An Overview of Seismic Provisions in ASCE 7-16

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Chapter 11

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New Site Amplification Factors

- **First update since 1994 UBC**
  - Much more data!
- **F_a and F_v range between 80%-120% of previous values**
- **Site Class D is no longer default for F_a**
  - $F_a \geq 1.2$ (Site Class C "controls" in high shaking areas)

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Table 11.4-1 Site Coefficient, F_a

Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short

SITE CLASS	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7				

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Table 11.4-1 Site Coefficient, F_a

Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short

SITE CLASS	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S = 1.25$	$S_S \geq 1.5$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.9	0.9	0.9	0.9	0.9	0.9
C	1.3	1.3	1.2	1.2	1.2	1.2
D	1.6	1.4	1.2	1.1	1.0	1.0
E	2.4	1.7	1.3	See Section 11.4.8		
F	See Section 11.4.8					

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Table 11.4-1 Site Coefficient, F_a

Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short

SITE CLASS	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S = 1.25$	$S_S \geq 1.5$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.9	0.9	0.9	0.9	0.9	0.9
C	1.3	1.3	1.2	1.2	1.2	1.2
D	1.6	1.4	1.2	1.1	1.0	1.0
E	2.4	1.7	1.3	See Section 11.4.8		
F	See Section 11.4.8					

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Table 11.4-2 Long-Period Coefficient, F_V

Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R)
Spectral Response Acceleration Parameter at 1-s Period

SITE CLASS	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7				

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Table 11.4-2 Long-Period Coefficient, F_V

Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R)
Spectral Response Acceleration Parameter at 1-s Period

SITE CLASS	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 = 0.5$	$S_S \geq 0.6$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.8	0.8	0.8	0.8	0.8	0.8
C	1.5	1.5	1.5	1.5	1.5	1.4
D	2.4	2.2 [a]	2.0 [a]	1.9 [a]	1.8 [a]	1.7 [a]
E	4.2	See Section 11.4.8				
F	See Section 11.4.8					

[a] Also, see requirements for site specific ground motions in Section 11.4.8

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Table 11.4-2 Long-Period Coefficient, F_V

Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R)
Spectral Response Acceleration Parameter at 1-s Period

SITE CLASS	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 = 0.5$	$S_S \geq 0.6$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.8	0.8	0.8	0.8	0.8	0.8
C	1.5	1.5	1.5	1.5	1.5	1.4
D	2.4	2.2 [a]	2.0 [a]	1.9 [a]	1.8 [a]	1.7 [a]
E	4.2	See Section 11.4.8				
F	See Section 11.4.8					

[a] Also, see requirements for site specific ground motions in Section 11.4.8

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Background for Section 11.4.8 Requirement

- **Use of only two response periods (0.2s and 1.0s) generally not sufficient to accurately represent response spectral acceleration for all design periods**
  - Reasonably **Accurate** (or Conservative) for Stiff Soil Sites, **Site Classes A-C**
  - Generally **Non-conservative** for Soft Soil Sites, **Site Classes D-F** whose seismic hazard is dominated by large magnitude events

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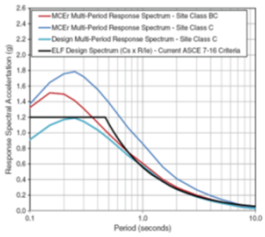
Site Class C Example



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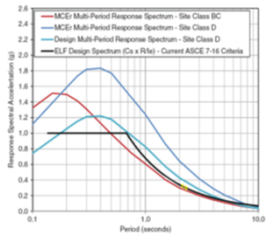
Site Class D Example



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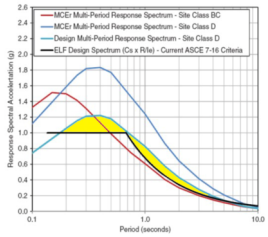
Site Class D Example



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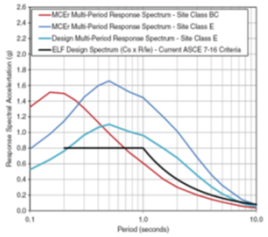
Site Class E Example



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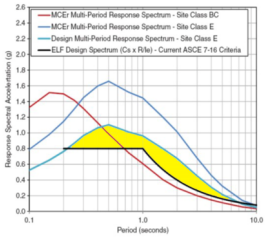
Site Class E Example



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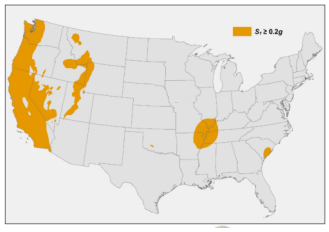
Locations Where Site-Specific Analysis is Required

Conterminous United States Regions with $S_1 \geq 0.2g$



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Exceptions to requiring Site-Specific Spectra

- Structures on Site Class E sites with $S_s \geq 1.0$, provided F_a taken as from Site Class C
- Structures on Site Class D & E sites with $S_1 \geq 0.2$, provided C_s is
  - determined by Eq. 12.8-2 for $T \leq 1.5T_s$ and
  - **taken as 1.5 times value** computed by Eq. 12.8-3 for $T_L \geq T > 1.5T_s$ or Eq. 12.8-4 for $T > T_L$
- Structures on Site Class E Sites with $S_1 \geq 0.2$, provided $T \leq T_s$ and ELF is used for the analysis

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New Vertical Ground Motions

- Section 11.9 provides *OPTIONAL* vertical ground motions in lieu of Section 12.4.2.2 (E_v) for SDC C through F
- Keyed to S_{MS} (MCE_R-level ground motions)
- Design spectrum taken as 2/3 MCE_R spectrum

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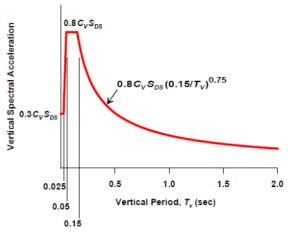
New Vertical Ground Motions



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Chapter 12

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Seismic Load Combinations

- Expanded seismic load combinations in Sections 12.4.2.3 and 12.4.3.2 moved to Chapter 2
- Seismic load effects definitions remain in Section 12.4 (E, E_h, E_v, E_m, E_{mh}, and Ω_o)

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Seismic Load Combinations

- **Introduces a new term, E_{cl}:**
  - The capacity-limited horizontal seismic load effect, equal to the maximum force that can develop in the element as determined by rational, plastic mechanism Analysis
  - $E_{mh} = \Omega_o Q_E$ need not be taken as larger than E_{cl}
  - E_{cl} also used in AISC 341-16

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Updated Requirements for Determination of C_s and E_v for short, regular structures

- **Section 12.8.1.3 allows S_{DS} = 1.0 but not less than 70% of S_{DS} defined in Section 11.4.4**
  - No irregularities
  - Does not exceed five stories
  - T < 0.5sec
  - Meets the requirements for ρ = 1.0
  - Risk Category I and II

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Accidental Torsion Change

- **Section 12.8.4.2. requires accidental torsional moments (M_{ta}) be applied for determination of horizontal irregularities**
- **M_{ta} need NOT be included when determining the seismic forces E for:**
  - Design of the structure
  - Determination of design story drift
- **Except for two important cases…**

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Accidental Torsion Change

- **These two cases are:**
  1. Structures assigned to Seismic Design Category B with Type 1b horizontal irregularity
  2. Structures assigned to Seismic Design Category C, D, E, and F with Type 1a and Type 1b horizontal structural irregularity

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New Diaphragm Requirements

- **Section 12.10.3 required for precast concrete diaphragms; alternative for others**
- **Complete new formulation**
  - Includes potential reduction for diaphragm ductility
- **Based on analytical and experimental research**

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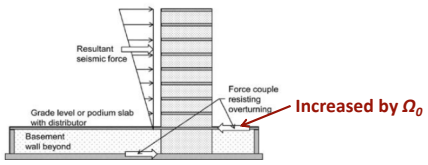
New Diaphragm Requirements

- **Change also requires the use of Ω_0 for transfer diaphragms (Horizontal Irregularity Type 4—Out-of-Plane Offset)**



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Strength Design Alternative for Foundations

- New Section 12.13.5 Strength Design for Nominal Foundation Geotechnical Capacity
- Used when Strength Load Combinations are applied in design
- Foundation Capacity, Q_{us}, determined by geotechnical engineer
- Resistance Factors (ϕ) provided

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Strength Design Alternative for Foundations

Table 12.13-1 Resistance Factors for Strength Design of Soil-Foundation Interface

Direction and Type of Resistance	Resistance Factors, ϕ
Vertical Resistance	
Compression (Bearing) Strength	0.45
Pile Friction (either upward or downwards)	0.45
Horizontal Resistance	
Lateral Bearing Pressure	0.5
Sliding (by either Friction or Cohesion)	0.85

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New Structural Requirements for Sites Susceptible to Liquefaction

- Current Section 11.8.2 requires geotechnical investigation, including liquefaction and lateral spreading
- New Section 12.13.9 provides design requirements
  - 12.13.9.2 Shallow Foundation Design
  - 12.13.9.3 Deep Foundation Design

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Section 12.13.9.2 Shallow Foundations

- **Buildings permitted to be supported on shallow foundations provided:**

Table 12.13-1 Upper Limit on Lateral Spreading Horizontal Ground Displacement for Shallow Foundations Beyond which Deep Foundations are Required

Risk Category		
I or II	III	IV
18 in.	12 in.	4 in.

Table 12.13-2 Differential Settlement Threshold,

Structure Type	Risk Category		
	I or II	III	IV
Single-story structures with concrete or masonry wall systems.	0.0075	0.005	0.002
Other single-story structures.	0.015	0.010	0.002
Multi-story structures with concrete or masonry wall systems.	0.005	0.003	0.002
Other multi-story structures.	0.010	0.006	0.002

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Section 12.13.9.2 Shallow Foundations

- **Shallow foundations meeting differential settlement criteria need only need to follow deem-to-comply detailing:**
  - Individual footing ties: $F_{tie} = 0.5\mu Pu$
  - Footings integral with minimum 5" slab-on-ground with $\rho > 0.0025$
- **Mat foundations need to be designed to accommodate expected vertical differential settlements**

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Section 12.13.9.3 Deep Foundations

- **Design requirements account for:**
  - Downdrag demands
  - Reduced lateral resistance
  - Concrete pile detailing (ACI reference)
  - Lateral spreading affect on piles deformations and demands
  - Foundation ties

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Modifications to Modal Response Spectrum Analysis Method

- **Modified to require 100% of the mass**
  - Introduces rigid body mode concept for T<0.05s
  - Exception allows 90% of mass as currently done
- **15% scaling reduction relative to ELF results is eliminated; must scale to 100% of ELF results**

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Linear Response History Analysis

- **Added to Section 12.9**
- **Advantage of LRHA vs. MRSA**
  - The *algebraic signs* of all forces and deformations are *retained* in LRHA; The signs are lost in the modal combinations used in MRSA
  - *Concurrency of actions* (axial force and bending moment) are *retained* in LRHA. Recovery of concurrent actions is not possible in MRSA.

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Chapter 13

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Some Highlights

Topic	ASCE/SEI 7-10	ASCE/SEI 7-16
Egress	Egress stairs designated as $I_e = 1.5$	Explicit provisions for egress stair design (based on NZ earthquake)
Anchor design	Omega sub zero values added for anchors in concrete	Omega sub zero also applies to anchors in masonry and max. omega reduced to 2.0
Ballasted equipment	Friction due to gravity load disallowed for resisting F_p.	Provisions added for ballasted PV solar
Drop ceilings	Acoustic drop ceiling provisions harmonized with ASTM standards	Additional requirements for perimeter attachment of drop ceilings

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Exterior Wall Elements (13.5.3)

- **Revision of requirements for connector rods for exterior panels**
  - Rods must be low carbon or stainless steel and as fabricated meet requirements of F1554 Gr. 36 or satisfy Gr. 55 Supplement 1 annealing reqts.
  - L/d ≤ 4 for connections using slots or oversize holes
  - For connections that accommodate story drift by rod bending:

$$\frac{(L/d)}{D_{pl}} \geq 6 \quad [1/\text{in.}]$$

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13.5.6.2.2 Lay-in Panel Ceilings

- **Experiments with large-scale specimens revealed weaknesses not revealed in qualification tests**


- **Reference: Rhamanishamsi, E., et al., "Seismic Response of Ceiling/Piping/Partition Systems in NEESR-GC System-level Experiments," Proceedings of the ASCE Structures Congress, Boston, April 2014.**

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Lay-in Panel Ceilings (13.5.6.2.2)

- **New requirements for seismic clips and the perimeter closure angle**
  - Qualified supporting clips can still be used with ¾-in. closure angles
  - Closure angles must be screwed or otherwise positively attached to supporting framing (no screws into drywall…)
  - Each clip must be attached with minimum two screws

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Egress Stairs and Ramps (13.5.10)

- **Require that sliding connections with fail-safe attributes accommodate D_{pl} but not less than 1/2 in**
- **Sliding connections without fail-safe must accommodate 1.5 D_{pl} but not less than 1 in.**
- **Metal supports must accommodate 1.5 D_{pl}**
- **All fasteners and attachments designed for $R_p = a_p = \Omega_o = 2.5$**
- **In the absence of sliding or ductile connections, include stair in structural model**

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Sprinklers (Table 13.6.8.2)

- **NFPA 13-16 deemed to comply**
  - Additional clearance requirement **(3 inches)** for drops and sprigs

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Chapter 15

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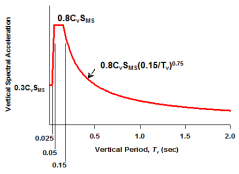
Vertical Seismic Ground Motions (11.9)

- ASCE 7-16 adopted the vertical ground motions based on the work of Bozorgnia and Campbell (2004)
- These ground motions (currently) required for certain nonbuilding structures:
  - liquid and granular storage tanks/vessels
  - suspended structures (such as boilers)
  - nonbuilding structures incorporating horizontal cantilevers



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Accidental Torsion (15.4.1)

- The accidental torsion requirements of section 12.8.4.2 need not be accounted for in nonbuilding structures if certain criteria is met – low R-value, regular, and inherent torsion accounted for
- Primary factors that contribute to the effects of accidental torsion are frequently not present in many nonbuilding structures

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Foundations of Liquefiable Soils (12.13.7 & 15.4.10)

- New Section 12.13.7 is a "get out of jail free card" for shallow foundations on liquefiable soils (under certain conditions).
- 15.4.10 takes back the "get out of jail free card" unless it can be demonstrated that the structure and its foundation can accommodate the liquefaction.

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Foundations of Liquefiable Soils (12.13.7 & 15.4.10)

- New Section for shallow foundations nditions).
- 15.4.10 takes nless it can be demonstrat on can accommoda

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Major Additions

- **Wind Turbine Structures (15.6.7)**
  - Specific values for R, C_d, and Ω_o added to Table 15.4-2
- **MH 16.3 Steel Cantilevered Storage Racks (15.5.3.2)**
  - New system added with specific values for R, C_d, and Ω_o added to Table 15.4-1
  - ASCE 7 now contains provisions for two types of steel storage racks often found in warehouse stores

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Chapter 16

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Big Picture

- **ASCE 7-10**
  - Chapter 16 covered linear and nonlinear response history analysis
  - Conducted at Design Earthquake shaking
  - Acceptance values = 2/3 of failure level demands
  - Alternate procedure to ELF, RSA
- **ASCE 7-16**
  - Chapter 16 limited to nonlinear response history analysis
    - Linear moved to Chapter 12
  - Conducted at MCE_R shaking
  - Acceptance values taken at statistical probability of failure
  - Supplementary procedure to ELF, RSA, or linear response history

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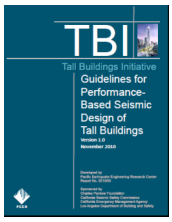
Motivation: Performance-based Seismic Design of Tall Buildings



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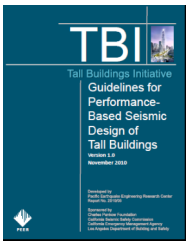
Important New Concepts



- Acceptance based on local and global behavior
- Failure probability tied to overall performance goal of 10% probability collapse given MCE_R

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16.1.1 Scope

- Applicability – any structure
- Scope – Demonstrate acceptable strength, stiffness and ductility to resist MCE_R demands with acceptable performance
  - Linear analysis per Chapter 12
  - Nonlinear analysis
  - Independent structural (peer) review

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Chapter 22

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New Seismic Design Maps:

- **Based on USGS's 2014 National Seismic Hazard Maps**
  - New/updated fault characterizations
  - New Ground Motion Prediction Equations (Ground Motion Models)

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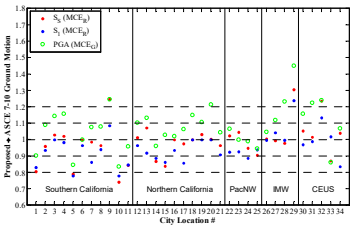
Changes in MCE_R and MCE_G Values



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Summary of Most Impactful Changes:

- **Changes to Site Amplification Factors/Introduction of Site-specific ground motion requirements**
- **Amplification of diaphragm transfer forces by Ω_o**
- **MRSA results scaled to 100% of ELF results**
- **New Structural Requirements for Sites Susceptible to Liquefaction**
  - But not for non-building structures
- **Explicit provisions for egress stairs**
- **Update to Chapter 16 Nonlinear Response History Analysis**
- **Updated seismic design values for all locations**

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Questions?

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