

A New Framework for Quantifying Ground Motion Intensity to Estimate Collapse Vulnerability of Buildings

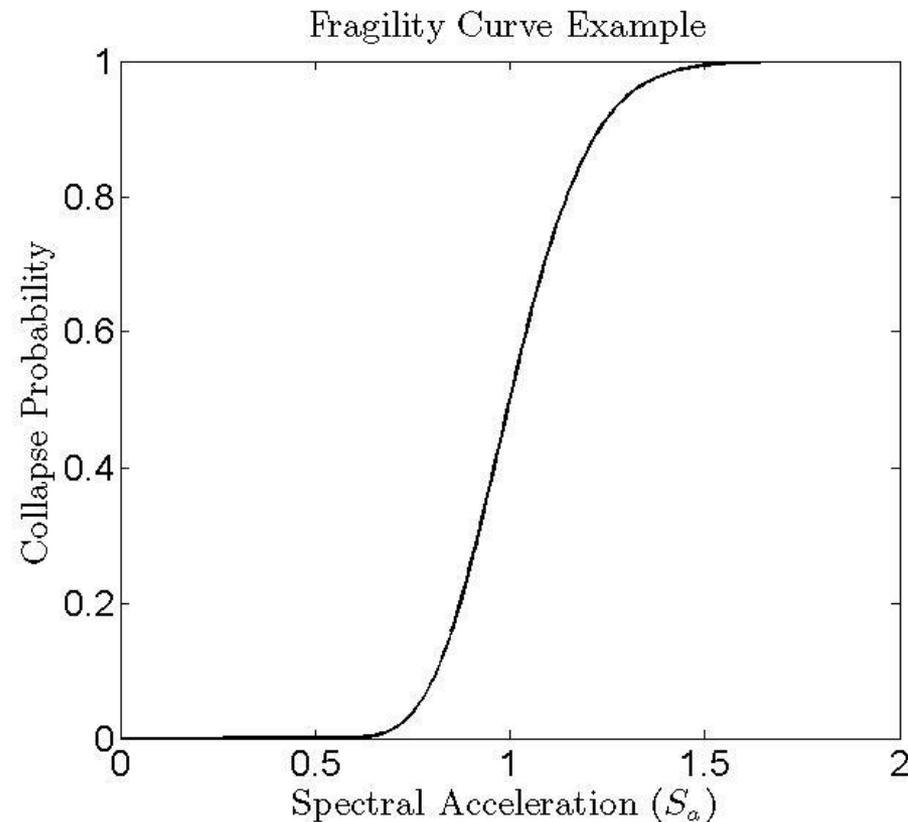


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Motivation

- What makes a ground motion “strong”?
 - Examine building response (damage, collapse, etc.)





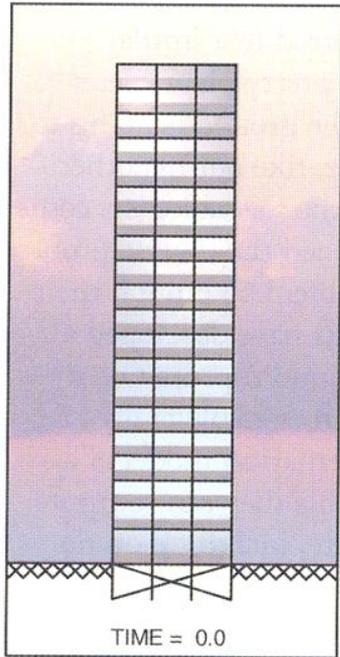
Motivation

- What makes a ground motion “strong”?
 - Examine building response (damage, collapse, etc.)
- Traditional ground motion intensity measures
 - Peak ground acceleration (PGA)
 - Peak ground velocity (PGV)
 - Peak ground displacement (PGD)
 - Spectral acceleration (S_a)
 - Epsilon (ϵ)
- Which ground intensity measure(s) best predict building collapse?

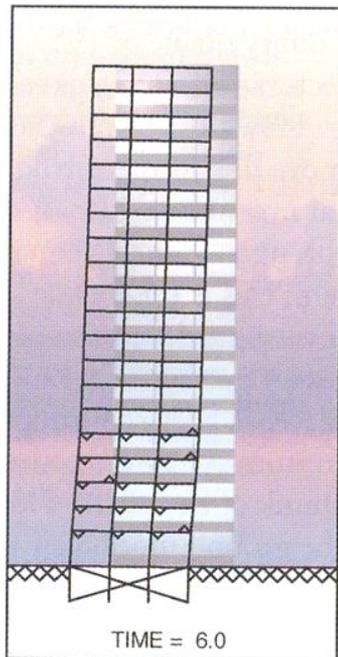


P- Δ Collapse

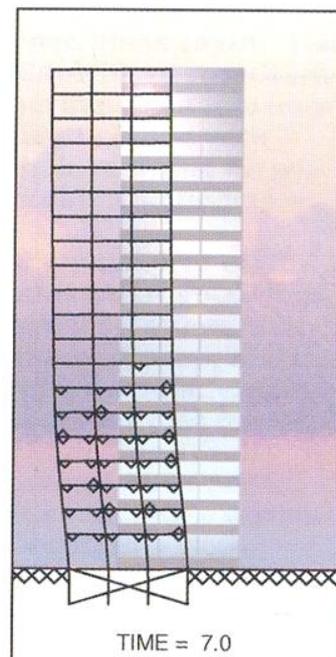
The 20-story building before the C5 ground motion hits. The displacement pulse will be toward the left.



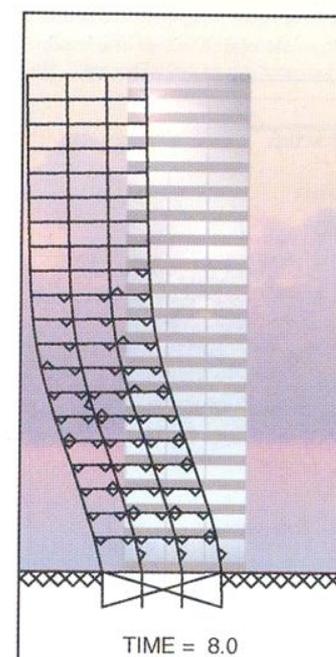
At t=6 seconds, the ground is approaching its maximum horizontal displacement of 182 centimeters.



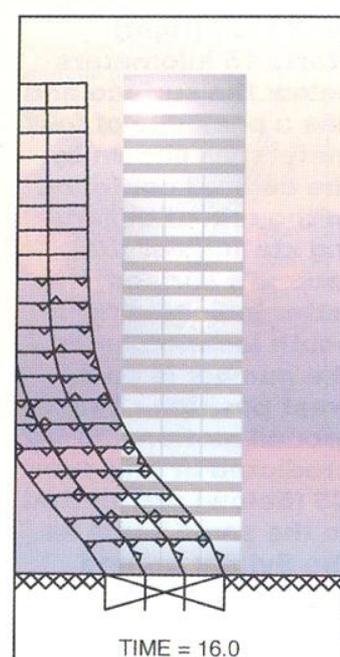
At t=7 seconds, the ground is returning to its original position, causing the building to "crack the whip."



This flexure creates a ripple of breaking welds that travels up the building.



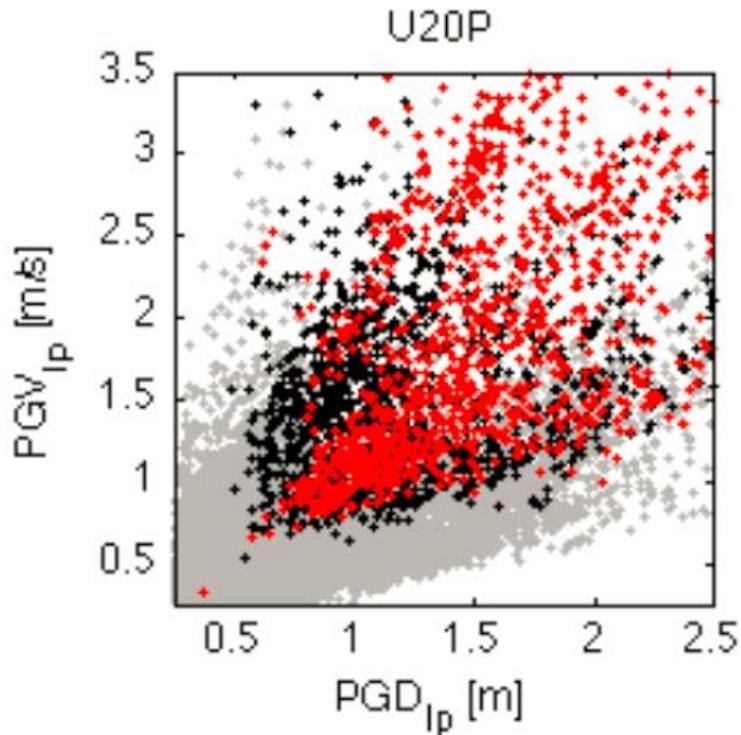
By t=16 seconds, the building is hopelessly overbalanced and on its way to oblivion.



- triangles indicate failure of welded beam-column connections



PGD and PGV to Predict Collapse

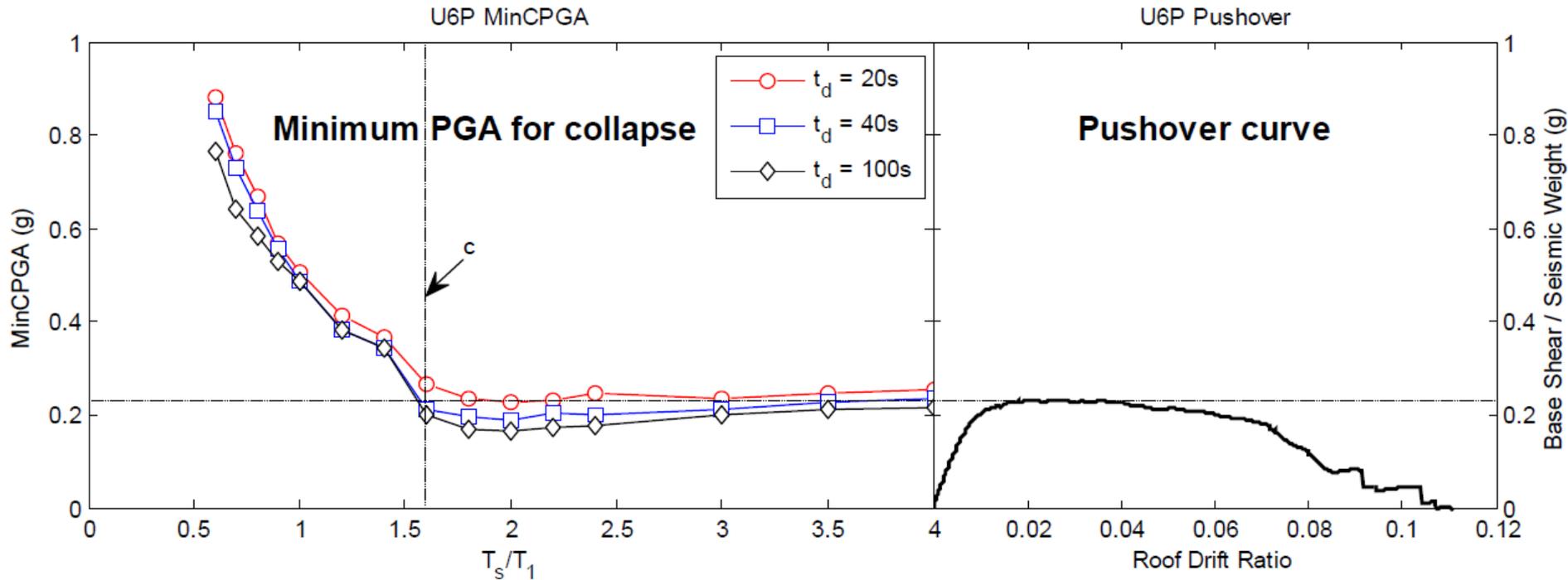


- Repairable
- Not Repairable
- Collapse

- Olsen, Heaton, and Hall (2014, Spectra)
- 64,000 synthetic ground motions
- Classify building response as “repairable,” “not repairable,” or “collapse”
- (PGD, PGV) better predictor of collapse than (S_a, ϵ)
- Ground motion must have large enough PGD *and* PGV to induce collapse



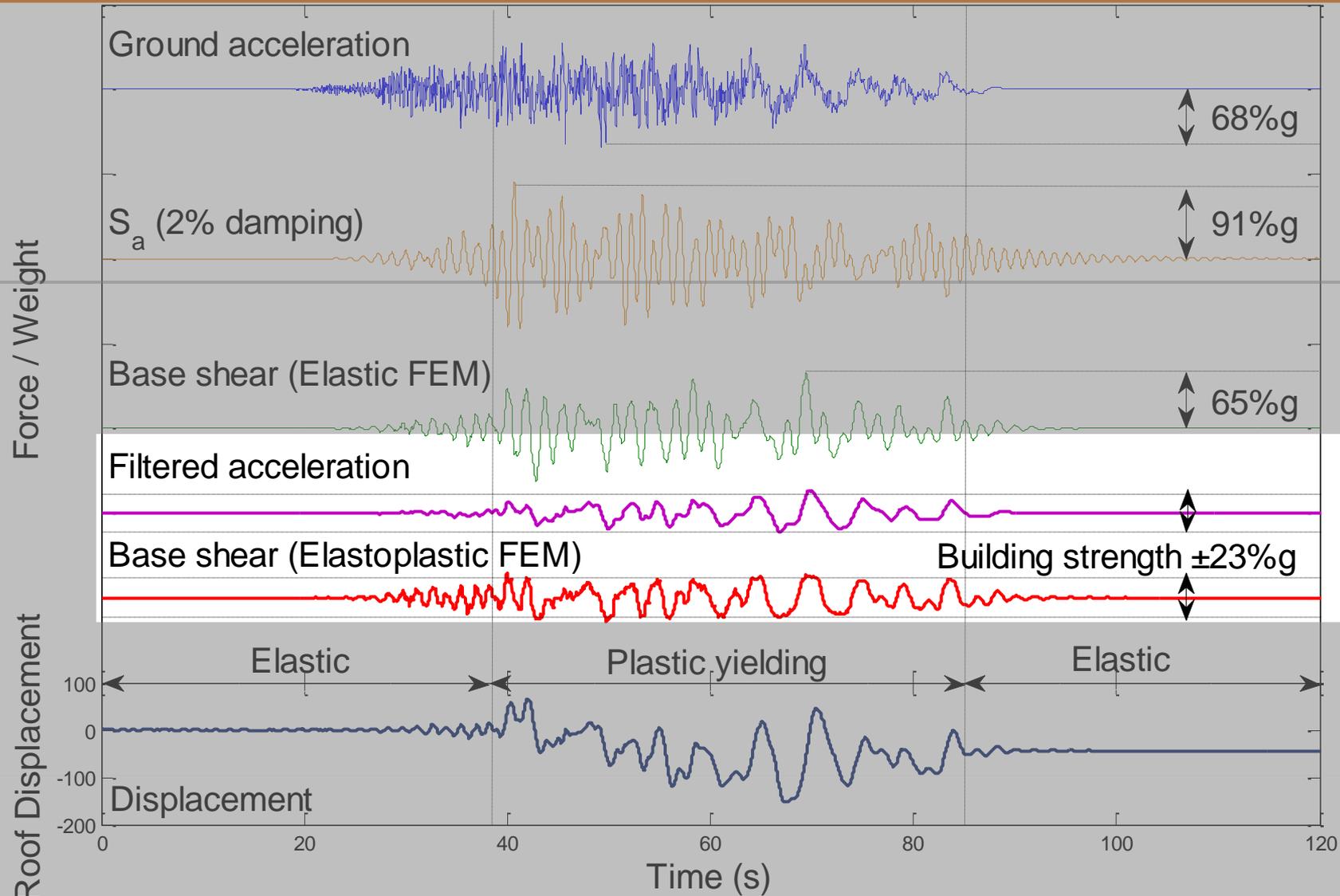
Collapse due to Sinusoidal Ground Motion



- Song (2014, Ph.D. Thesis)
- Incremental dynamic analysis (IDA) to find minimum amplitude of sinusoidal motion needed for collapse
- “Easier” to induce collapse with long period motion
 - We can low-pass filter ground motions to extract long-period components

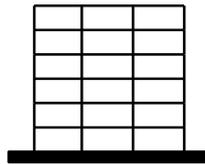


Filtered Acceleration and Base Shear

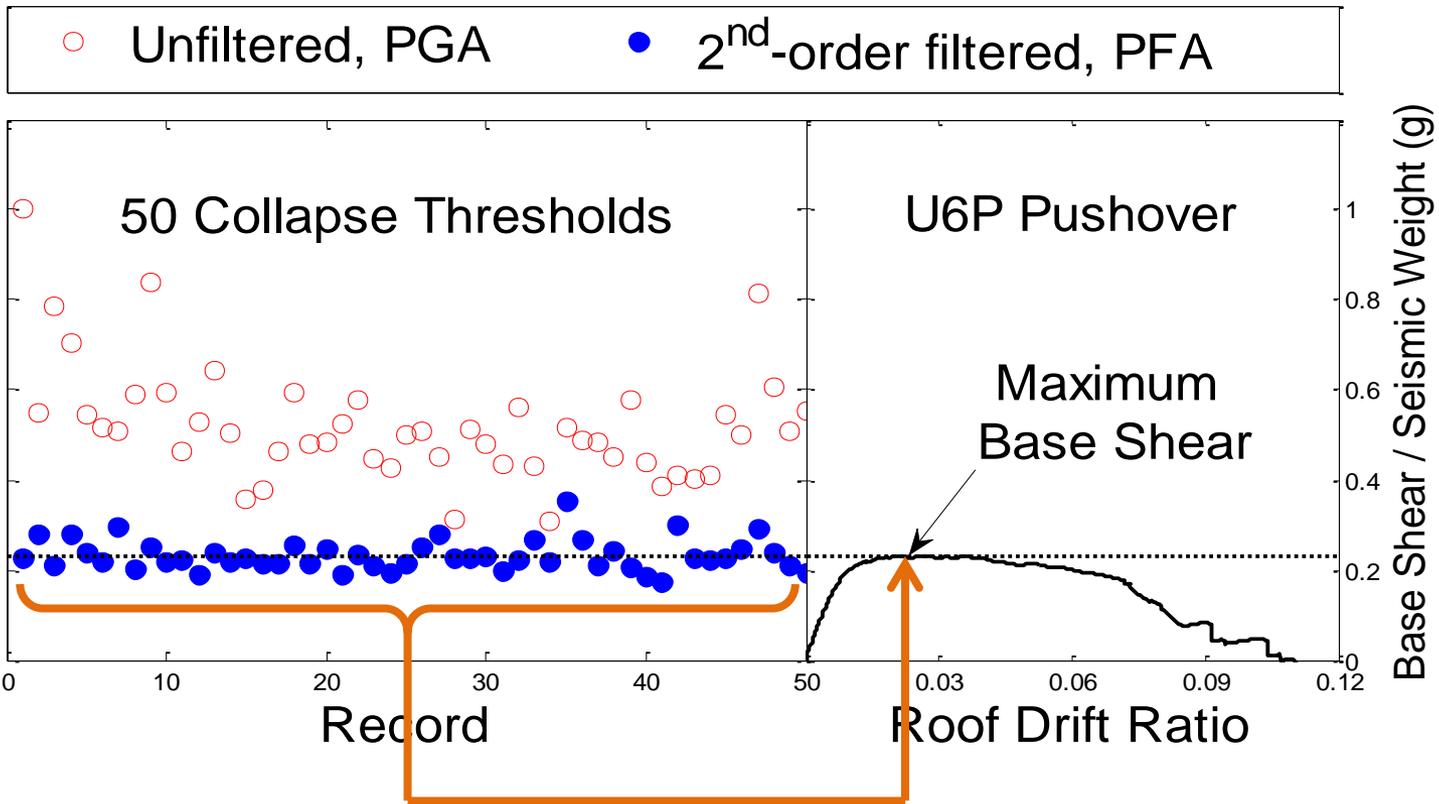




50 Records Scaled to Cause Collapse



U6P in Long-period Ground Motions



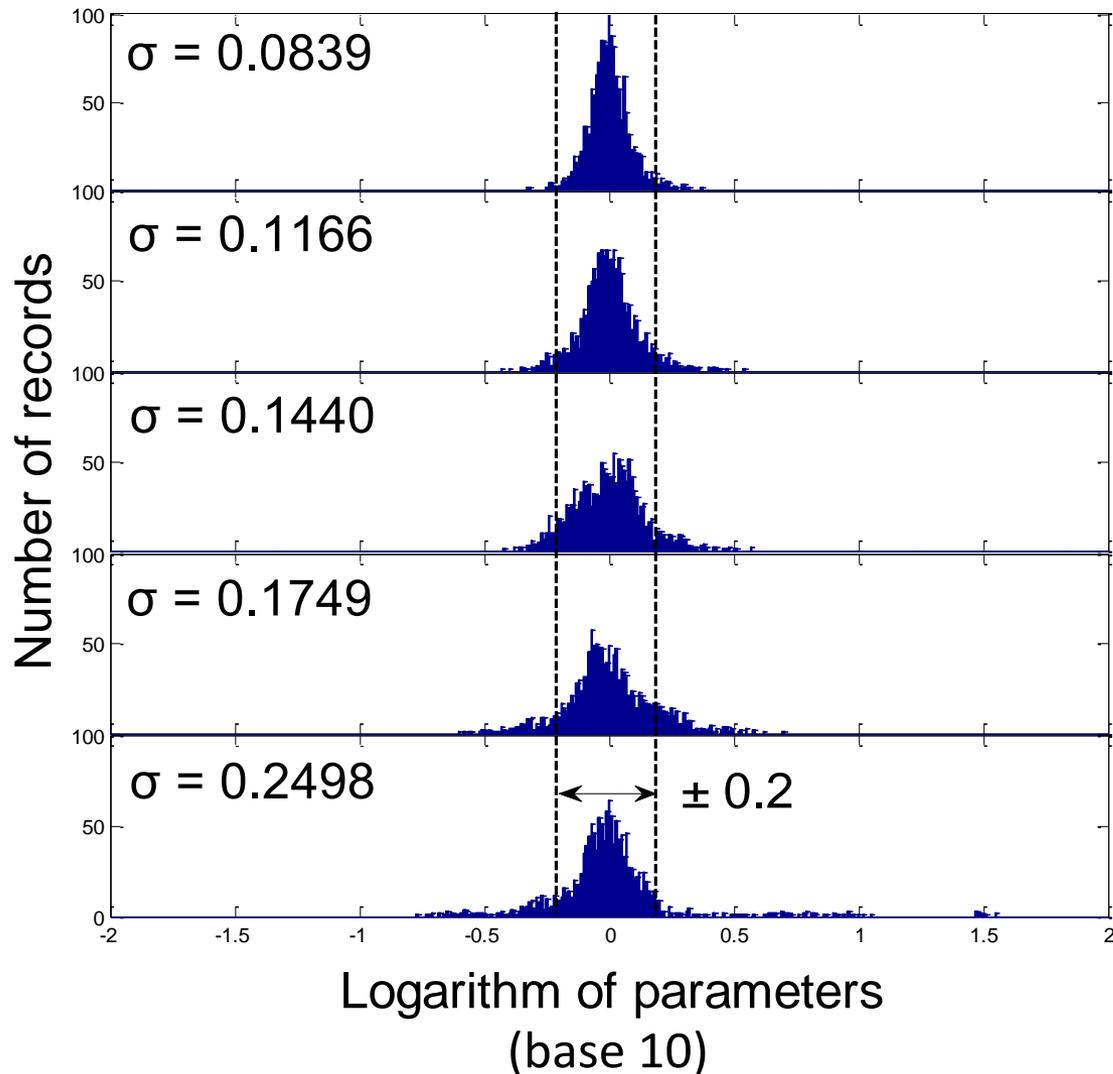
Approach to a constant



Comparison to Traditional Ground Intensity Measures

Histogram of parameters

Best
↓
Worst



PFA
↓
PGV
↓
 S_a
↓
PGA
↓
PGD



Conclusions

- Together, PGD and PGV are better collapse predictors than S_a and ε .
- Peak filtered acceleration (PFA) is a better collapse predictor than any single traditional ground intensity measure
- **BIG IDEA: Ground motions with large long-period components are most likely to cause P- Δ collapse**



Next Project

- How far “beyond-the-code” are buildings designed in the US and in Japan?
 - How do typical existing buildings perform compared to theoretical “to-code” buildings?
 - Apply collapse prediction framework to “as-built” and “to-code” buildings
 - **We will need designs of existing Japanese buildings**
 - Compare collapse vulnerability of seismic codes and engineering practice in both countries



References

- Olsen, A. H., et al., 2014, “Characterizing ground motions that collapse steel, special moment-resisting frames or make them unreparable,” Earthquake Spectra.
- Song, S., 2014, “A new ground motion intensity measure, peak filtered acceleration (PFA), to estimate collapse vulnerability of buildings in earthquakes,” Ph.D. thesis, California Institute of Technology, Pasadena, CA.