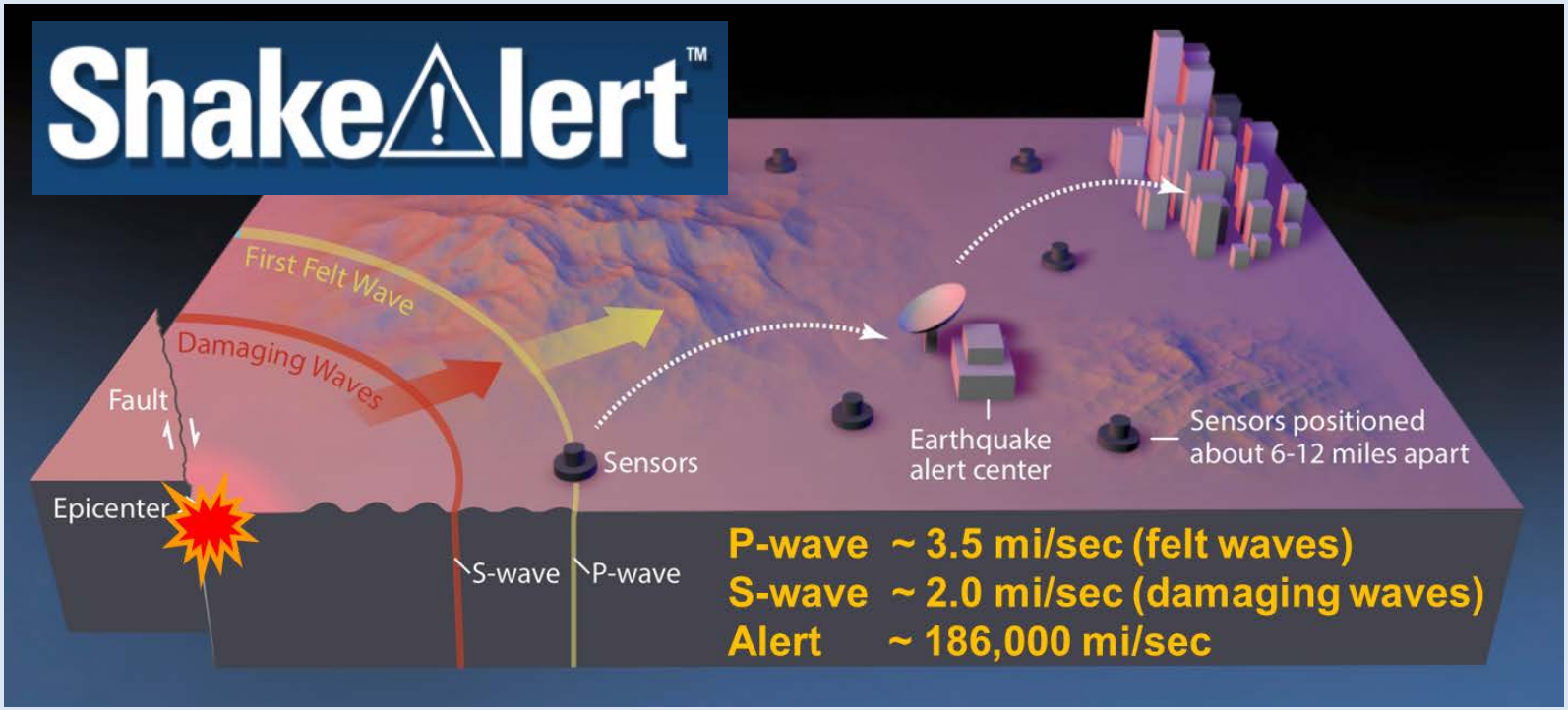
ShakeAlert West Coast Earthquake Early Warning



Margaret Vinci, Caltech
ShakeAlert SoCal Regional Coordinator

What is ShakeAlert™?

- The U.S. Geological Survey (USGS) along with a coalition of state and university partners is developing and testing an earthquake early warning (EEW) system for the West Coast of the United States. The system is called ShakeAlert™.

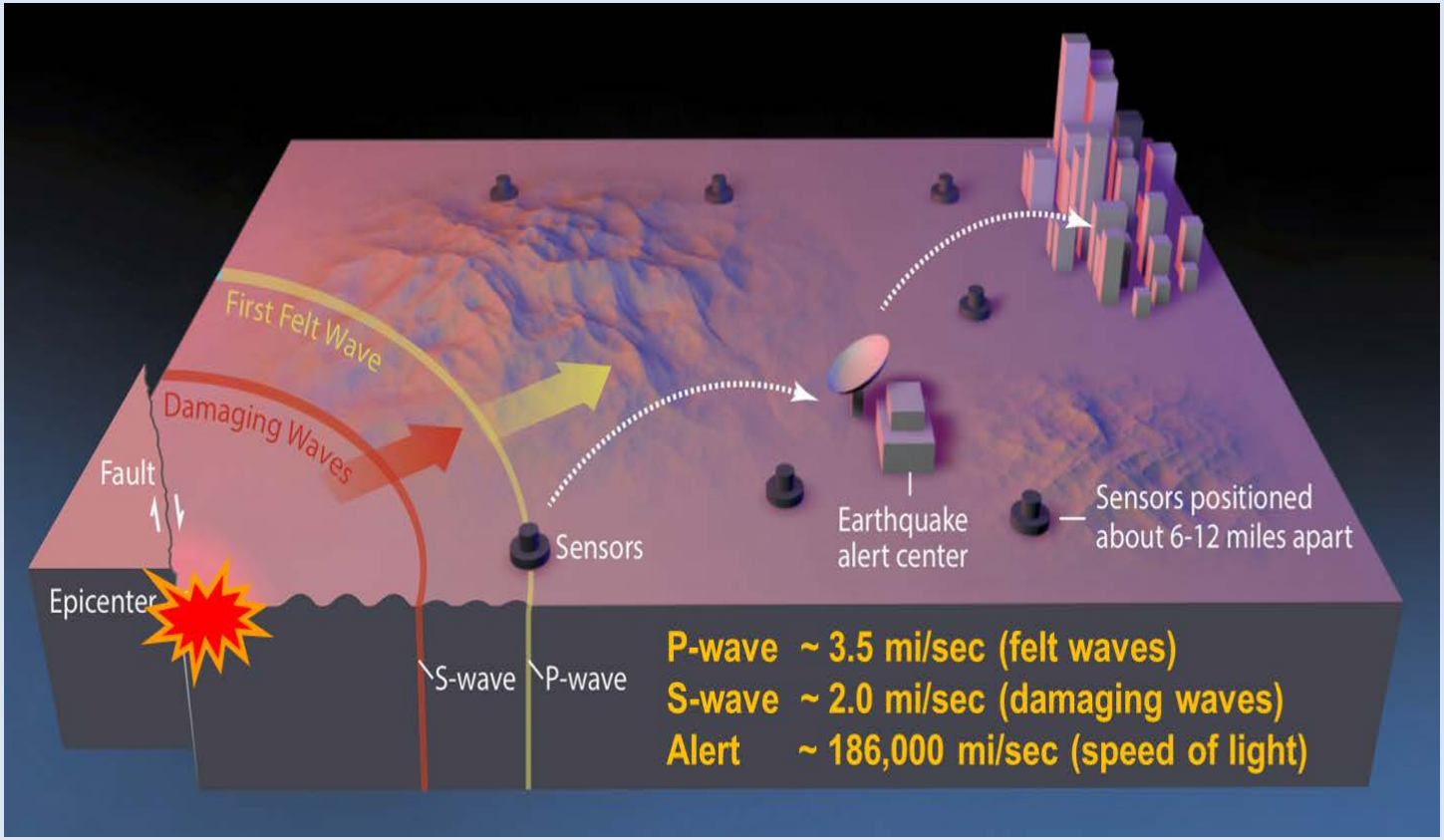
- ShakeAlert™ is an earthquake early warning (EEW) system that detects earthquakes so quickly that alerts can reach many people, infrastructure systems, or precision equipment before damaging shaking arrives.

- **A *ShakeAlert*** is an early warning from the ShakeAlert™ System

- <u>ShakeAlert™ is not earthquake prediction</u>; the earthquake has already started

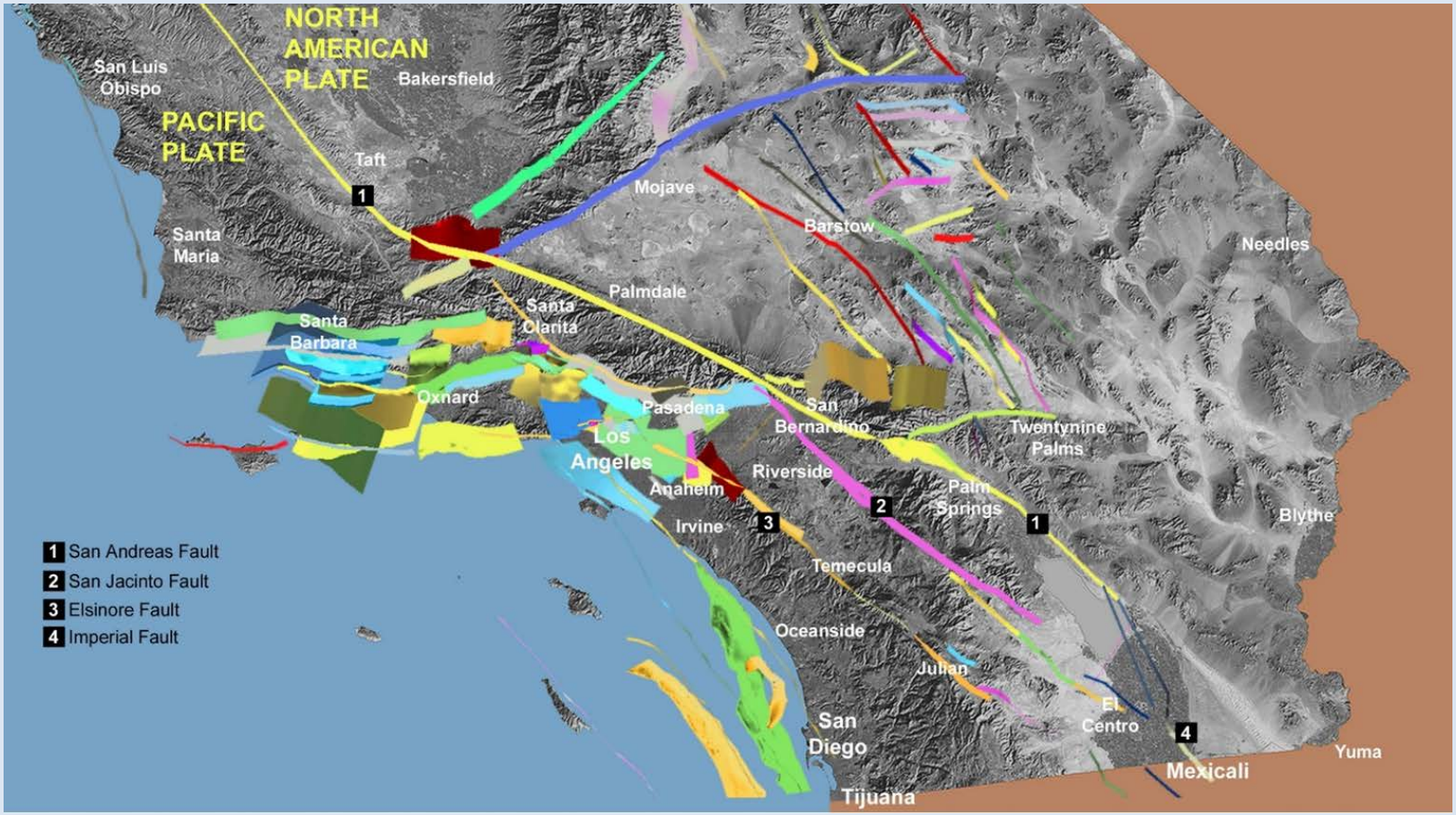
How Does ShakeAlert™ Work?

- Simply, sensors in the ground quickly detect seismic waves as an earthquake happens, computers calculate the maximum expected shaking intensity, and centers deliver alerts to surrounding communities before damaging shaking arrives.



Farther away from the earthquake = more warning time

Why do we need Earthquake Early Warning?

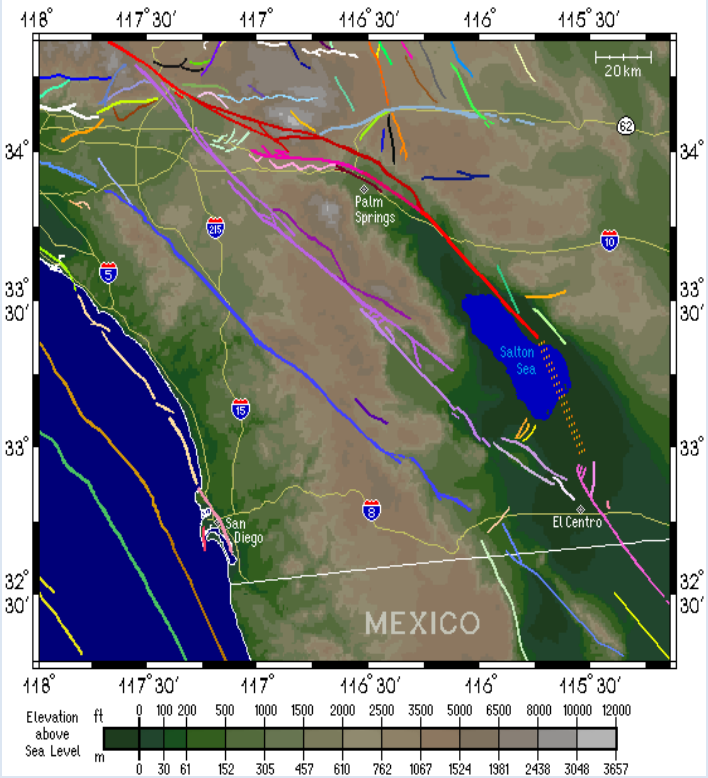


There are 300 known earthquake faults in SoCal

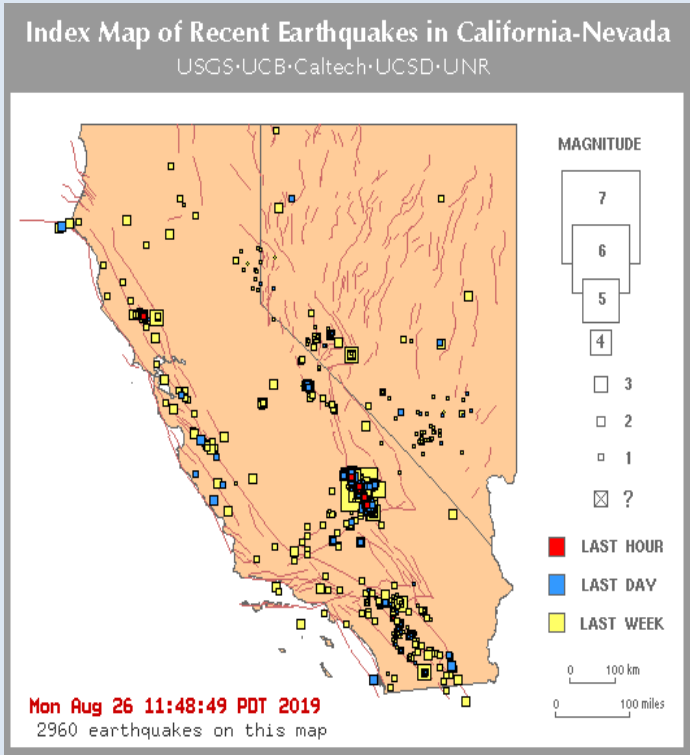
- There are 24 faults capable of producing a large, damaging earthquake
- 12 faults within LA Basin are capable of producing large earthquakes
- 30 – 50 earthquakes a day many in San Diego but mostly M1's and M2's

San Diego Seismic Risk

fewer damaging events but high risk



- Imperial Fault **
- Elsinore Fault
- Newport – Inglewood/
- Rose Canyon
- Palos Verdes



69.9% probability of damaging event in next 50 yrs capable of a M6.0 to a M9.0

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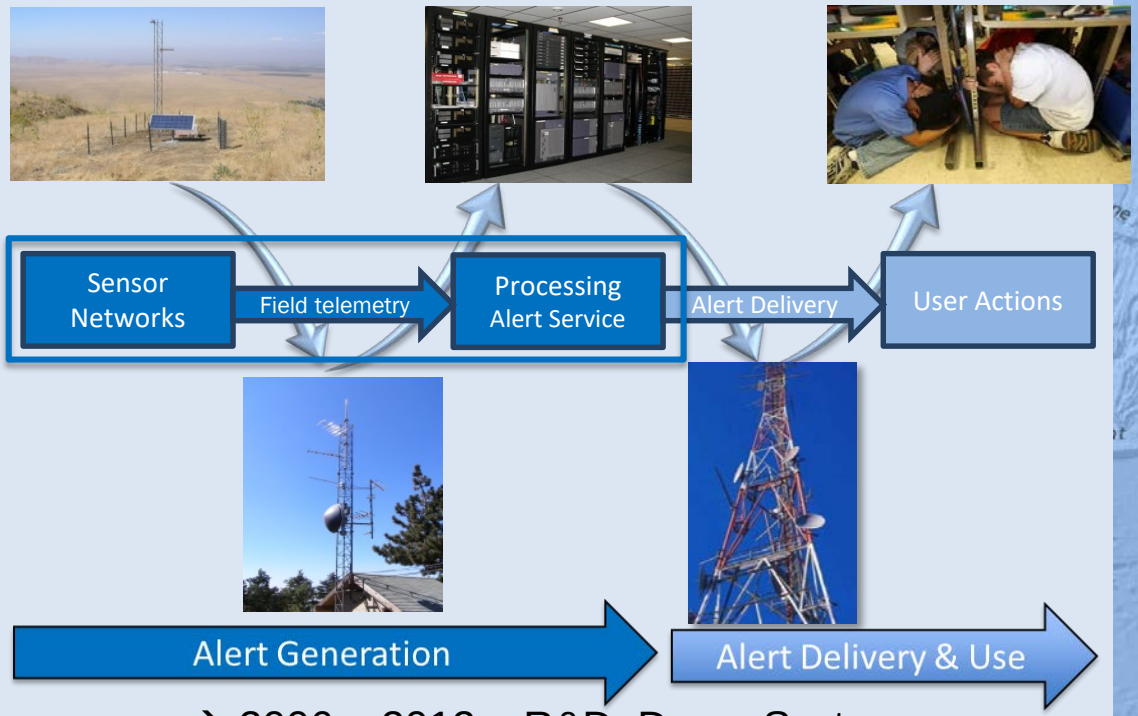
ShakeAlert™ Components



Project Phases

→ 2006 – 2012 – R&D, Demo System

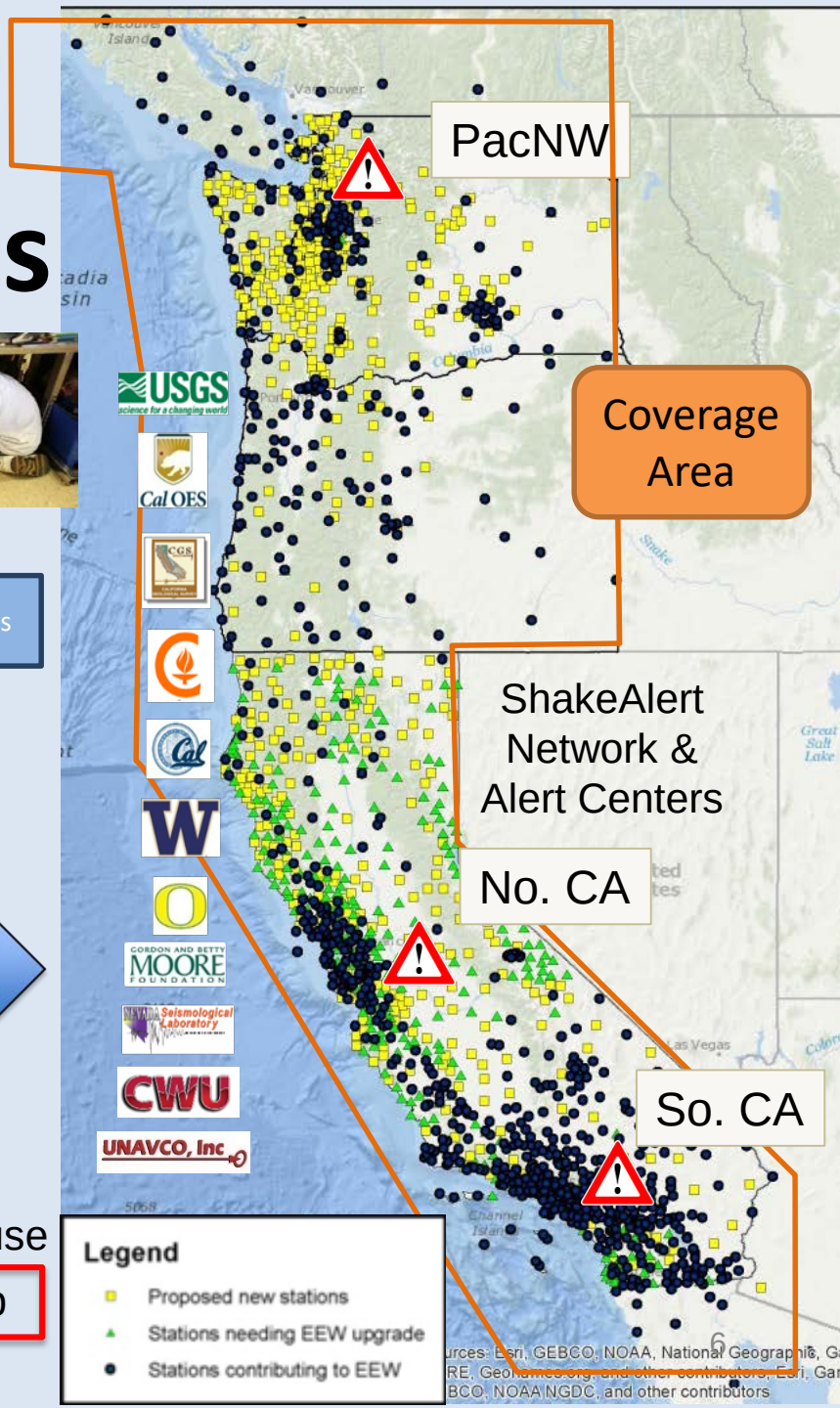
→ 2016 – CA Production Prototype

→ 2017 – West Coast Prototype

→ 2018 – Open for Business, Institutional use

→ **2019 – CA rollout**, WEA and Public app

→ 2022? – Full West Coast Operation



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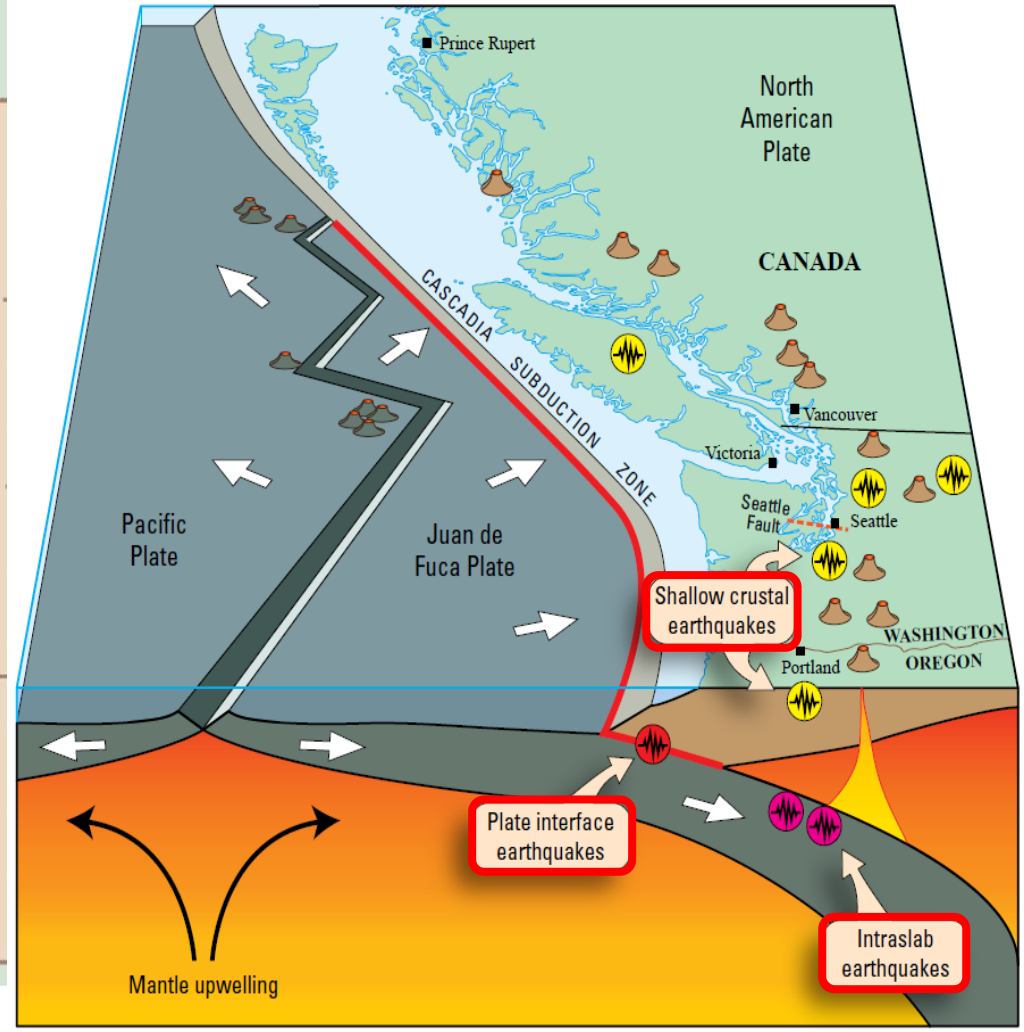
Earthquake Physics:

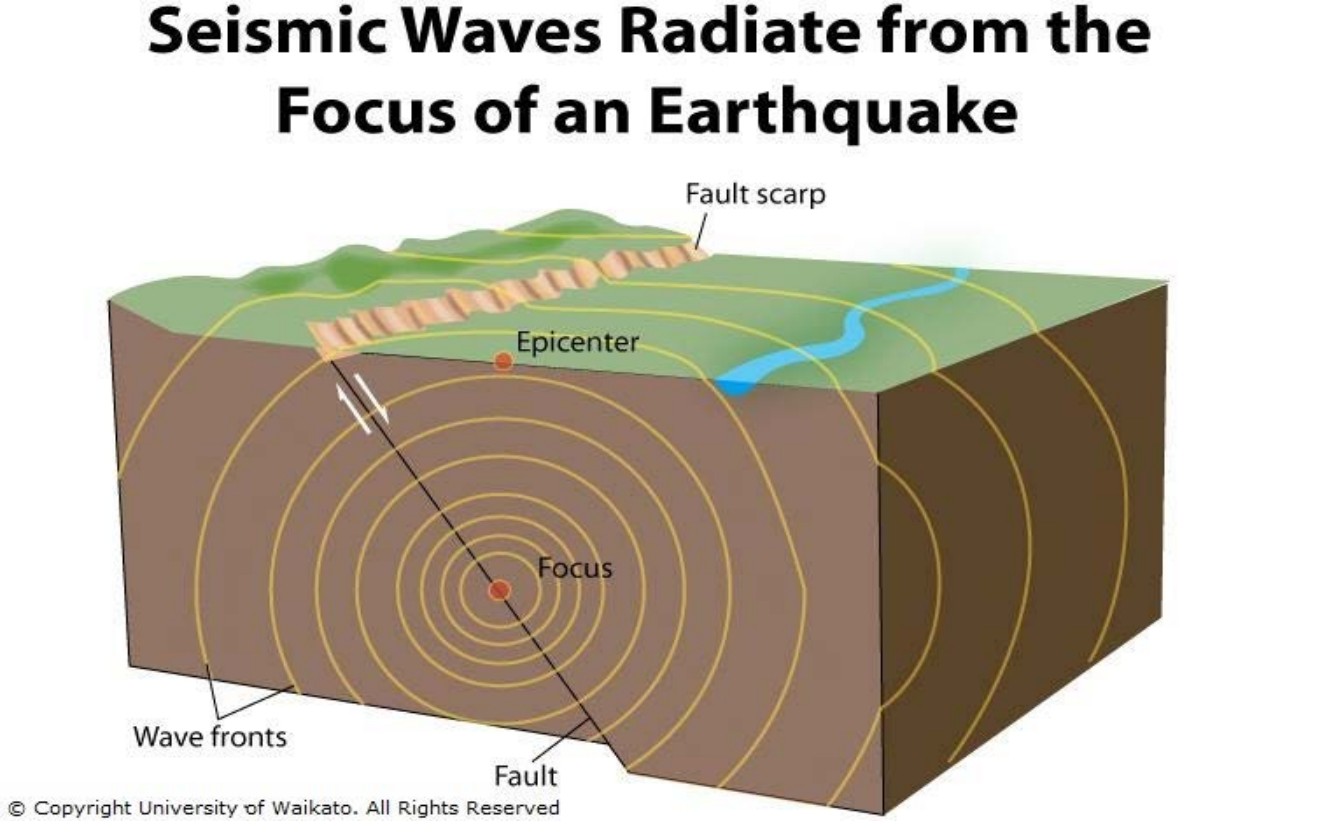
Three Types of Earthquakes on the West Coast

Economist.com



What is An Earthquake?

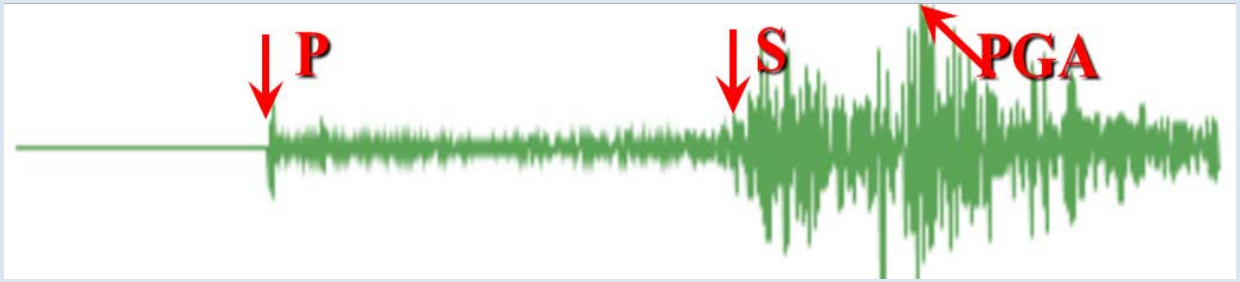
An earthquake is the movement of two blocks of the Earth as they suddenly slip past one another releasing energy in the form or seismic waves that radiate across the surface of the Earth



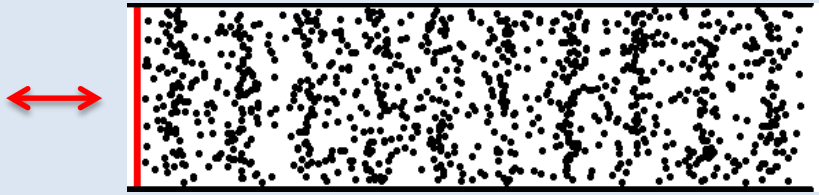
Earthquake Physics:

Earthquake waves

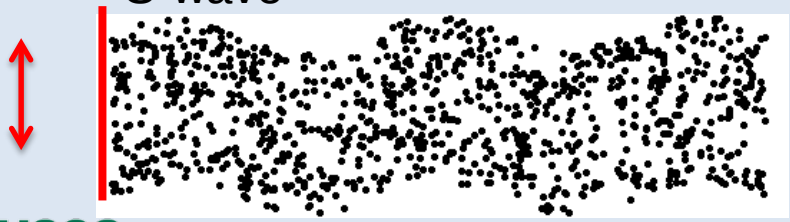
- **P-wave**
  - **Faster**
  - **Less destructive**
- **S-wave**
  - **Slower**
  - **More destructive**

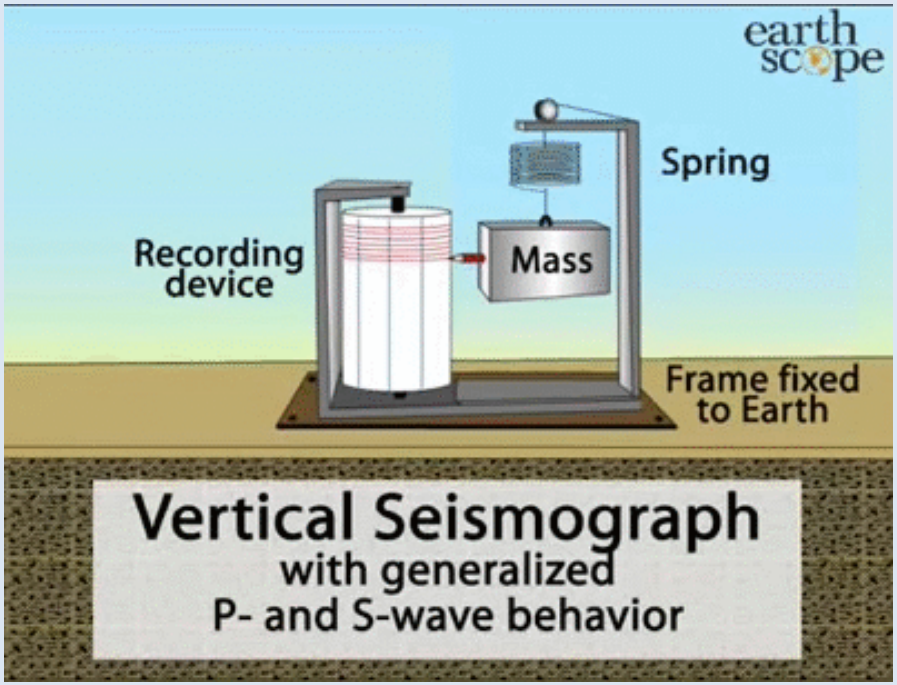


P-wave



S-wave

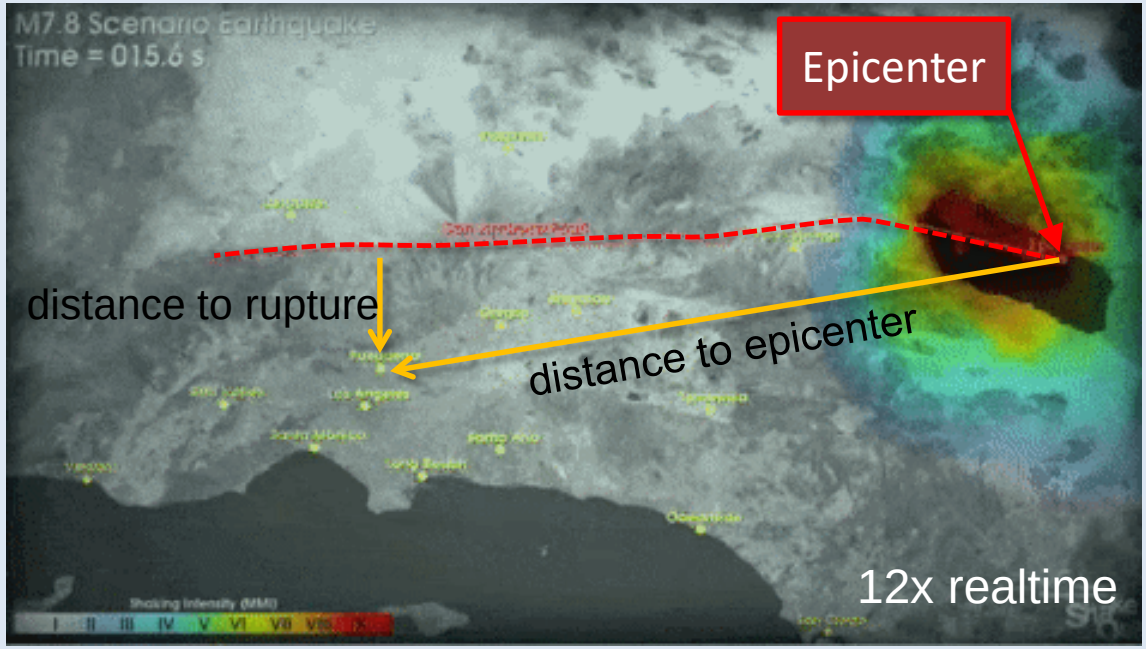




Earthquake Physics:

Big Earthquakes Rupture Long Faults

- **Big earthquakes are not points (epicenter)**
- **Fault rupture & magnitude grow with time**
- **We can't predict how far the rupture will go**
- **Shaking intensity depends on distance to the rupture NOT the epicenter**



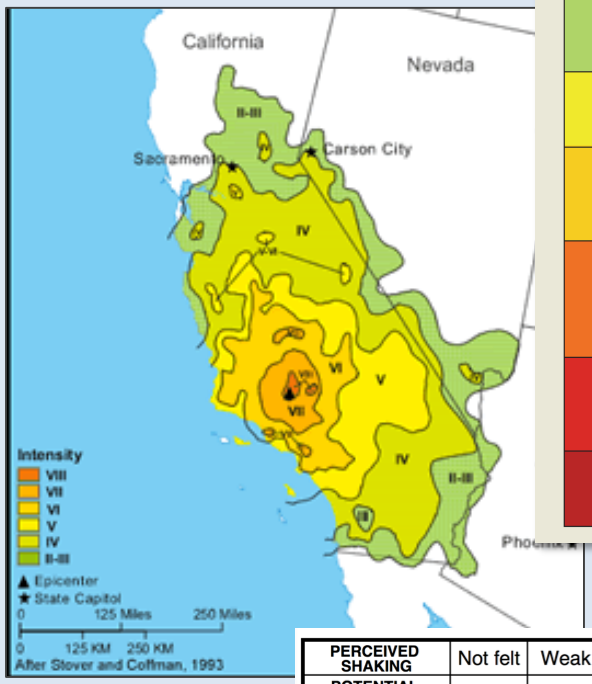
M7.8 - Shakeout Scenario Simulation
- Rupture length = 180 miles
- Rupture duration = ~1:40 min.

Earthquake Physics:

Magnitude is NOT Intensity

Magnitude describes the relative size of earthquakes. The scale is arbitrary, has no physical units, and uses a logarithmic scale (10x).

Intensity describes the severity of shaking at a place. It depends on magnitude, distance to the fault, and the local soil/rock type.



Intensity	Shaking	Description
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X+	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

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ShakeAlert

ShakeAlert

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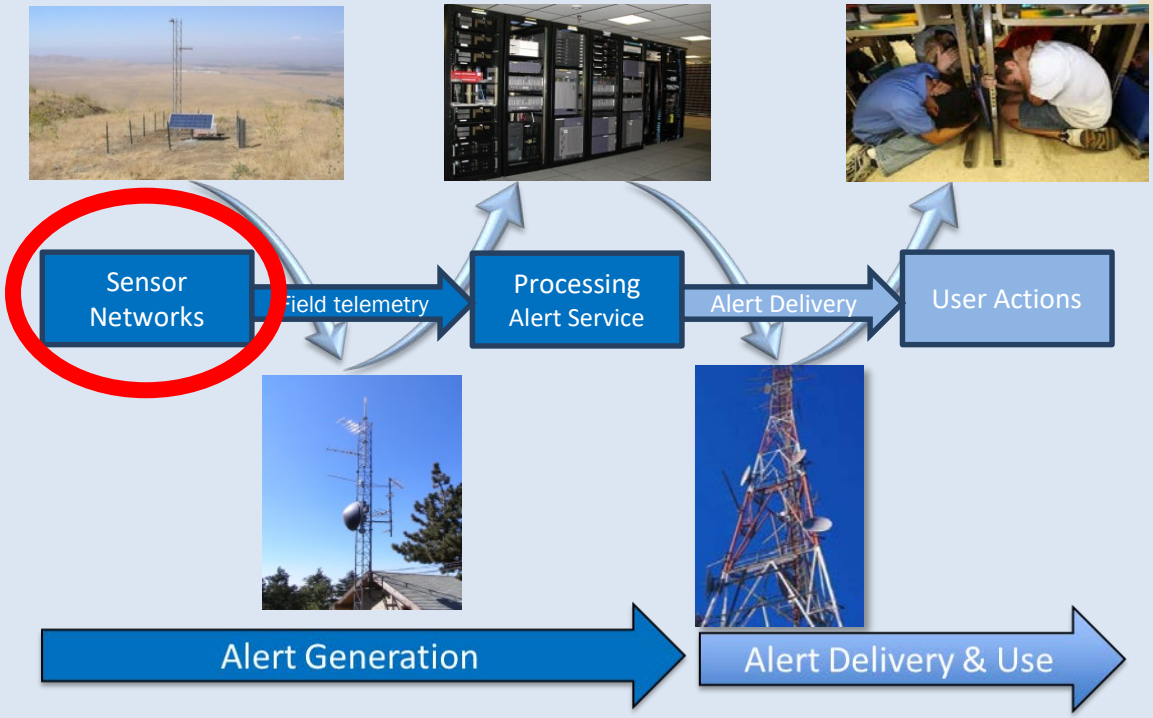

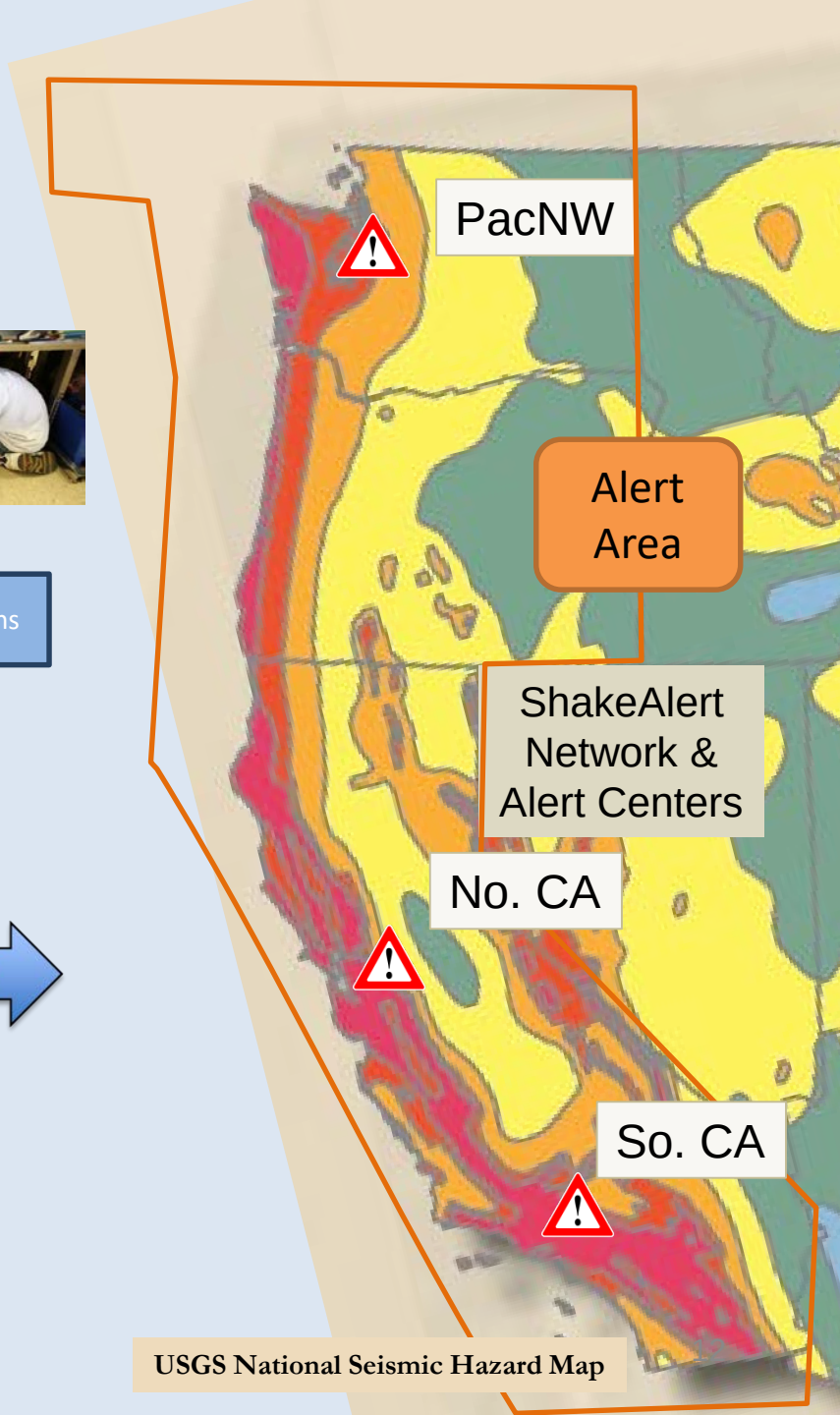

USGS National Seismic Hazard Map

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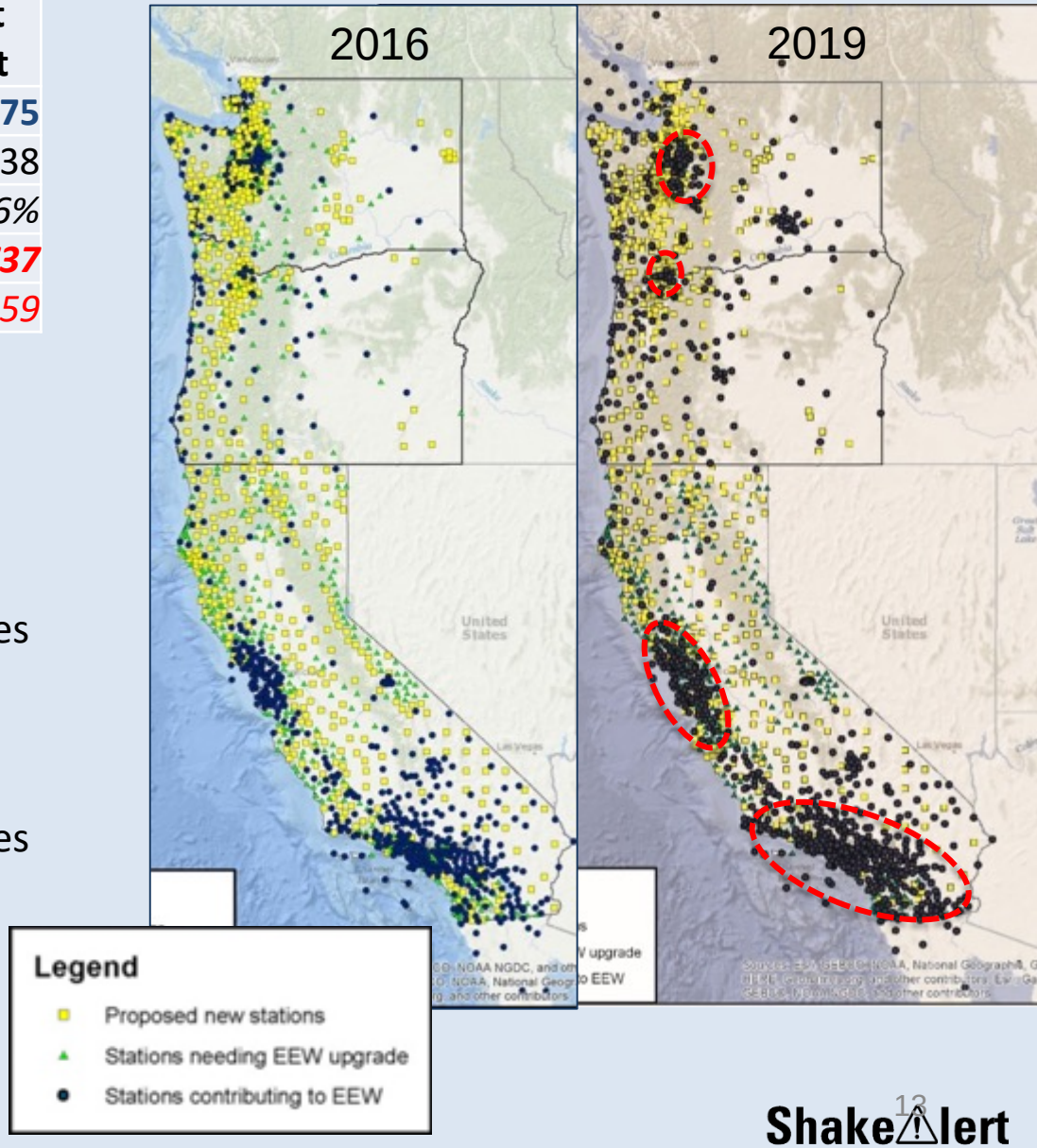
USGS Station Build-out Progress

ShakeAlert Seismic Station Inventory	CISN	PNSN	West Coast
Target Number	**1,115**	**560**	**1,675**
Contributing now	624	314	938
Percent complete	*56%*	*56%*	*56%*
Station to be built	***491***	***246***	***737***
Station unfunded	*126*	*133*	*259*

- USGS capital funds
  - FY 18 $10M
    - 96 Seismic upgrades
    - 208 GNSS upgrades
    - Telemetry & server upgrades
  - FY 19 $5M
    - 78 Seismic upgrades
    - 53 GNSS upgrades
    - Telemetry & server upgrades
- Cal OES capital funds
  - FY18 $15M: ~ 263 stations
  - FY19 $16M: TBD



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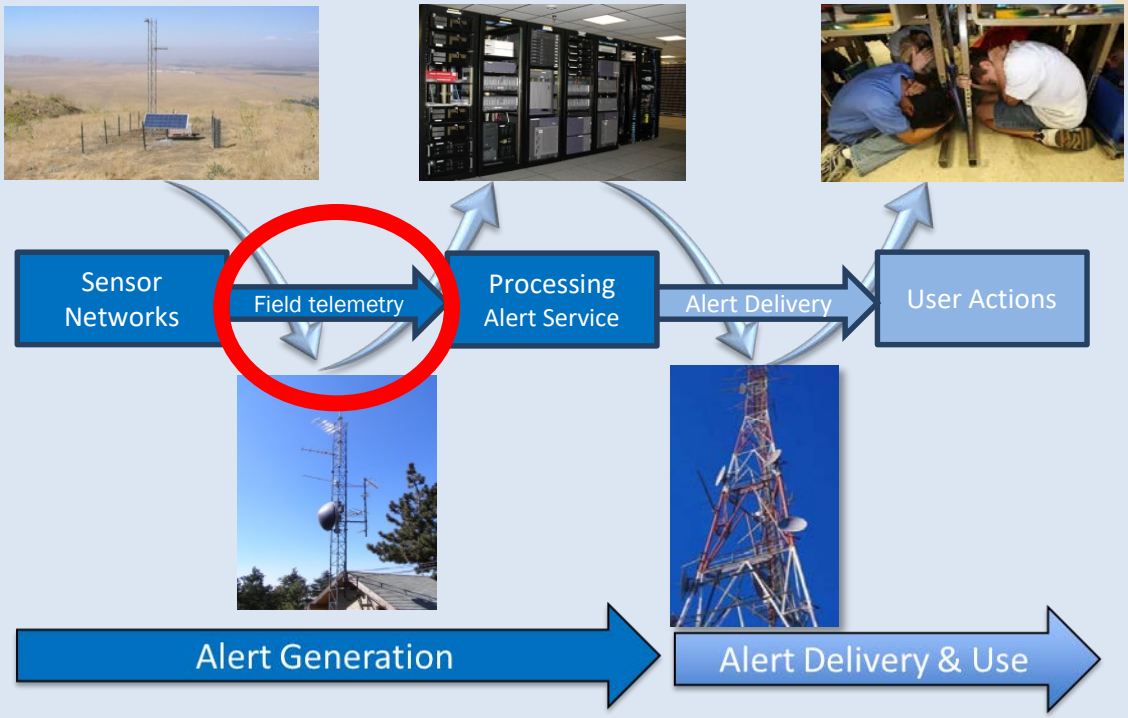

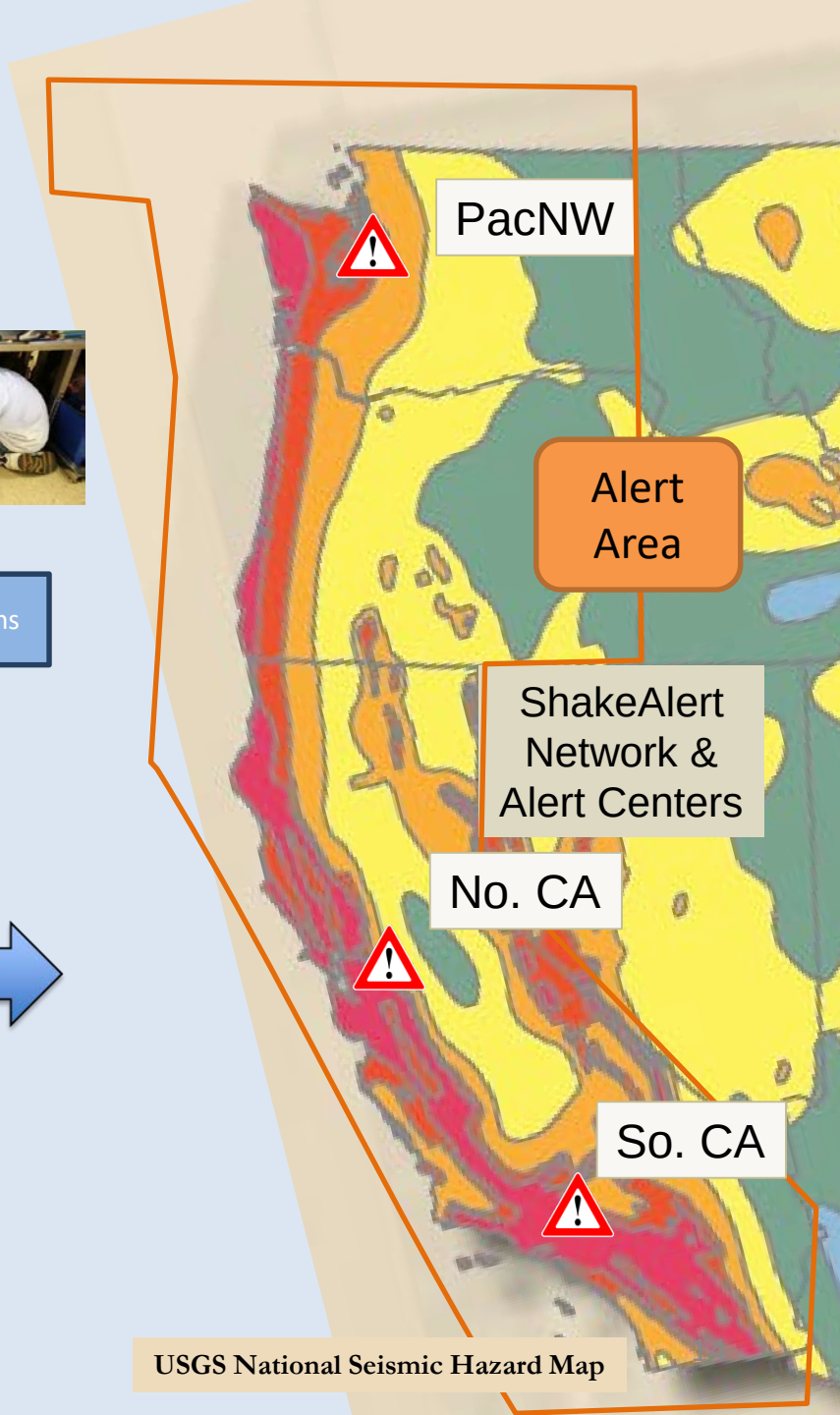

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Field Telemetry

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ShakeAlert

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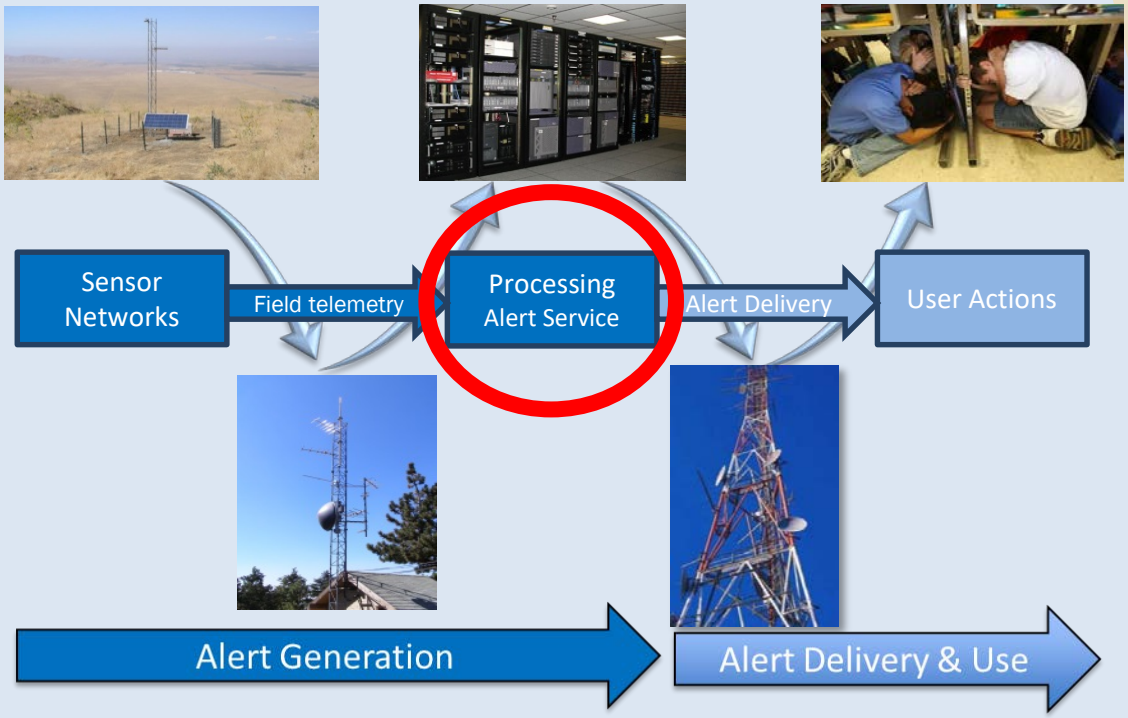

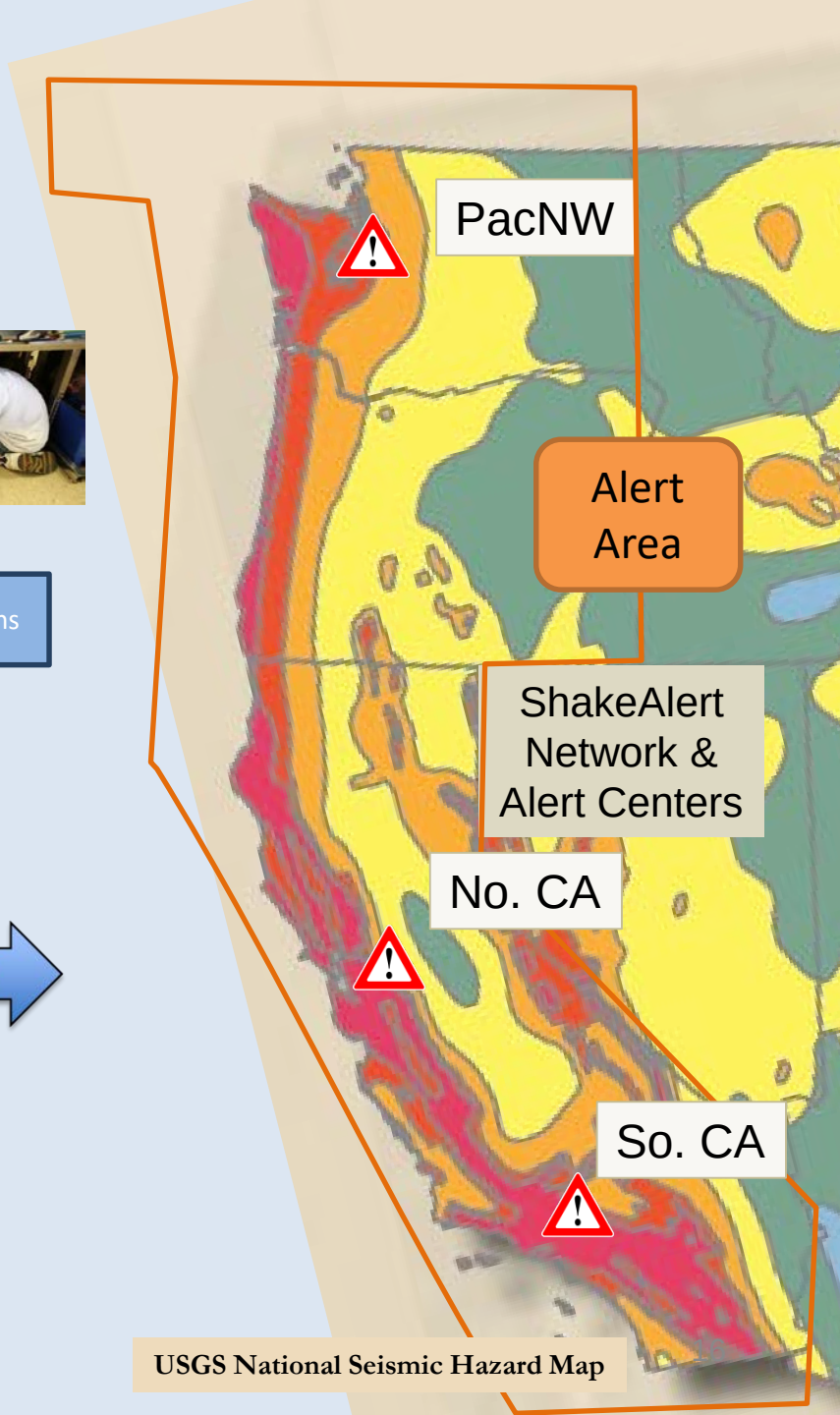

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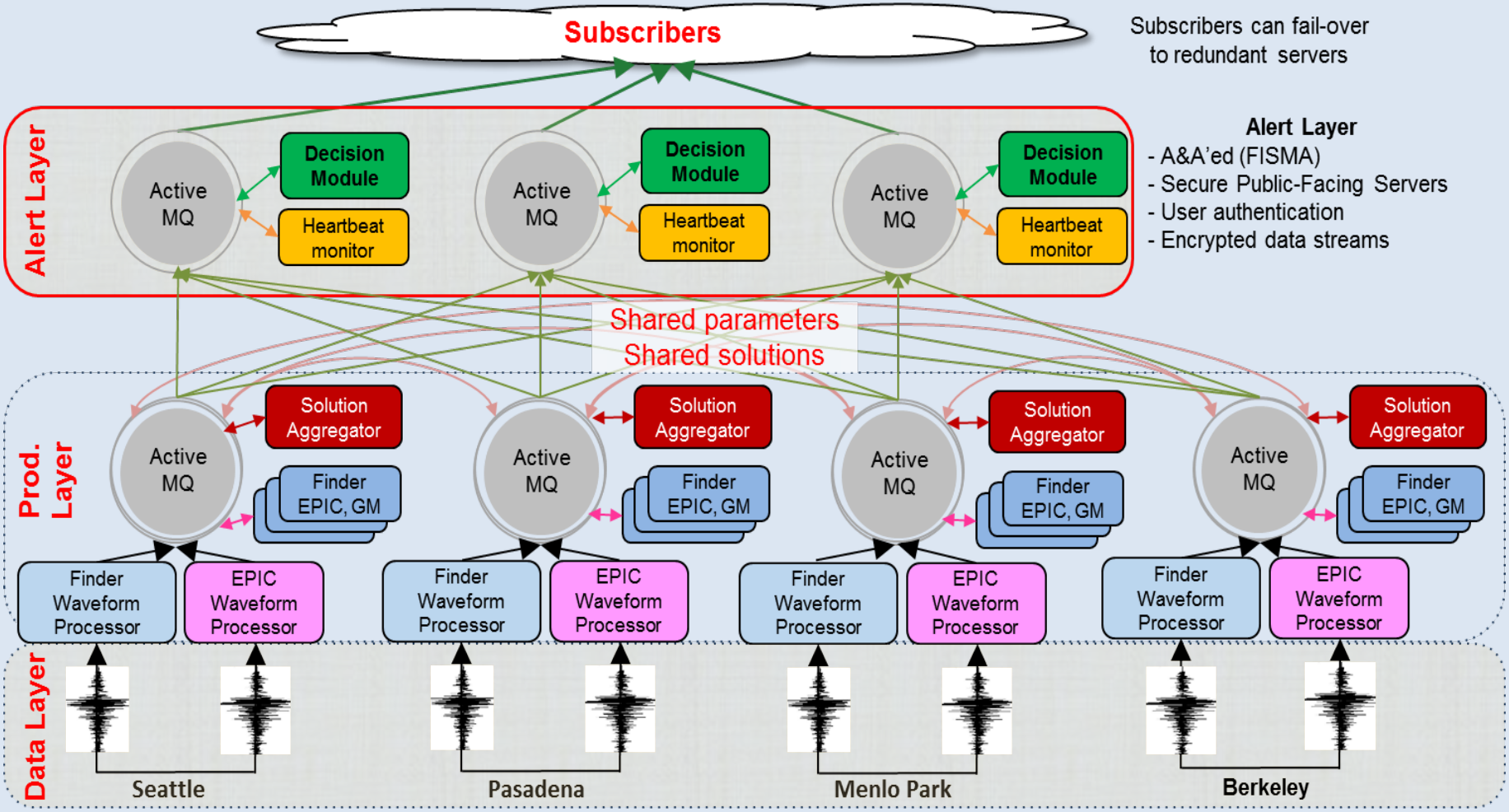
ShakeAlert Processing and Alert Architecture



Overview of the architecture of the ShakeAlert v2.0 system. Data processing flows upward from the Data Layer, up through the Production Layer, then to the Alert Layer, which publishes alerts for subscribers.

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ShakeAlert Products: 3 Primary Messages

1) Event Message

- Earthquake Source
  - Point: location, magnitude & uncertainty
  - "Finite fault" (If M6.0+)

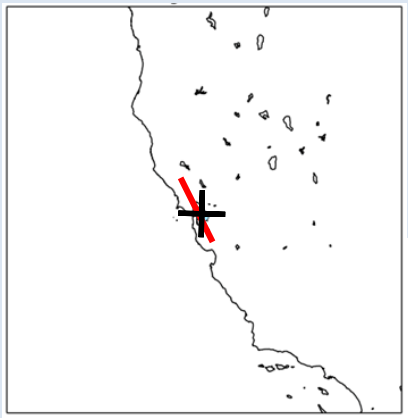
2) Ground Motion Contour Message

- **Event Message** + MMI contours
  - nested 8-pt polygons enclosing areas by MMI, PGA, PGV

3) Ground Motion Grid Message

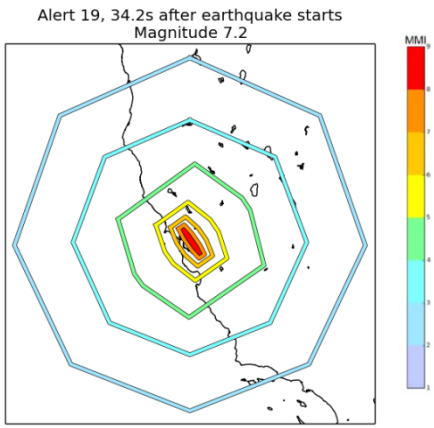
- **Event Message** + MMI grid
  - grid map of MMI, PGA, PGV
  - ~20km spacing

Also specialized formats like CAP & QuakeML

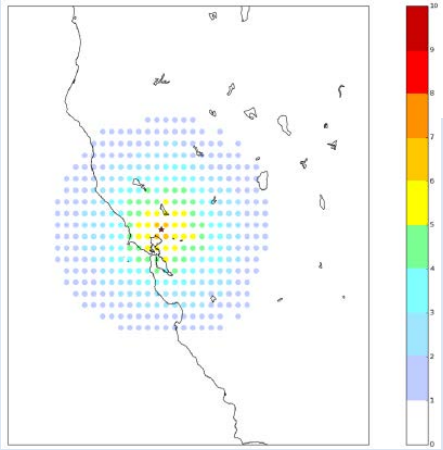


1) Event Source

Hayward M7.0 Simulation



2) Contour Map



3) Grid Map

An alert updates as event grows

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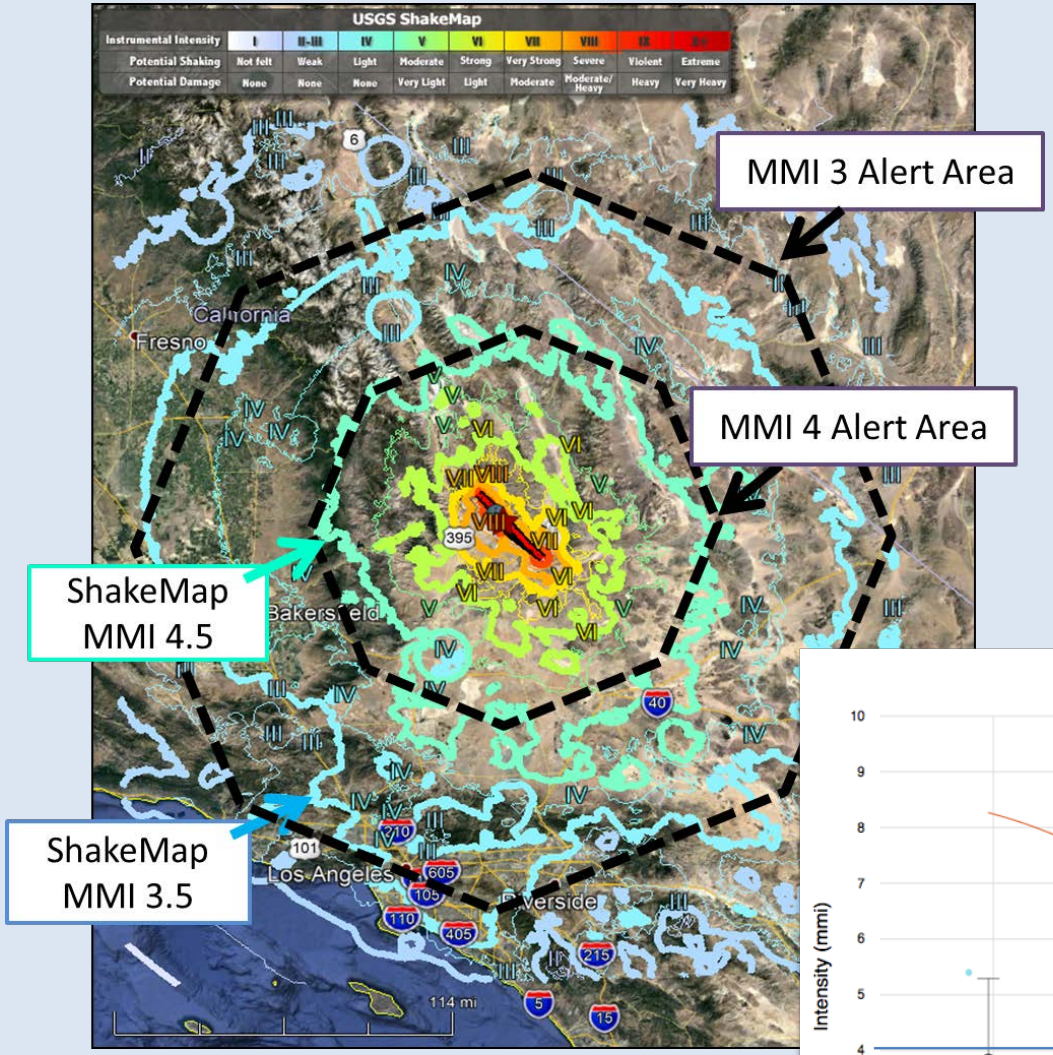
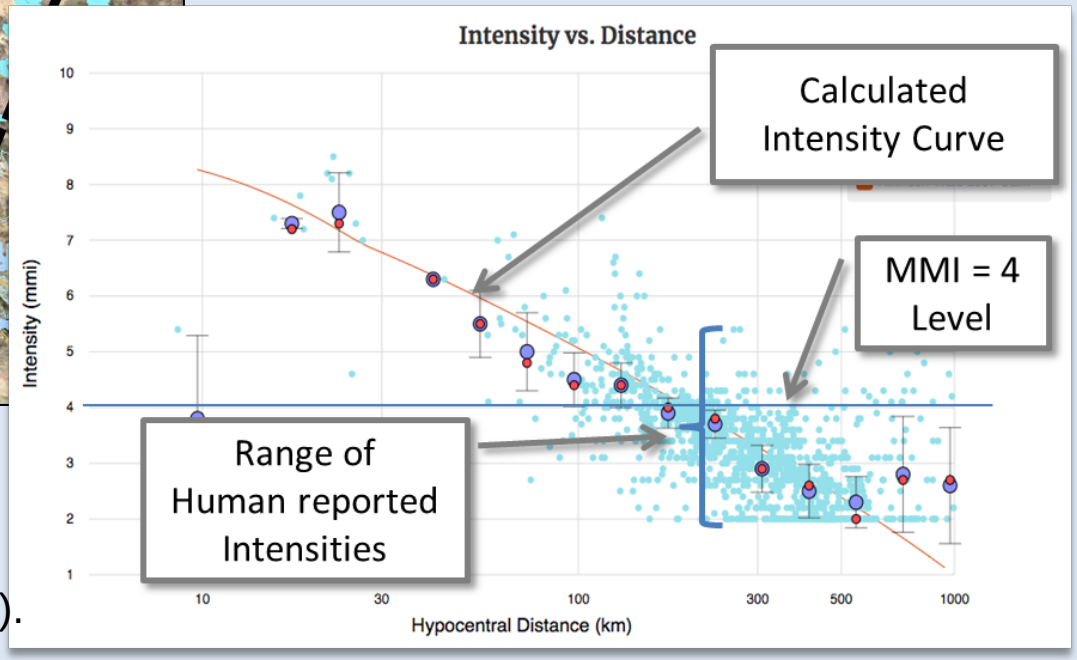
ShakeAlert

M7.1 Alert Area

ShakeAlert intensity estimate was ~0.5 MMI level lower than ShakeMap



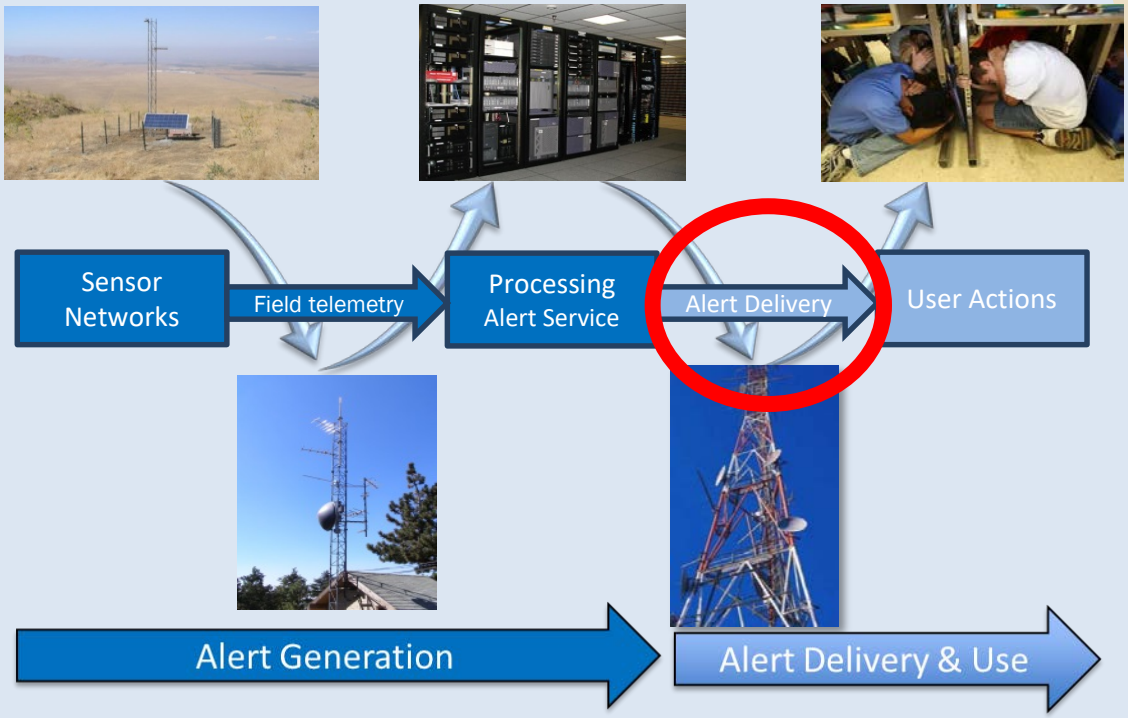
Final ShakeMap estimate of intensity (colored contours) and ShakeAlert estimates (black polygons). Public is alerted for MMI 4+ (potential damage).

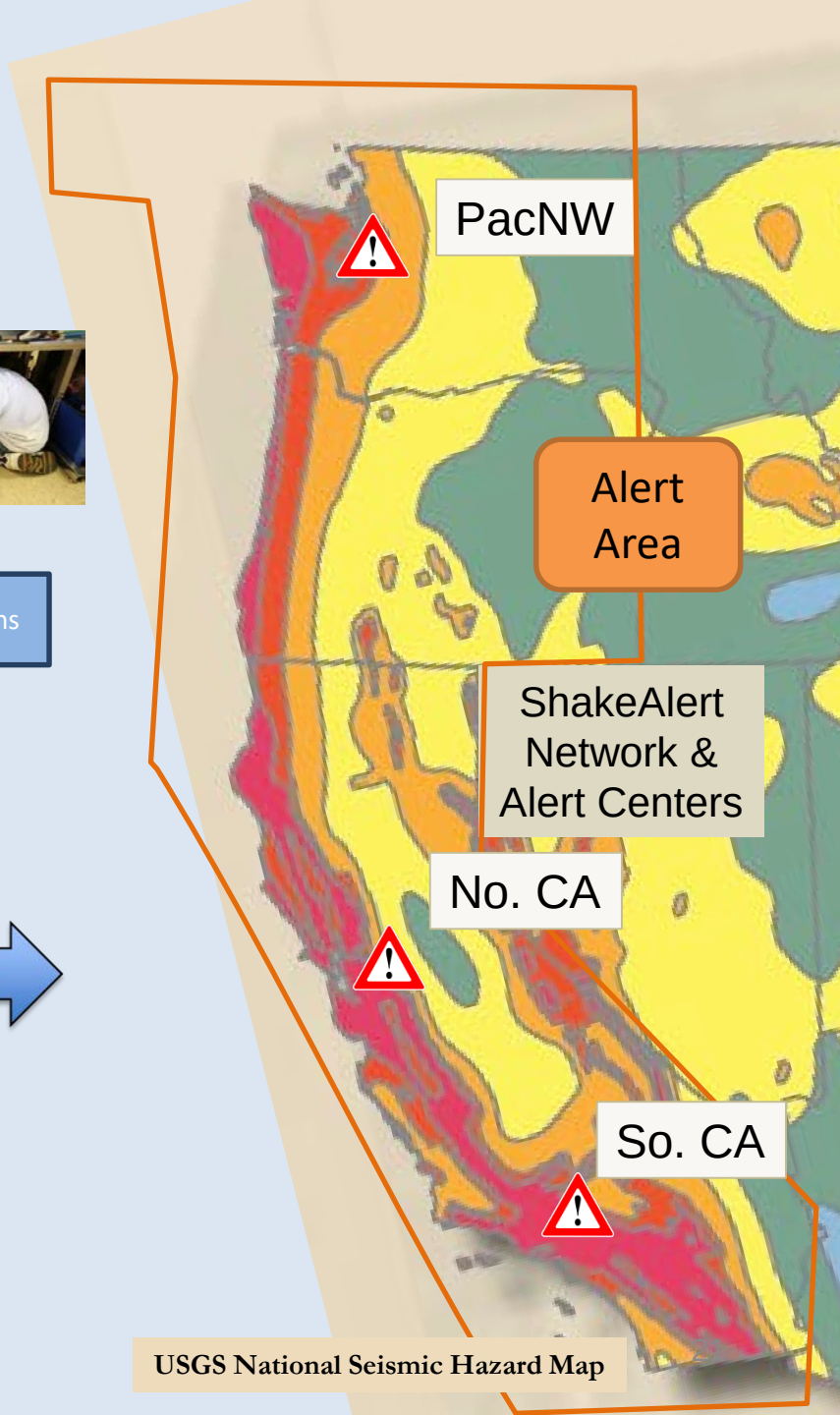


Did You Feel It? - human reports of shaking

ShakeAlert

shakealert.org





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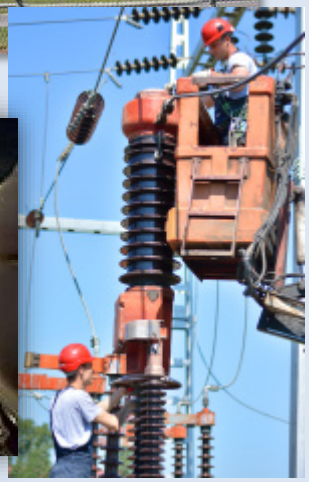
Two Main User Categories

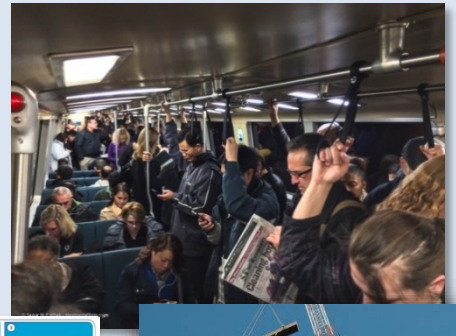
People (personnel, public)

- Drop, cover, and hold on
- Move away from hazardous areas
- Secure delicate medical procedures

Things (automated systems)

- Slow/stop trains, traffic, aircraft, vulnerable actions
- Close valves, stop pumps, blowers, other processes
- Park delicate machinery in safe mode





>50 ShakeAlert Pilots

Come In! ShakeAlert is OPEN For Business

Commercial developers

- **Early Warning Labs**
  - **Actuators & enunciators + App (QuakeAlert)**
- **ESRI**
  - **Integrate with GIS GeoEvent suite**
- **Mass Notification - Everbridge, Regroup, AtHoc**
  - **Integrate with notification systems, 8+ sec delay**
- **Global Security Systems**
  - **AlertFM, actuators & enunciators**
- **Water controls - RH2 Engineering, Varius, Inc.**
  - **> 10 water companies taking actions**
  - **2 water companies taking actions**
- **SkyAlert**
  - **Actuators & enunciators + App (SkyAlert)**
- **Weir-Jones**
- **Valcom**
- ***Various other tech sector companies***

Challenges:

- Creating an EEW industry
- Educating users
- Understanding cost/benefit

Selected End Users (**bold** = taking actions)

- AstraZeneca
- **Bay Area Rapid Transit -slowing trains (automatically)**
- **Biola University**
- California Institute of Technology (Caltech)
- **Cedars-Sinai Medical Center**
- Chevron Corporation
- **City of Los Angeles – ShakeAlertLA, city hall PA system**
- **Eugene Water and Electric Board (EWEB)**
- International School of the Peninsula (ISTP)
- Jet Propulsion Laboratory (JPL)
- Los Angeles County Department of Health Services
- **Los Angeles Metro -slowing trains (manually)**
- **Los Angeles Unified School District (LAUSD)**
- **NBCUniversal – open fire station doors, alert personnel**
- **Northridge Hospital Medical Center**
- Oregon Department of Transportation (ODOT)
- Pacific Gas and Electric Company (PG&E)
- **Paramount Studio**
- **Regatta condominium complex – alert residents, open doors**
- Northeast Sammamish Sewer and Water District
- **Menlo Park Fire Department**
- Santa Monica Community College
- **Santa Monica Library**
- University of California, Berkeley Police Department
- Washington State Department of Transportation (WSDOT)
- WhatFloor
- *Many more…*

What is the Message You Will Receive?

- When an earthquake is detected and reaches the alerting threshold an alert will be activated
  - current Pilot threshold = shaking intensity IV <u>and</u> earthquake magnitude 5+

- You will receive an alert tone and a voice activated message broadcast over the audio system:
  1. Short alert tone
  2. Voice message

     “Earthquake! Earthquake!”
     “Expect shaking”
     “Drop, Cover, Hold On”
     “Protect Yourself Now!”

When Will You Receive an Alert?

- You may receive a ShakeAlert before, during or after shaking arrives at your location depending on your distance from the earthquake and the alert delivery mechanism you are using.

- In general, the farther you are from the earthquake the more alert time you are likely to receive. You can receive seconds to tens of seconds of advanced warning.

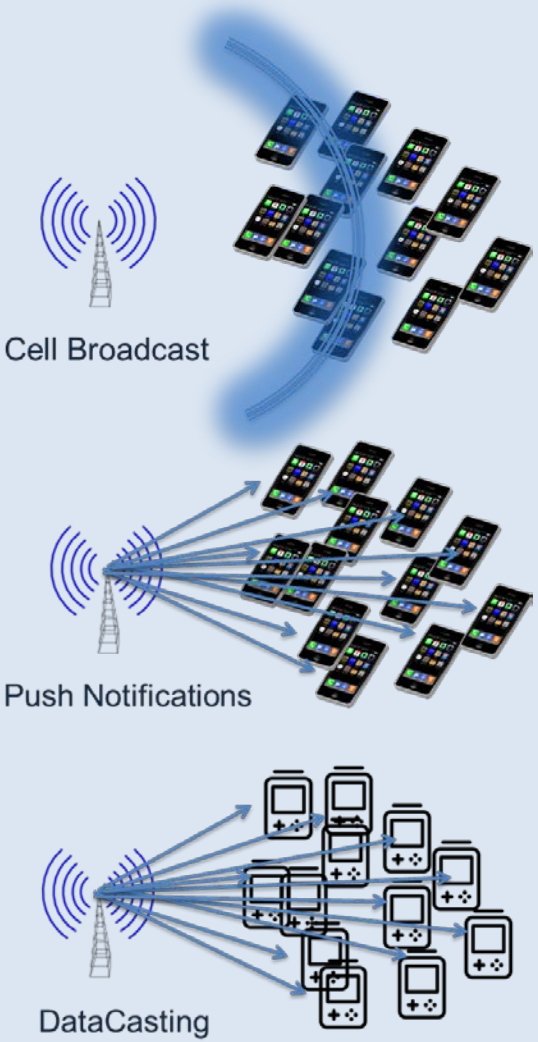
- The USGS and its partners are in the process of determining appropriate thresholds that define when and how ShakeAlerts will be delivered.

- You may feel shaking and not get a ShakeAlert because the shaking level at your location was below the set thresholds. Still take protective action when you feel shaking.

- In rare instances you may receive an alert for non-earthquake shaking like a quarry blast or other large explosion. Still take protective action when you receive a ShakeAlert.

Public Mass Alerting Technologies

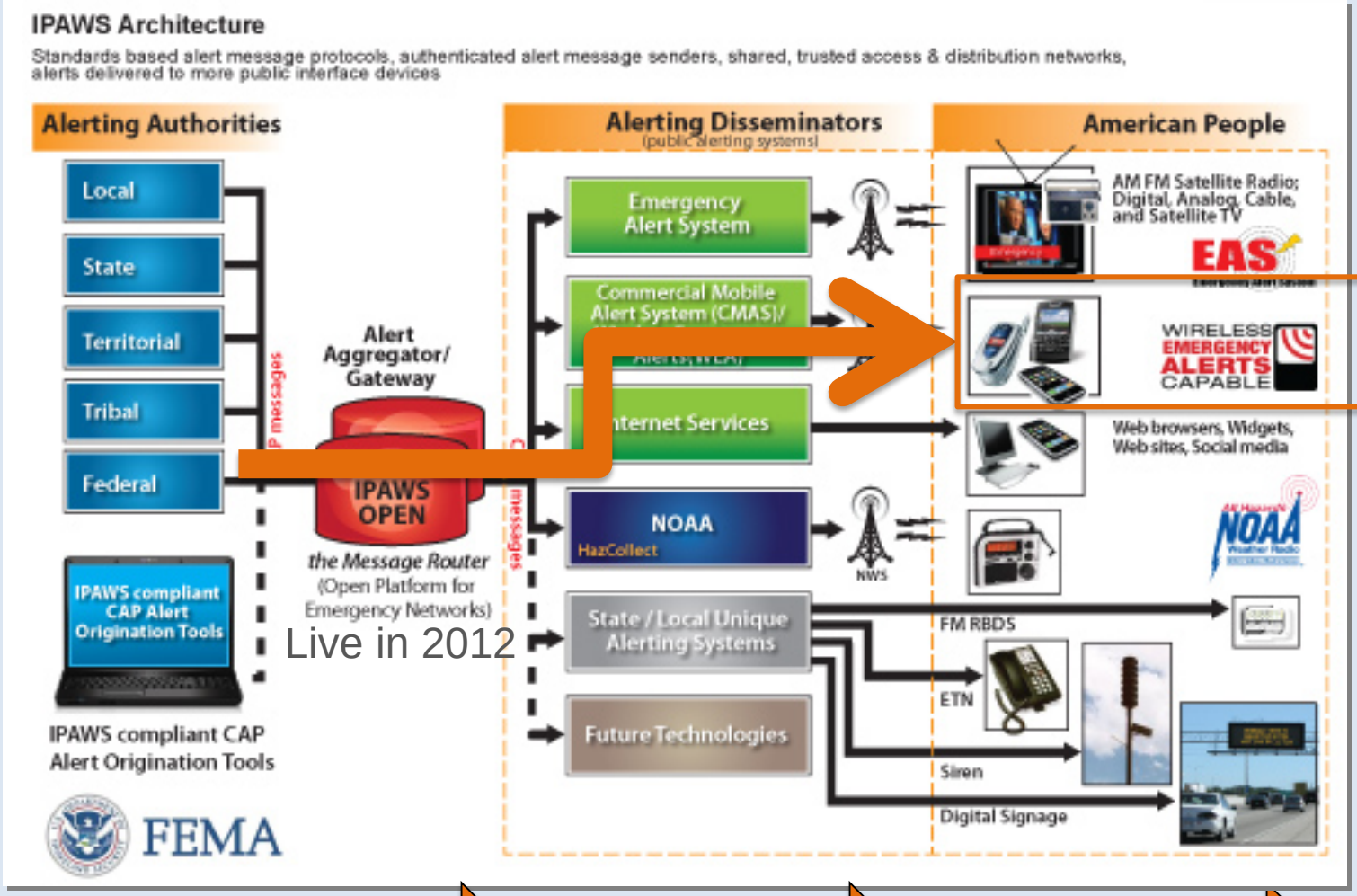
- Cell-broadcast, IPAWS/WEA
  - Speed uncertain (test next year)
  - No EEW-specific sound
- Cell apps, push notifications
  - Scalability & speed unknown (Tests by City of L.A. and others)
  - Someone must provide the service
- DataCasting, alert encoded in TV broadcast signal
  - Crude geotargetting
  - Requires special receiver (not displayed on TV)



IPAWS: Integrated Public Alert & Warning System

EAS: Emergency Alert System (TV, radio)

WEA: Wireless Emergency Alerts (Cell phones)



EAS

WEA

IP systems

Wx. radio

Other Systems (few)

USGS/ShakeAlert → FEMA/IPAWS → Cell Carriers (WEA)

Recommended Cell Alert Signals

- Alert sound (TBD)
- Alert text (voice on some phones)
  - **Earthquake! Earthquake!**
  - **Expect shaking.**
    Drop, Cover, Hold on.
    Protect yourself now.
- Message, sound, vibrate, voice
- Follow up message later
- Social science

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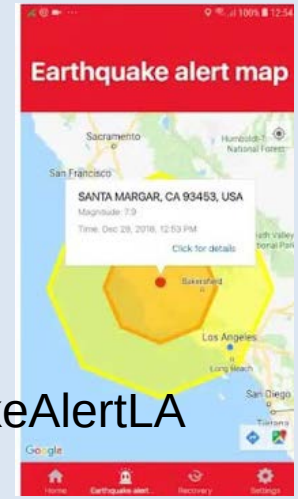
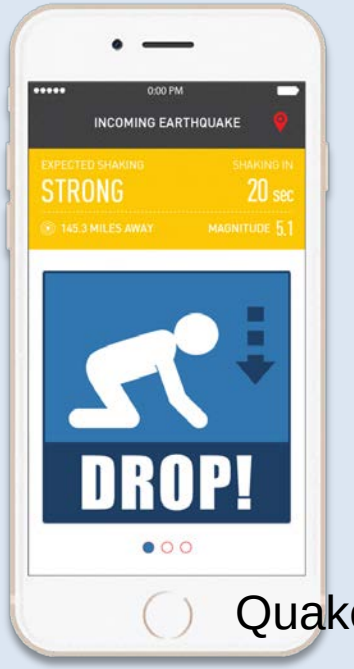
ShakeAlert

ShakeAlert Partner Apps

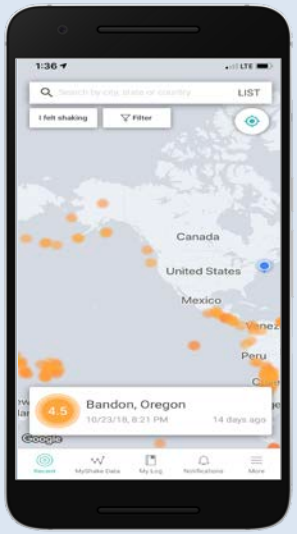
- ShakeAlertLA
  LA/*AT&T/Colwox*
- MyShake
  Cal OES/UC Berkeley
- QuakeAlert
  Early Warning Labs
- SkyAlert
- Others coming....



ShakeAlertLA



QuakeAlert



MyShak
e

SkyAlert

USGS
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ShakeAlert

Los Angeles Times

L.A.'s ShakeAlert earthquake warning app worked exactly as planned. That's the problem

Shake Alert LA

The New York Times

Californians' Alert Apps Didn't Sound for 2 Big Earthquakes. Why Not?

Many Los Angeles residents thought the ShakeAlertLA app on their phones should have given warning. Officials said the system had worked as designed — but promised some changes.

ShakeAlertLA app:

- Done under contract with AT&T & Colworx
- Released Dec. 31, 2018
- >775,000 downloads (as of July 2019)
- Scalability of push notification is unknown
- Designed to alert for potentially damaging shaking (MMI 4+) per USGS recommendation

Mechanism	Recipients	Magnitude	Area Alerted (Intensity)
WEA to smartphones (Future: DataCasting, EAS, etc.)	General Public (many untrained)	5.0+	MMI 4+
Cell Phone Apps	Initially: City of LA and others to test groups. Eventually: all those who download the app	4.5+	MMI 2+ user selectable
Human interfaces: PA systems, lights, sirens, VoIP, in-house apps, etc.	Institutional users: alerts to students, employees, and people on premises	4.0+	MMI 2+ user selectable
Automatic interfaces: (M2M)	Institutional users: for automated systems		

USGS Alerting Threshold Recommendations

Ridgecrest quakes:

- App did not alert for either event because MMI 4 was not predicted in LA County
- But many felt shaking (MMI 2-3)
- Many people expected alert for felt shaking not damaging shaking
- City changing to alert MMI 3+ area
- Press event Aug. 8
- 300,000 new downloads since quakes
- LA plans to expand to other counties

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ShakeAlert

Ridgecrest Sequence Takeaways

1. People want lower-threshold alerts
   - not just for damaging quakes, alerts for “felt” quakes
   - it is better to over-alert than under-alert
2. ShakeAlert performed well
   - M6.4: Excellent speed, magnitude, location, and intensity
   - M7.1: Excellent speed and location
     magnitude too low and intensity too low, but not by much
3. The seismic and IT networks performed well up to a point
   - sensors provided data with few exceptions (some delays)
   - no ShakeAlert IT infrastructure or load issues
   - USGS websites and social media served millions but had some issues due to web traffic and network capacity
4. Robust early warning delivery requires a healthy program
   - ShakeAlert is part of a continuum of information
   - Emergency managers, the media, and the public are all hungry for post-event situational awareness info and expert guidance
   - Continuous R&D, assessment, and improvement is essential

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ShakeAlert™ CEO Plan

- **CRWG** = Community Resources Working Group (WG)
- **EAWG** = External Affairs WG
- **EMWG** = Emergency Management WG
- **ERWG** = Educational Resources WG
- **SSWG** = Social Science WG
- **TUWG** = Technical User WG

Priority Areas*+

1. Public Safety, Preparedness, and Resilience [EMWG]
   - ShakeOut 2019, etc.
   - Education sector symposia (CA x2, 2018, OR & WA, 2019)
   - Develop strategic partnerships with orgs such as ECA, FEMA, etc.
2. Technical Implementation and User Engagement [TUWG]
   - ShakeAlert is "Open for Business"
   - Expand and Broaden ShakeAlert technical partnerships across the System.
   - Advance Technical Assitance Agreement partners to the License to Operate (LtO) stage
   - Health Care and Power sector symposia in Sept 2019 (Pasadena, CA and Portland, OR respectively)
3. Consistent Messaging and Communication [EAWG, CRWG, & SSWG]
   - Social science research, JCCEO collaboration, media, and strategic messagaging plan
   - Close collaboration with USGS Office of Communications and Publishing and Legislative Affairs
   - Contract with NUSURA, Inc. to do stakeholder engagement planning, materials development.
4. Integration with Other Federal and State Earthquake Hazards Products [EAWG & TUWG]
   - Integration and promotion of ShakeAlert as part of the suite of tools offered by the USGS that support the mission of the Earthquake Hazards Program.
5. ShakeAlert Educational Resources Development and Dissemination [ERWG]
   - Partnership with IRIS (videos and activities) and emerging partnership with UNAVCO
   - Build strategic partnerships with those providing services in a broad spectrum of learning contexts and venues.

***Social research projects are a part of most priorities (e.g. post alert messaging, WEA messaging, protective actions, logo style guide, WEA test analysis, etc. Priority of all projects are to serve critical needs for ShakeAlert Operations.**

+ Special consideration will be to given to addressing the needs of diverse communities: e.g. limited literacy, limited English proficiency, disabilities, access, and functional needs. ShakeAlert is committed to serving all end users.

ShakeAlert™

Discussion

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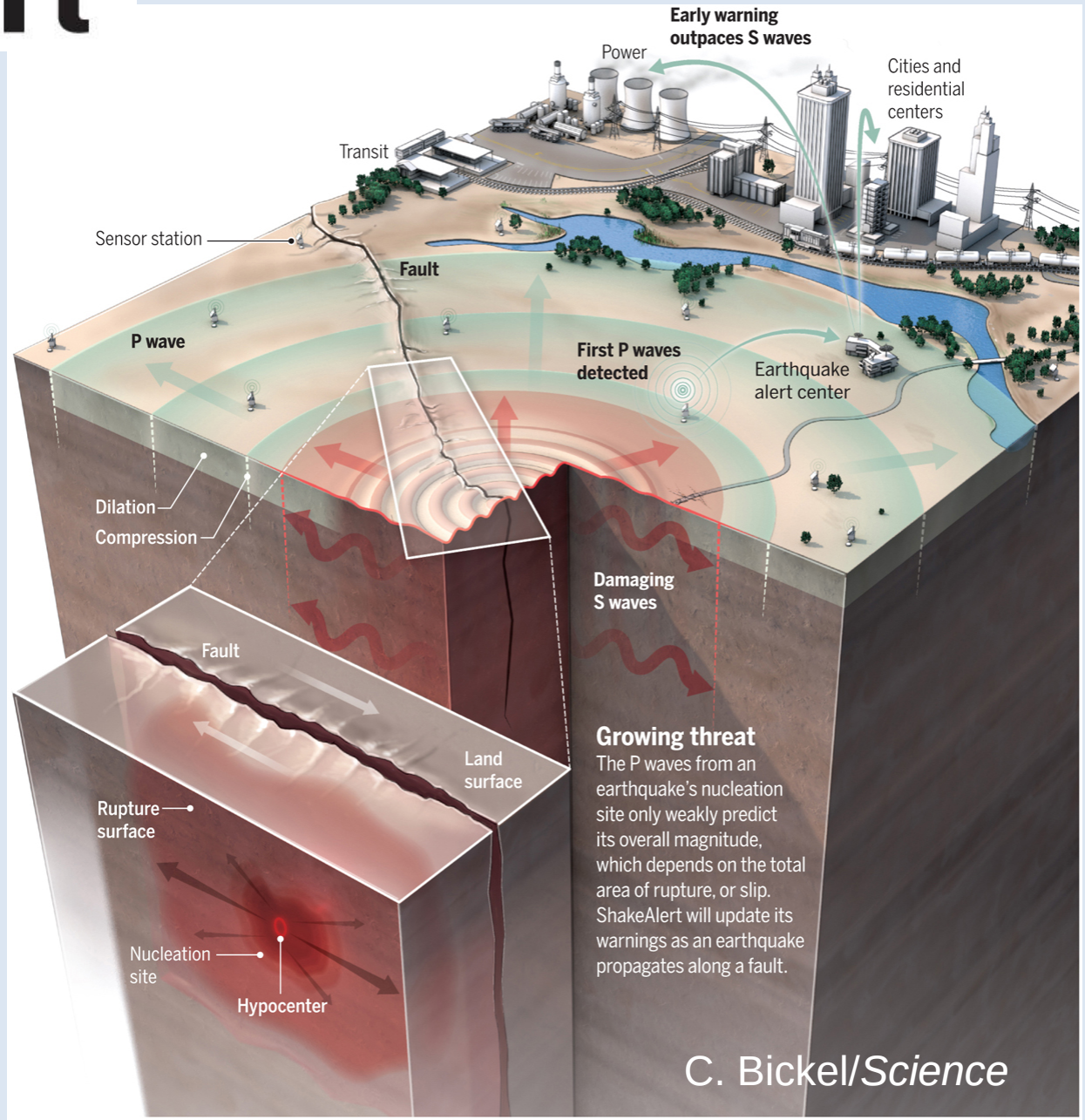

C. Bickel/*Science*

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