New Ground Motion Requirements of ASCE 7-16

Building Seismic Safety Council Webinar – July 28, 2017

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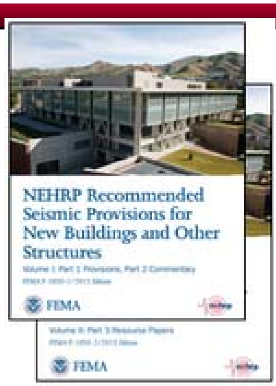
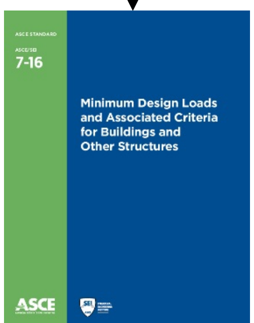
Seismic Code Development Process



- 2015 NEHRP Recommended Provisions
  - Building Seismic Safety Council (BSSC) for the Federal Emergency Management Agency (FEMA)
    - **Provisions Update Committee (PUC)**



- ASCE 7-16 - Minimum Design Loads on Buildings and Other Structures
  - Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE)
    - **ASCE 7 Seismic Subcommittee (SSC)**

- 2018 International Building Code (IBC)
  - International Code Council, Codes and Standards
    - **IBC Structural Committee**

1. Background

- Seismic Code Development Process
- Ground Motions - What's New (or Not)?
- Ground Motion Design Parameters
- ASCE 7 Hazard Tool
- USGS National Seismic Hazard Mapping Project
- PEER NGA West2 Project

Ground Motions - What's New (or Not)?

What's New (or Changed)?

- **Site Class Coefficients**
  - **Tables 11.4-1 and 11.4-2**
- Ground Motion Parameter Values
  - MCE_R Ground Motion Maps, Section 11.4.2 (Chapter 22)
- **Site-Specific Procedures**
  - **Section 11.4.8**
  - **Sections 21.2.3/21.3/21.4**
- Vertical Ground Motions
  - Section 11.9
- Nonlinear RHA Ground Motions
  - Section 16.2
  - Section 11.4.1 (Near-Fault)

What's Not New?

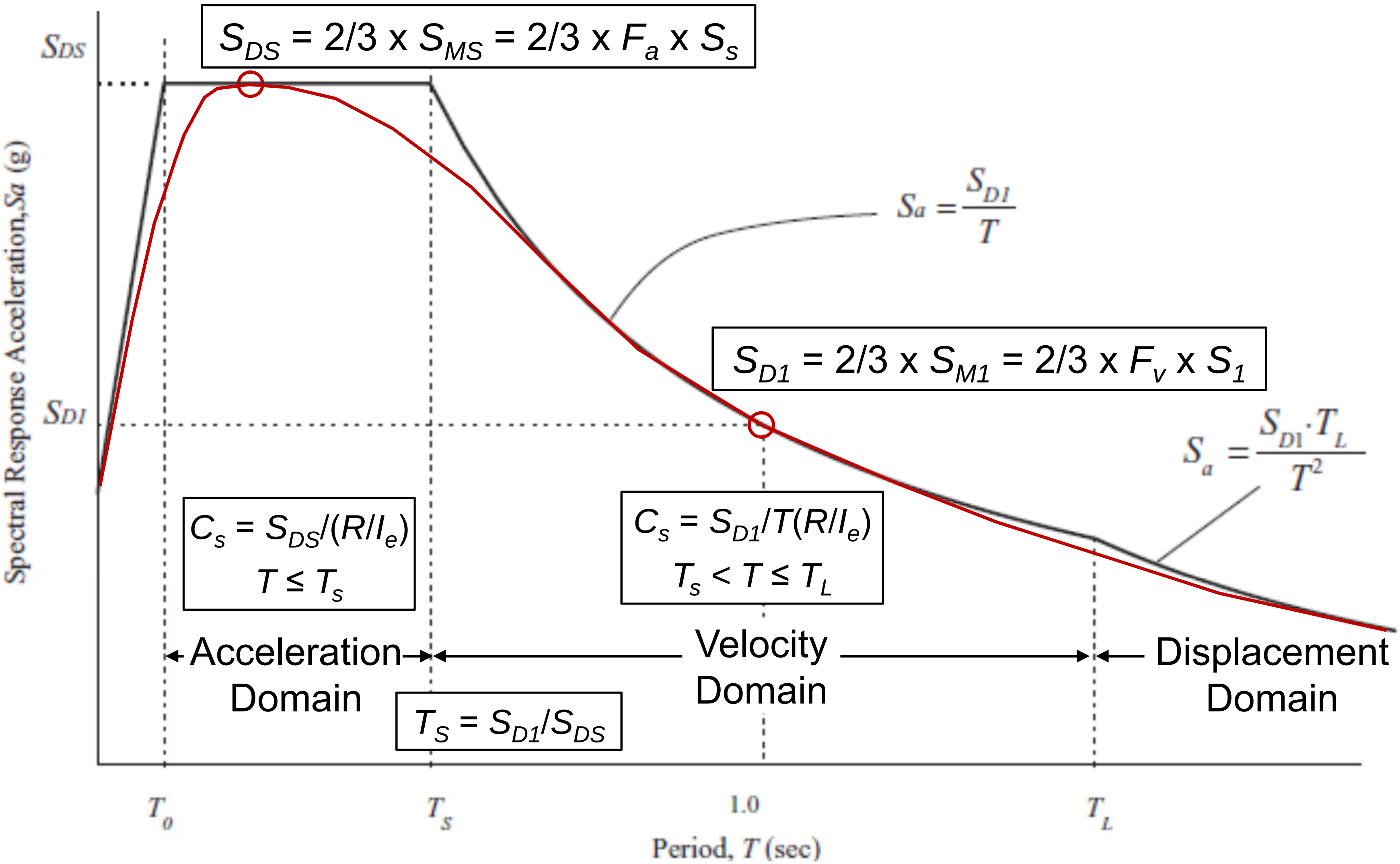
- Site Classification
  - Section 11.4.3 (Table 20.3-1)
- Ground Motion Parameter Definitions and Formulas
  - Sections 11.4.4 and 11.4.5
- Design Response Spectrum
  - Figure 11.4-1 (Section 11.4.6)
- Probabilistic and Deterministic MCE_R Definitions and Methods
  - Section 21.2 (except 21.2.3)
- Nonlinear RHA Ground Motions (Isolation/Damping Systems)
  - Section 17.3 and Section 18.2.2

Ground Motion Design Parameters (Sections 11.4/11.5)

- **MCE_R Ground Motions – Reference Site Conditions ($v_{s,30}$ = 2,500 fps)**
  - **S_S** Mapped MCE_R short-period, 5%-damped, response (Ch. 22)
  - **S_1** Mapped MCE_R 1-second, 5%-damped, response (Ch. 22)
- **Site Coefficients – Site Class of Interest**
  - **F_a** Short-period site coefficient (Table 11.4-1, function of S_S)
  - **F_v** 1-second site coefficient (Table 11.4-2, function of S_1)
- **MCE_R Ground Motions – Site Class of Interest**
  - **S_{MS}** MCE_R short-period, 5%-damped, response ($S_{MS} = F_a \times S_S$)
  - **S_{M1}** MCE_R 1-second, 5%-damped, response ($S_{M1} = F_v \times S_1$)
- **Design Ground Motions – Site Class of Interest**
  - **S_{DS}** Design short-period, 5%-damped, response ($S_{DS} = 2/3 \times S_{MS}$)
  - **S_{D1}** Design 1-second, 5%-damped, response ($S_{D1} = 2/3 \times S_{M1}$)

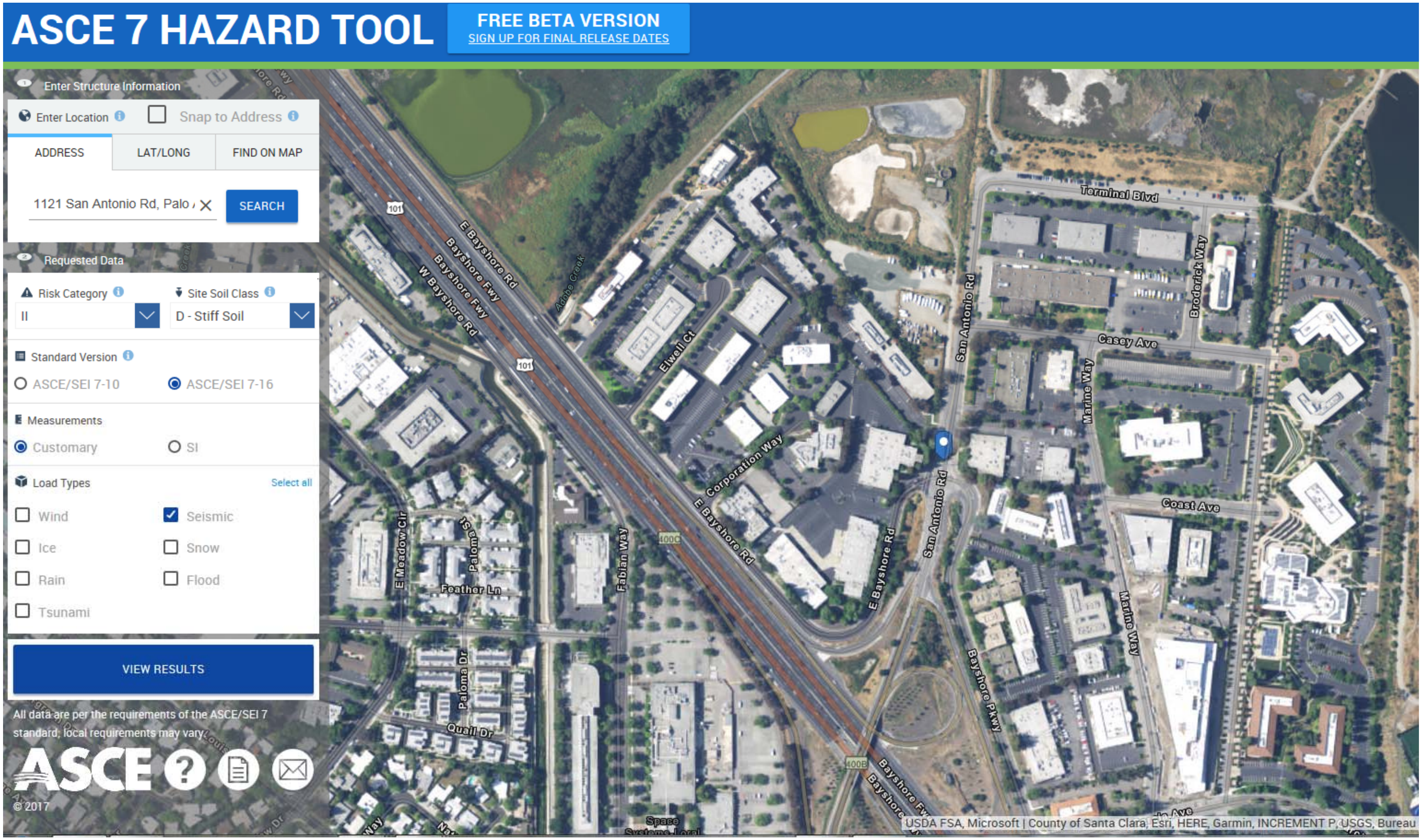
Design Response Spectrum

(Figure 11.4-1, ASCE 7-10 and ASCE 7-16 with annotation)



ASCE 7 Hazard Tool – Dialogue Boxes

(https://asce7hazardtool.online/)



ASCE Hazard Tool – Hazards Report

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

ASCE 7 Hazards Report

Location:
1121 San Antonio Rd
Palo Alto, California
94303

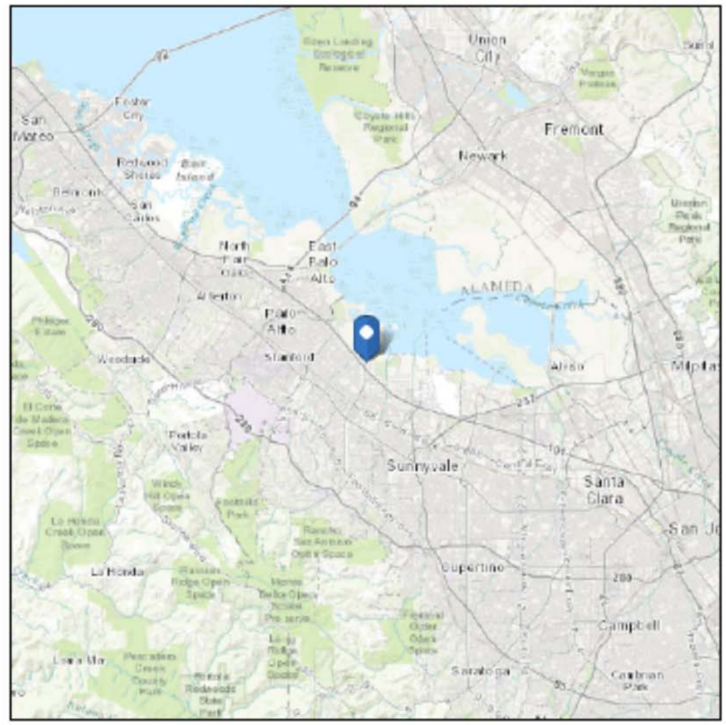
Elevation: 5 ft
Lat: 37.431015
Long: -122.100494

Risk Category:
II

Standard Version:
ASCE/SEI 7-10

Soil Class: D - Stiff Soil

Elevation Reference Datum:
North American Vertical Datum of 1988 (NAVD 88)

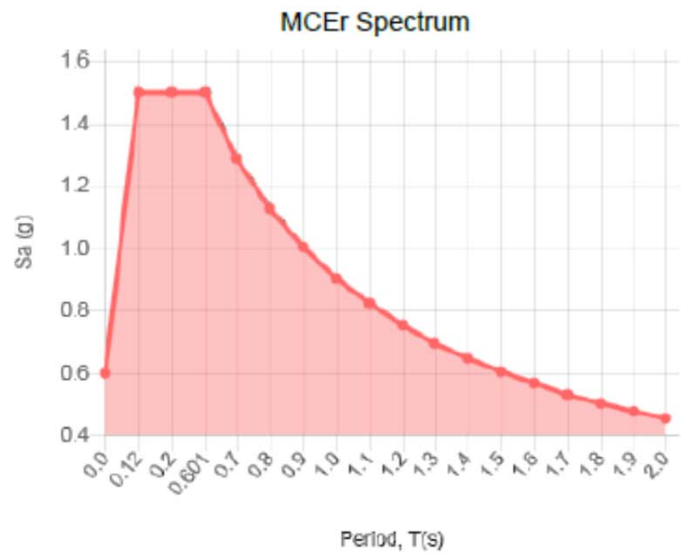


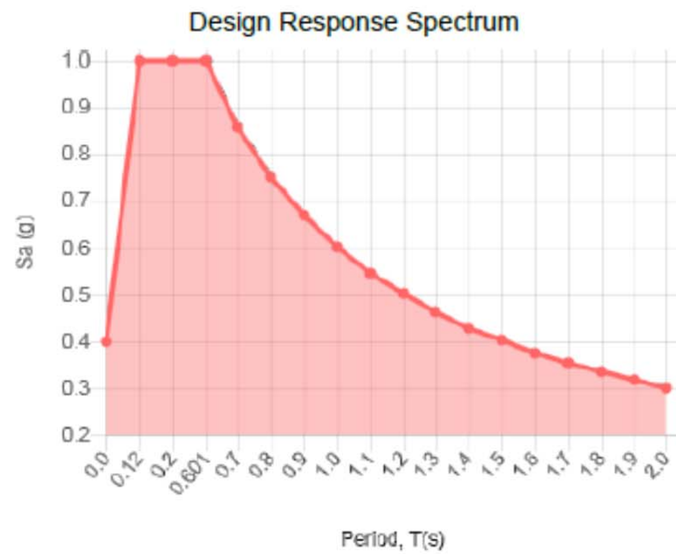
ASCE Hazard Tool – Seismic Report

AMERICAN SOCIETY OF CIVIL ENGINEERS

Seismic

Site Soil Class:	D - Stiff Soil
Results:	
S_S:	1.500
S_1:	0.601
S_{MS}:	1.500
S_{M1}:	0.901
S_{DS}:	1.000
S_{D1}:	0.601

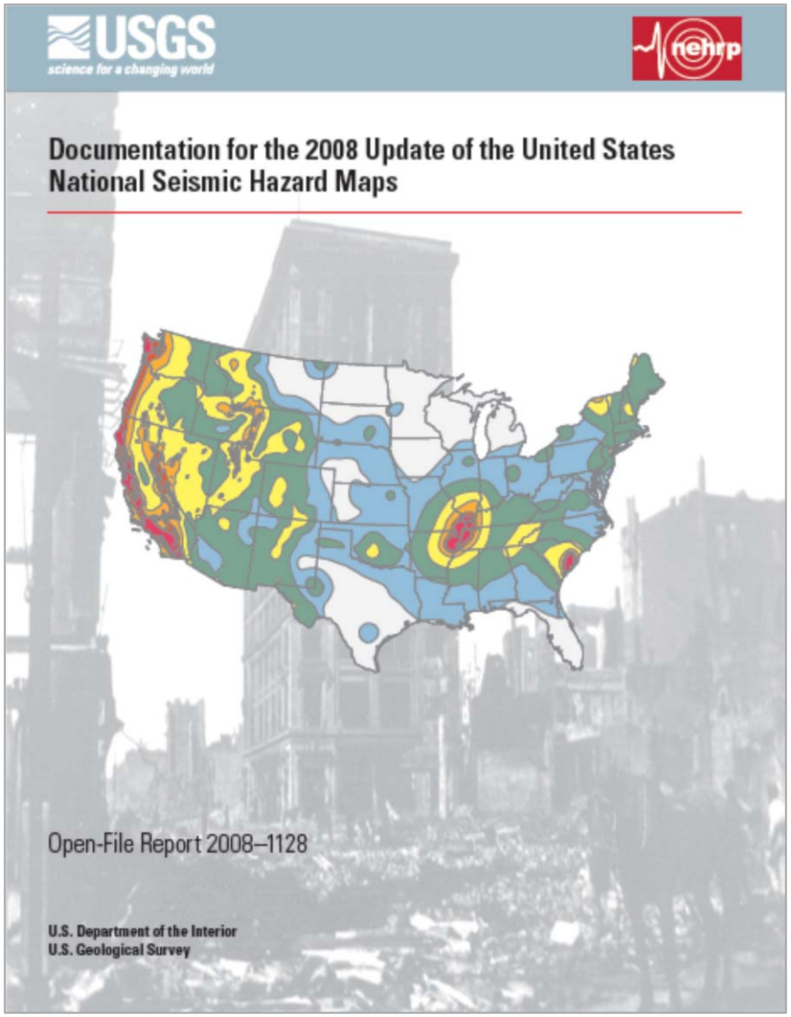




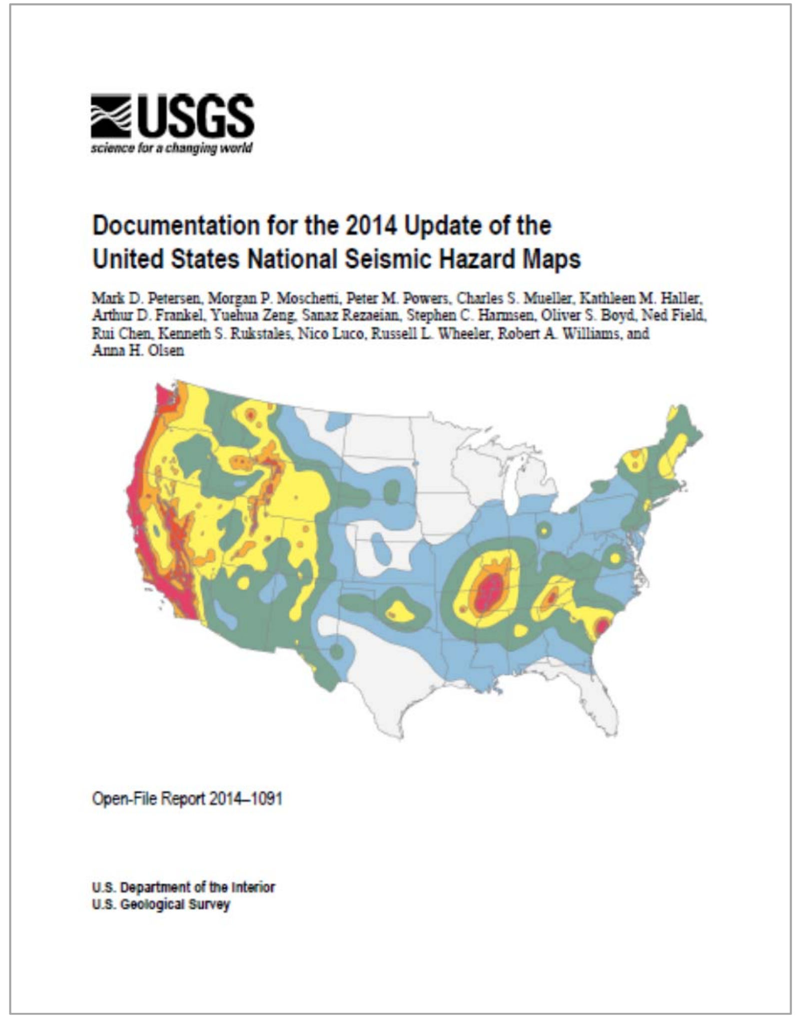
New Design Values Maps of MCE_R Ground Motion Parameters, S_s and S_1 (Chapter 22 of ASCE 7-16)

- New (updated) science, but not new (site-specific) MCE_R methods:
  - Design values maps of MCE_R ground motion parameters, S_s and S_1, are based on the site-specific MCE_R methods of Chapter 21 of ASCE 7-16 (but these methods did not change substantially from those of ASCE 7-10)
- New (updated) Science – Design values are based on the USGS updates of the National Seismic Hazard Maps:
  - National Seismic Hazard Maps provide updated estimates of 2% in 50-year uniform hazard spectra (UHS) of median (RotD50) ground motions
  - The design values of ASCE 7-10 were derived from the 2009 update of the NSHMP maps (USGS OFR 2008-1128)
  - The design values of ASCE 7-16 were derived form the 2014 update of the NSHMP maps (USGS OFR 2014-1091)

USGS Open File Reports Documenting Development of United States National Seismic Hazard Maps – 2008 (ASCE 7-10) and 2014 (ASCE 7-16)



USGS OFR 2008-1128



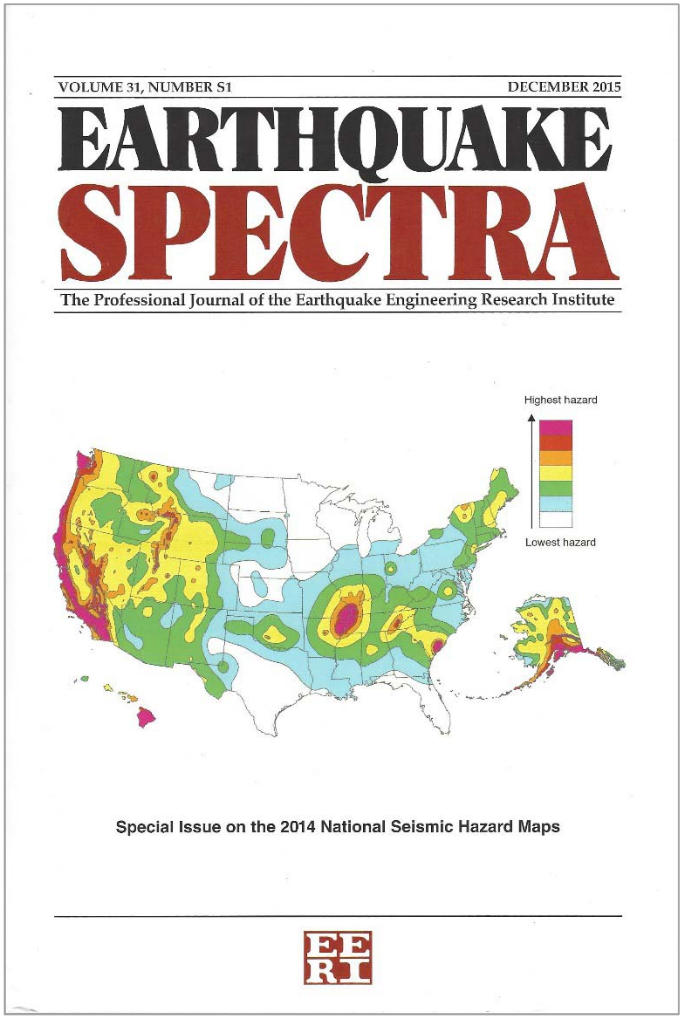
USGS OFR 2014-1091

Research Projects Contributing to 2014 USGS NSHM Updates (Luco, USGS)

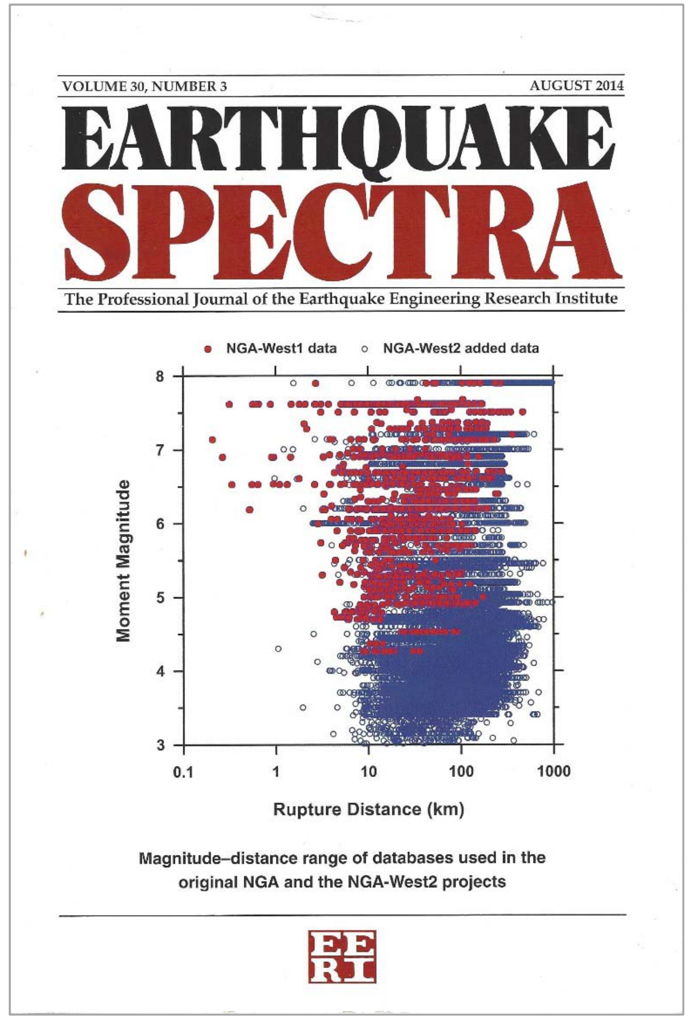
Project Name	Lead(s)	Duration	Sponsors
Central & Eastern US Seismic Source Characterization for Nuclear Facilities **(CEUS-SSC)**	Consultants	2008-2011	US DOE, EPRI, US NRC
Uniform California Earthquake Rupture Forecast, Version 3 **(UCERF3)**	USGS, CGS, SCEC (WGCEP)	2010-2013	CEA
Next Generation Attenuation Relations for Western US, Version 2 **(NGA-West2)**	PEER	2010-2013	CEA, Caltrans, PG&E

+ Dozens of other updates summarized in the Commentary to Chapter 22 of ASCE 7-16 and explained in the December 2015 Special Issue of *Earthquake Spectra* journal

Relevant Special Issues of *Earthquake Spectra*



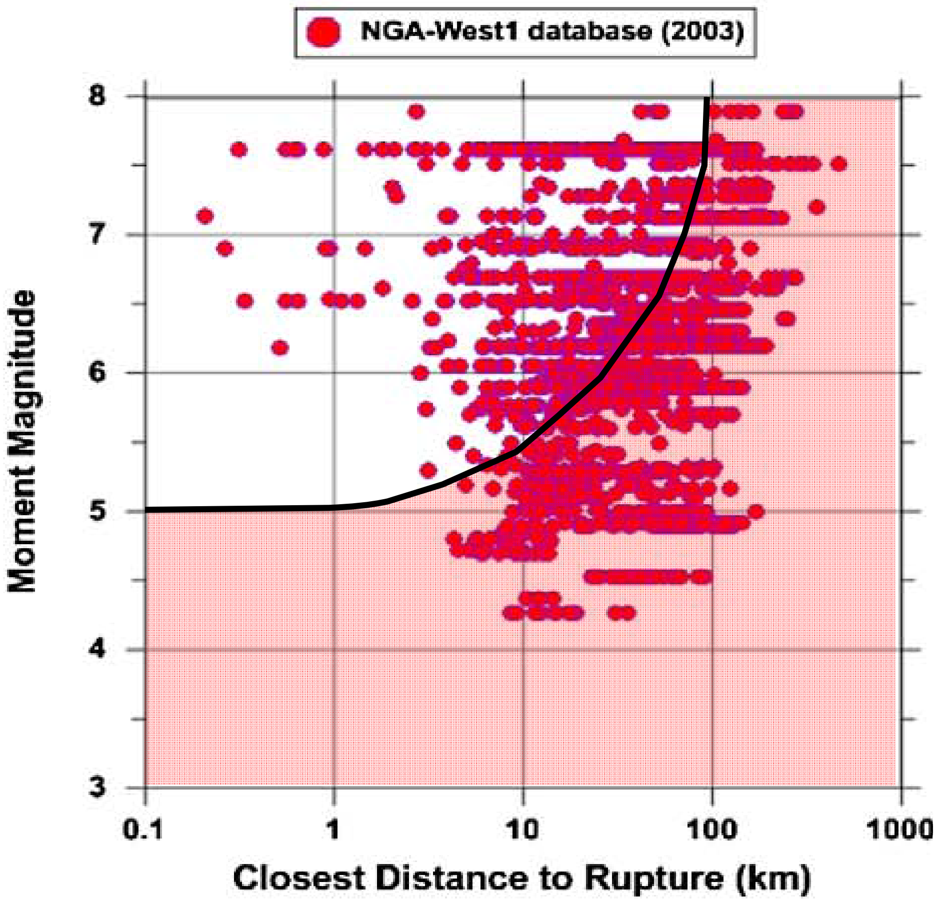
2014 National Seismic Hazard Maps



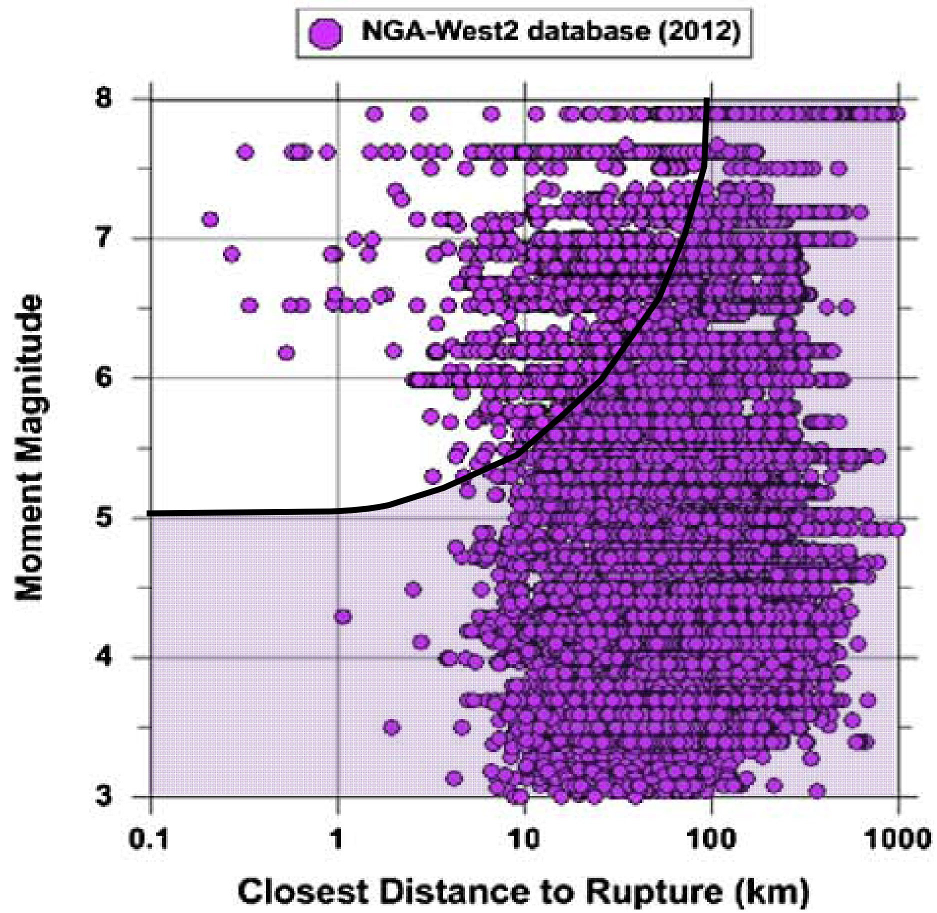
PEER NGA –West2 Project

PEER NGA Earthquake Databases and GMPEs
(Bozorgnia et al., *Earthquake Spectra*, Vol. 30, No. 3, August 2014, EERI)

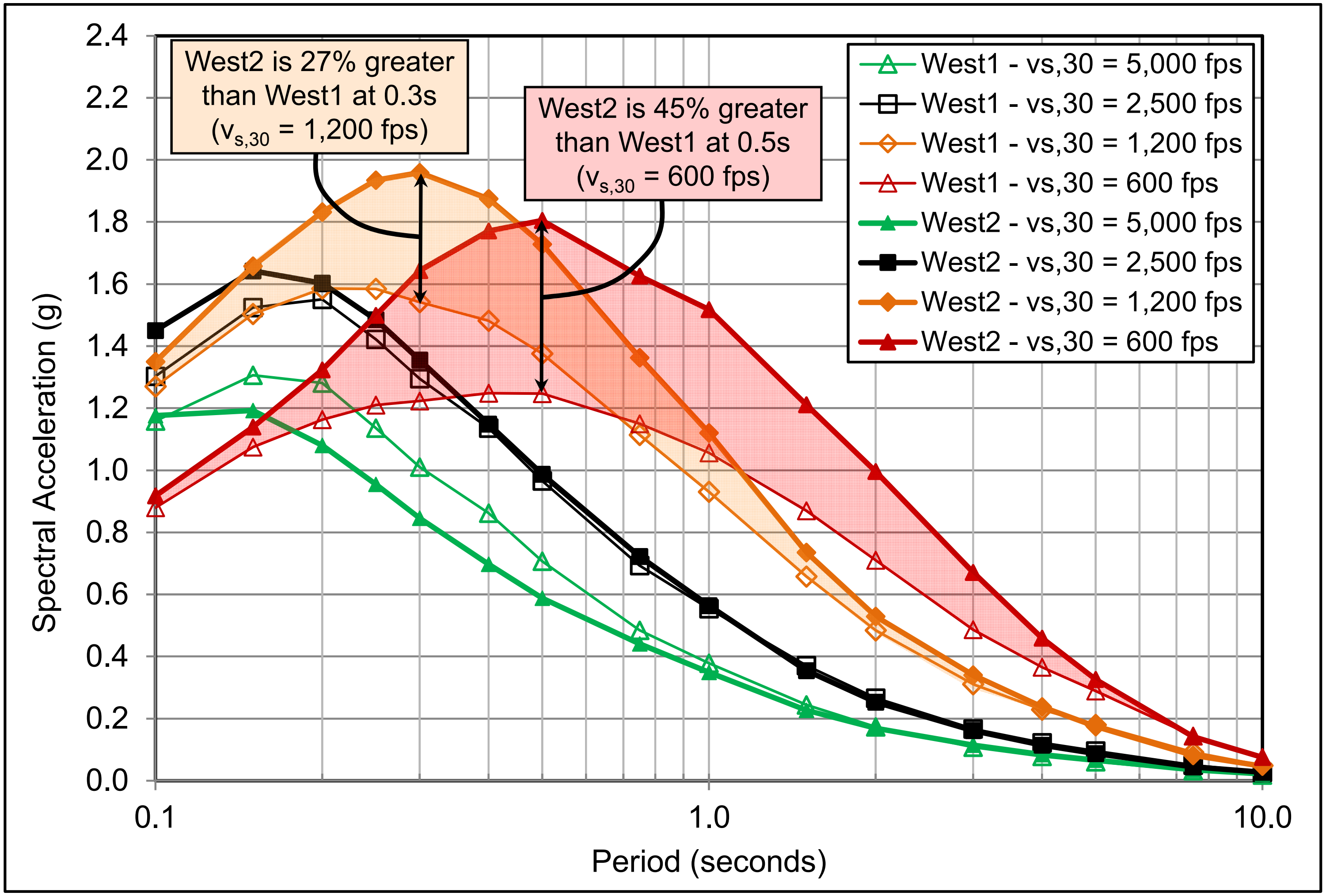
NGA-West1 Database – 3,550 Records
(West1 GMPEs used for ASCE 7-10 maps)



NGA-West2 Database – 21,332 Records
(West2 GMPEs used for ASCE 7-16 maps)



Example Comparison of Deterministic MCE_R Ground Motions
NGA West1 and NGA West2 GMPEs (M7.0 at R_x = 6 km, Site Class boundaries)



PEER NGA GMPE spreadsheet calculations: West1 based on Al Atik, 2009, West2 based on Seyhan, 2014)

Seismic Code Development "Yo-Yo" Dilemma

- **Earth Science**. The underlying earth science of earthquakes is rapidly evolving and will necessarily change as research advances our understanding of earthquake ground motions.
- **Seismic Codes**. Building owners and other stakeholders assume that seismic codes reflect "settled science" and that the seismic criteria required for building design only change when there is a compelling reason (e.g., discovery of a new active fault).
- **Seismic Design Criteria Yo-Yo**. Up and down changes to seismic design criteria (each code cycle) erode stakeholder confidence in seismic codes and the underlying earth science they are based on.

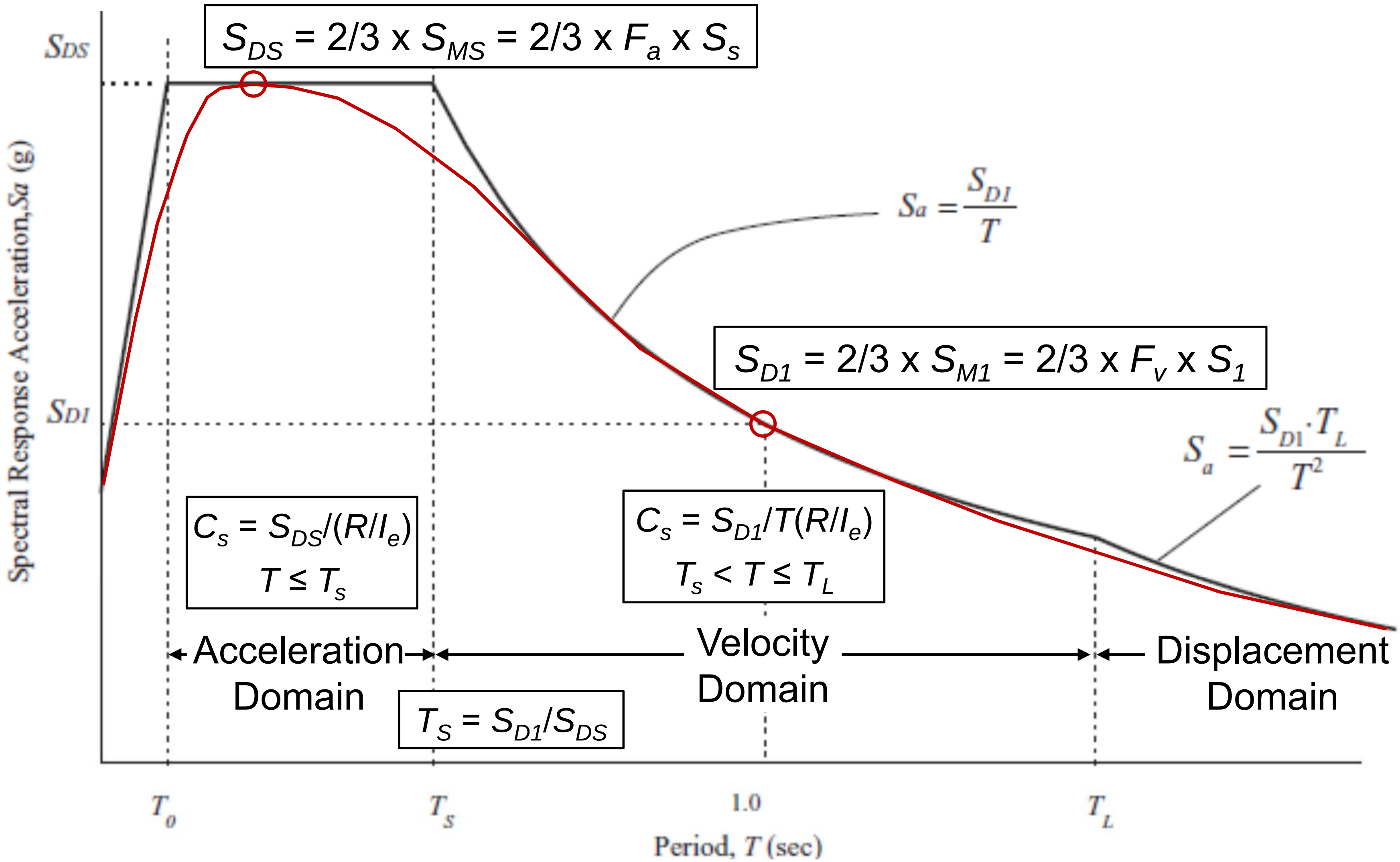
2. The "Problem"

- With Code Characterization of Ground Motions

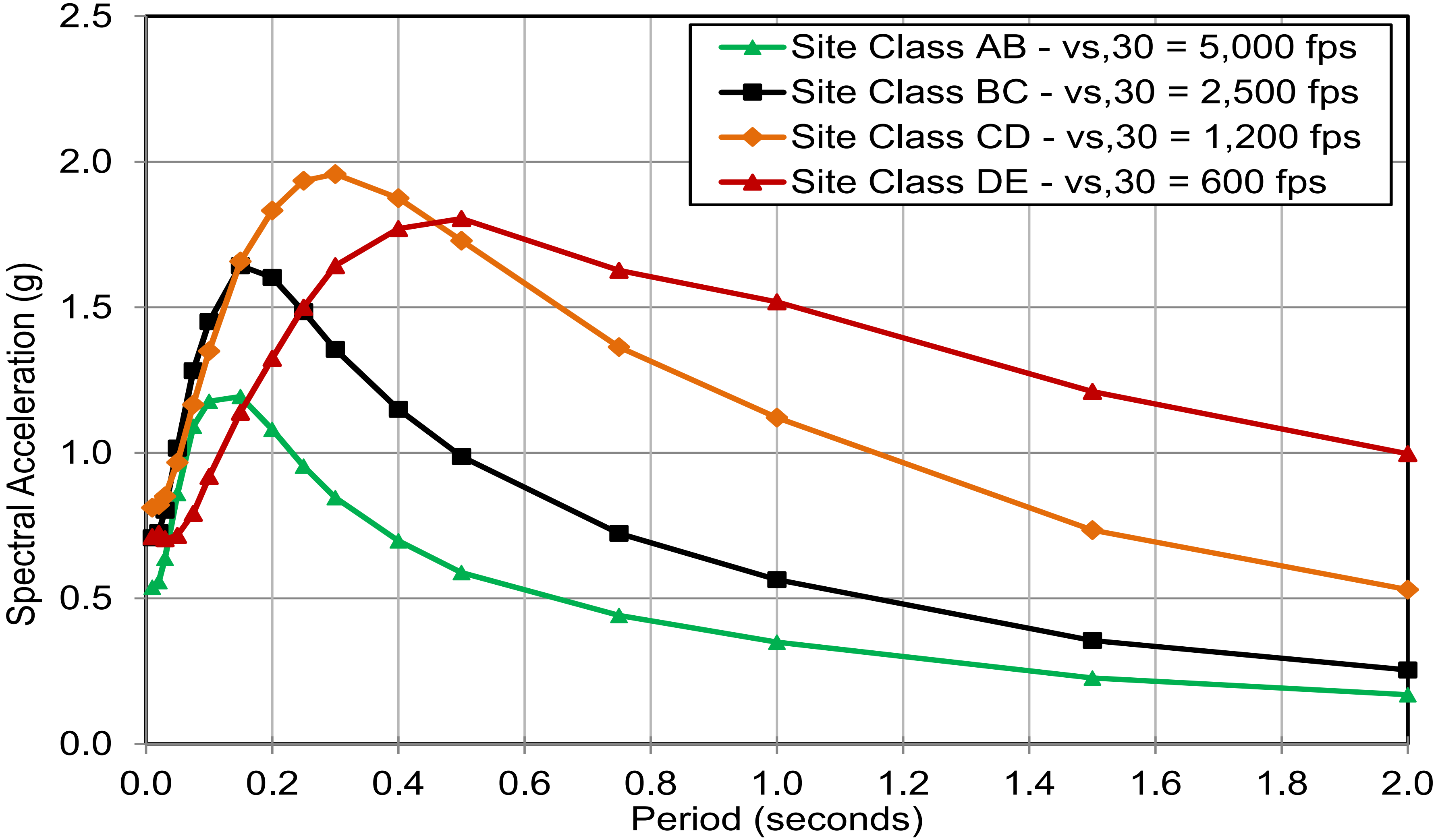
  Use of only two response periods (0.2s and 1.0s) to define ELF (and MRSA) design forces is not sufficient, in general, to accurately represent response spectral acceleration for all design periods of interest

Design Response Spectrum

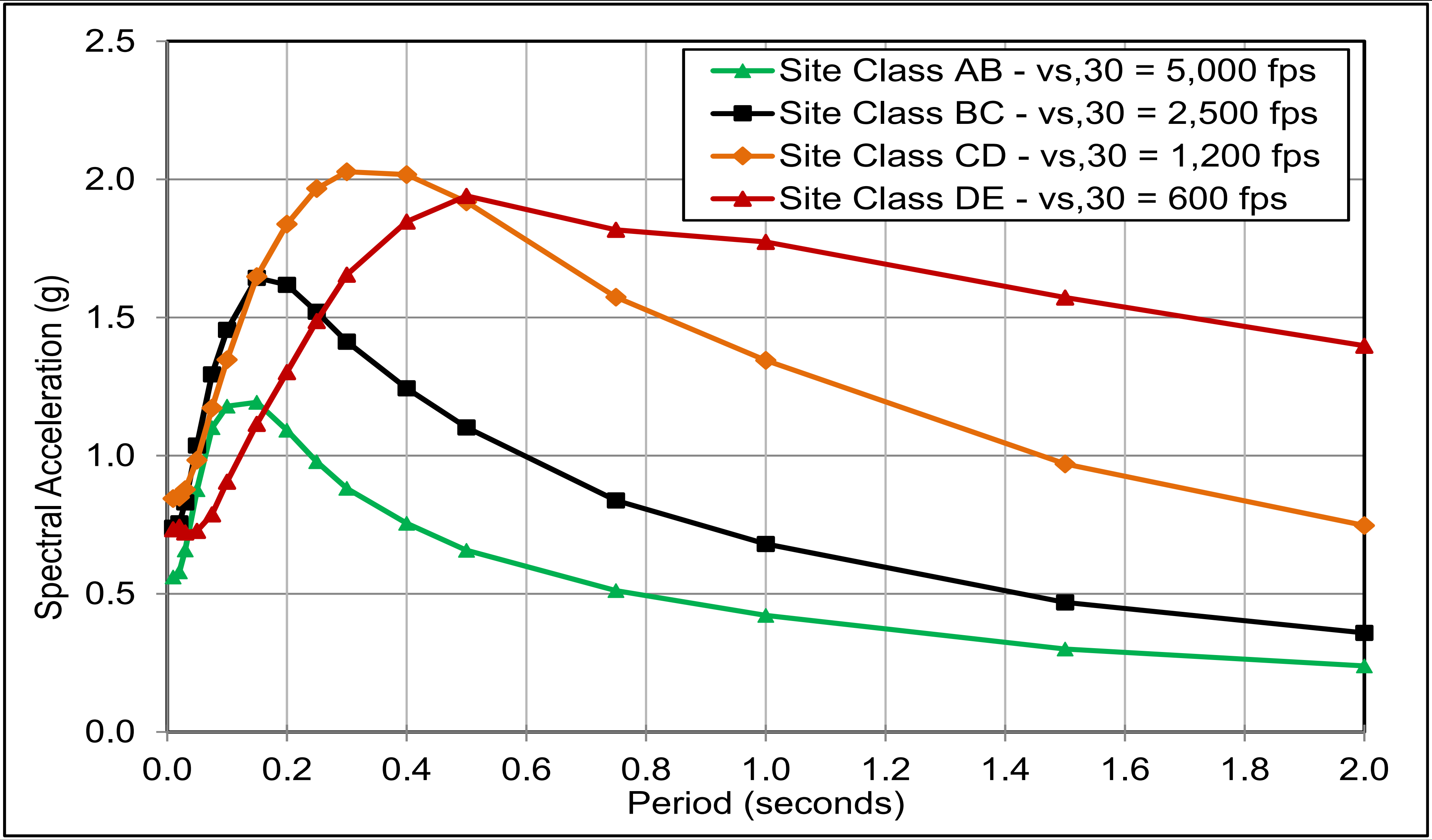
(Figure 11.4-1, ASCE 7-10 and ASCE 7-16 with annotation)



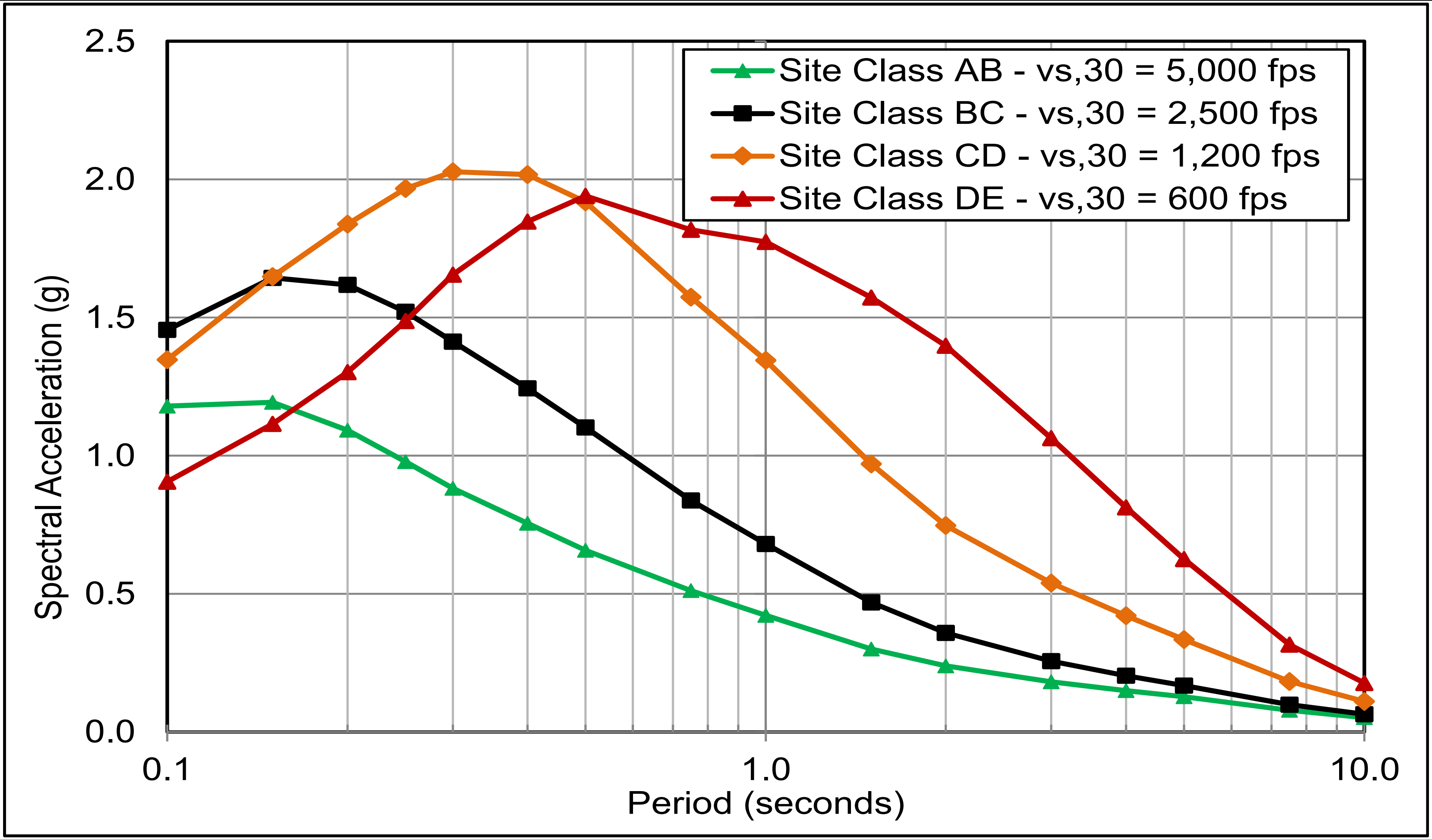
Example Design Spectra - Deterministic MCE_R Ground Motions (ASCE 7-16)
PEER NGA West2 GMPEs (M7.0 at R_x = 6 km, Site Class boundaries)



Example Design Spectra - Deterministic MCE_R Ground Motions (ASCE 7-16)
PEER NGA West2 GMPEs (M8.0 at R_x = 8.5 km, Site Class boundaries)



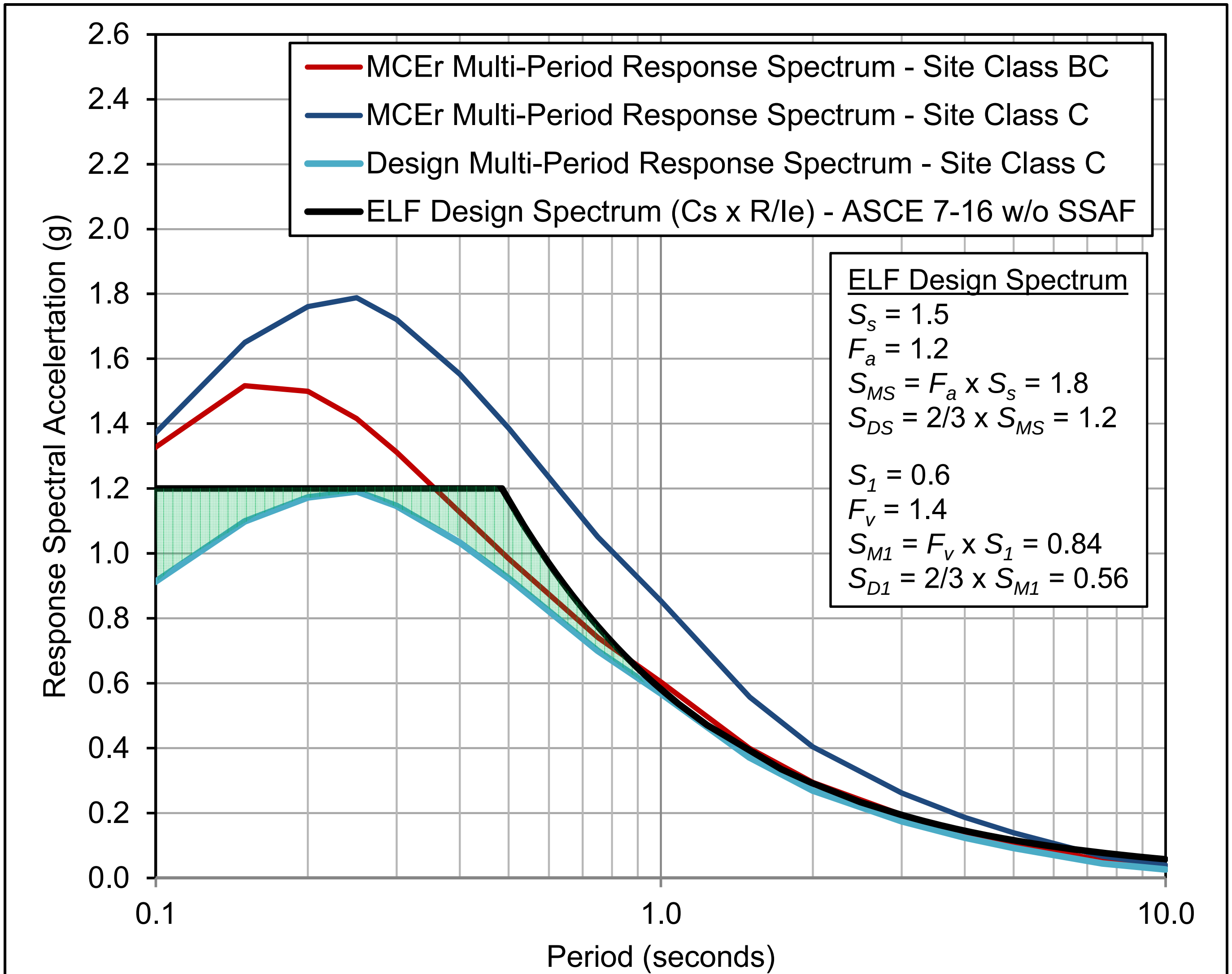
Example Design Spectra - Deterministic MCE_R Ground Motions (ASCE 7-16)
PEER NGA West2 GMPEs (M8.0 at R_x = 8.5 km, Site Class boundaries)



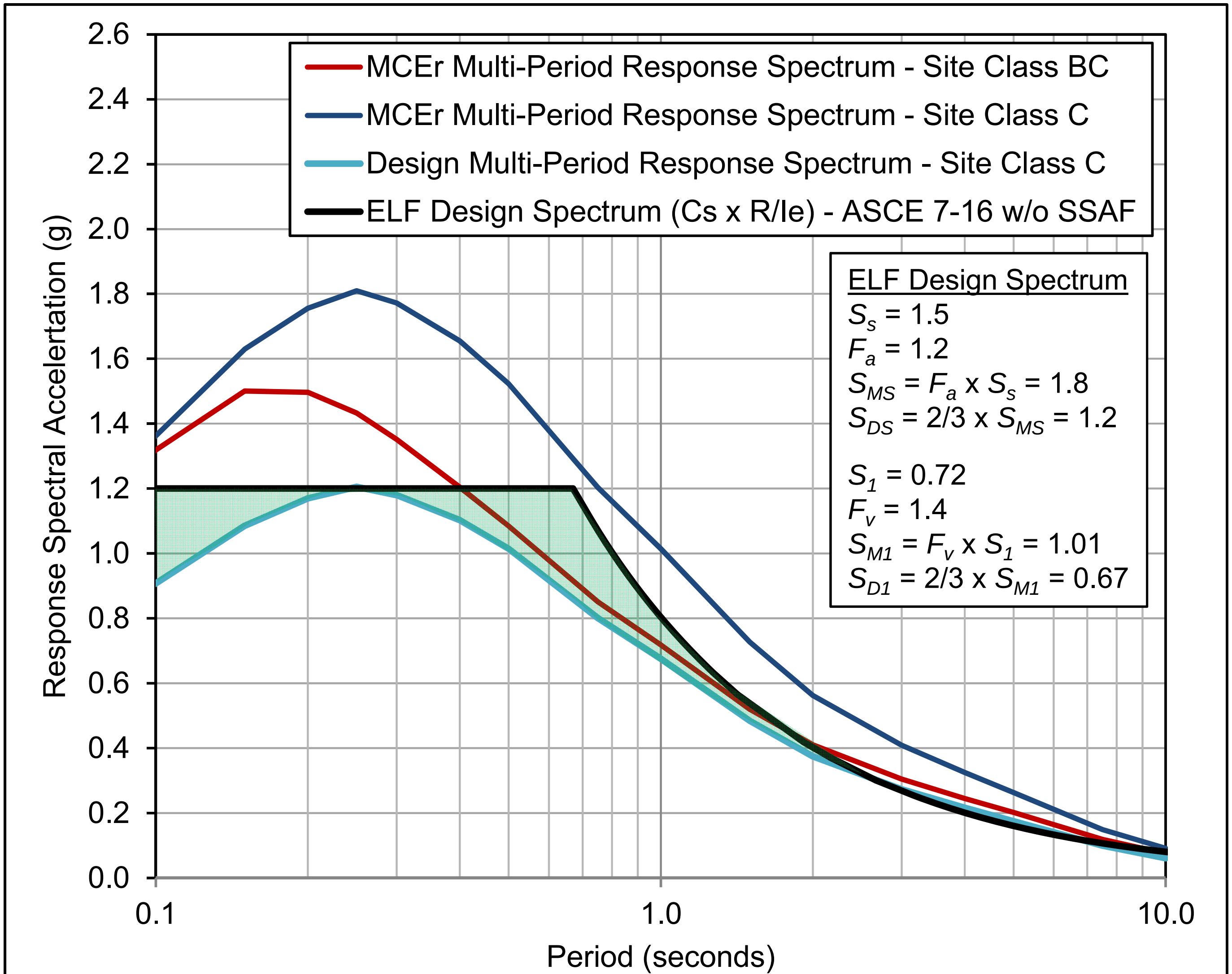
Short-Coming in Code Methods

- Use of only two response periods (0.2s and 1.0s) to define ELF (and MRSA) design forces is not sufficient, in general, to accurately represent response spectral acceleration for all design periods of interest
  - **Reasonably Accurate (or Conservative)** – When peak MCE_R response spectral acceleration occurs at or near 0.2s and peak MCE_R response spectral velocity occurs at or near 1.0s for the site of interest
  - **Potentially Non-conservative** – When peak MCE_R response spectral velocity occurs at periods greater than 1.0s for the site of interest
    - Softer soil sites whose seismic hazard is dominated by large magnitude events

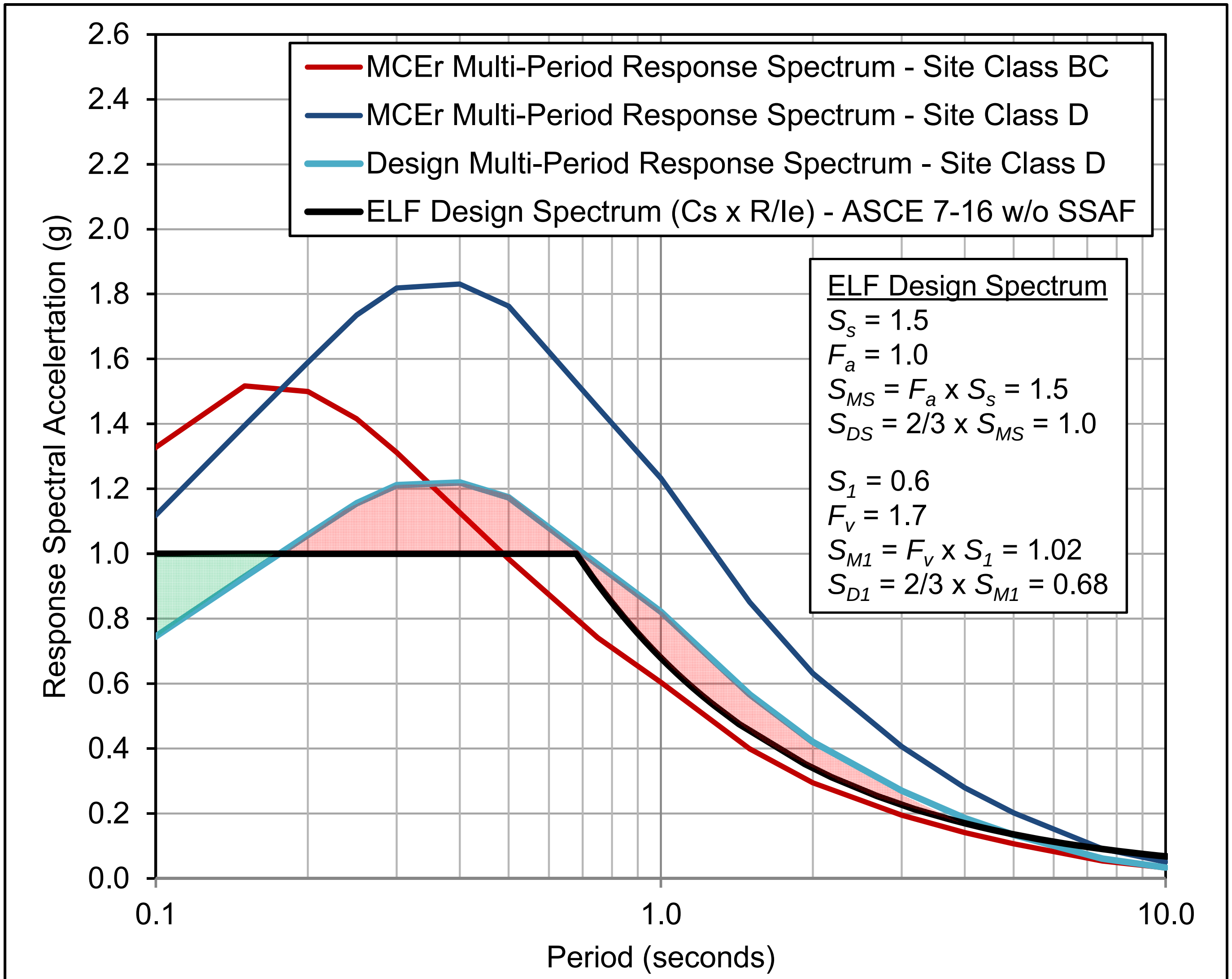
Example ELF “Design Spectrum” - ASCE 7-16 w/o New Site-Specific Requirements
M7.0 earthquake ground motions at R_X = 6.8 km, Site Class C



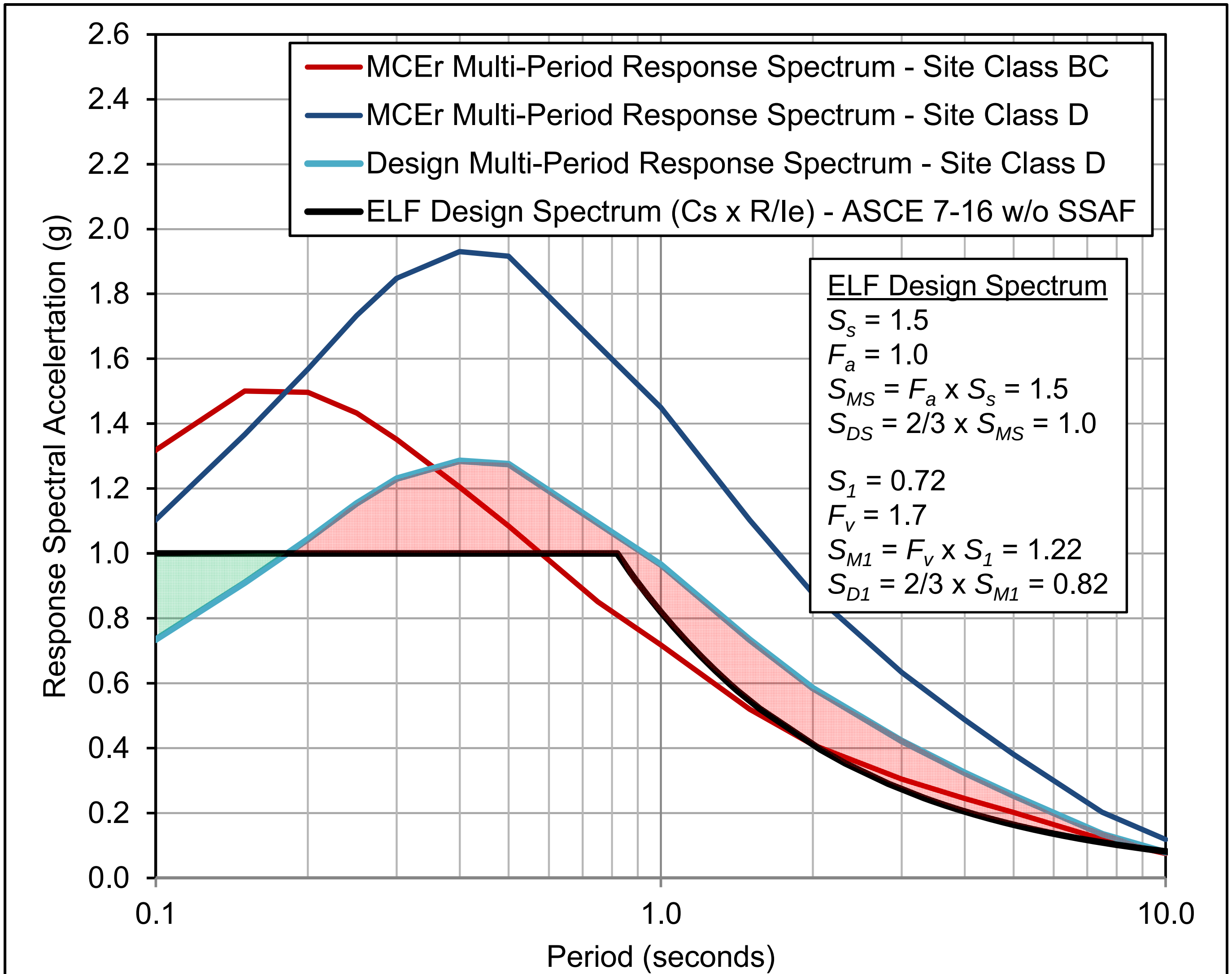
Example ELF "Design Spectrum" - ASCE 7-16 w/o New Site-Specific Requirements
M8.0 earthquake ground motions at R_X = 9.9 km, Site Class C



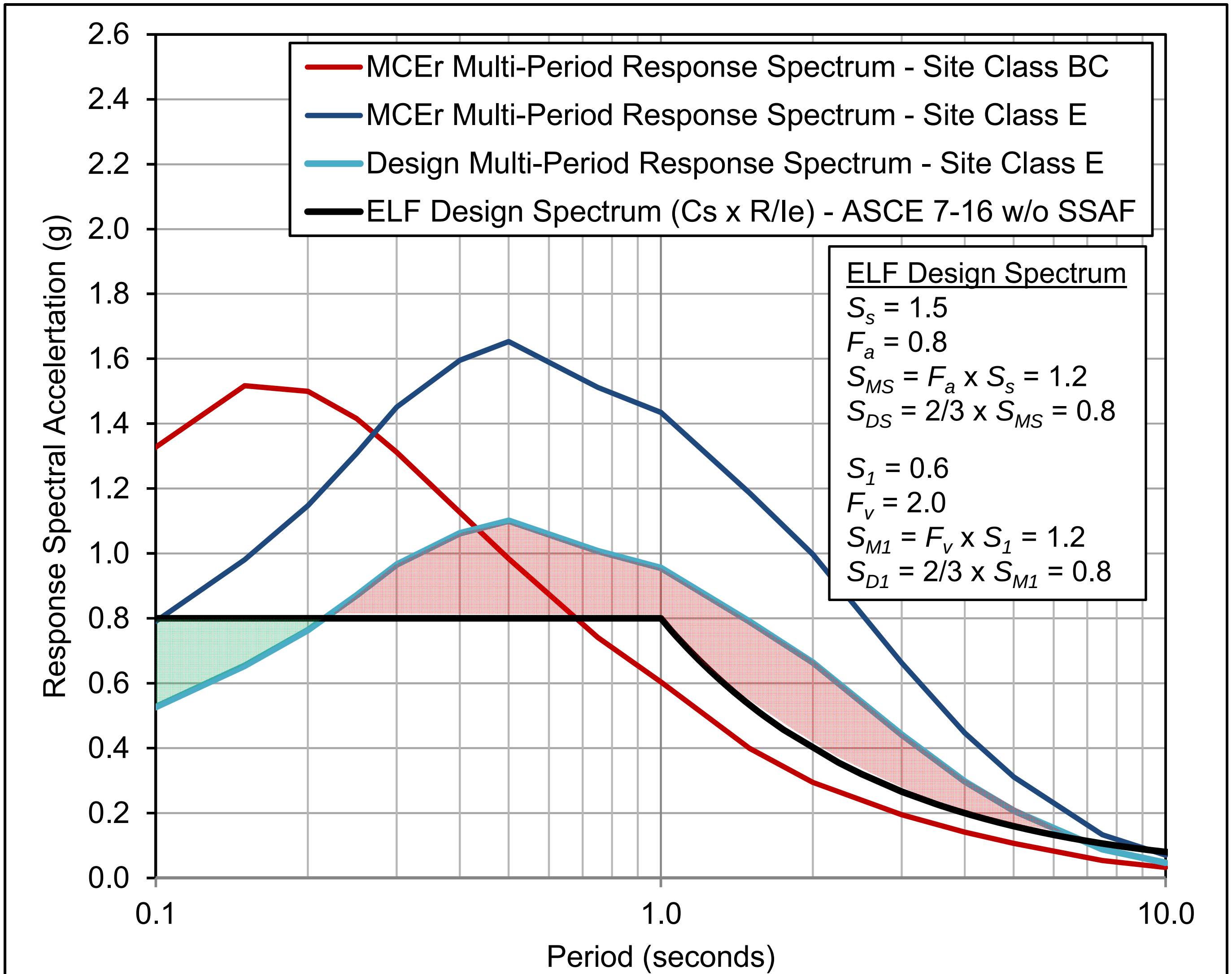
Example ELF "Design Spectrum" - ASCE 7-16 w/o New Site-Specific Requirements
M7.0 earthquake ground motions at R_X = 6.8 km, Site Class D



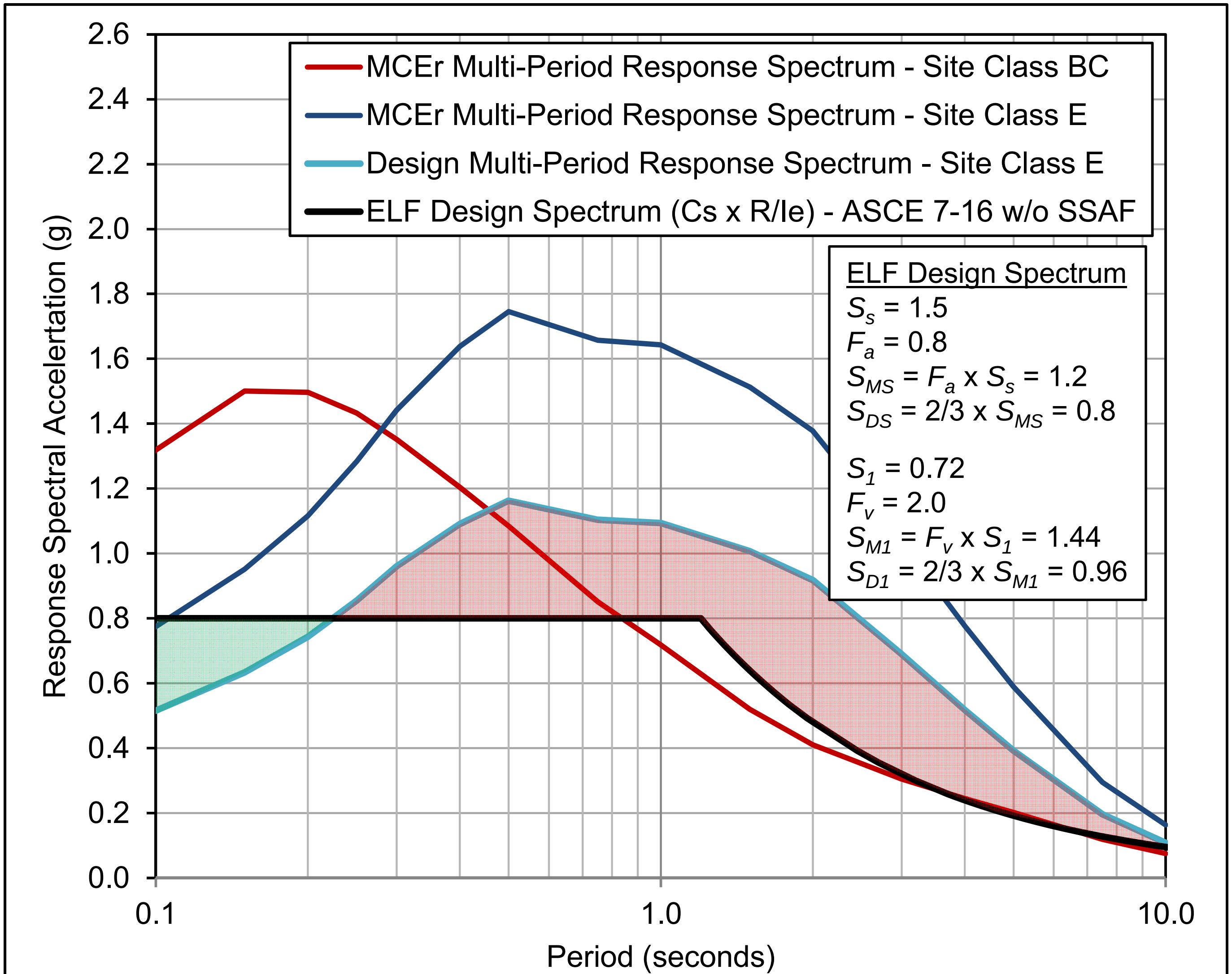
Example ELF "Design Spectrum" - ASCE 7-16 w/o New Site-Specific Requirements
M8.0 earthquake ground motions at R_X = 9.9 km, Site Class D



Example ELF "Design Spectrum" - ASCE 7-16 w/o New Site-Specific Requirements
M7.0 earthquake ground motions at R_X = 6.8 km, Site Class E



Example ELF "Design Spectrum" - ASCE 7-16 w/o New Site-Specific Requirements
M8.0 earthquake ground motions at R_X = 9.9 km, Site Class E

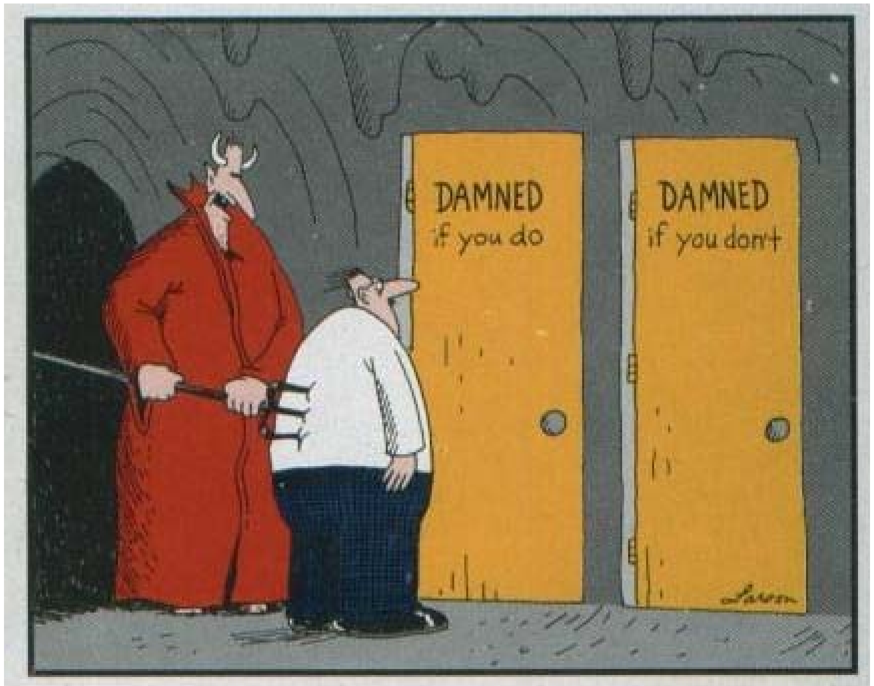


Long-Term Solution (Project 17/ASCE 7-22)

- Develop and adopt multi-period design spectrum approach
  - Not feasible in current code cycle (ASCE 7-16)
- Multi-period spectrum approach will require:
  - Reworking of seismic design requirements and criteria now based on two response periods
  - Development of new ground motion design parameters (by the USGS) for each new response period of interest
  - Development of new site factors for each new response period of interest (or site effects embedded directly in ground motion design values maps)
- Challenges:
  - Non-WUS sites? - GMPEs may not be available for all U.S. regions
  - Too Many Maps (Too Many Tables)? – Can ground motion design parameters be provided electronically (e.g., via the web) without direct inclusion in ASCE 7 or the IBC?

Short-Term Solution Options (BSSC PUC)

- Option 1 - Re-formulate seismic parameters to eliminate potential non-conservatism in ELF (and MRSA) seismic forces
- Option 2 - Require site-specific analysis when ELF (and MSRA) seismic forces could be potentially non-conservative



"C'mon, c'mon — it's either one or the other."

Short-Term Solution Homework (NIBS BSSC Study)

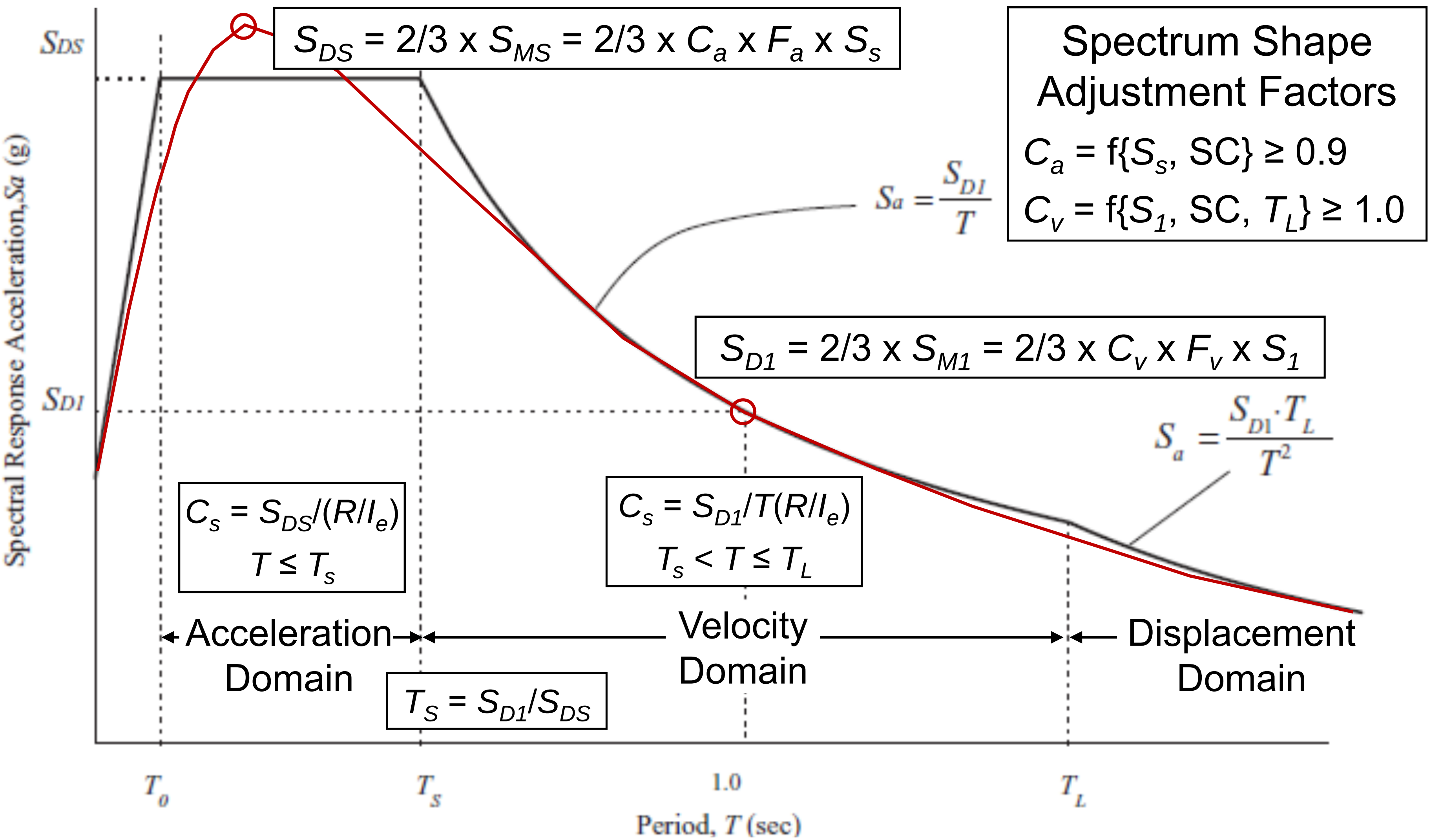
- FEMA-funded NIBS BSSC study (Kircher & Associates):

  "Investigation of an Identified Short-coming in the Seismic Design Procedures of ASCE 7-10 and Development of Recommended Improvements For ASCE 7-16"

  https://www.nibs.org/resource/resmgr/BSSC2/Seismic_Factor_Study.pdf
- Study Advisors and Contributors:
  - Nico Luco (USGS)
  - Sanaz Rezaeian (USGS)
  - C. B. Crouse (URS)
  - Jonathan Stewart (UCLA)
  - Kevin Milner (SCEC)
  - David Bonnevile (Degenkolb) – BSSC PUC Chair
  - John Hooper (MKA) – ASCE 7-16 SSC Chair
- PEER Center - Next Generation Attenuation Relations
  - Linda Al Atik (PEER NGA West1 GMPEs spreadsheet)
  - Emil Seyhan (PEER NGA West2 GMPEs spreadsheet)

Option 1 - Spectrum Shape Adjustment Factor Reformulation

(Figure 11.4-1 annotated to show proposed new spectrum shape Adjustment Factors, C_a and C_v)



Short-Term Solution (ASCE 7-16)

- Require site-specific analysis when site factors (alone) are not sufficiently conservative
- Provide exceptions to site-specific requirements that allow designers the option to design for conservative forces in lieu of performing a site-specific analysis
- Develop “conservative” criteria of exceptions using the results of the NIBS BSSC study

3. New Ground Motion Requirements of Section 11.4

- Site coefficients of Tables 11.4-1 and 11.4-2
- Site-specific requirements of Section 11.4.8
- Example values of the design coefficient, C_S, of ASCE 7-16 and comparisons of these values with those of ASCE 7-10

Site Classification and Shear Wave Velocity ($v_{s,30}$) Criteria (Table 20.3-1 of ASCE 7-05, ASCE 7-10 and ASCE 7-16)

Site Class	v_s	N or N_{ch}	s_u
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the following characteristics: —Plasticity index $PI > 20$, —Moisture content $w \geq 40\%$, —Undrained shear strength $s_u < 500$ psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

New Values of the Site Coefficient, F_a (Table 11.4-1 of ASCE7-16)
(shown as proposed changes to ASCE 7-10)

Table 11.4-1 Site Coefficient, F_a

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short Period					
	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S = 1.25$	$S_S \geq 1.5$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	~~1.0~~ 0.9	~~1.0~~ 0.9	~~1.0~~ 0.9	~~1.0~~ 0.9	~~1.0~~ 0.9	0.9
C	~~1.2~~ 1.3	~~1.2~~ 1.3	~~1.1~~ 1.2	~~1.0~~ 1.2	~~1.0~~ 1.2	1.2
D	1.6	1.4	1.2	1.1	1.0	1.0
E	~~2.5~~ 2.4	1.7	~~1.2~~ 1.3	See Section 11.4.8		
F	See Section 11.4.8					

Note: Use straight-line interpolation for intermediate values of S_S. At the Site Class B-C boundary, F_a = 1.0 for all S_s levels. If site classes A or B is established without the use of on-site geophysical measurements of shear wave velocity, use F_a = 1.0.

Note – Site Class B is no longer the “reference” site class of MCE_R ground motion parameters S_s and S_1 (i.e., new coefficients reflect Site Class BC boundary of 2,500 f/s) and Site Class D is no longer the “default” site class (when Site Class C amplification is greater, i.e., $S_S \geq 1.0$)

Note – Site-Specific analysis required for Site Class E sites where $S_S \geq 1.0$ w/exception

New Values of the Site Coefficient, F_v (Table 11.4-2 of ASCE7-16)

(shown as proposed changes to ASCE 7-10)

Table 11.4-2 Site Coefficient, *F_v*

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at 1-s Period					
	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 = 0.5$	$S_1 \geq 0.6$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	~~1.0~~ 0.8	~~1.0~~ 0.8	~~1.0~~ 0.8	~~1.0~~ 0.8	~~1.0~~ 0.8	0.8
C	~~1.7~~ 1.5	~~1.6~~ 1.5	1.5	~~1.4~~ 1.5	~~1.3~~ 1.5	1.4
D	2.4	~~2.0~~ 2.2	~~1.8~~ 2.0	~~1.6~~ 1.9	~~1.5~~ 1.8	1.7
E	~~3.5~~ 4.2	See Section 11.4.8				
F	See Section 11.4.8					

Note: Use straight-line interpolation for intermediate values of S_1. At the Site Class B-C boundary, F_v = 1.0 for all S_1 levels. If site classes A or B are established without the use of on-site geophysical measurements of shear wave velocity, use F_v = 1.0.

Note – Site Class B is no longer the “reference” site class of MCE_R ground motion parameters S_s and S_1 (i.e., new coefficients reflect Site Class BC boundary of 2,500 f/s).

Note - Site-Specific analysis required for Site Class D sites where $S_1 \geq 0.2$ w/exceptions
Site-Specific analysis required for Site Class E sites where $S_1 \geq 0.2$ w/o exception

Site-Specific Requirements ASCE 7-10

- Section 11.4.7 – Site-Specific Ground Motion Procedures:
  - Chapter 21 procedures are permitted for any structure
  - Section 21.1 procedures are required for structures on Site Class F sites (i.e., soil failure)
  - Section 21.2 procedures are required for isolated or damped structures when $S_1 \geq 0.6$ g
- Site-specific requirements of Section 11.4.7 of ASCE 7-10 are included in the site-specific requirements of Section 11.4..8 of ASCE 7-16

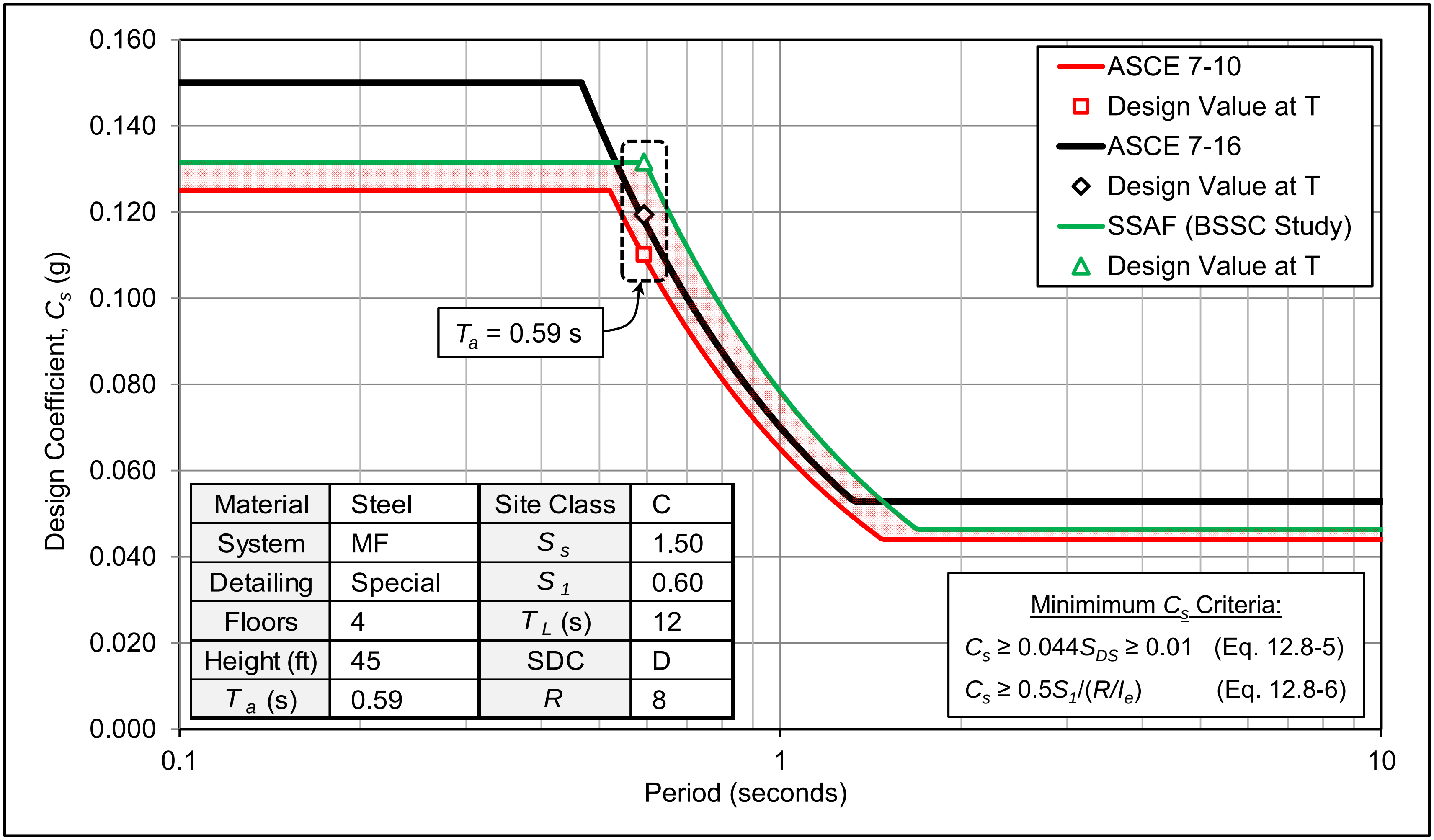
New Requirements of Section 11.4.8 of ASCE 7-16

- Require site-specific ground motion procedures for:
  - structures on Site Class E sites with S_S greater than or equal to 1.0.
  - structures on Site Class D and E sites with S_1 greater than or equal to 0.2.
- Permit ELF (and MRSA) design using conservative values of seismic coefficients:
  - Structures on Site Class E sites with S_S greater than or equal to 1.0, provided the site coefficient F_a is taken as equal to that of Site Class C.
  - Structures on Site Class D sites with S_1 greater than or equal to 0.2, provided the value of the seismic response coefficient C_s is increased by up to 50 percent at periods greater than T_s (by effectively extending the acceleration domain to $1.5T_s$).
  - Structures on Site Class E sites with S_1 greater than or equal to 0.2, provided that T is less than or equal to T_s and the equivalent static force procedure is used for design.

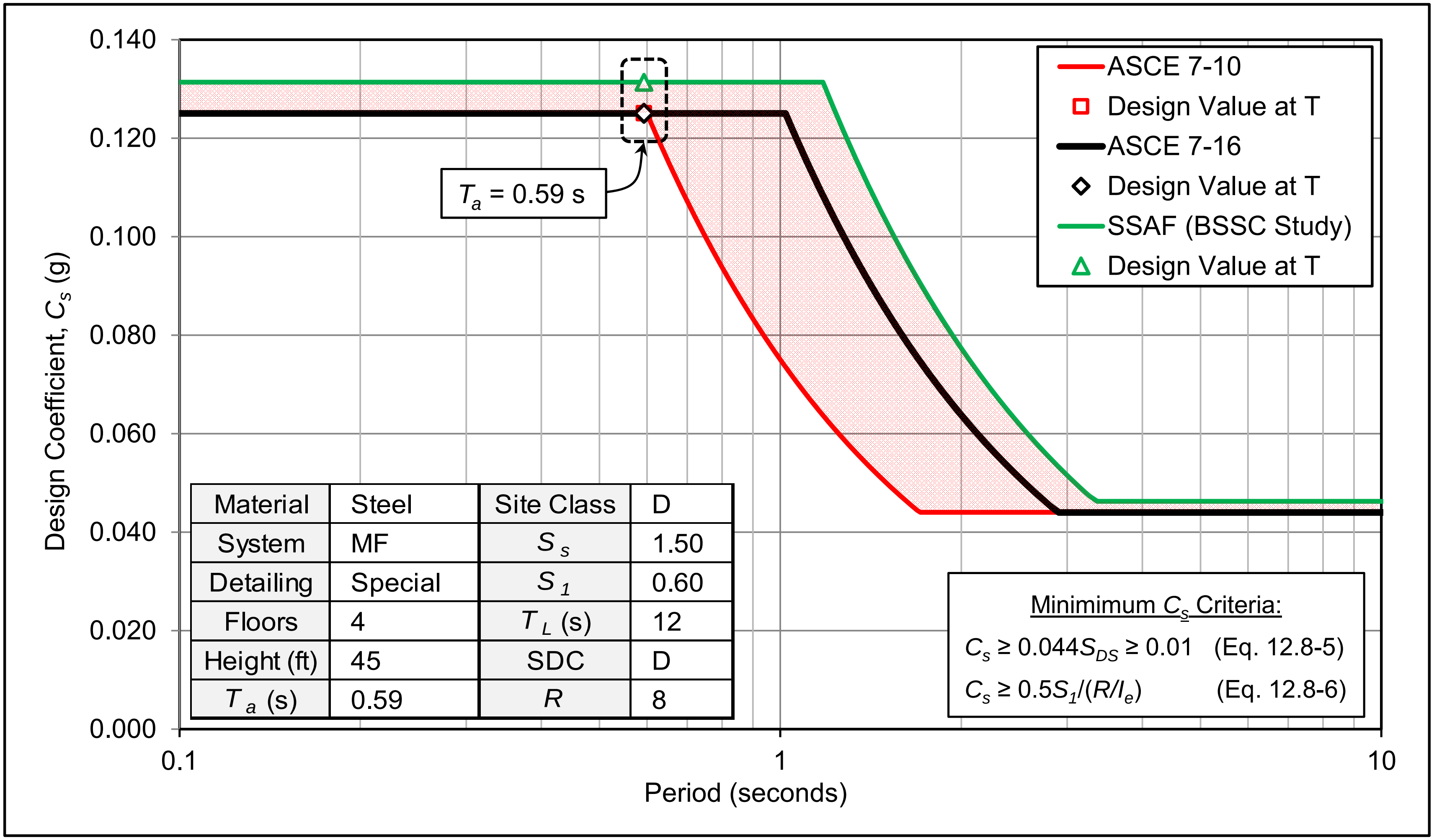
Example Values of the Design Coefficient (C_s)

- One (High Seismic) Site - S_s = 1.5 g, S_1 – 0.6 g
- Two Structural Systems:
  – 4-Story Steel SMF Building – T_a = 0.59 s (acceleration domain)
  – 16-Story Steel SMF Building – T_a = 1.71 s (velocity domain)
- Three Site Conditions (each system) – Site Class C, D and E
- Three Sets of ELF Design Criteria (each example):
  – ASCE 7-10 – Existing design requirements of ASCE 7-10
  – **ASCE 7-16 – New design requirements of ASCE 7-16 including the new site-specific requirements and exceptions of Section 11.4.8**
  – SSAF (BSSC Study) - What if ASCE 7-16 had adopted the spectrum shape adjustment factors (SSAFs) of BSSC study (Kircher et al., 2015) to modify the frequency content of the Design Spectrum?

Example Comparison of the Design Coefficient (C_s)
4-Story Steel Special Moment Frame Building - Site Class C

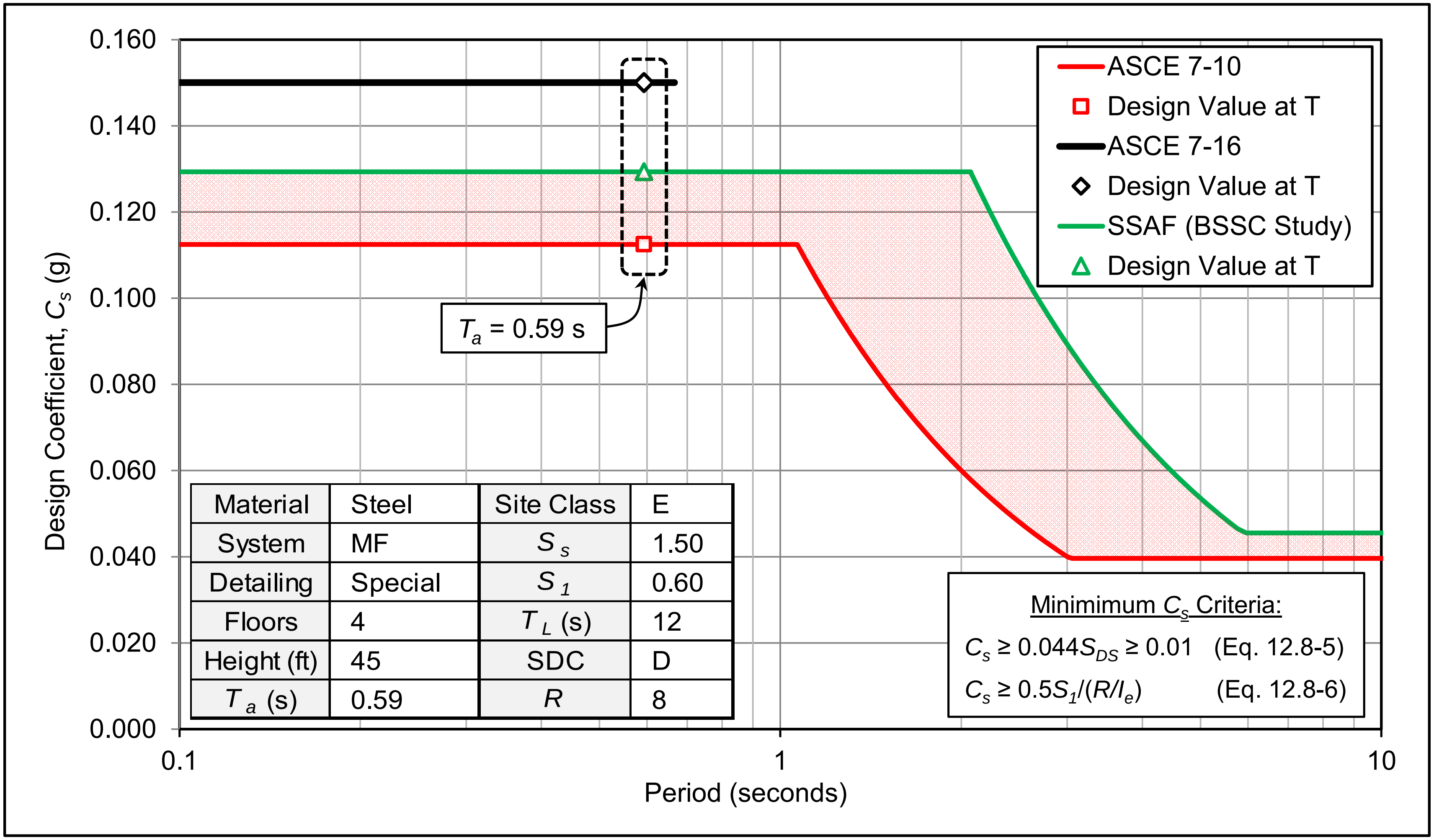


Example Comparison of the Design Coefficient (C_s)
4-Story Steel Special Moment Frame Building - Site Class D

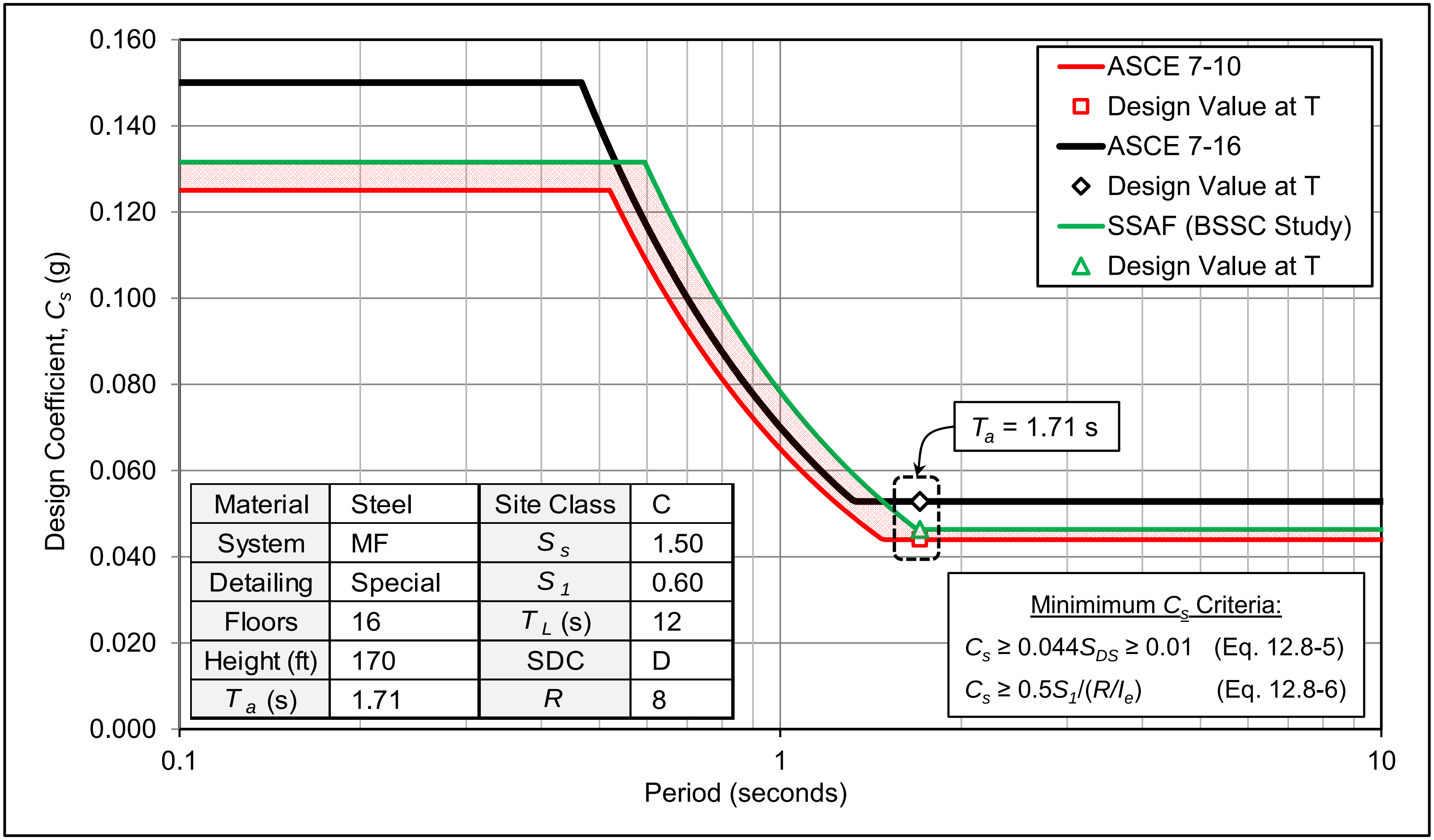


Material	Steel	Site Class	D
System	MF	S_s	1.50
Detailing	Special	S_1	0.60
Floors	4	T_L (s)	12
Height (ft)	45	SDC	D
T_a (s)	0.59	R	8

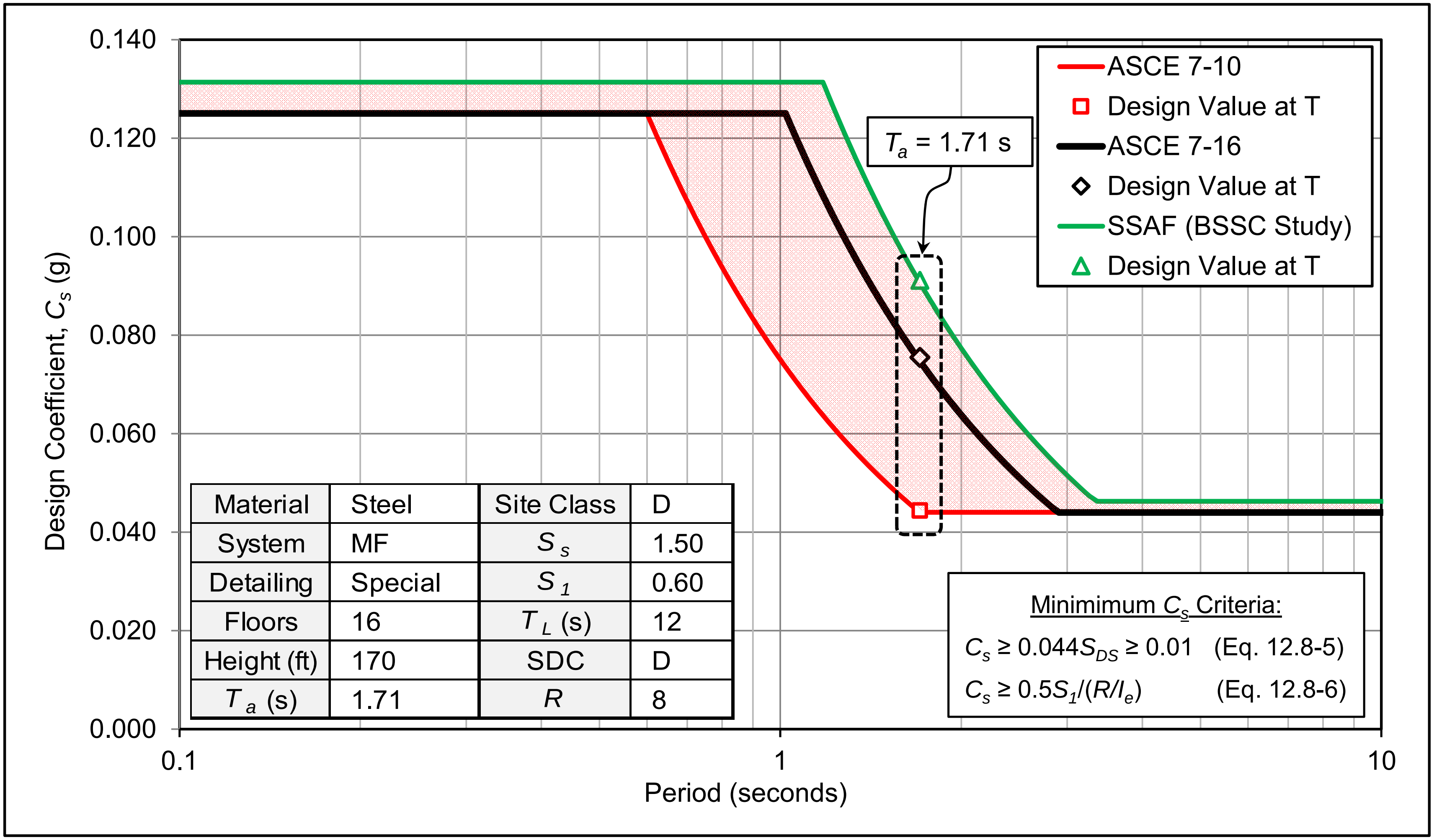
Example Comparison of the Design Coefficient (C_s)
4-Story Steel Special Moment Frame Building - Site Class E



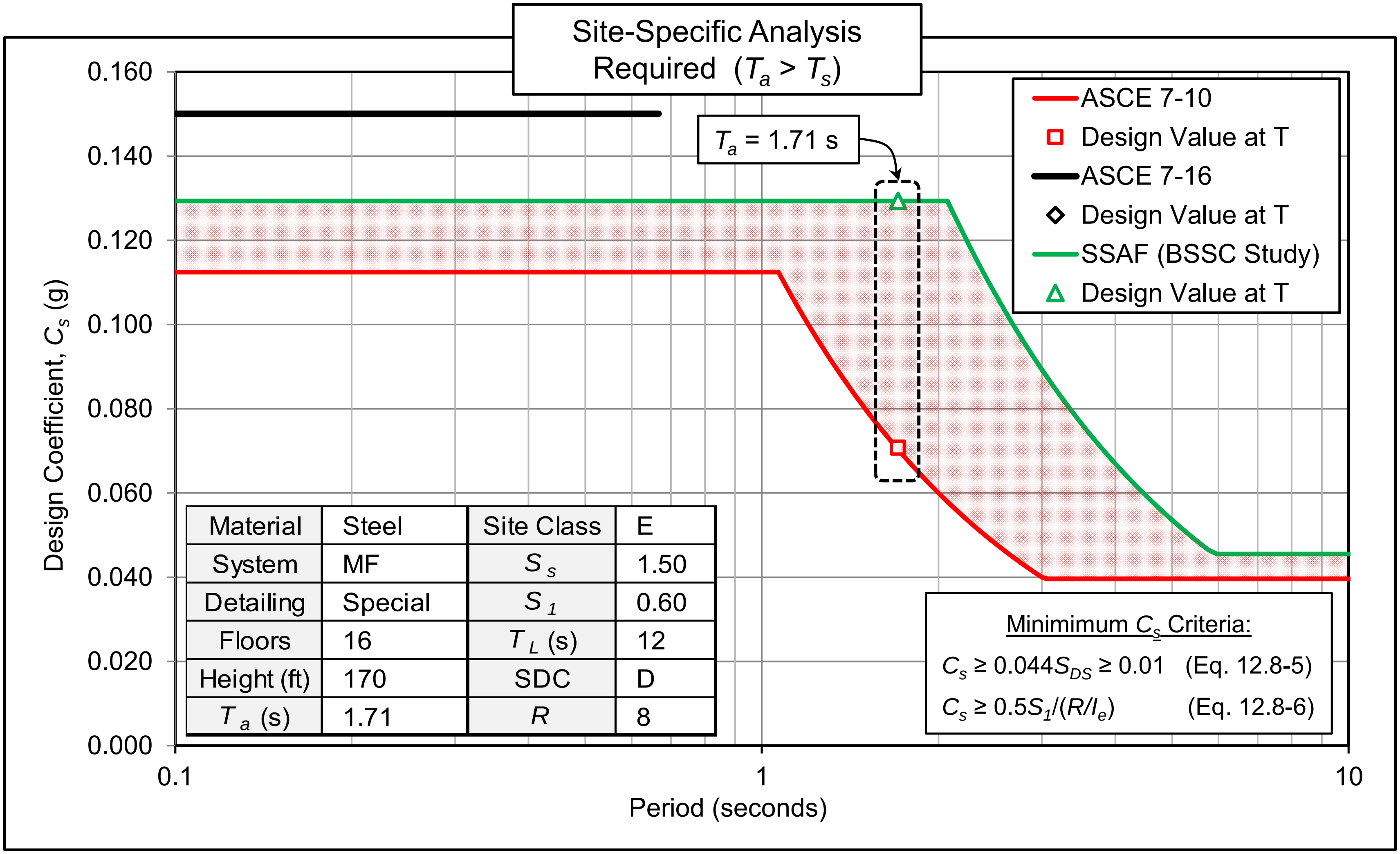
Example Comparison of the Design Coefficient (C_s)
16-Story Steel Special Moment Frame Building - Site Class C



Example Comparison of the Design Coefficient (C_s)
16-Story Steel Special Moment Frame Building - Site Class D



Example Comparison of the Design Coefficient (C_s)
16-Story Steel Special Moment Frame Building - Site Class E



Material	Steel	Site Class	E
System	MF	S_s	1.50
Detailing	Special	S_1	0.60
Floors	16	T_L (s)	12
Height (ft)	170	SDC	D
T_a (s)	1.71	R	8

What Types of Systems/Heights Require Site-Specific Analysis for Site Class E Site Conditions?

Seismic Force Resisting System (Table 12.2-1, ASCE 7-10)				Seismic Design Criteria				Site-Specific Required for Site Class E?
SFRS	Material	System	Detailing	SDC (RC II)	R Factor	h_{max} (ft)	T [h_{max}] (sec)	
A.15	Wood	SW	Light Frame	D	6.5	65	0.46	Not Required
B.2	Steel	CBF	Special	D	6	160	0.90	h > 107 ft.
B.3	Steel	CBF	Oridinary	D	3.25	35	0.29	Not Required
B.4	Concrete	SW	Special	D	6	160	0.90	h > 107 ft.
B.5	Concrete	SW	Ordinary	C	5	NL	NA	Not Required
B.25	Steel	BF	BRBF	D	8	160	1.35	h > 62 ft.
C.1	Steel	MF	Special	D	8	NL	NA	h > 52 ft.
C.3	Steel	MF	Intermediate	D	4.5	35	0.48	Not Required
C.4	Steel	MF	Ordinary	C	3.5	NL	NA	Not Required
C.5	Concrete	MF	Special	D	8	NL	NA	h > 63 ft.
C.6	Concrete	MF	Intermediate	C	5	NL	NA	Not Required

4. New Site-Specific Methods of Chapter 21

- Section 21.4 – Design Acceleration Parameters
  - New criteria for determining values of S_{DS} (S_{MS}) and S_{D1} (S_{M1}) from the site-specific design spectrum
- Section 21.2.2 – Deterministic (MCE_R) Ground Motions
  - New criteria for calculating the deterministic lower limit (floor) on the MCE_R response spectrum (Figure 21.2-1)
- Section 21.3 – Design Response Spectrum
  - New criteria for determining lower-bound "safety net" limit on site-specific design response spectrum (80 percent of Section 11.4 ground motions)
- Example calculation of site-specific ground motions including the new limits of Sections 21.2.2 and 2.3

Illustration of the Criteria of Section 21.4 of ASCE 7-10

Site Class DE, M8 at R = 8.5 km (PEER NGA-West1 Relations)

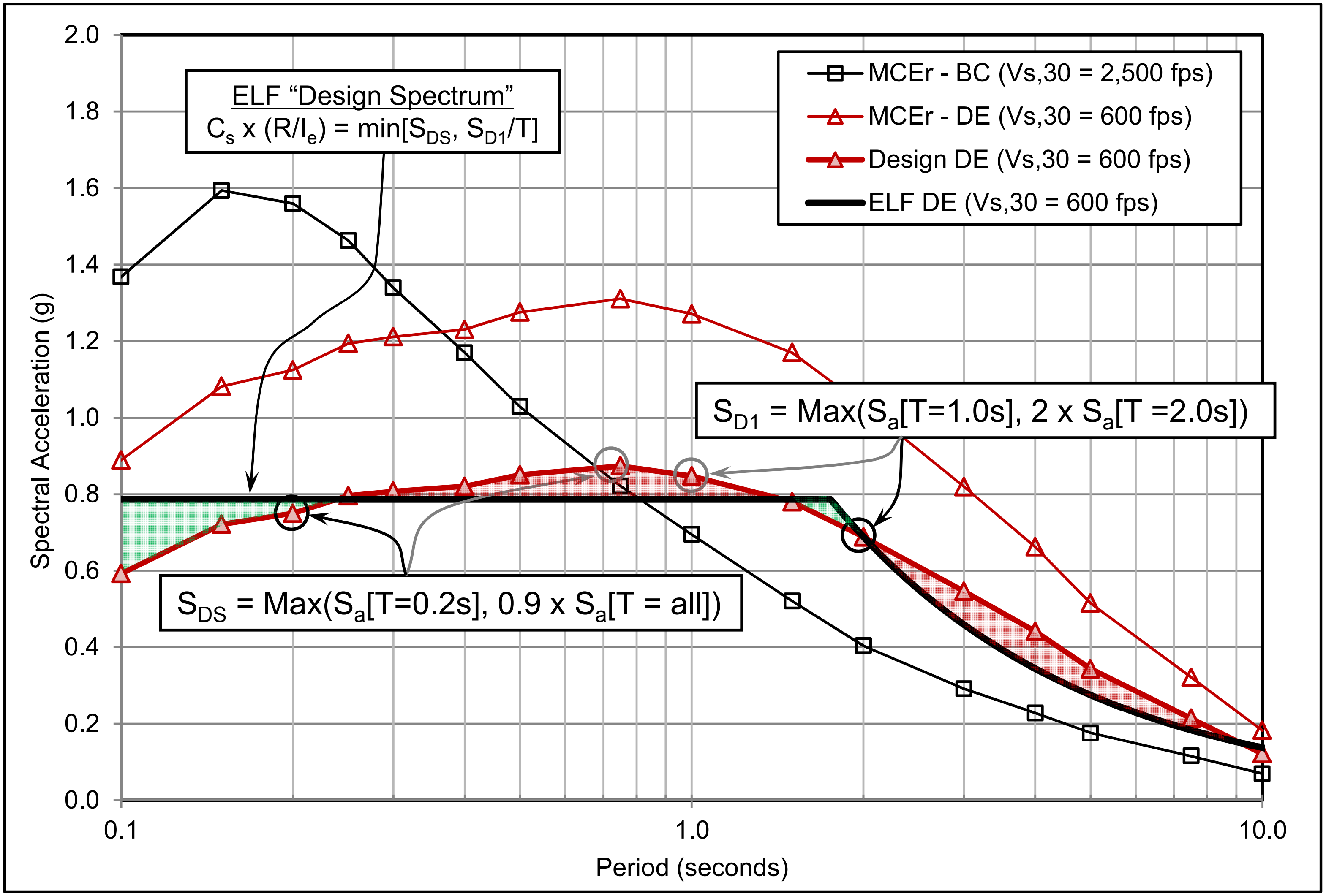
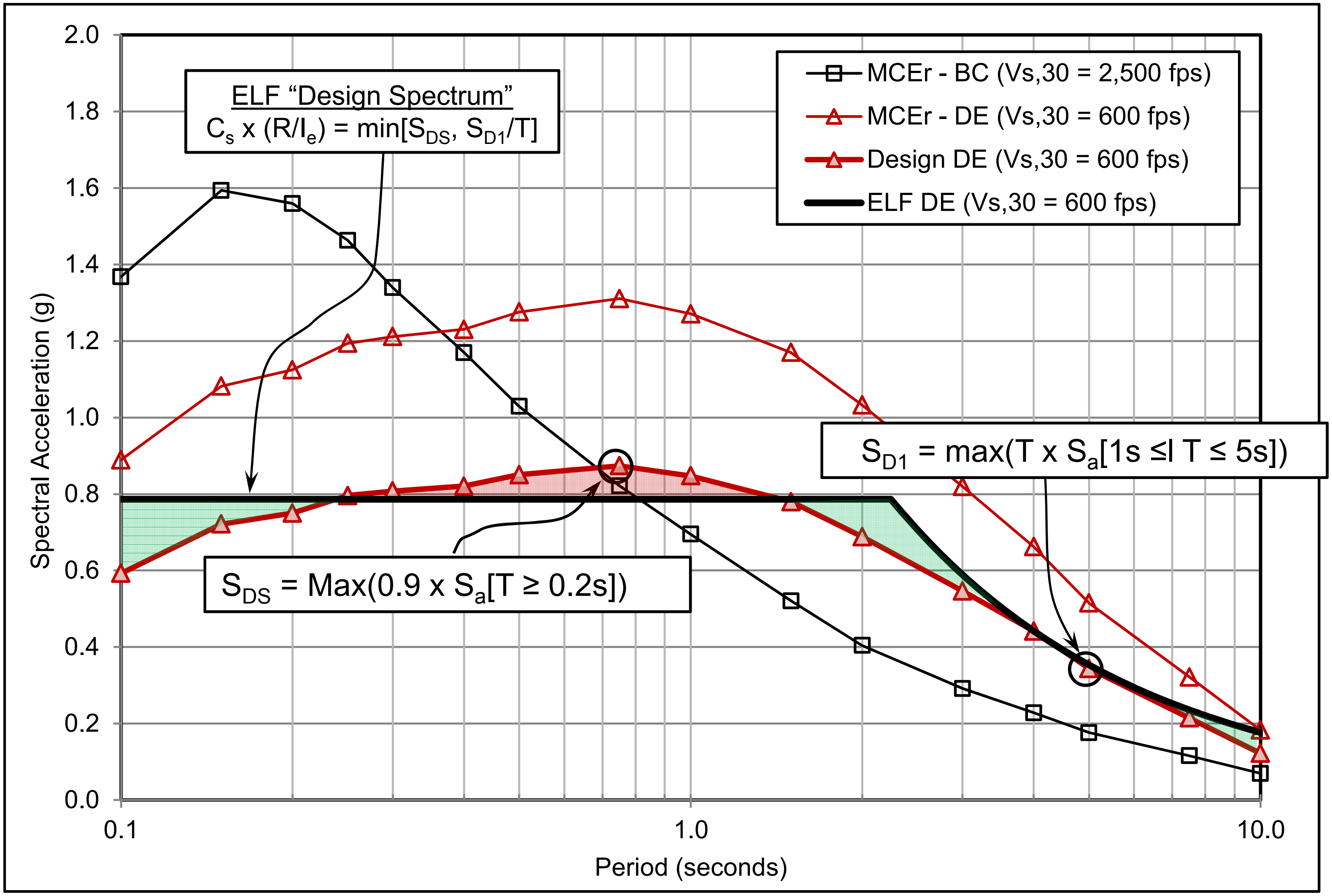


Illustration of the New Criteria of Section 21.4

Site Class DE, M8 at R = 8.5 km (PEER NGA-West1 Relations)



Lower-Bound Limit on Deterministic (MCE_R) Ground Motions
Section 21.2.2 of ASCE 7-16

Section 21.2.2 Deterministic (*MCE_R*) Ground Motions. The deterministic spectral response acceleration at each period shall be calculated as an 84th-percentile 5% damped spectral response acceleration in the direction of maximum horizontal response computed at that period. The largest such acceleration calculated for the characteristic earthquakes on all known active faults within the region shall be used.

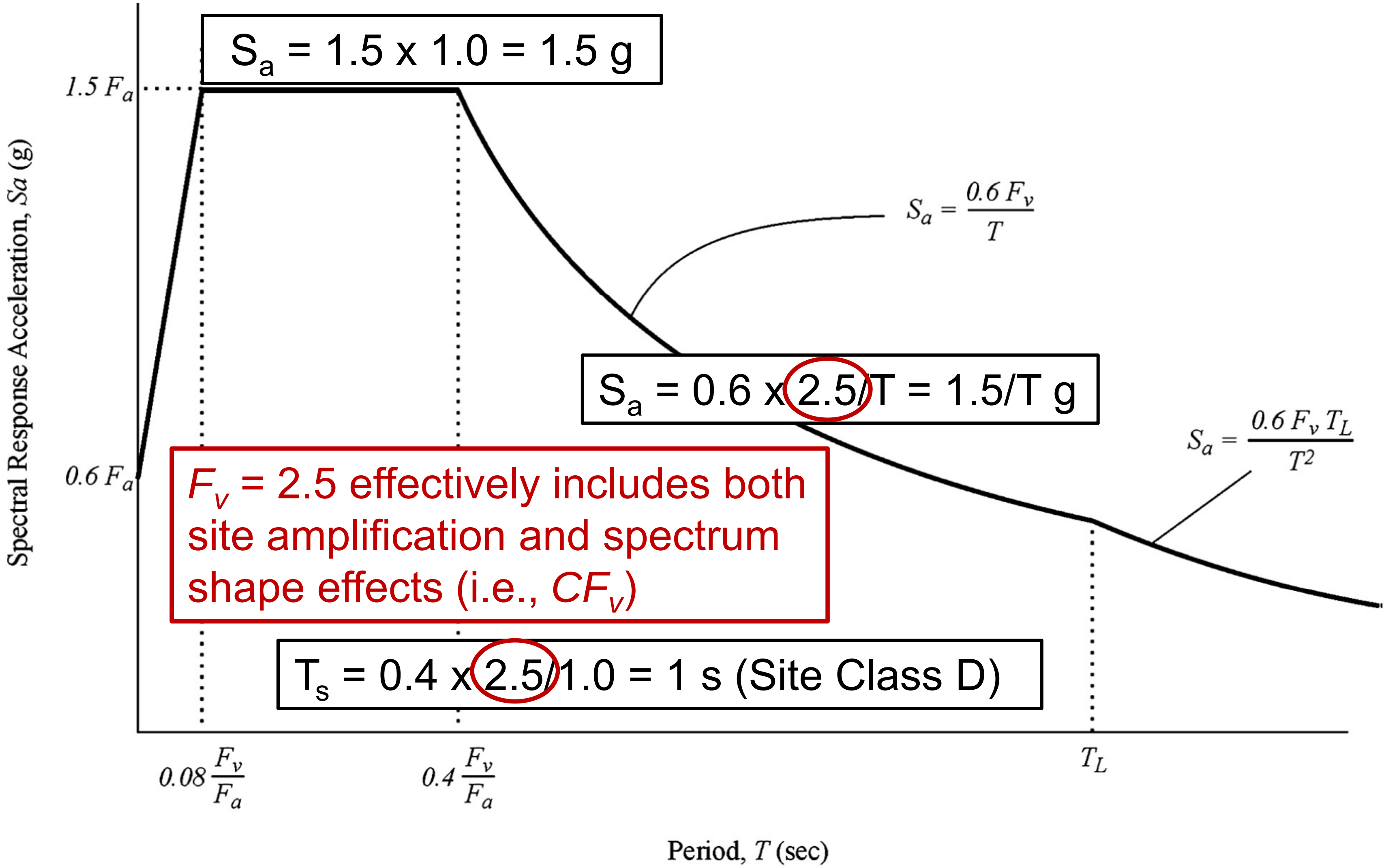
~~For the purposes of this standard, the~~ **ordinates of the deterministic ground motion response spectrum shall not be taken as lower than the corresponding ordinates of the response spectrum determined in accordance with Fig. 21.2-1**~~, where F_a and F_v are determined using Tables 11.4-1 and 11.4-2, respectively, with the value of S_S taken as 1.5 and the value of S_1 taken as 0.6~~. **<u>For the purposes of calculating the ordinates.</u>**

(i) <u>for Site Classes A, B or C: F_a and F_v shall be determined using Tables 11.4-1 and 11.4-2, with the value of S_S taken as 1.5 and the value of S_1 taken as 0.6;</u>

(ii) <u>for Site Class D: F_a shall be taken as 1.0, and F_v shall be taken as 2.5; and</u>

<u>(iii) for Site Classes E and F: F_a shall be taken as 1.0, and F_v shall be taken as 4.0.</u>

Figure 21.2-1 Deterministic Lower Limit on MCE_R Response Spectrum for Site Class D



80 Percent Limit on the Design Response Spectrum Section 21.3 of ASCE 7-16

The design spectral response acceleration at any period shall be determined from Eq. 21.3-1.

$$S_a = 2/3\ S_{aM} \qquad (21.3\text{-}1)$$

where S_{aM} is the MCE spectral response acceleration obtained from Section 21.1 or 21.2.

The design spectral response acceleration at any period shall not be taken less than 80 percent of S_a determined in accordance with Section 11.4.5, where F_a and F_v are determined as follows:

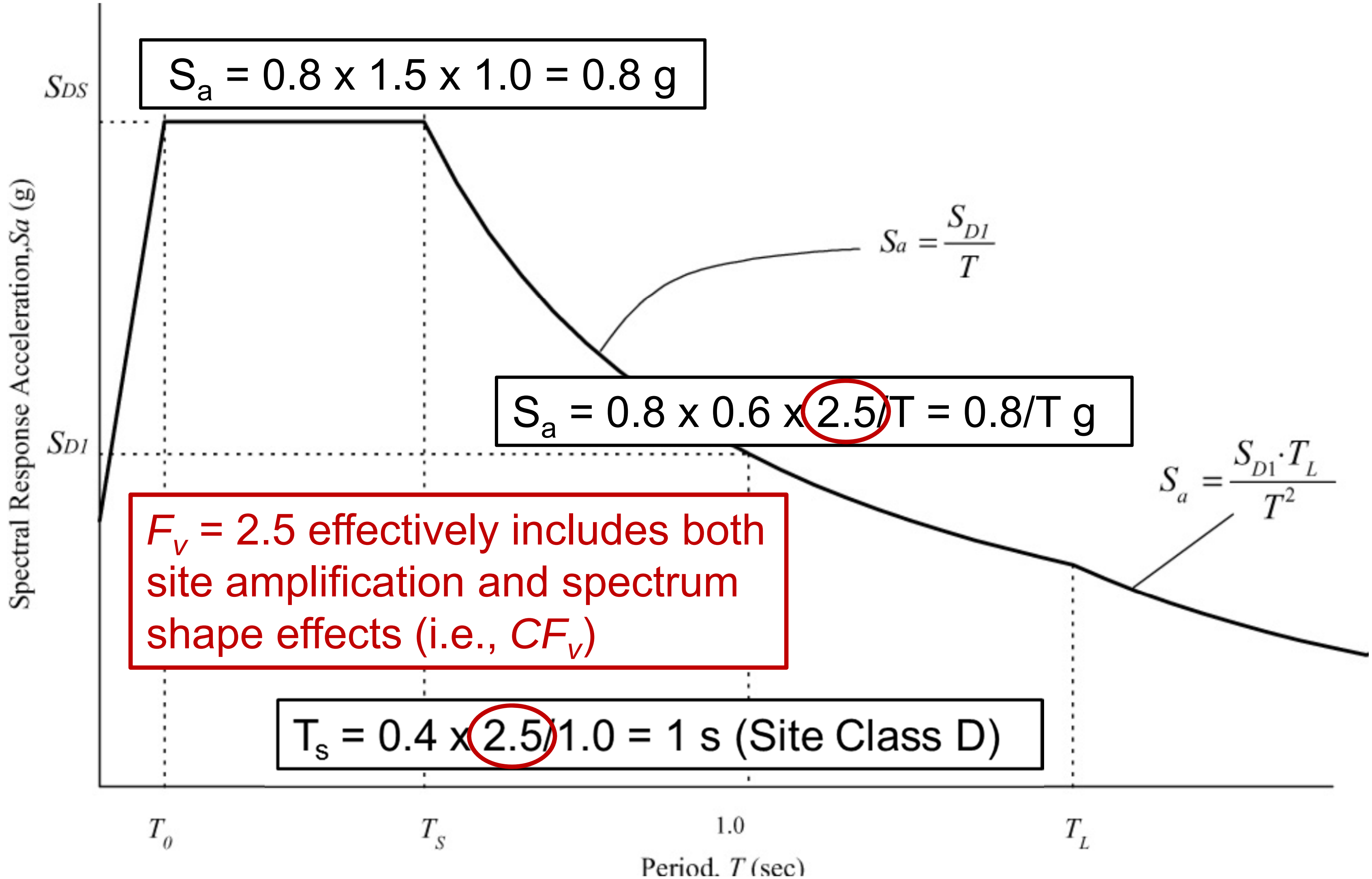
(i) for Site Class A, B, and C: F_a and F_v are determined using Tables 11.4-1 and 11.4-2, respectively;

(ii) for Site Class D: F_a is determined using Table 11.4-1, and F_v is taken as 2.4 for $S_1 < 0.2$ or 2.5 for $S_1 \geq 0.2$; and

(iii) for Site Class E: F_a is determined using Table 11.4-1 for $S_S < 1.0$ or taken as 1.0 for $S_S \geq 1.0$, and F_v is taken as 4.2 for $S_1 \leq 0.1$ or 4.0 for $S_1 > 0.1$.

For sites classified as Site Class F requiring site-specific analysis in accordance with Section 11.4.7, the design spectral response acceleration at any period shall not be less than 80 percent of S_a determined for Site Class E in accordance with Section 11.4.5.

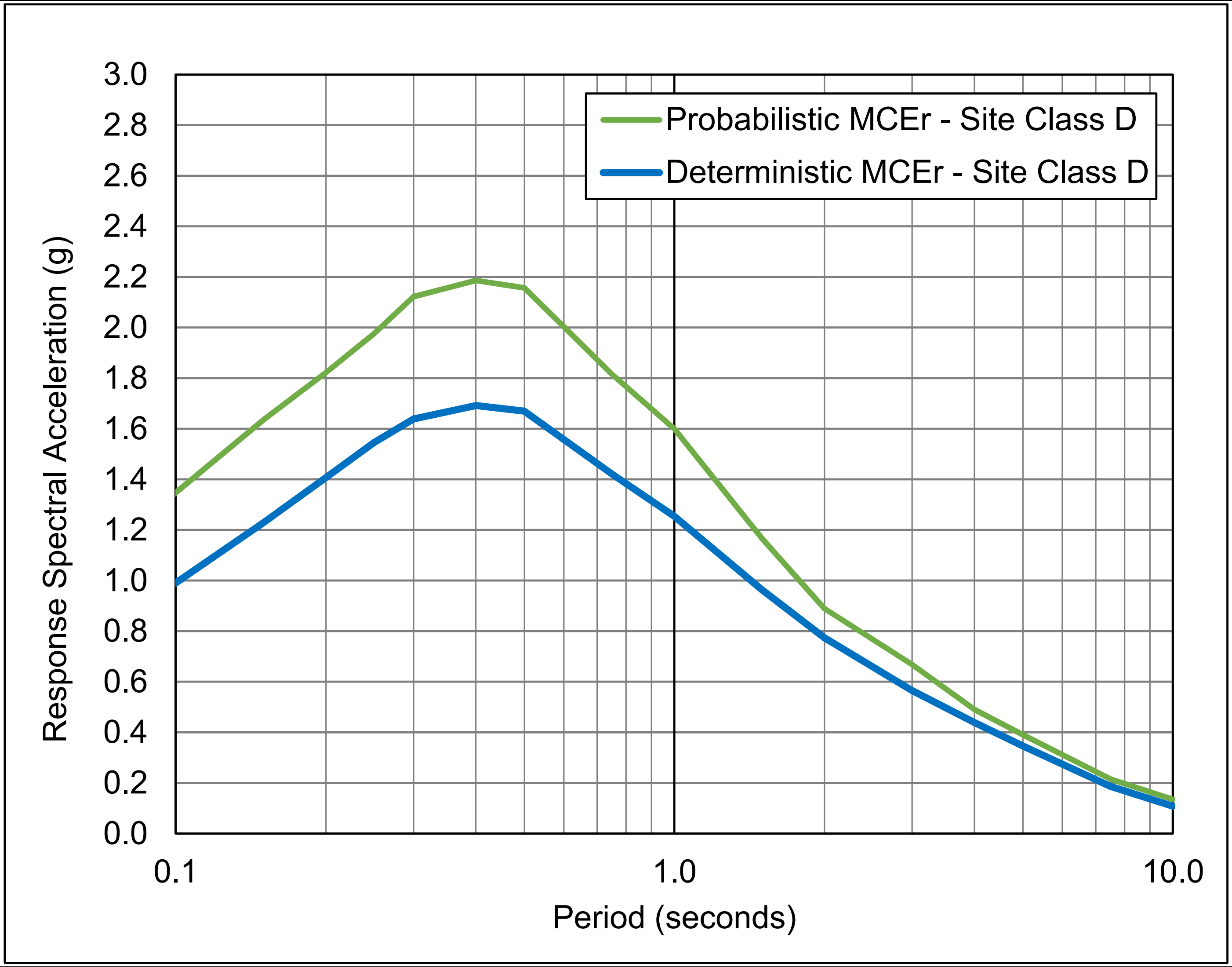
80 Percent of the Design Response Spectrum (Figure 11.4-1) for Site Class D and S_s = 1.5 and S_1 = 0.6



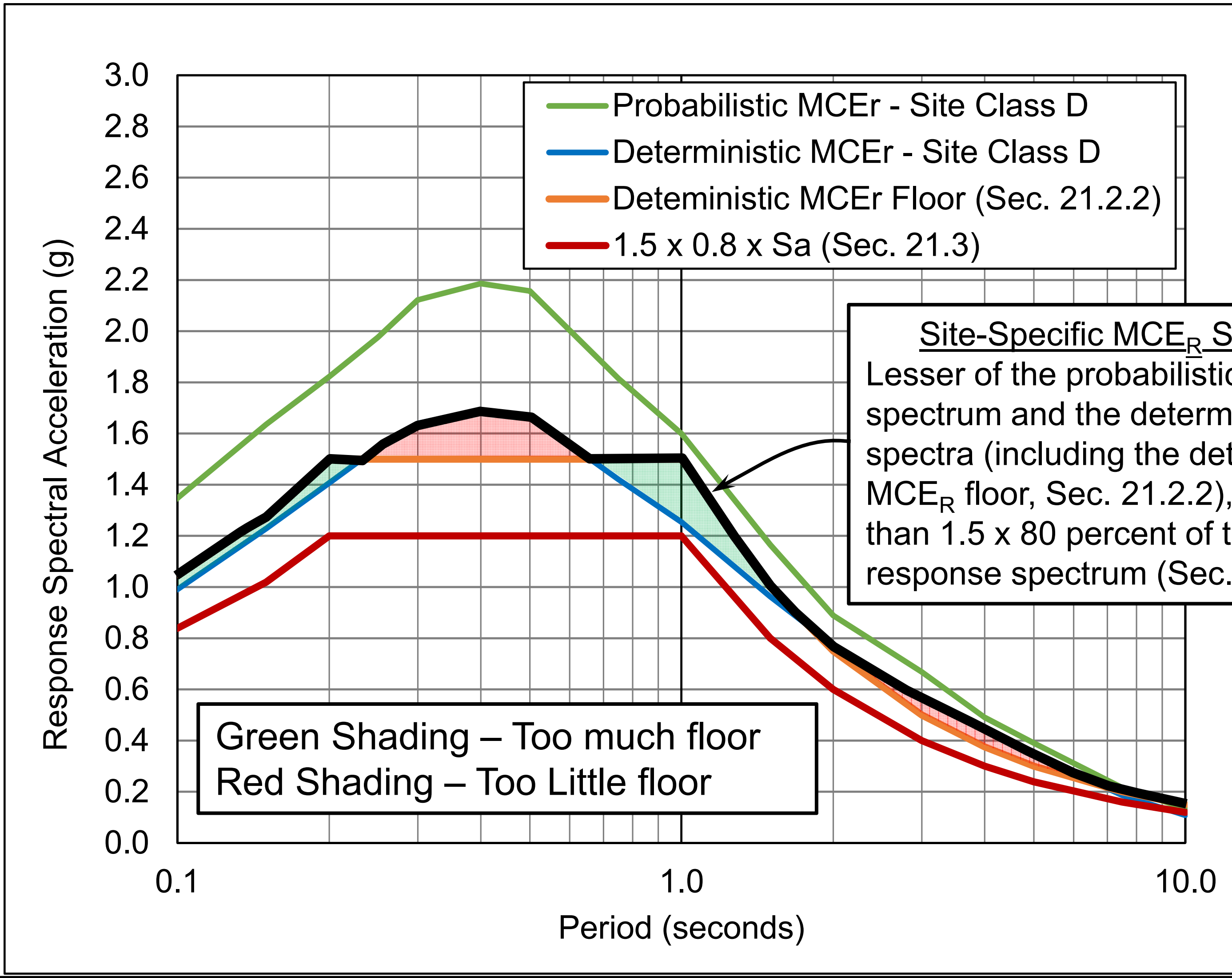
Example Calculation of Site-Specific Ground Motions

- High Seismic Site
  - San Francisco, SOMA district
  - Governing Source - San Andreas Fault at 13.5 km
- Three Hypothetical Site Conditions
  - Site Class D – $v_{s,30}$ = 870 fps
  - Site Class D – $v_{s,30}$ = 1,200 fps (CD boundary)
  - Site Class D – $v_{s,30}$ = 600 fps (DE boundary)

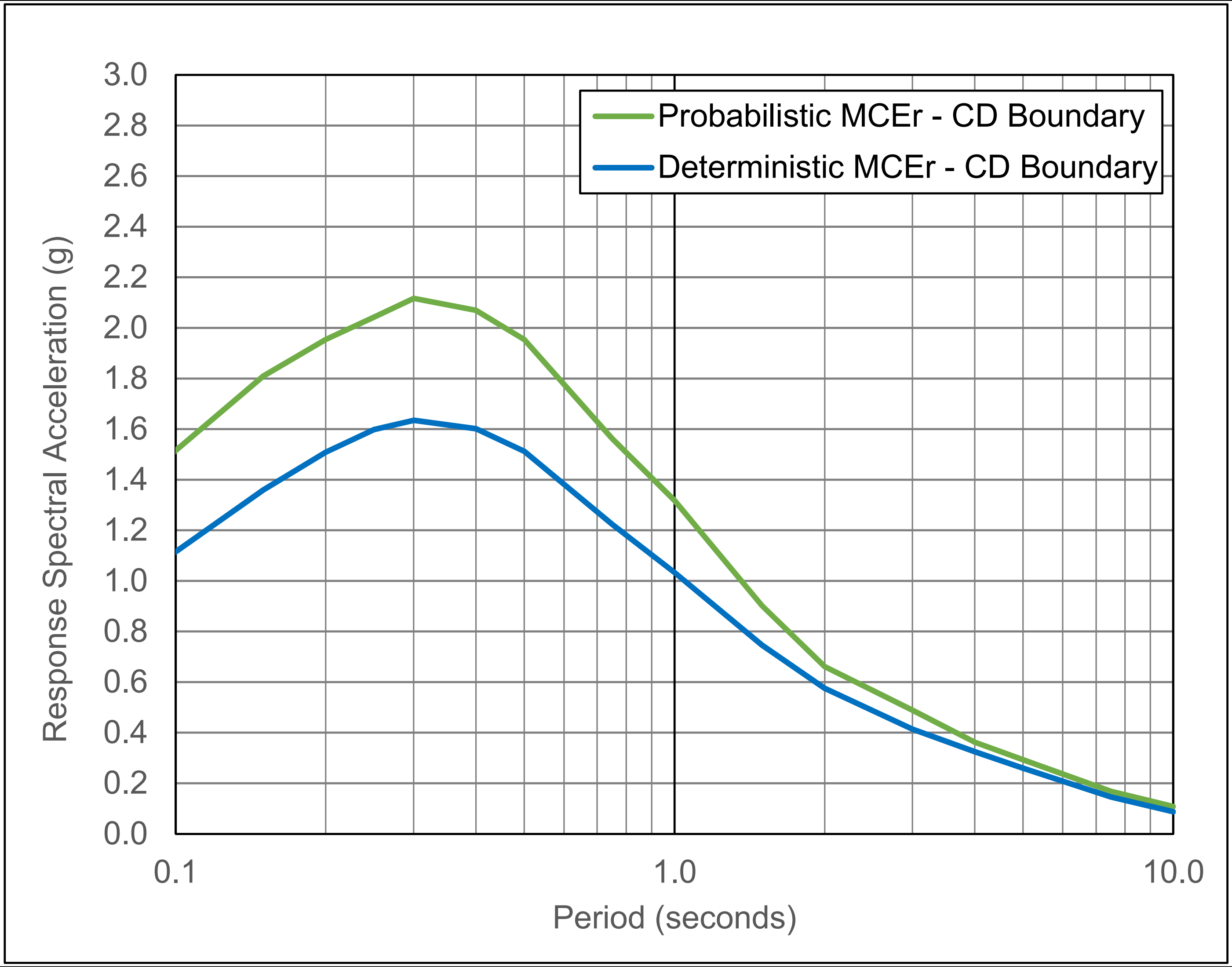
Example Probabilistic MCE_R and Deterministic MCE_R Response Spectra for the Subject Site with Shear Wave Velocity, $v_{s,30}$ = 870 fps



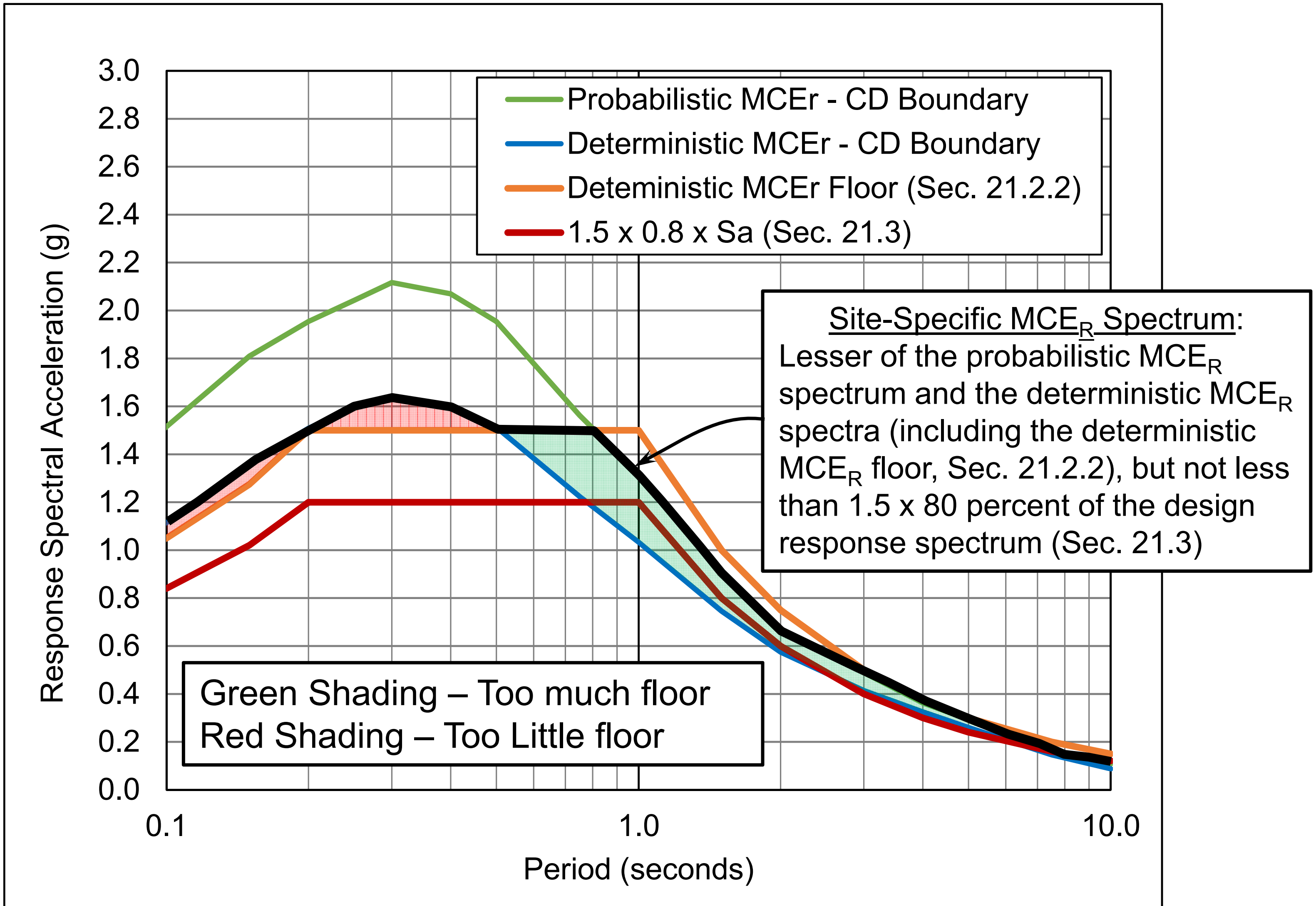
Example Development of Site-Specific MCE_R Ground Motions for the Subject Site with Shear Wave Velocity, $v_{s,30}$ = 870 fps



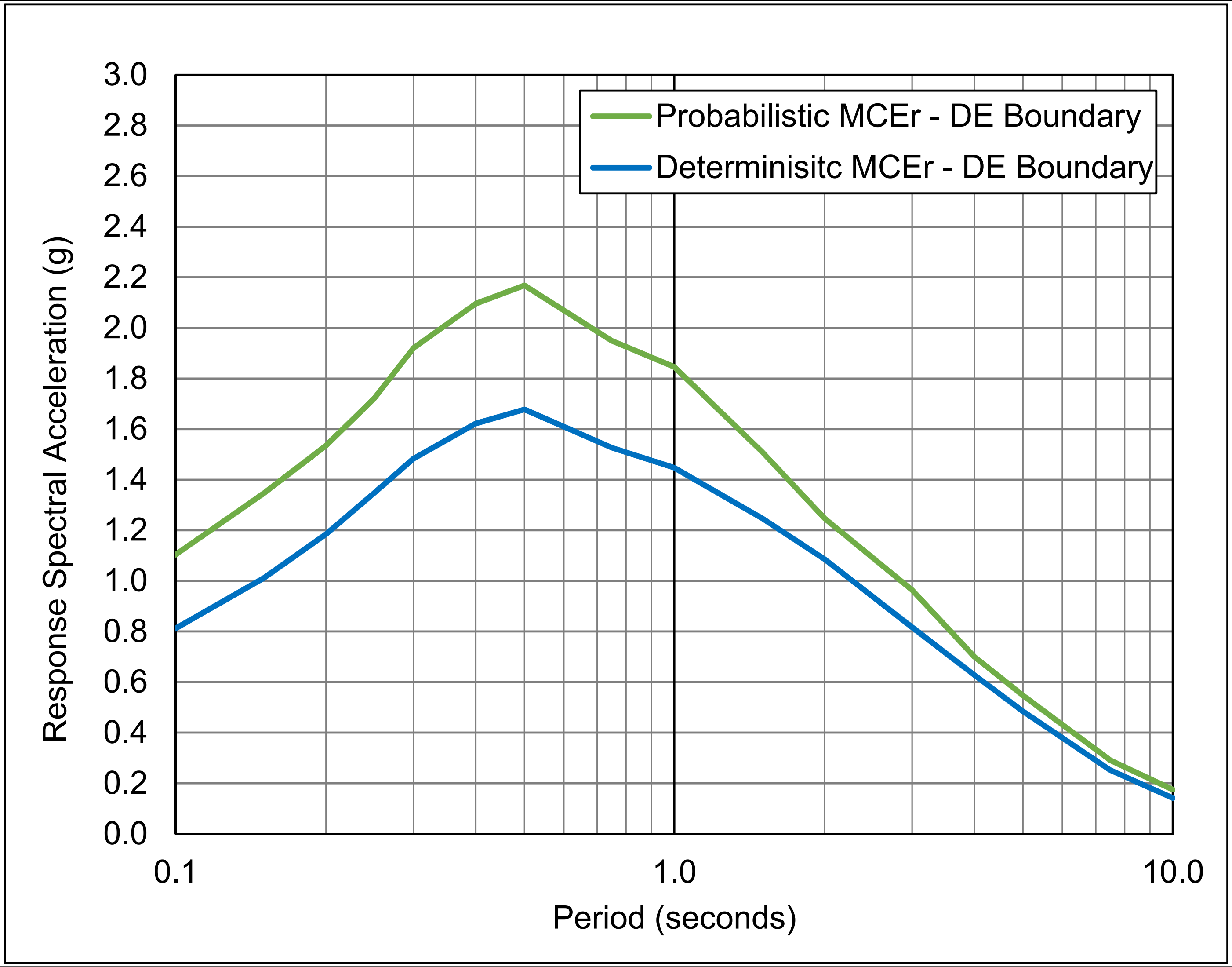
Example Probabilistic MCE_R and Deterministic MCE_R Response Spectra for the Subject Site with Shear Wave Velocity, $v_{s,30}$ = 1,200 fps



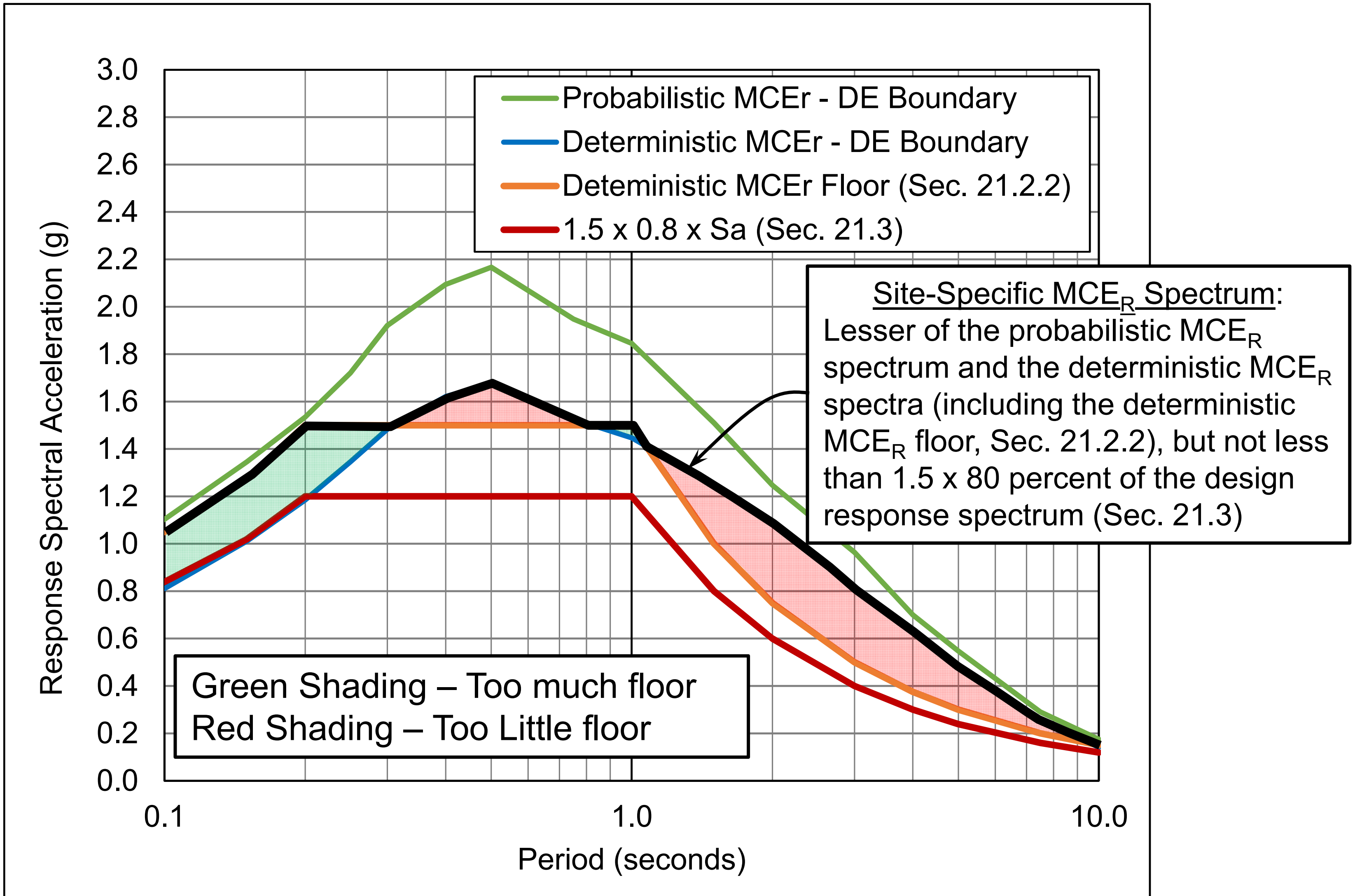
Example Development of Site-Specific MCE_R Ground Motions for the Subject Site with Shear Wave Velocity, $v_{s,30}$ = 1,200 fps



Example Probabilistic MCE_R and Deterministic MCE_R Response Spectra for the Subject Site with Shear Wave Velocity, $v_{s,30}$ = 600 fps



Example Development of Site-Specific MCE_R Ground Motions for the Subject Site with Shear Wave Velocity, $v_{s,30}$ = 600 fps



Questions?