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

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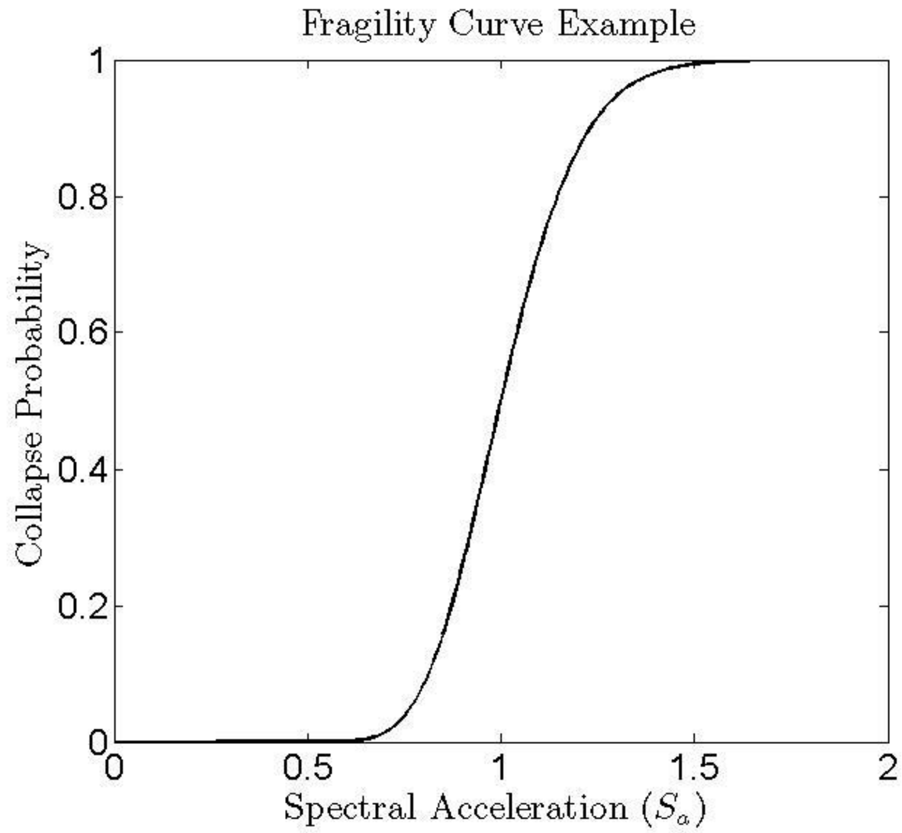
Motivation

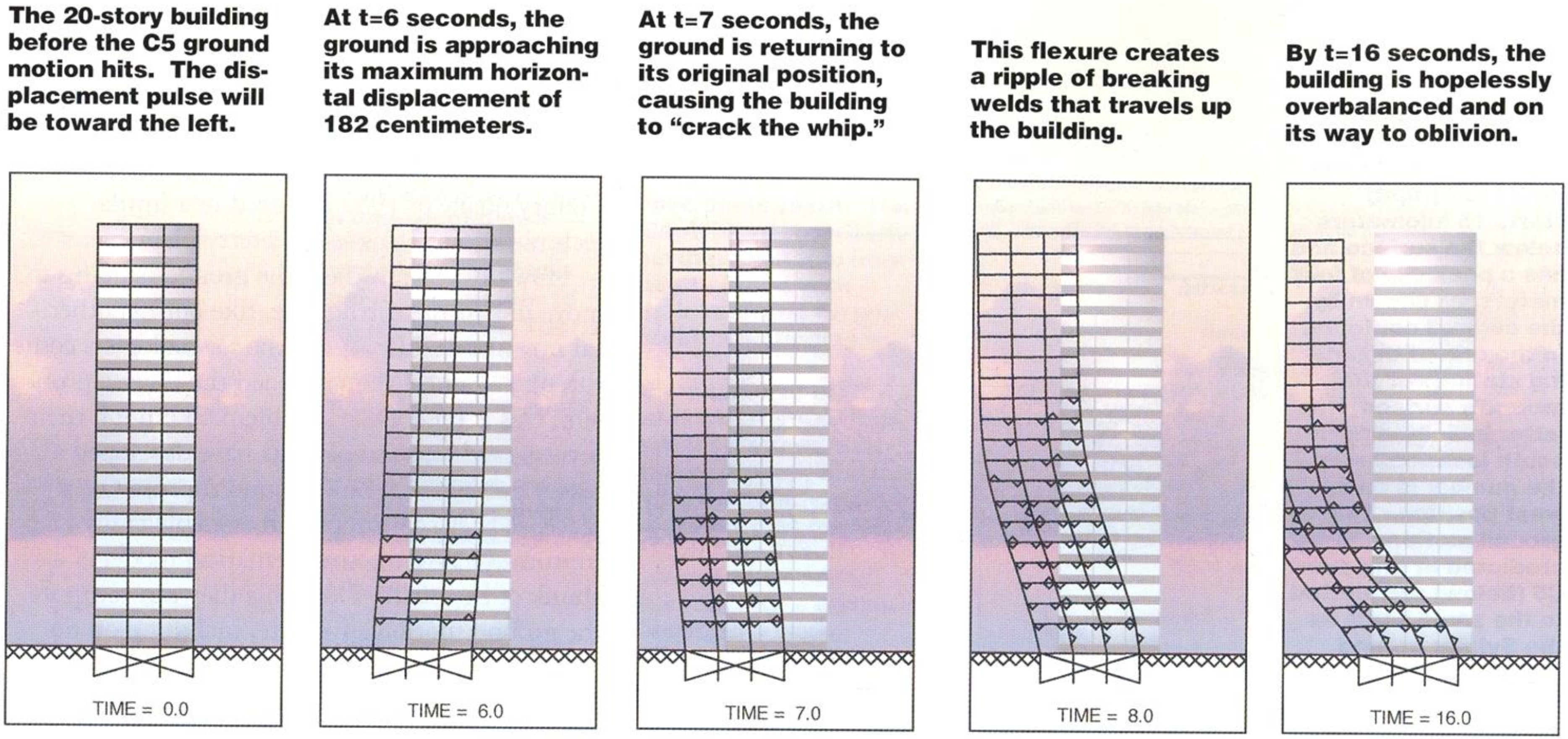
- What makes a ground motion "strong"?
  - Examine building response (damage, collapse, etc.)



Motivation

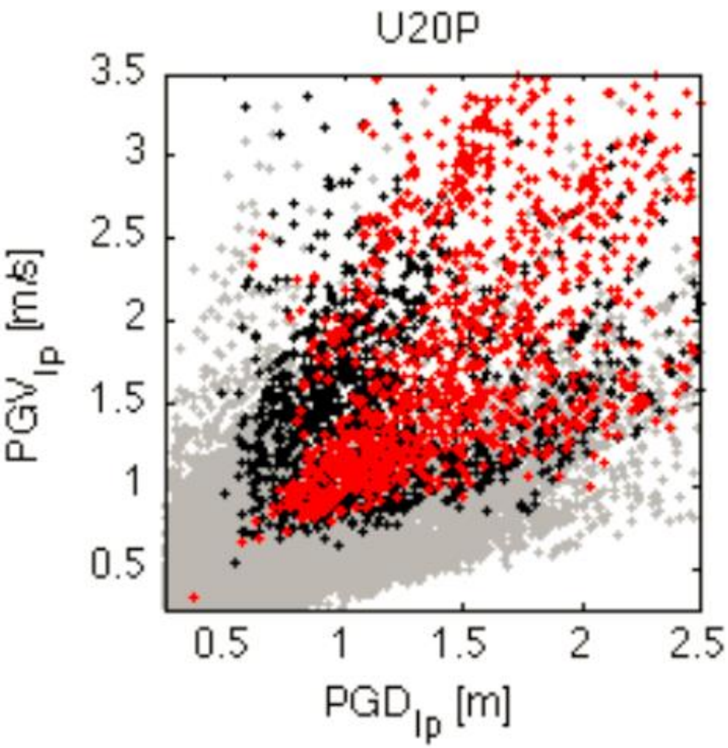
- What makes a ground motion “strong”?
  - Examine building response (damage, collapse, etc.)
- Traditional ground motion intensity measures
  - Peak ground acceleration (PGA)
  - Peak ground velocity (PGV)
  - Peak ground displacement (PGD)
  - Spectral acceleration (S_a)
    - Epsilon (ε)
- Which ground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

P-Δ Collapse



- triangles indicate failure of welded beam-column connections

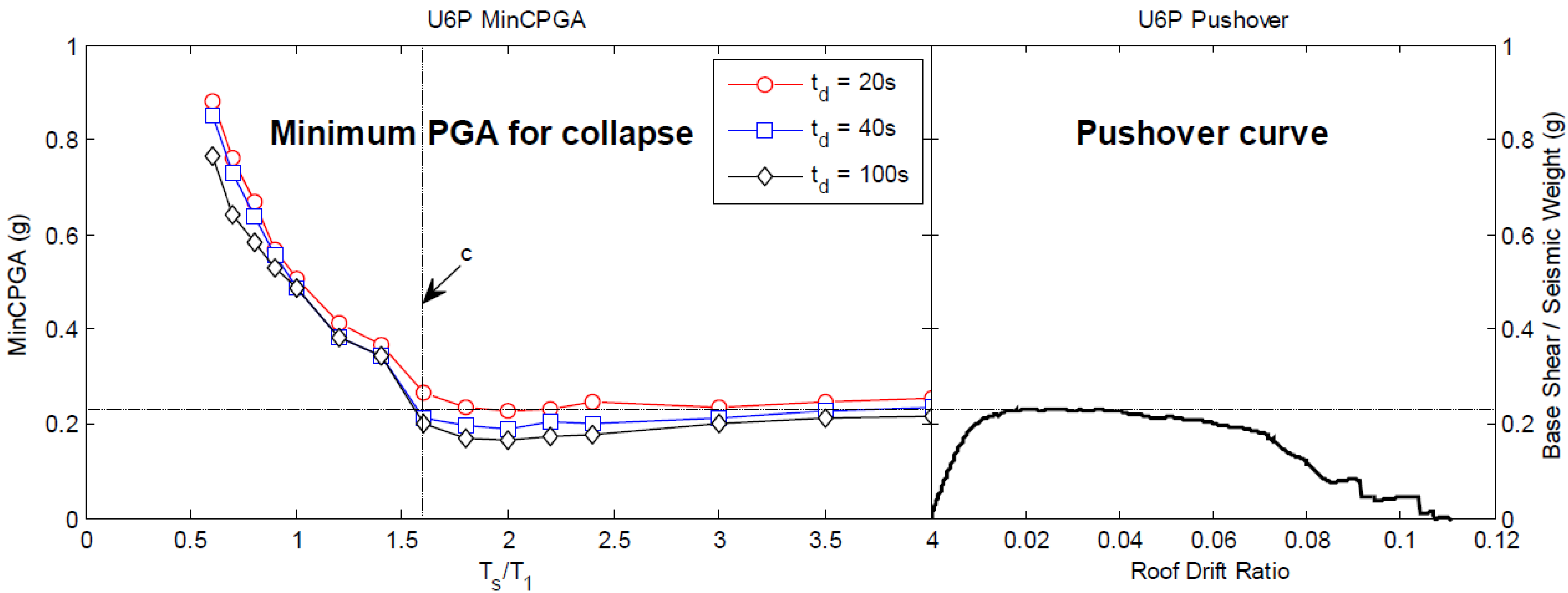
PGD and PGV to Predict Collapse



- Repairable
- Not Repairable
- Collapse

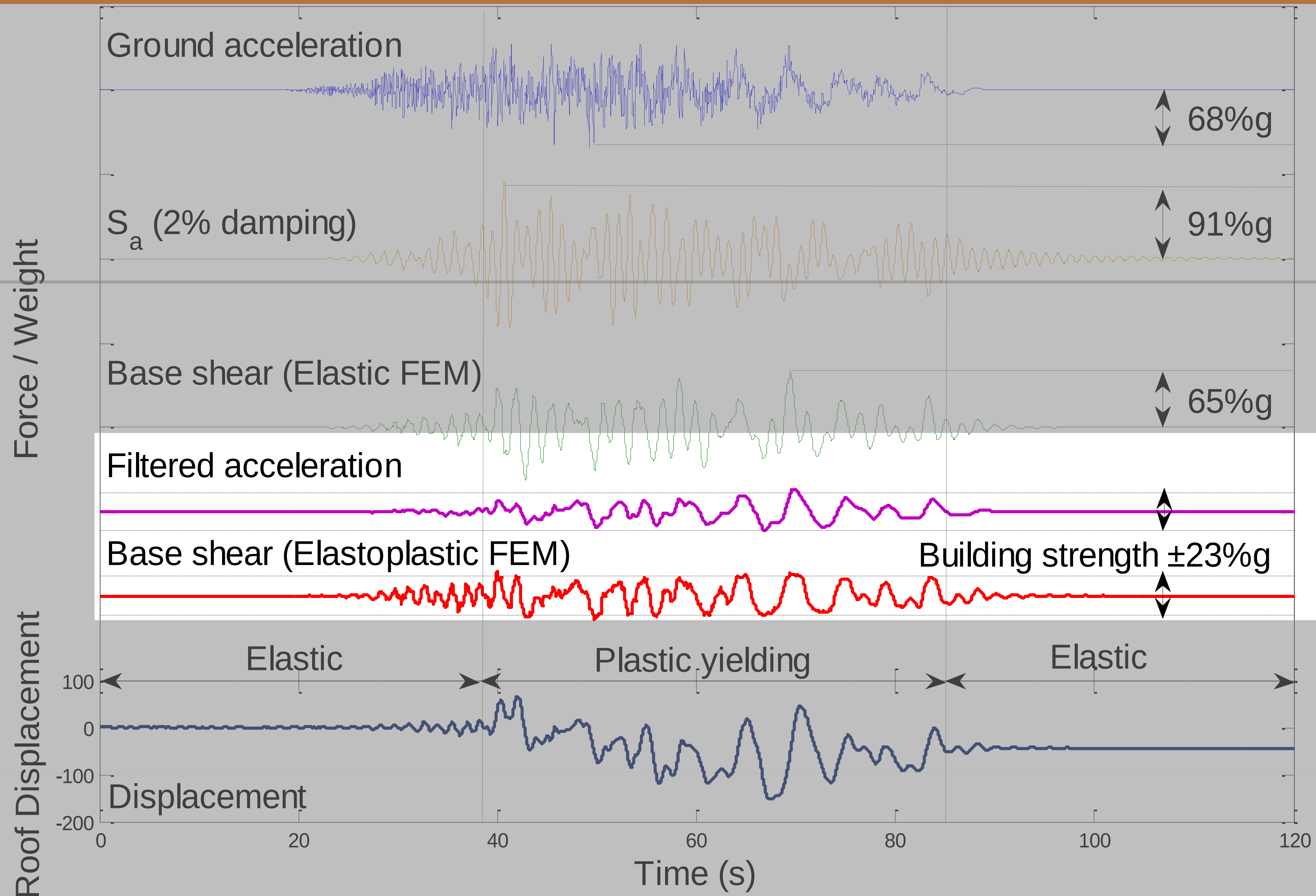
- Olsen, Heaton, and Hall (2014, Spectra)
- 64,000 synthetic ground motions
- Classify building response as "repairable," "not repairable," or "collapse"
- (PGD, PGV) better predictor of collapse than (S_a,ε)
- Ground motion must have large enough PGD *and* PGV to induce collapse

Collapse due to Sinusoidal Ground Motion

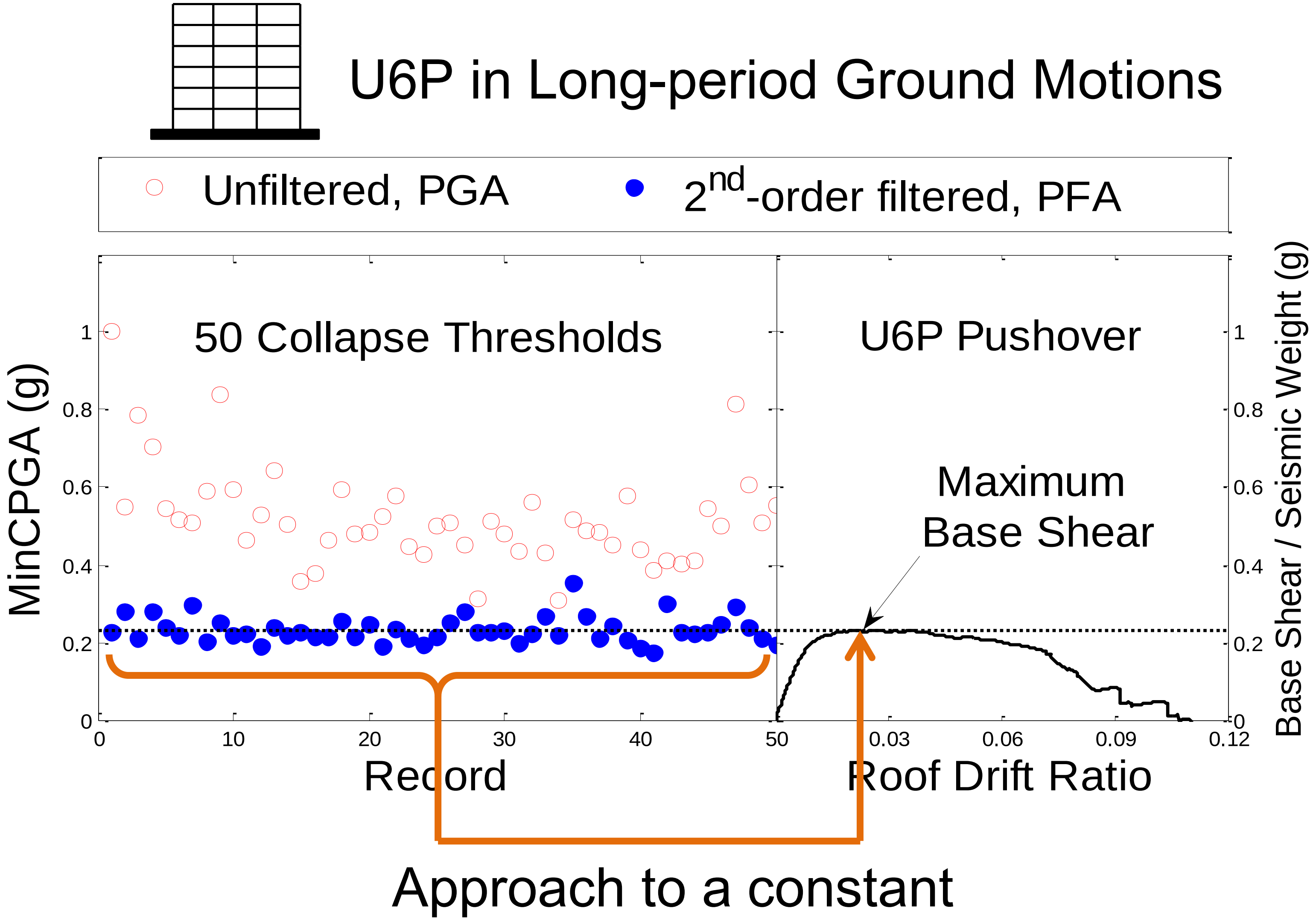


- Song (2014, Ph.D. Thesis)
- Incremental dynamic analysis (IDA) to find minimum amplitude of sinusoidal motion needed for collapse
- "Easier" to induce collapse with long period motion
  - We can low-pass filter ground motions to extract long-period components

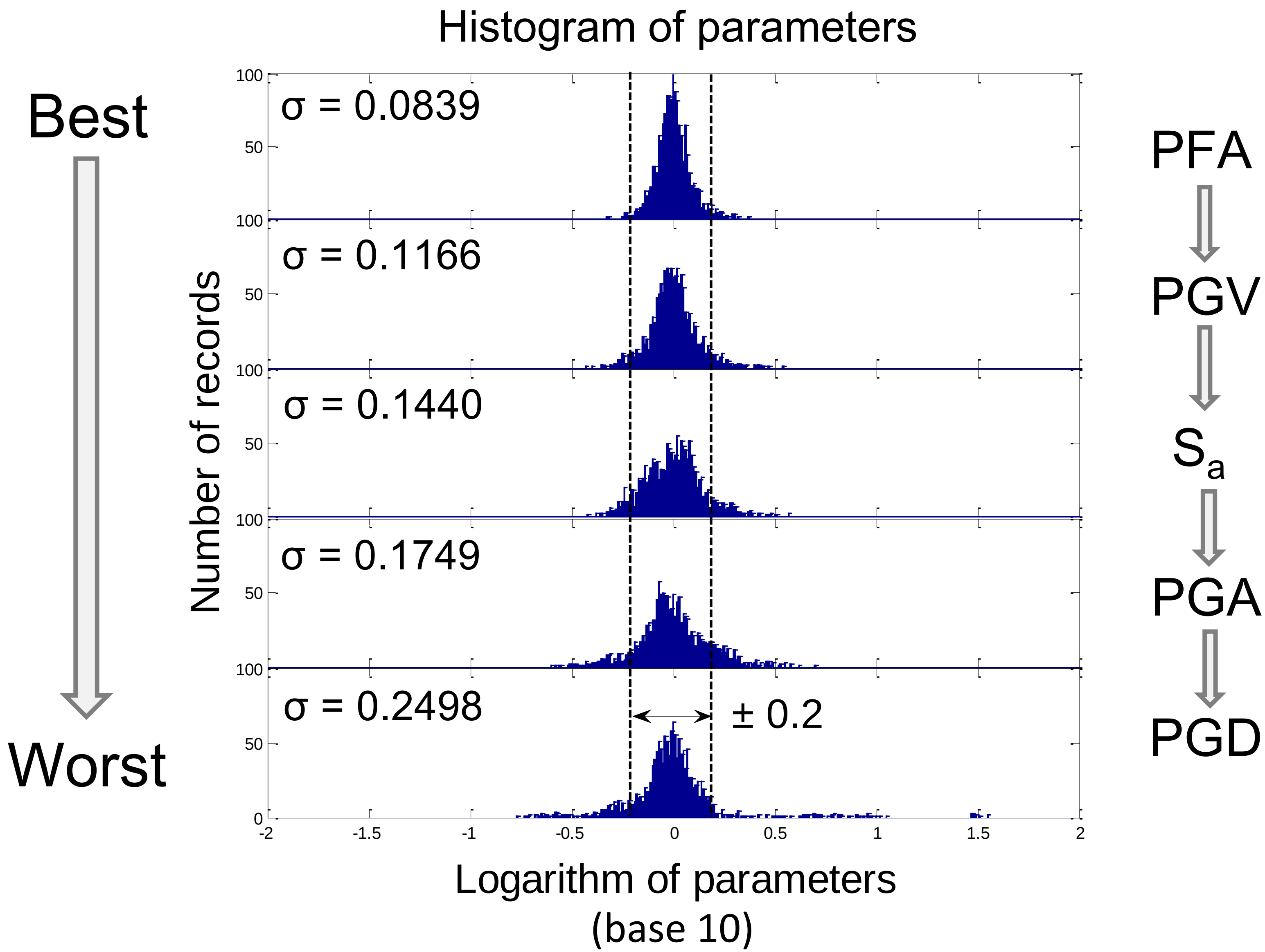
Filtered Acceleration and Base Shear



50 Records Scaled to Cause Collapse



Comparison to Traditional Ground Intensity Measures



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 unrepairable," 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.