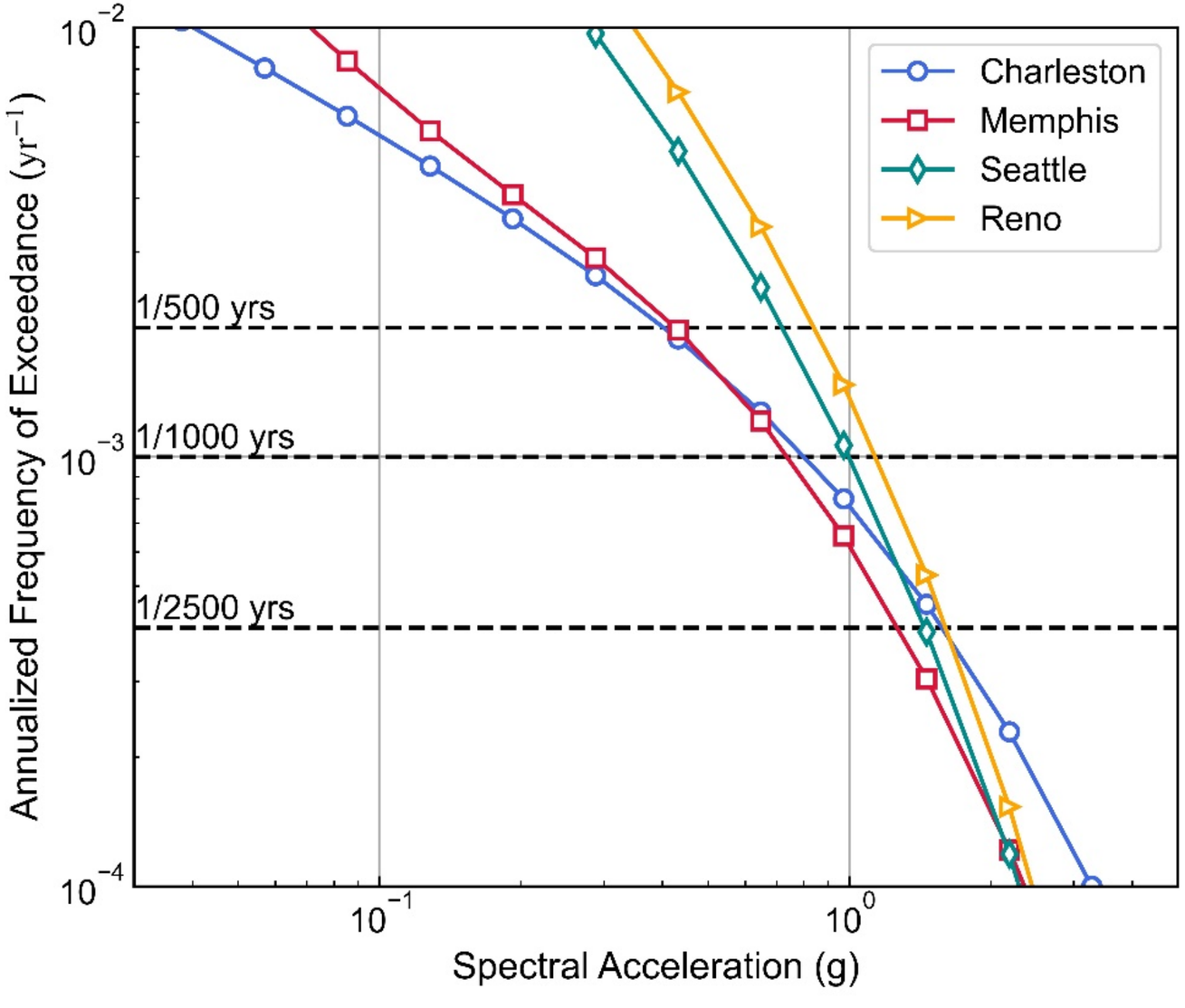


2018 USGS Uniform Hazard vs. Current AASHTO Uniform Hazard



Motivation for Risk-Targeted Motions

- Dramatic reductions in design motions in eastern US
- Risk is unequal across the country due to variations in the nature of the hazard
- Single return period cannot account for these variations
- No explicit consideration of what might happen if larger event occurs
- ASCE 7 moved to risk-targeted for these reasons



Uniform Hazard

- A single point along the hazard curve is chosen for design
- Ignores variation with location
- Doesn't address the question: what happens if a bigger earthquake occurs?

Risk-Targeted Ground Motions (RTGM)

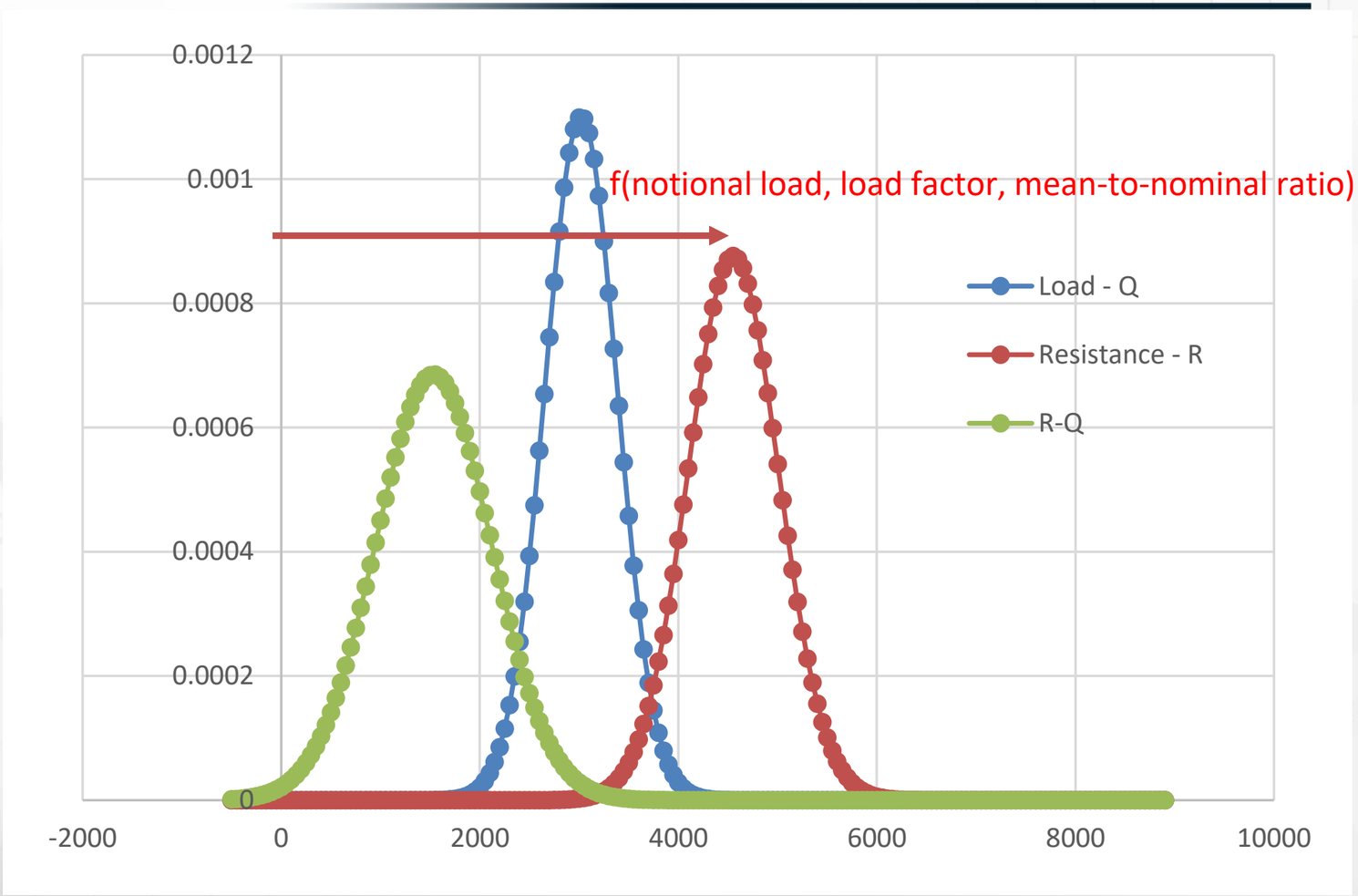
- In RTGM, design ground motion adjusted to result in a targeted probability of failure
- Similar to the development of LRFD for non-seismic loads
- An attempt to calibrate the design process to result in more uniform reliability
- Main cause of non-uniformity is the variation in the nature of the hazard with location

Common Terminology

- Hazard – Ground-motion-induced SDOF structural response (likelihood of spectral acceleration or displacements being exceeded in a time frame – say 75 years)
- Fragility – Structural-response damage function (likelihood of yield, spalling, collapse)
- Risk – Consequence of hazard combined with fragility (likelihood of damage [e.g., incipient collapse] in 75 years)
- Risk-Targeted Ground Motions – Design motions resulting in equal risk (more uniform likelihood of damage across a geographic area)

LRFD – Load and Resistance Distributions

- Calibration of LRFD BDS – f(Q&R distributions)
- Used notional load (HL-93) and resistance factors to achieve target β of 3.5



Risk Calculation for Seismic Loads

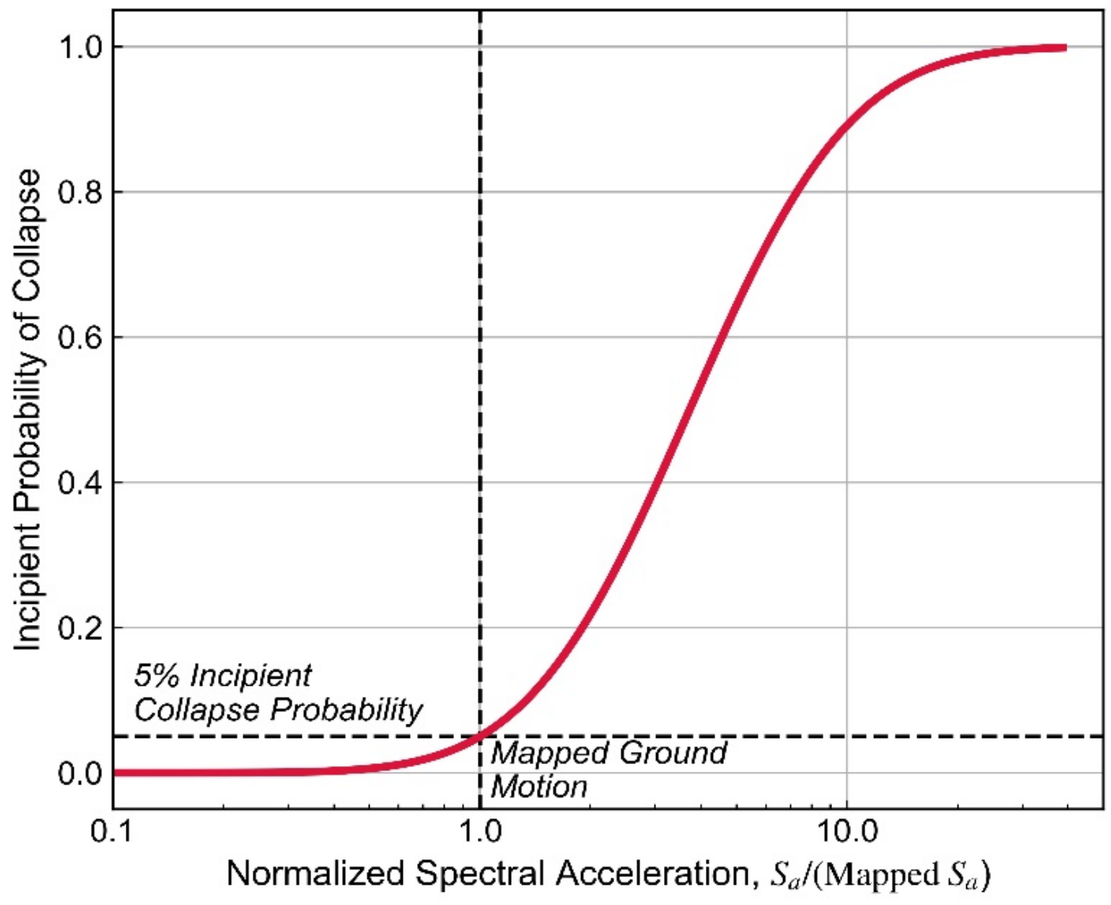
- Because of differences with classical load and resistance, calculation is different

$$R = \int_0^{\infty} Fr(a) \cdot \frac{dH(a)}{da} da$$

- Despite differences in details of the calculation, concepts are the same as LRFD calibration; varying the design resistance to achieve uniform reliability
- In RTGM, we vary the design ground motion to achieve a target risk level

RTGM – Fragility Function

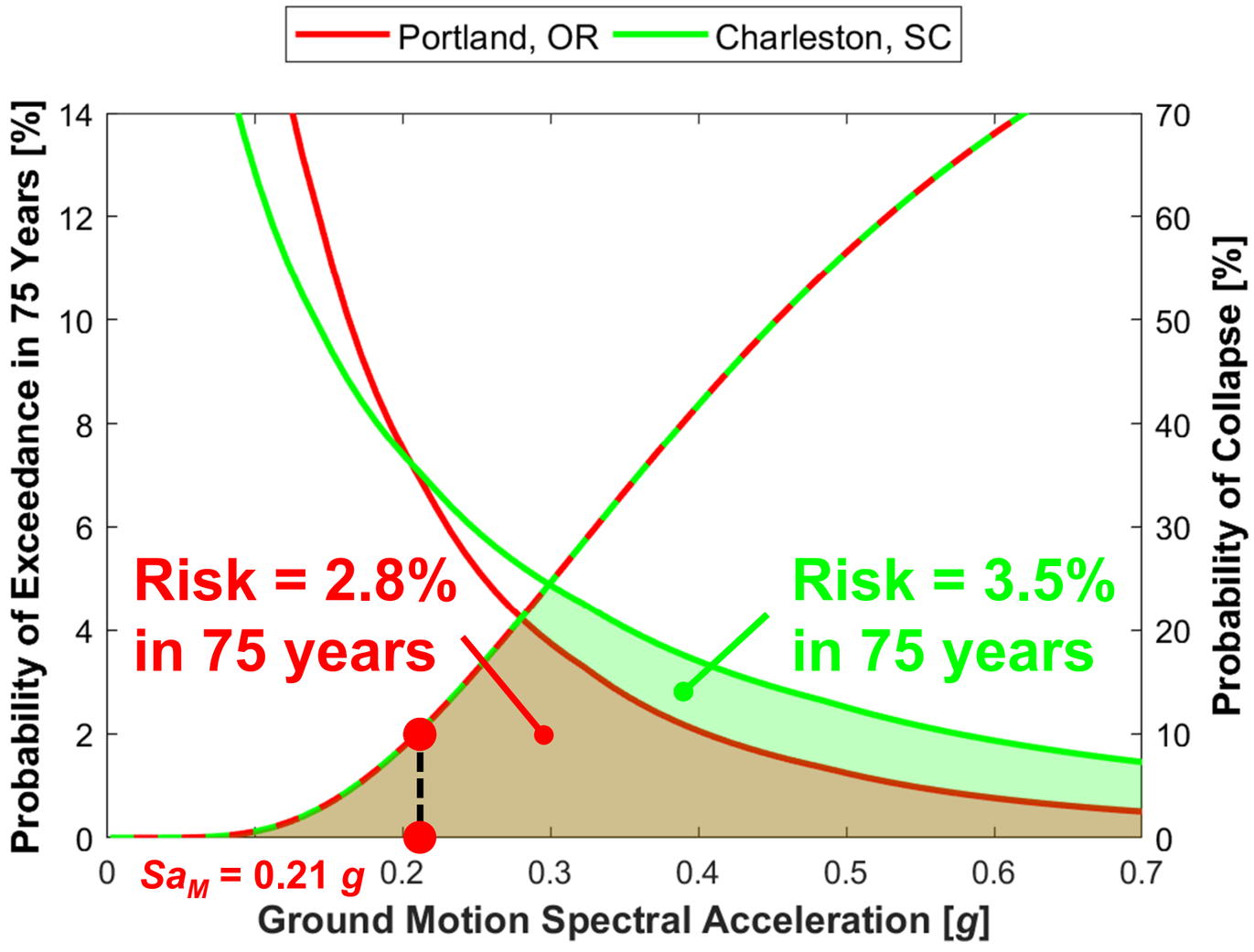
- Need a fragility function for the calculation
- Based on plastic hinging behavior of concrete column
- Representative, “notional” relationship adopted
- Lognormal distribution, 0.6 standard deviation, median ~2.7 times design, design at 5% probability of collapse



RTGM – Notional Fragility Function

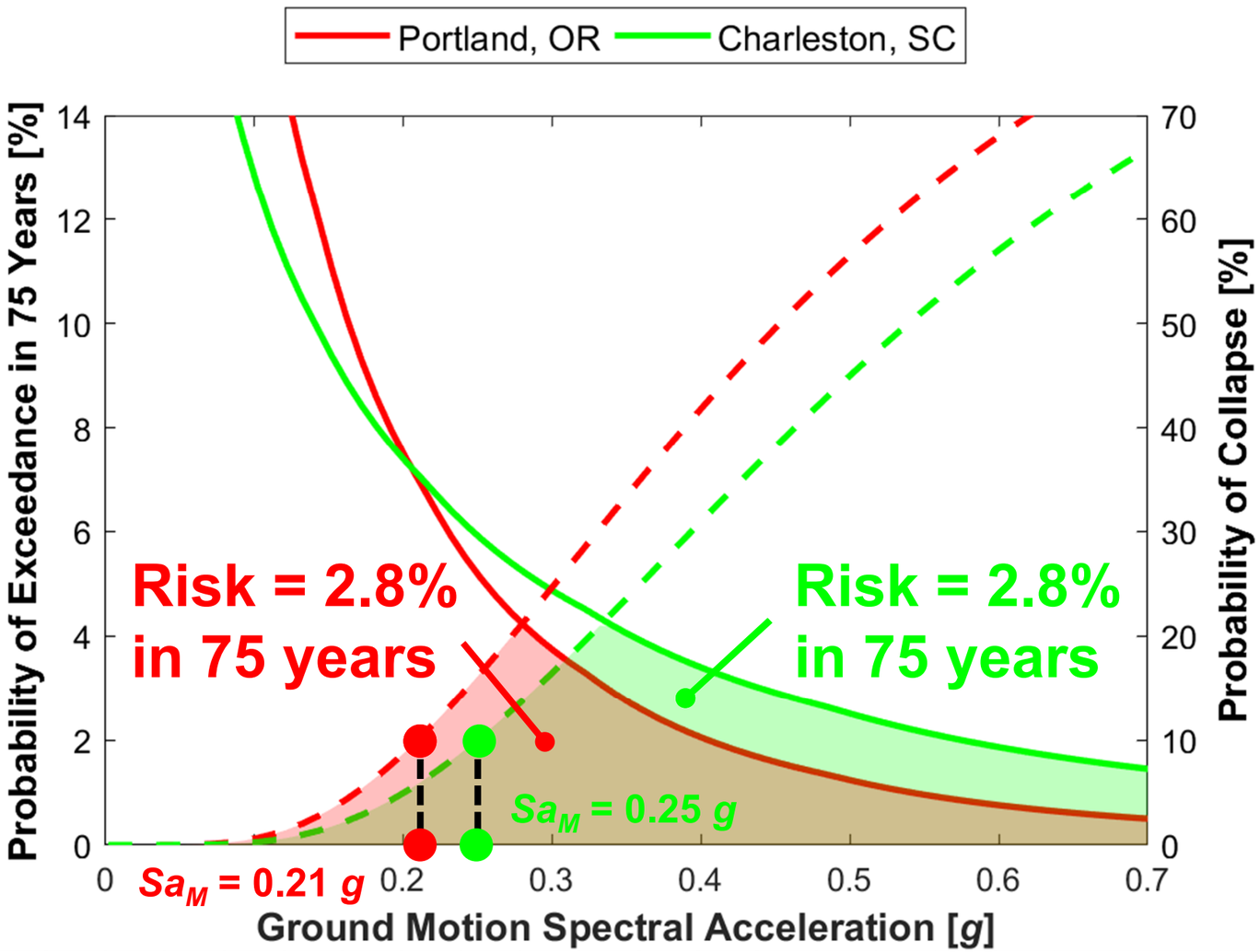
- Notional – similar to the notional design truck. Termed “Notional” because it is not intended to represent any particular bridge
- Based on bridge-specific fragilities from literature review for columns
- Resulting Design Ground Motions relatively insensitive to choice of notional fragility function (risk value may change though)
- If the fragility’s conditional probability of collapse is 5% at the design ground motion, then most of the risk of collapse (combo of fragility with hazard) will come from motions in excess of design

Calculation of Risk-Targeted Maps



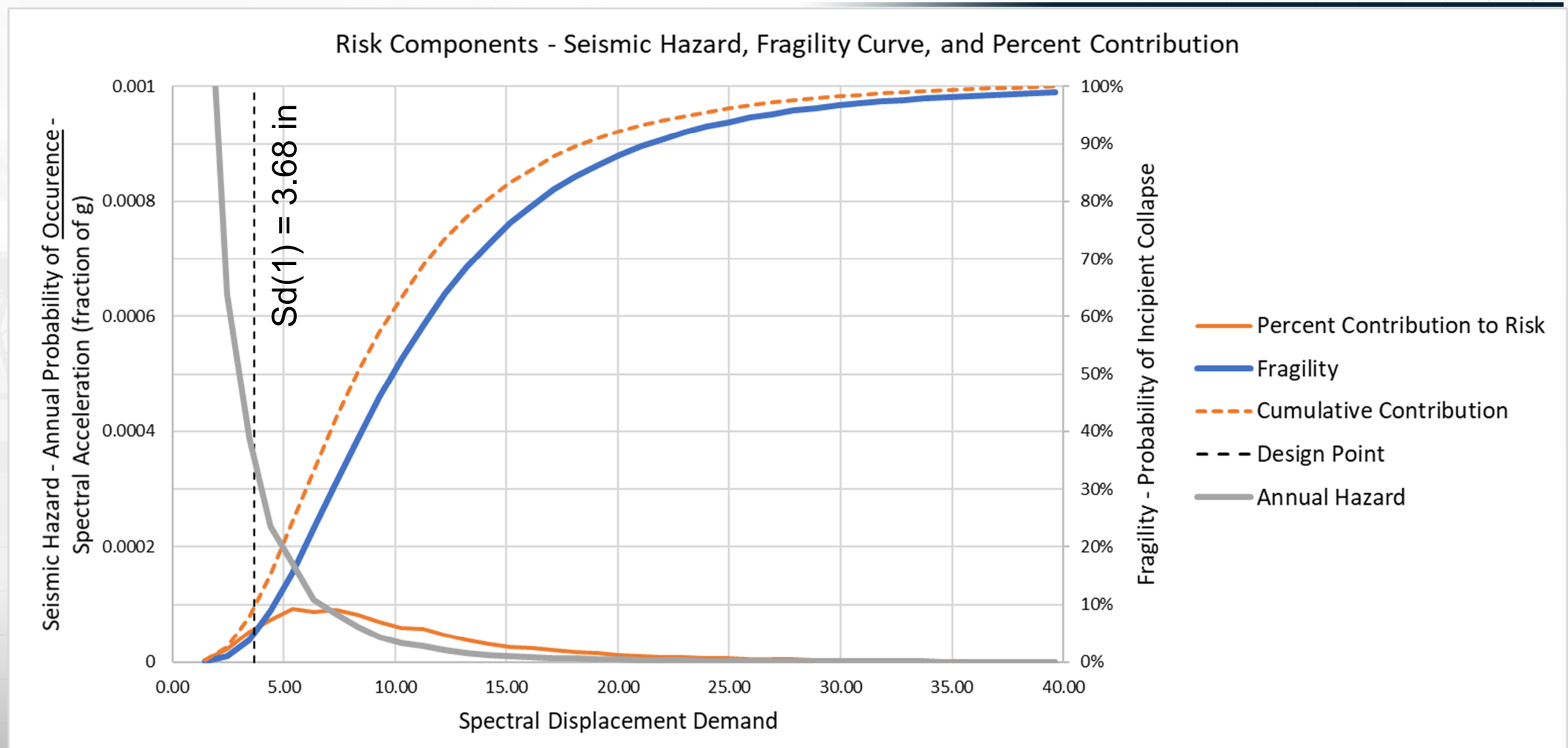
- **Uniform-hazard maps result in non-uniform risk.**

Calculation of Risk-Targeted Maps

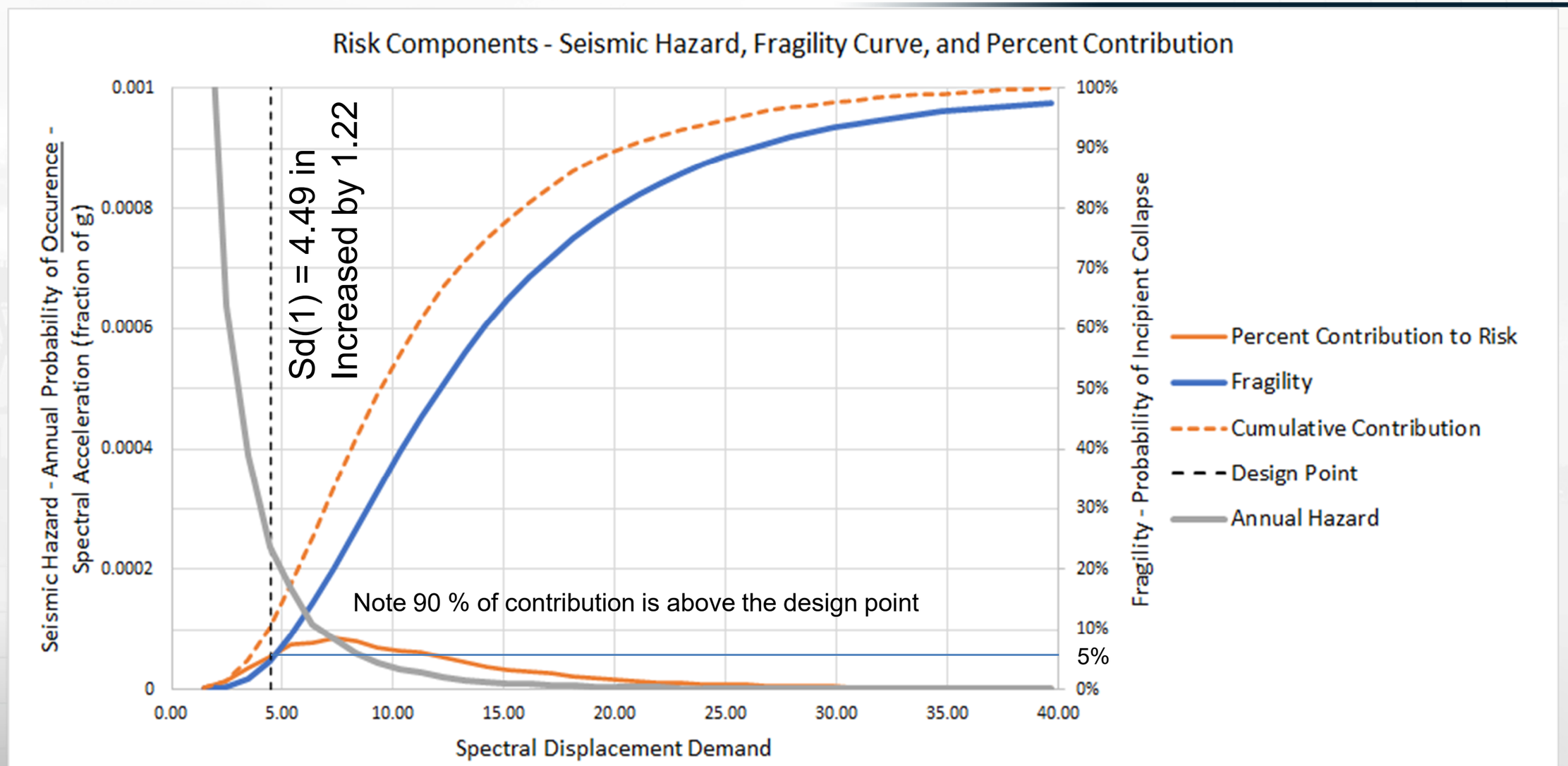


- **Uniform-hazard maps result in non-uniform risk.**
- To decrease risk, increase mapped spectral acceleration (or vice versa).
- Relative to uniform-hazard AASHTO maps, **risk-targeted maps increase S_{aM} in the Central & Eastern U.S.**
- Note: Shaded area is conceptually indicative of risk, not mathematically equal to risk.

Memphis Risk Calculation – 2.1% Prob of Collapse in 75 Years

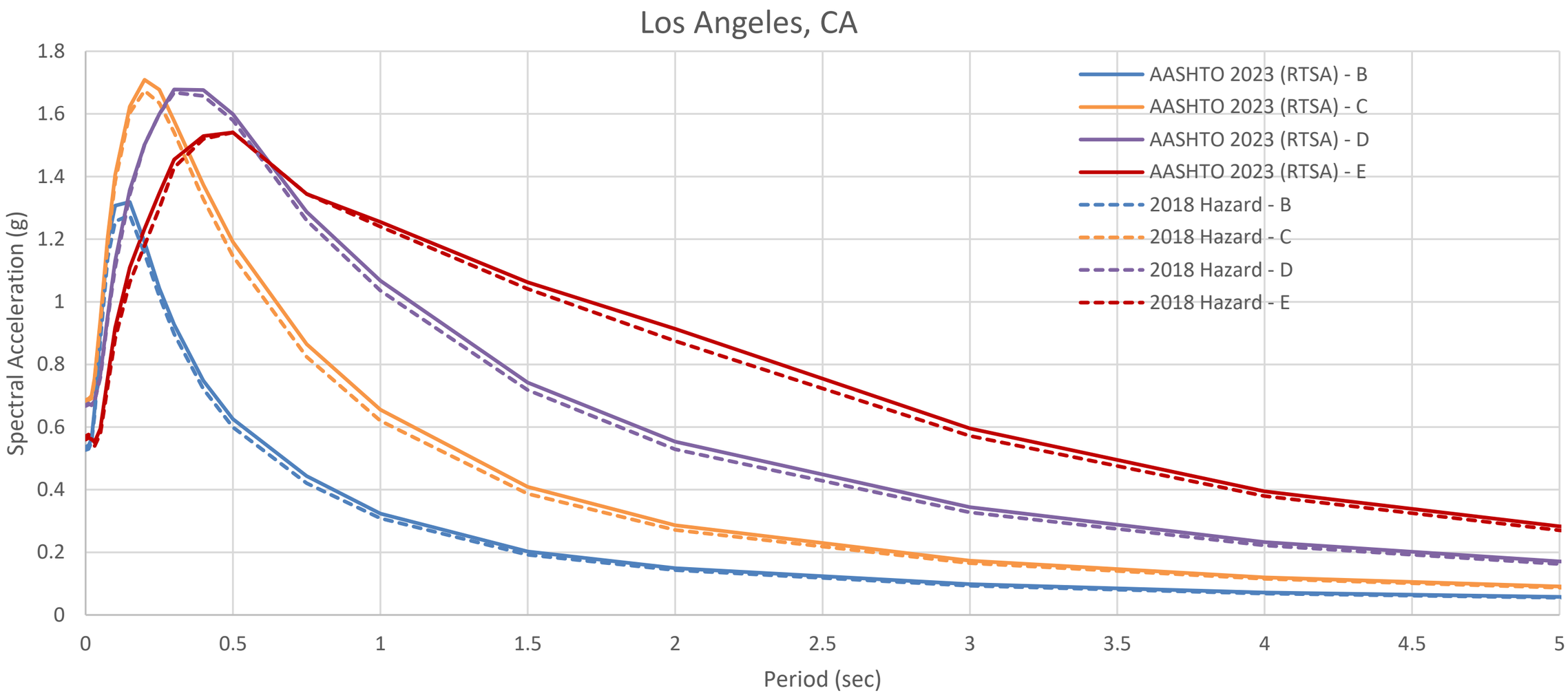


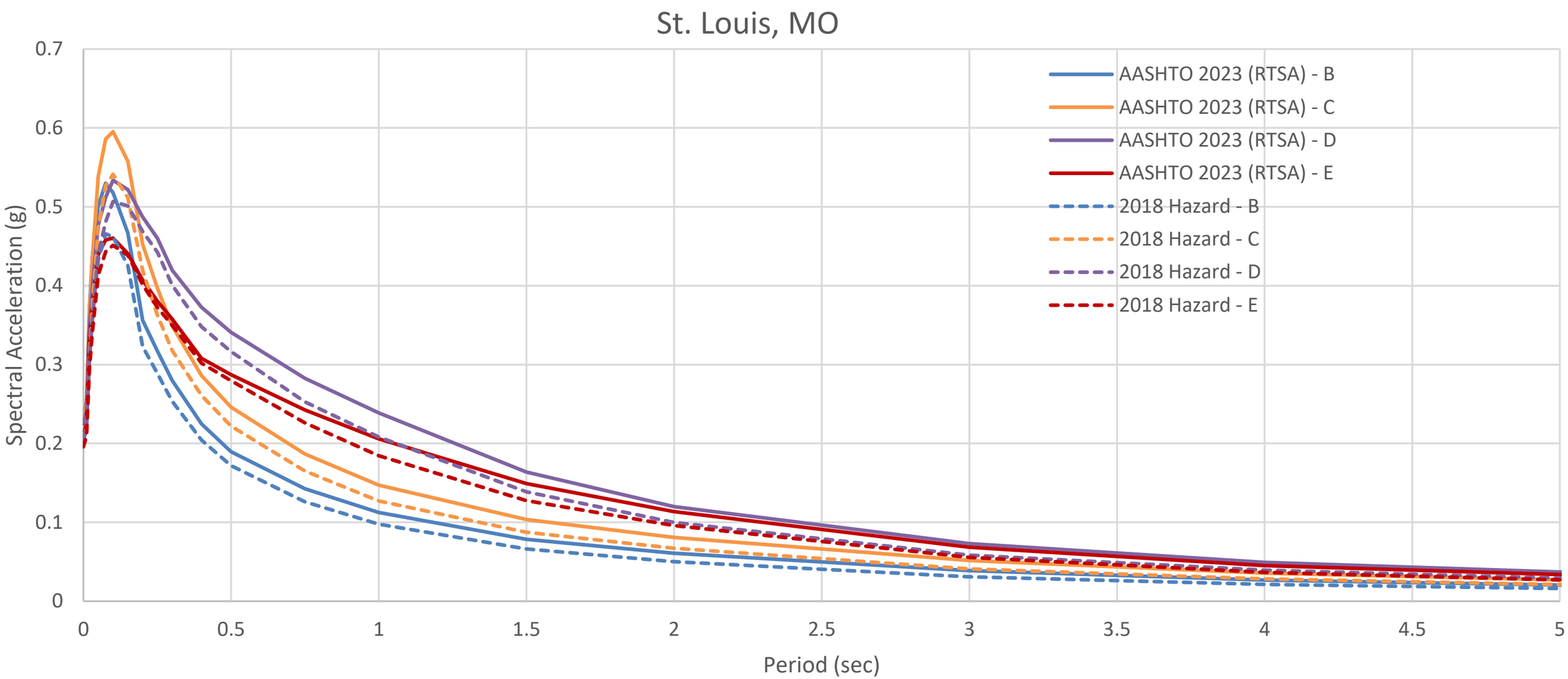
Memphis Risk Calculation – 1.5% Prob of Collapse in 75 Years

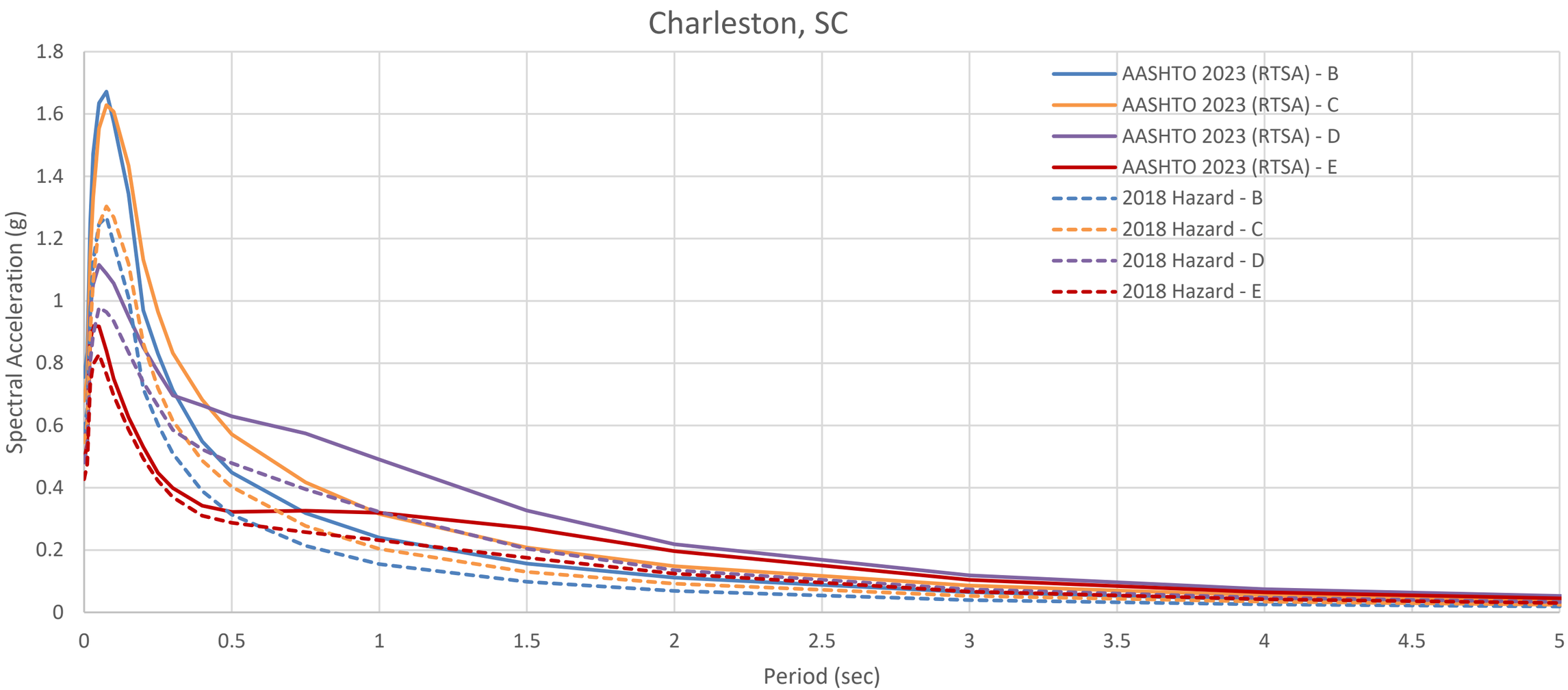


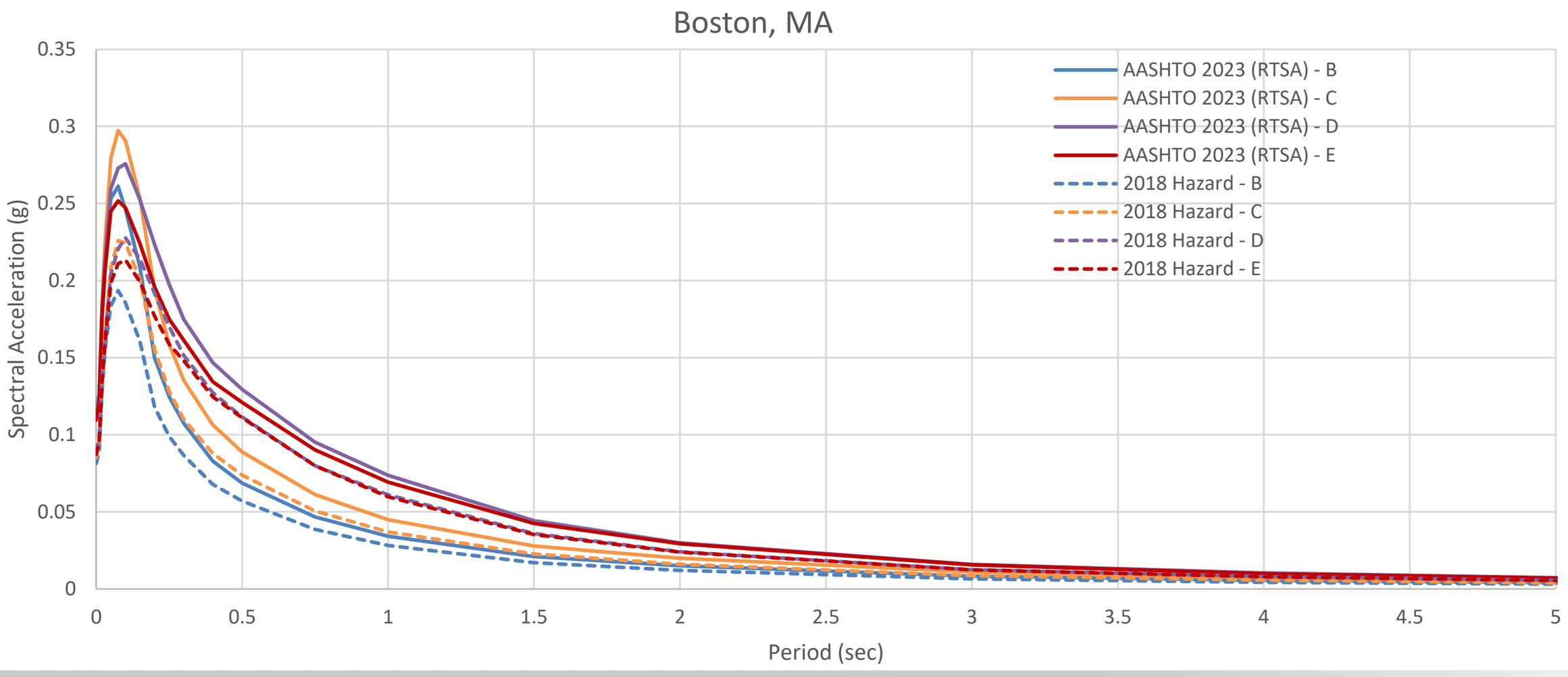
RTGM Spreadsheet Results for One Second

Location	Mult for 1.5%	Design Sd(1)	Prob for UHS	Des Sd(1) UHS
Oakland, CA	0.95	11.7”	1.3 % in 75 yrs	12.3”
Seattle, WA	1.05	8.7”	1.70 %	8.2”
Memphis, TN	1.22	4.5”	2.12 %	3.7”
Charleston, SC	1.54	4.3”	2.77 %	2.8”


Los Angeles, CA
Spectral Acceleration (g)
Period (sec)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
AASHTO 2023 (RTSA) - B
AASHTO 2023 (RTSA) - C
AASHTO 2023 (RTSA) - D
AASHTO 2023 (RTSA) - E
2018 Hazard - B
2018 Hazard - C
2018 Hazard - D
2018 Hazard - E


St. Louis, MO
Spectral Acceleration (g)
Period (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
AASHTO 2023 (RTSA) - B
AASHTO 2023 (RTSA) - C
AASHTO 2023 (RTSA) - D
AASHTO 2023 (RTSA) - E
2018 Hazard - B
2018 Hazard - C
2018 Hazard - D
2018 Hazard - E

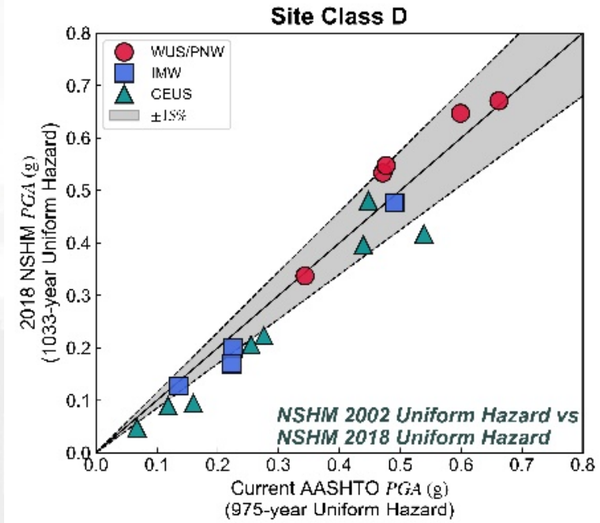

Charleston, SC
Spectral Acceleration (g)
Period (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
AASHTO 2023 (RTSA) - B
AASHTO 2023 (RTSA) - C
AASHTO 2023 (RTSA) - D
AASHTO 2023 (RTSA) - E
2018 Hazard - B
2018 Hazard - C
2018 Hazard - D
2018 Hazard - E

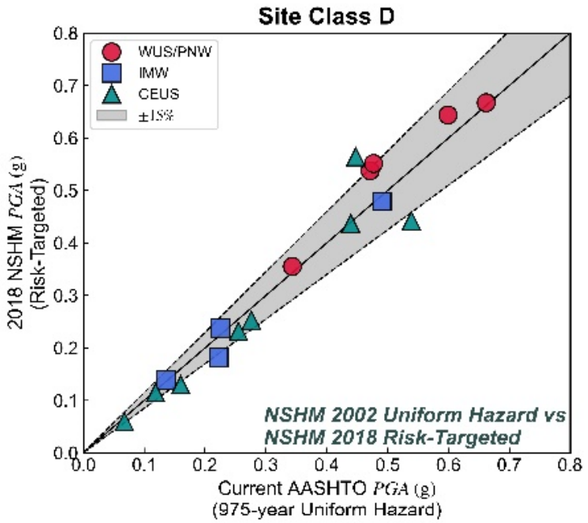

Boston, MA
Spectral Acceleration (g)
Period (sec)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
AASHTO 2023 (RTSA) - B
AASHTO 2023 (RTSA) - C
AASHTO 2023 (RTSA) - D
AASHTO 2023 (RTSA) - E
2018 Hazard - B
2018 Hazard - C
2018 Hazard - D
2018 Hazard - E

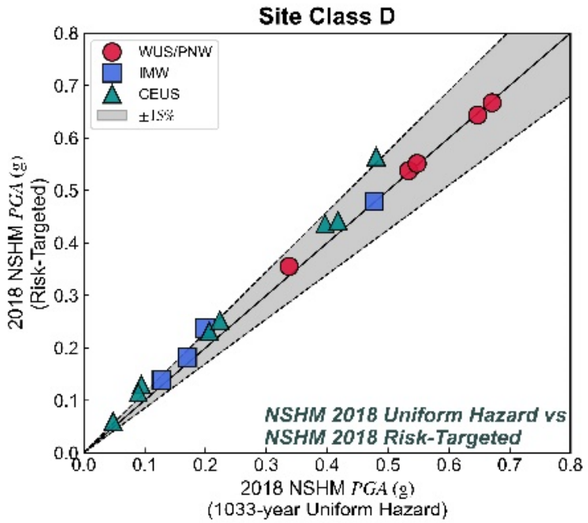
Can RTGM Based on Column Fragility be Used for Geotechnical Design?

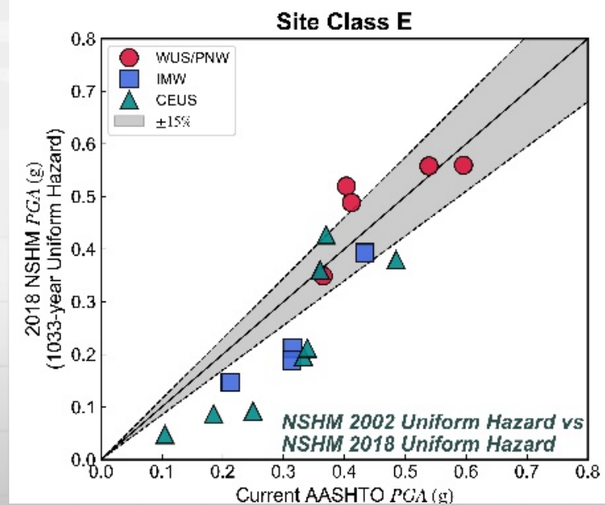
- RTGM relatively insensitive to the choice of fragility function – calibrated to past practice
- Similar to past practice – no explicit consideration of differences in probabilities between structural and geotechnical outcomes
- Differences between Uniform-Hazard PGA's and RTGM PGA's not large

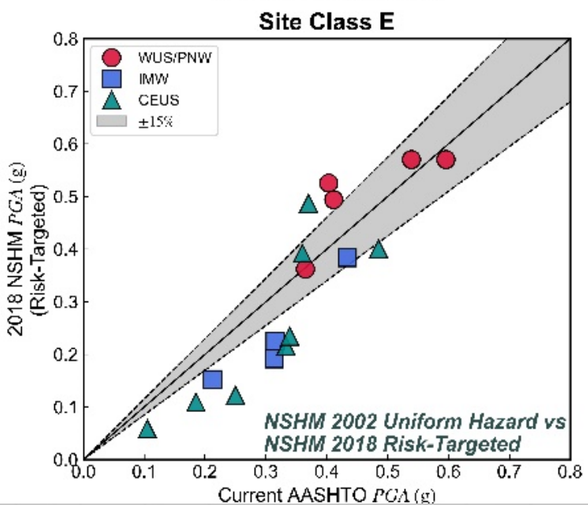
PGA Comparisons

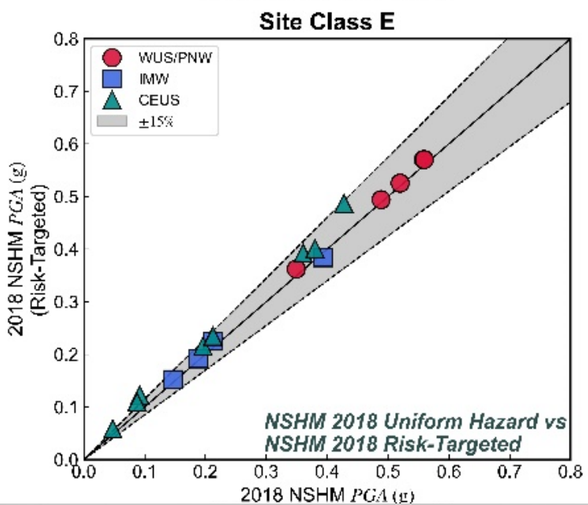












- Note small differences in PGA from NSHM 2018 USH and RTGM
- Conclude -- can use PGA from RTGM for geotechnical evaluations

How Do We Handle Site-Specific Hazard and Ground Response Analyses with RTGM?

- Four approaches are outlined in Appendix C:

1. For site-specific probabilistic seismic hazard analysis (PSHA)
   - Develop hazard curves at ground surface for V_{s30} using designer's PSHA software
   - Use USGS risk-targeting tool to convert to RTGM after hazard developed
2. To add site-specific ground response analysis to above (e.g., Site Class F)
   - Develop risk-targeted response spectrum for Site Class BC using designer's PSHA software
   - Scale/match acceleration records to risk-targeted spectrum as input in 1D or 2D ground response software to propagate motions to ground surface

[Note: could use designer's risk targeting tool rather than USGS]

How Do We Handle Site-Specific Hazard and Ground Response Analyses with RTGM? (Cont.)

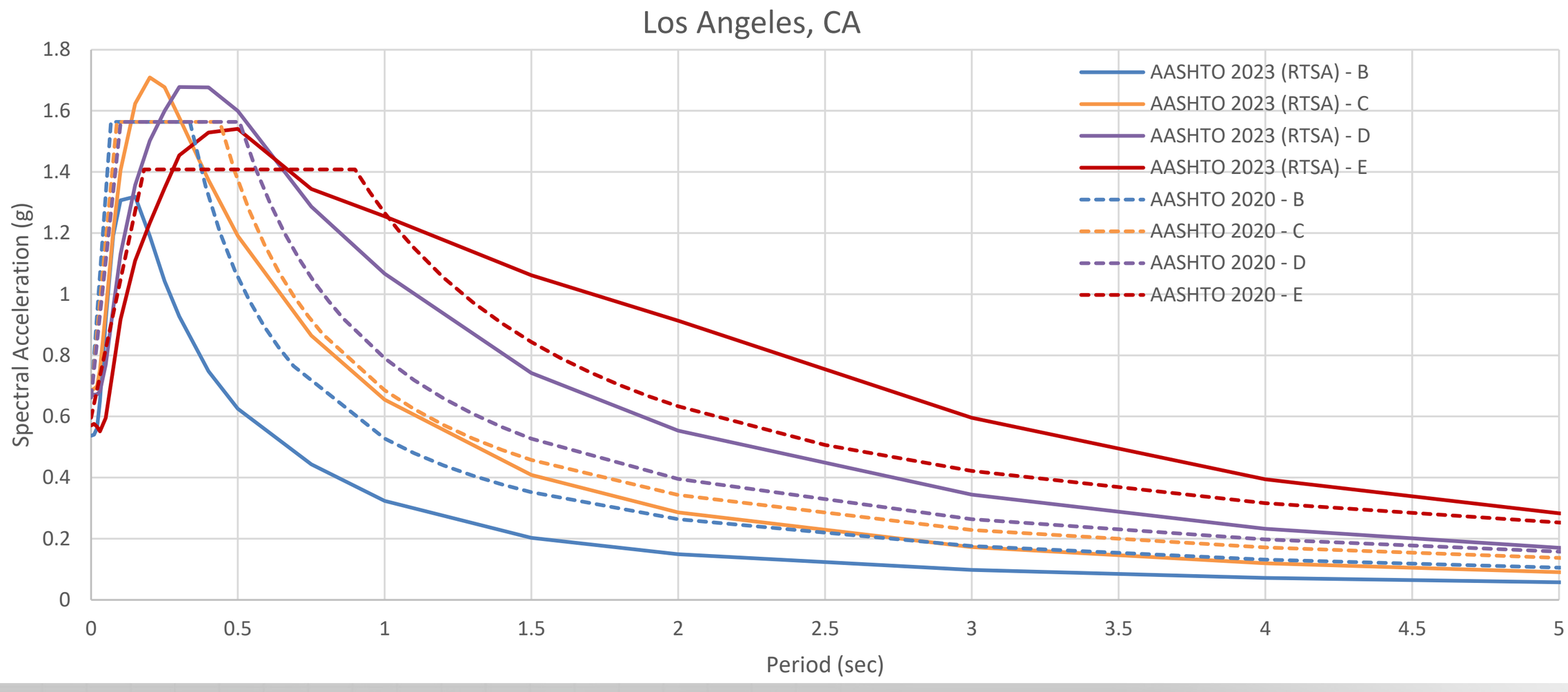
3. General Procedure with site-specific ground response analysis (e.g., Site Class F)
   - Use AASHTO-USGS Seismic Design Web Service to develop risk-targeted response spectrum for Site Class BC location
   - Scale or match acceleration time histories to acceleration response spectrum at BC location
   - Conduct site-specific ground response analysis using 1D or 2D software to propagate ground motions to surface
4. Deterministic seismic hazard analyses (DSHA) conducted essentially as they are now, limited to no lower than 80% of the risk-targeted motions

Are There Procedures for Disaggregating RTGM to Identify Source-Magnitude-Distance Information?

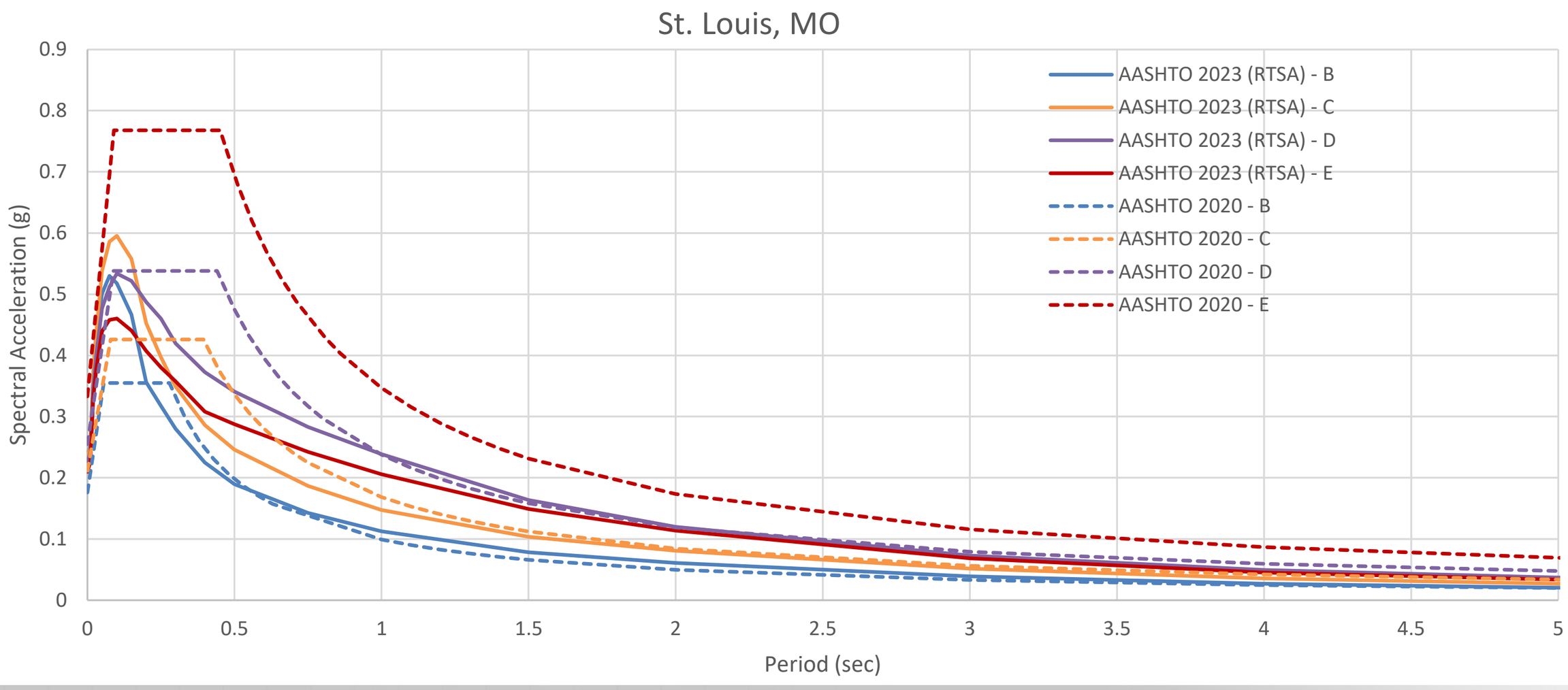
- Sometimes need distance-magnitude information for risk-targeted ground motions (e.g., liquefaction triggering, determining contribution of different sources, development of acceleration records, etc.)
  - USGS provides hazard tool to disaggregate the motions for broad range of spectral periods and site classes – either user-defgined return UH return period or user-defined ground motion value (e.g., Sa at 1 second)
  - Doesn't particularly depend on whether they are RTGM or Uniform Hazard, just need to input the magnitude of the ground motion to be disaggregated

Comparison Between Current and Recently Adopted Design Ground Motions

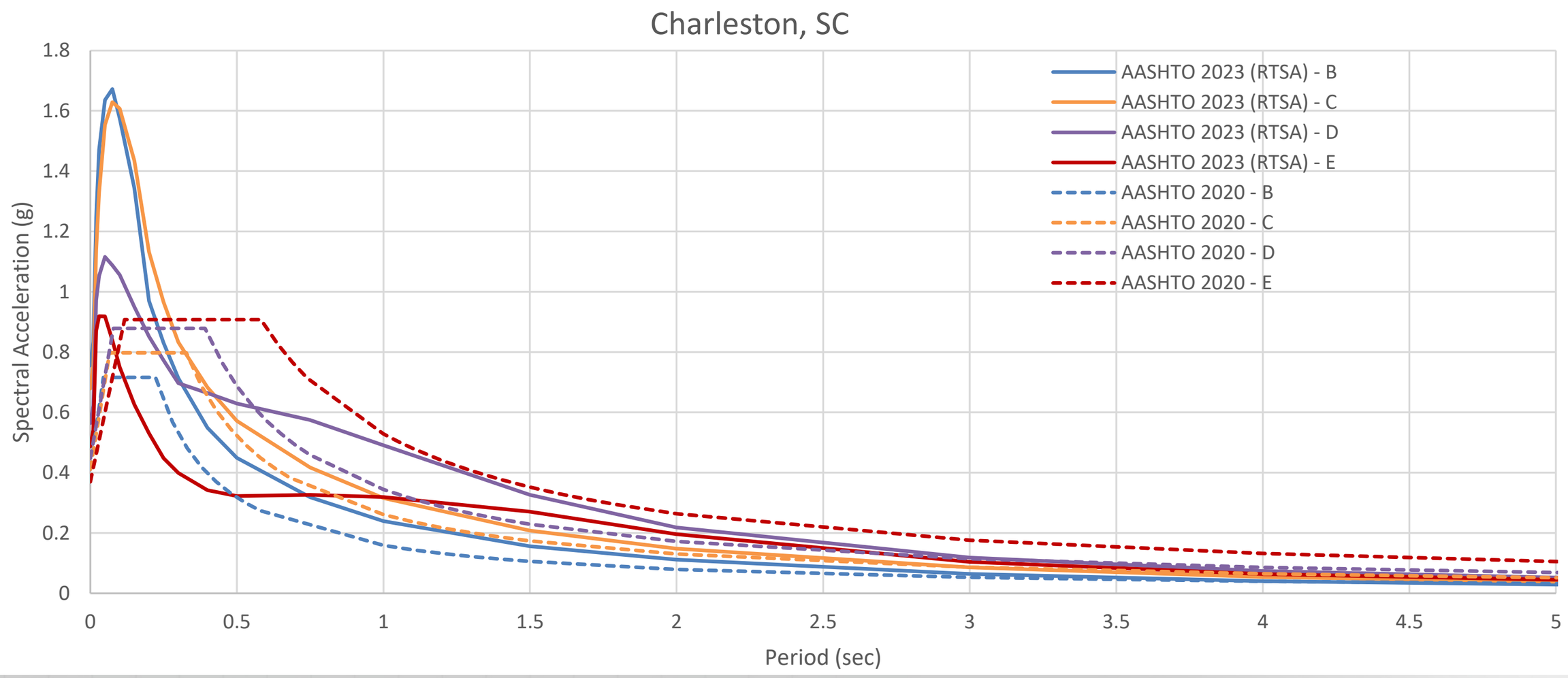
RTGM vs. Current AASHTO Uniform Hazard



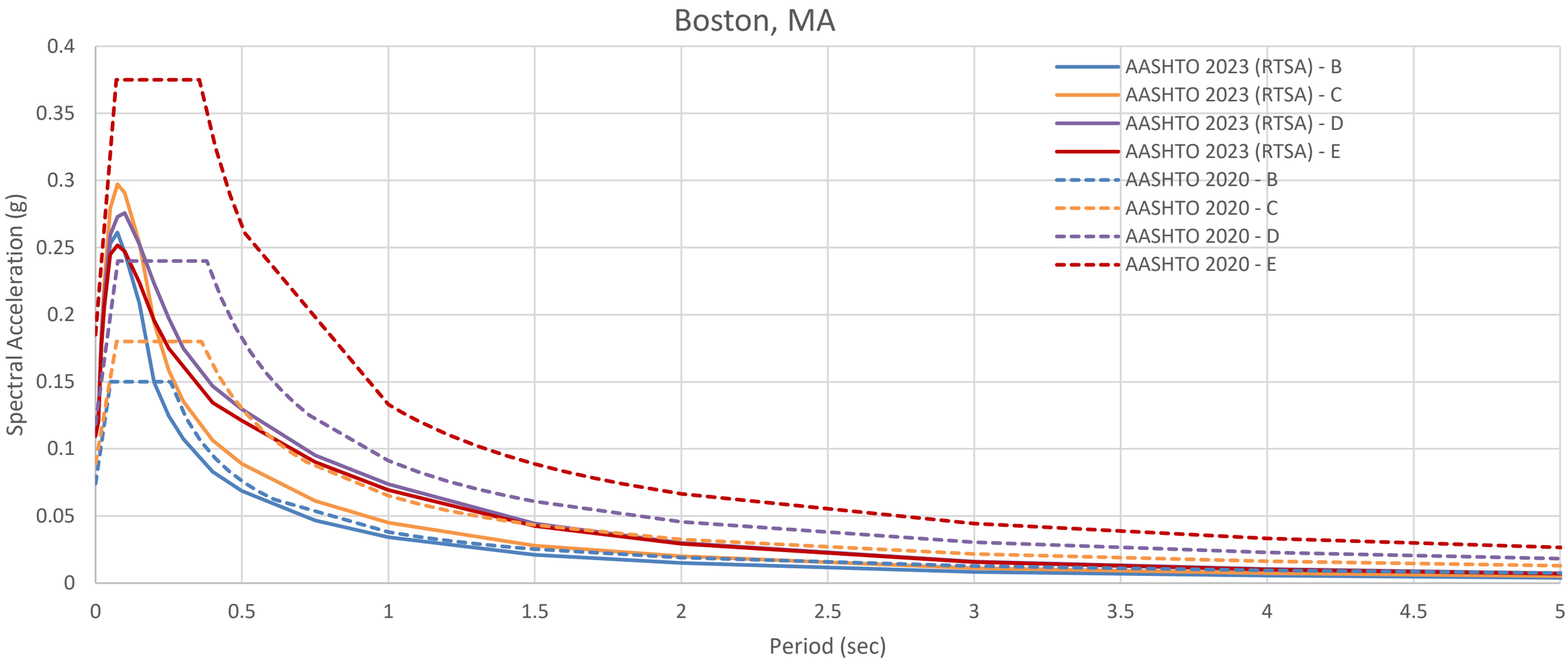
RTGM vs. Current AASHTO Uniform Hazard



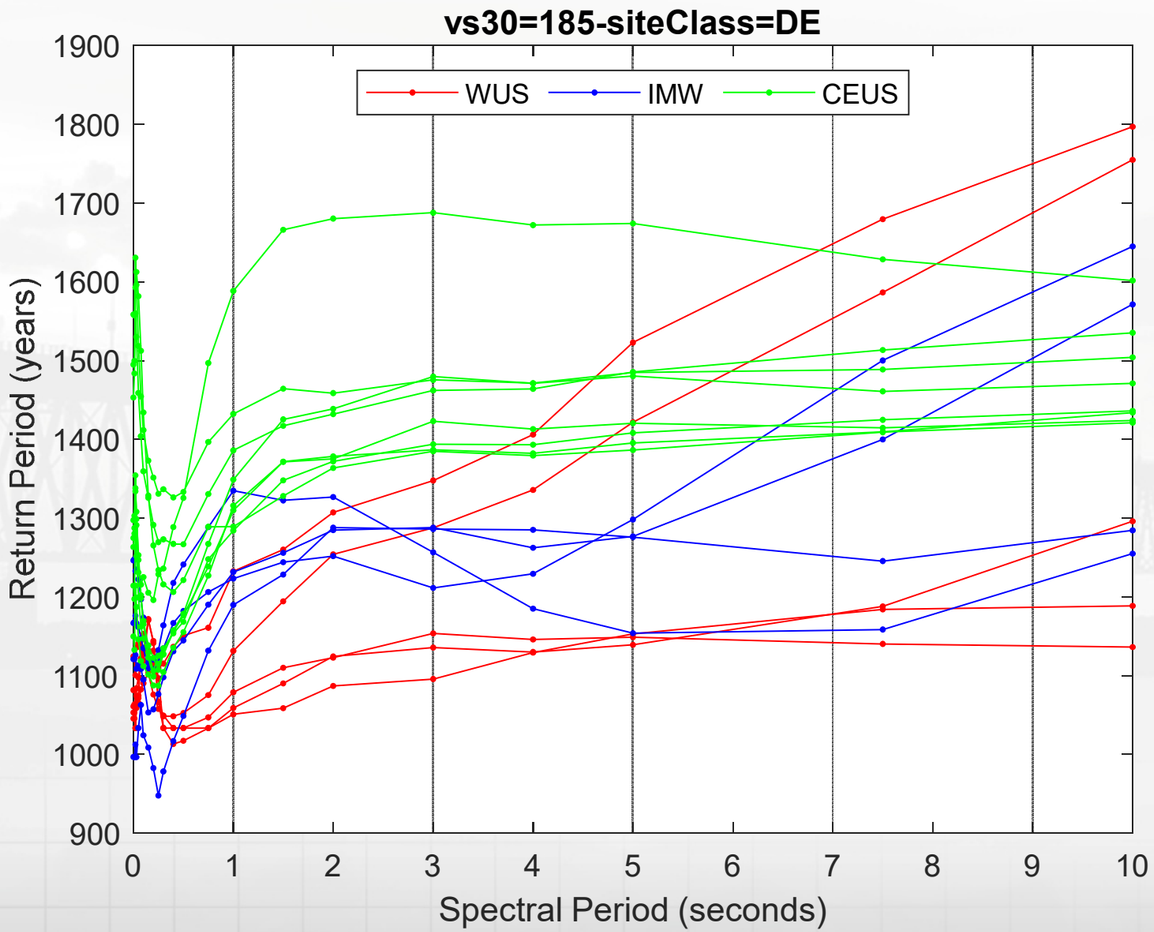
RTGM vs. Current AASHTO Uniform Hazard

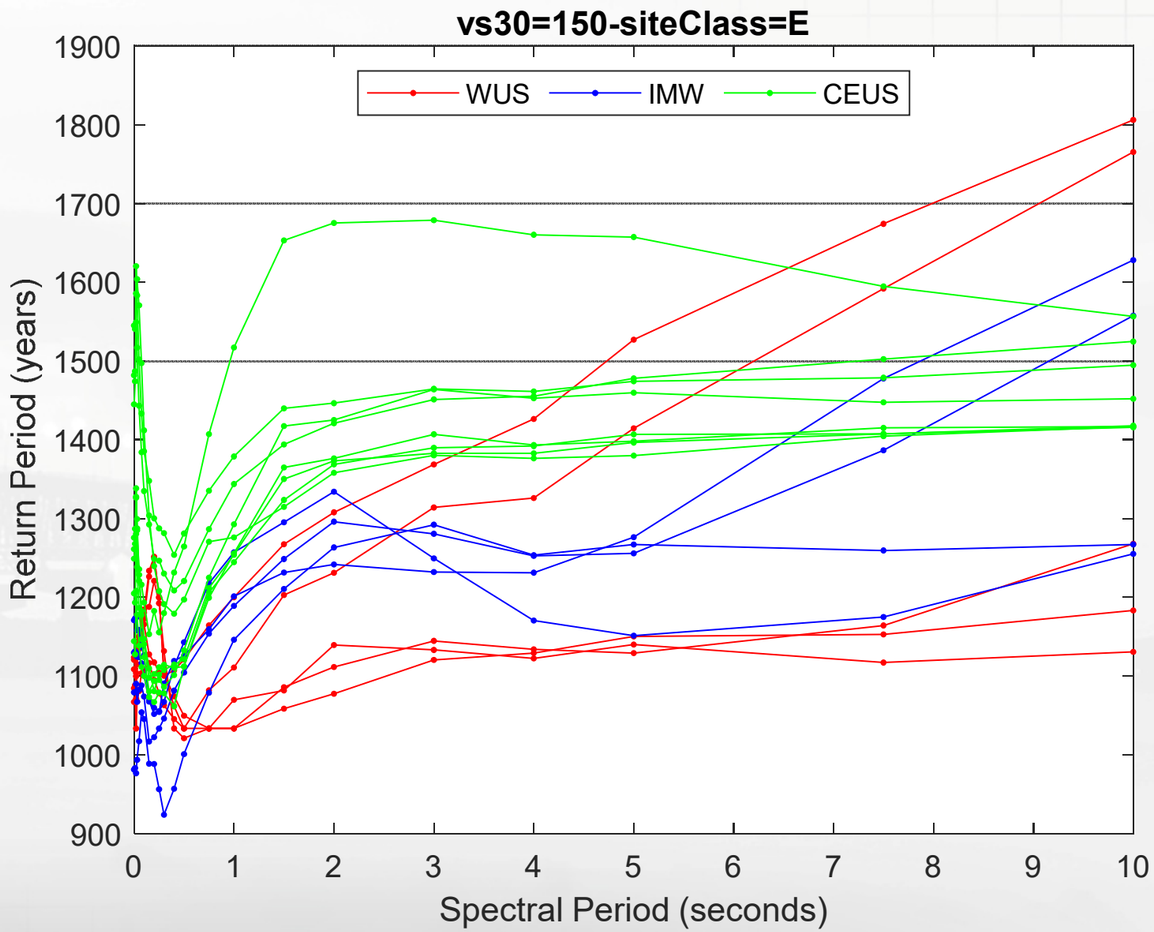


RTGM vs. Current AASHTO Uniform Hazard



Return Periods of Risk-Targeted SAs





USGS science for a changing world

Summary of Changes to AASHTO

- No maps will be included, ground motions contained in the AASHTO-USGS Seismic Design Ground Motion Database.
- Webtool on USGS website will provide 22 point spectra
- If motions are needed for T>10 s, site specific study is required
- Additional site classes added (BC, CD, DE)
- Blow count and s_u methods of determining site class removed

Summary of Changes to AASHTO (cont.)

- SDC's were based on 1 s acceleration from the standard design spectra shape
- Method for calculating an equivalent 1 s spectrum acceleration provided
- Similar method provided for calculating corner period for short period amplification

Appendix C to the LRFD Seismic Bridge Design Guide Specs

- Provides background to RTGM and procedures for development of site-specific RTGM
- It is fully expected that more and improved fragility functions will be developed – need a basis for how to implement
- Example calculation of the seismic risk

Q/A

Today's presenters

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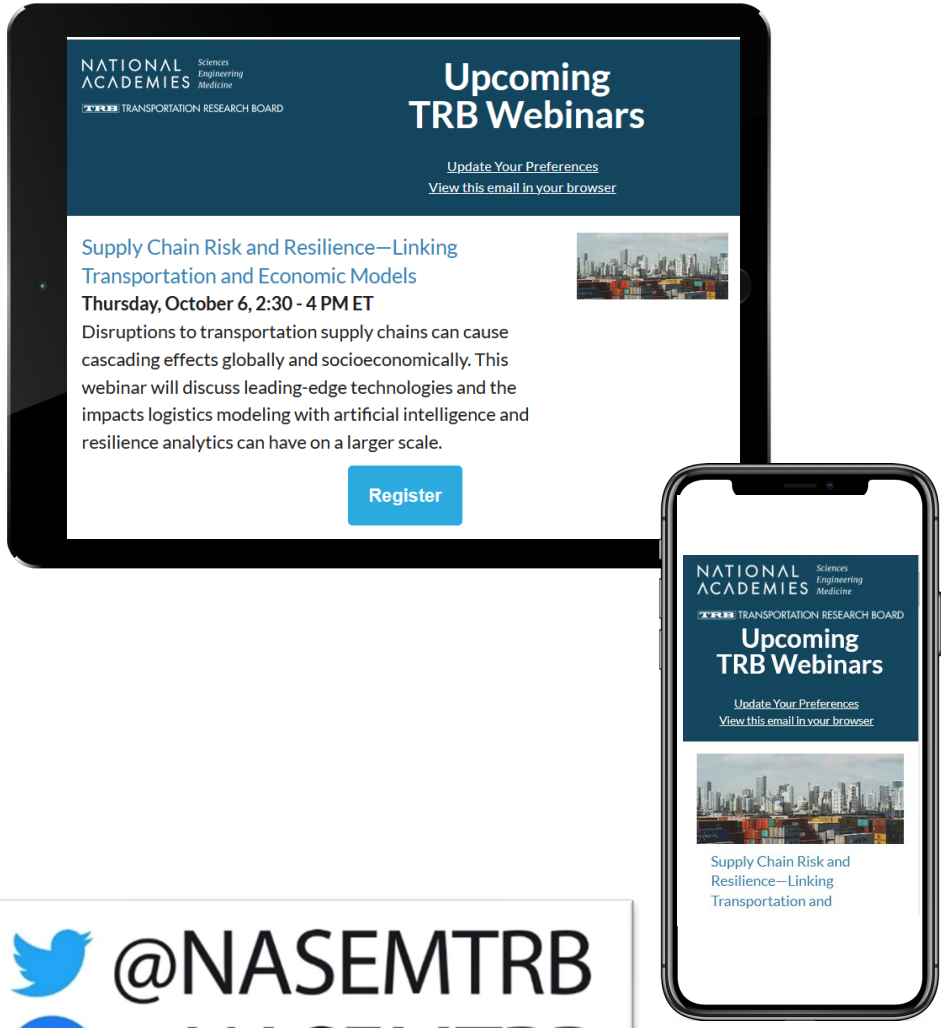

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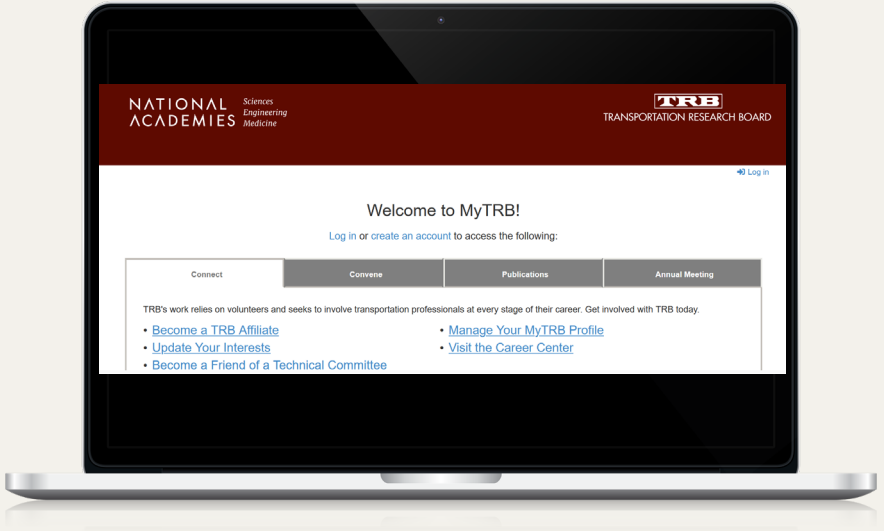

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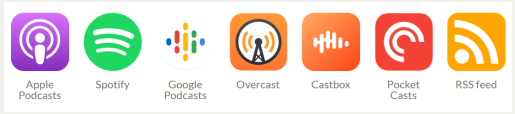

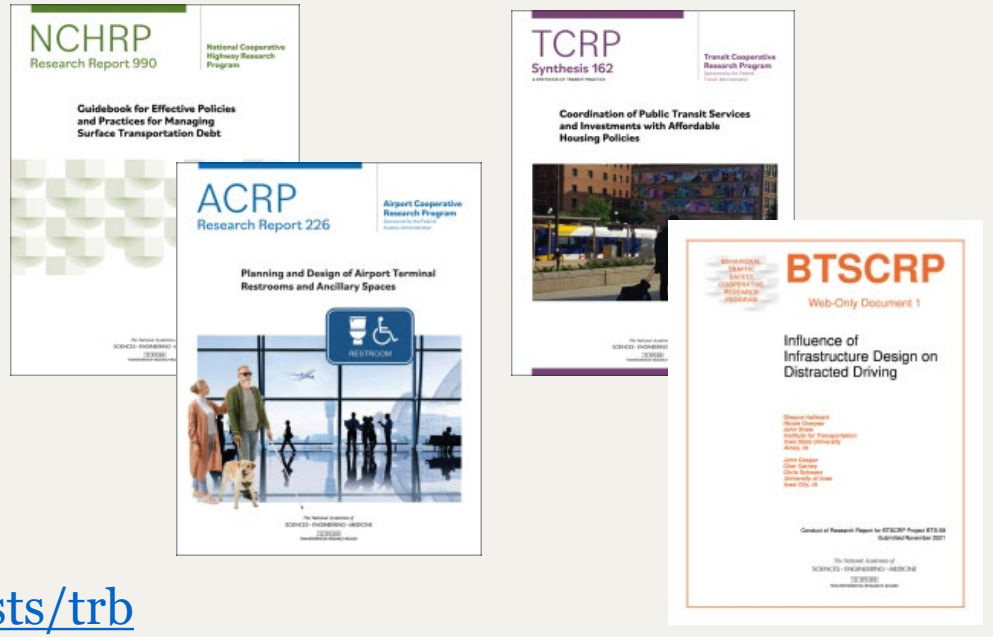

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