

Nonlinear Response-History Analysis for the Design of New Buildings: Update to ASCE7 Chapter 16

Project by: Large Issue Team

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BSSC Colloquium

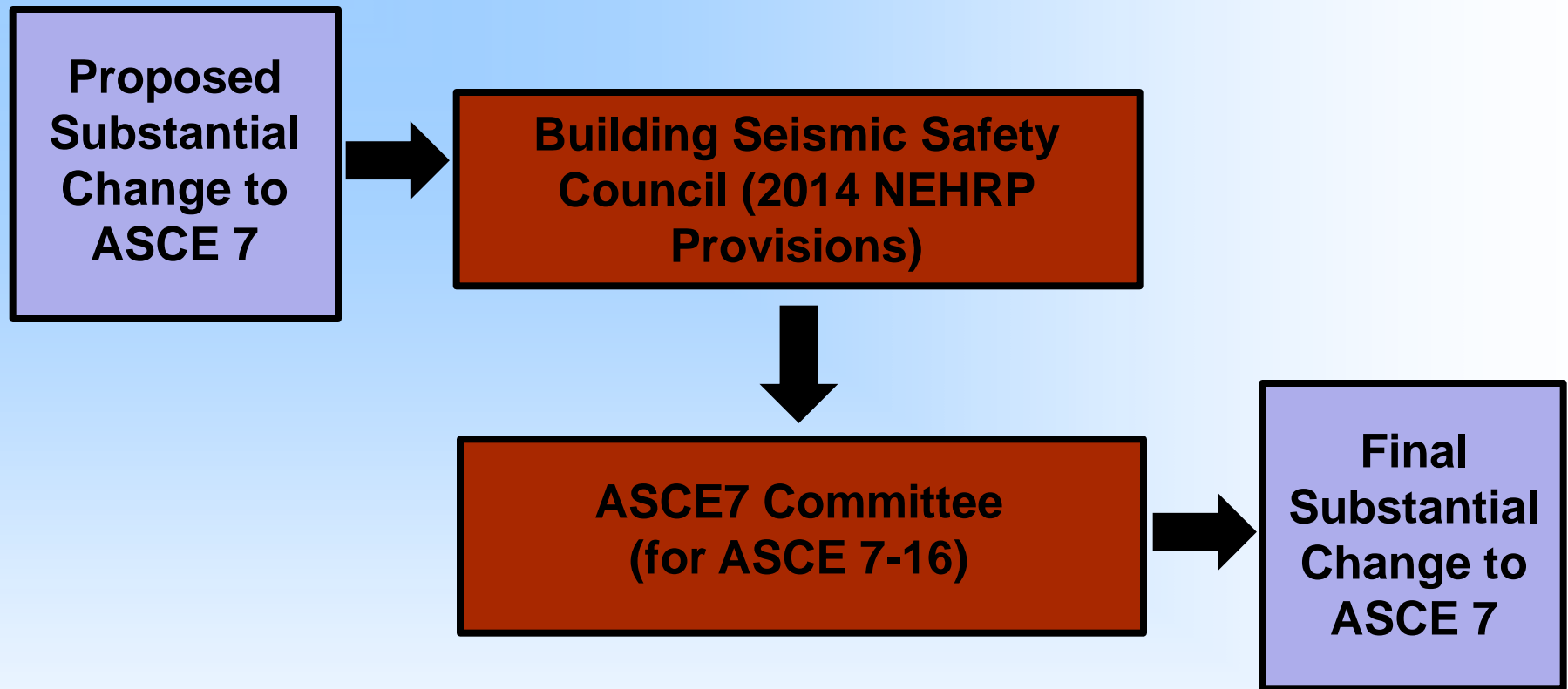
Burlingame, CA



**Building Seismic Safety Council
Issue Team 4 on Response History Analysis**



Reminder of the ASCE7 Process



Issue Team Charge and Deliverables

- **Issue Team Objective:** Develop recommendations to the BSSC Committee regarding proposed improvements to Chapter 16 of ASCE7.
- **Issue Team Deliverables:**
 - Chapter 16 Code language (completely revised)
 - Chapter 16 Commentary language (completely revised)
 - Earthquake Spectra sister papers – (1&2) Development , (3) Example Applications, and (4) Evaluation

The Issue Team Membership

Industry

- CB Crouse, URS Corp.
- Chung-Soo Doo, SOM
- Andy Fry, MKA
- Mahmoud Hachem, Degenkolb
- Ron Hamburger, SGH
- John Hooper, MKA
- Afshar Jalalian, R&C
- Charles Kircher, Kircher & Assoc.
- Silvia Mazzoni, Degenkolb
- Bob Pekelnicky, Degenkolb
- Mark Sinclair, Degenkolb
- Rafael Sabelli, Walter P Moore
- Reid Zimmerman, R&C

Academic

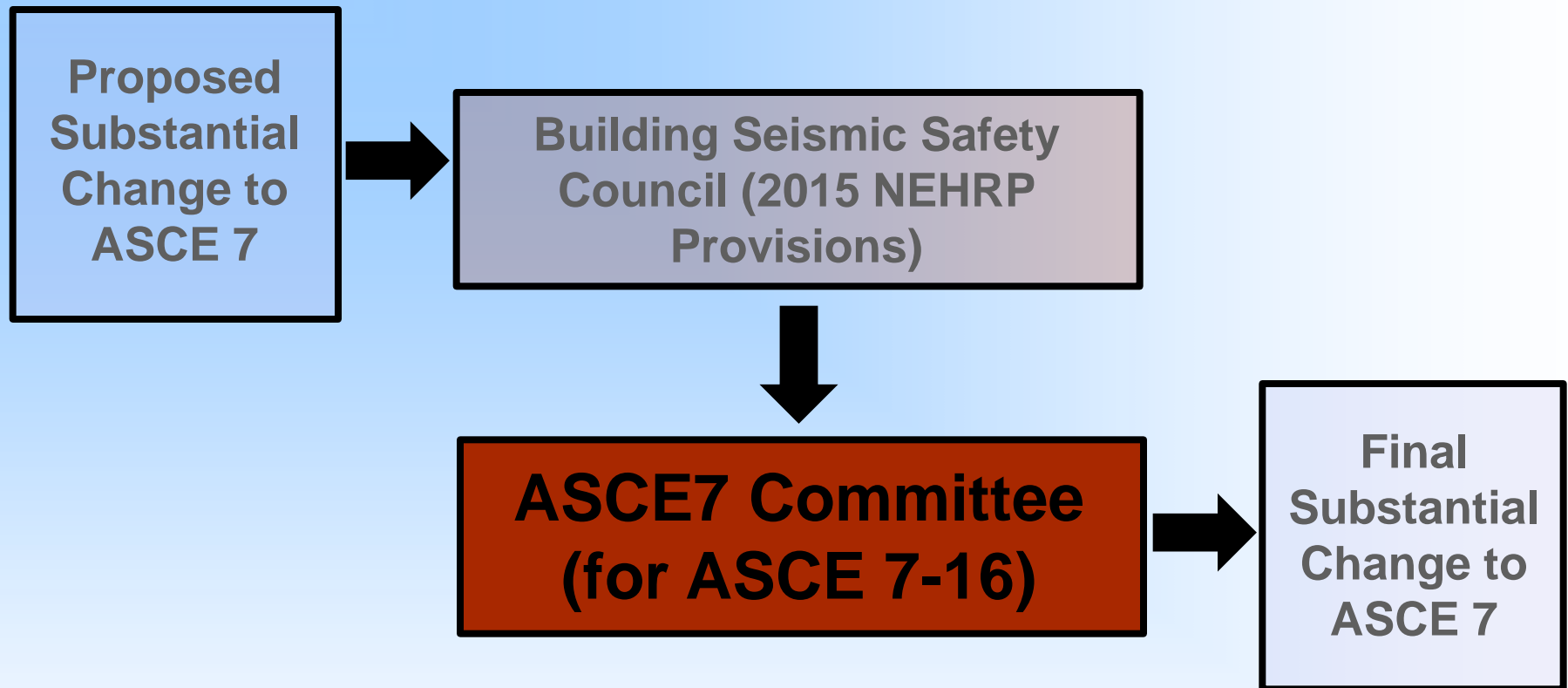
- Curt Haselton, CSUC, Team Chair
- Jack Baker, Stanford University
- Finley Charney, Virginian Tech
- Greg Deierlein, Stanford Univ.
- Ken Elwood, Univ. of British Col.
- Steve Mahin, UC Berkeley
- Graham Powell, UC Berkeley Em.
- Jon Stewart, UCLA
- Andrew Whittaker, SUNY Buffalo

Government

- Robert Hanson, FEMA
- Jay Harris, NIST
- Nico Luco, USGS
- Mike Tong, FEMA



Current Status of Chapter 16



Literature Review

- We now have a lot to draw on (which was not the case only a few years ago)...
- *An Alternative Procedure for Seismic Analysis and Design of Tall Buildings Located in the Los Angeles Region*, 2008 Edition with Supplement #1 (LATBSDC, 2008).
- *Guidelines for Performance-Based Seismic Design of Tall Buildings*, PEER Center, Tall Building Initiative (PEER, 2010).
- *Requirements and Guidelines for the Seismic Design of New Tall Buildings using Non-Prescriptive Seismic-Design Procedures*, 2010 San Francisco Building Code Administrative Bulletin 083 (AB-083, 2008).

Building Safety Goals

- Basic goals are from ASCE 7-10 Table C.1.3.1b:

Risk Category	Tolerable Probability of Collapse	Ground Motion Level
I or II	10%	MCE_R
III	6%	MCE_R
IV	3%	MCE_R

Chapter 16 Proposal: Overall Structure

- **Section 16.1:** General Requirements
- **Section 16.2:** Ground Motions
- **Section 16.3:** Modeling and Analysis
- **Section 16.4:** Analysis Results and Accept. Criteria
- **Section 16.5:** Design Review

Proposal: Section 16.1 (General)

- The basic structure of the design approach is:
 - Linear DBE-level analysis (to enforce minimum base shear, enforce basic load combinations, etc.).
 - Nonlinear MCE-level response-history analysis.

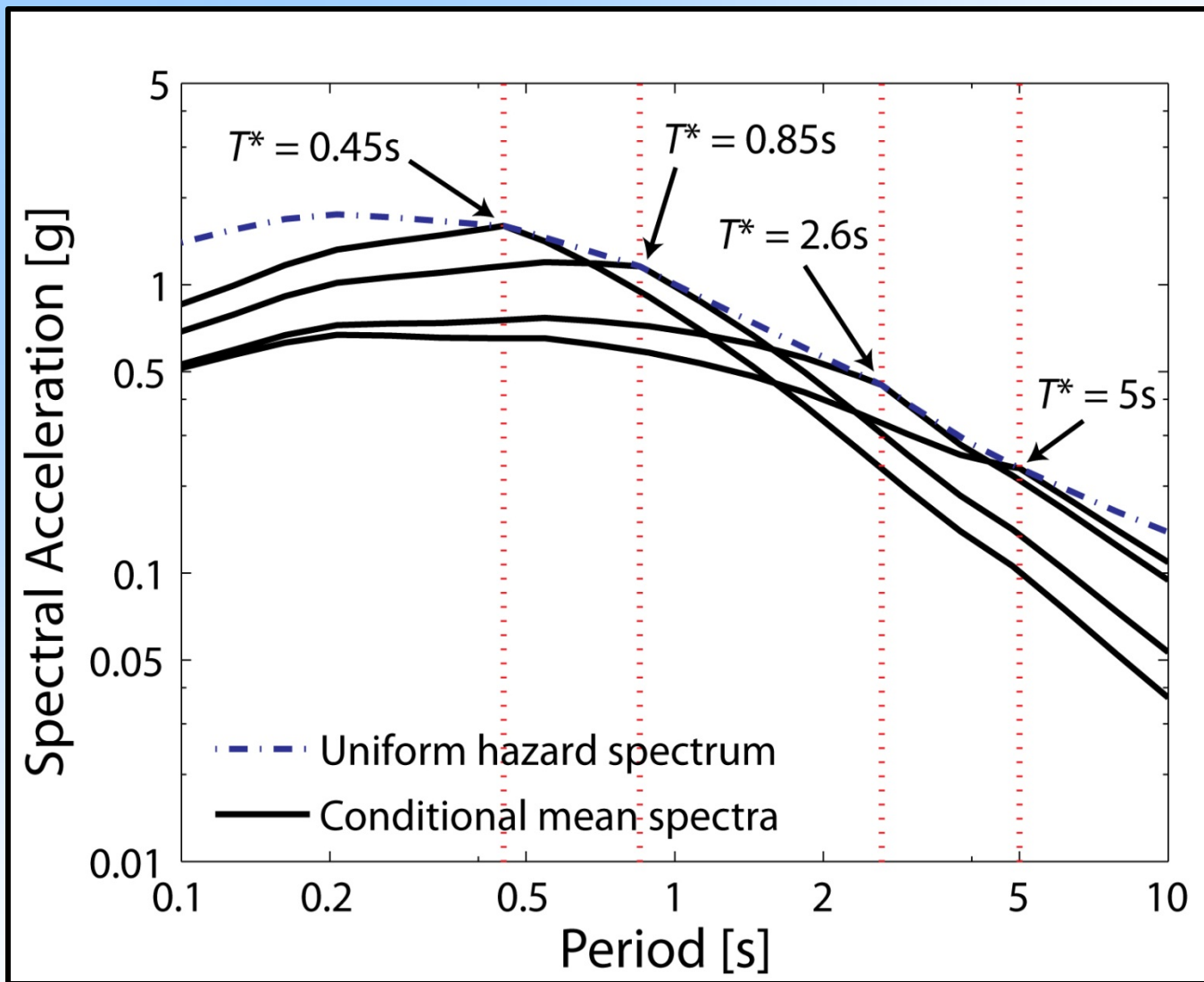
Proposal: Section 16.2 (Ground Motion)

- Ground motion level: MCE_R
- Number of ground motions: 11 motions
- Selection of motions:
 - Same general language.
 - Added: “It is also desirable for ground motion spectral shapes to be comparable to the target response spectrum of Section 16.2.2.”
- Scaling of motions: Scale the maximum direction S_a to the target spectrum (which is max. direction).
- Period range: $0.2T_1$ to $2.0T_1$, but also 90% mass.
- Spectral matching: Each comp. must meet target.

Proposal: Section 16.2 (Ground Motion)

- Target spectrum:
 - Method 1: Typical MCE_R spectrum.
 - Method 2: Multiple “scenario” spectra (typically two scenarios).

Proposal: Section 16.2 (Ground Motion)



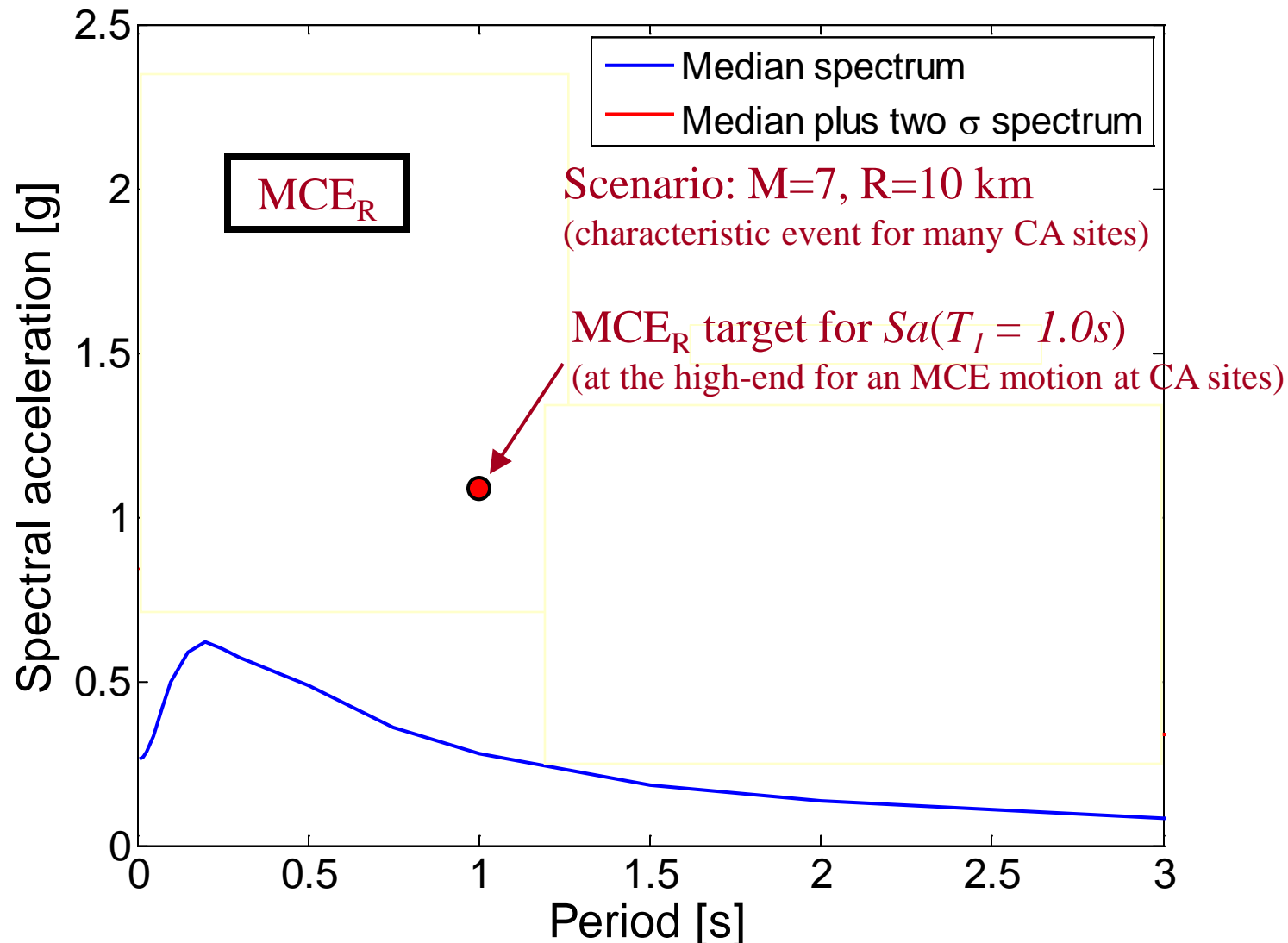
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Proposal: Section 16.2 (Ground Motion)



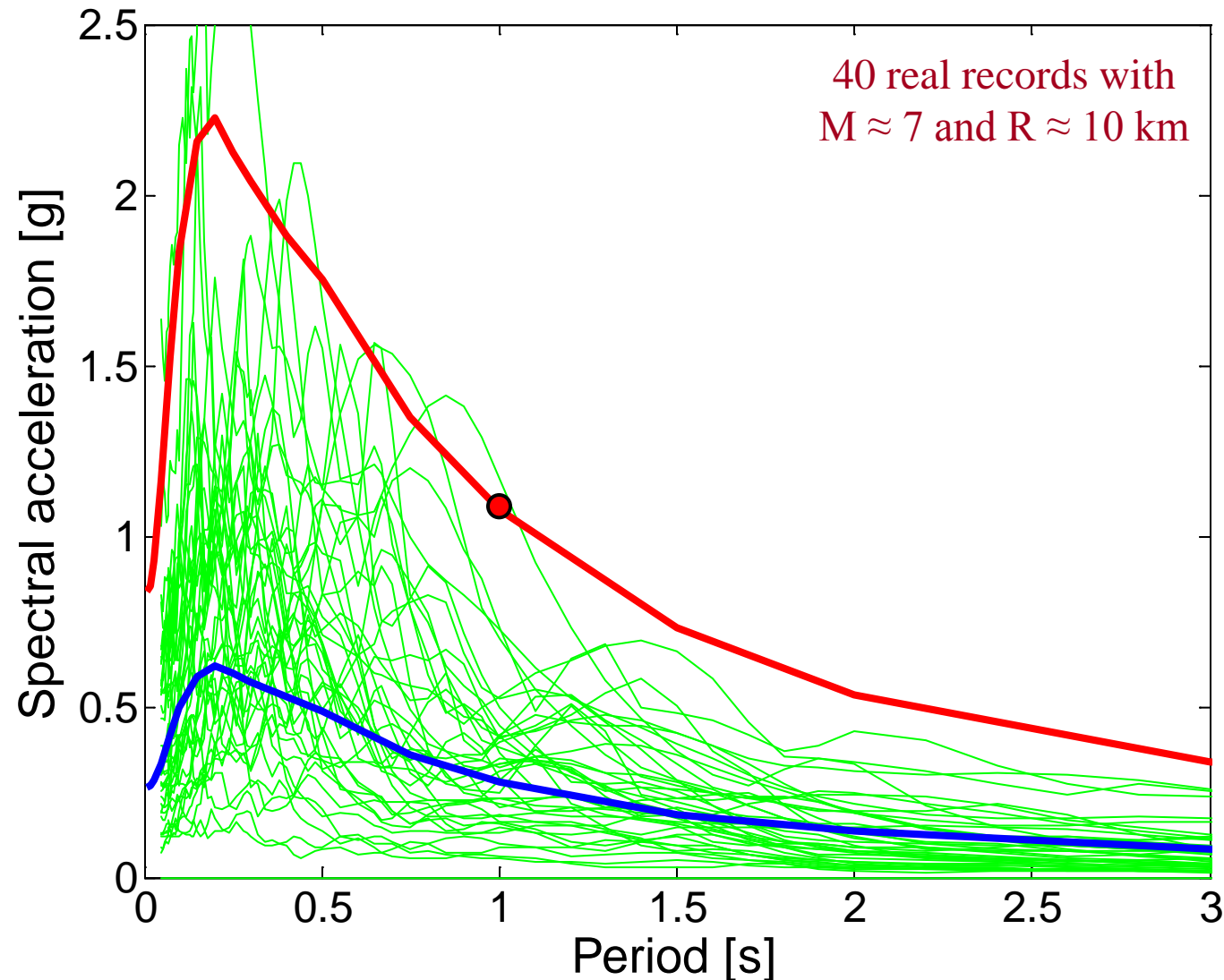
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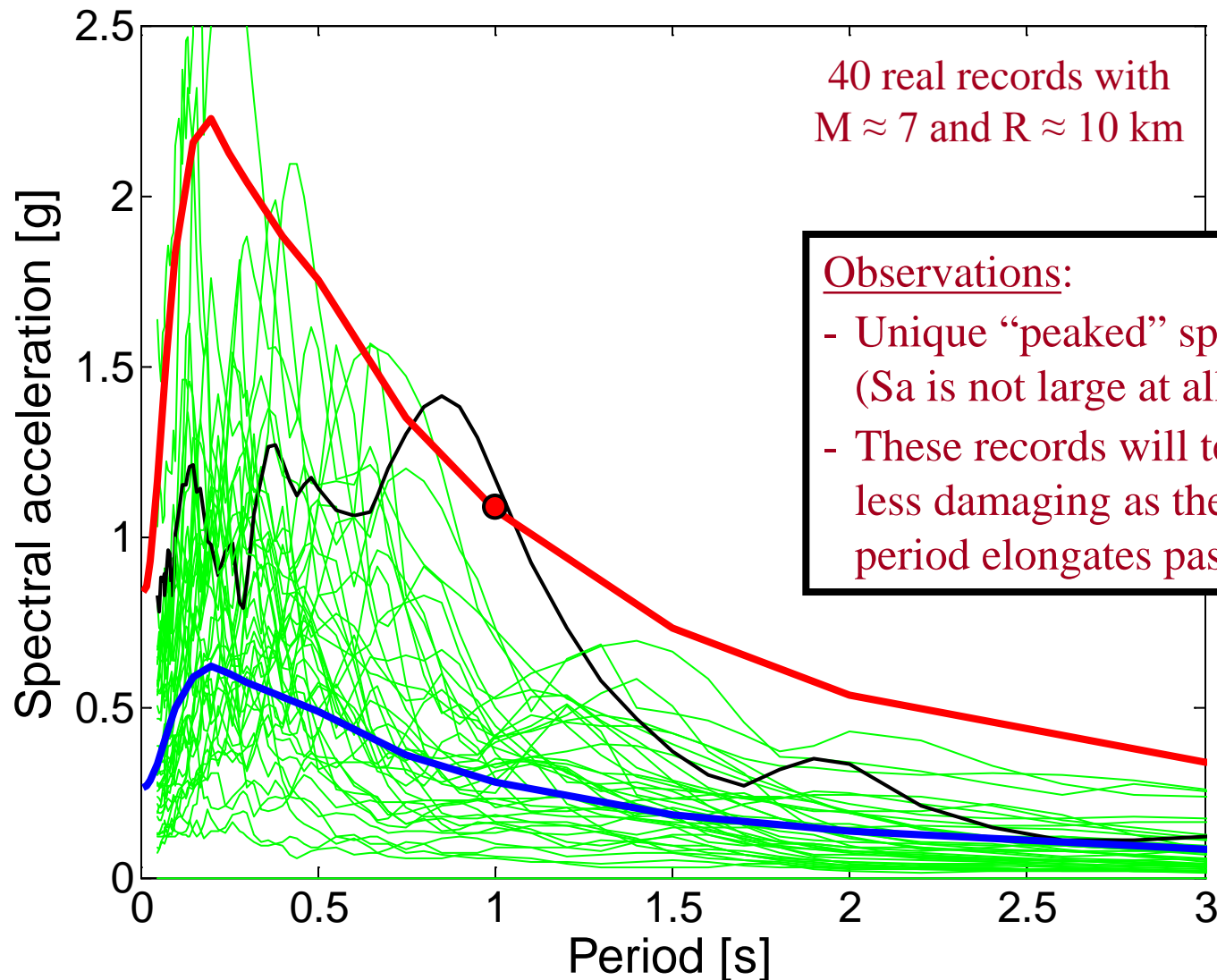


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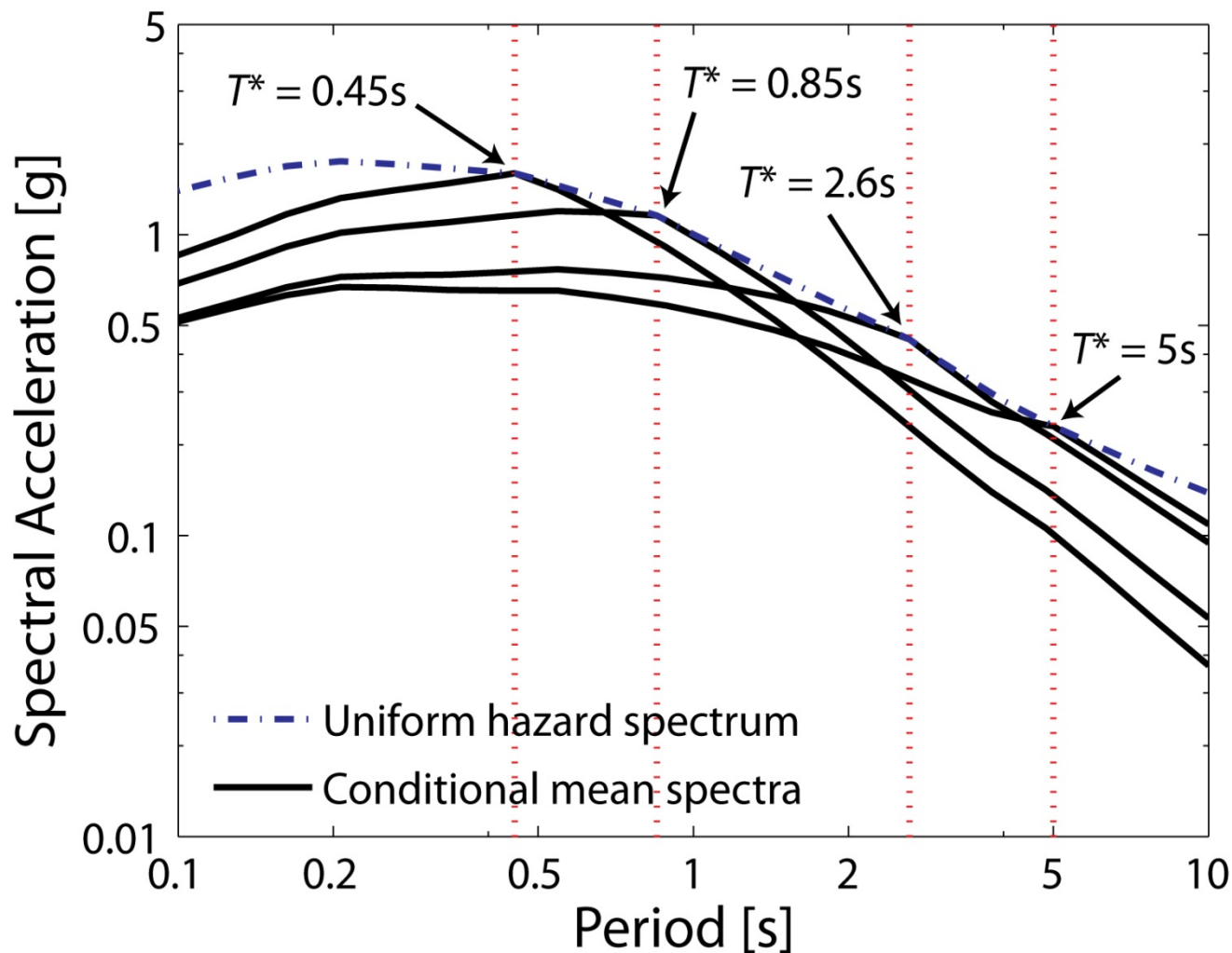
Proposal: Section 16.2 (Ground Motion)



Proposal: Section 16.2 (Ground Motion)



Proposal: Section 16.2 (Ground Motion)



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Proposal: Sec. 16.3 (Modeling & Analysis)

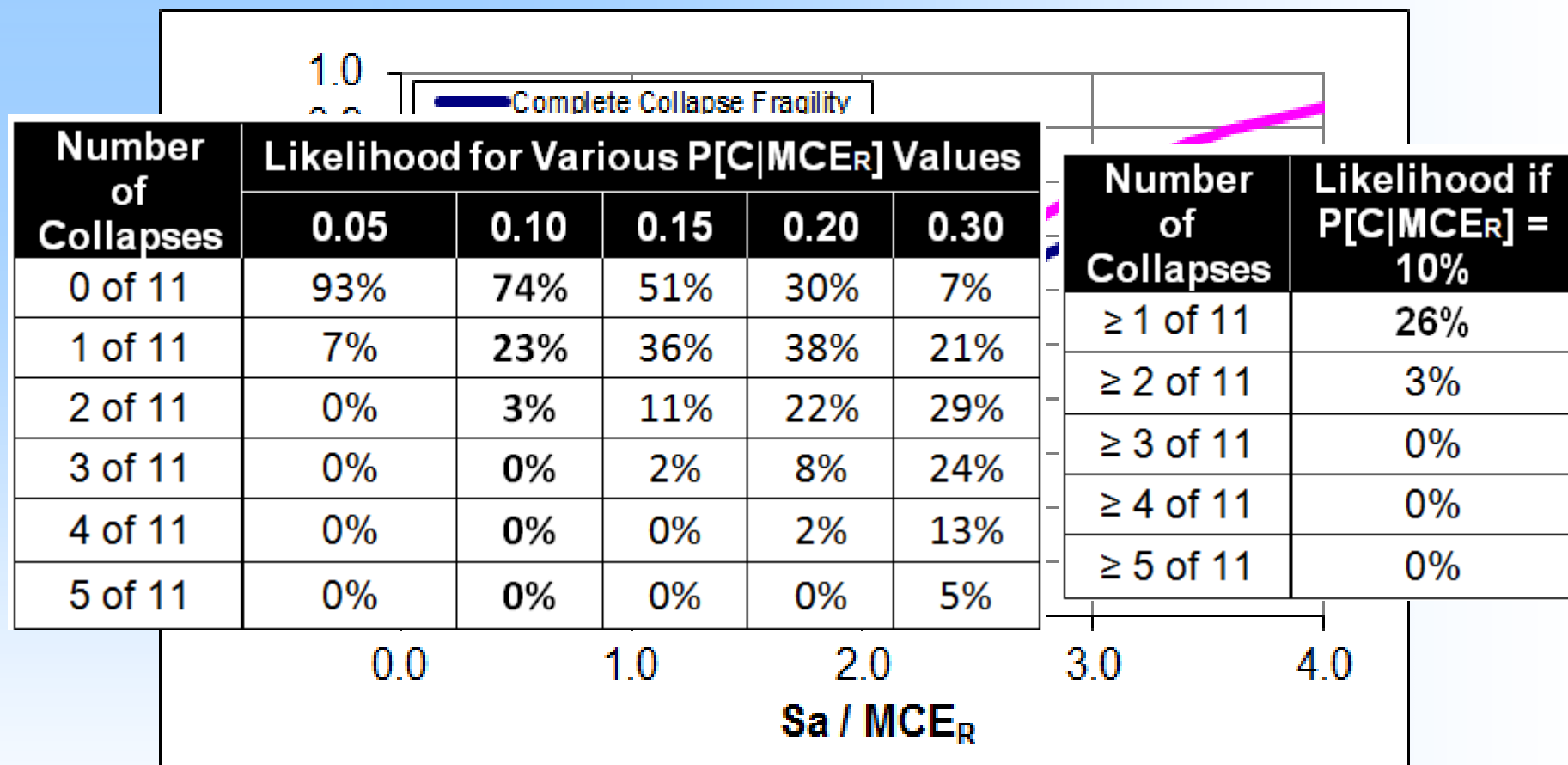
- This section says what to do but not how to do it.
- This was intentionally not written to be a nonlinear analysis guideline.

Proposal: Section 16.4 (Accept. Criteria)

- Treatment of “collapses” and other “unacceptable responses”:
 - **Current Treatment in ASCE7-10:** Nothing but silence....
 - **Philosophical Camp #1:**
 - ✓ Outliers are statistically meaningless.
 - ✓ Acceptance criteria should be based only on mean/median.
 - ✓ If we have 5/11 (or 3/7) “collapses”, this means nothing.
 - **Philosophical Camp #2:**
 - ✓ Outliers are statistically meaningless, but are still a concern.
 - ✓ Acceptance criteria should also consider “collapses”.
 - ✓ If we have 5/11 (or 3/7) “collapses”, this is a great concern.

Proposal: Section 16.4 (Accept. Criteria)

- Results of a statistical collapse study:



Proposal: Section 16.4 (Accept. Criteria)

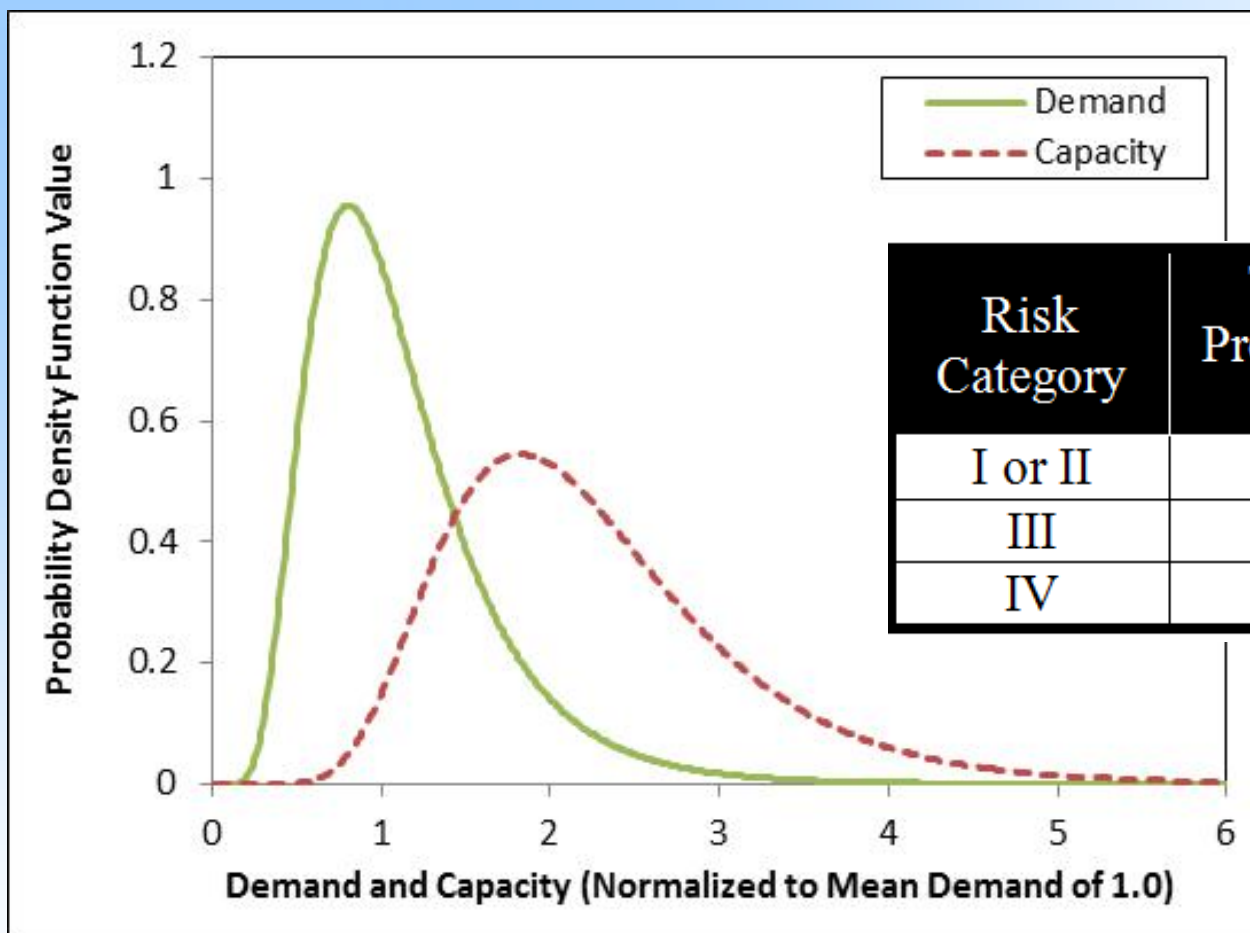
- **Conclusions of collapse study:**
 - Even with 0/11 collapses, this in no way proves that the $P[C|MCE_R] \leq 10\%$. There is way too much uncertainty. We must rely on the other mean-based acceptance criteria.
 - Even if $P[C|MCE_R] = 10\%$, there is still a 26% chance of getting 1+ collapses (i.e. “false positive”). Therefore, an acceptance criterion of “no collapses allowed” would not be appropriate.
 - If $P[C|MCE_R] = 10\%$, it is highly unlikely (only a 3% chance) that we will see 2+ collapses. Therefore, an acceptance criterion that prohibits two collapses would be reasonable.
- **Proposed Criterion:** Allow up to 1/11 “collapses” but not 2/11.

Proposal: Section 16.4 (Accept. Criteria)

- Component-level acceptance criteria are separated by:
 - Force-controlled (brittle) components
 - Deformation-controlled (ductile) components

Proposal: Section 16.4 (Accept. Criteria)

- Force-controlled (like Wallace, but no overstrength)



Risk Category	Tolerable Probability of Collapse	Ground Motion Level
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Proposal: Section 16.4 (Accept. Criteria)

■ Force-controlled (brittle) components:

Table 4. Assumed Variability and Uncertainty Values for the Component Demand and Capacity.

(a)

Demand Dispersion (β_D)		Variability in the Force Demand
General	Well-Defined Mechanism	
0.50	0.25	Record-to-record variability (for MCE_R ground motions)
0.50	0.25	$\beta_{D-TOTAL}$

(b)

Capacity Dispersion (β_C)		Variabilities and Uncertainties in the Final As-Built Capacity of the Component
General	Well-Defined Mechanism	
0.20	0.30	Uncertainty from estimating force demands using structural model (modeling <u>uncert.</u>)
0.15	0.08	Variability from estimating force demands from mean of only 11 ground motions
0.30	0.30	Typical variability in strength equation for $F_{n,e}$ (from available data)
0.10	0.10	Typical uncertainty in strength equation for $F_{n,e}$ (extrapolation beyond available data)
0.20	0.20	Uncertainty in as-built strength due to construction quality and possible errors
0.45	0.49	$\beta_{C-TOTAL}$



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Proposal: Section 16.4 (Accept. Criteria)

- Force-controlled (brittle) components:
 - Case 1 (critical): *“If the failure of the component would likely to lead to a progressive global collapse of the building,”*
 - Case 2: *“If the failure of the component would lead to only a local collapse,”*
 - Case 3 (non-critical): *“If the failure of the component would not lead to any structural instability,”*
 - Requirements (with exception for capacity-controlled):

$$2.0 I_e F_{meanDemand} \leq F_{meanStrength} \quad [\phi = 1.0]$$

$$1.5 I_e F_{meanDemand} \leq F_{meanStrength}$$

$$1.0 I_e F_{meanDemand} \leq F_{meanStrength}$$



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Proposal: Section 16.4 (Accept. Criteria)

- Deformation-controlled (ductile) components:
 - Similar “cases” as force-controlled components.
 - Acceptance criteria are based on mean component deformation capacity.
 - “Pre-approved” uses of ASCE41 are also provided.

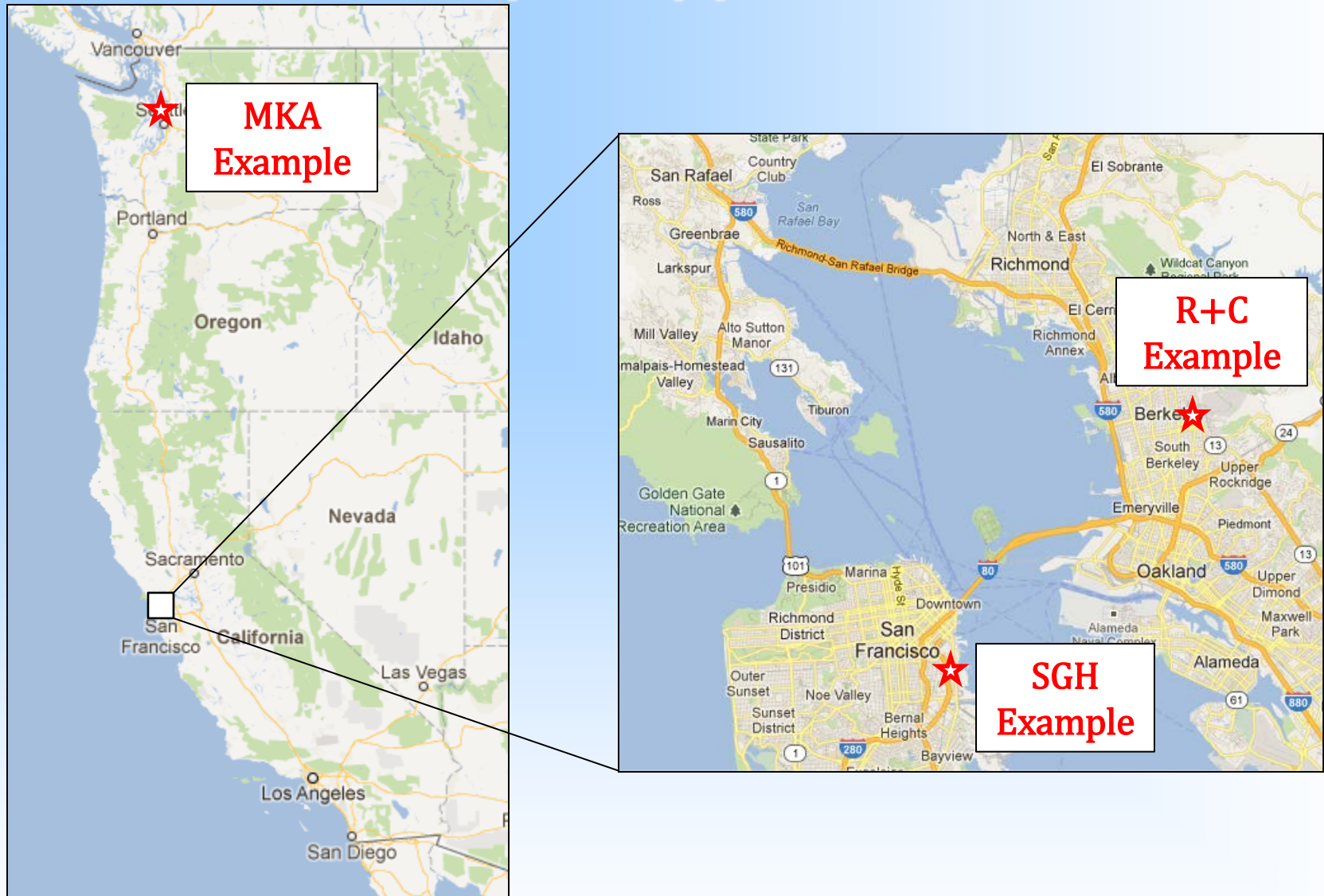
Proposal: Section 16.4 (Accept. Criteria)

- Drift limits:
 - Mean drift \leq twice the normal limit
 - The factor of two comes from:
 - ✓ $1.5 = \text{MCE} / \text{DBE}$
 - ✓ $1.25 = \text{Approx. ratio of } R / C_d$
 - ✓ $1.1 = \text{A little extra because we trust NL RHA more}$

Proposal: Section 16.5 (Design Review)

- Typical requirements and language...
- Design review is critical!

Example Applications



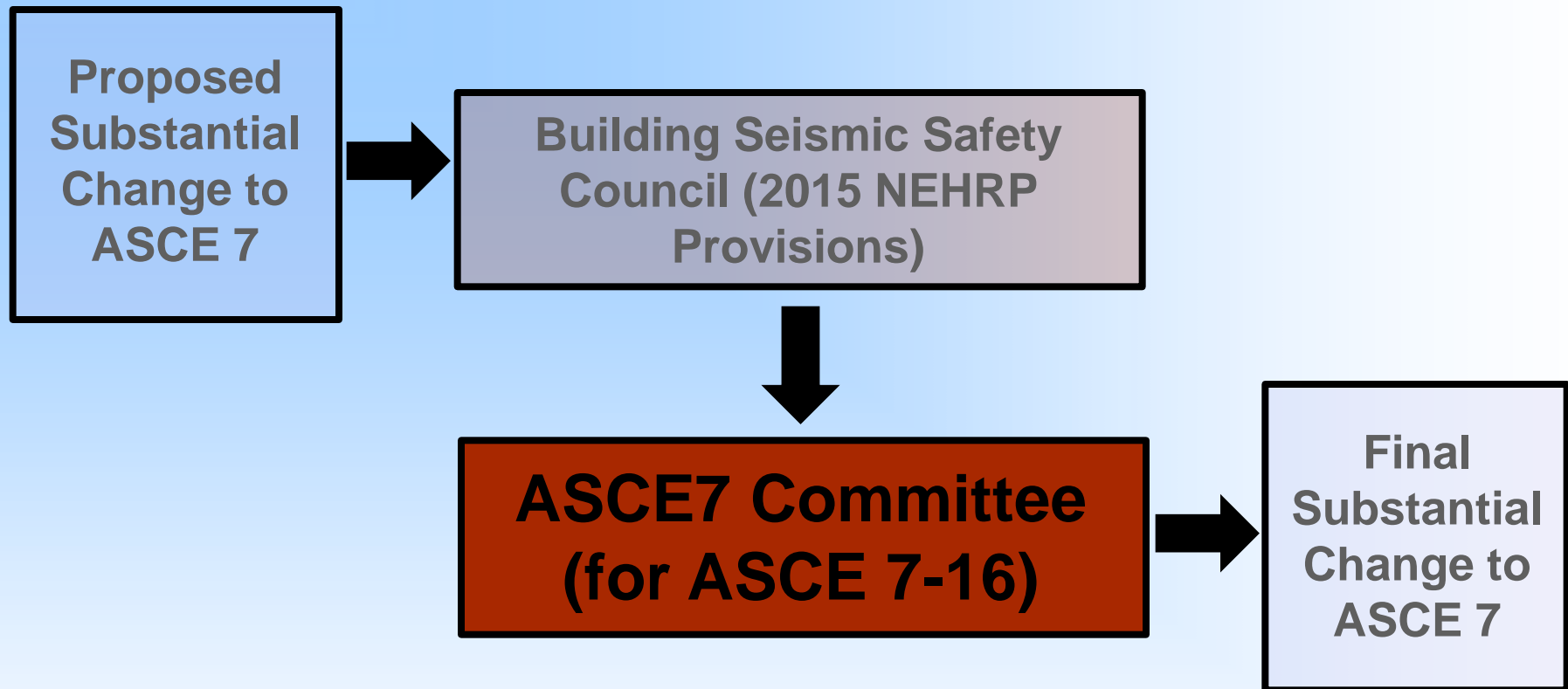
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Current Status of Chapter 16



Questions/Comments?

- Thanks you for your time.
- Please contact me if you would like more information/background because a short presentation is not enough!
- Contact:
 - E-mail: curt@hbrisk.com. chaselton@csuchico.edu
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