BIGHORN - San Jacinto Events

UCSD Shake Table Tests

SJFZ GMPE

Frank Vernon PGC/AUG 30 Aug 2018

Background

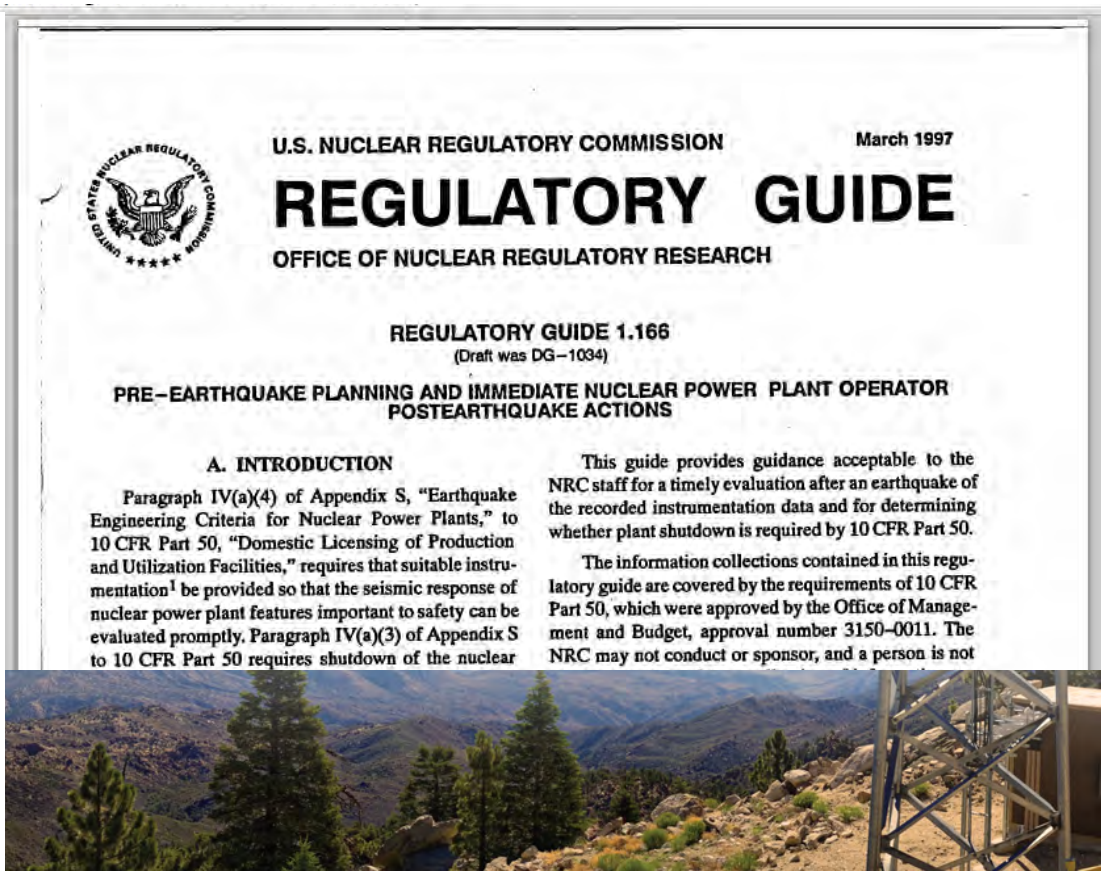
- In 1988, EPRI conducted a study (NP-5930) that set out to determine what constitutes damaging earthquake ground motion and to develop criteria for determining exceedance of the Operating Basis Earthquake (OBE)
- In this study, several ground motion characteristics were investigated and trends were established based on observed structural damage for over 250 earthquake histories
- The conclusion reached was that a combination of two parameters is best suited for assessing the potential damage of a given ground motion history;
  - PSA = peak spectral response pseudo-acceleration
  - CAV = cumulative absolute velocity

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Background

- In 1997 the NRC published a regulatory guide (NRC-1.166) that provided details on implementation of post-earthquake actions for nuclear power plants (NPPs)
- It included PSA and CAV as well as a new exceedance check using velocity response spectra
- If a M5 or greater EQ occurs within a 200 km radius, a NPP must shutdown unless it can reliably advise the NRC, within 4 hours, that the earthquake's effects on the plant have not exceeded its OBE or CAV design requirements



U.S. NUCLEAR REGULATORY COMMISSION March 1997

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 1.166
(Draft was DG–1034)

PRE–EARTHQUAKE PLANNING AND IMMEDIATE NUCLEAR POWER PLANT OPERATOR POSTEARTHQUAKE ACTIONS

A. INTRODUCTION

Paragraph IV(a)(4) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation[1] be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly. Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear

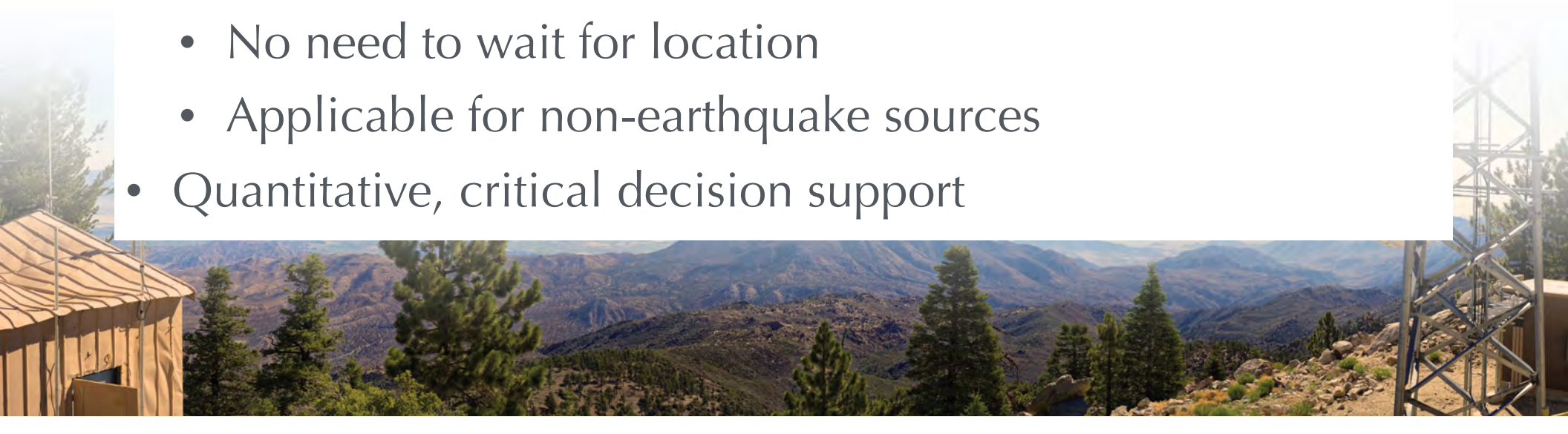
This guide provides guidance acceptable to the NRC staff for a timely evaluation after an earthquake of the recorded instrumentation data and for determining whether plant shutdown is required by 10 CFR Part 50.

The information collections contained in this regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget, approval number 3150–0011. The NRC may not conduct or sponsor, and a person is not

Bighorn

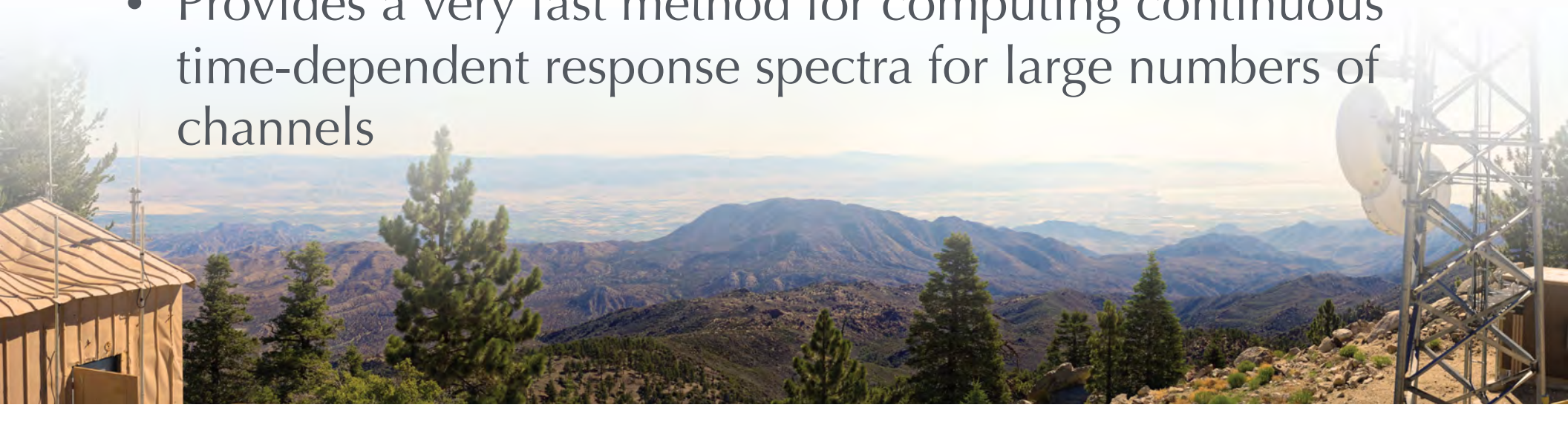
Main Features

- Now-casting of wavefield spectral content
- Real-time, continuous response spectra exceedence
- Immediate results tailored for response team
- Automatic alarms against engineered criteria (Structural Health Monitoring)
- Independent of Earthquake Location
  - No need to wait for location
  - Applicable for non-earthquake sources
- Quantitative, critical decision support



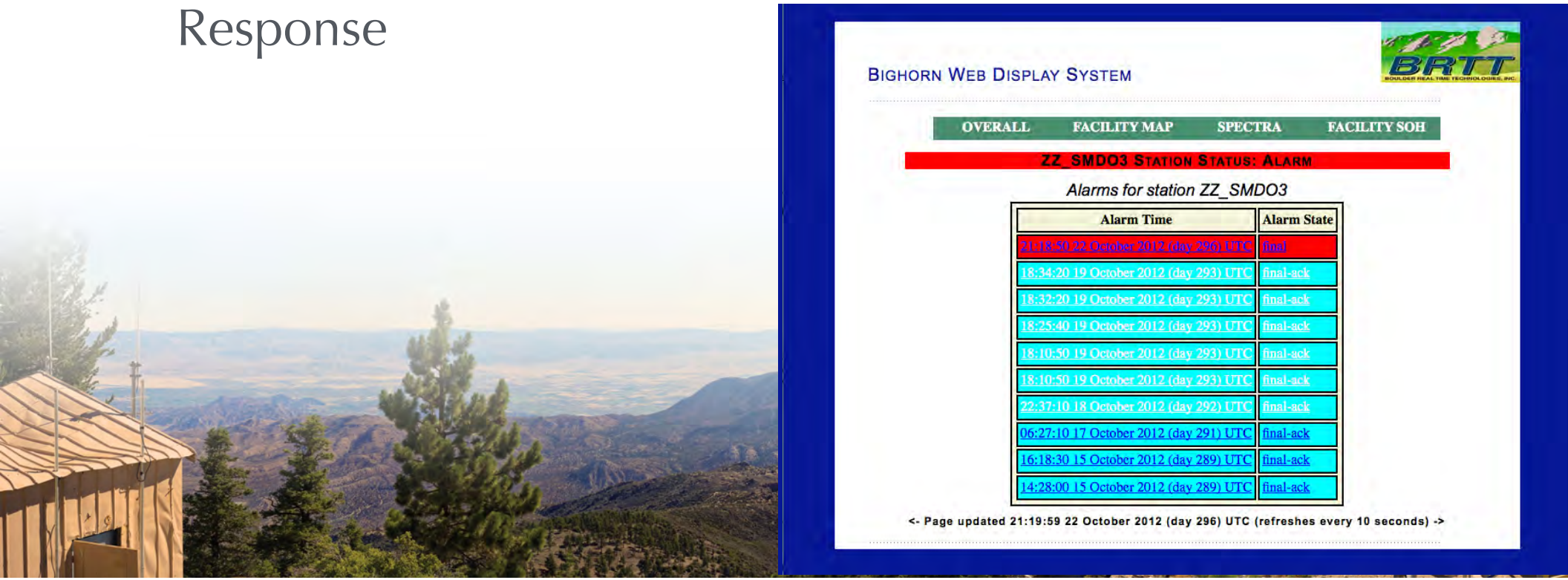
Bighorn - orbsmrsp

- Ability developed for producing continuous time-dependent strong motion response spectra
- Expanded floating point data representations within ORB packets and Datascope waveform files
- Pf ORB packets to represent time continuous strong motion response spectra
- Provides a very fast method for computing continuous time-dependent response spectra for large numbers of channels

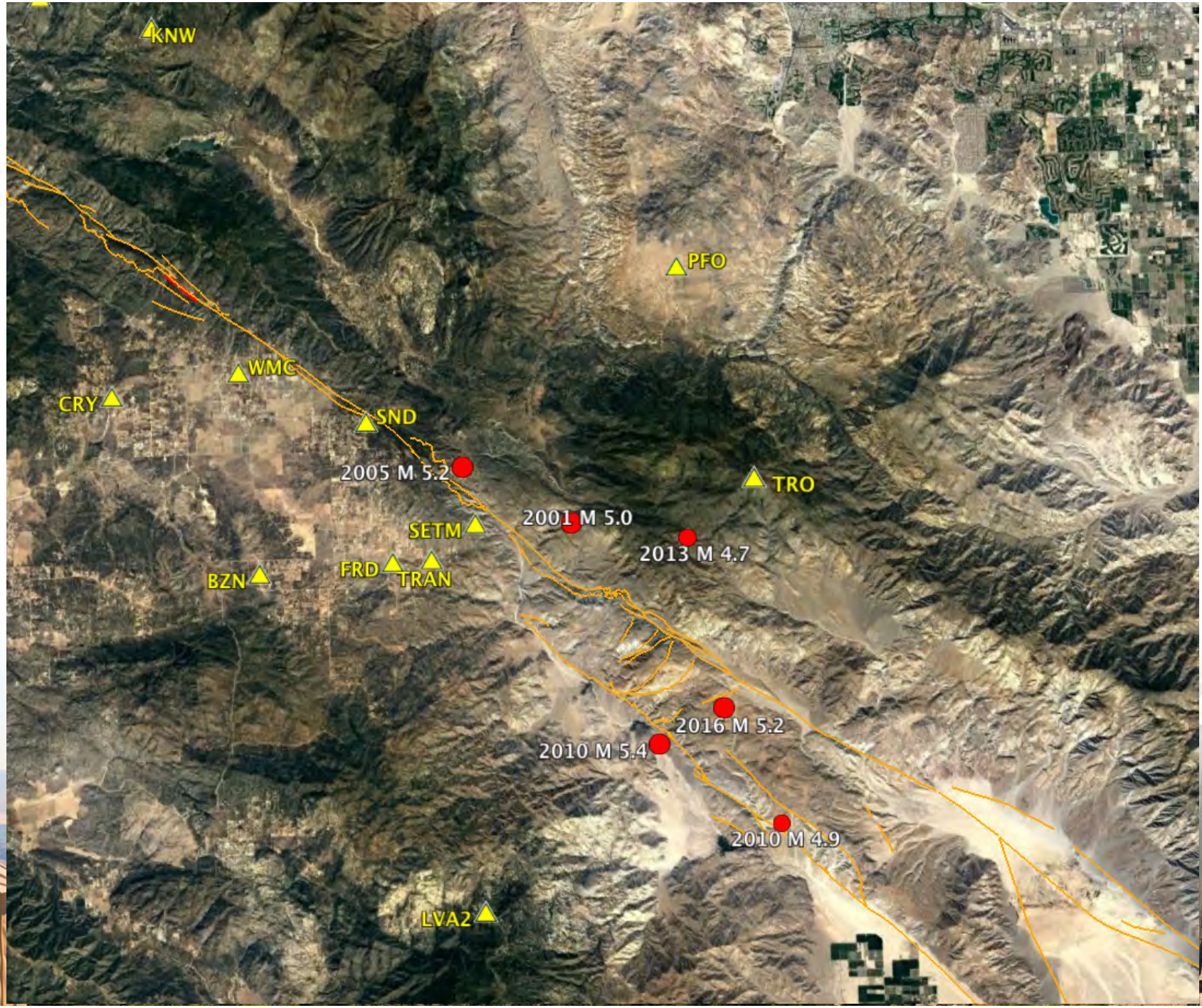


Bighorn

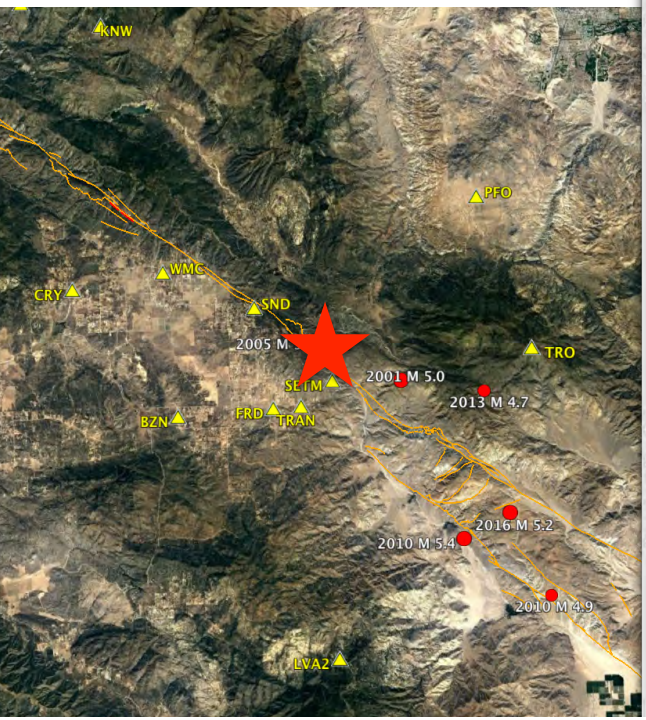
- Alarms based on exceedence of Operating Basis Earthquake (OBE)
- Building-block nature of Antelope/Bighorn system and open-architecture APIs allow construction of wide variety of systems for Structural-Health Nowcasting, Earthquake Early Warning, and Post-Earthquake Response

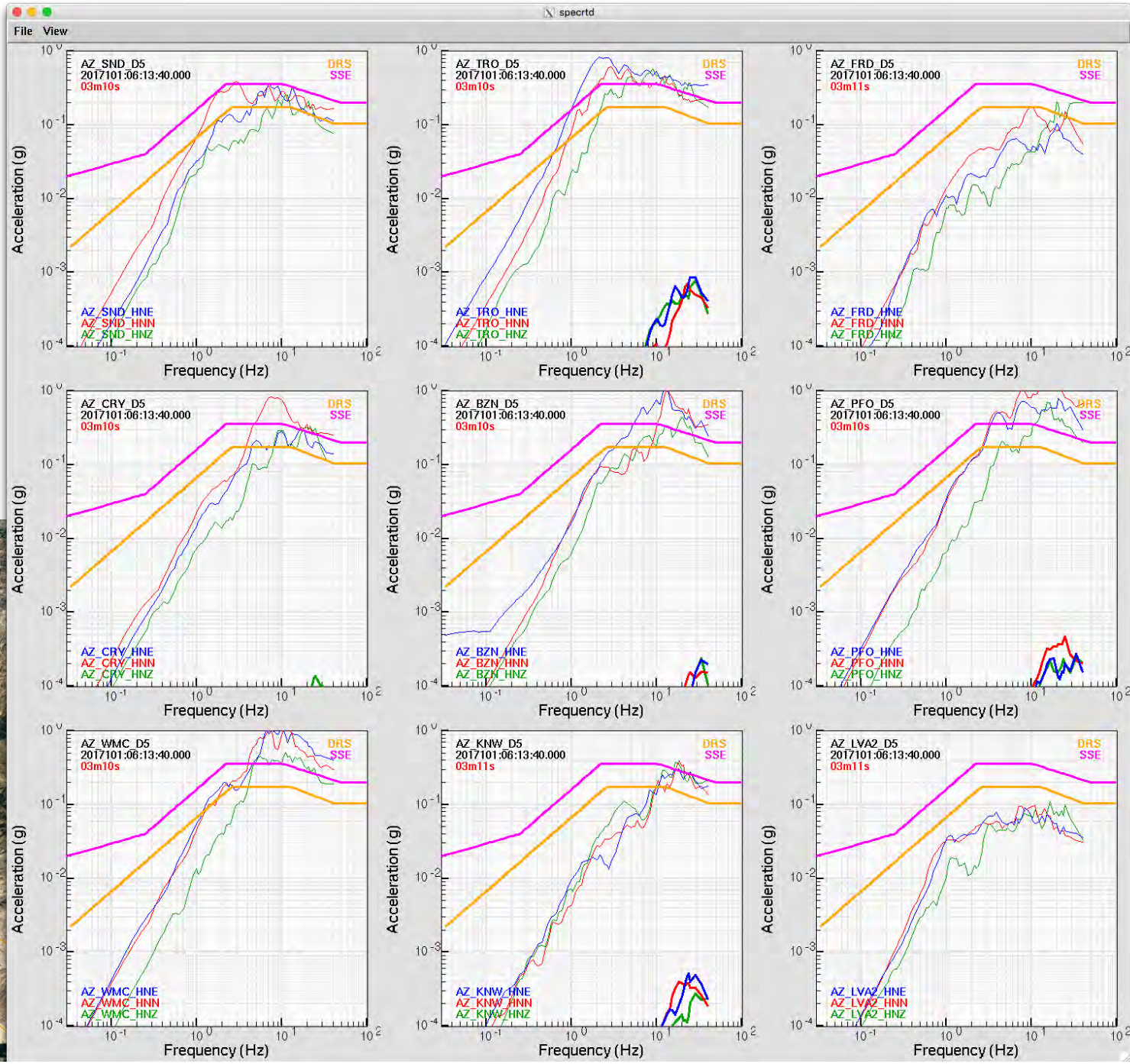


ANZA Events and Stations

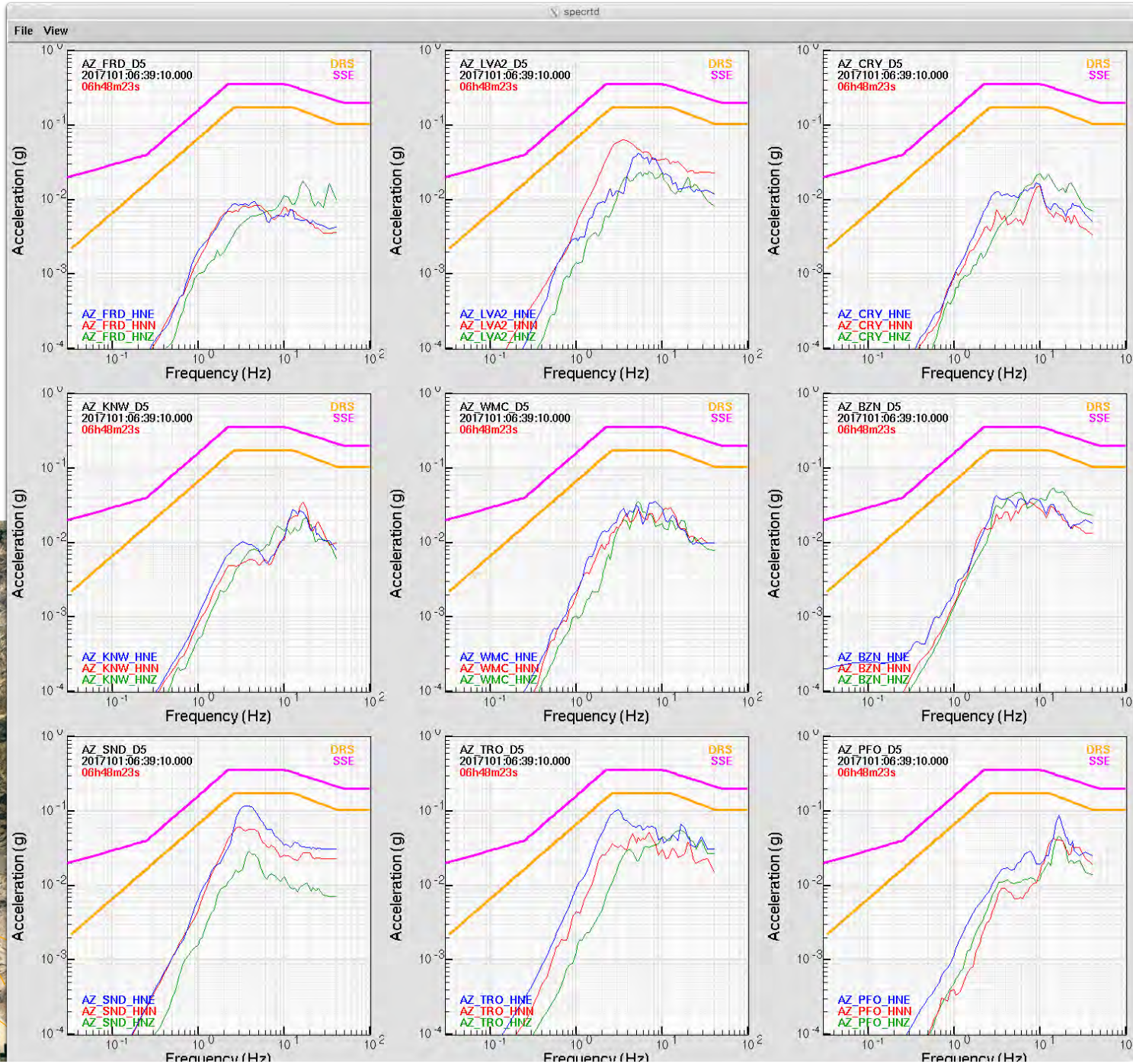


ANZA 2005 Mw 5.2





ANZA 2010 Mw 4.9



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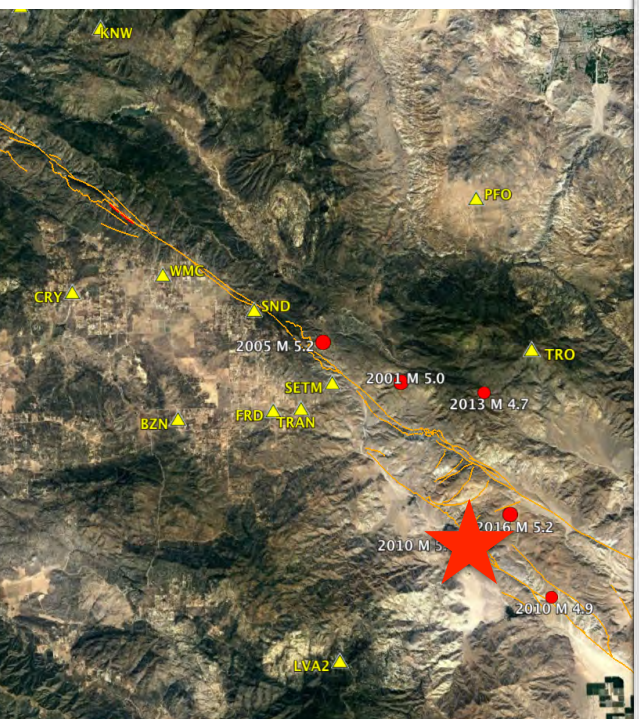
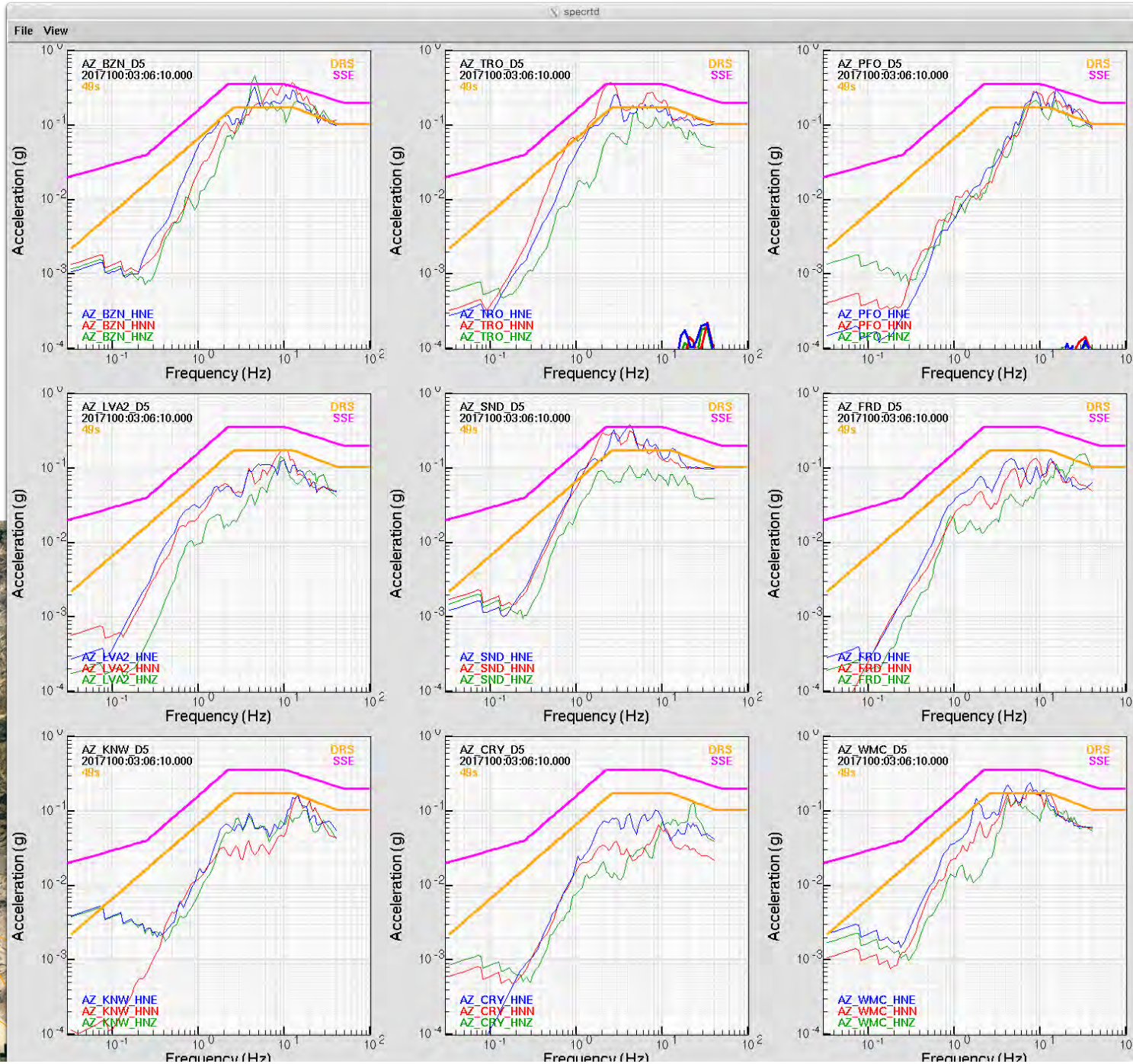
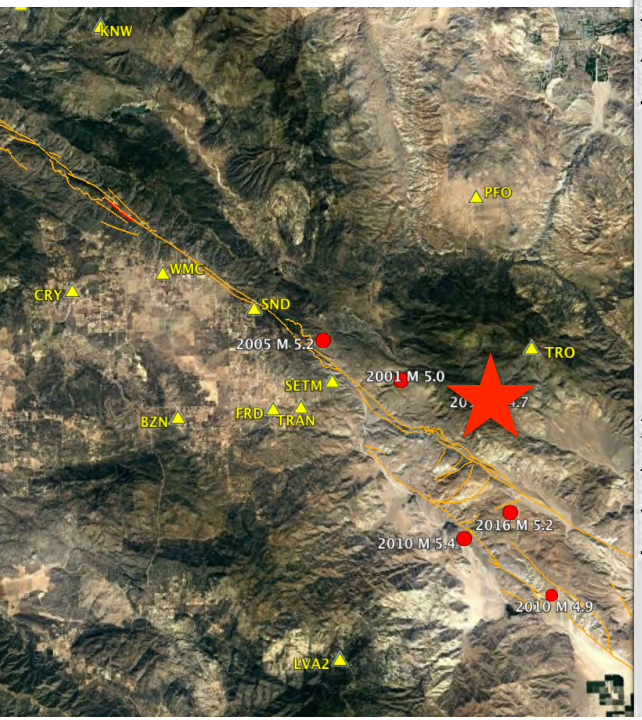
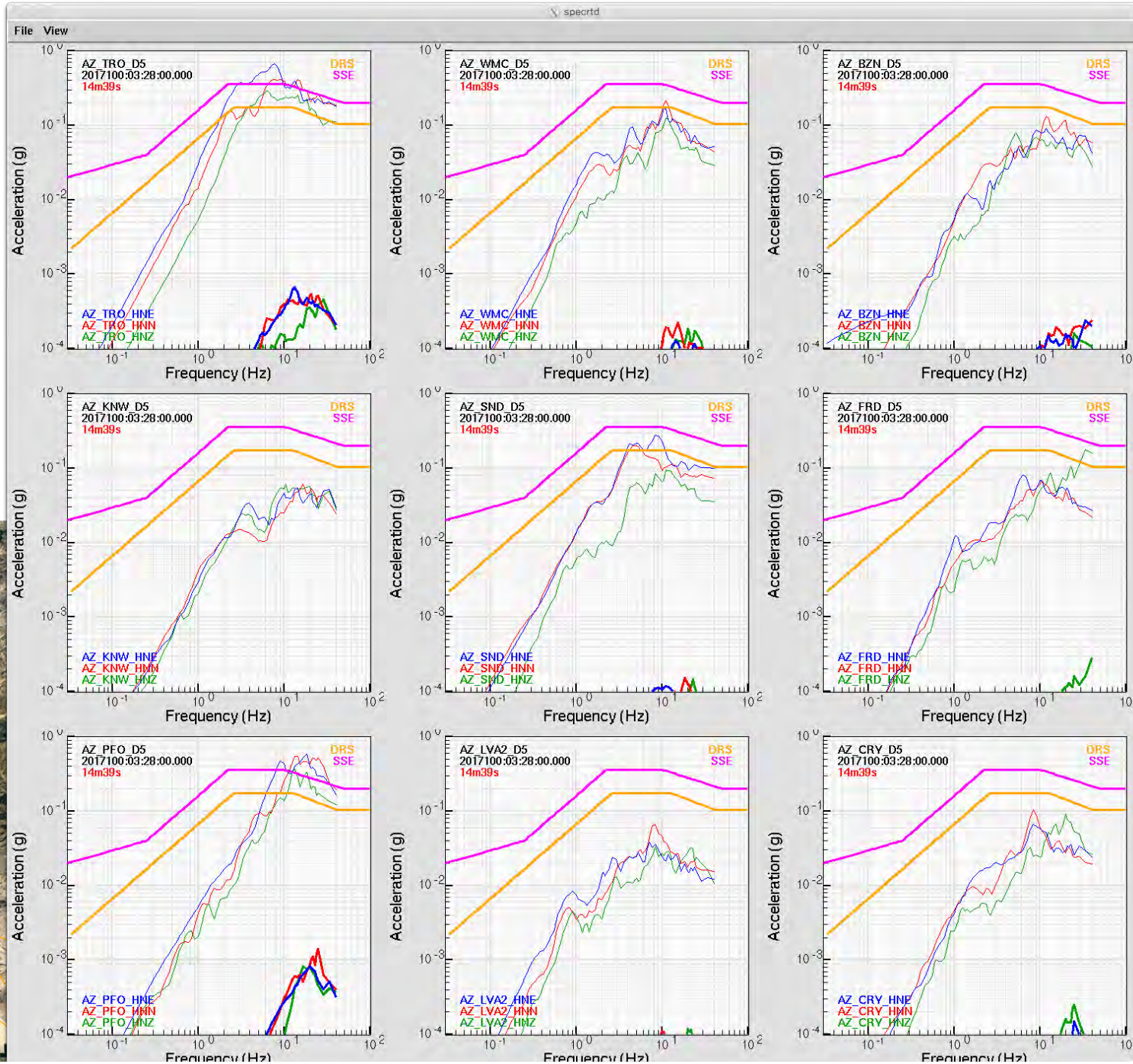


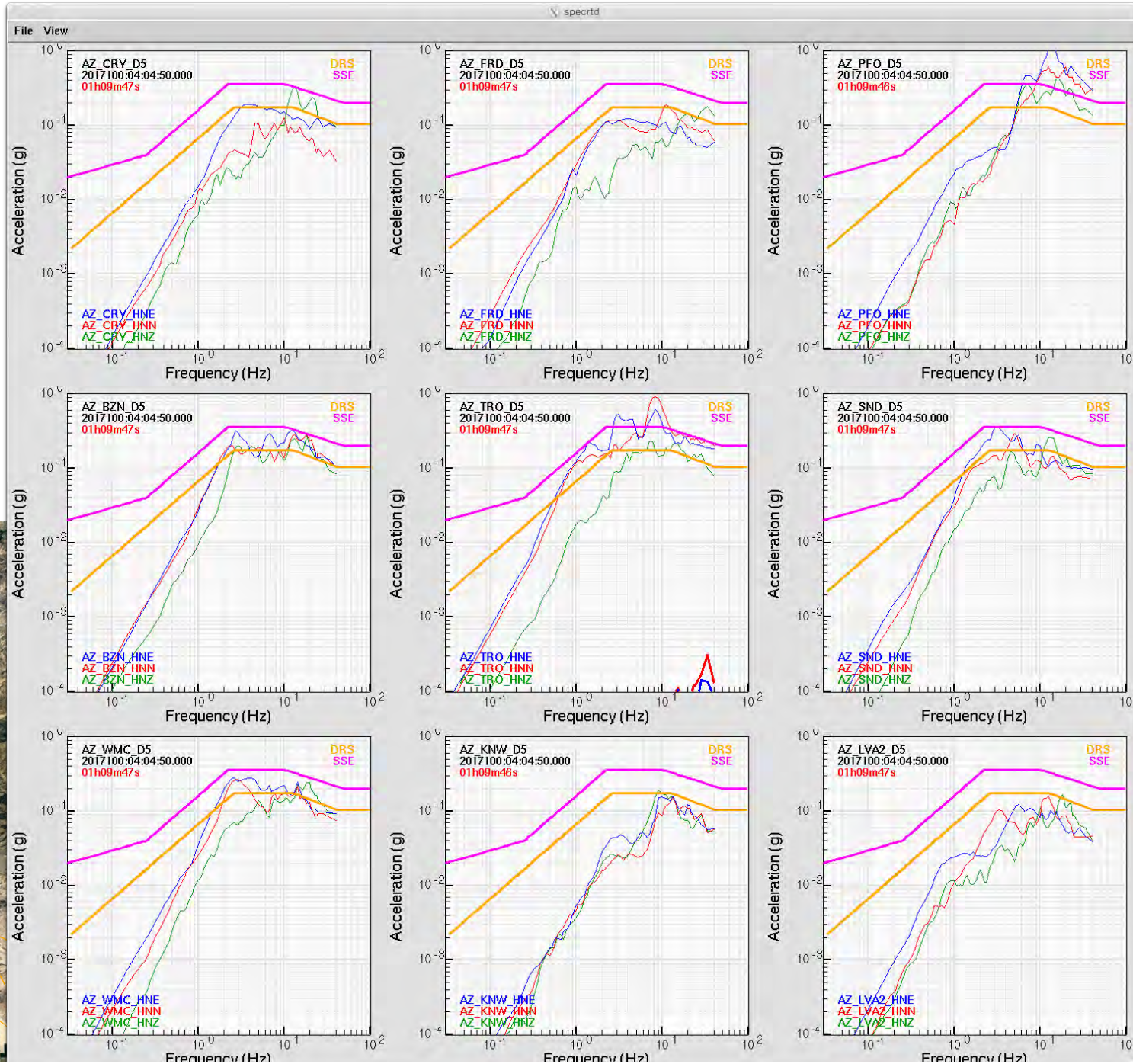


ANZA 2013 Mw 4.7





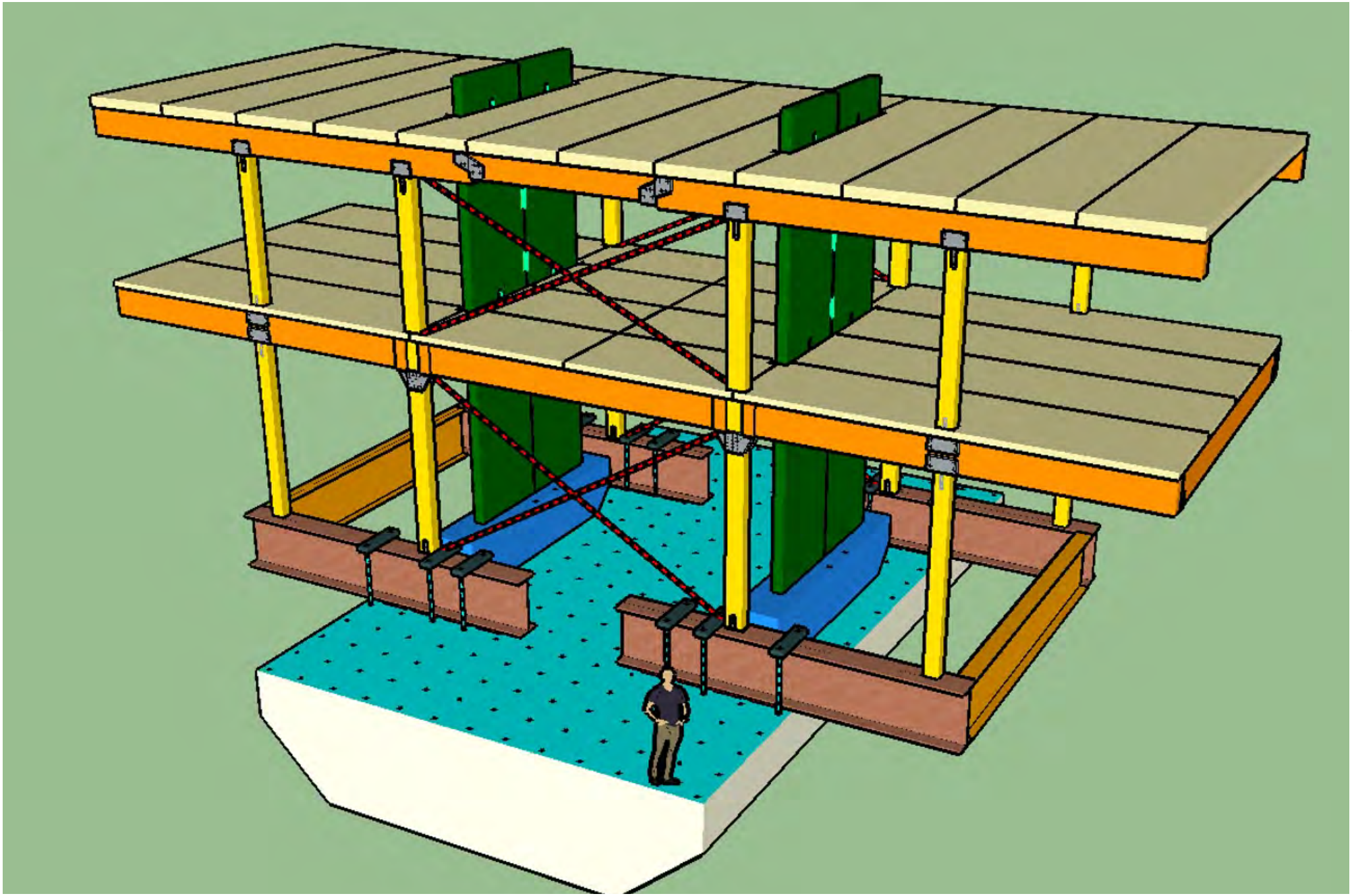
ANZA 2016 Mw 5.2



UCSD Shake Table Tests

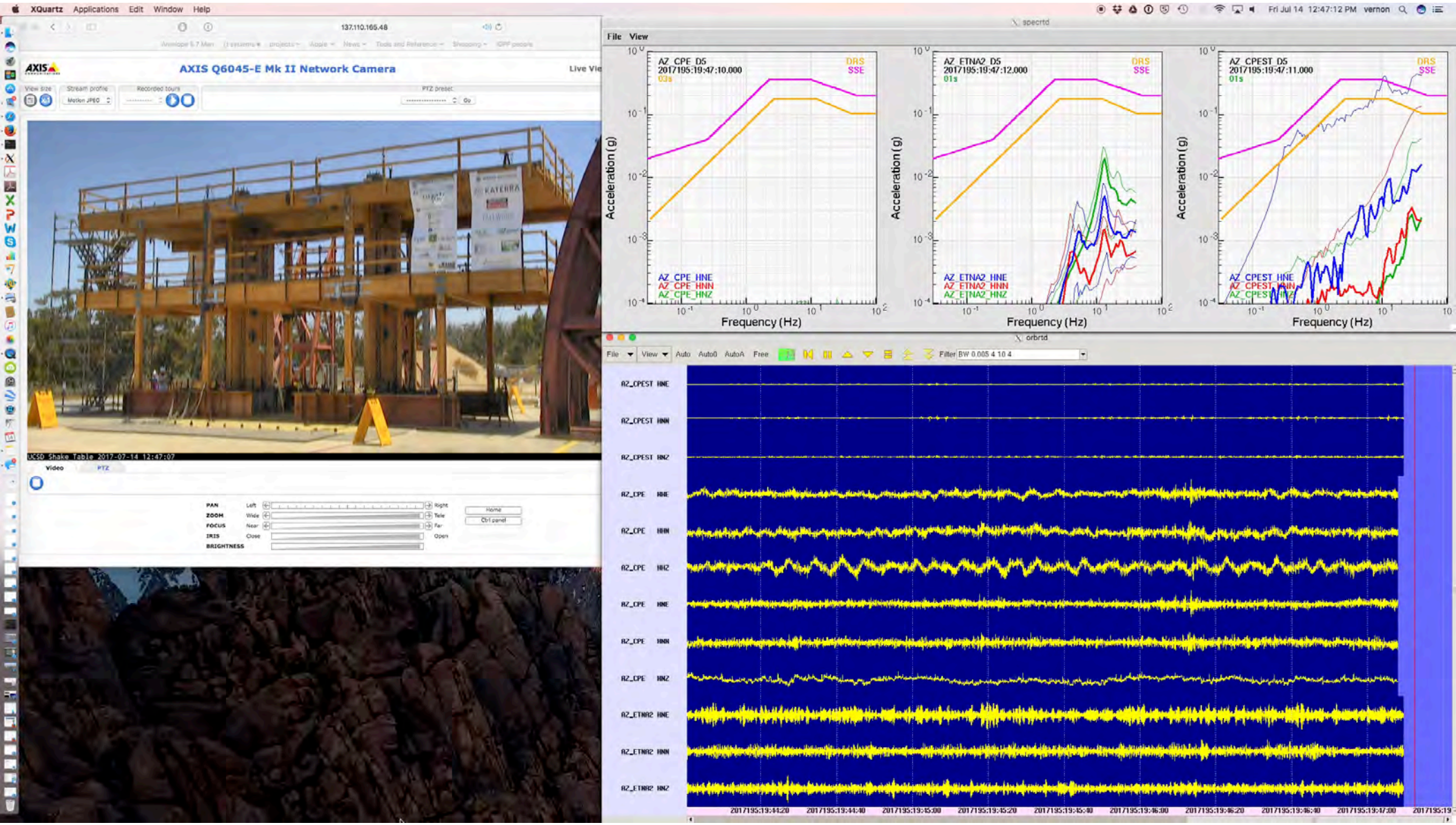
- Development and Validation of a Resilience-based Seismic Design Methodology for Tall Wood Buildings: Phase I Test
- demands for tall residential and mixed-use buildings in the range of 8~20 stories are increasing.
- One new structural system in this height range are tall wood buildings which have been built in select locations around the world using a relatively new heavy timber structural material known as cross laminated timber (CLT).
- The majority of existing tall CLT buildings are located in non-seismic or low-seismic regions of the world.

UCSD Shake Table Tests

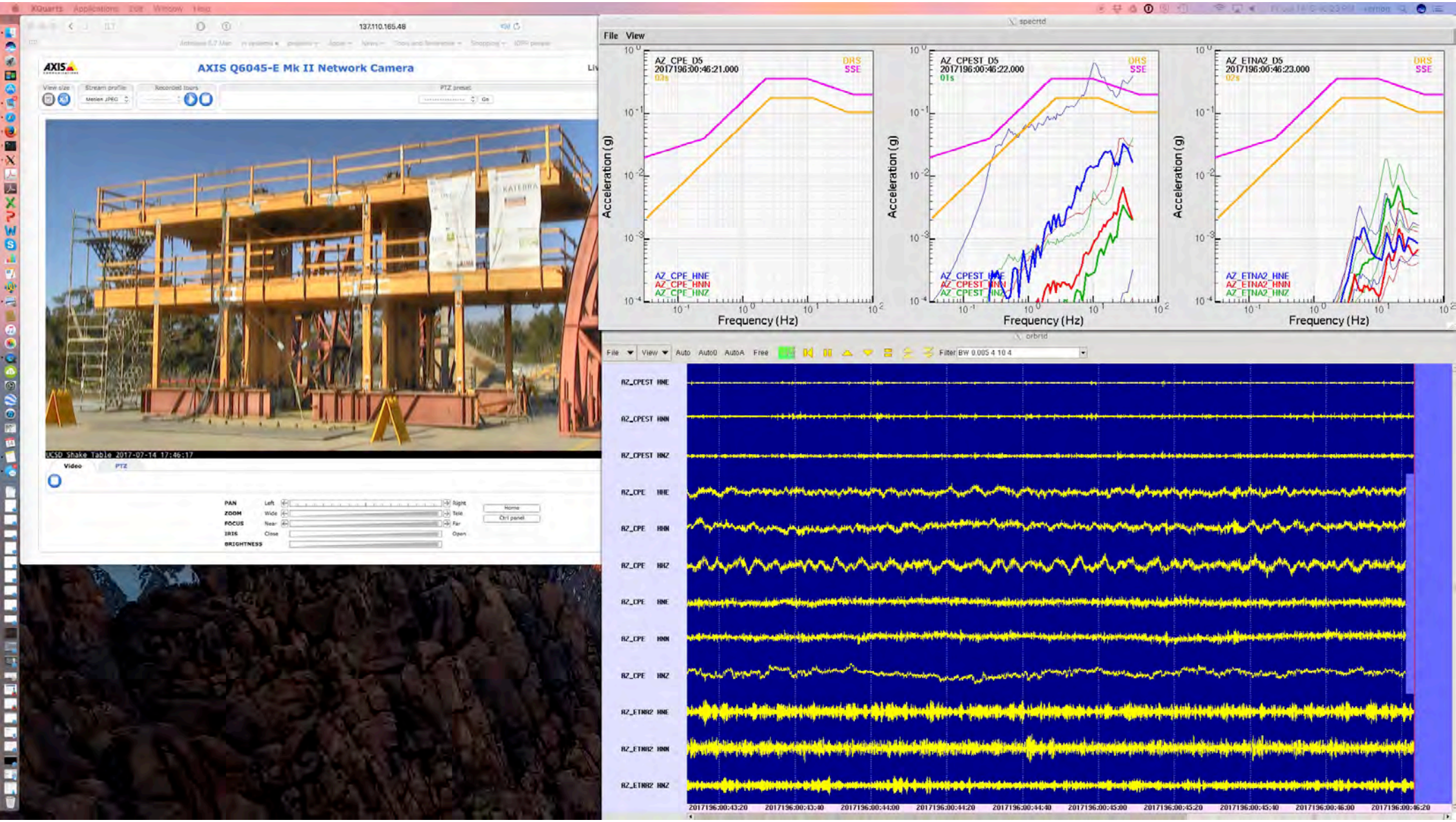


UCSD Shake Table Tests

Loma Prieta - Design Baseline Eq



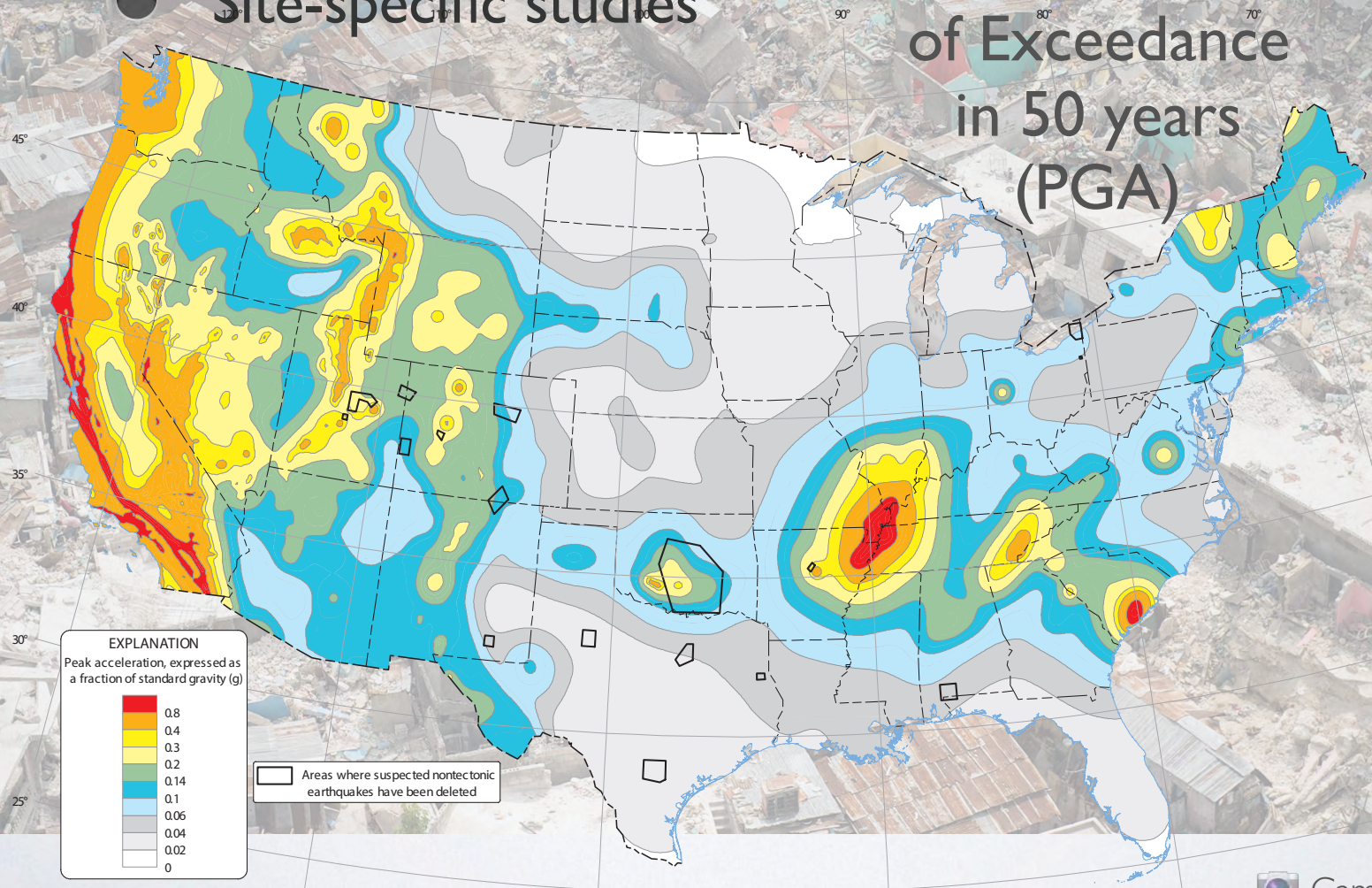
Northridge - Max Credible Eq * 1.2



SEISMIC HAZARD ANALYSIS

- Hazard - Estimates of Shaking
  - Hazard Maps
  - Site-specific studies

2% Probability of Exceedance in 50 years (PGA)



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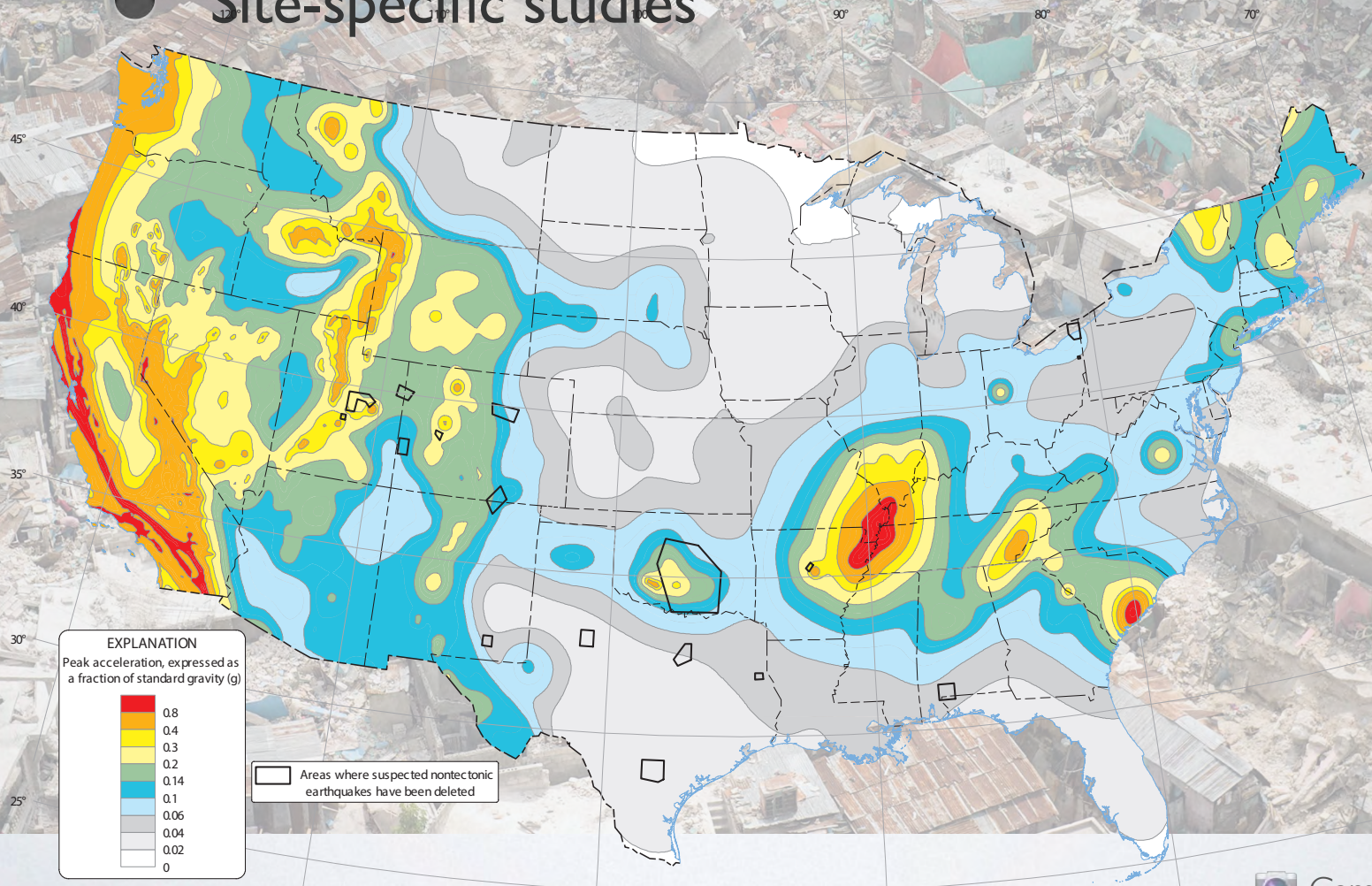

Cameron Davis/Corbis

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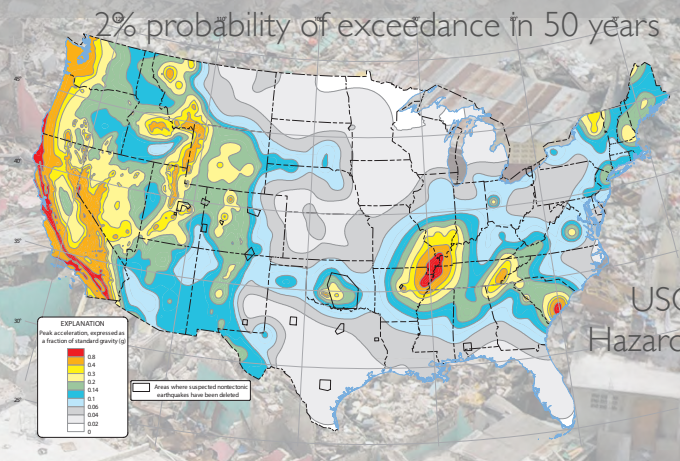


USGS Hazard Map

- Risk
  - Mitigate loss and fatalities
  - Aid in disaster response

USGS science for a changing world

Earthquake Shaking — Red Alert

USAID FROM THE AMERICAN PEOPLE

GSN ANSS

M 6.2, CENTRAL ITALY

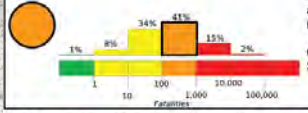
Origin Time: Wed 2016-08-24 01:36:32 UTC (03:36:32 local)

Location: 42.72°N 13.19°E Depth: 4 km

PAGER Version 8

Created: 5 weeks, 6 days after earthquake

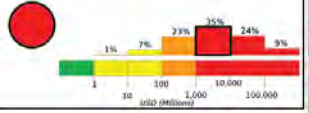
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of Italy. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Economic Losses



Estimated Population Exposed to Earthquake Shaking

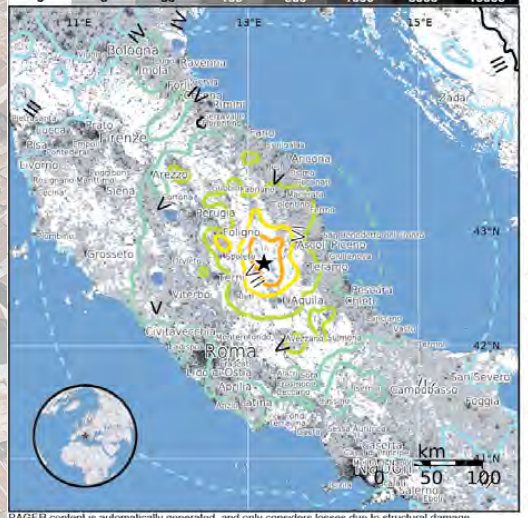
ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	3,522k*	14,037k*	5,753k	1,171k	145k	19k	3k	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

USGS PAGER

Population Exposure

population per ~1 sq. km from Landscan

0 | 5 | 50 | 100 | 500 | 1000 | 5000 | 10000



PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

http://earthquake.usgs.gov/earthquakes/eventpage/us10006g7d

Structures:
Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. The predominant vulnerable building types are unreinforced brick with mud and mid-rise nonductile concrete frame with infill construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1997-09-26	51	6.0	VIII(10k)	11
1997-09-26	46	5.7	VIII(2k)	14
1980-11-23	278	6.9	IX(37k)	2k

Recent earthquakes in this area have caused secondary hazards such as landslides that might have contributed to losses.

Selected City Exposure

from GeoNames.org

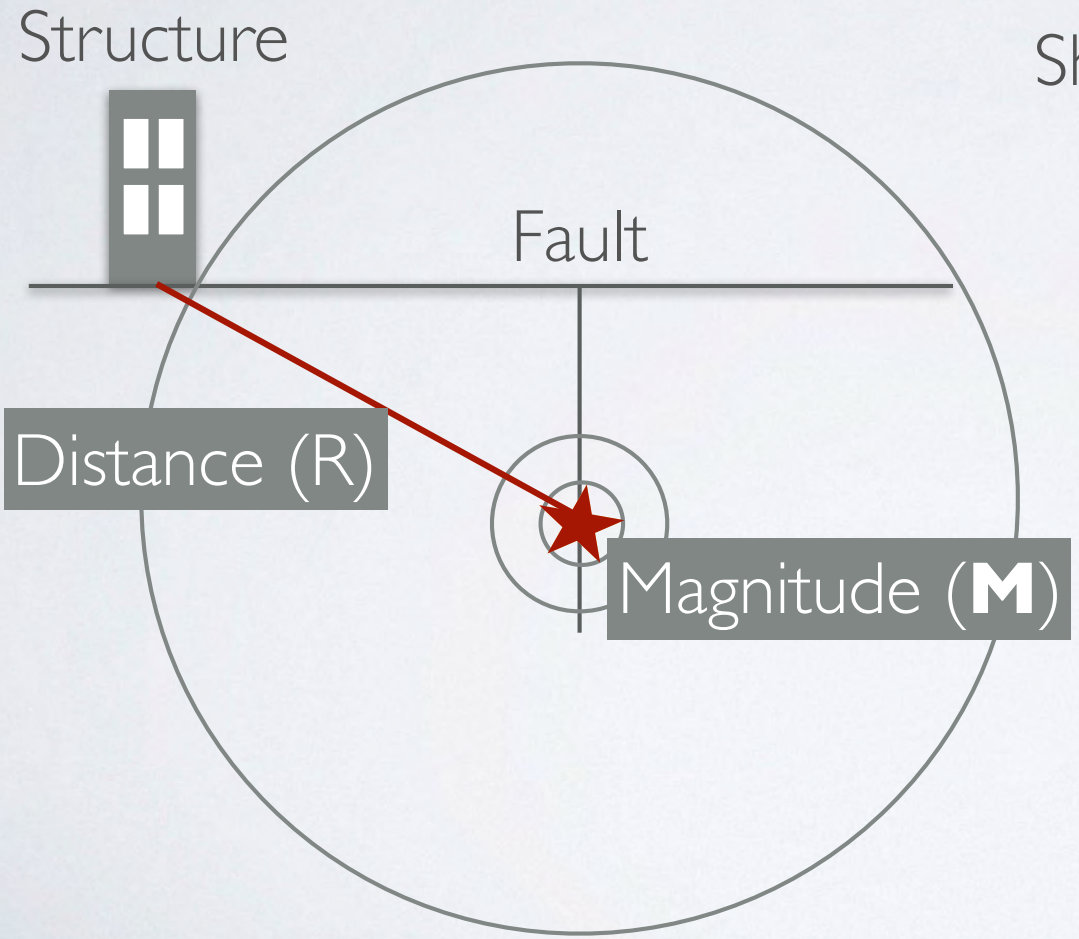
MMI	City	Population
IX	Amatrice	3k
IX	Accumoli	< 1k
VIII	Arquata del Tronto	1k
VIII	Norcia	5k
VIII	Montefortino	1k
V	Perugia	149k
IV	Roma	2,563k
IV	Firenze	372k
IV	Napoli	989k
III	Bologna	371k

bold cities appear on map (k = x1000)

Event ID: us10006g7c

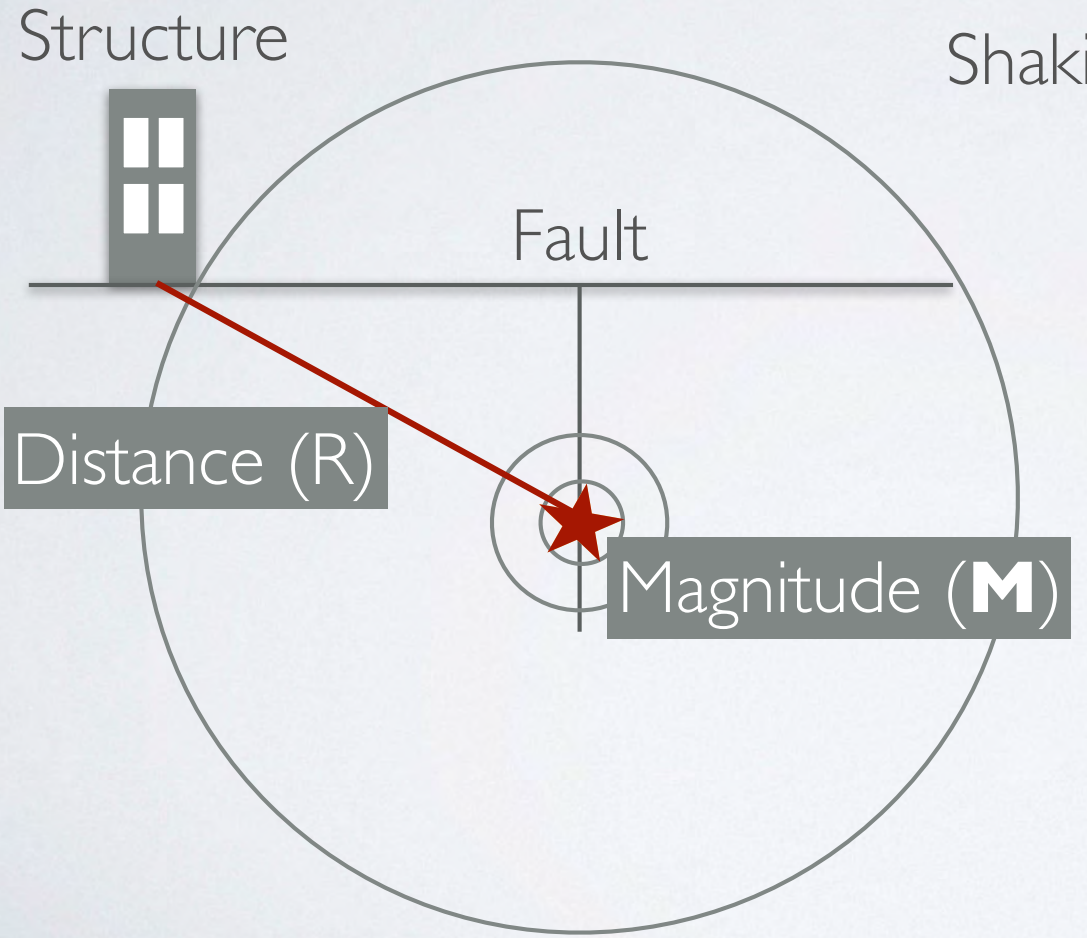
Cameron Davis/Corbis

GROUND MOTION PREDICTION EQUATIONS (GMPEs)



Shaking = a1*Magnitude
+ a2*Distance
+ a3*some other stuff

GROUND MOTION PREDICTION EQUATIONS (GMPES)

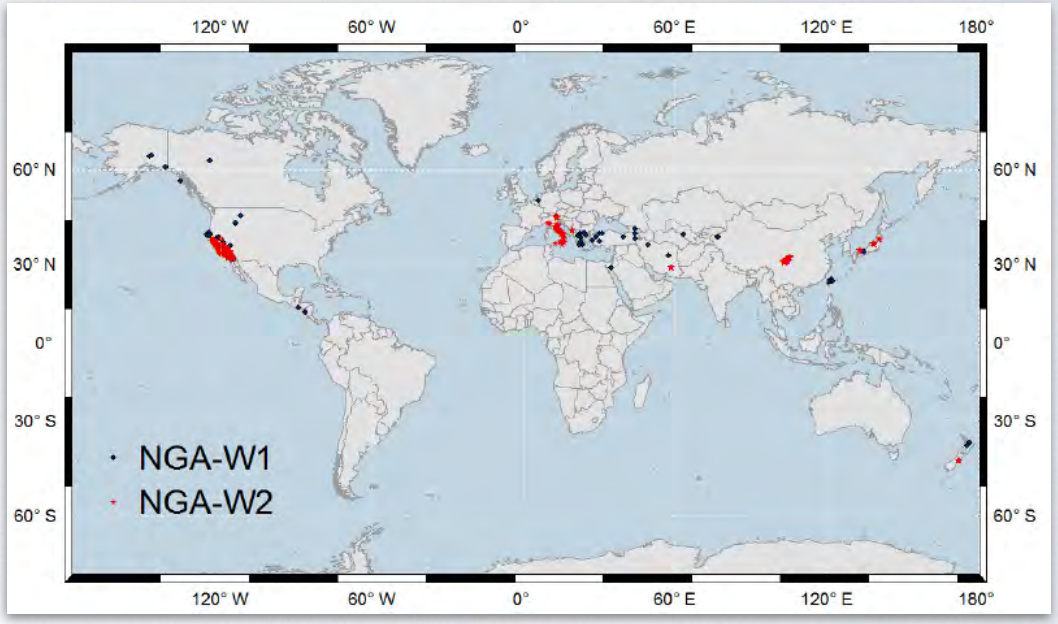


Shaking = a1*Magnitude Source
+ a2*Distance Path
+ a3*some other stuff Site

HOW THEY'RE MADE

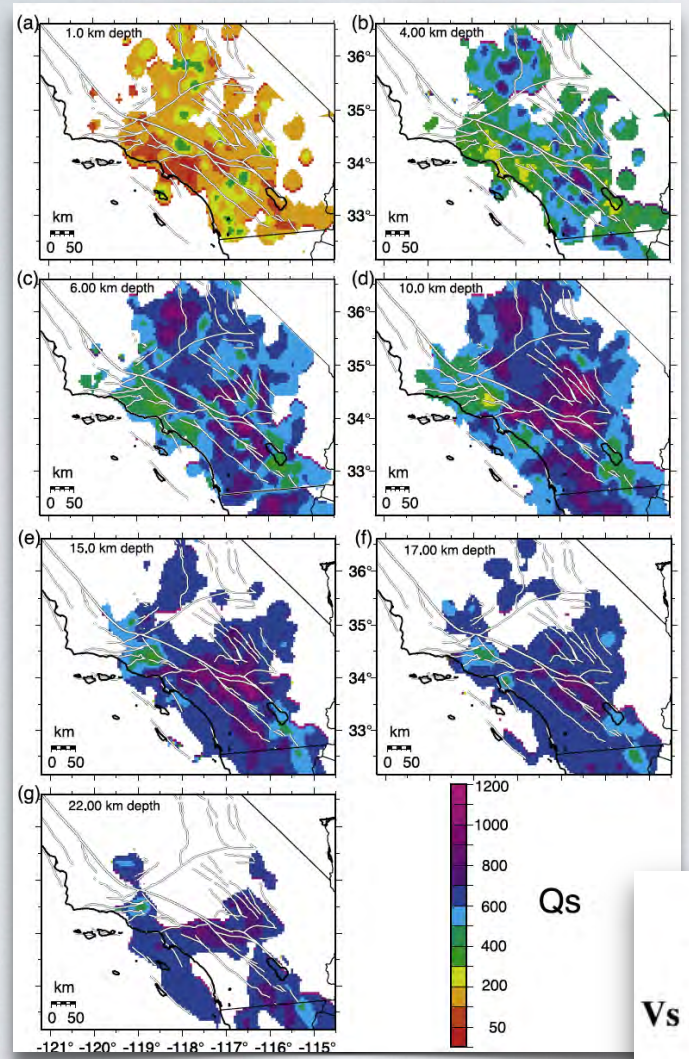
Shaking = a1*Distance
+ a2*Magnitude
+ a3*some other stuff

- Use data from over 20,000 earthquakes…globally
- Get a1, a2, and a3 (generally speaking…)

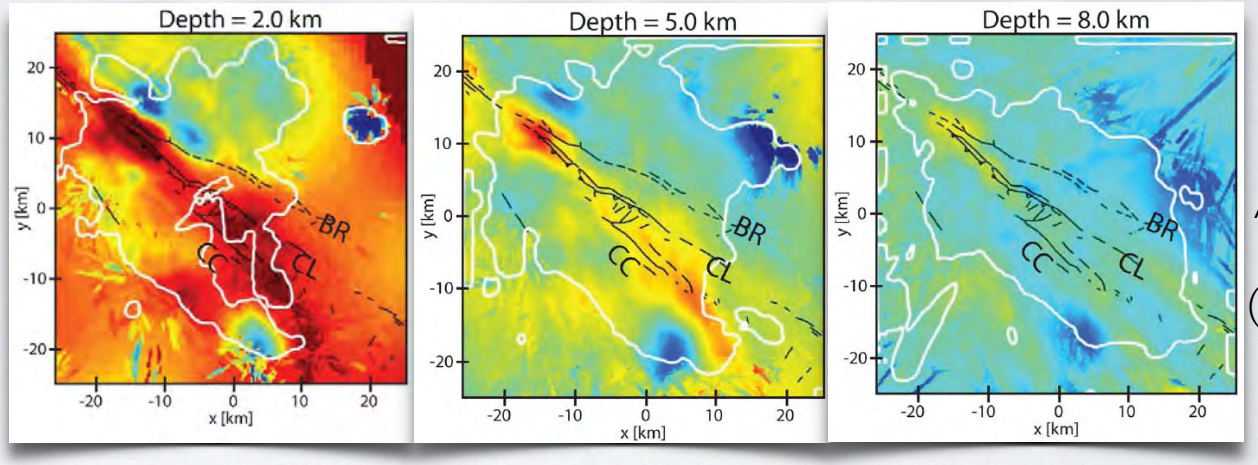


ANZA REGION

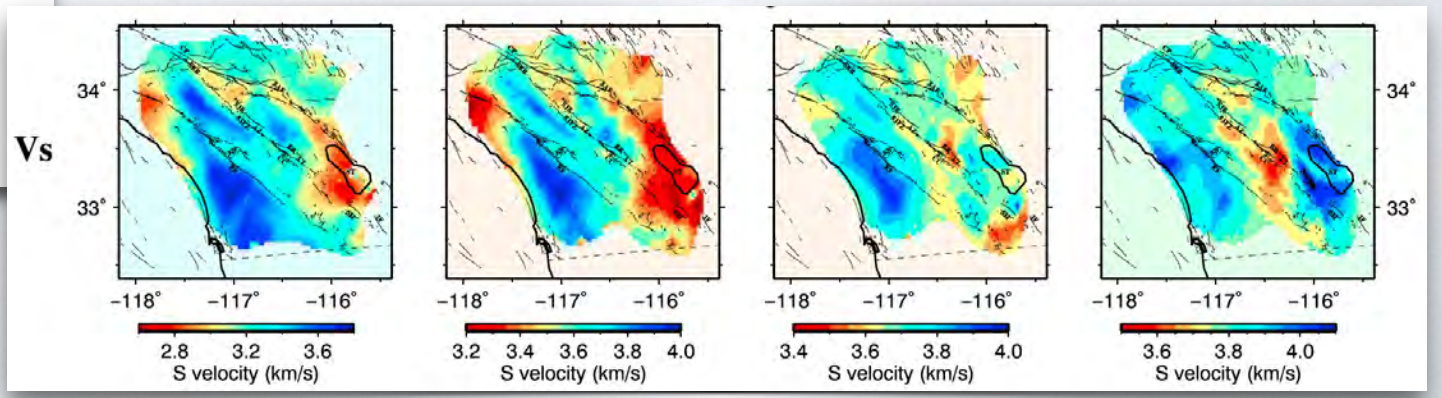
- Data-rich region
- Vp, Vs, Qp, and Qs
- Detailed fault mapping



Hauksson and Shearer (2006)



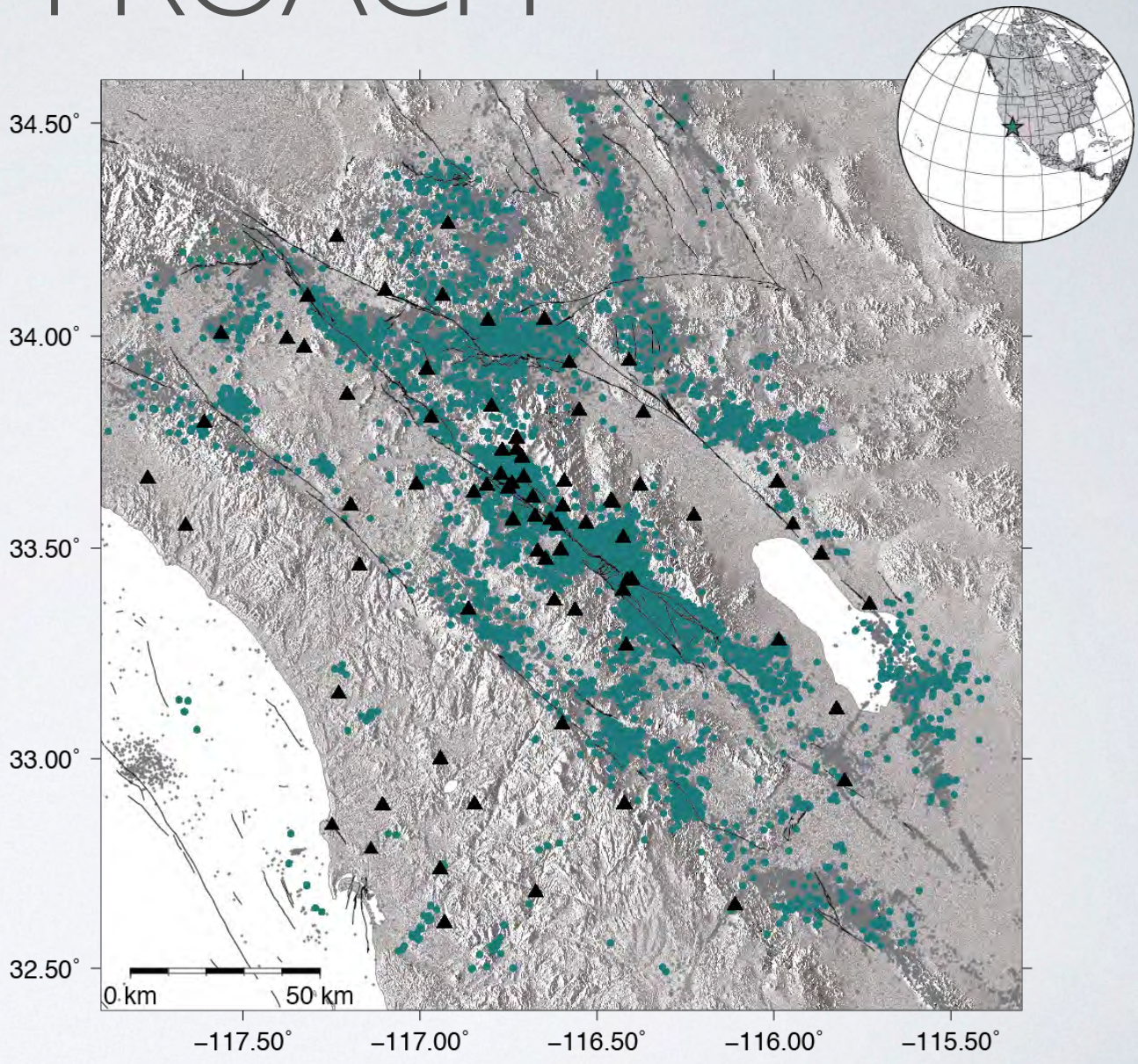
Allam et al. (2014)



Fang et al. (2016)

APPROACH

- Data from Southern California
  - > 10,000 events
  - 80 stations
- > 120,000 recordings
- **M** ~1 - 4
- Distance ~0 - 180km

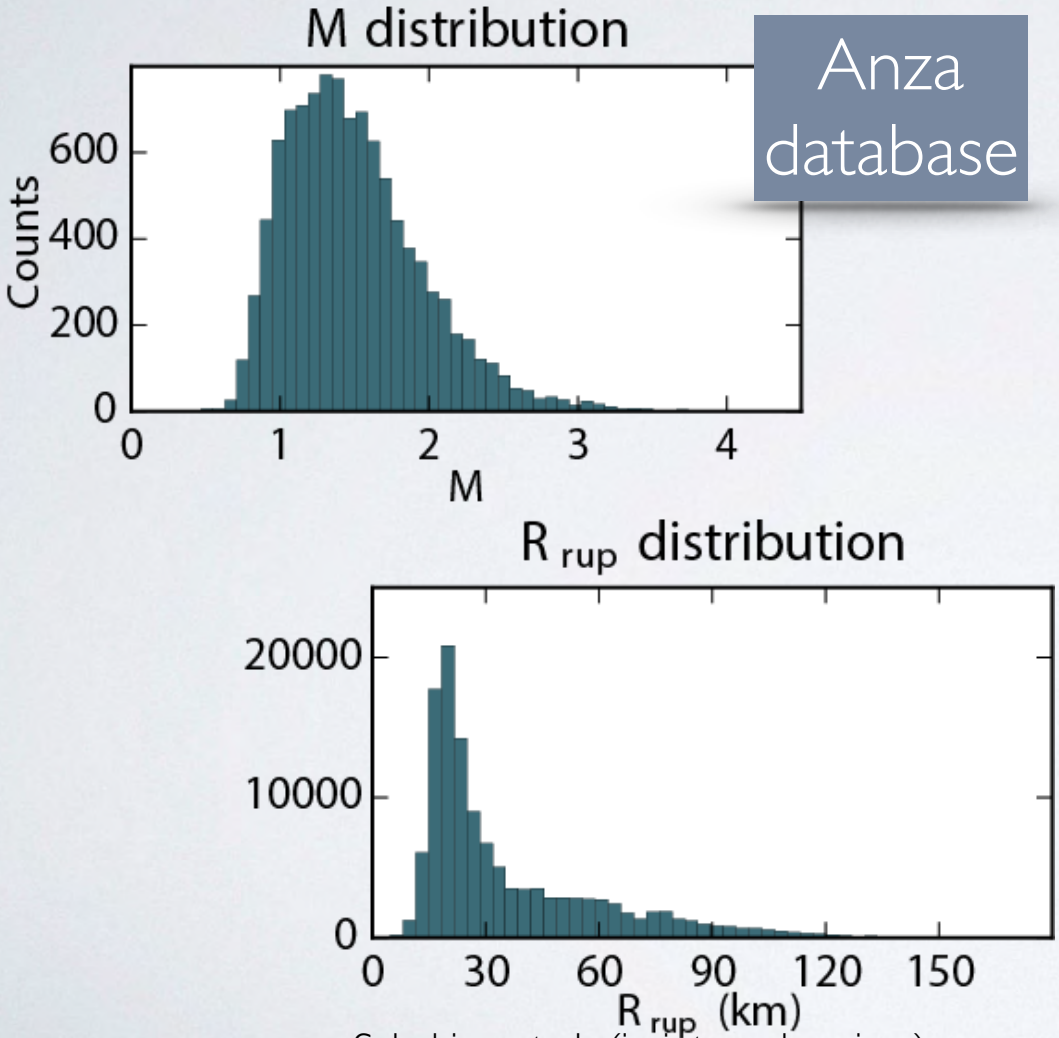


Sahakian et al., (in internal review)

METHODS

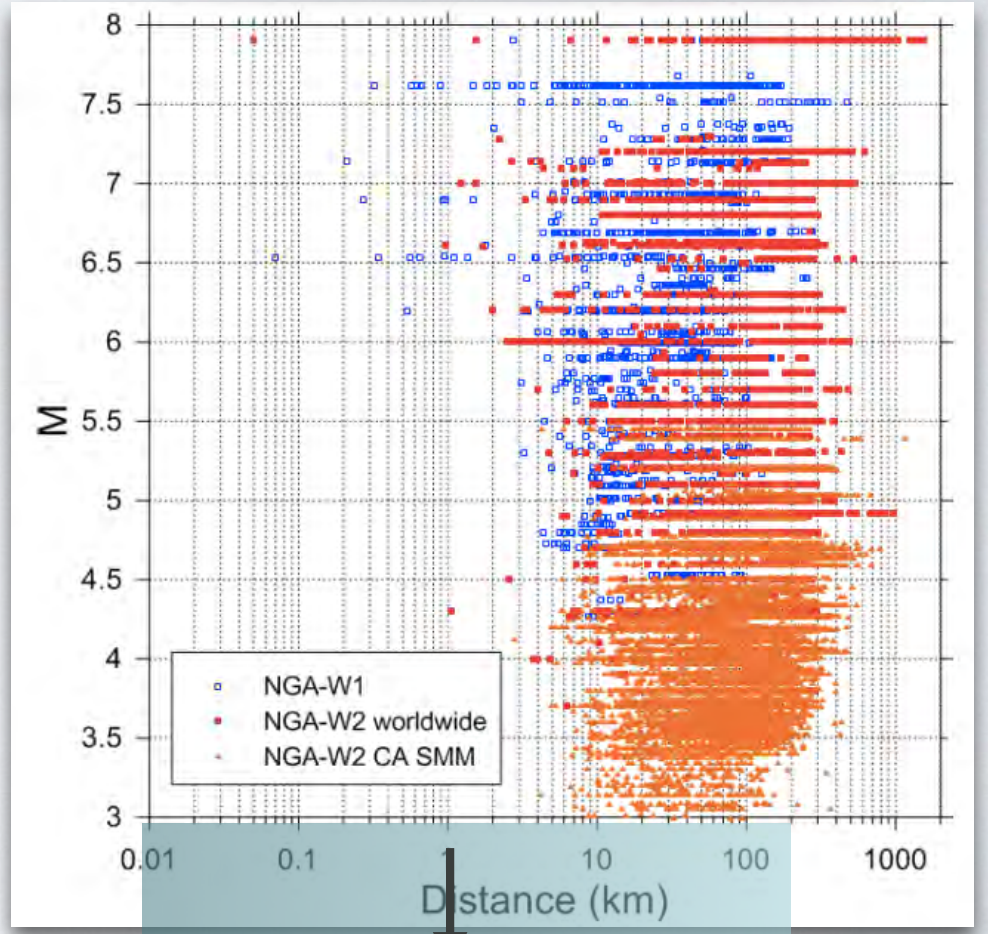
- Need a small **M** GMPE in a flexible framework
- Invert data for an Anza regional GMPE

Anza database



Sahakian et al., (in internal review)

NGA-West2 database



Ancheta et al. (2013)

DATABASE OPS

- Properly built dbmaster
  - site information, instrumentation information
- Build standard event oriented database
  - event, origin, assoc, arrival tables
- Select only P wave arrivals
- Use dbwfmeas to load PGA, PGV, and PGD into wfmeas table

DATABASE OPS CONTINUED

- In Python or Matlab
  - Join arrival, assoc, origin, event, netmag tables
  - Select preferred origin
  - Join to wfmeas table
  - Select PGA
  - Plot

Southern California PGA