ECA Southern California

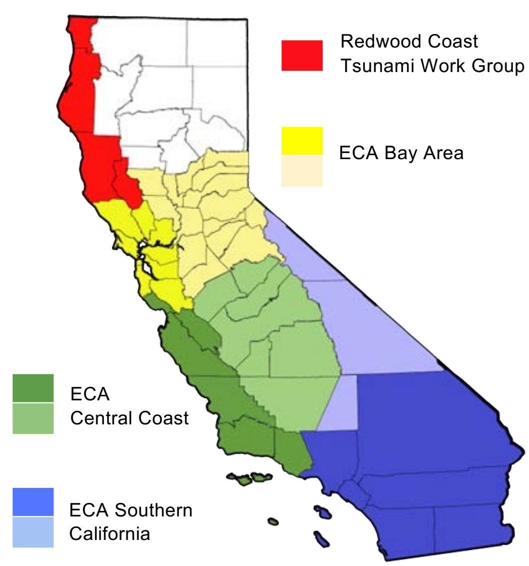
Spring 2024 Online Workshop

June 5, 2024

Earthquake Country Alliance

Earthquake Country Alliance

- 4000+ *Public-Private-Grassroots* leaders
- Subject matter expert *Committees* develop resources and programs
- *Regional Alliances* organize meetings and outreach activities
- California's Office of Emergency Services provides FEMA NEHRP funding for ECA earthquake mitigation activities
- USC's Statewide California Earthquake Center (SCEC.org) administers ECA



Join: **EarthquakeCountry.org/join**

Co-Chairs, ECA SoCal Coordinating Committee

Margaret Vinci
Caltech

Heidi Rosofsky
Global Vision Consortium

Alan Hanson
Simpson Strong-Tie, retired

EarthquakeCountry.org/socal

ECA SoCal Coordinating Committee

Coordinating Committee Chairs: **Heidi Rosofsky (Global Vision)**
Margaret Vinci (Caltech)
Alan Hanson (Simpson Strong-Tie)

Media Bureau Coordinators: **Marilyn Jimenez (LA Red Cross)**
Mimi Teller (LA Red Cross)

Participation Bureau Coordinator: **Pei Lee (Orange County Emergency Management)**
Also positions for each county

Events Bureau Coordinators: **John Hammett & Lance Webster (Volunteers)**

ShakeOut Events Coordinator: **Pauline Louie (EPA)**

Communications Coordinator: **Open position**

Quarterly Workshops Coordinator: **Open position**

Membership Coordinator: **Open position**

Today's Agenda

Welcome from the ECA SoCal Chairs
Alan Hanson (Simpson Strong-Tie, retired)
Margaret Vinci (Caltech)

Earthquake Impacts on Utilities and Other Lifelines and How to Reduce Them
Craig Davis, Ph.D., P.E., G.E. (C A Davis Engineering)

Potential New Information Tools and Solving Challenges with Earthquake Early Warning
Jessie Saunders, Ph.D. (Caltech)

Quake Break & "*Shake to the Beat*"
Gabrielle Tepp (Caltech)

ECA 2024 Activities & Opportunities:
Mini Awards Update; Materials Order Form; Quake Heroes Expos
Mark Benthien (SCEC/ECA)

Open Discussion, Sharing, and Networking

Earthquake Impacts on Lifeline Infrastructure Systems and How to Reduce Them

Craig A. Davis, Ph.D., P.E., G.E.
C A Davis Engineering
Los Angeles Department of Water & Power (retired)

Earthquake Country Alliance
SoCal Spring 2024 Online Workshop
Wednesday June 5, 2024

CADE
CA Davis Engineering

Earthquake Country Alliance

Contents

- Lifeline Infrastructure Systems Overview
- Earthquake effects on Lifeline Infrastructure Systems
  - 1971 San Fernando Earthquake Examples
  - 1994 Northridge Earthquake Examples
- Societal Impacts from Lifeline Infrastructure Damages
  - Service Losses
- Reducing the Impacts

Lifeline Infrastructure Systems

- Lifeline Infrastructure Systems are the subset of built infrastructure systems that are essential for any modern city, economy, and society to function.
- They include the following utility and mobility systems:
  - Water
  - Wastewater
  - Storm Water
  - Electric Power
  - Communication
  - Gas and Liquid Fuels
  - Transportation
  - Solid Waste

Lifeline Infrastructure Systems Overview

- Large geographically distributed systems
  - Some cover multiple regions, states, or countries
  - Others limited to city scale
- Made of numerous interlinked specialized components
  - Designed & built over long timeframes
  - Using a variety of standards, procedures, and materials
- Interdependent & Co-located
  - Performance of one effects the others
  - Proximity means failure of one can result in unintended damage to others
- Systems need intimate coordination
  - Yet tend to operate in silos

Lifeline Infrastructure Systems Overview

- Failures in a single system can result in
  - Cascading failures in other systems
  - Public health and safety concerns
    - Flooding
    - Explosion
    - Fire
    - Electrocution
    - Contaminated water
    - Blocking mobility or communication
    - Wide loss of services

Photo: Balboa Blvd. 1994 Northridge Earthquake, damages to multiple lifelines (road, water, gas, electric power) – cascading failures and hazards

Earthquake Effects on Lifeline Infrastructure Systems

1971 San Fernando Earthquake

History of Lifeline Earthquake Engineering

- 2024 is the 53-year anniversary of Lifeline Earthquake Engineering
- On February 9, 1971 a M6.6 earthquake struck the northern San Fernando Valley.
- This event prompted the development of Lifeline Earthquake Engineering
- Damage was wide-spread in Los Angeles and nearby cities
  - Schools
  - Hospitals
  - Homes
  - Other buildings
  - All lifeline systems

San Fernando Earthquake – Lifeline Systems

Fault rupture in Interstate 210 – Caltrans photo

Scarp at Foothill Nursing Home – USGS Photo

San Fernando Earthquake – Lifeline Systems

Upper San Fernando Dam showing movement of parapet wall – LADWP photo

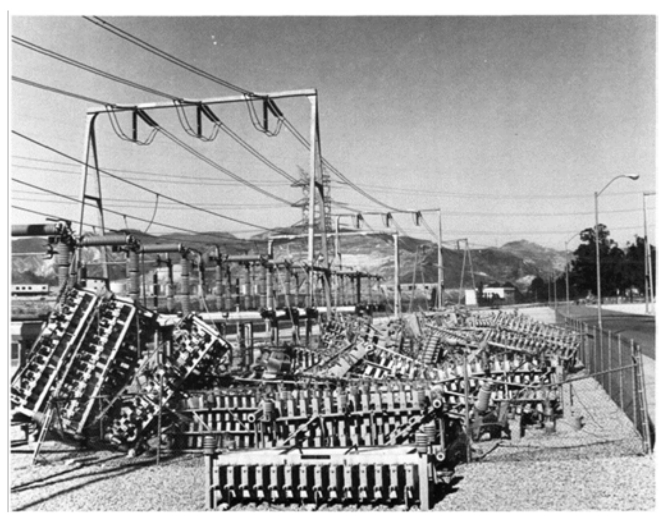
Lower San Fernando Dam – remains of crest after upstream slope failure – LADWP photo

San Fernando Earthquake – Lifeline Systems

Damaged Section of the 49.5 inch diameter Granada Trunkline in the Utility Corridor – LADWP photo

Buckle in the 2- million gallon Sesnon Tank where steel plate thickness changed from 9/16-inch to 7/16-inch – LADWP photo

San Fernando Earthquake – Lifeline Systems



Damaged Power Equipment at Sylmar Switching Station – LADWP photos

San Fernando Earthquake – Lifeline Systems

Gas pipe taken from the shear-thrust zone across Glenoaks Boulevard – USGS photo

San Fernando Earthquake – Lifeline Systems

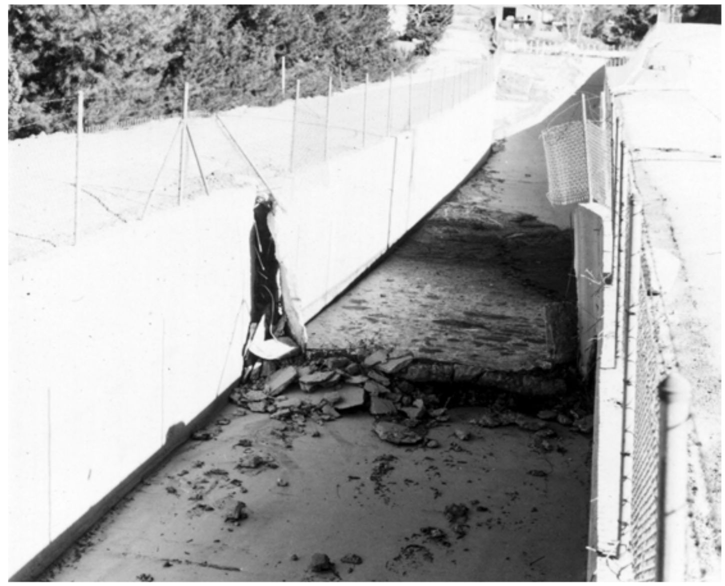
GTE (General Telephone) CO sustained extensive damage to the equipment – Photos courtesy Alex Tang

Service persons trying to sort out the line to transfer to San Fernando

. Electro-mechanical equipment collapsed

San Fernando Earthquake – Lifeline Systems

stormwater channel along Sepulveda Blvd. at Sylmar converter Station – USGS photo



Reverse fault rupture through an LA County concrete storm drainage channel – USGS photo

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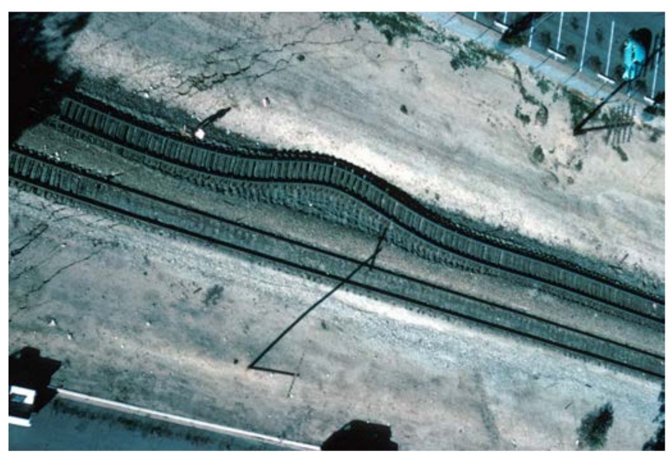
San Fernando Earthquake – Lifeline Systems

Highway Bridge Collapse – Caltrans Photo



Displaced Southern Pacific Railroad tracks near Los Angeles County Juvenile Hall. – USGS Photo

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Post-1971 Improvements

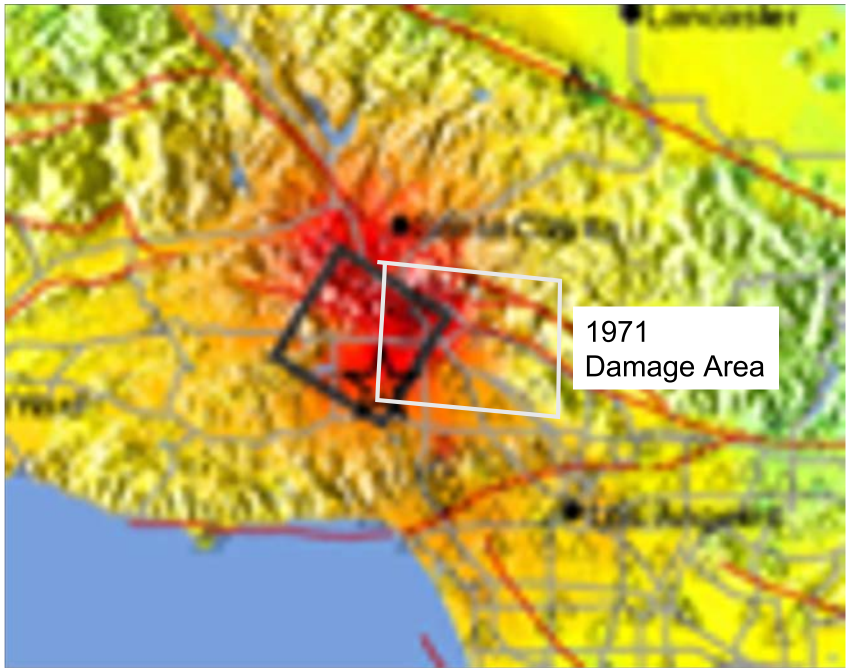
- Following the 1971 earthquake
  - All lifeline infrastructure systems worked together and made significant improvements to their systems
  - Examples from LA Water System (among many other things)
    - Re-evaluated all dams and reservoirs and rebuilt most
    - Upgraded/rebuilt most storage tanks
    - Improved all pumping and Chlorination stations
  - Numerous code and regulation changes
  - Lifelines were recognized as essential systems for cities

NORTHRIDGE 30
1994 2024

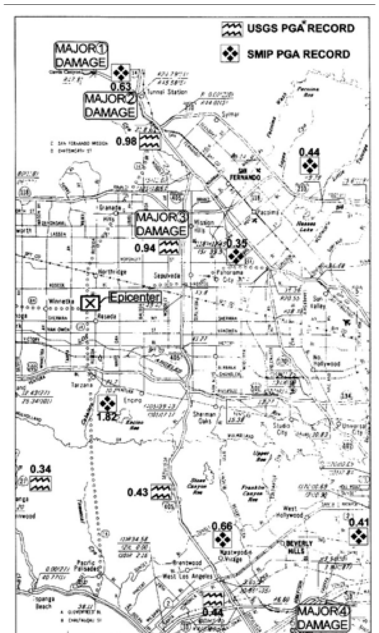
Earthquake Effects on Lifeline Infrastructure Systems

1994 Northridge Earthquake

(See also the Northridge 30 webinar)



Highway Bridges – Caltrans (courtesy M. Yashinsky)



Bridge Location	Bridge Name	Bridge #	Yr Built	Length	Type
1) Gavin Canyon (I-5)	Gavin Canyon Bridge	53-1797R/L	1967	741 ft	QBC CBC*
2) 14/5 Interchange	Rte 14/5 Sep. & OH North Connector OC	53-1960F 53-1964F	1971-74 1971-74	1582 ft 1532 ft	QB CBC QBC CBC
3) 118 west of 405	Mission Gothic UC Bull Creek Cyn Ch Br	53-2205 53-2206	1976 1976	532 ft 256 ft	QBC QBC
4) I-10@ downtown	La Cienega-Venice UC Fairfax-Washington UC	53-1609 53-1580	1964 1964	871 ft 577 ft	CBC CBC

* QBC - cast in place prestressed box girder continuous; CBC - concrete box girder continuous.


Gavin Canyon Undercrossing

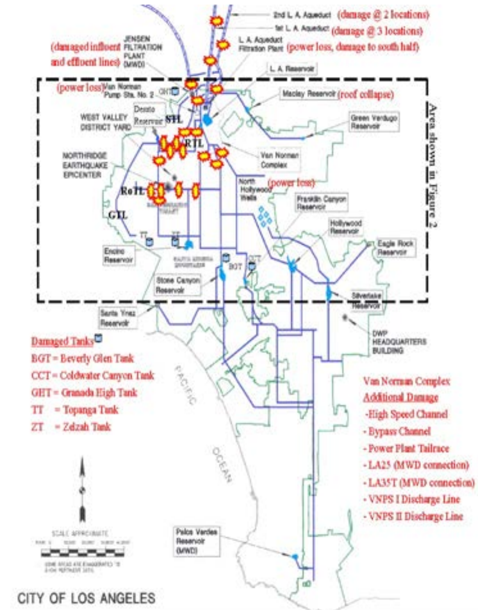

Route 14/5 Separation & Overhead


La Cienega-Venice Blvd Undercrossing


Mission Gothic Undercrossing

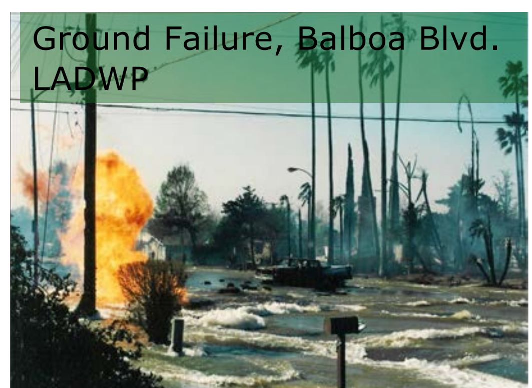
Water and Sewer Systems
(Most impacts to LA City Systems)

- Water Systems
  - Thousands of pipe repairs
  - Damage to Aqueduct and transmission lines
  - Damage to tanks, reservoirs, & treatment plants
  - Service impacts to ~1,000,000 people
  - Boil Water notices issued
  - Loss of water to fight fires
  - All services restored within weeks
  - System repairs completed in years
- Sewer Systems
  - Pipe and treatment plant damages
  - Service outages not substantial



Natural Gas (So. California Gas Company)

- Pipe damages
  - 35 transmission (old lines)
    - 3 fires
  - 154 distribution (steel)
- All newer pipes performed well
- 151,000 customers out of service (88% shut off own service)
- 51 natural gas related fires (private property)
- 172 mobile homes destroyed by fire (lack of seismic bracing)
- 82% of customers restored in 2-3 weeks



Ground Failure, Balboa Blvd. LADWP

https://wtop.com/national/2019/01/northridge-earthquake-shattered-los-angeles-25-years-ago/

Electric Power (LADWP and SCE most impacted)

- Damage to Transmission Towers, Converter & Receiving Stations.
- Power lost to entire City of LA for 1st time ever
- LA restored 93% customers in 1.5 days, completed within 2 days
- SCE had 825,000 customer outages, restored in 20 hours
- Power Grid impacts resulted in outages across Western USA and Canada

Other Systems

- Communication Systems
  - Performed reasonably well
  - Notable service outages for several hours
- Liquid Fuels
  - Old pipeline damages
  - Oil spills resulting in fire

Service Recovery

- These infrastructure systems were fairly resilient
  - Resilience is usually described in terms of a rapid recovery.
- They were able to recover their basic services to the communities experiencing the disaster in a timely manner.
- This was a result of having experienced a similar-sized earthquake-caused disaster 23 years prior in the same area.
  - Post-1971 earthquake improvements were made over the decades and paid dividends in 1994!
  - Yet there was still significant damage and service disruptions
- **What about areas not as prepared?**
- **What about larger events?**

Societal Impacts from Service Losses

- Loss of Lifeline Infrastructure Services Severely Effect:
  - Emergency response
    - Communications
    - Electric Power
    - Transportation
    - Water for Firefighting
  - Public health and safety
  - Basic survival (life, social, economic) of populations
  - Post-earthquake recovery
- Lifeline Infrastructure System Services are needed for all of these important issues
  - Yet, examples show we cannot prevent infrastructure service disruptions in extreme events

Resilience Thinking Helps to Reduce Impacts

- Be prepared to adapt
- Understand the interdependencies and be prepared
- Communities need to be prepared to have services disrupted for some period of time
- Lifeline Infrastructure systems need to be prepared to restore any disrupted services when the communities need them
  - Not all services are needed at the same time
  - e.g., hospitals and first responders need services before recreational facilities
- Mitigating infrastructure vulnerabilities
- Adding redundancy to systems
- There are many other resilience activities that can be undertaken

Developing Methods to Improve and Maintain the Resilience of Lifeline Infrastructure Systems

- Identifying the characteristics of Resilient Lifeline Infrastructure Systems
- Main elements making up processes for assessing, managing, and governing for infrastructure resilience
- Interactions between infrastructure system services and communities
  - Resilience requires broad engagement and communications
- Processes for Identifying Service Recovery Objectives to meet societal needs
  - We need consistency across lifeline sectors to support community needs
- Frameworks for Designing and Managing Lifeline Infrastructure to meet Recovery Based Objectives

Making Resilient Lifeline Infrastructure

- Community resilience planning incorporating infrastructure service needs
  - Accomplished at community level involving infrastructure systems
- Infrastructure Resilience Plans incorporating user needs
  - Accomplished at Infrastructure system level involving stakeholders
- Designing infrastructure components and systems to meet recovery-based objectives
  - Utilize newly developed processes by FEMA and NIST

Lifeline Resilience Program

Process was generalized and published for use by others

- Defines 17 Characteristics
- 119 achievement indicators

Establishing Characteristics to Operationalize Resilience for Lifeline Systems

Craig A. Davis, Ph.D., P.E., M.ASCE[1]; Ali Mostafavi, Ph.D., A.M.ASCE[2]; and Haizhong Wang, Ph.D., A.M.ASCE[3]

Abstract: The purpose of this paper is to provide information useful for creating and maintaining resilient utility lifeline systems. …

Introduction

Utility lifeline systems are infrastructure networks vital to the communities they serve. …

© ASCE 04018014-1 Nat. Hazards Rev.

2019 ASCE webinar:
http://mylearning.asce.org/diweb/catalog/item?id=5077710
EERI webinar provides summary:
https://www.youtube.com/watch?v=is68pcU86x0

Based on work published in:

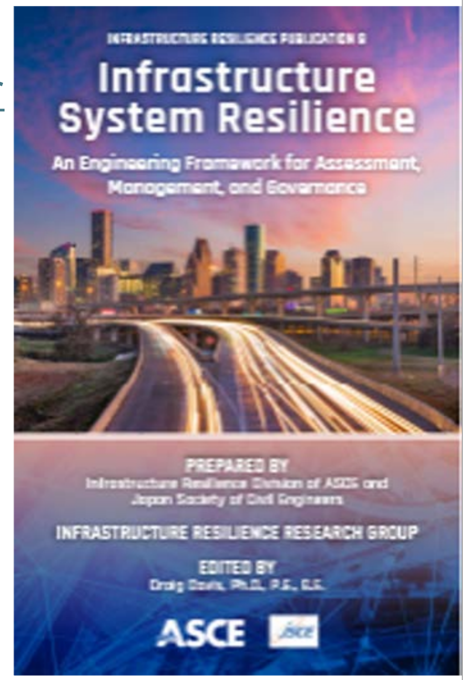
Davis, C.A., A. Mostafavi, and H. Wang (2018). "Establishing Characteristics to Operationalize Resilience for Lifeline Systems," ASCE Natural Hazards Review Journal, 19(4), DOI 10.1061/(ASCE)NH.1527-6996.0000303

Infrastructure Resilience Framework

- ASCE and JSCE developed an engineering framework for assessment, management, and governance

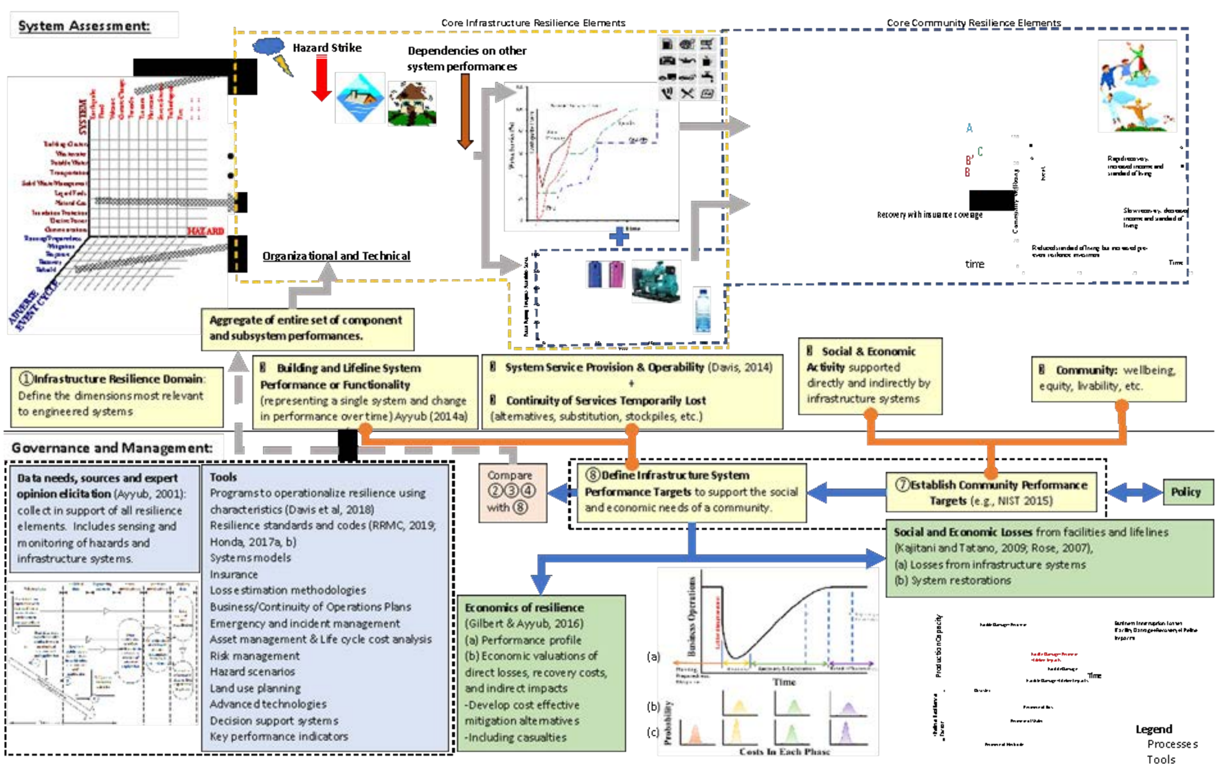
https://sp360.asce.org/PersonifyEbusiness/Merchandise/Product-Details/productId/303911505

- Meets need for engineers to operationalize resilience, covering
  - all infrastructure systems and hazards,
  - all event cycle phases
- Identifies the 8 elements for infrastructure resilience
  1. Infrastructure Resilience Domain
  2. Infrastructure Performance or Functionality
  3. Service Provision and Operability
  4. Continuity of Services Temporarily Lost
  5. The Supported Social & Economic Activities
  6. Community wellbeing, equity, livability
  7. Establish Community Performance Targets
  8. Define Infrastructure Performance Targets



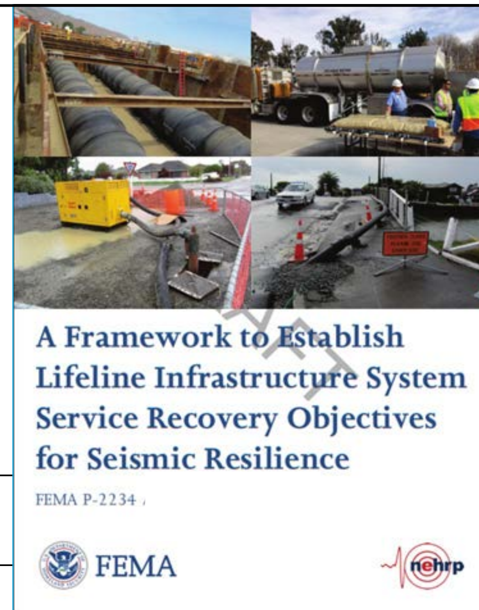
Infrastructure Resilience Framework

ASCE – JSCE Framework



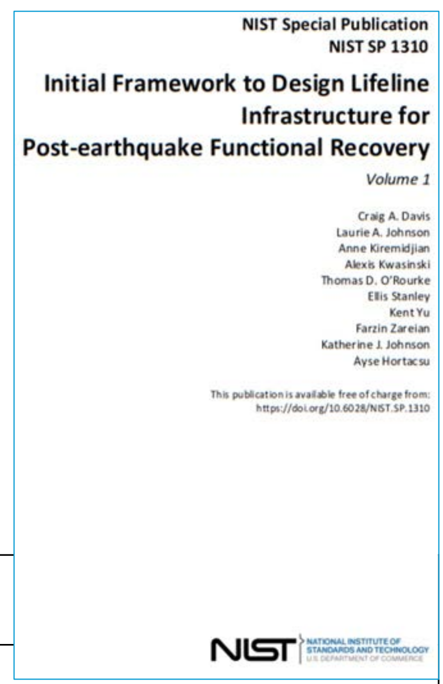
FEMA P-2234 “A Framework to Establish Lifeline Infrastructure System Service Recovery Objectives for Seismic Resilience”

in review – to be published soon



FEMA project funding & guidance	Mike Mahoney (Retired), Laurie Johnson (subject matter expert)
Applied Technology Council	Ayse Hortacsu, Project Manager
Project Technical Committee	Craig Davis, Ron Eguchi, Rachel Davidson, James Kendra
Project Review Panel	Thomas O’Rourke, Katie Miller, Xavier Arias, Bill Maggiore, Bill Heubach
Working Group Members	Adam Andresen, Lucy Arendt, Georgiana Esquivias, Zhenghui Hu, Ryan Kersting, Yajie Lee

NIST SP 1310 & 1311 “Initial Framework to Design Lifeline Infrastructure for Post-Earthquake Functional Recovery” Published March 2024


NIST Special Publication
NIST SP 1310

Initial Framework to Design Lifeline Infrastructure for Post-earthquake Functional Recovery

Volume 1

Craig A. Davis
Laurie A. Johnson
Anne Kiremidjian
Alexis Kwasinski
Thomas D. O’Rourke
Ellis Stanley
Kent Yu
Farzin Zareian
Katherine J. Johnson
Ayse Hortacsu

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1310

NIST National Institute of Standards and Technology U.S. Department of Commerce

NIST project funding & guidance	Katherine (Jo) Johnson
Applied Technology Council	Ayse Hortacsu, Project Manager
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Project Review Panel	Katie Miller, Don Cutler, Leon Kempner, Ryan Kersting

Team Effort

- We all need to work together to enhance our resilience
- Resilience covers more than just earthquakes
- Climate change and normal operations are putting significant pressures on lifeline infrastructure systems and need to be addresses together with earthquakes
- Lifeline Infrastructure System services are critical to creating resilient communities
- It is essential to engage the lifeline infrastructure systems serving your communities to encourage and help them improve their resilience
- Everyone needs to be aware of the tools that are recently developed to help improve lifeline infrastructure system resilience

For questions and input feel free to contact me at

cadavisengr@yahoo.com

Q&A

To be notified of future events and recordings, join ECA (free!):
EarthquakeCountry.org/join

Please take our survey:
SurveyMonkey.com/r/DDYMFHM

Questions?
info@earthquakecountry.org

Potential New Information Tools and Solving Challenges with Earthquake Early Warning

Jessie Saunders, Ph.D.
Caltech

ShakeAlert in Southern California

Jessie K. Saunders

June 5, 2024

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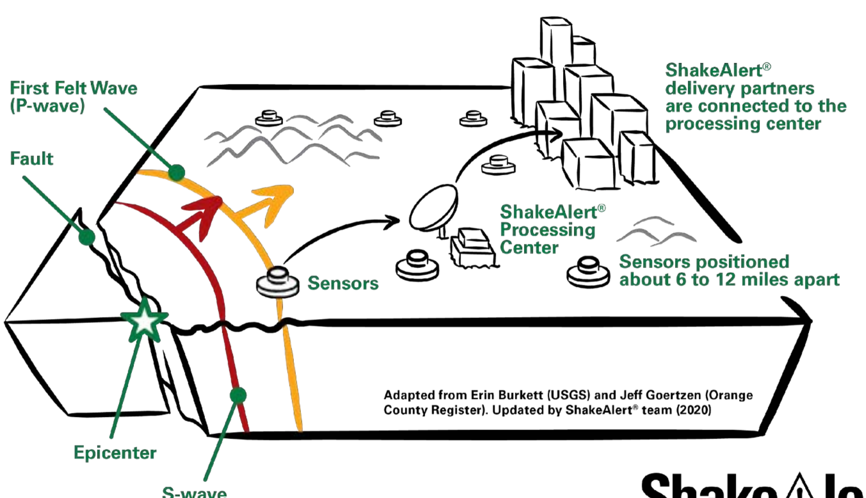
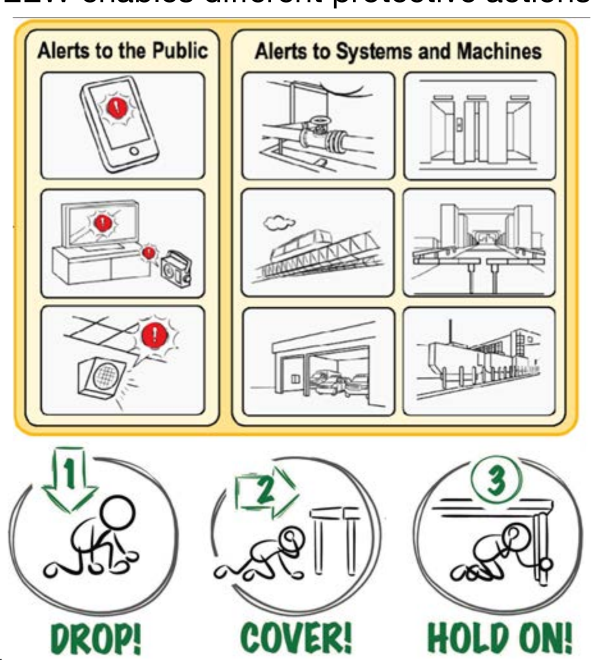
EEW aims to give a few seconds notice before shaking arrives

Earthquake early warning (EEW):

- Detects an earthquake as it begins
- Rapidly estimates ground-motion distributions
- Issues alerts to locations expected to experience significant shaking



EEW enables different protective actions



ShakeAlert™

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EEW is one part of a spectrum of earthquake response products

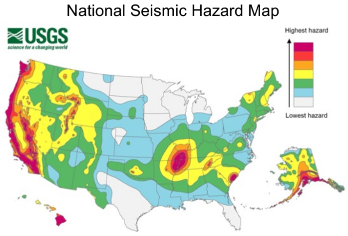
Before the earthquake | Earthquake begins | After the earthquake

EEW is one part of a spectrum of earthquake response products

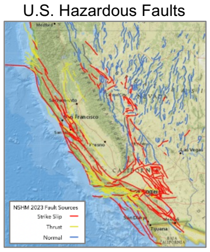
Before the earthquake | Earthquake begins | After the earthquake

Long-term earthquake hazard products

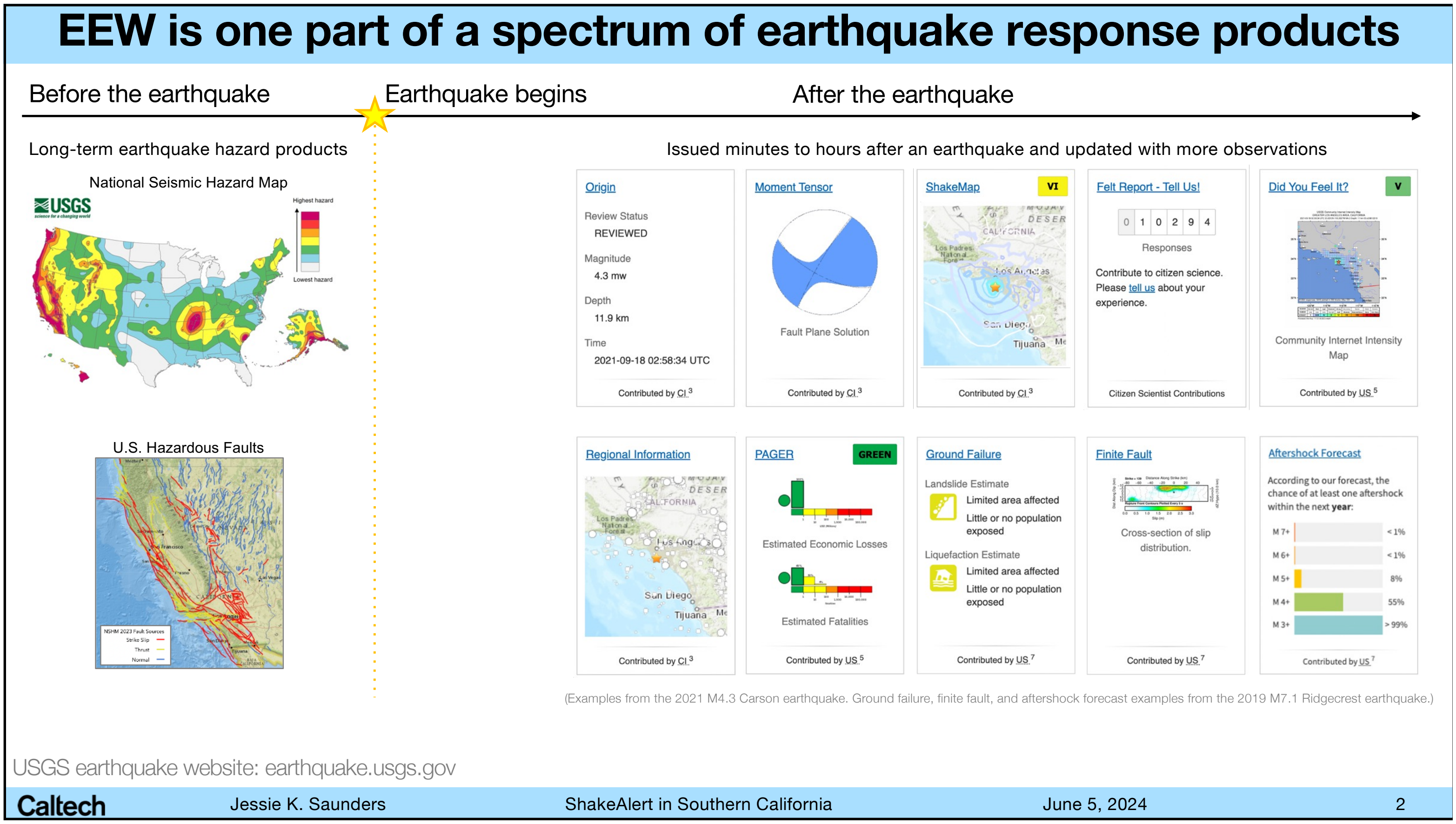
National Seismic Hazard Map



U.S. Hazardous Faults



USGS earthquake website: earthquake.usgs.gov


EEW is one part of a spectrum of earthquake response products
Before the earthquake
Earthquake begins
After the earthquake
Long-term earthquake hazard products
National Seismic Hazard Map
USGS
Highest hazard
Lowest hazard
U.S. Hazardous Faults
Issued minutes to hours after an earthquake and updated with more observations
Origin
Review Status
REVIEWED
Magnitude
4.3 mw
Depth
11.9 km
Time
2021-09-18 02:58:34 UTC
Contributed by CI 3
Moment Tensor
Fault Plane Solution
Contributed by CI 3
ShakeMap
VI
Contributed by CI 3
Felt Report - Tell Us!
0 1 0 2 9 4
Responses
Contribute to citizen science. Please tell us about your experience.
Citizen Scientist Contributions
Did You Feel It?
V
Community Internet Intensity Map
Contributed by US 5
Regional Information
Contributed by CI 3
PAGER
GREEN
Estimated Economic Losses
Estimated Fatalities
Contributed by US 5
Ground Failure
Landslide Estimate
Limited area affected
Little or no population exposed
Liquefaction Estimate
Limited area affected
Little or no population exposed
Contributed by US 7
Finite Fault
Cross-section of slip distribution.
Contributed by US 7
Aftershock Forecast
According to our forecast, the chance of at least one aftershock within the next year:
M 7+ < 1%
M 6+ < 1%
M 5+ 8%
M 4+ 55%
M 3+ > 99%
Contributed by US 7
(Examples from the 2021 M4.3 Carson earthquake. Ground failure, finite fault, and aftershock forecast examples from the 2019 M7.1 Ridgecrest earthquake.)
USGS earthquake website: earthquake.usgs.gov
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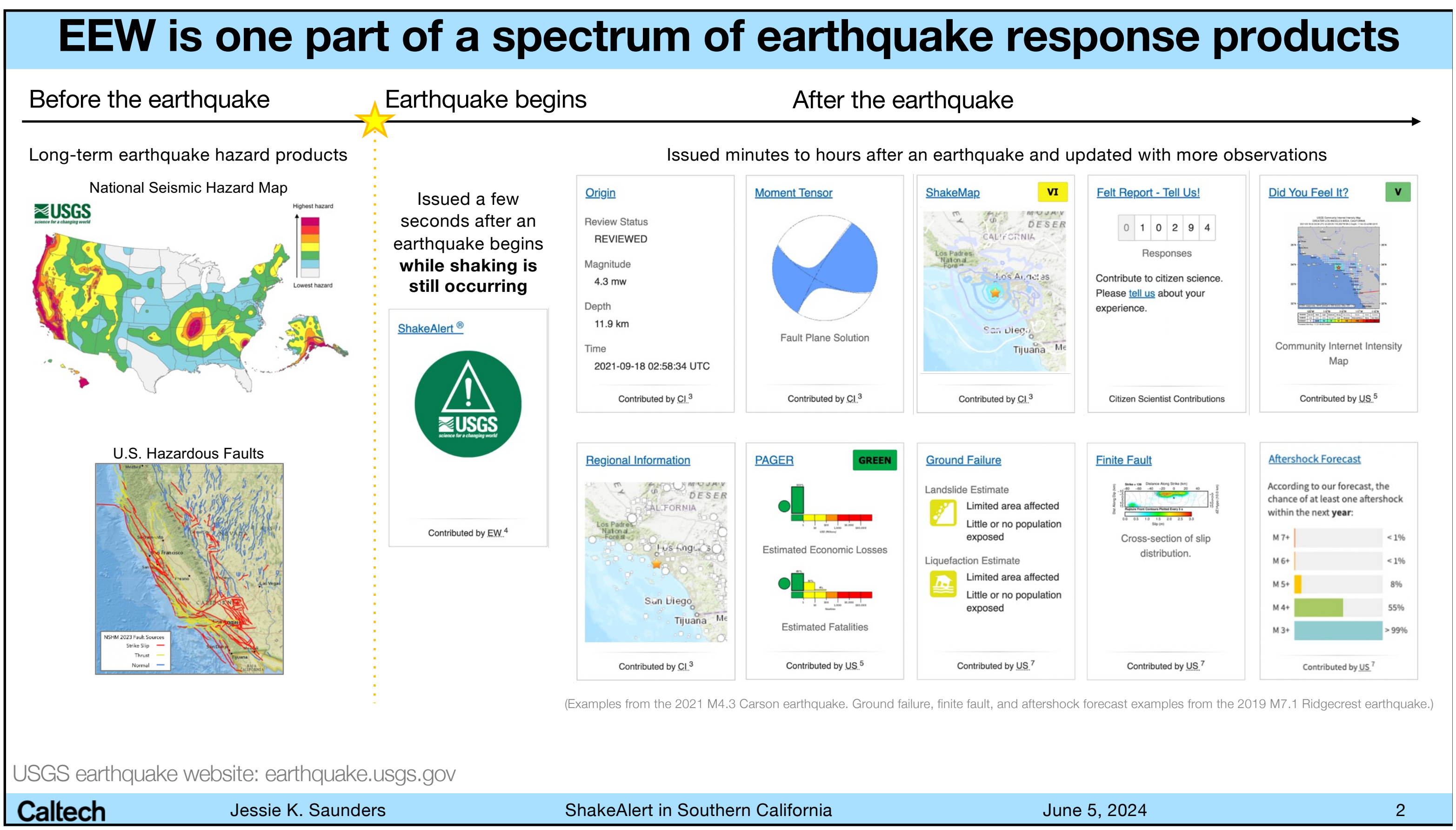
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USGS
Highest hazard
Lowest hazard
U.S. Hazardous Faults
Issued a few seconds after an earthquake begins **while shaking is still occurring**
ShakeAlert ®
USGS
Contributed by EW 4
Issued minutes to hours after an earthquake and updated with more observations
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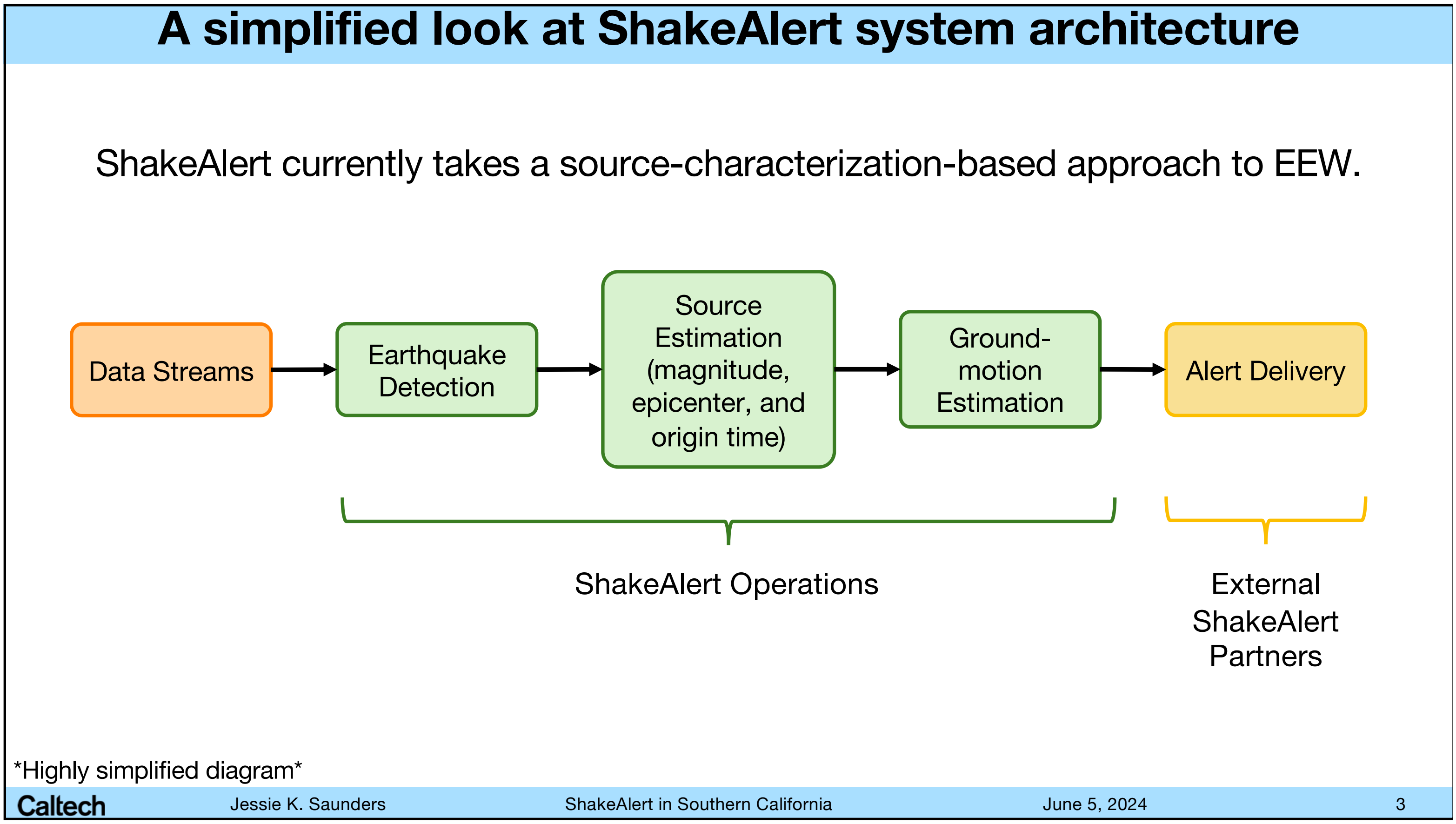
A simplified look at ShakeAlert system architecture
ShakeAlert currently takes a source-characterization-based approach to EEW.
Data Streams
Earthquake Detection
Source Estimation (magnitude, epicenter, and origin time)
Ground-motion Estimation
Alert Delivery
ShakeAlert Operations
External ShakeAlert Partners
Highly simplified diagram
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ShakeAlert in Southern California
June 5, 2024
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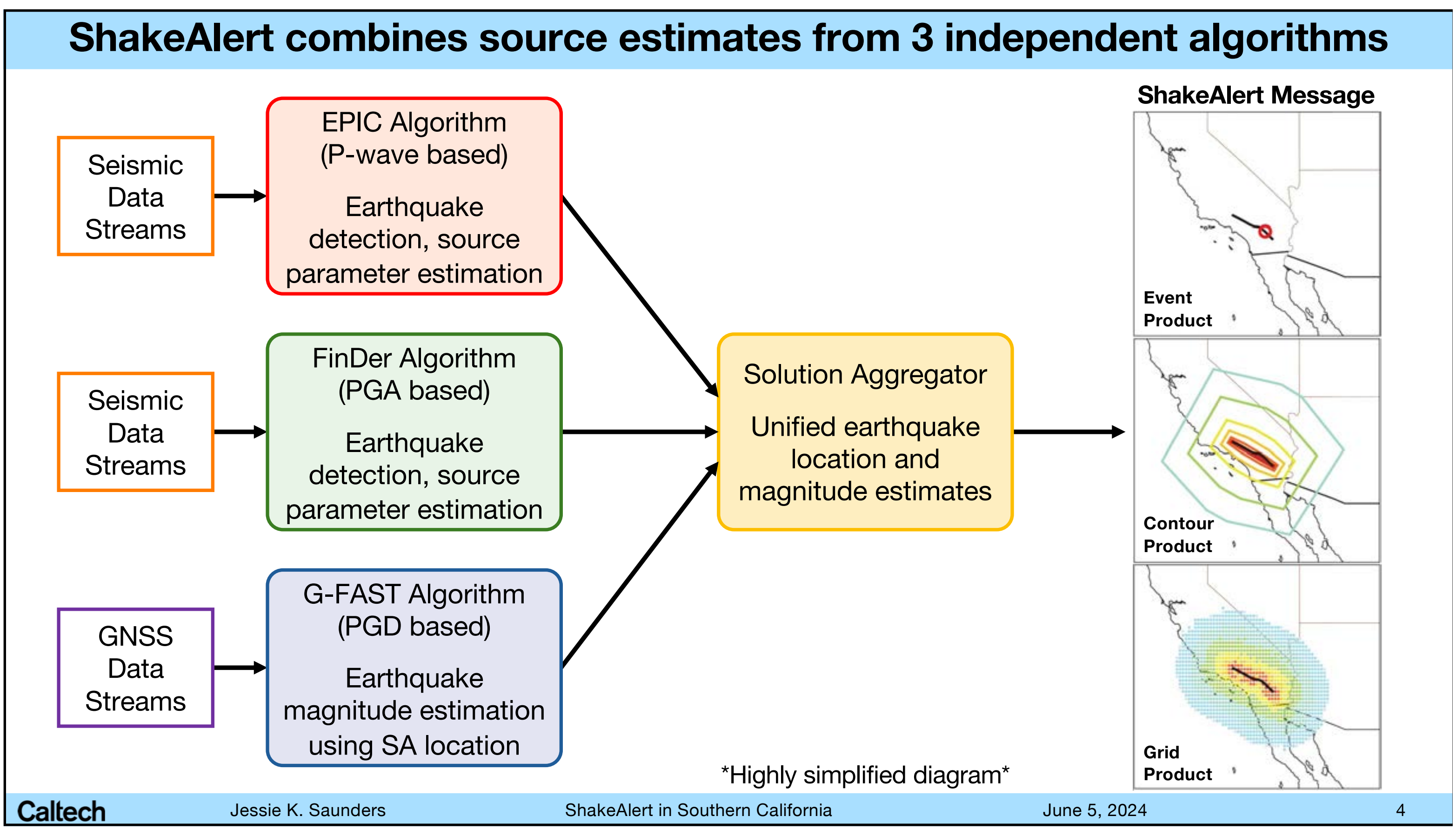
ShakeAlert combines source estimates from 3 independent algorithms
Seismic Data Streams
EPIC Algorithm (P-wave based)
Earthquake detection, source parameter estimation
Seismic Data Streams
FinDer Algorithm (PGA based)
Earthquake detection, source parameter estimation
GNSS Data Streams
G-FAST Algorithm (PGD based)
Earthquake magnitude estimation using SA location
Solution Aggregator
Unified earthquake location and magnitude estimates
ShakeAlert Message
Event Product
Contour Product
Grid Product
Highly simplified diagram
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EPIC: Earthquake Point-Source Integration Code

Seismic Data Streams → EPIC Algorithm (P-wave based)

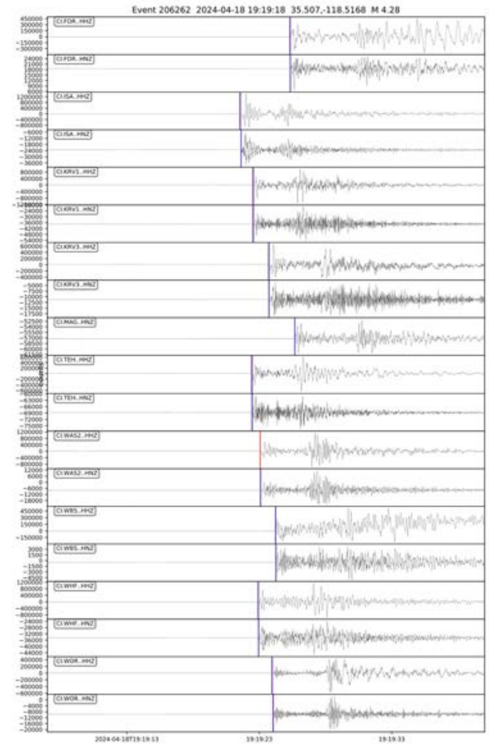
Earthquake detection, source parameter estimation

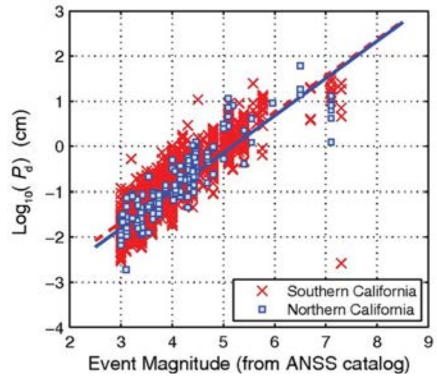
Seismic Data Streams → FinDer Algorithm (PGA based)

Earthquake detection, source parameter estimation

GNSS Data Streams → G-FAST Algorithm (PGD based)

Earthquake magnitude estimation using SA location





Kuyuk et al. (2013, BSSA)

FinDer: Finite-Fault Rupture Detector

Seismic Data Streams → EPIC Algorithm (P-wave based)

Earthquake detection, source parameter estimation

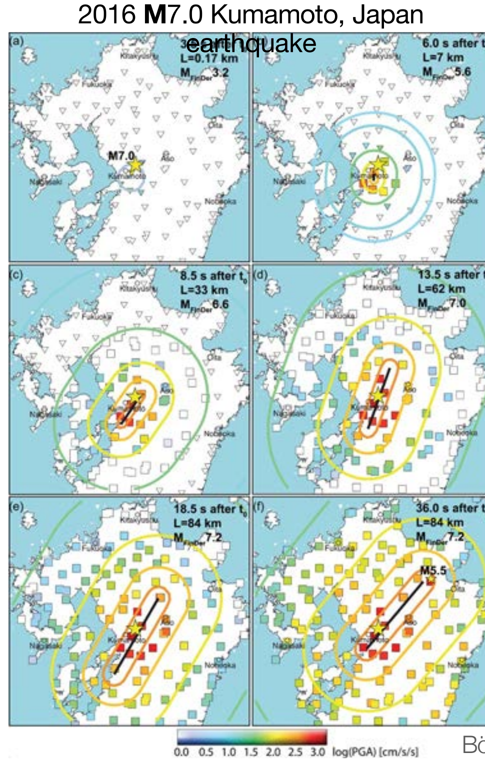
Seismic Data Streams → FinDer Algorithm (PGA based)

Earthquake detection, source parameter estimation

GNSS Data Streams → G-FAST Algorithm (PGD based)

Earthquake magnitude estimation using SA location

2016 **M**7.0 Kumamoto, Japan earthquake



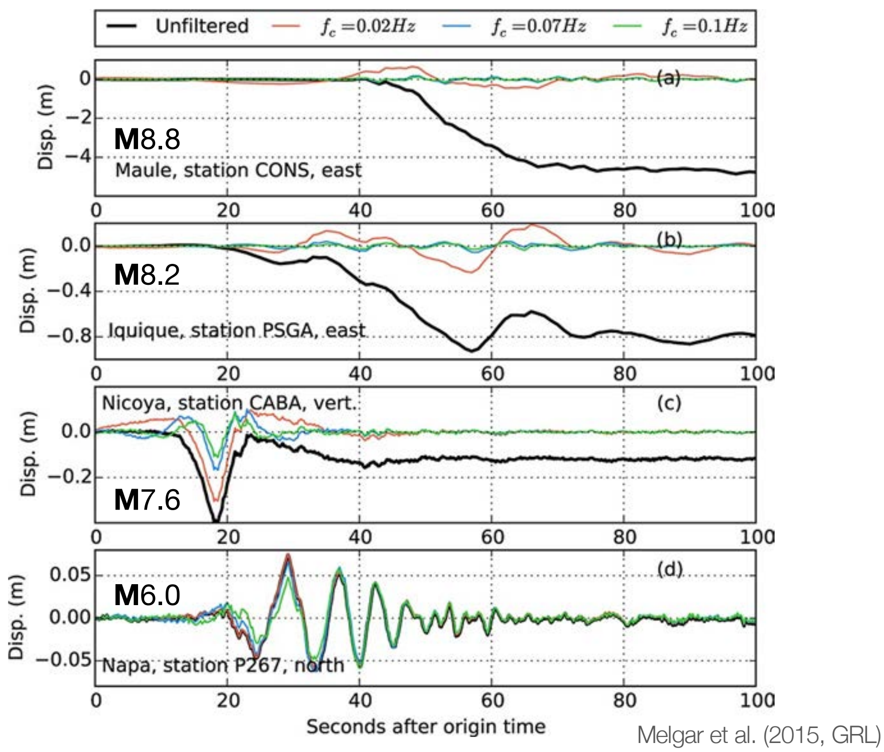
Böse et al. (2018, GJI)

G-FAST: Geodetic First Approximation of Size and Time

Seismic Data Streams → EPIC Algorithm (P-wave based) Earthquake detection, source parameter estimation

Seismic Data Streams → FinDer Algorithm (PGA based) Earthquake detection, source parameter estimation

GNSS Data Streams → G-FAST Algorithm (PGD based) Earthquake magnitude estimation using SA location



Melgar et al. (2015, GRL)

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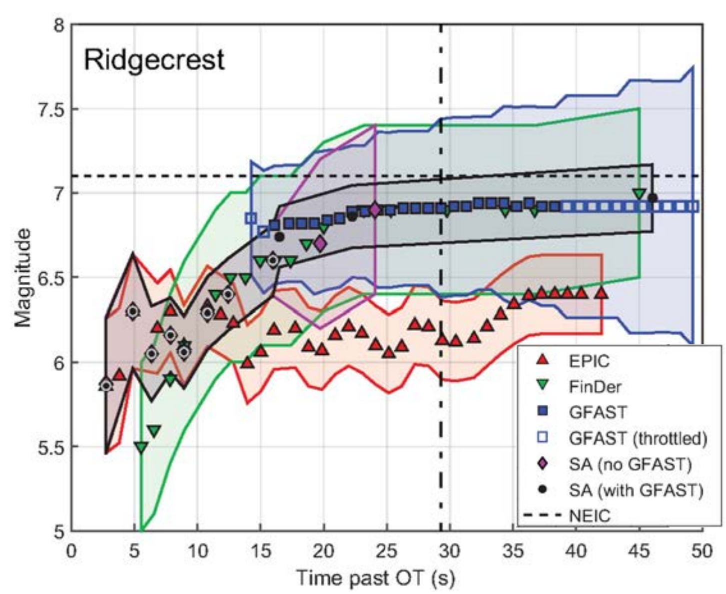
ShakeAlert combines source estimates from 3 independent algorithms

Seismic Data Streams → EPIC Algorithm (P-wave based) Earthquake detection, source parameter estimation

Seismic Data Streams → FinDer Algorithm (PGA based) Earthquake detection, source parameter estimation

GNSS Data Streams → G-FAST Algorithm (PGD based) Earthquake magnitude estimation using SA location



Murray et al. (2023, BSSA)

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Southern CA ShakeAlert performance for March 1 – June 4

Earthquakes with public EEW alerts issued to cell phones

Date	Location	Magnitude	Number of DYFI reports	Maximum intensity	ShakeAlert peak magnitude estimate	ShakeAlert first alert time relative to earthquake origin
2024-04-18	Bodfish, CA	4.3	806	MMI V	4.5	9.3 s
2024-05-01	Corona, CA	4.1	8,384	MMI V	4.5	4.4 s
2024-05-08	Delta, B.C., MX	4.1	25	MMI IV	4.6	8.7 s
2024-05-12	**Delta, B.C., MX**	**4.9**	**340**	**MMI VI**	**5.6**	**12.1 s**
2024-05-12	**Delta, B.C., MX**	**4.6**	**41**	**MMI V**	**5.0**	**7.9 s**
2024-05-13	Delta, B.C., MX	4.2	27	MMI IV	4.5	10.2 s
2024-05-20	Ocotillo Wells, CA	4.1	1,008	MMI V	4.7	6.3 s
2024-05-27	*Mexico*	*4.2*	*5*	*MMI IV*	*4.6*	*21.5 s*

Since March 1, 2024:

- There were 8 earthquakes with ShakeAlert magnitude estimates of M≥4.5 (the threshold for many public alerts)
- There were 13 earthquakes with ShakeAlert magnitude estimates of M≥4.0
  (M4.0 is the threshold at which ShakeAlert performance summaries are published on the USGS webpages)
- All 27 M3.5+ earthquakes were detected by ShakeAlert, and 24 had ShakeAlert magnitude estimates of M≥3.5
- An additional 8 M3.0-3.5 earthquakes had ShakeAlert magnitude estimates of M≥3.5
  (M3.5 is the threshold at which ShakeAlert Messages are published on the alert servers)

2024-05-12 M4.9 Delta, B.C., MX earthquake

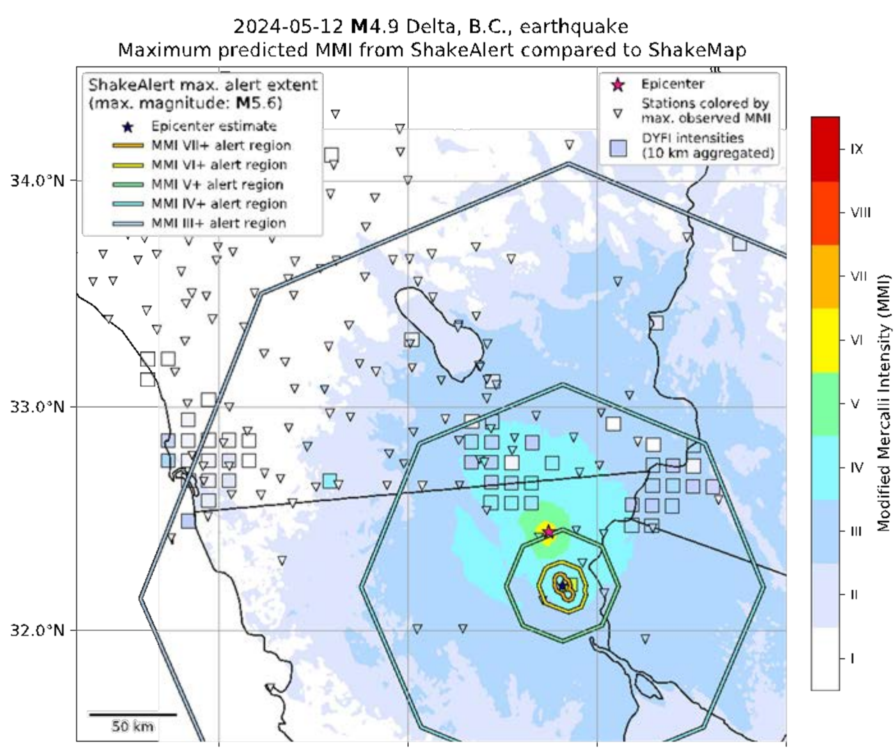
Offshore and edge-of-network earthquakes are challenging for ShakeAlert algorithms due to poor station coverage.

ShakeAlert overestimated this earthquake's magnitude in part due to a poor location estimate by the EPIC algorithm.

However, the MMI IV+ alert region used for alerts delivered through WEA still encompass the area that experienced likely-felt shaking.

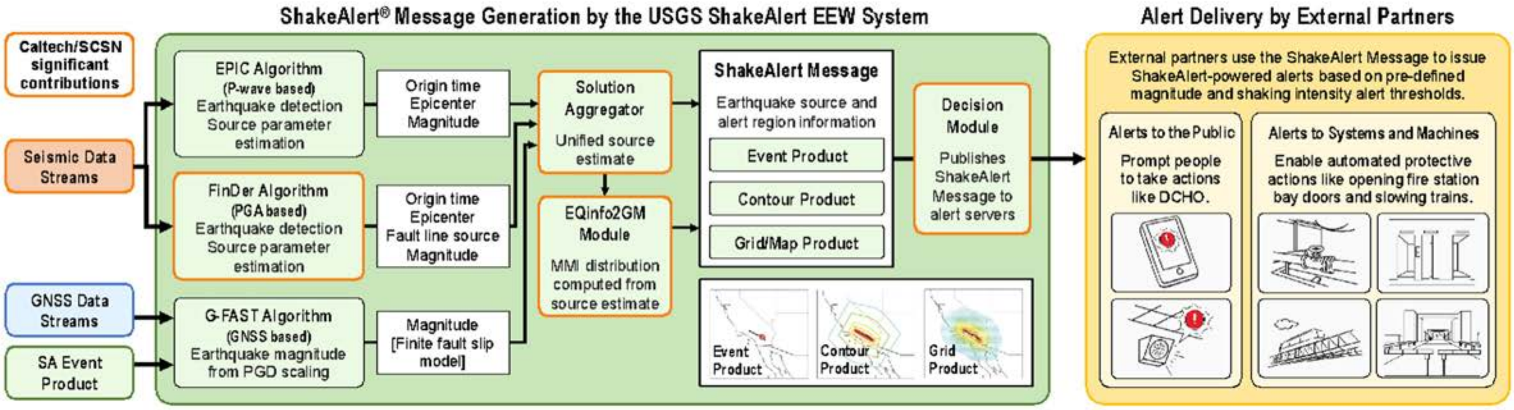
FinDer performed well during this event, but ShakeAlert prefers EPIC for M<6 estimates.

Combining the individual EEW algorithms (EPIC, FinDer, G-FAST) in terms of their predicted ground motions rather than their magnitude and location estimates could produce more accurate alerts.



Summary

ShakeAlert produces alerts by combining earthquake source estimates from EEW algorithms that have different strengths and weaknesses, which makes the system more robust:



While ShakeAlert is successfully producing alerts for significant earthquakes, some challenges remain, including out-of-network earthquakes and complex sequences like earthquake swarms.

We are always looking for ways to improve the current ShakeAlert system.

How can you sign up to get ShakeAlert EEW alerts?

Alert Thresholds

To Alert People

	Who is Alerted	Magnitude Threshold	Intensity Threshold
Wireless Emergency Alert (WEA)	General public with WEA-capable devices	5.0+	MMI IV+
Cell Phone Apps	People who have downloaded a cell phone app	4.5+	MMI III+ (user selectable)
Android Operating System	Android cell phone users through push notifications	4.5+	MMI III - MMI IV
	Android cell phone users through full-screen takeover	4.5+	MMI V+
Automated Alerts through Public Address Systems, Lights, Sirens, In-House Apps, etc.	Institutions that use ShakeAlert to alert people to take a protective action	4.0+	MMI III+

MyShake
Alert San Diego

To Alert Systems and Machines

	Who is Alerted	Magnitude Threshold	Intensity Threshold
Automated "Machine-to-Machine" Alerts	Institutions that use ShakeAlert to automate actions to mitigate damage to vital equipment, systems, and infrastructure	4.0+	MMI III+

ShakeAlert

As of June 2021

Q&A

To be notified of future events and recordings, join ECA (free!):
EarthquakeCountry.org/join

Please take our survey:
SurveyMonkey.com/r/DDYMFHM

Questions?
info@earthquakecountry.org

Quake Break: So Cal Seismic Activity

Including:

Shake to the Beat: Exploring the Seismic Signals and Stadium Response of Concerts and Music Fans

Gabrielle Tepp
Caltech

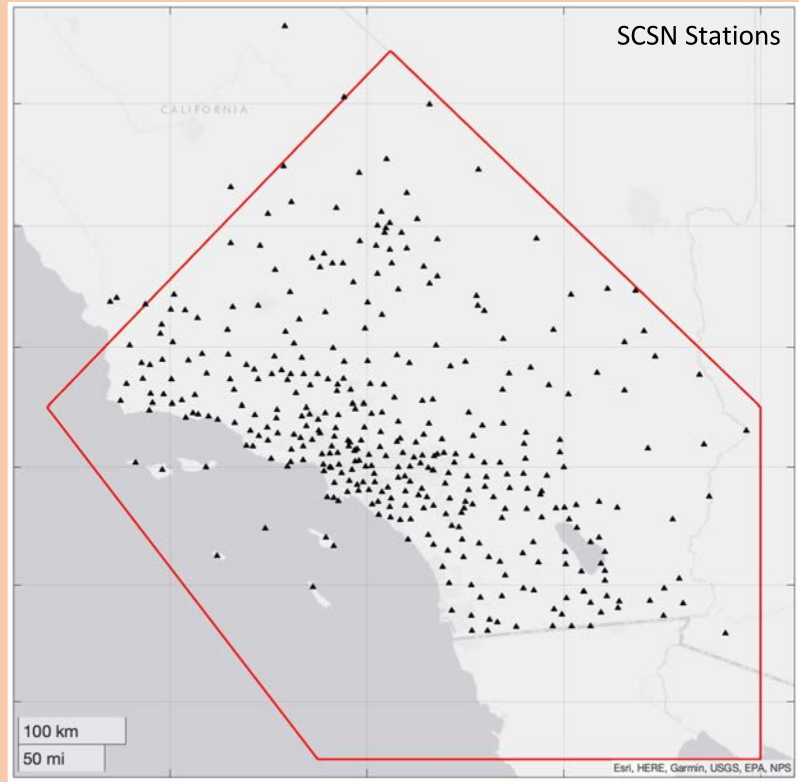
Quake Break – Southern California

March – May 2024

Gabrielle
Tepp

SCSN/Caltech

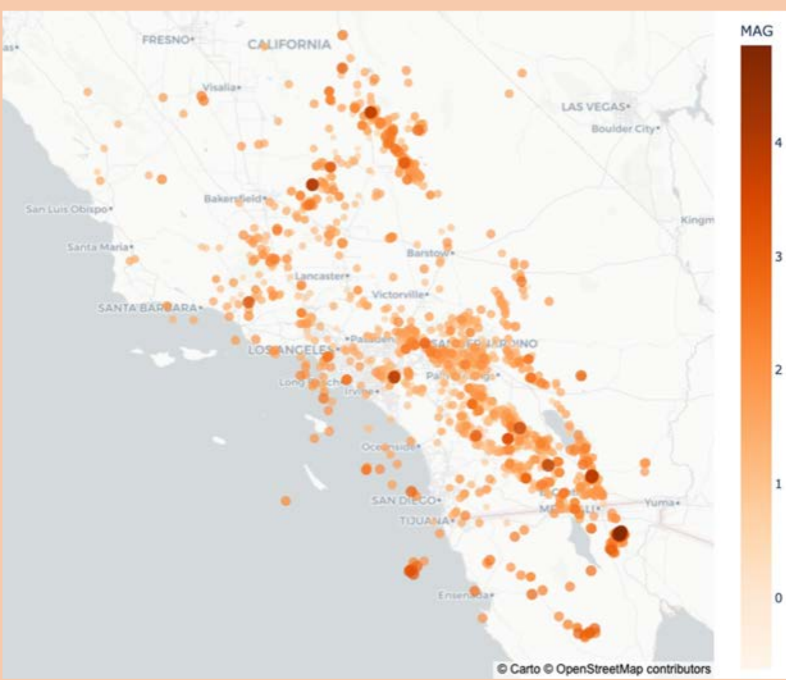
* Follow us on social media: @CaltechSeismo
* For earthquake notifications: @CaltechQuake (X/Twitter)



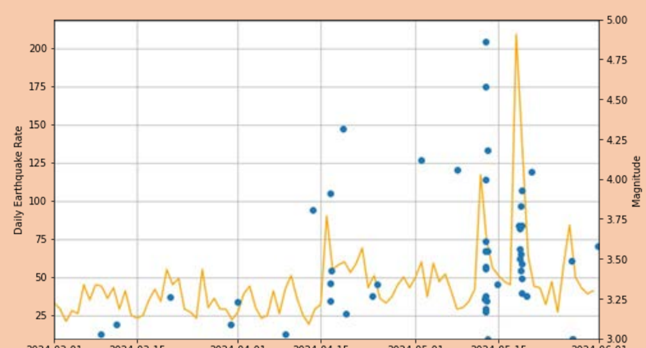
This quarter in Southern California there were:

3,993 earthquakes + 135 quarry blasts
- M>2 – 396
- M>3 – 56
- M>4 – 8

4/18/24 – M4.3 - S of Bodfish, California
5/01/24 – M4.1 - SW of Corona, California
5/07/24 – M4.1 - NW of Delta, B.C., Mexico
5/12/24 – M4.9 - NNW of Delta, B.C., Mexico
5/12/24 – M4.0 - NW of Delta, B.C., Mexico
5/12/24 – M4.6 - NW of Delta, B.C., Mexico
5/12/24 – M4.2 - NNW of Delta, B.C., Mexico
5/20/24 – M4.1 - SE of Ocotillo Wells, California



Average daily earthquake rate: 45
Max rate of 209 on 05/18/2024



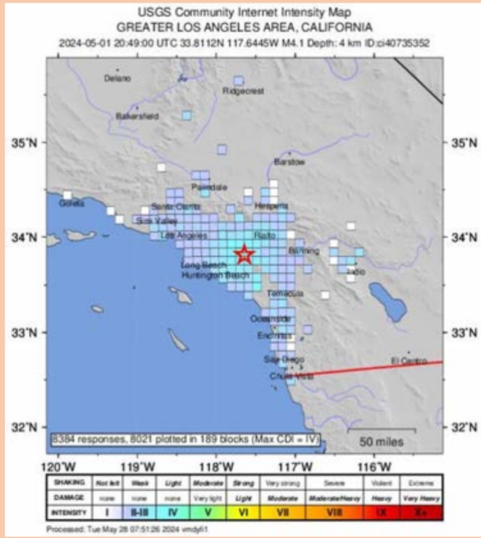
M4.1 Corona Sequence

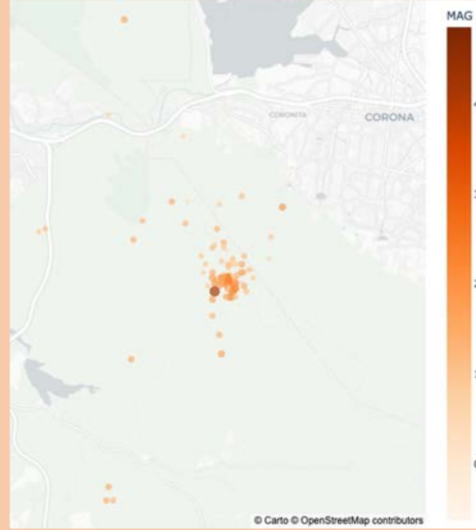
(May 1, 13:49:00 PDT, 4.6 km depth)

This sequence had 13 foreshocks in the 5 days before and ~50 aftershocks by the end of May.

Largest Foreshock:
M2.8 on 4/30/24 at 19:26:38 PDT

Largest Aftershock:
M2.5 on 5/1/24 at 17:52:58 PDT

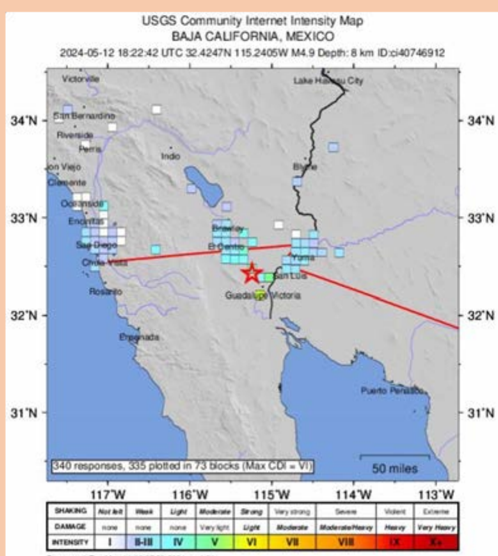


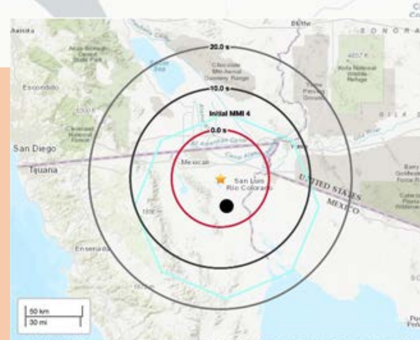


May 12 Baja Sequence/Swarm

This sequence had ~70 located events, of which 16 were M3+.

4.9	5/12/24	11:22:42
3.6	5/12/24	11:25:28
3.5	5/12/24	11:25:54
4.0	5/12/24	11:33:44
3.6	5/12/24	11:45:00
3.6	5/12/24	11:53:40
4.6	5/12/24	12:04:00
4.2	5/12/24	21:02:18
3.6	5/12/24	21:07:34

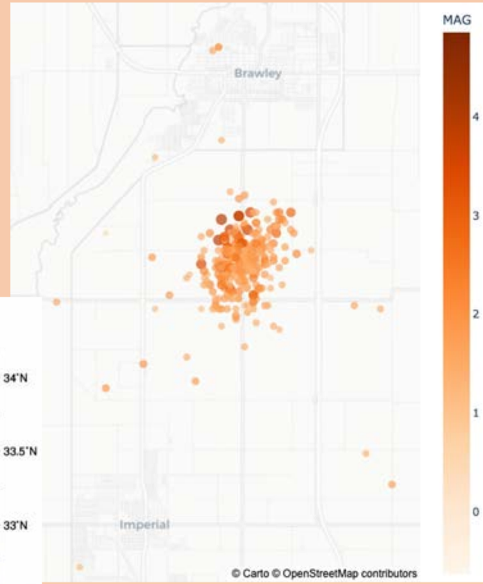


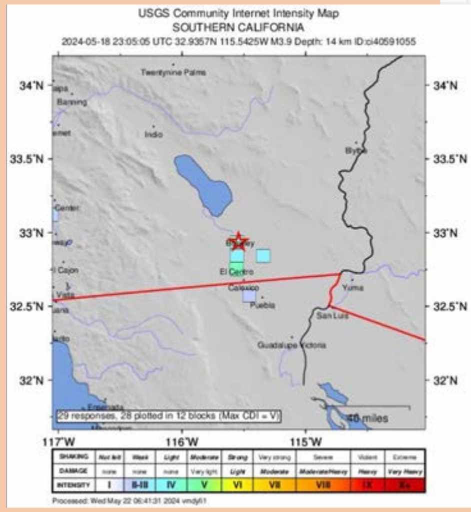


May 18-20 Brawley Swarm

This swarm included 270 earthquakes, of which 13 were M3+.

3.7	05/18/24 02:36:37,	11.7 km
3.6	05/18/24 05:38:00,	13.8 km
3.5	05/18/24 05:41:52,	13.9 km
3.7	05/18/24 08:52:13,	12.3 km
3.5	05/18/24 09:30:18,	10.3 km
3.8	05/18/24 12:17:22,	10.8 km
3.5	05/18/24 15:58:19,	10.5 km
3.9	05/18/24 16:05:05,	14.2 km
3.7	05/18/24 16:13:26,	13.8 km

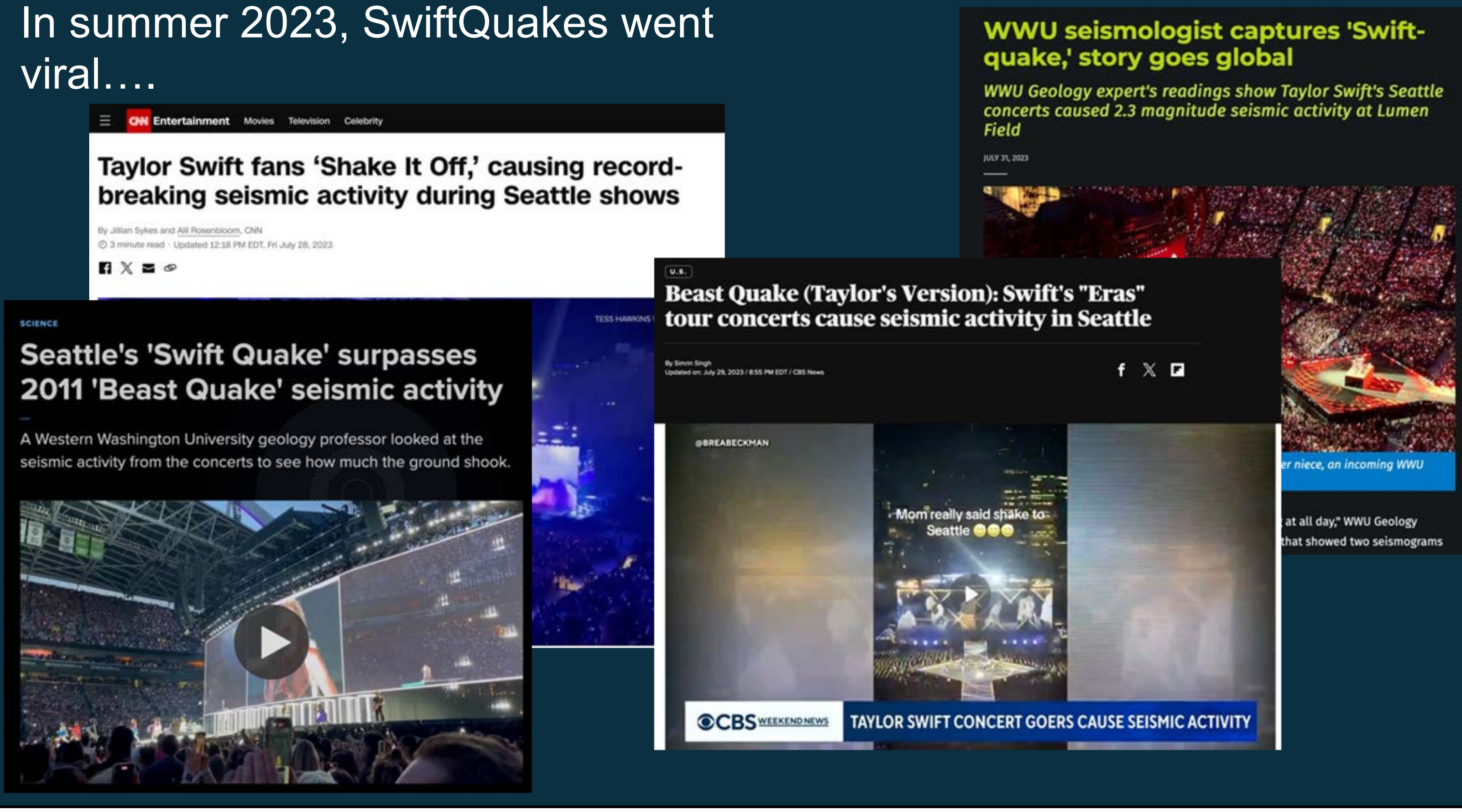




Shake to the Beat: Exploring the Seismic Signals and Stadium Response of Concerts and Music Fans

G. Tepp[1], I. Stubailo[1], M. Kohler[1], R. Guy[2], Y. Bozorgnia[2]
1 – Caltech
2 - UCLA

In summer 2023, SwiftQuakes went viral….

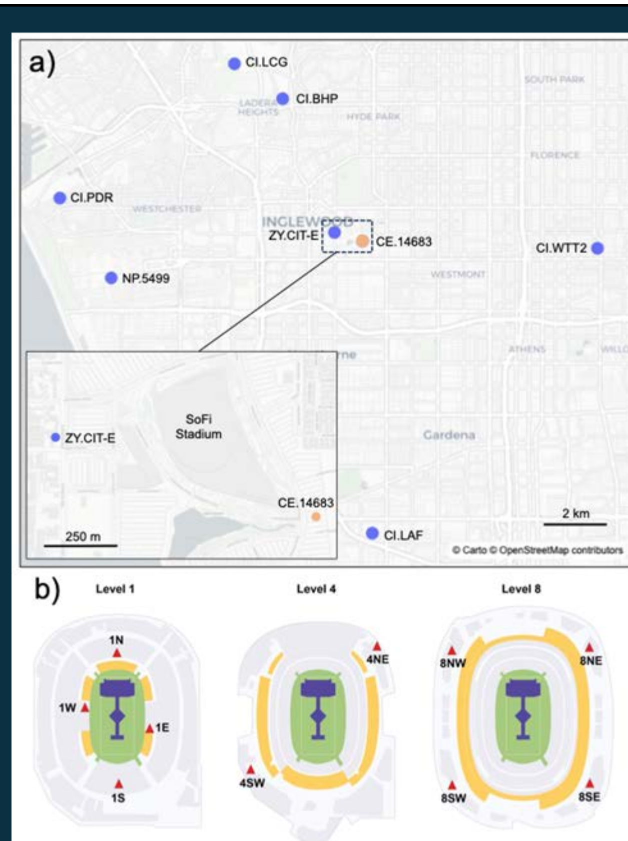


…. and we decided to do an investigation in LA

We deployed:

- 1 Basalt data logger/accelerometer across the street at a hotel
- 10 CSN accelerometers inside the stadium

Additional detections came from the permanent network stations



We found interesting signals

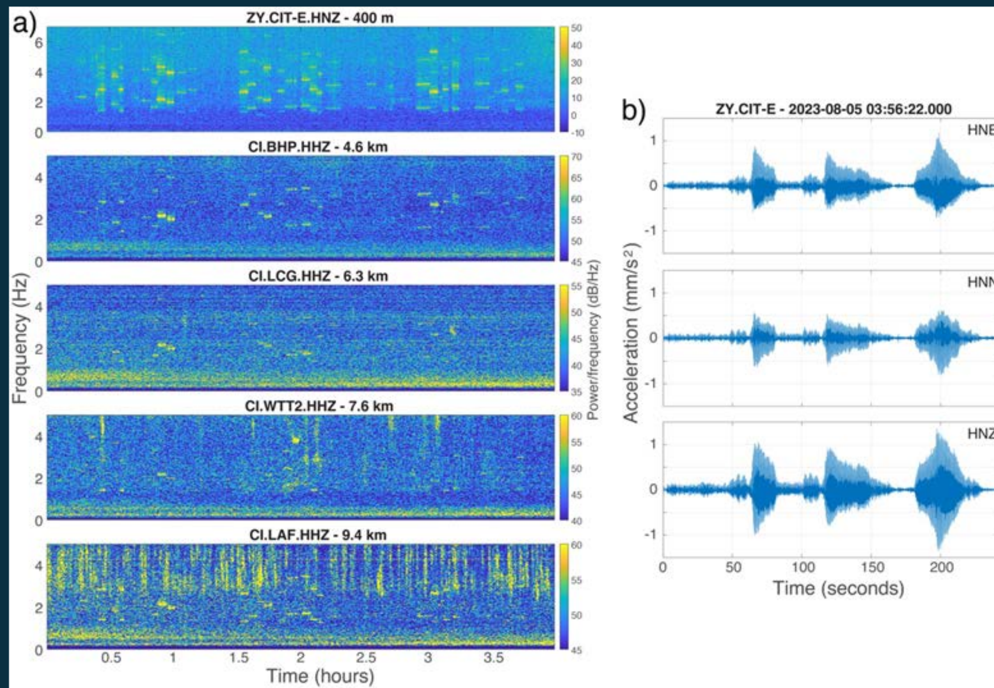
low frequency (~1-10 Hz) harmonics

-> what causes these?

-> how strong are these signals?

43 of 45 songs recorded

- frequencies of signals related to song beat rate



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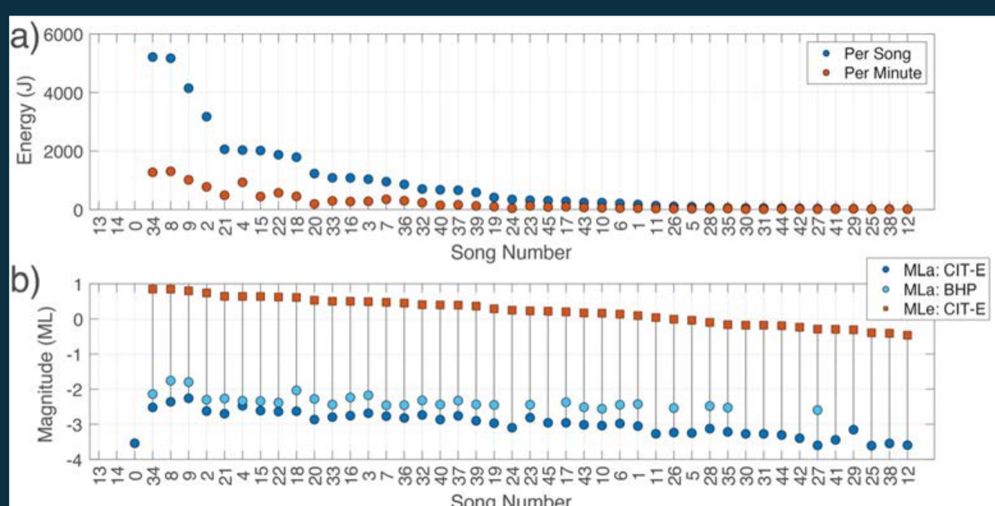
But how strong are the signals?

Traditional magnitudes (ML) based on amplitude

-> assume energy is focused in one short burst

Energy is better measure for extended signals

- can look at energy (and equivalent magnitude) for entire song or per time unit



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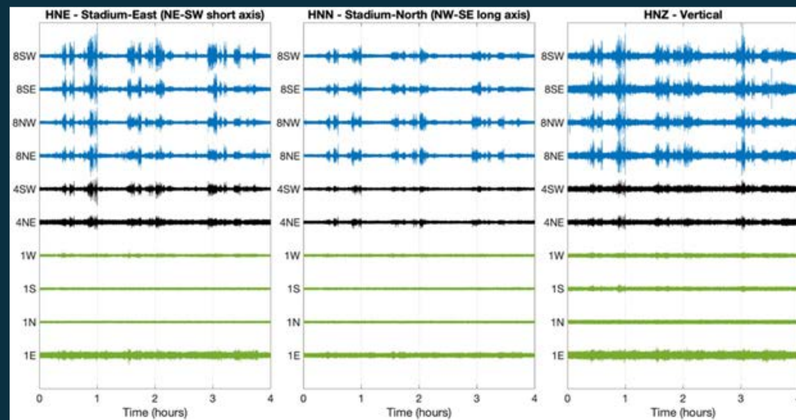
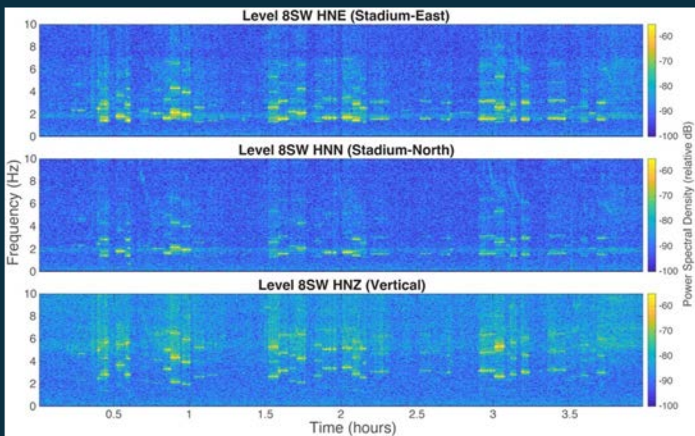
Meanwhile, inside the stadium, it was vibrating





similar to signal recorded outside stadium

maximum amplitude ~1 %g
-> equivalent to MMI II-III

So what creates this harmonic signal?

It's the crowd!

No, it has to be the speakers/instruments!

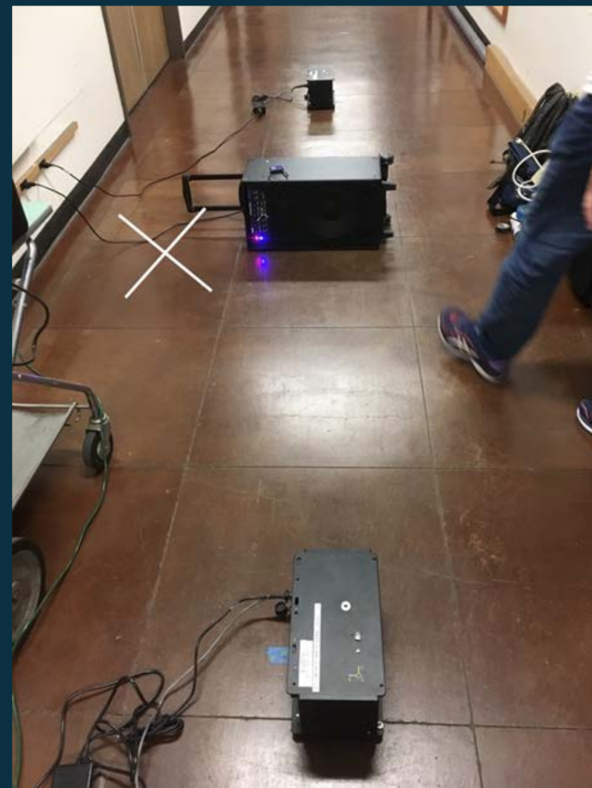
Are we *really* sure it's not the music….?

If it's the speakers/music, then can we recover the harmonic signal from an audio file?

No.

Okay, maybe it's something specific to the seismic recording or speaker?

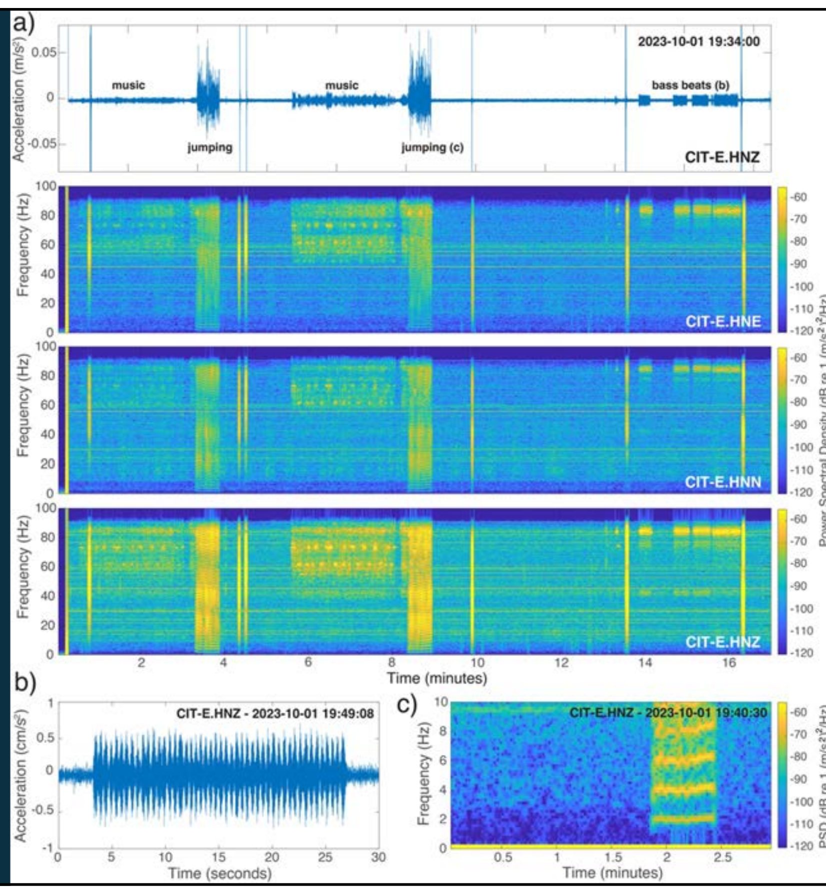
Let's experiment!



We tested:

- a Swift song
- a simple beat with a bass guitar
- jumping to a chorus

Only the jumping produced the low frequency harmonic signal!



Read the paper:
Tepp et al., SRL, 2024

* Open-access pre-print also available through ESSOAR

Thanks!

Questions?

Acknowledgements

We thank Hiroo Kanamori for helpful discussions about energy and magnitude, Jackie Caplan-Auerbach for interesting discussions about the concert signals, Jim Meyer for very detailed information about stadium concert sound systems, and Rafael Sabelli and Mark Waggoner for useful information about stadium structural response parameters. We thank Dave Branum for retrieving data from the CE station that is usually only archived for triggered earthquakes.

Q&A

To be notified of future events and recordings, join ECA (free!):
EarthquakeCountry.org/join

Please take our survey:
SurveyMonkey.com/r/DDYMFHM

Questions?
info@earthquakecountry.org

ECA 2024 Activities & Opportunities

Mark Benthien
Southern California Earthquake Center (USC)
ECA Executive Director

ECA Statewide Activities

Develop Messaging and Resources:
- EarthquakeCountry.org
- EarthquakeCountry.org/resources
- Terremotos.org

Support Tsunami Preparedness Week:
- TsunamiZone.org/california

March 23-31, 2024

Created and Coordinate
The Great California ShakeOut:
- ShakeOut.org/california

ShakeOut

Oct. 17, 2024

Webinars & other events
- EarthquakeCountry.org/calendar

ECA Sector-Based Outreach Committees

- Businesses
- Public Sector
- Non-Profit & Faith-Based Organizations
- Accessibility
- Healthcare
- Higher Education
- PreK-12 Education

Each meets bimonthly; Join us!

EarthquakeCountry.org/committees

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ECA Events Bureau

- Speakers for online/in-person events
  - The Seven Steps to Earthquake Safety
  - Tsunami Preparedness
  - Earthquake Safety for People with Disabilities
  - Community Earthquake Preparedness
  - Organizing a Community ShakeOut Event
  - School Earthquake Preparedness
  - The Science of Earthquakes
  - Earthquake Insurance
  - Emergency Planning for Apartment Residents
  - Is Your Business Prepared for Disasters?
  - ShakeAlert Earthquake Early Warning System
  - Map Your Neighborhood
- Booths or info tables at events
- We may simply send materials in advance
- Request presenter or information table: **EarthquakeCountry.org/eca-events**

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ECA Mini Awards

- **Purpose:** provide materials for ECA member projects that improve earthquake resilience by promoting mitigation, awareness, and preparedness, and multiply impact of programs
- **Purchases**: $500 to $1000 each
- **Eligibility:** Proposals for earthquake **mitigation** and **education** activities
- **New packages:** For 2024 you'll be able to fully customize the materials for your project (furniture straps, printed materials, etc.)
- **2024 Awards:** New application process in JUNE

Federal |

READY AMERICA
THE DISASTER SUPPLY PROFESSIONALS

Secure WORKPLACE $500 Package

ITEM #	ITEM NAME	IMAGE	QUANTITY
4160-64	Furniture Strap		15
4740	File Cabinet Strap		15
5040	Bookcase Strap		15
4173	Home Electronics Safety Strap, Black		30
4338	A-Maze-ing Picture Hook, 4 Pack		10
4250	Kitchen & Cabinet Door Latch, 4 Pack		10
88111	QuakeHOLD! Museum Putty		10

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Seven Steps To Earthquake Safety

EarthquakeCountry.org/sevensteps

Terremotos.org/sietepasos

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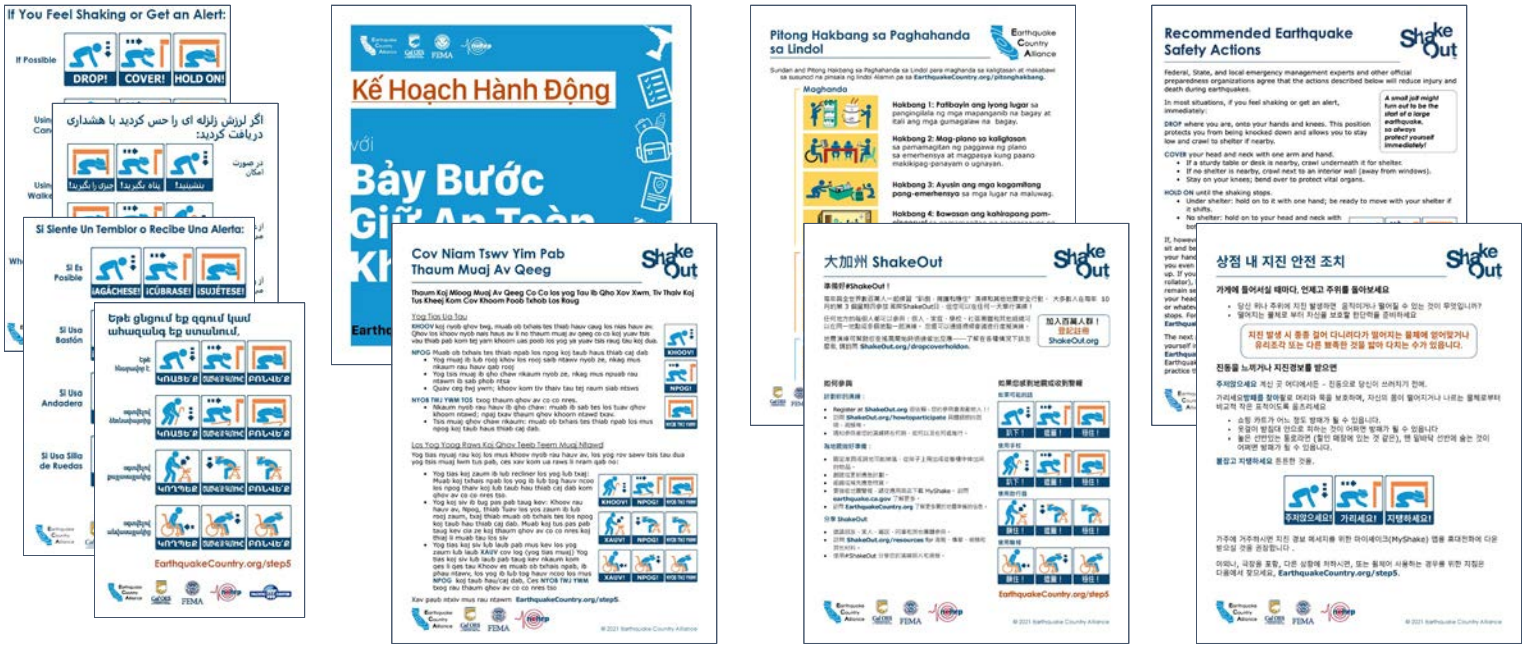
Updated Materials in 16 Languages



EarthquakeCountry.org/languages

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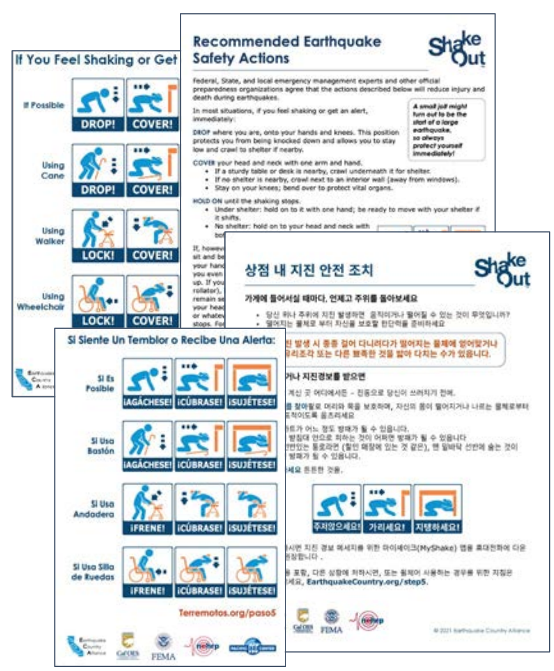
Printed Materials Ordering Process

- Cal OES NEHRP funding now supporting printing & shipping of ECA materials to local governments, non-profits, and others (on approval)
- A new ordering form will be available mid-June
- Request from many ECA printed materials
- Items will be printed and shipped to you for free
- Limits will apply per person/organization
- For larger quantities, purchases will be possible



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Northridge 30th Anniversary Campaign

- SCEC/ECA is leading the development of a year-long educational campaign to commemorate the 30th anniversary of the Jan. 17, 1994, Northridge earthquake
- Purpose: increase awareness about earthquake hazards, encourage preparedness and mitigation, and inform about self-protective actions and response skills.
- Grant funding and sponsorships, including:
  - Cal OES
    - California Seismic Safety Commission
    - Earthquake Program via FEMA NEHRP
  - California Earthquake Authority
  - Optimum Seismic
  - **Other public/private partners**
- Primary activity: many “Quake Heroes Expo” events.
- **Campaign website at** **EarthquakeCountry.org/northridge**

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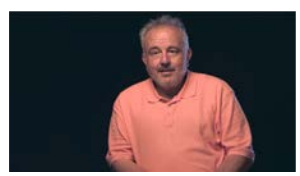
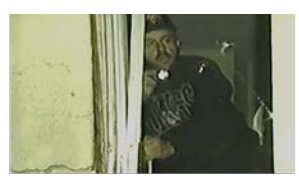
Quake Heroes

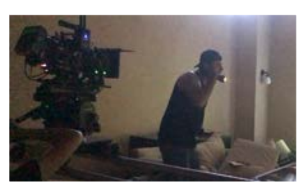
- Stories of people who experienced the 1994 Northridge earthquake in Los Angeles, and how they helped others
- Key moments tied to the *Seven Steps to Earthquake Safety*
- Scientists and engineers share how they informed the public about what happened, and learned key lessons for reducing future losses (tuck-under parking buildings are featured)
- Encourages viewers to become trained (CERT, CPR, etc.) so they are prepared to help others
- Production sponsored by FEMA, NSF, USGS, Structural Engineers Association of Southern California, Simpson Strong-Tie, Hero in You Foundation, Safe-T-Proof, and others



RETROSPECTIVE INTERVIEWS



ARCHIVAL NEWS FOOTAGE



CINEMATIC RE-ENACTMENTS

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Quake Heroes Expos

- Screenings for large groups
- May include panel discussion before the film with local leaders, scientists, engineers, etc.
- After viewing the film, attendees can immediately take actions at a *Seven Steps to Earthquake Safety* resource/information fair where they can:
  - register for CERT and other trainings
  - receive free or low-cost disaster supplies and earthquake safety fasteners
  - learn about earthquake insurance and retrofitting
  - sign up for alerts
  - experience an earthquake simulator

- **Learn more and schedule a discussion at QuakeHeroes.org!**

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Quake Heroes Events

- YMCA Westchester Quake Heroes Expo (Dec 1)
- Cal State Northridge (Feb 3)
- Coachella Valley (March 30)
- Washington DC, Dept. of State (April 2-4)
- Venice Neighboorhood (June 29)
- Gardena (August 10)
- Walt Disney Studios (September)
- Long Beach (September 21)
- Oakland: Summer (two events)
- Laguna Woods (September)
- Chino (September/October)
- Berkeley Lab (September)
- County of San Bernardino (Oct. 17)
- Many more in the works!

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Great ShakeOut Earthquake Drills

- Annual opportunity for schools, organizations, and families to practice earthquake safety and other aspects of their emergency plans
- 2024 International ShakeOut Day: **October 17**
- Learn more and register: **ShakeOut.org**
- How to participate, guides, etc.: **ShakeOut.org/howtoparticipate**

ShakeOut™

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Q&A

To be notified of future events and recordings, join ECA (free!):
EarthquakeCountry.org/join

Please take our survey:
SurveyMonkey.com/r/DDYMFHM

Questions?
info@earthquakecountry.org

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Short Announcements from Attendees

Please take our brief survey about today's workshop:
SurveyMonkey.com/r/DDYMFHM

Open Discussion & Networking

Please take our brief survey about today's workshop:
SurveyMonkey.com/r/DDYMFHM

What is something that you:

learned
will do
will use
will tell others

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Connect with ECA

- EarthquakeCountry.org
  EarthquakeCountry.org/socal
- Terremotos.org
- Twitter.com/eca
- info@earthquakecountry.org

Earthquake Country Alliance

Please take our brief survey about today's workshop:
SurveyMonkey.com/r/DDYMFHM

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