Performance-Based Earthquake Engineering to Create Safe and Resilient Communities

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PEER

Stanford ENGINEERING | Blume Earthquake Engineering Center

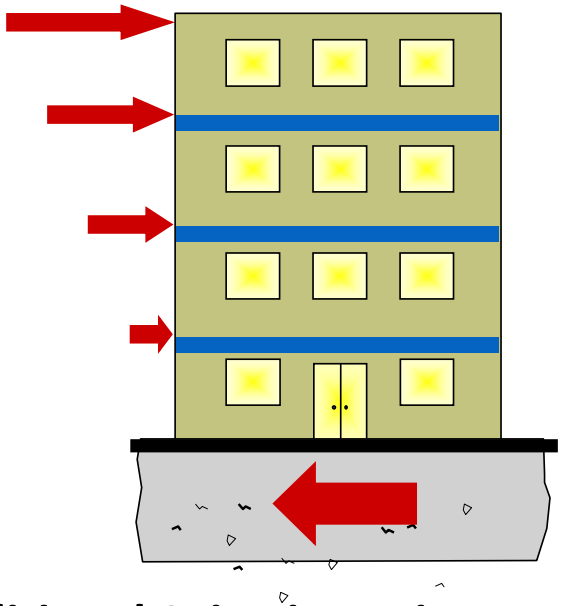
SimCenter NHERI
Center for Computational Modeling and Simulation

Evolution in Earthquake Engineering

1933 Long Beach

1971 San Fernando

1994 Northridge

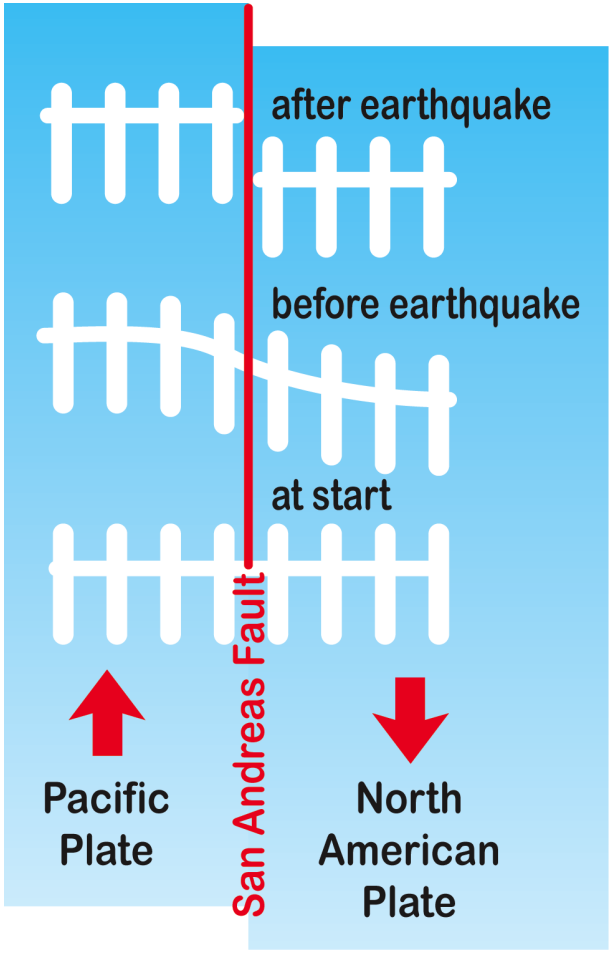


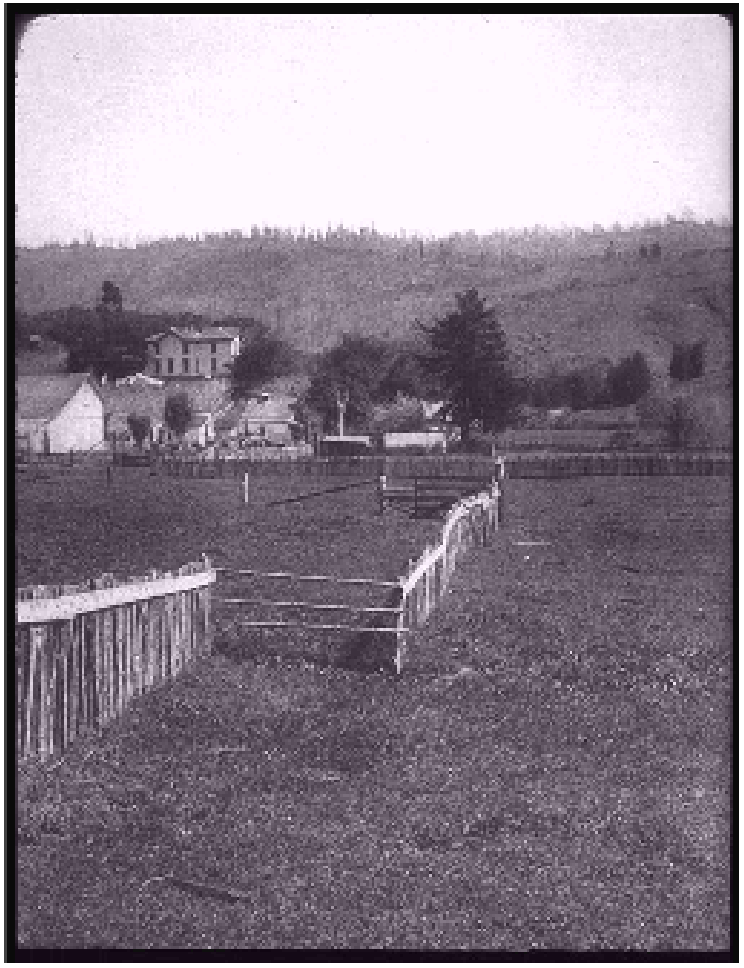
Traditional Seismic Design:

Equivalent lateral loads applied to simplified model of building system

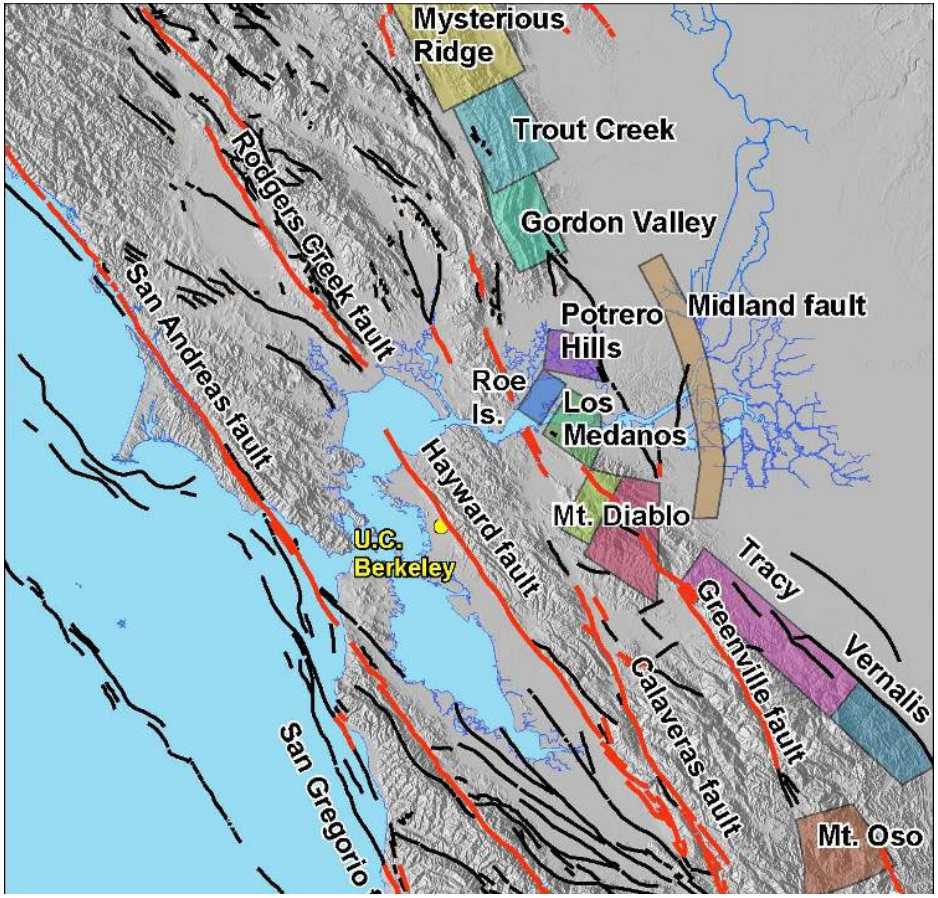
Intuitive basis in physics, but design requirements are highly prescriptive

H.F. Reid's (1910) "Elastic Rebound" Theory

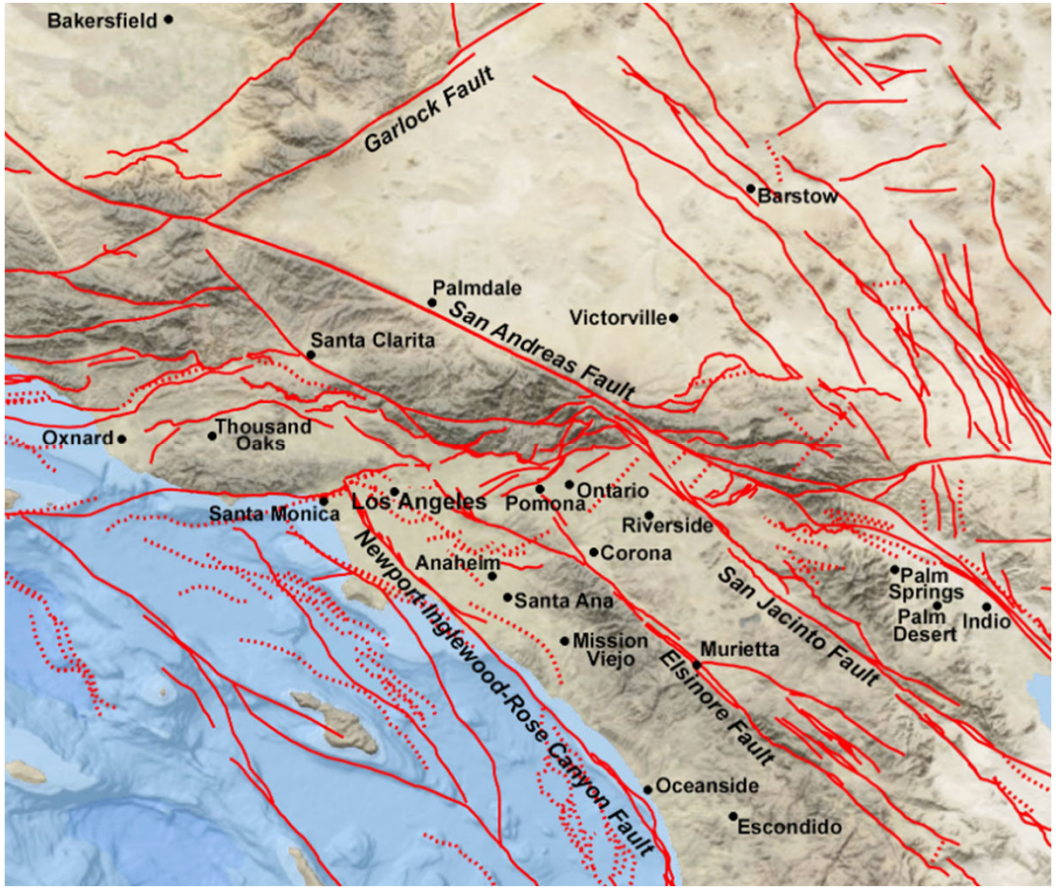




Earthquake Faults in California



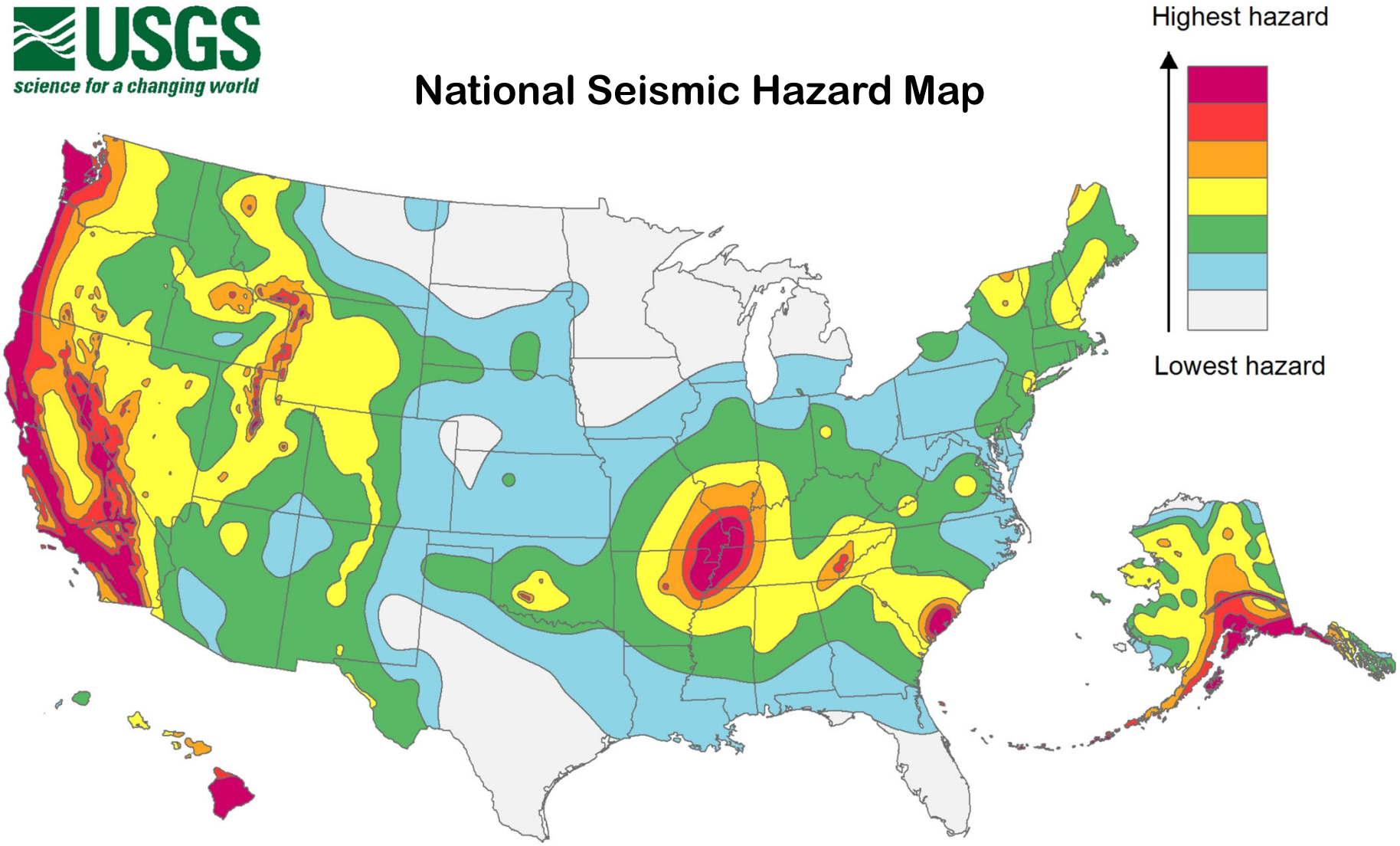
San Francisco Bay Area



Los Angeles Metropolitan Area

USGS
science for a changing world

National Seismic Hazard Map

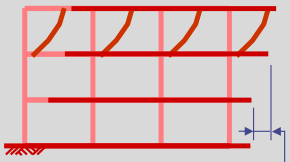


Performance-Based Engineering Framework

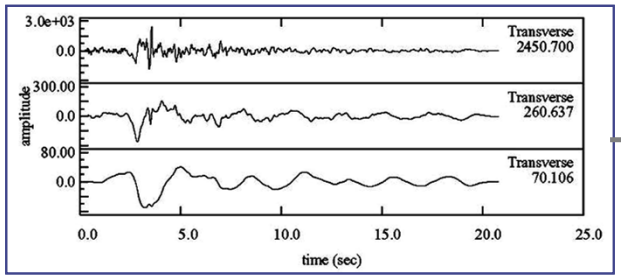
- Collapse & Casualties
- Direct Financial Loss
- Downtime

Consequence

Building Damage



Structural Response

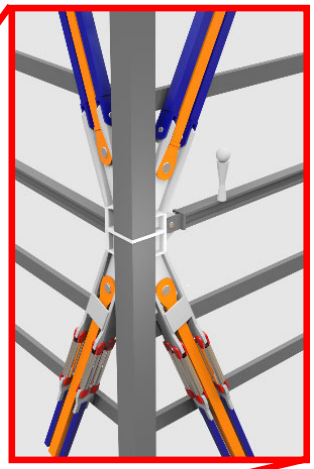


Intensity Measure

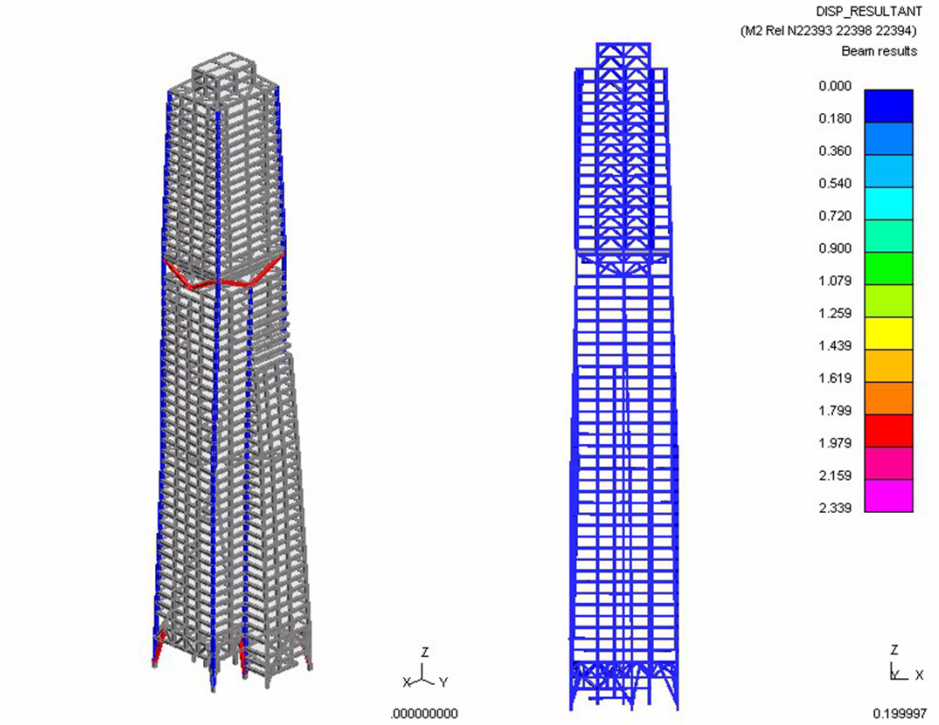
Moehle/PEER

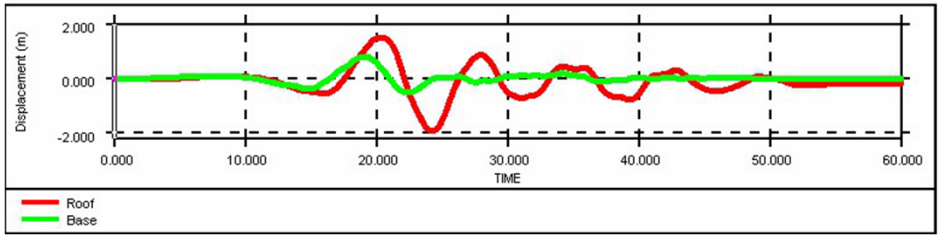
Seismic Response of Tall Buildings

181 Fremont Building

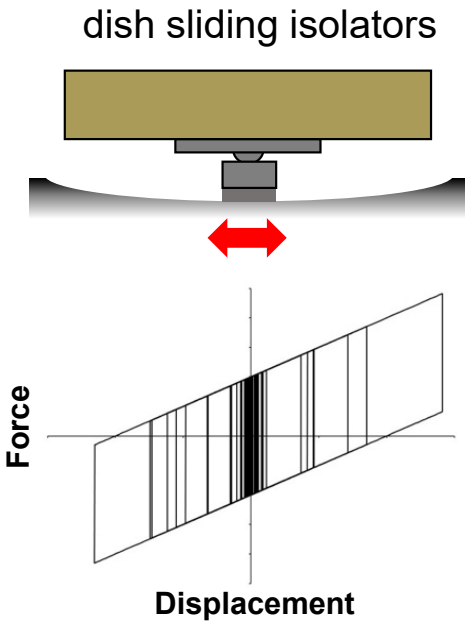


Energy dissipating ductile steel braces and oil dampers

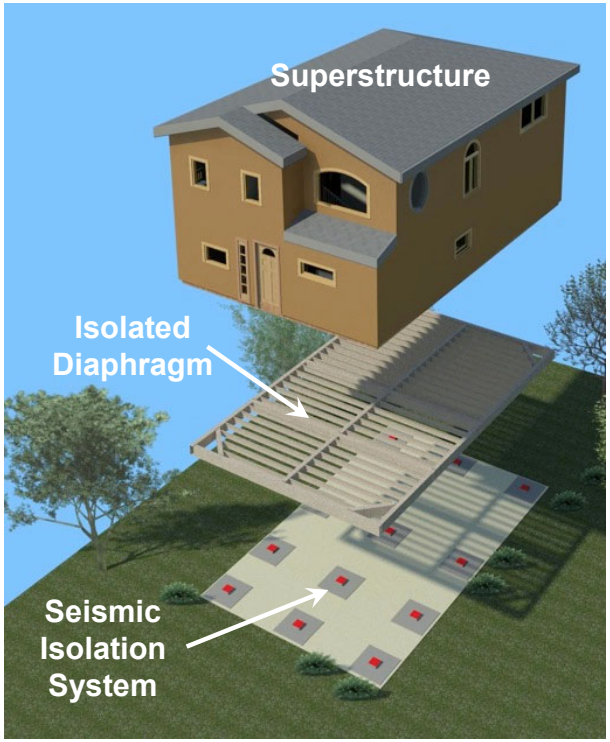




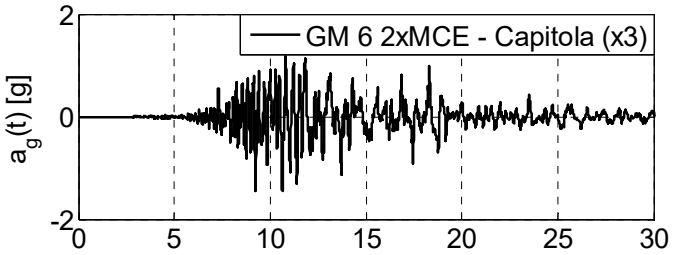
Low-Cost Seismic (Base) Isolation for Housing



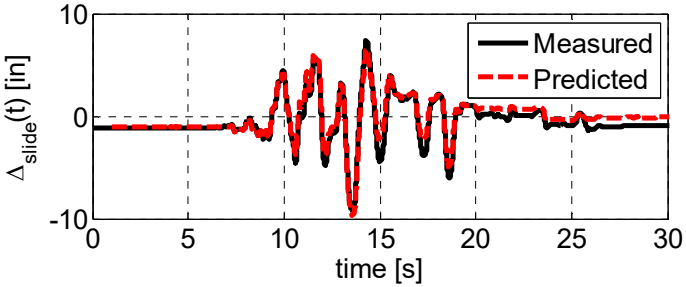
friction μ ~ 0.20
dish radius = 2 m (80 in)



Sliding Dish Isolators on Foundation

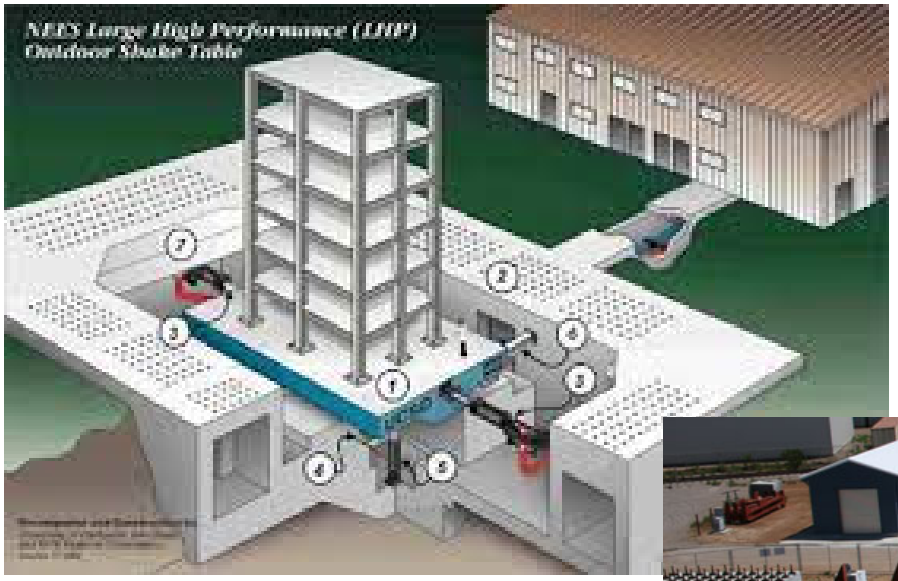


EQ Ground Acceleration



Isolator Sliding Displacement

Earthquake Simulator (Shake Table)



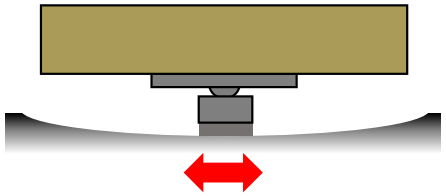
Outdoor Shake Table

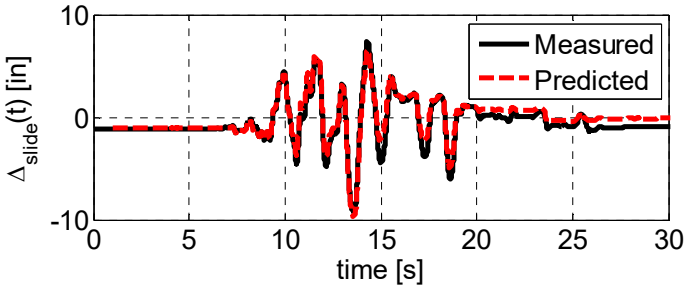
Plan Dimension: 8 x 12 meter

EQ Stroke: +/- 0.75 meter

NHERI@ UCSan Diego

dish sliding isolators





Isolator Sliding Displacement

Wood-Frame House Risk Mitigation

Economic Benefits/Incentives of Foundation Wall Retrofit

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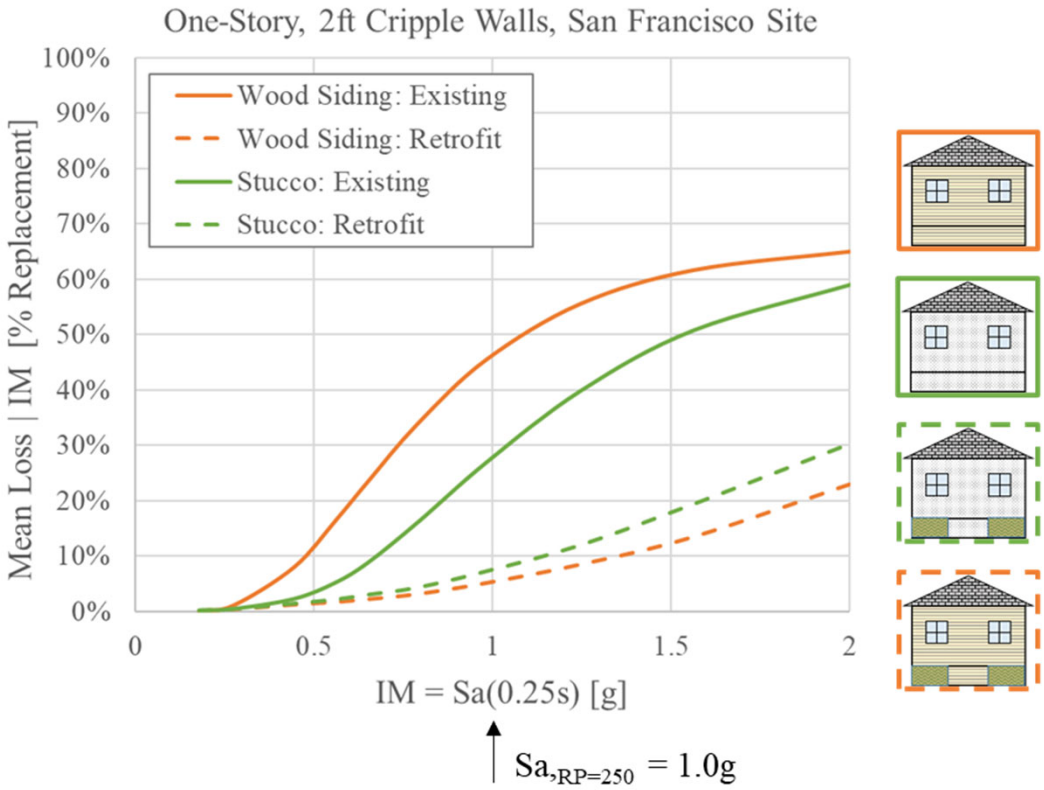
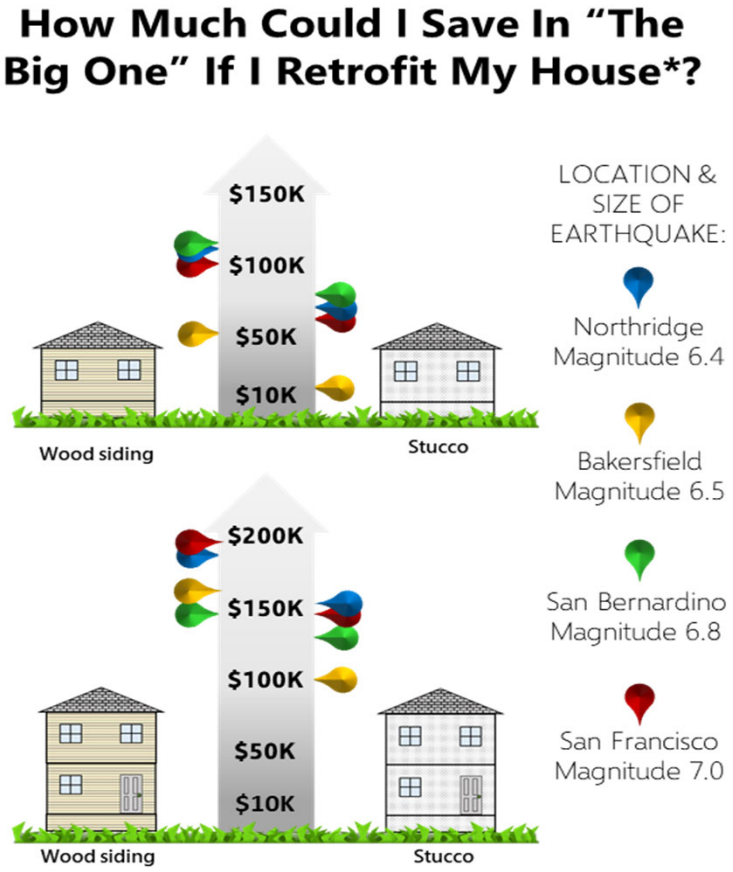
Wood-Frame House Risk Mitigation



Loss versus Earthquake Intensity



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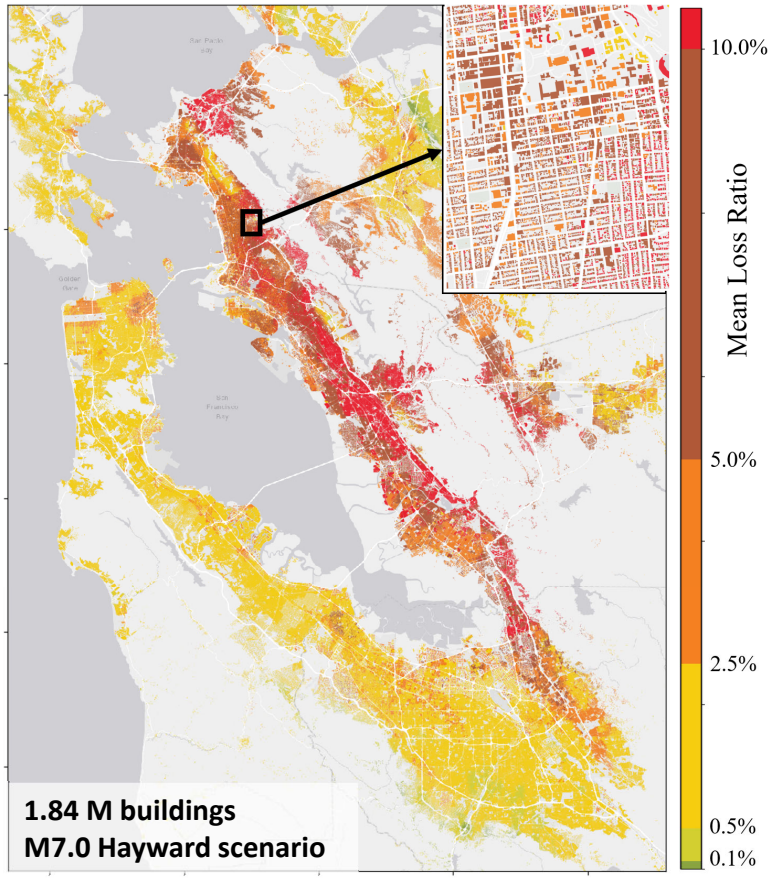
San Francisco Bay Area M7.0 Earthquake Testbed

- **M7.0 Hayward simulation (LLNL-SW4)**
- **1.84 M individual buildings**
- **Parcel-level inventory enhanced by AI tools**
- **Building Evaluations**
  - *HAZUS building configurations*
  - *OpenSees MDOF (story shear) models*
  - *25 pairs of ground motions*
  - *HAZUS story-level damage functions*
  - *modeling uncertainty*
- **DesignSafe HPC (Stampede2)**
  - *16 hr runtime on 12,800 cores*



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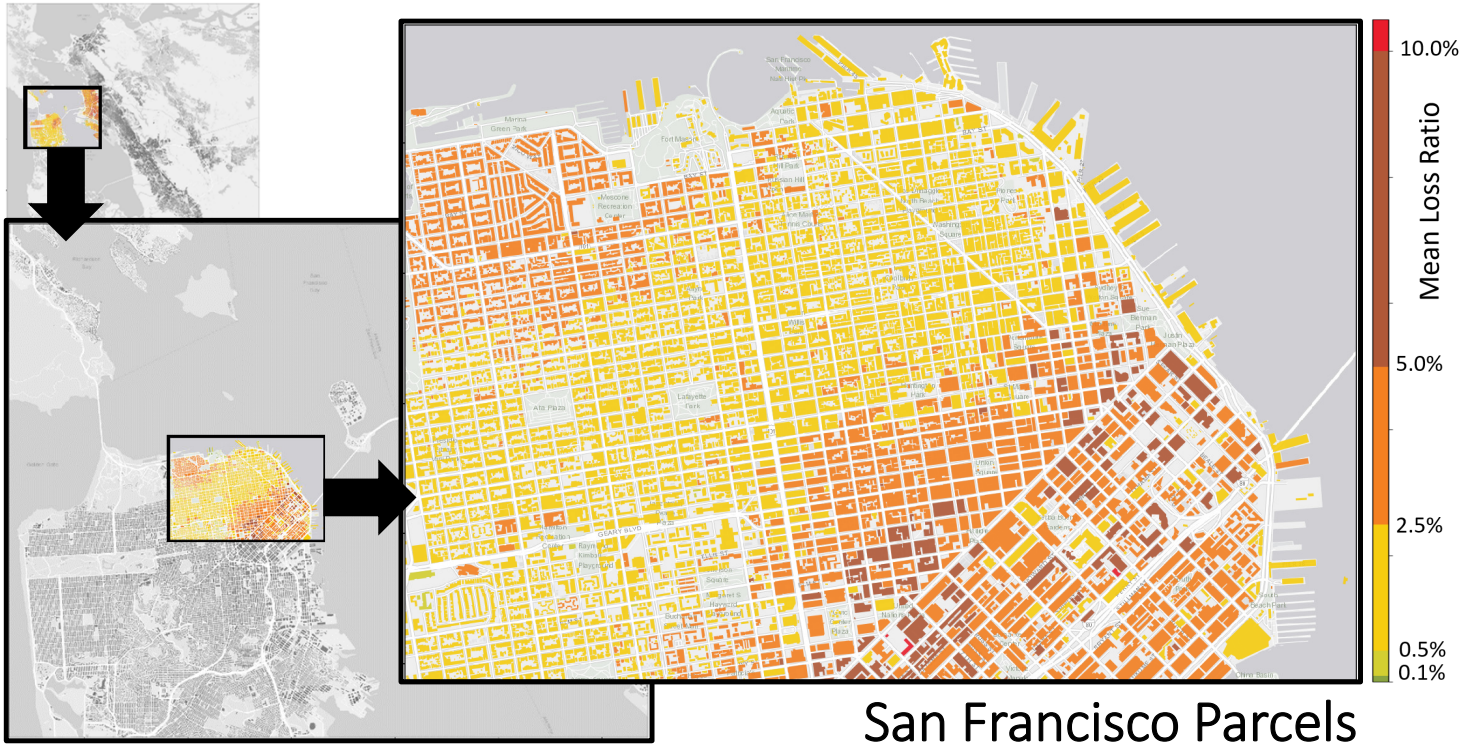
San Francisco Bay Area M7.0 Earthquake Testbed

High Resolution Modeling: Parcel-level resolution enables unprecedented quantification of *engineered interventions for policy level decisions*



San Francisco Parcels

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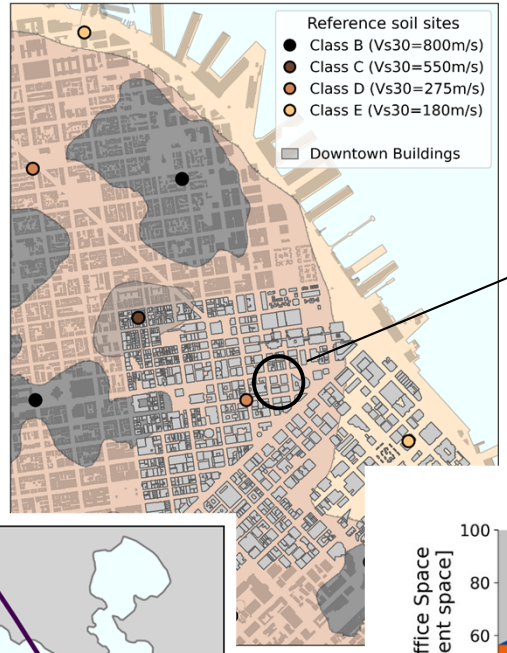
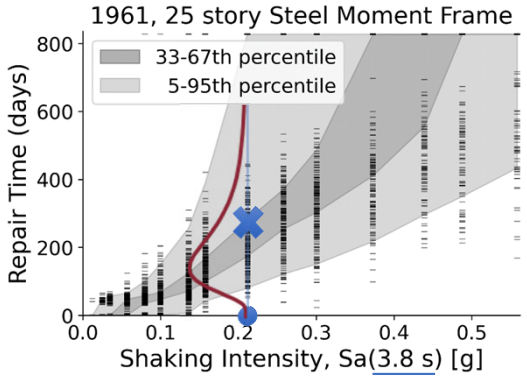
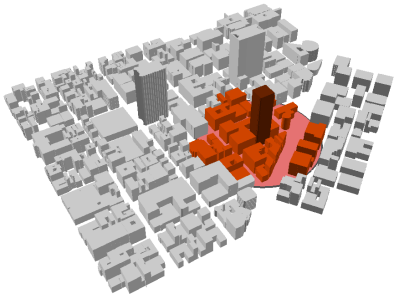
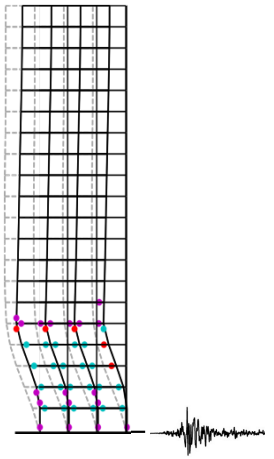
San Francisco Downtown Recovery

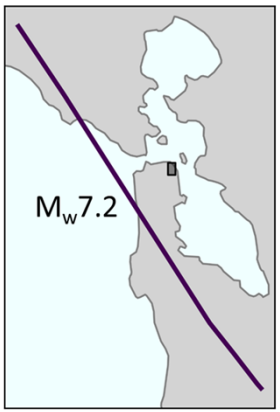


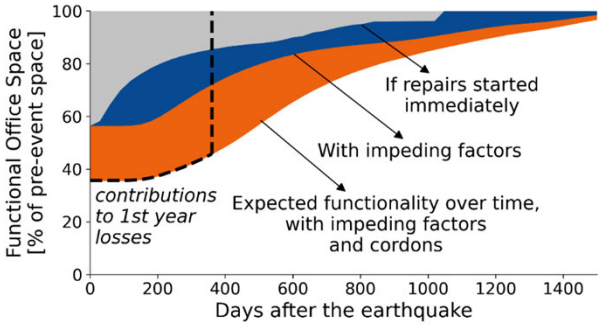






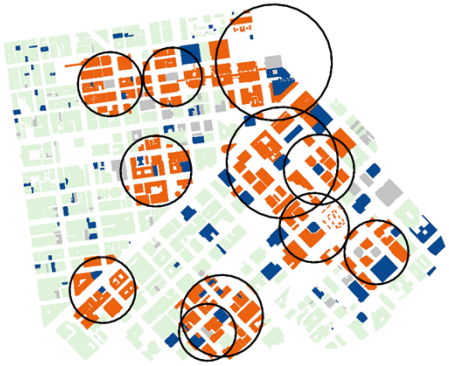
Influence of Tall Building Cordons on Recovery





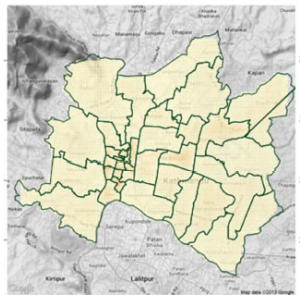
Recovery of Office Space

4 months



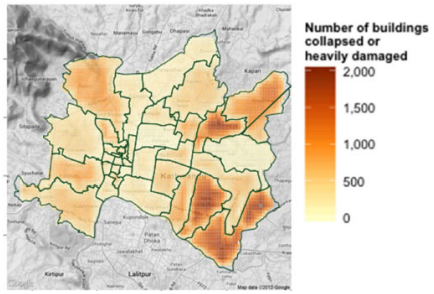
12 months

Urban Risk Forecasting

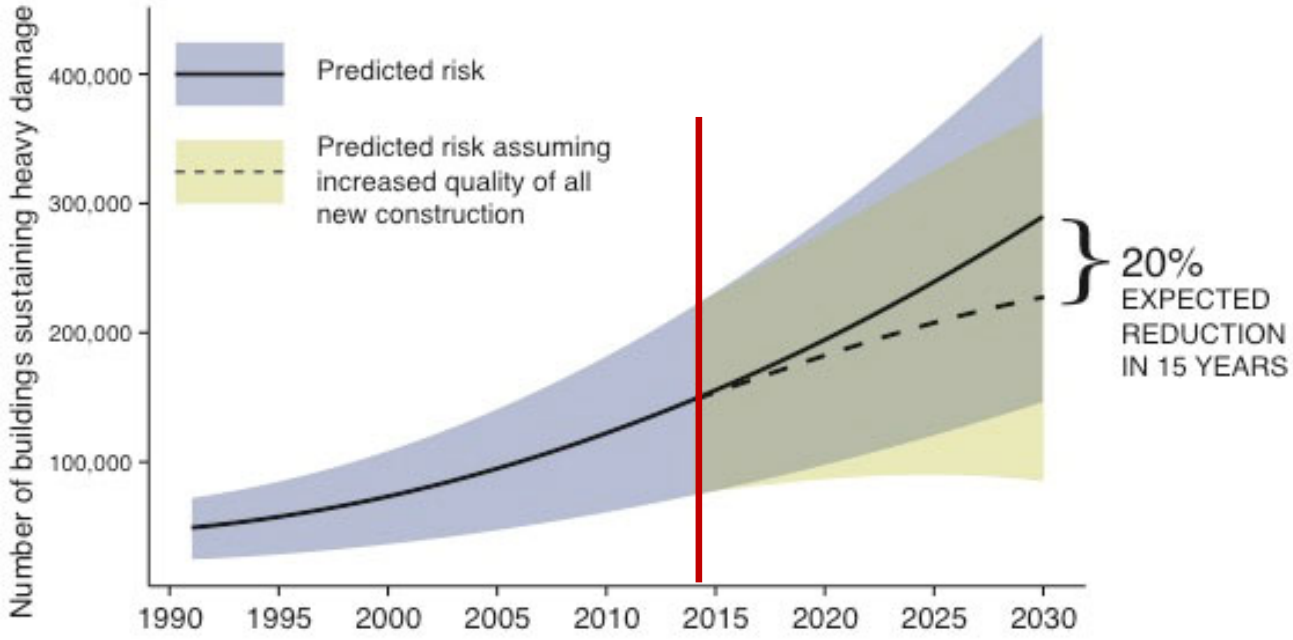


1991 Inventory

2010 Inventory (est)



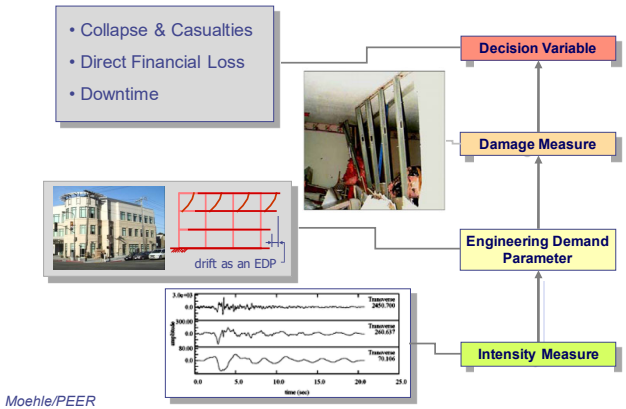
2020 Inventory (est)



Urban Growth & Evolving Risk (Kathmandu, Nepal)

Lallemant, D., Wong, S., Morales, K., Kiremidjian, A. (2014), "A Framework and Case study for Urban Seismic Risk Forecasting," *Proc.10NCEE, Los Angeles.*

Engineering a Resilient Future



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