

Regional-scale earthquake simulations with the DOE EQSIM framework and action items from the 2021 PEER Pacific Rim Forum

PEER – LBNL workshop

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U.S. DEPARTMENT OF
ENERGY

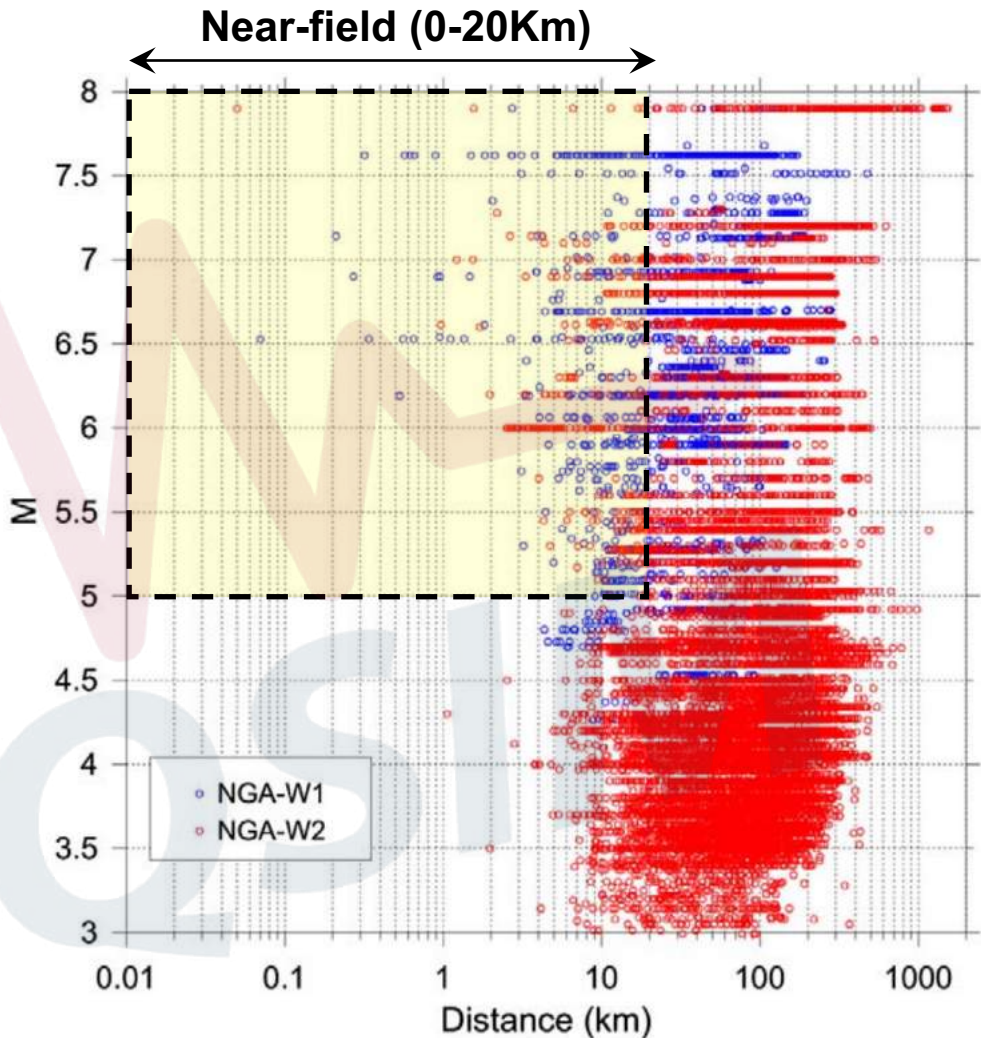
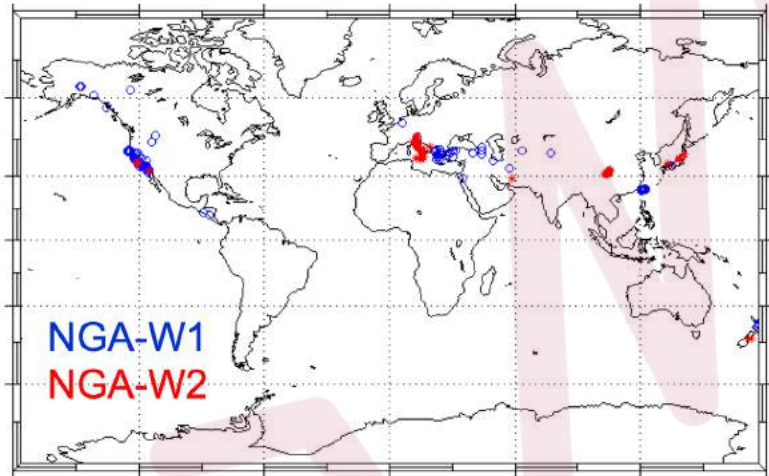
Office of
 Cybersecurity, Energy Security,
 and Emergency Response



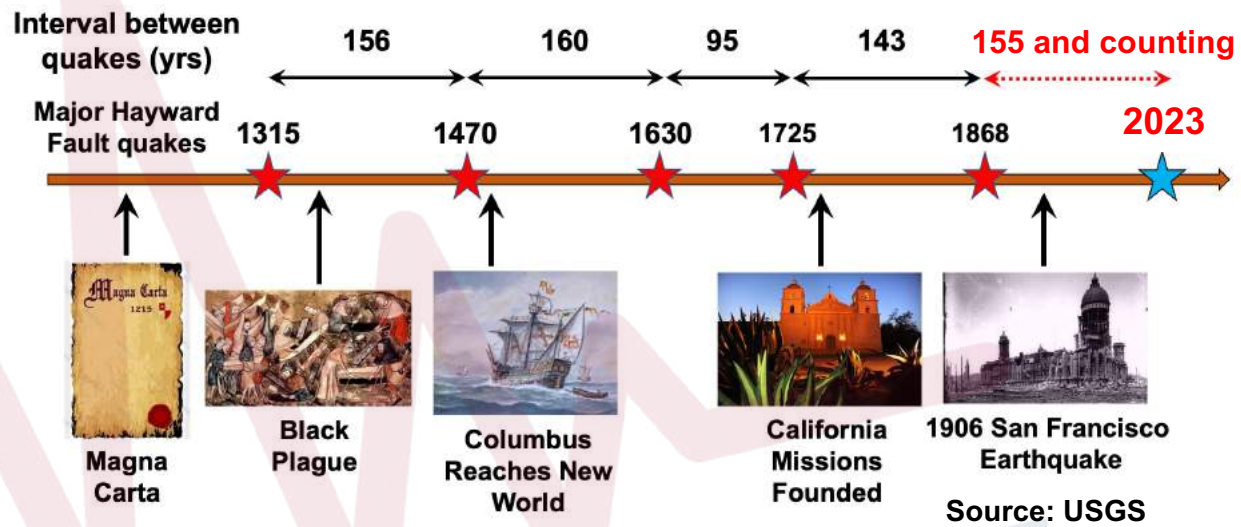
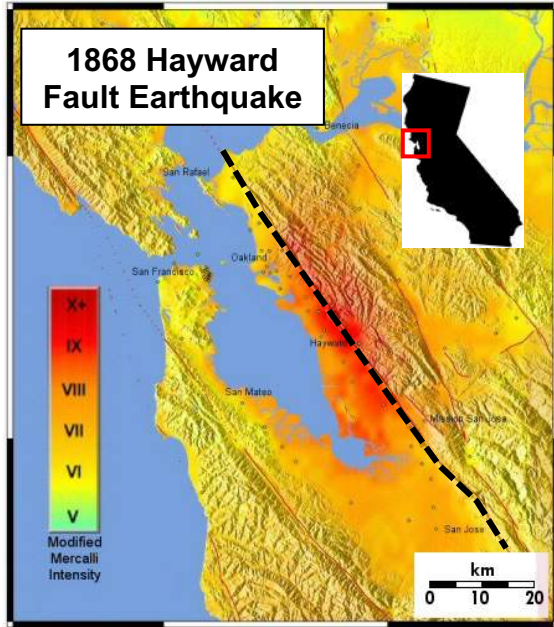
Challenges to characterizing earthquake hazard – empirical models based on sparse data



World-wide
Strong Motion Database

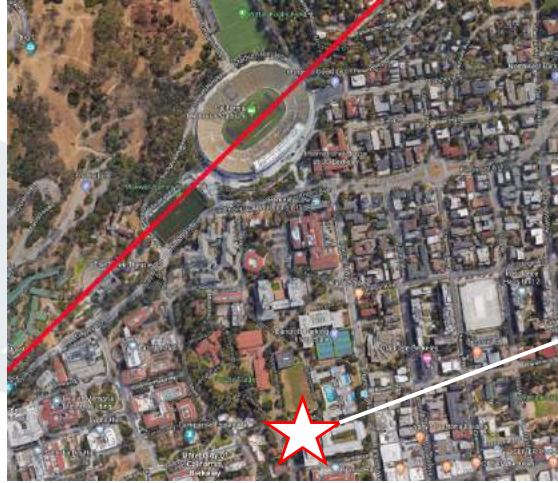


For the San Francisco Bay Area, historical strong motion data from large events doesn't exist



Today

1868



You are here!

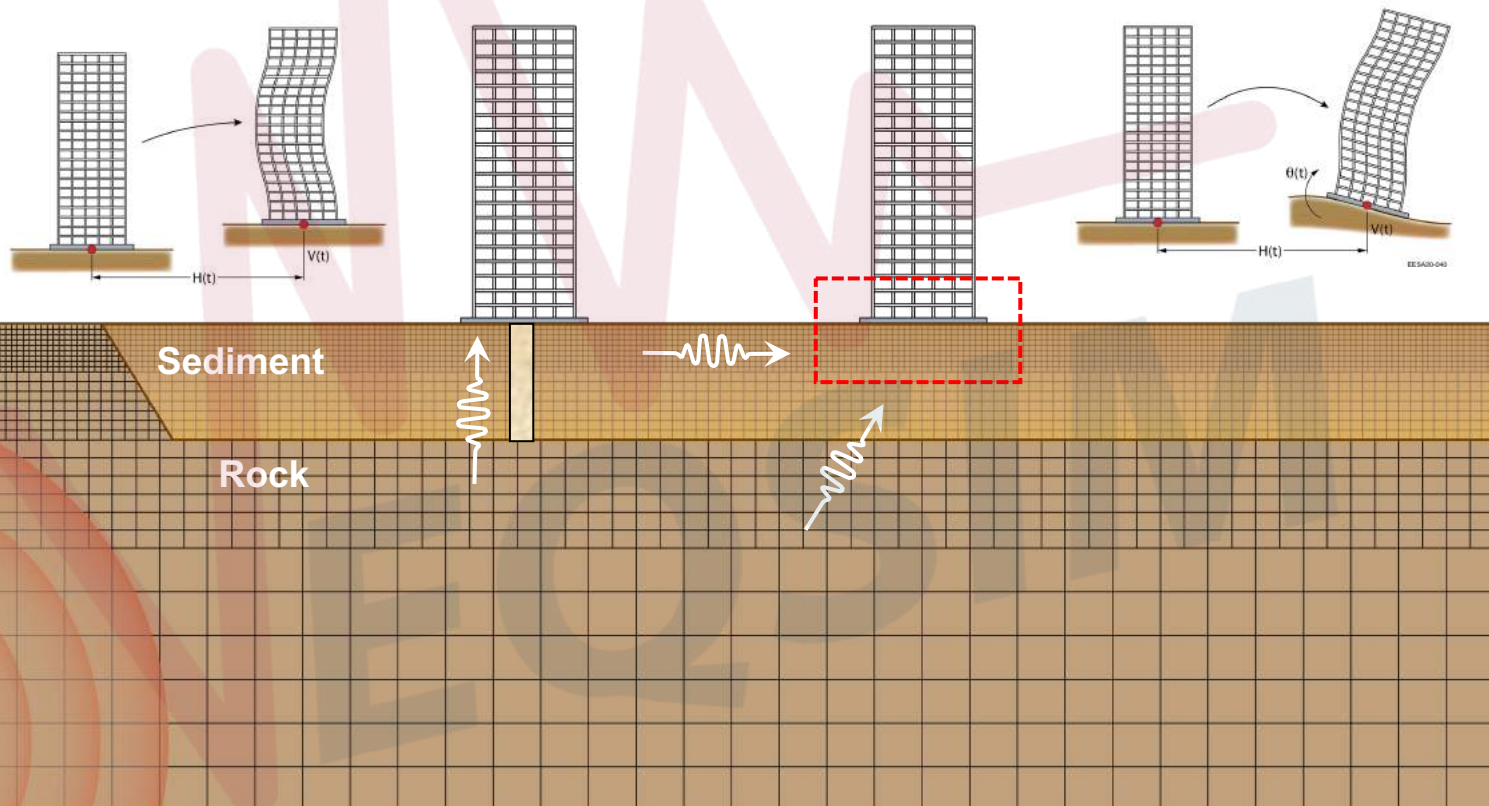
Challenges to characterizing earthquake risk – process models that may not be representative

1-D site response

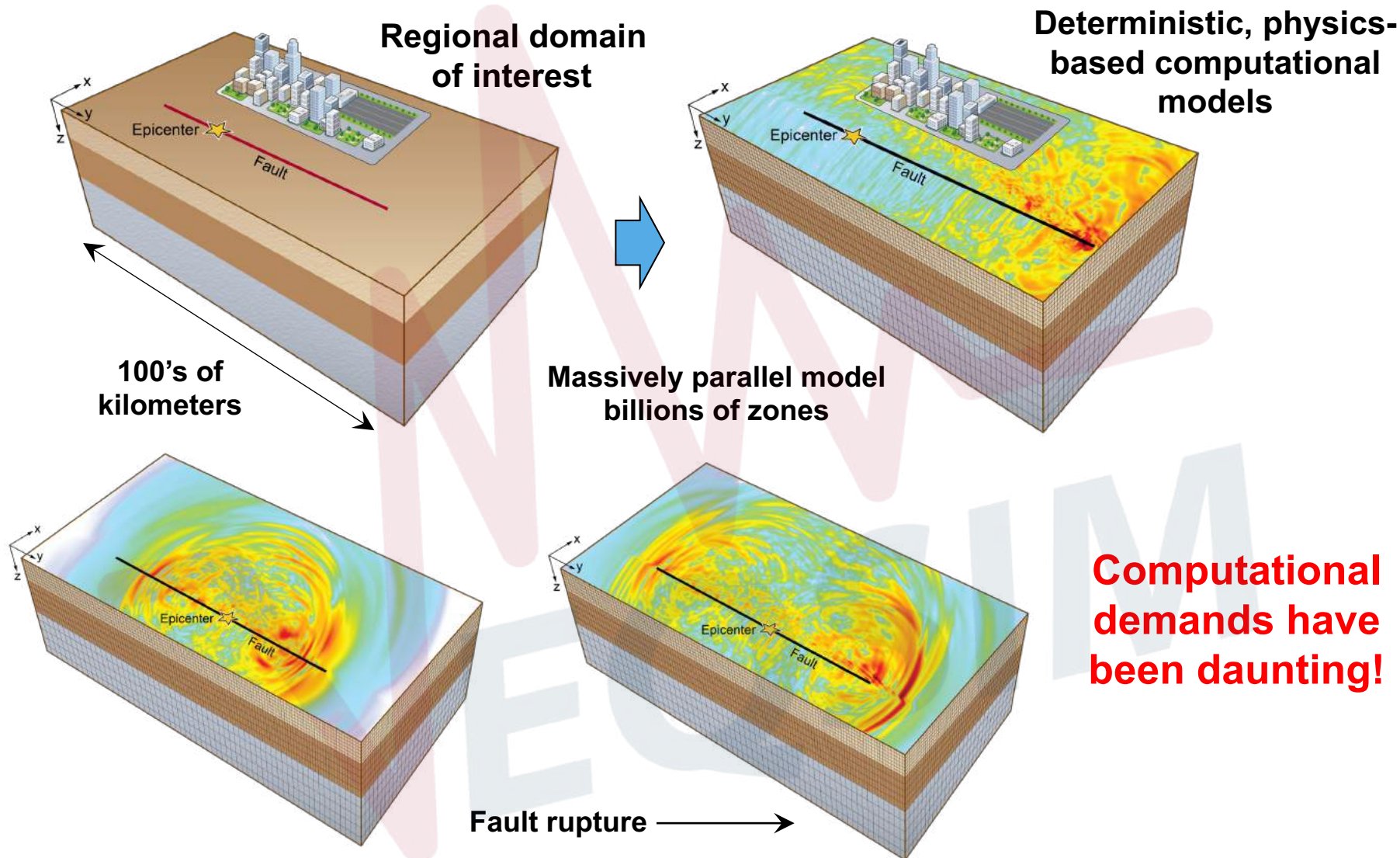
- Assume vertically propagating waves
- Pure translational motion
- Uniform particle motion across the base of the structure

3-D site response

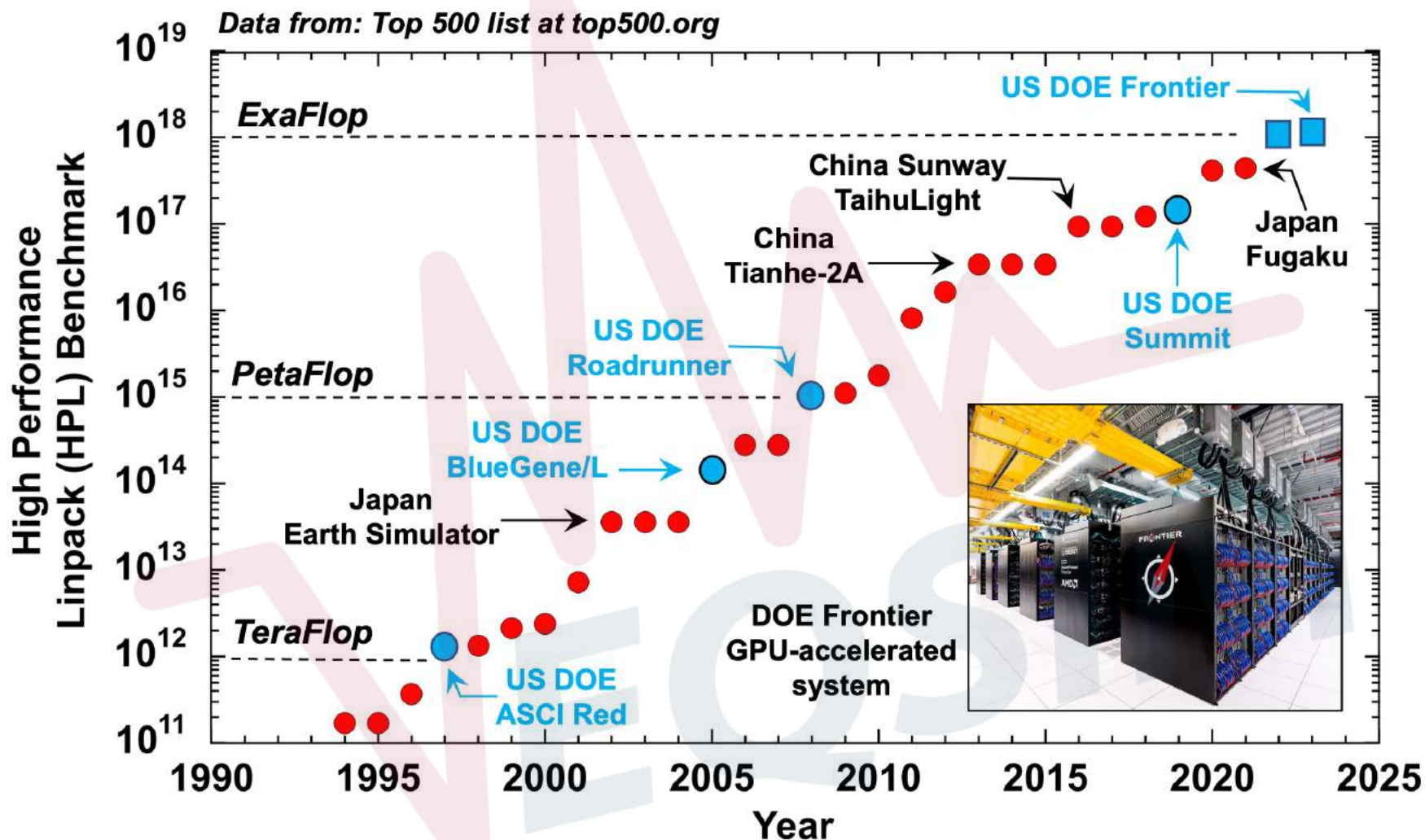
- Surface waves
- Inclined body waves
- Ground translations plus rotations
- SSI



Interest has been rapidly growing in physics-based regional-scale earthquake simulations



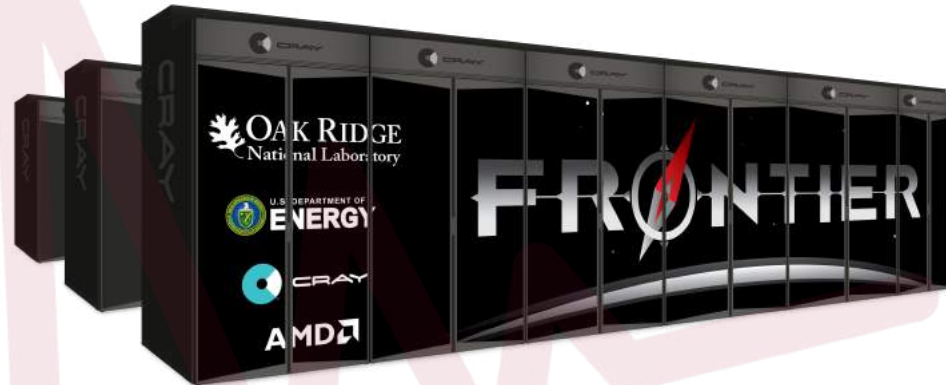
DOE's emerging GPU-accelerated systems are making extreme regional simulations tractable



We are finally getting computers big enough and fast enough to solve this problem

1 Exaflop = 1,000,000,000,000,000,000 a billion-billion operations per second

FRONTIER
Oak Ridge National Lab



AURORA
Argonne National Lab



If each person on earth completed one calculation per second, it would take more than four years to do what an exascale computer can do in one second

The DOE Exascale Computing Project has been preparing to fully exploit a billion-billion FLOPS

Three parallel components of the Exascale program...

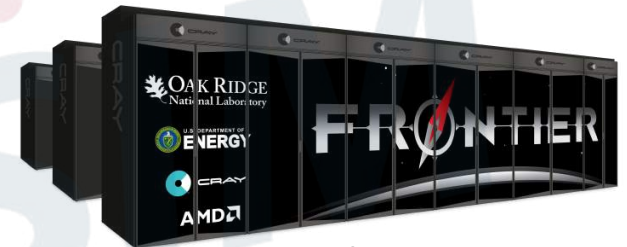


Supporting software stack for the Exascale computational ecosystems

Selected science applications (24) for Exascale platforms

Advanced computer hardware at the Exascale

— Developing the computational ecosystem —>



2017

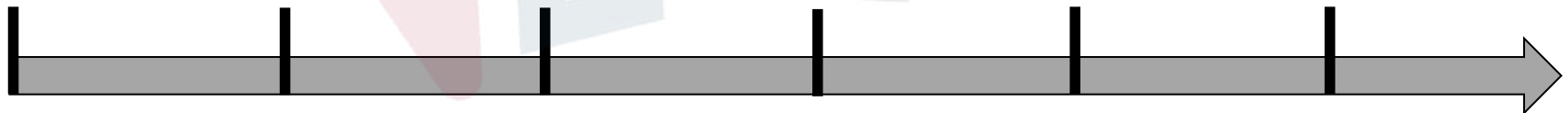
2018

2019

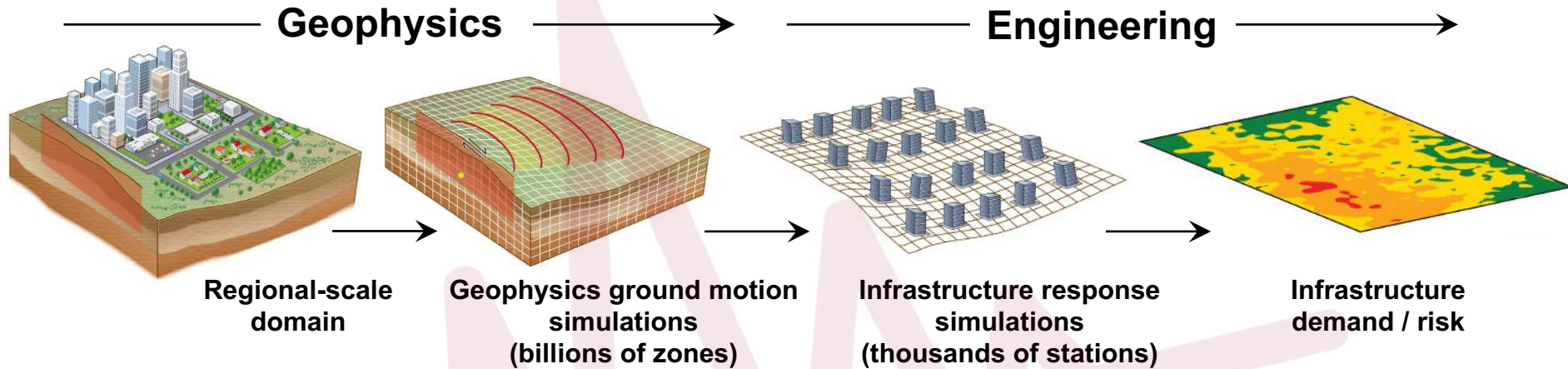
2020

2021

December 31, 2023

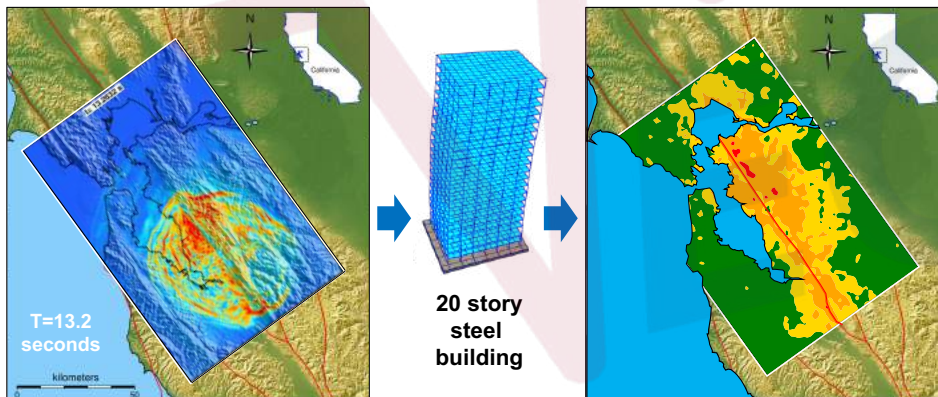


The DOE's EarthQuake SIMulation (EQSIM) application for fault-to-structure simulations

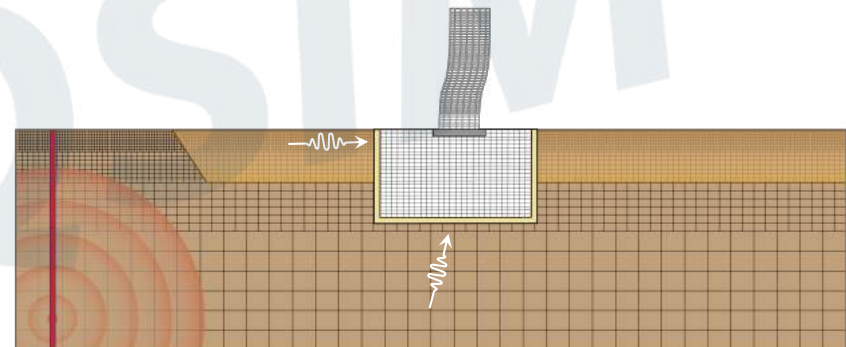


Key questions that can be addressed...

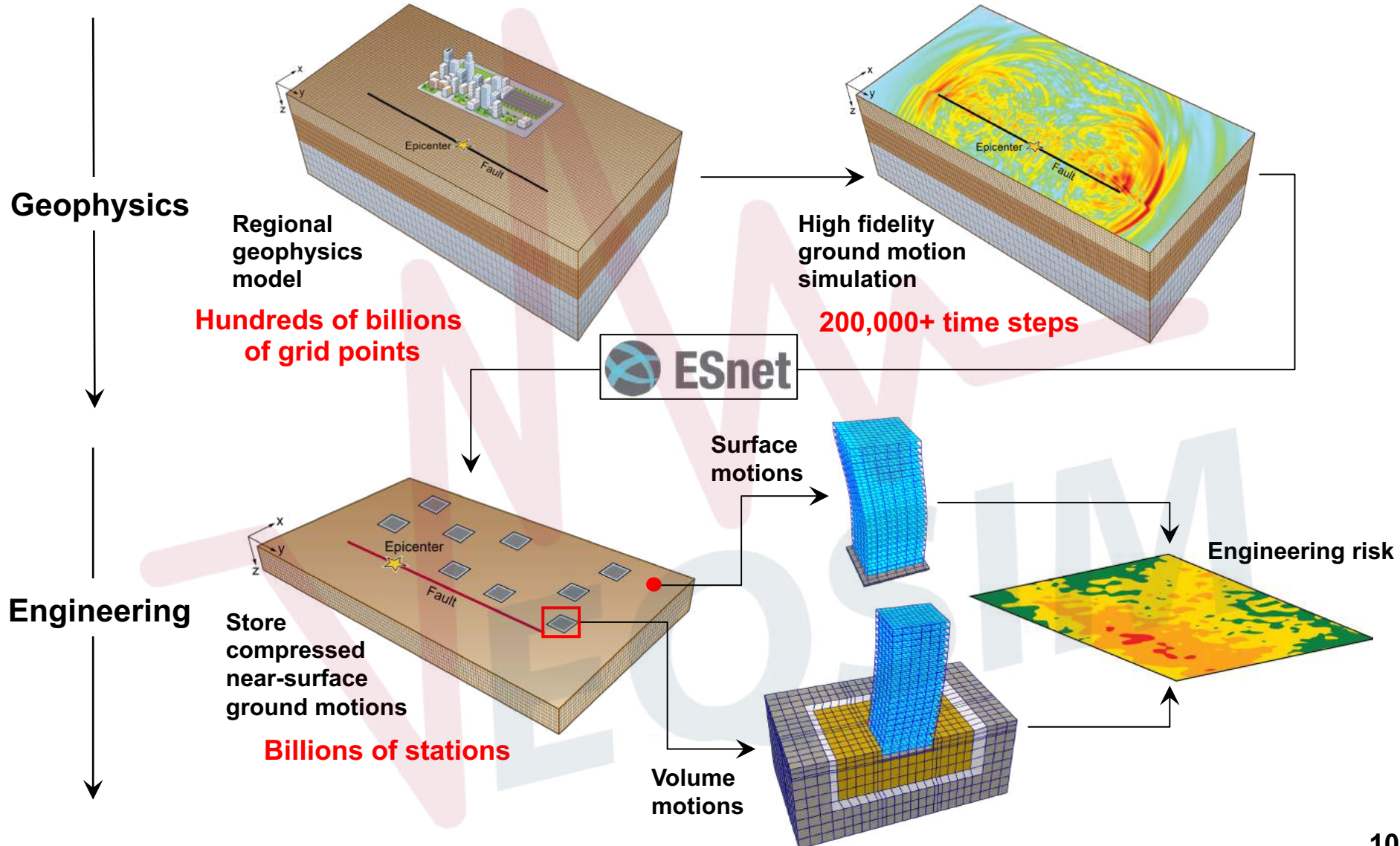
What is the regional distribution of ground motions and associated infrastructure response?



How do complex (realistic) incident seismic waves interact with infrastructure?

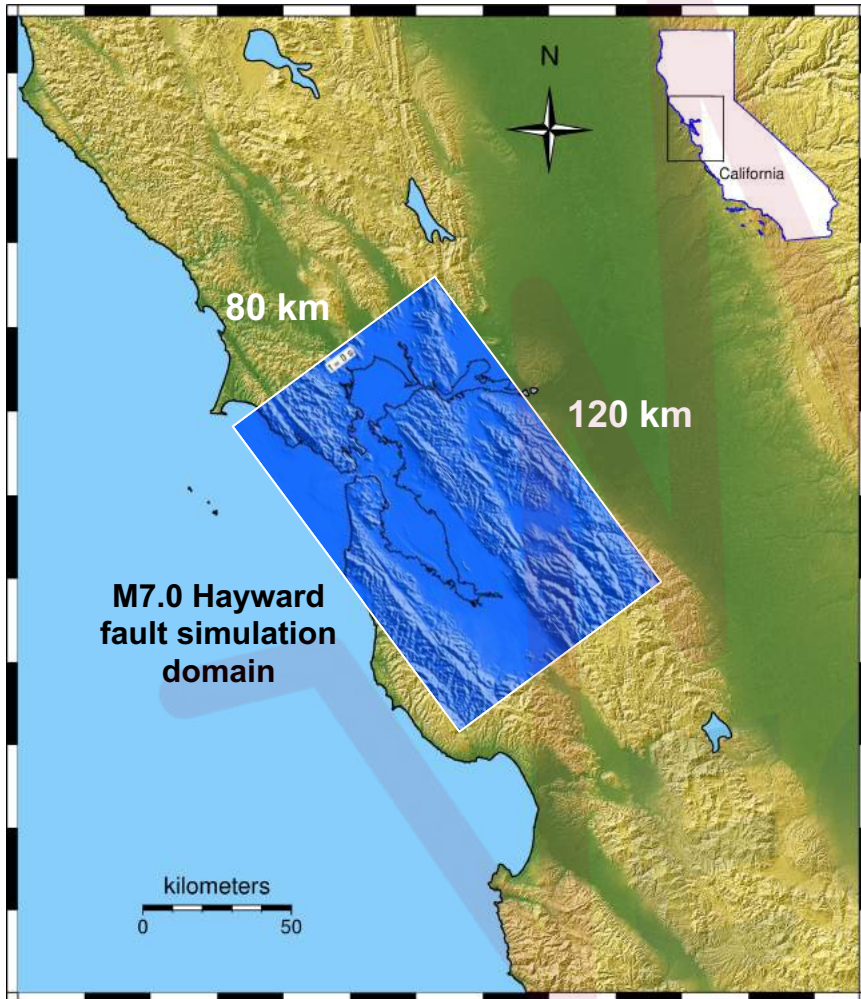


Six years have focused on developing advanced algorithms and fault-to-structure workflow



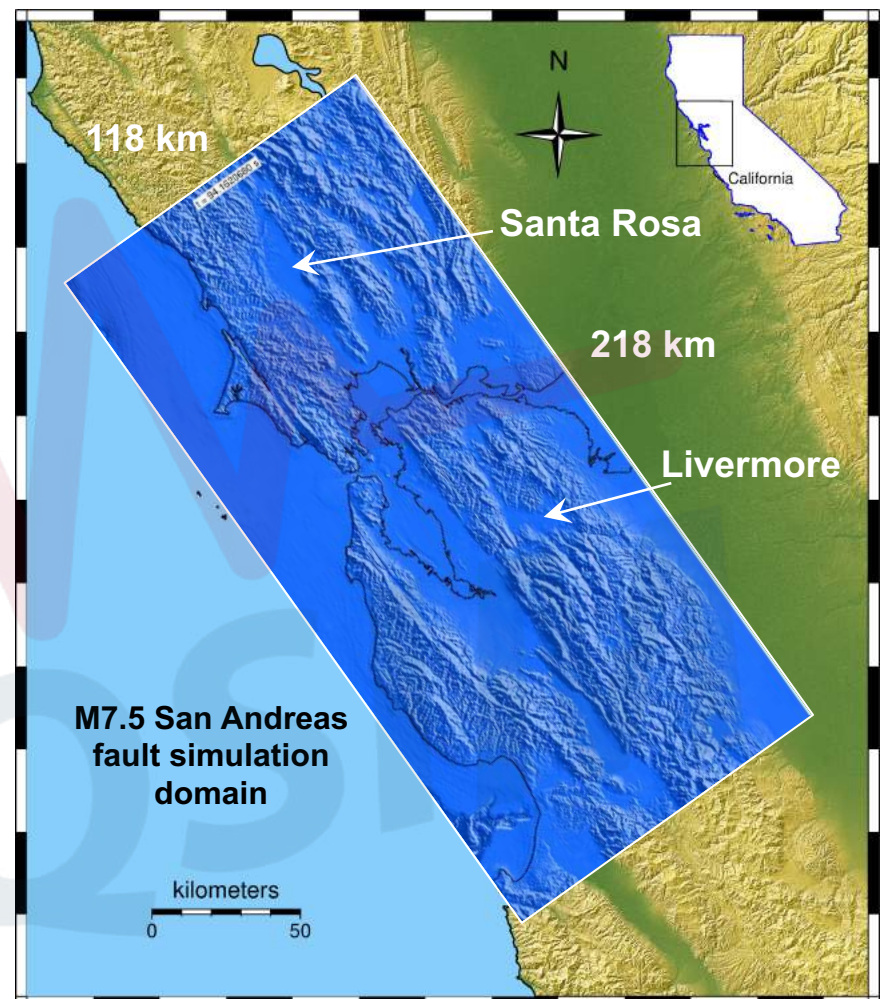
Exaflop computers provide unprecedented potential for fast, high-fidelity simulations

M7 Hayward realizations



5 Hz - 3 hours run time


M7.5 San Andreas realizations



5 Hz - 18 hours run time

The PEER 2021 Pacific Rim Forum helped frame an application roadmap for simulated motions

PEER Pacific Rim Forum
June 2021



PACIFIC EARTHQUAKE ENGINEERING
RESEARCH CENTER

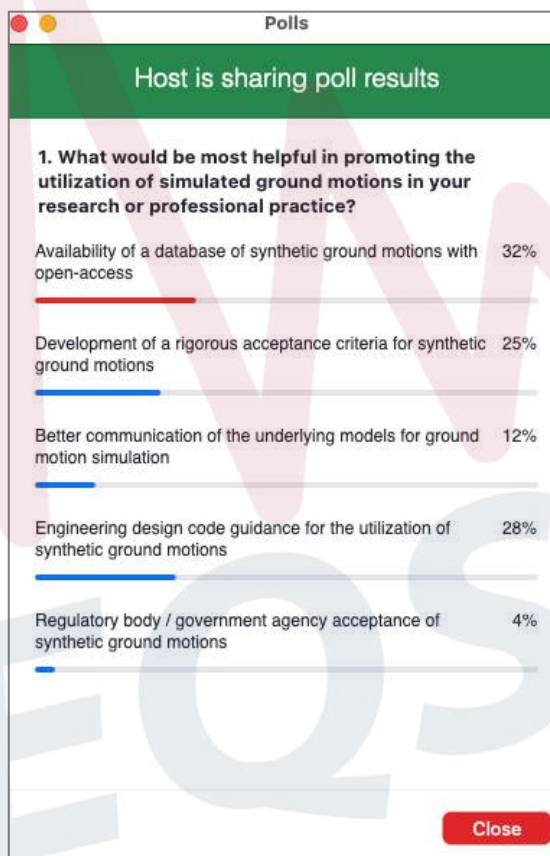
The PEER International Pacific Rim
Forum 2021: Regional-Scale Simulations
of Earthquake Ground Motions and
Infrastructure Response for
Performance-Based Earthquake Engineering

David McCallen
Floriana Petrone
Elnaz Esmailzadeh Seylabi
Arben Pitarka
Norman Abrahamson
Sherif Elfass

PEER Report No. 2022/04
Pacific Earthquake Engineering Research Center
Headquarters at the University of California, Berkeley
July 2022

PEER 2022/04
July 2022

261 International Participants
41 International Speakers



Attendees voted on
priorities

#1

Availability of a
database of synthetic
motions with open-
access

#2

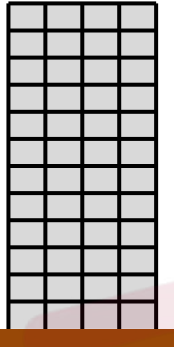
Engineering design
code guidance for
synthetic motion
utilization

#3

Development of
rigorous acceptance
criteria for synthetic
motions

Creating the database

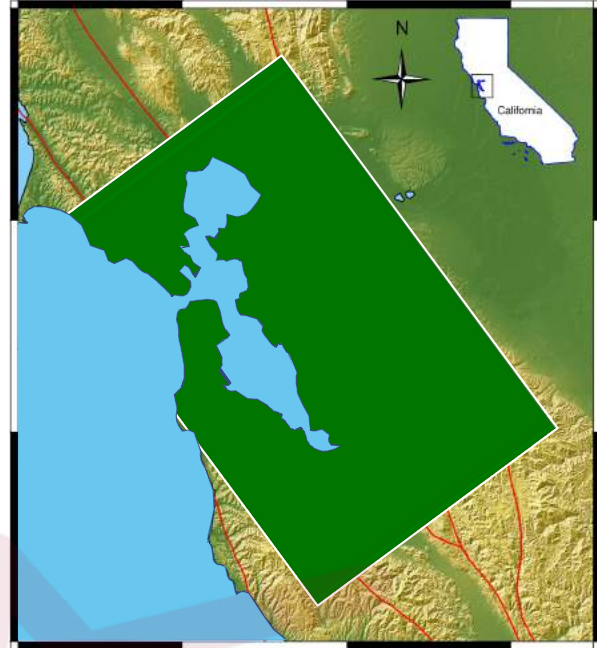
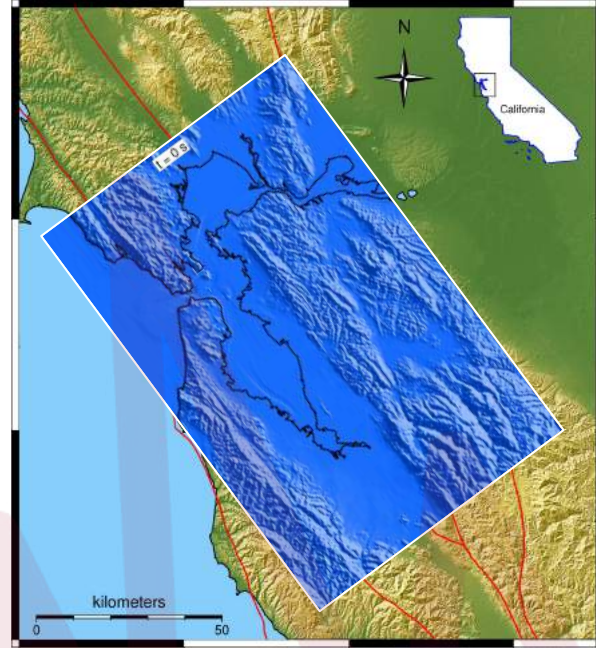
25 realizations of a M7 Hayward fault event have been generated (Inter-event variability example)



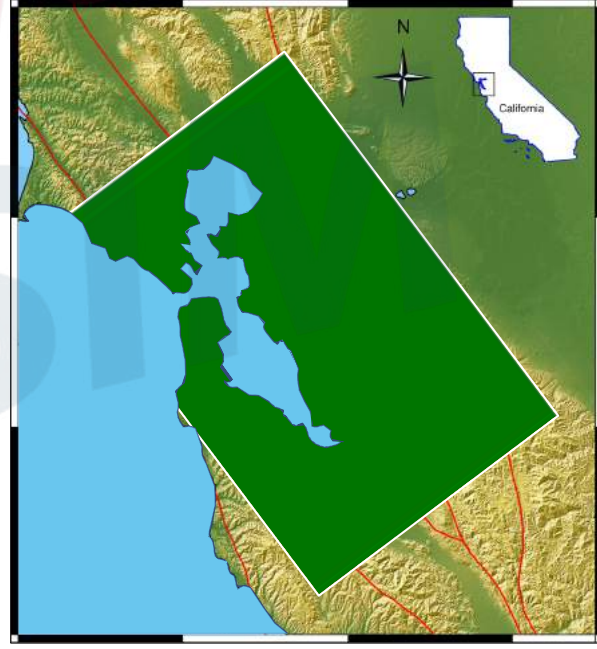
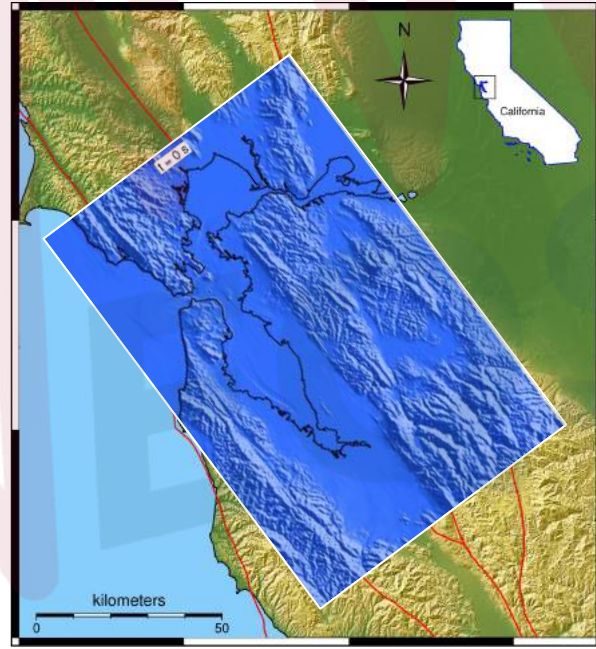
12 story RC frame
OpenSees fiber model



South hypocenter

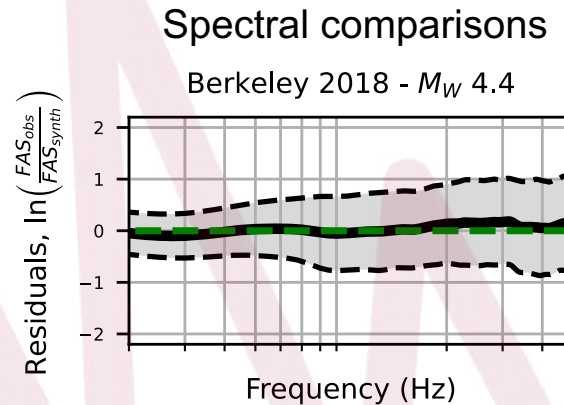
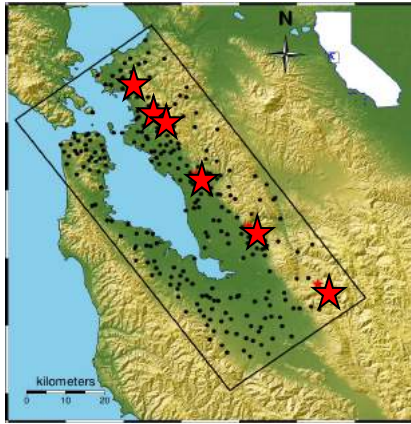


North hypocenter

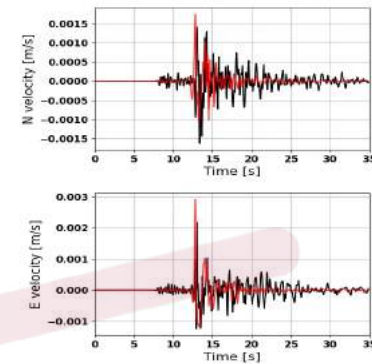


We are evaluating acceptance of the simulated motions for the 25 Hayward fault realizations

1) Stress testing the EQSIM model – 7 small Hayward fault event simulations

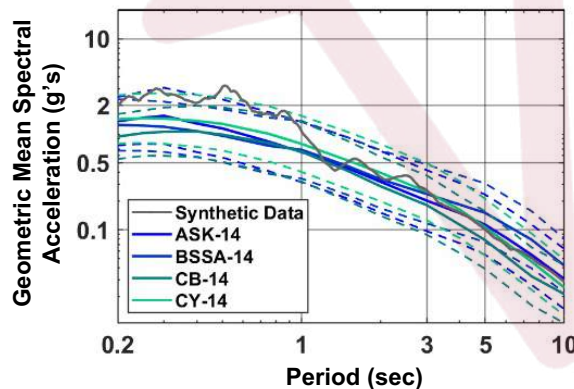


Comparison to measured ground motion waveforms



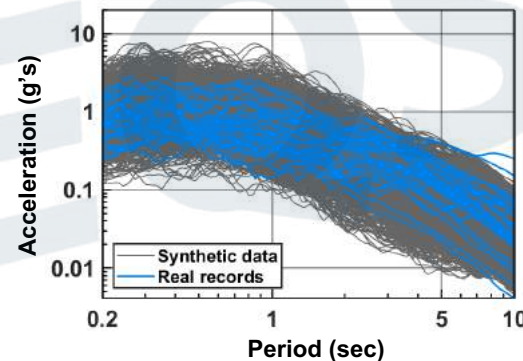
2) Evaluating the large events - 20 M7 Hayward fault realizations

Comparison to existing empirical GMP equations

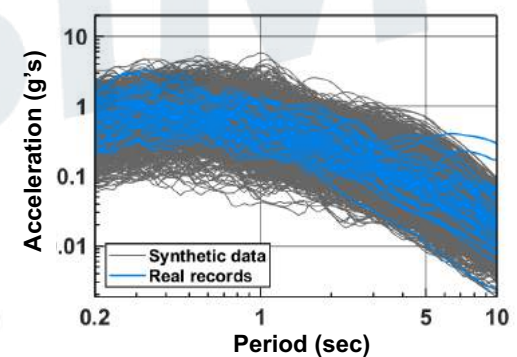


Comparison to existing commensurate ground motion data (near-fault sites < 10 km)

Spectral scatter - FaultNormal



Spectral scatter - FaultParallel

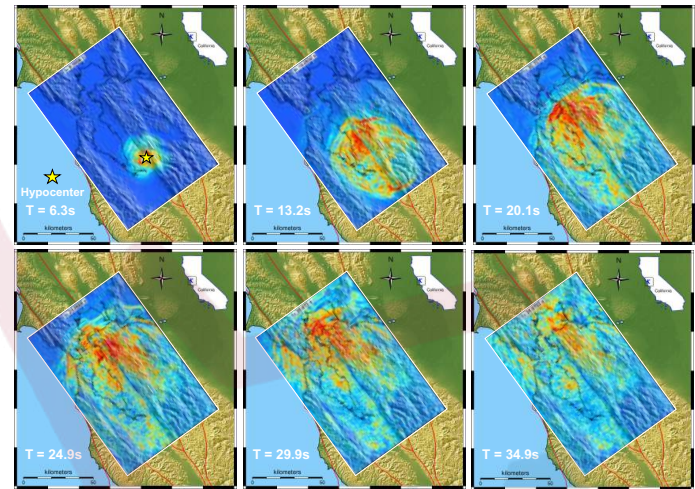


PEER will extend its database to include dense simulated motions for the user community

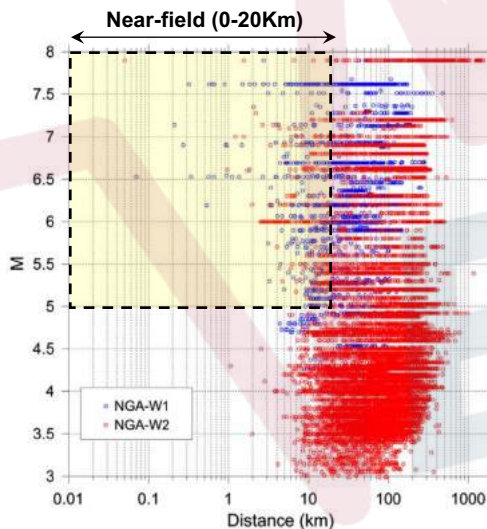
Existing - Spatially sparse measured motions



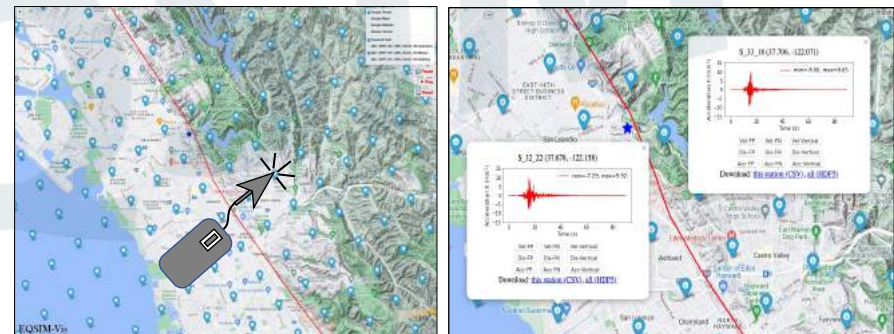
New - Spatially dense simulated motions for the San Francisco Bay Area



Sparse ground motions from everywhere

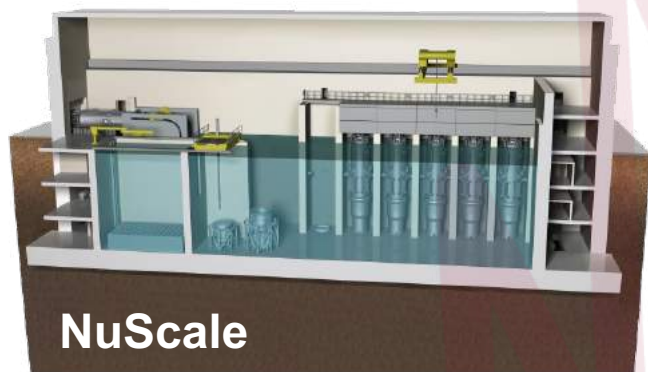


High-fidelity, spatially dense regional ground motions



DOE's motivation includes energy missions requiring earthquake resilience considerations

Next generation nuclear power reactors



Current and future energy systems



Clean
Energy
Earthshots



The next two days will be filled with both technical and application focused discussions

Day 1

- Expert technical views on elements of regional simulations
 - Source characterization
 - Simulated ground motion confidence building and validation
 - Representation of the near-surface geotechnical layer
- Simulated ground motion use cases 1

Day 2

- Simulated ground motion use cases 2
- The USGS SFBA velocity model
- EQSIM and generation of the initial SFBA database
- The PEER-LBNL simulated motion database
- Community interactions going forward

Poster presentations on technical topics