Towards Risk-Targeted Design Ground Motion Maps

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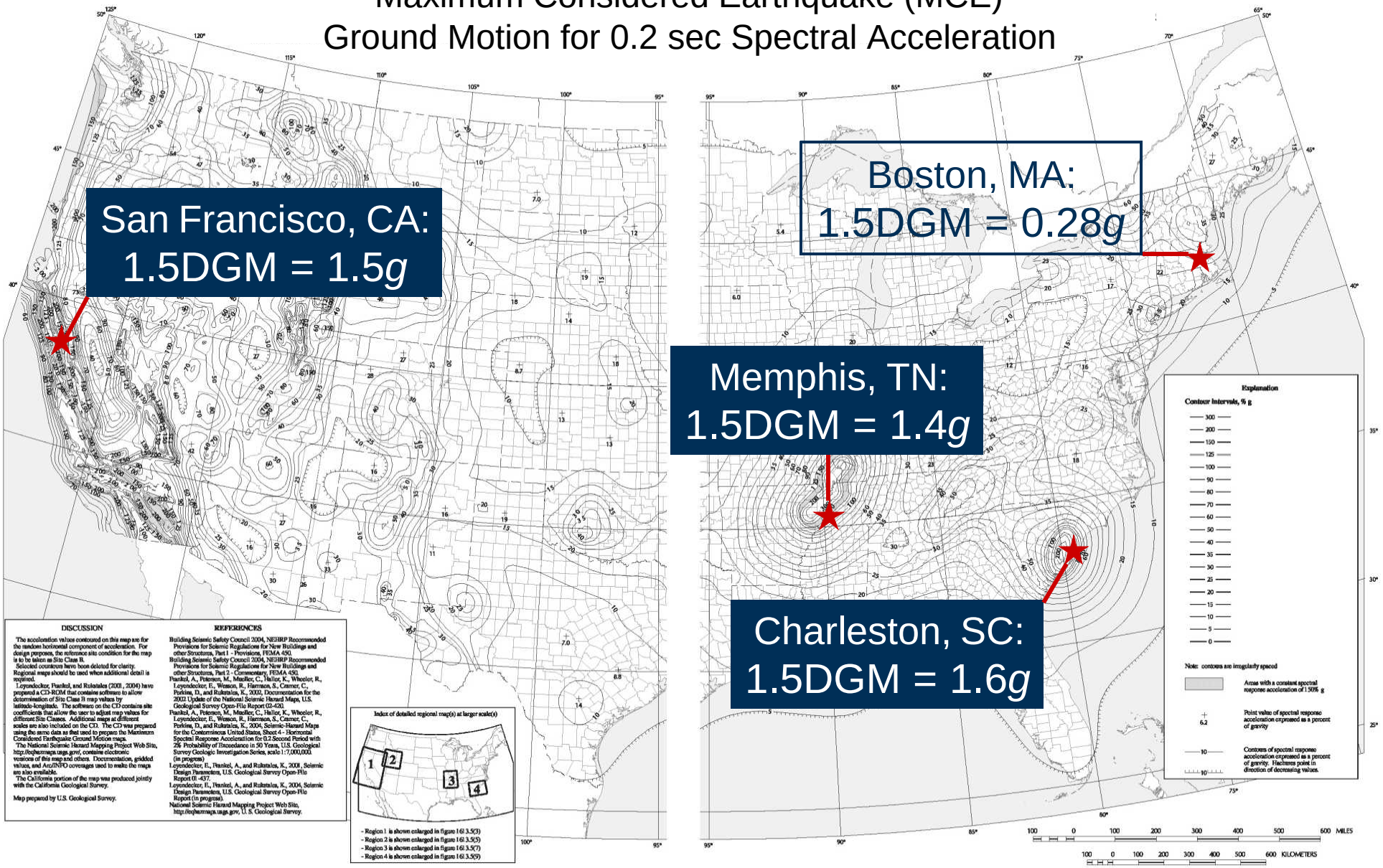
Motivation: CEUS Design Ground Motions

- In Memphis, as an example, the design ground motions in the International Building Code represent a significant increase:

	T = 0.2 sec	T = 1.0 sec
IBC (2006)	0.93*g*	0.28*g*
SBC (1999)	0.50*g*	0.24*g*
Recently Adopted	0.25*g*	0.07*g*

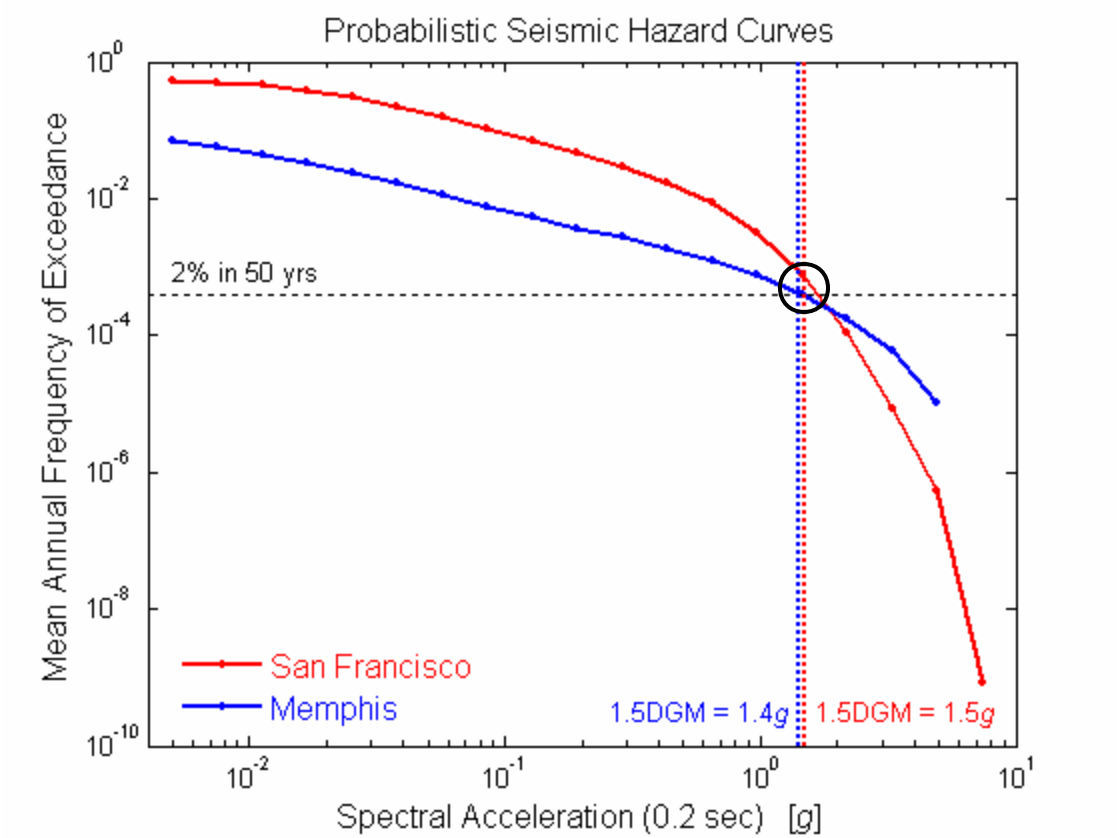
Further Motivation: CEUS vs. WUS

Maximum Considered Earthquake (MCE)
Ground Motion for 0.2 sec Spectral Acceleration



Example: Memphis vs. San Francisco

- The design ground motions are similar because they are based on the 2% in 50 year ground motions.
- The rest of the seismic hazard curves are quite different, however:



Quantifying Risk of Collapse

- The shape of the hazard curves affects the risk of collapse.
- "Risk Integral" …

$$P_f = \int_0^{\infty} H(a) \frac{\mathrm{d}P_f(a)}{\mathrm{d}a} \mathrm{d}a$$

RISK OF COLLAPSE
(probability of failure)

FRAGILITY CURVE
(conditional probability of failure)

HAZARD CURVE
(probability of ground motion exceedance)

Quantifying Fragility

- Refinements will come from ATC-63 Project (Kircher *et al*).
- From *1998 NEHRP Provisions* (App. A to *Commentary*) …

  "The collective opinion of the SDPG was that the seismic margin contained in the *1997 NEHRP Provisions* provides, as a minimum, a margin of about 1.5 times the design earthquake ground motions. In other words, **if a structure is subjected to a ground motion 1.5 times the design level, the structure should have a low likelihood of collapse**. The SDPG recognized that quantification of this margin is dependent on the type of structure, detailing requirements, etc., but the 1.5 factor was considered a conservative judgment appropriate for structures designed in accordance with the 1997 NEHRP Provisions. This seismic margin estimate is supported by Kennedy et al. (1994), Cornell (1994), and Ellingwood (1994), who evaluated structural design margins and reached similar conclusions."

- Corresponding assumption:

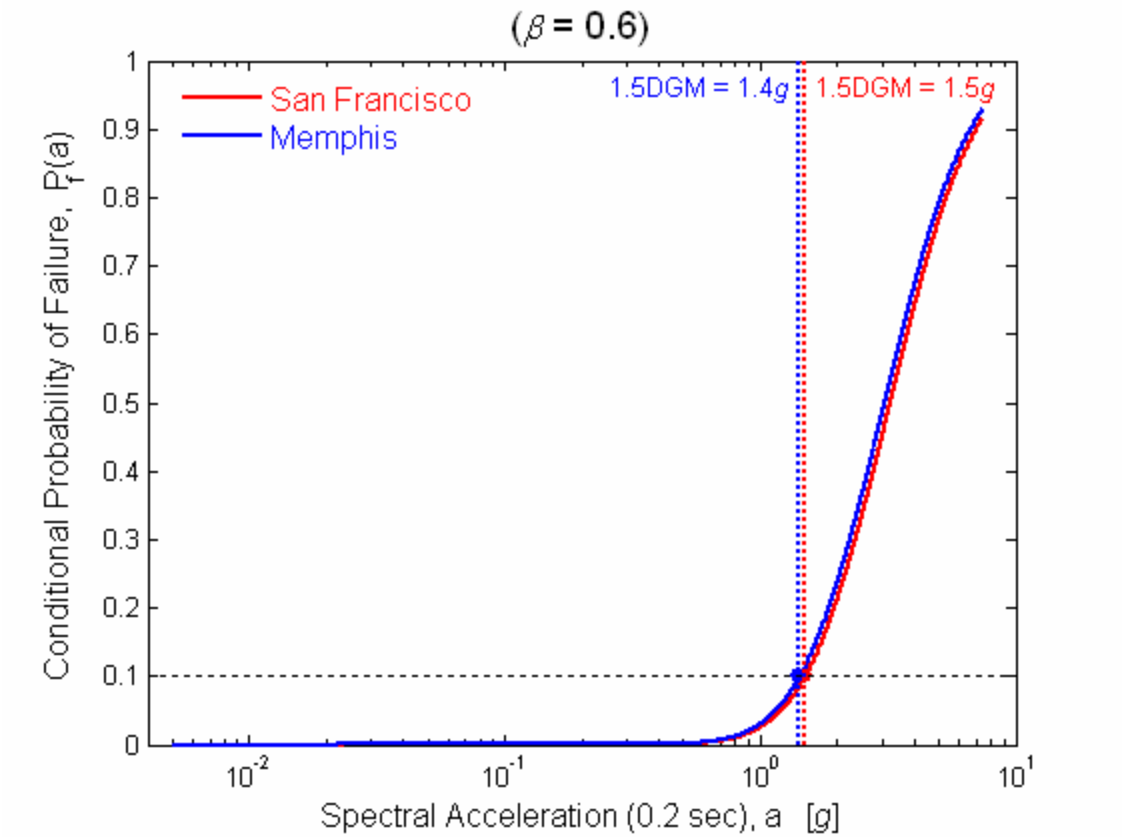
$$P_f(a = 1.5 \times DGM) = 10\%$$

Quantifying Fragility (continued)

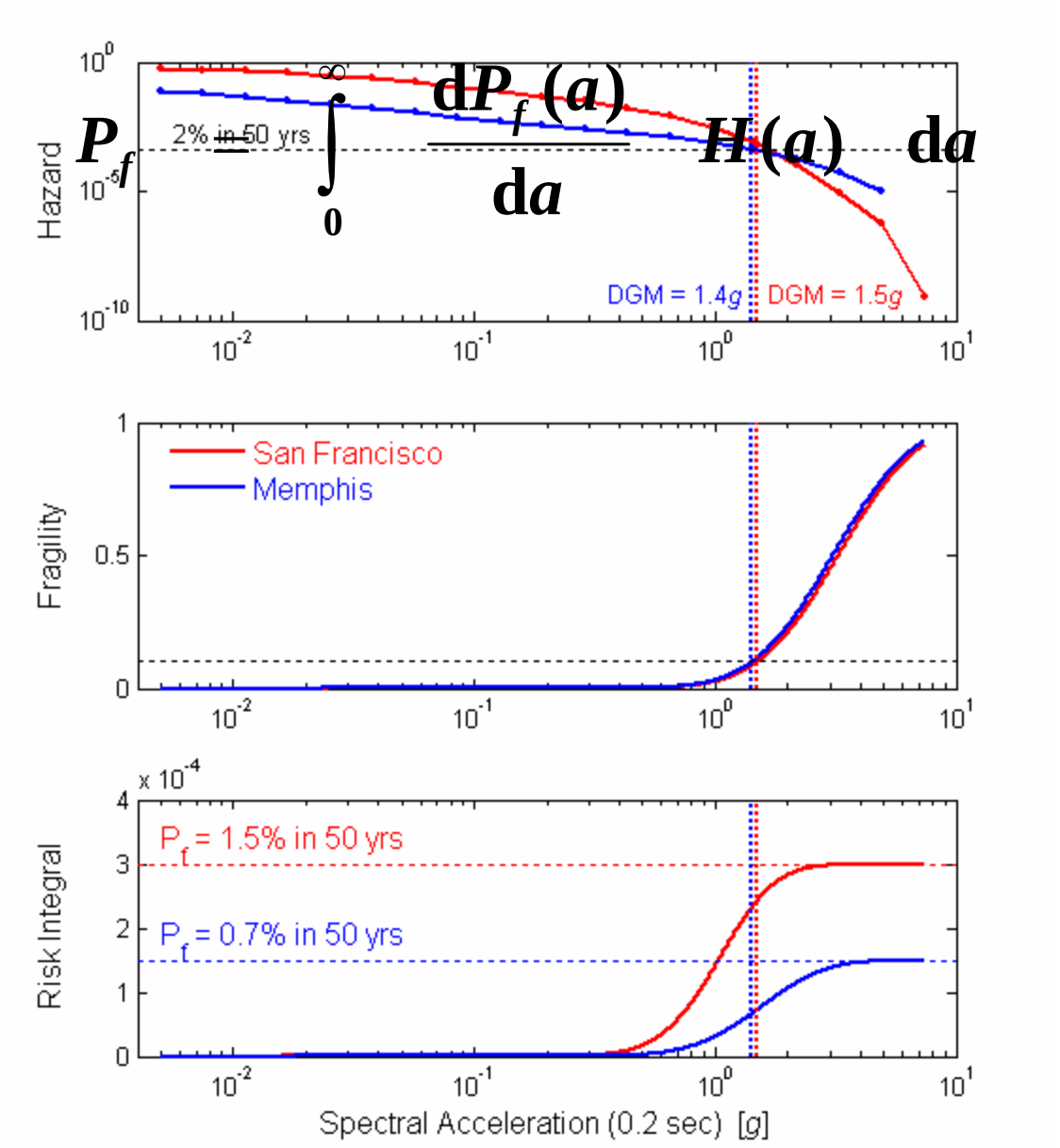
- Lognormal assumption:

$$P_f(a) = \Phi\left[\frac{\ln a - (\ln 1.5\boxed{DGM} + 1.28\boxed{\beta})}{\boxed{\beta}}\right]$$

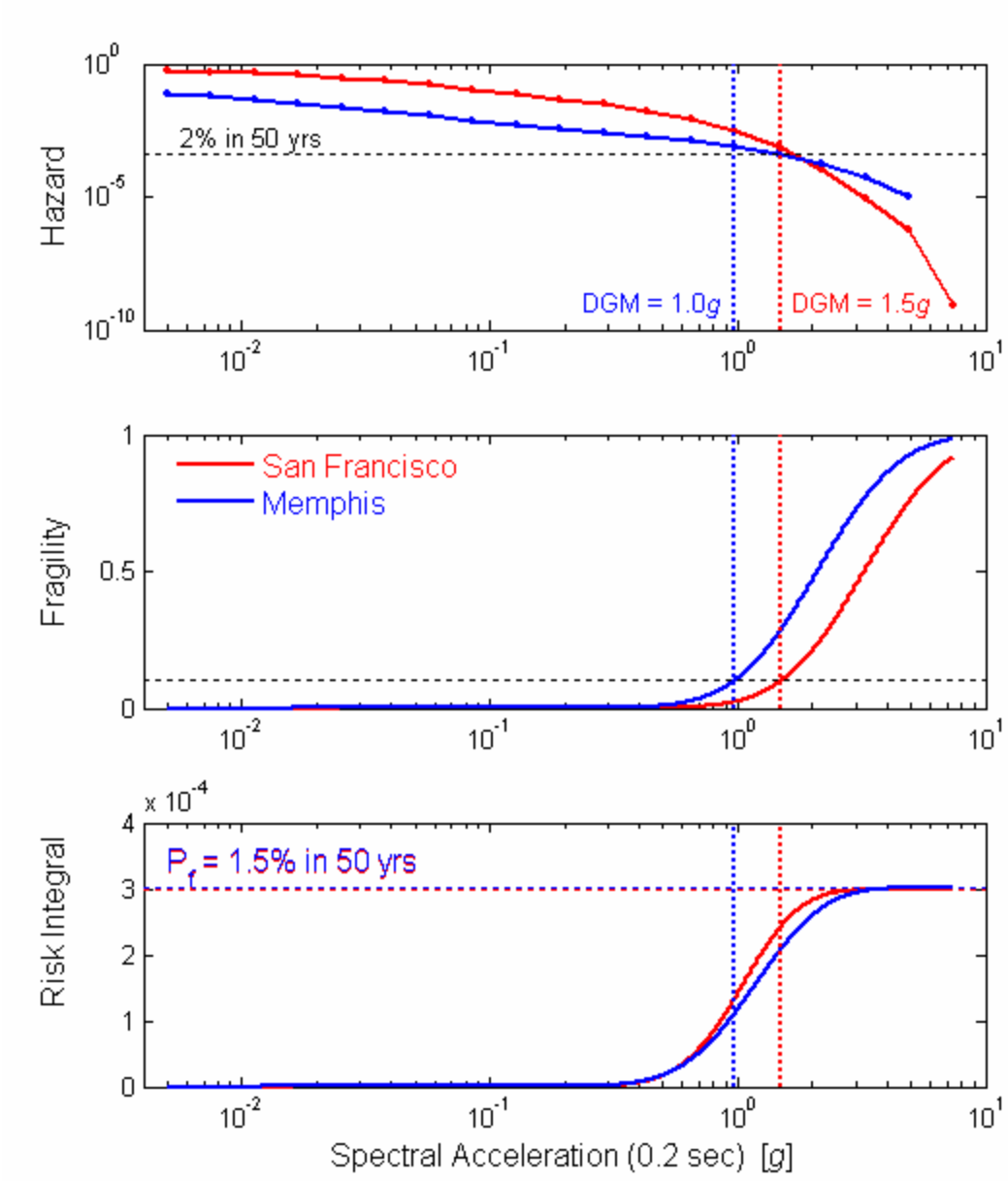
- From ASCE 43-05 for nuclear facilities: $\beta = 0.3 \text{ to } \underline{\underline{0.6}}$



Memphis vs. San Francisco Risk of Collapse



“Risk-Targeted” Design Ground Motions



$$P_f = \int_0^\infty \frac{dP_f(a)}{da} H(a) \, da$$

“Risk-Targeted” Design Ground Motions

- For target P_f = 1.5% in 50 years (from San Fran., T = 0.2 sec) …

	T = 0.2 sec	T = 1.0 sec
Memphis	1.0*g* / 1.4*g* = 0.7	0.27*g* / 0.39*g* = 0.7
San Francisco	1.5*g* / 1.5*g* = 1.0	0.69*g* / 0.60*g* = 1.15
Charleston	1.1x*g* / 1.6*g* = 0.7	0.27*g* / 0.39*g* = 0.7

$$\left(\frac{\text{Risk-Targeted DGM} \times 1.5}{\text{International Building Code DGM} \times 1.5} \right)$$

Results: Memphis Design Ground Motions

	T = 0.2 sec	T = 1.0 sec
IBC (2006)	0.93*g*	0.28*g*
SBC (1999)	0.50*g*	0.24*g*
Recently Adopted	0.25*g*	0.07*g*
"Risk-Targeted"	0.63*g*	0.19*g*

Conclusions

- The risk of collapse for buildings designed according to the MCE Ground Motion Maps is not uniform across the U.S.

- *"Risk-Targeted" Design Ground Motion (DGM) Maps* that result in uniform risk of collapse can be generated.

- If the target risk were set to that currently implicit in California, the DGMs in some parts of the CEUS would drop.

How would the DGM change in Boston?

- Seismic Design Category = B (vs. D in Memphis, San Fran.)
- More appropriate fragility assumptions (?):

$$P_f(a = 1.5 \times DGM) = 20\% \quad ; \quad \beta = 0.8$$

	San Francisco	Boston
0.2 sec	1.5*g* / 1.5*g* = 1.0	0.278*g* / 0.284*g* = 0.97
1.0 sec	0.69*g* / 0.60*g* = 1.15	0.069*g* / 0.069*g* = 1.0