ShakeAlert

Progress Toward Public Alerts & Integration with Tsunami Warning

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USGS
Earthquake Early Warning Coordinator

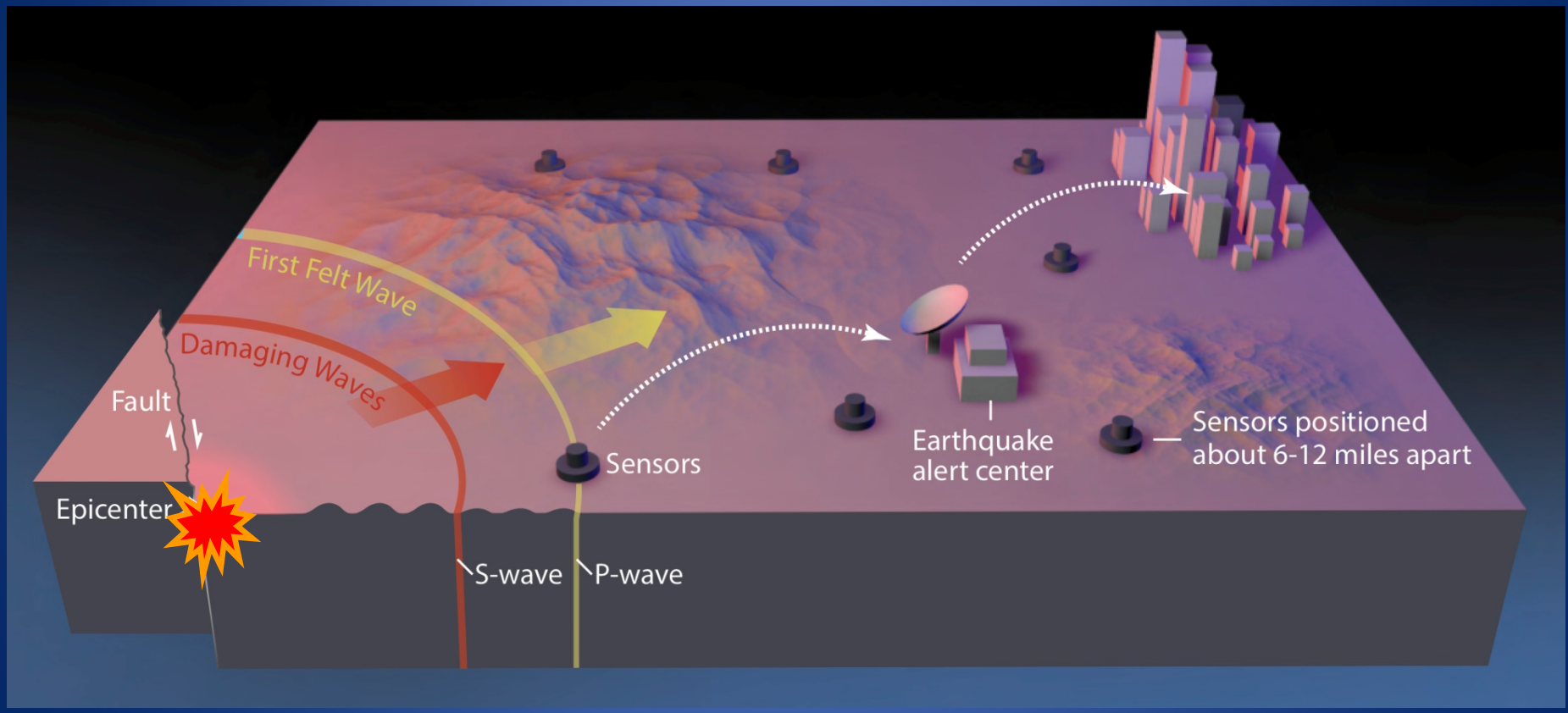
NTHMP Meeting
Feb. 3, 2016

Lead Organizations

- ***USGS***
- ***California OES***
- ***California Geological Survey***
- ***Caltech***
- ***UC Berkeley***
- ***U. of Washington***
- ***University of Oregon***
- ***Moore Foundation***

USGS science for a changing world
Earthquake Hazards Program

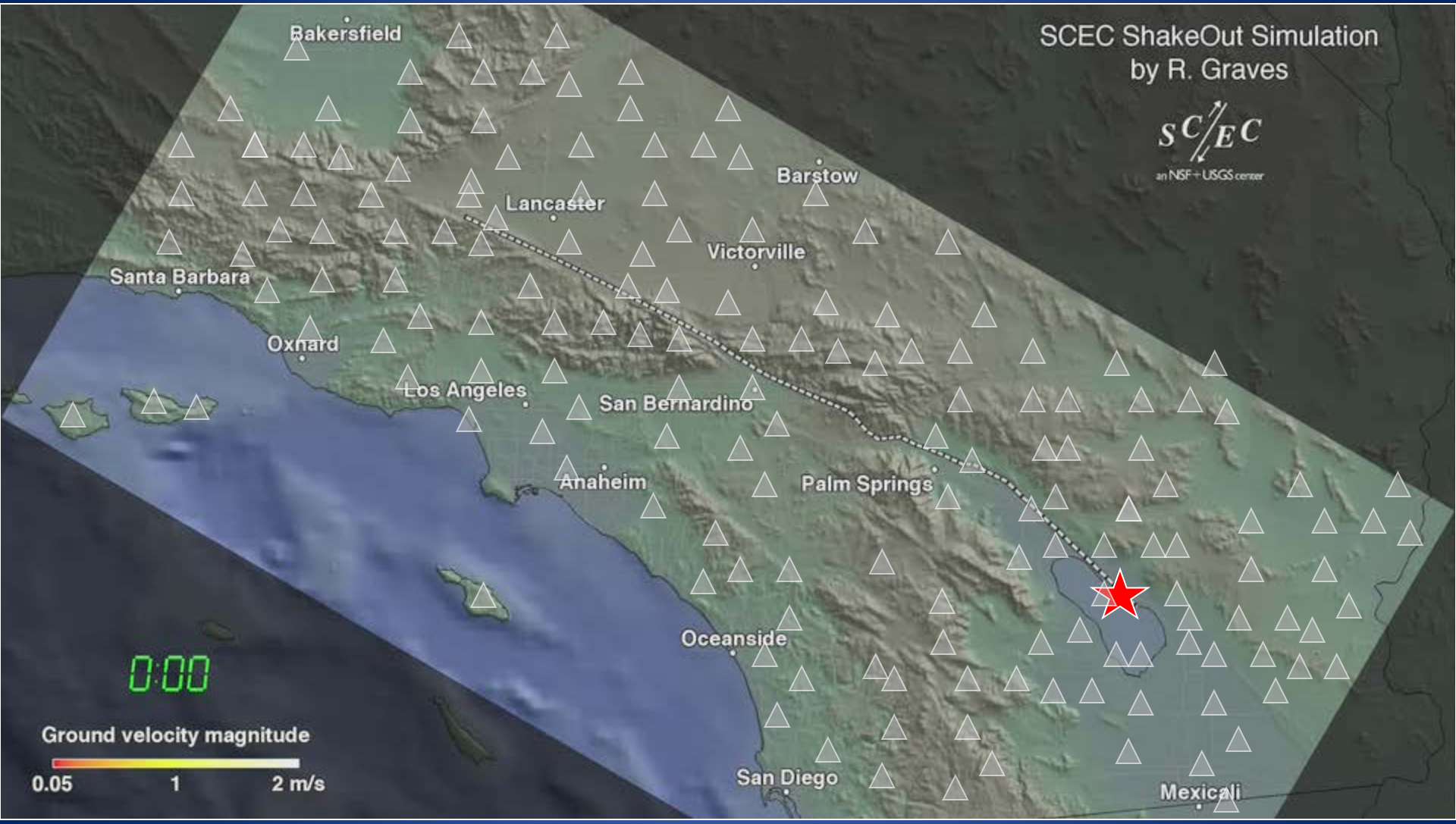
EEW Concept
Network Based Alerts



P-wave ~ 3.5 mi/sec (felt waves)
S-wave ~ 2.0 mi/sec (damaging waves)
Alert ~ 186,000 mi/sec

Sensors closer to the epicenter = more warning time

Earthquake Begins



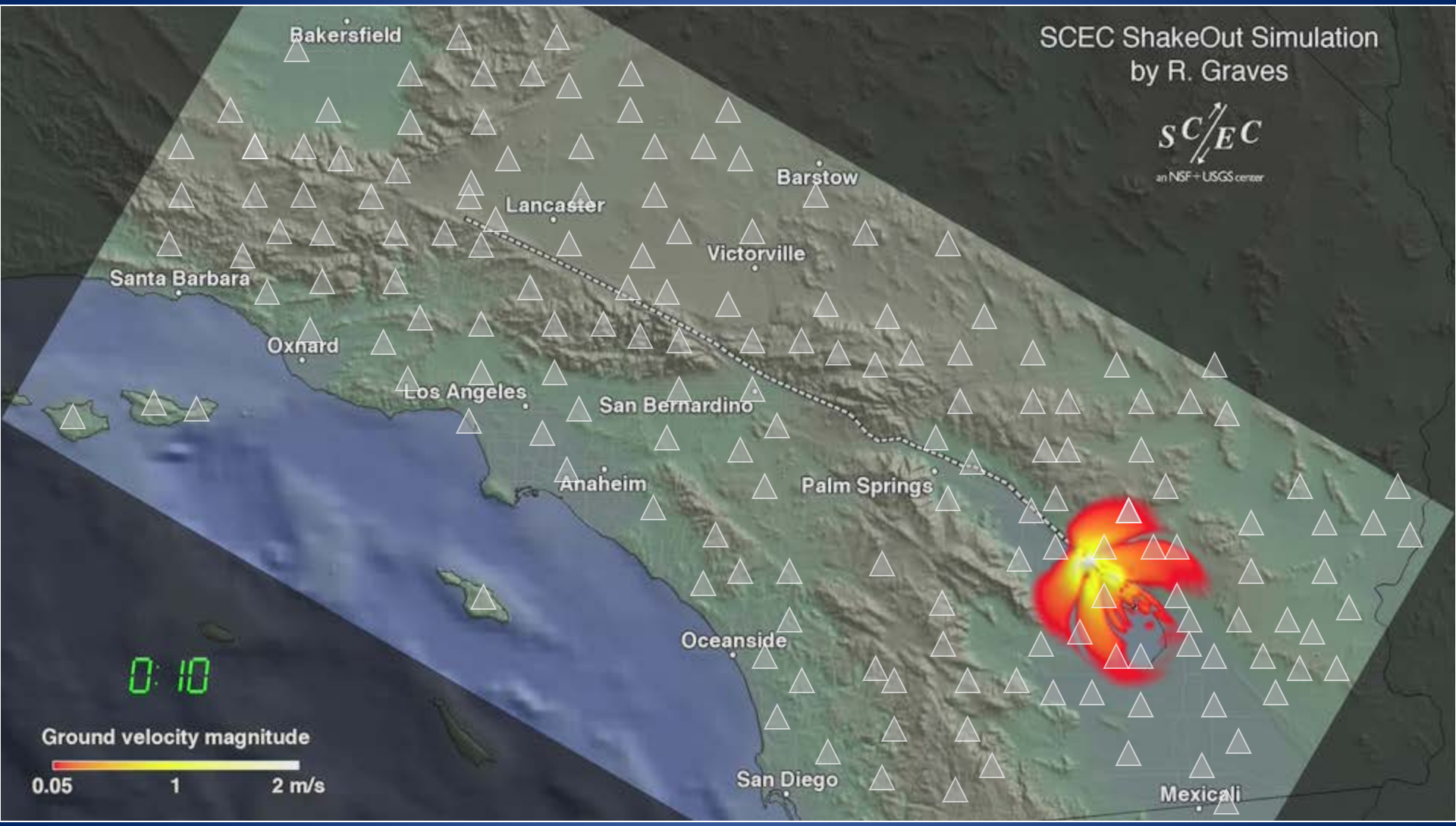
M7.8 SoSAFZ Scenario

Stations Sense Shaking

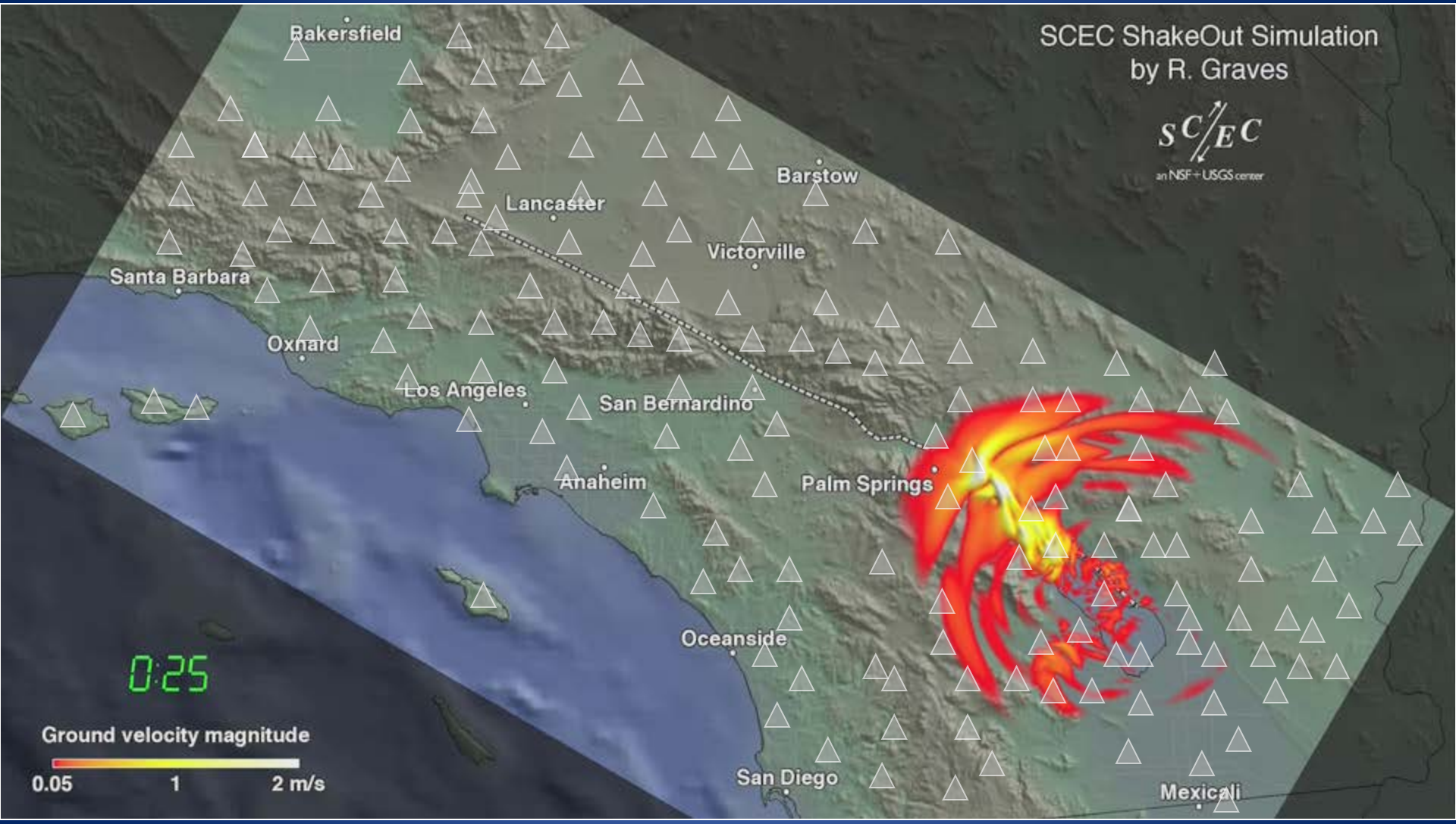
ShakeAlert Detects Event – Issues Alert

Size of "blind zone" depends on stations spacing and system speed.

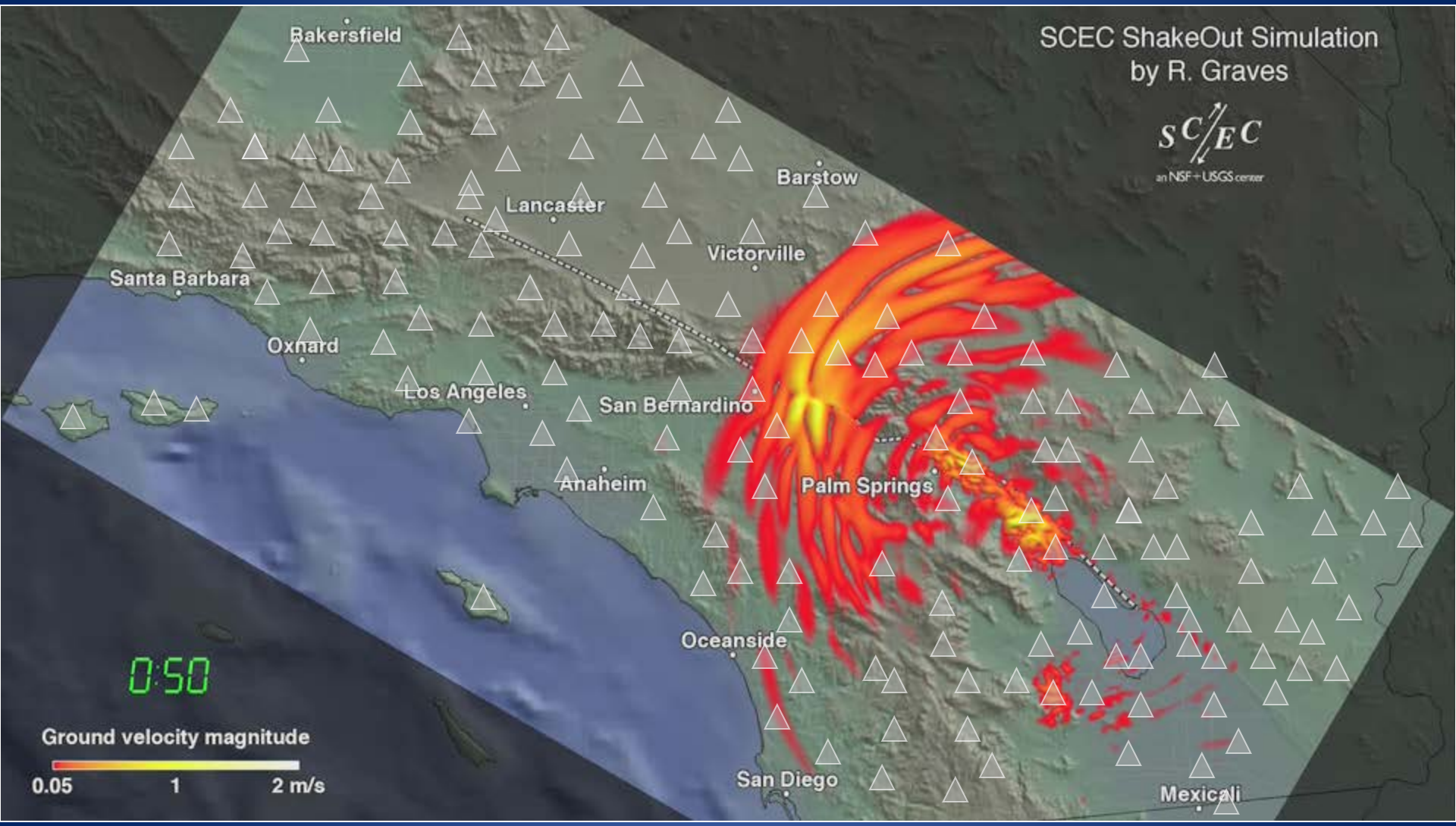
Rupture Moves Up Fault



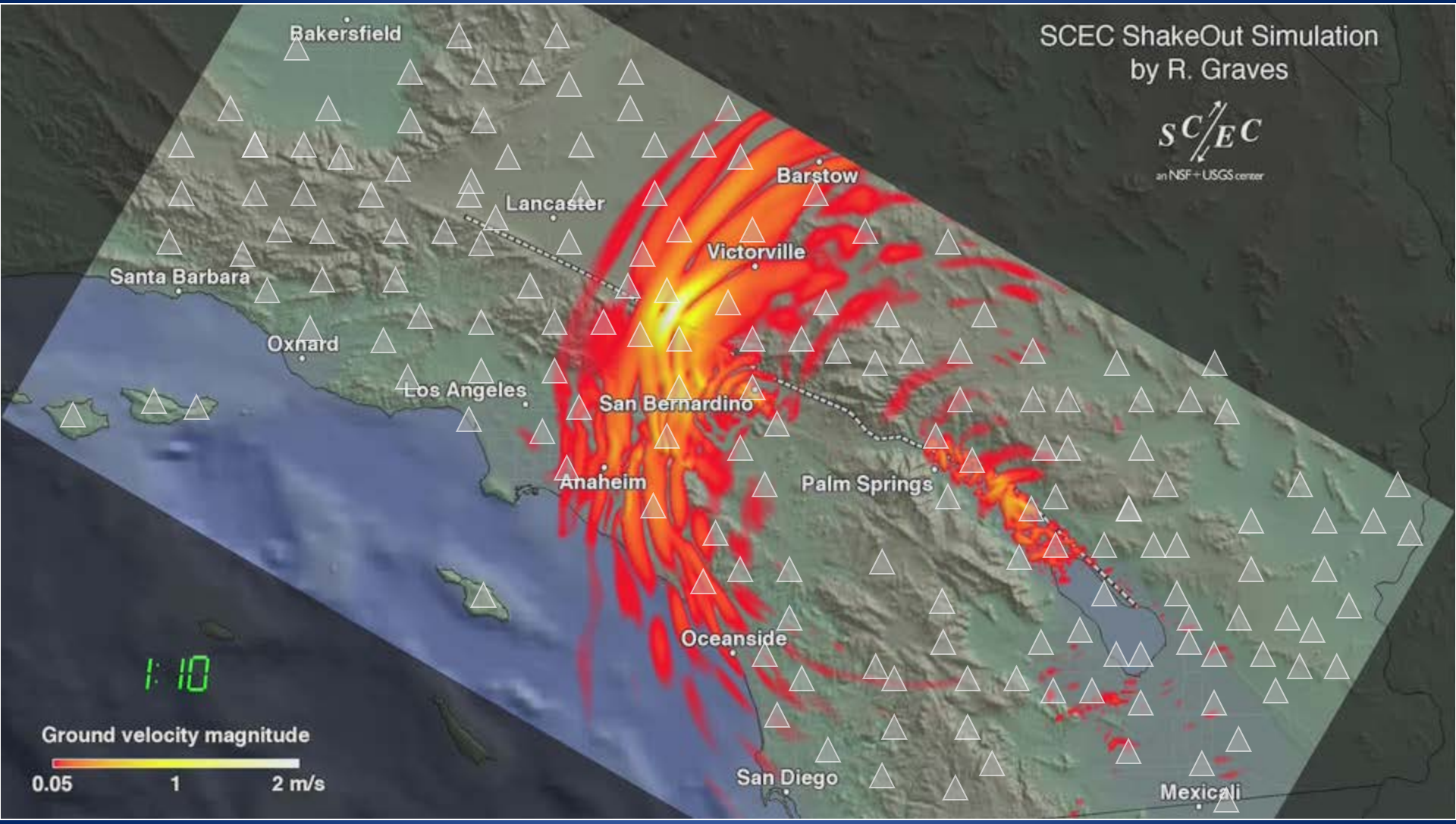
Strong Shaking Arrives – Palm Springs



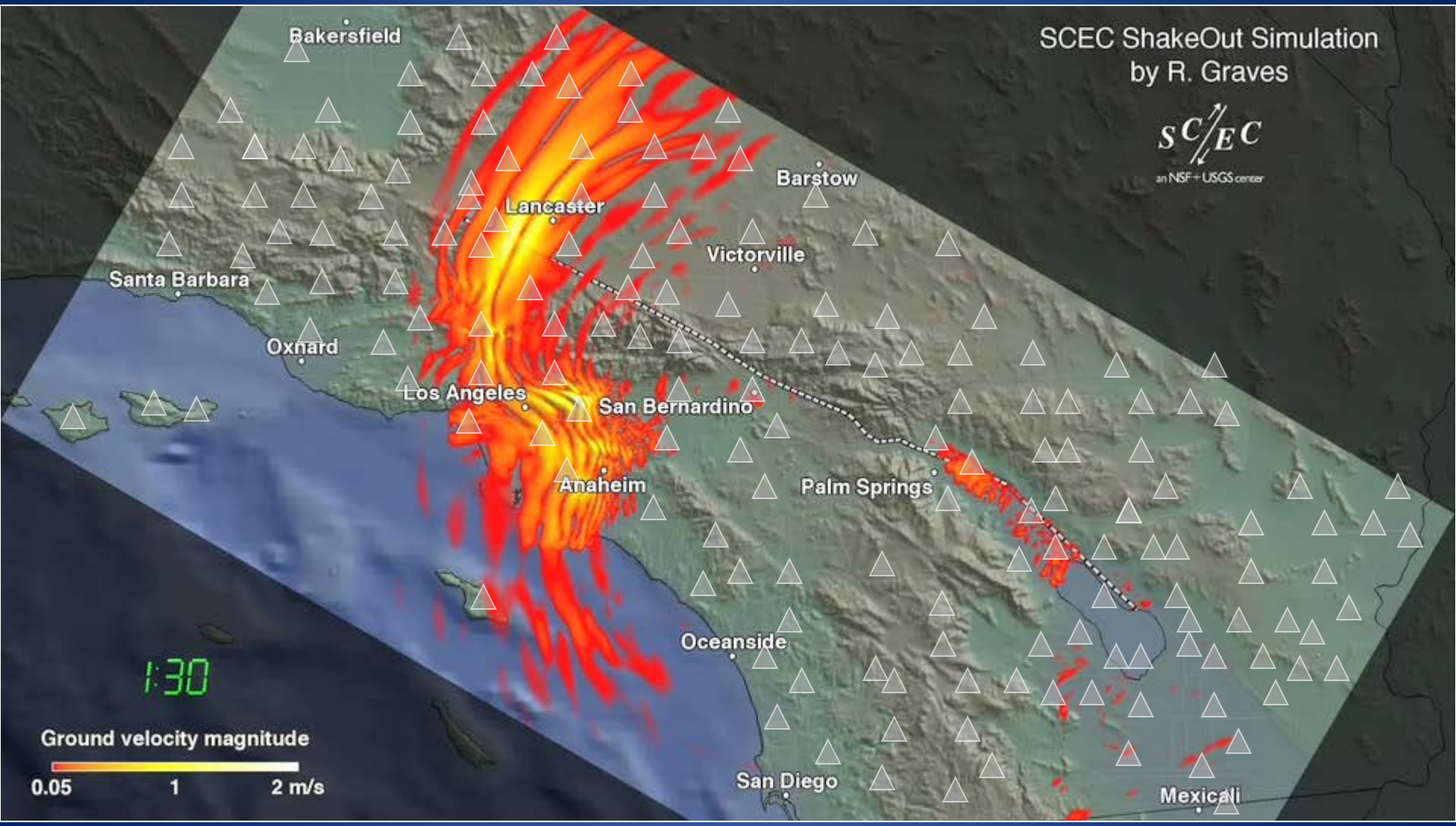
Strong Shaking Arrives – San Bernardino



Strong Shaking Arrives – Orange Co.



Strong Shaking Arrives – Los Angeles



Early Warning Actions

Seconds count…

1. Personal safety
   - moving to safety

2. Automated control
   - slowing/stopping/isolating sensitive systems

3. Situation awareness
   - initiating response before shaking

Brief History of EEW

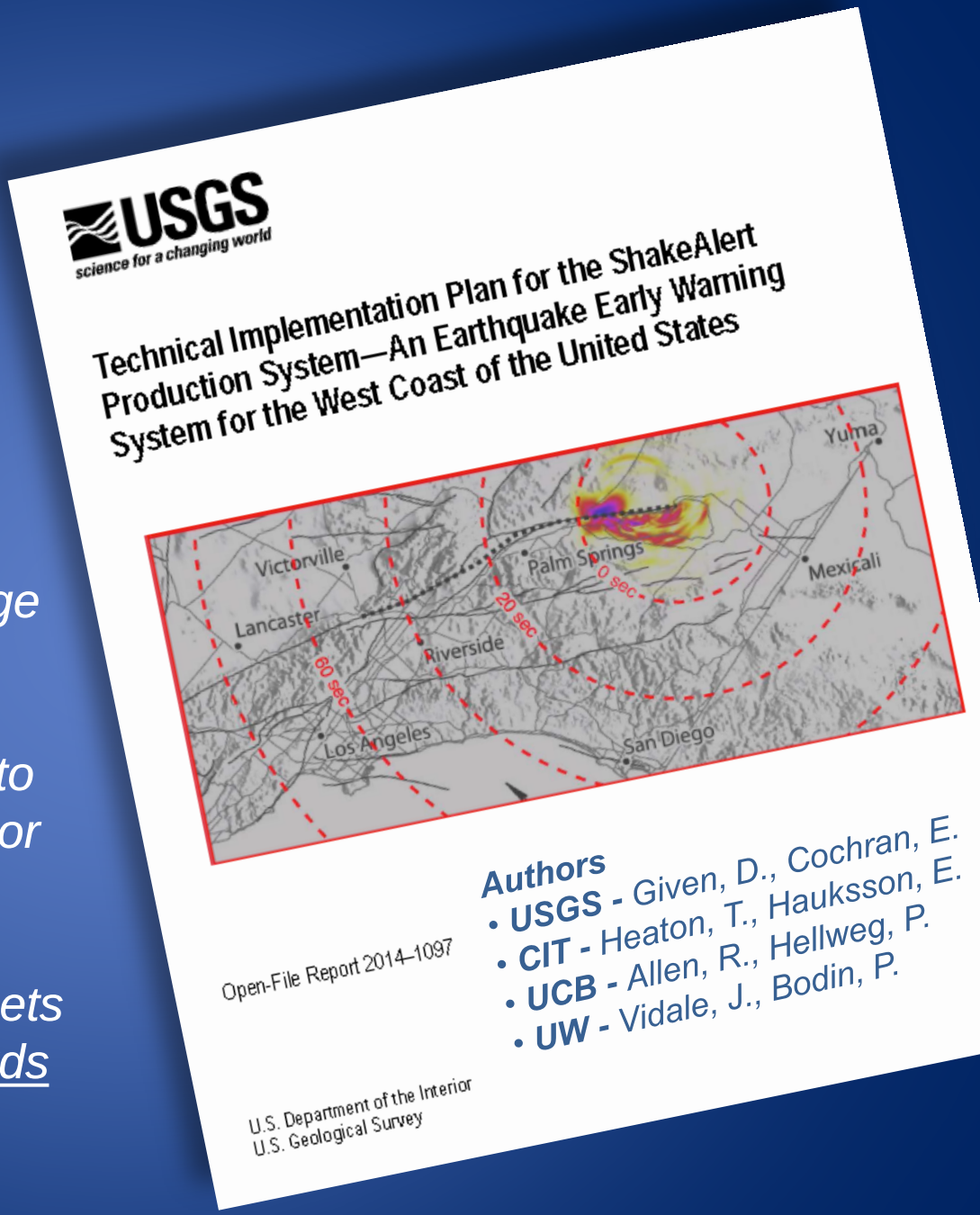
- 1868 Hayward, M6.8 (30 killed)
  - Dr. J.D. Cooper suggests EEW system
- 1964 Niigata M7.6 (36 killed)
  - Japan Railroad builds *Shinkansen*
  - Includes EEW for the system
- 1985 Mexico City M8.0 (~10,000 killed)
  - 1991 Mexico's EEW system goes live
- 1989 Loma Prieta M6.9 (57 killed)
  - USGS rapid-prototype EEW system
- 1995 Kobe M6.9 (6,400 killed)
  - 2007 JMA system goes live (~$500M)
- 2006 ShakeAlert development begins
  - 2012 Demonstration system live in CA
  - 2015 Demonstration system live in PNW
  - 2016 Production Prototype live in CA

ShakeAlert

Implementation Plan

USGS & ANSS partners will complete & operate a West Coast EEW system to…

- *Issue public warnings for large earthquakes and…*
- *…send warning parameters to government and private sector users…*
- *…as soon as ShakeAlert meets quality and reliability standards on a region by region basis.*



Open-File Report 2014-1097

The Path to ShakeAlert

Development Phases

I. 2006-2009 – R & D phase

II. 2009-2012 – "show me" phase

CA: *Demo System Live 1/2012*

III. 2012-2015 – Work on Production Prototype,

PacNW: live 2/15, continued development

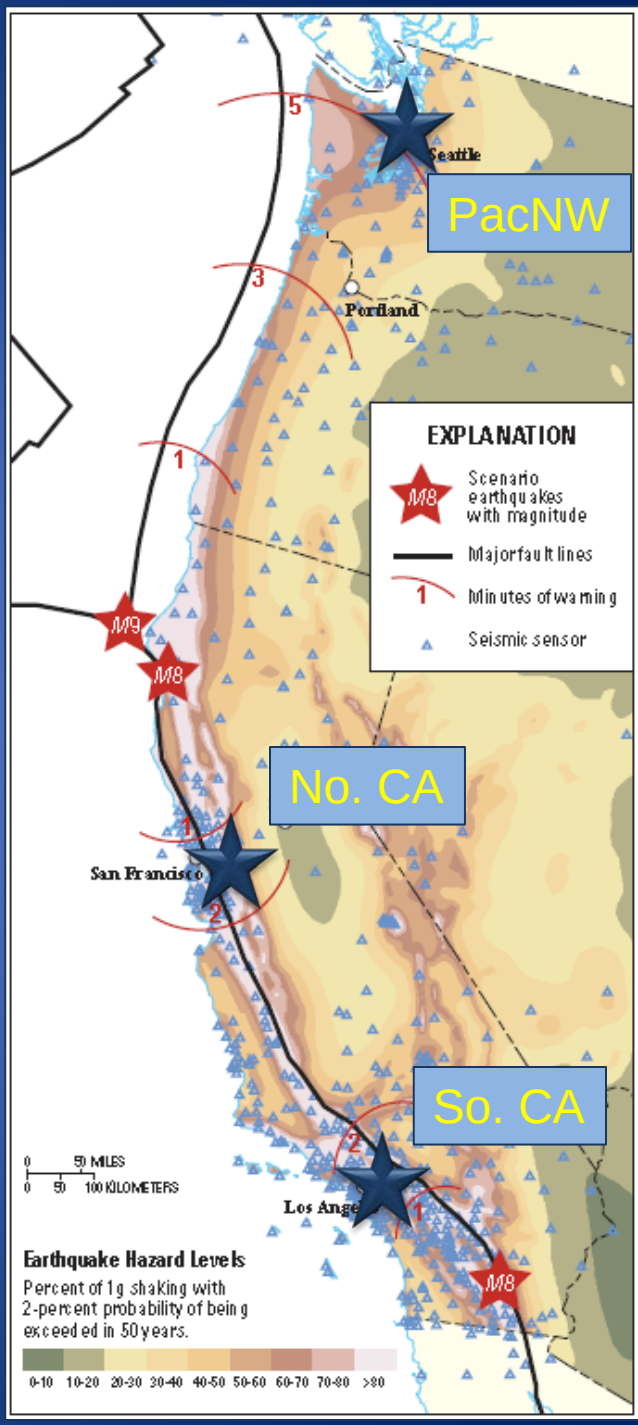
IV. 2015-2018 – continued improvement,

testing, Production Prototype live 2/16 (CA),

pilot applications *(current phase)*

V. ? Full Public Operation

(rate of progress depends on funding)



Organizations Receiving ShakeAlerts

(Beta Users)

- Alaska Airlines P
- Amgen S (medical products)
- Arx Pax N (magnetic base isolation)
- AtHoc N (mass communications)
- Bank of America S
- Bay Area Rapid Transit (BART) N
- Bonneville Power Administration P
- Boyd Gaming S, Las Vegas, NV
- British Columbia Provincial Emergency Management P
- British Petroleum (Olympic Pipeline) P
- Cal OES, Warning Center S
- Caltech Safety/Security/Facilities S
- Caltrans S (8 traffic mgmt. centers)
- City of Hesperia S
- City of Long Beach S EOC, FD, PD, Depts. of wastewater, transportation, gas, oil, water
- City of Ontario EOC S
- Disneyland S
- FEMA Region X P
- Google.org (Crisis Response) N
- Early Warning Labs S
- Intel Corporation P
- Jet Propulsion Lab, EOC, Deep Space Net s
- Kinemetrics (seismic sensor systems) S
- Long Beach Airport S
- Los Angeles City S, EMD, Police, Fire
- Los Angeles County OEM S, Sheriff, Fire
- Los Angeles Dept. of Water and Power S
- Los Angeles Metro S
- Los Angeles Unified School District S
- Metrolink S (dispatch)
- Metropolitan Water District S
- Microsoft P
- Natural Resources Canada P
- NOAA/Pacific Marine Environmental Lab P
- North County Transit District S (San Diego)
- Northwest Healthcare Response Network P
- Ocean Networks Canada P
- Orange Co. OEM S
- Orange Co. Sheriff S
- Oregon Department of Geology and Mineral Industries (DOGAMI) P
- Oregon Department of Transportation P
- Oregon Emergency Management P
- Paccar (truck manufacturer) P
- Port of Long Beach S
- Port of Seattle (SeaTac Airport and Seattle Marine Port) P
- Providence Health & Services (Washington & Oregon Hospitals) P
- Puget Sound Energy P
- Regroup N (mass communications)
- RESIG N (insurance)
- Riverside County OEM/Fire S
- San Bernardino OEC/Fire S
- San Diego County EOC S
- San Francisco DEM N
- Santa Barbara County OEM S
- Seattle City Light P
- Seattle Emergency Management P
- Seattle Public Utilities P
- Sound Transit P
- Southern California Edison S
- The Boeing Company P
- UC Berkeley OEP N
- Univ. of So California, EOC, Fire, facilities s
- Universal Studios S
- University of Oregon P
- University of So California Medical Center s
- University of Washington, Emergency Management P
- US Digital Designs, Inc. S
- Washington Department of Natural Resources P
- Washington State Dept. of Transportation P

P – Pacific Northwest, N – Northern California, S – Southern California. Orange are private companies

ShakeAlert

Performance

Speed and Accuracy

La Habra quake:

M 5.1, March 28, 2014. 9:09 pm PDT

ShakeAlert Timeline

09:09:42.3		Origin time
09:09:43.3	(+1.0s)	1st P-wave
09:09:46.3	**(+4.0s)**	1st Alert

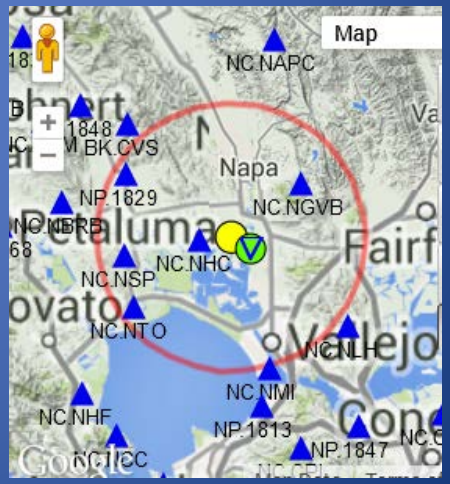
- Upgraded stations would be faster
- 4 stations required for alert
- Detection speed depends on # stations required to alert

South Napa quake:

M 6.0, Aug. 24th, 2014. 3:20am PDT

ShakeAlert Timeline

10:20:44.4		Origin time
10:20:49.5	**(+5.1s)**	1st Alert



Similar performance for:

M4.4 Encino Event of March 17, 2014

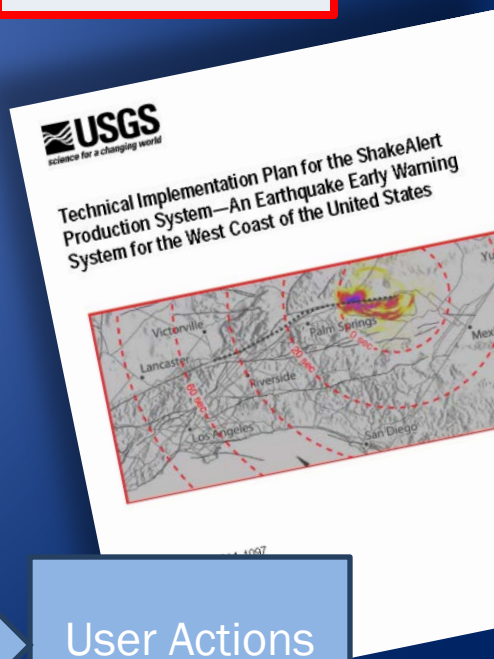
M4.2 Westwood Event of June 2, 2014

Full West Coast Implementation

(estimate from implementation plan)

In addition to current network operational costs	California		Pacific Northwest		*West Coast Total*
Construction	$23.1M	+	$15.2M	=	*$38.3M*
Annual O&M	$11.4M	+	$4.7M	=	***$16.1M***

- Add and upgrade sensors, both seismic & GPS
- Upgrade field telemetry
- Improve com & computing infrastructure
- Operate & maintain the system (staff, equipment)
- Continue R & D, improve the system
- Encourage user applications
- Public education and training



Sensor Networks → Field telemetry → Processing Alert Creation → Alert Delivery → User Actions

Investments in ShakeAlert

(Through FY16)

USGS Earthquake Program (2002-2014)

External coops R & D for EEW	
Phase I & II (2002-2012)	$2,093,851
Phase III (2012-2015)	$1,575,000
ARRA California (2009-2011)	$4,426,110
- Network equipment upgrades	
MultiHazards Project (2008-2014)	$2,342,150
TOTAL	**$10,437,111**

Moore Foundation R&D (2012-2015)

Caltech	$1,996,888
UC Berkeley	$2,040,889
Univ. of Washington	$1,848,351
USGS	$ 594,406
TOTAL	**$6,480,534**
New commitment FY16	**$3,600,000**

Federal Funding Trajectory (in USGS budget)

FY14

$1.5M = add-on to base

FY15

$6.5M = $1.5M base + **new $5 million**

FY16

$8.2 M = $6.5M base + $0.7M redirect + **new $1M**

City of Los Angeles – UASI funding

To Caltech FY 14 (SCSN) **$5,600,000**

- 125 new & upgraded SCSN stations
- 41 RT-GPS stations
- System infrastructure upgrades

USGS science for a changing world

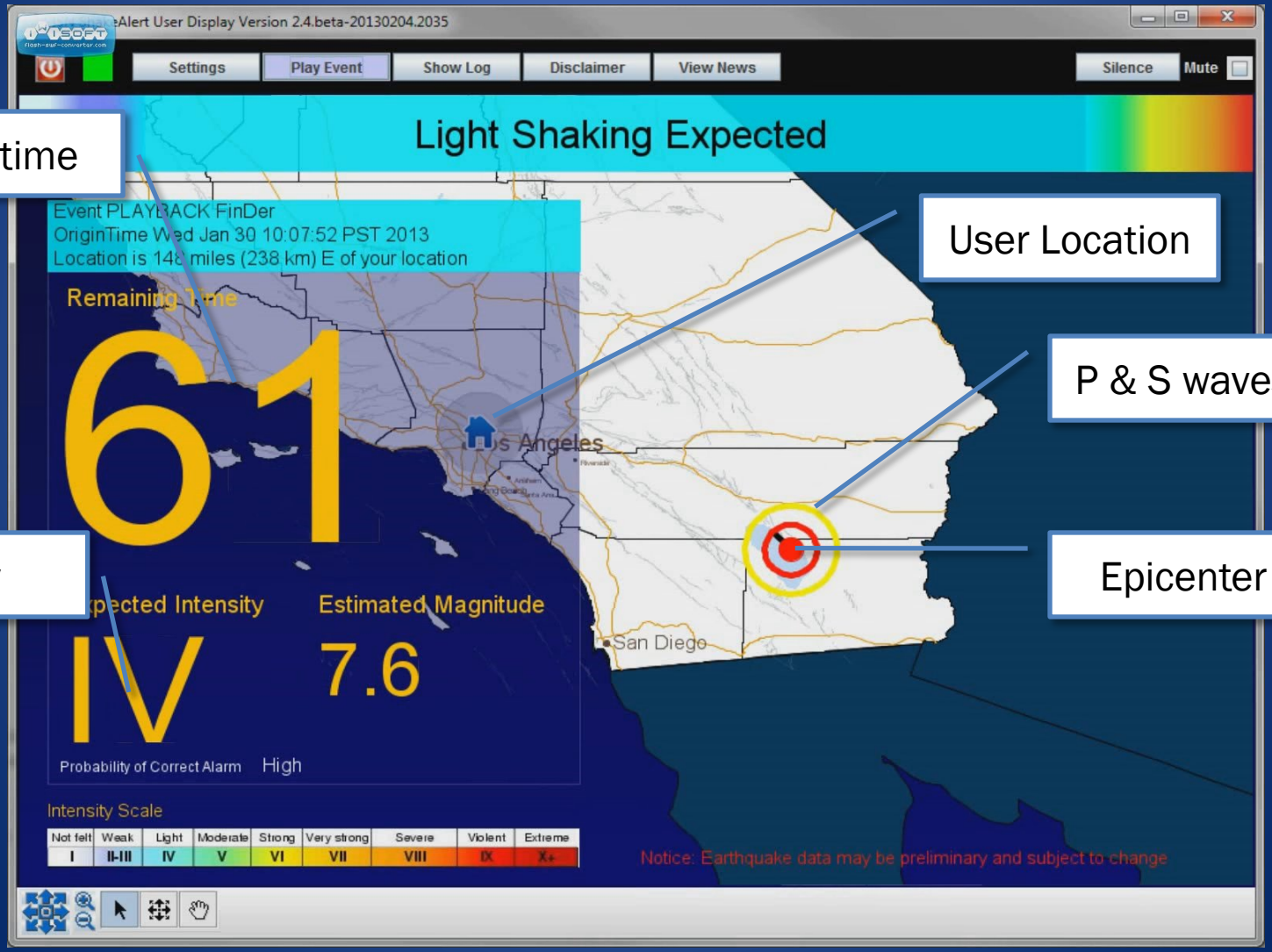
GORDON AND BETTY MOORE FOUNDATION

CITY OF LOS ANGELES FOUNDED 1781

Total = $ 42.3 million

UserDisplay – ShakeOut M7.8

Real-time Finite Fault Solution



UserDisplay – ShakeOut M7.8

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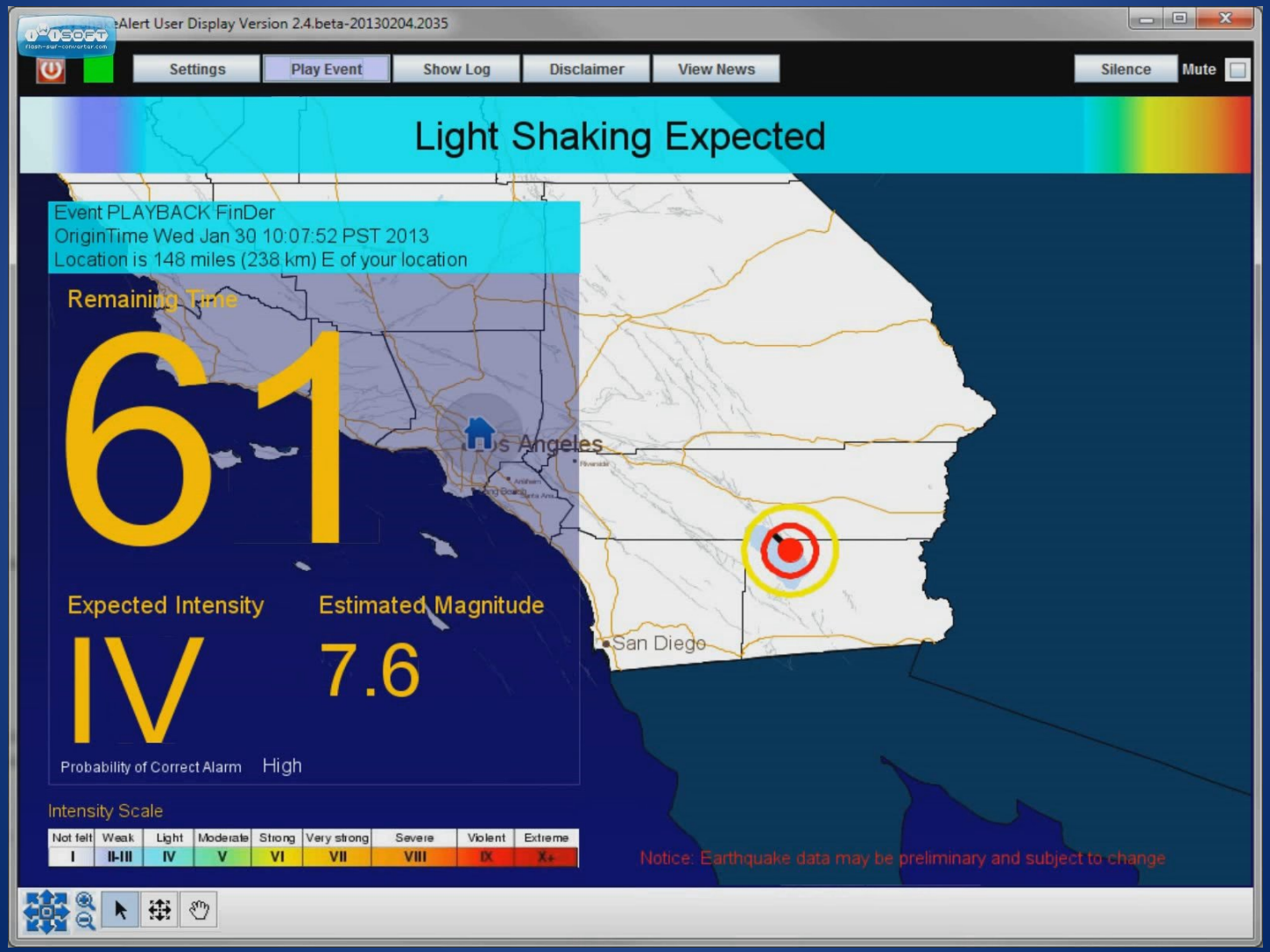

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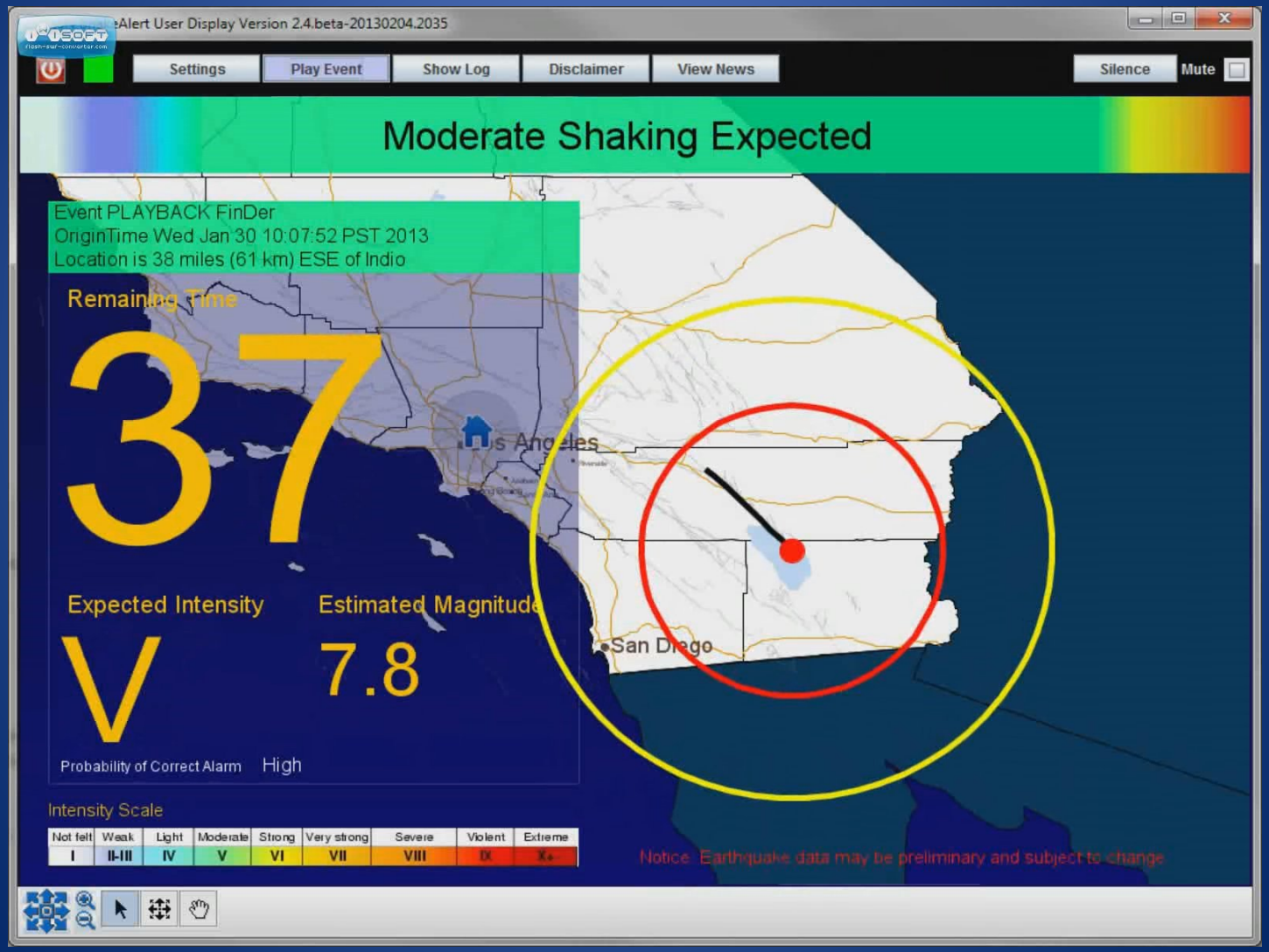

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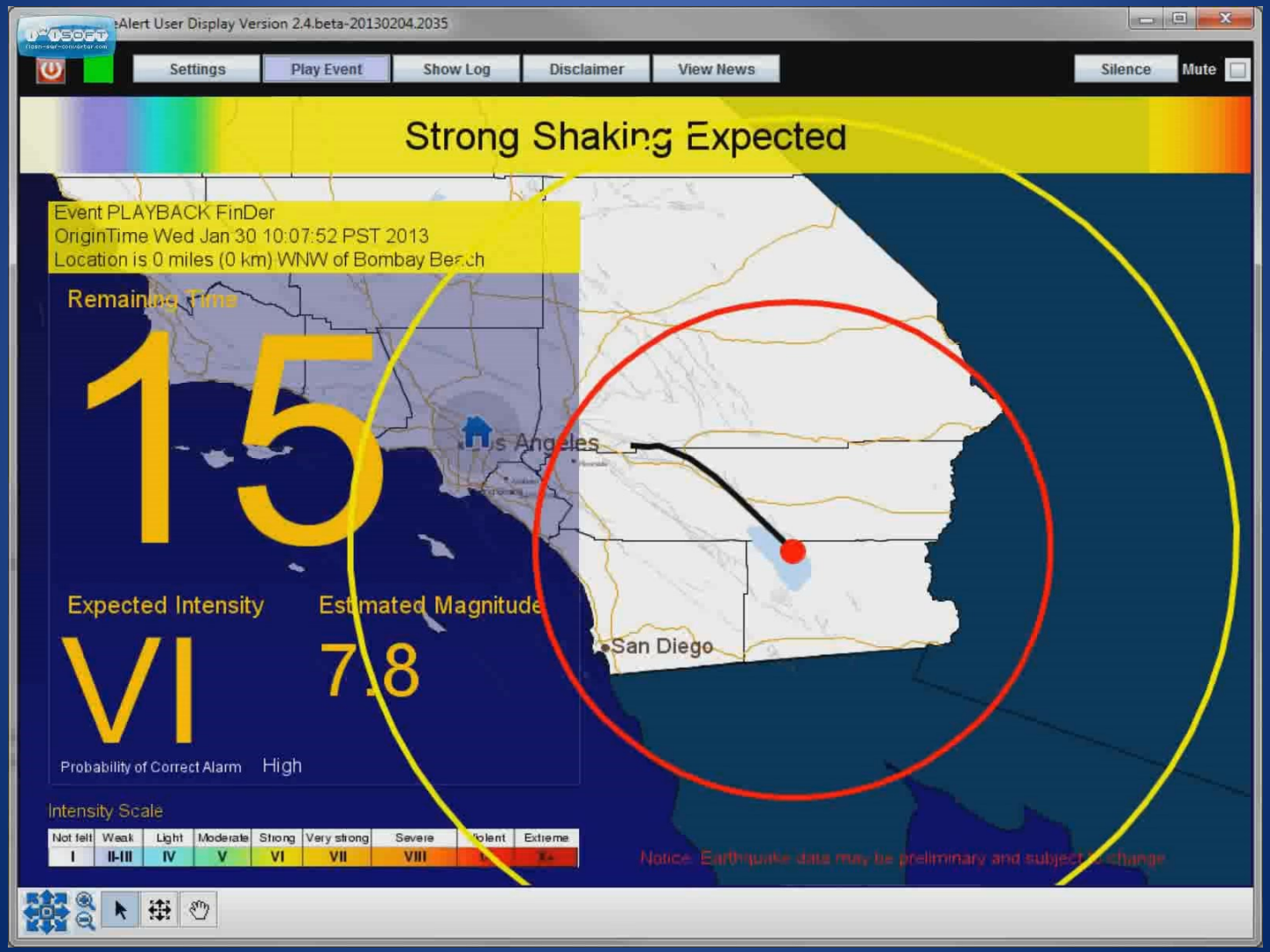

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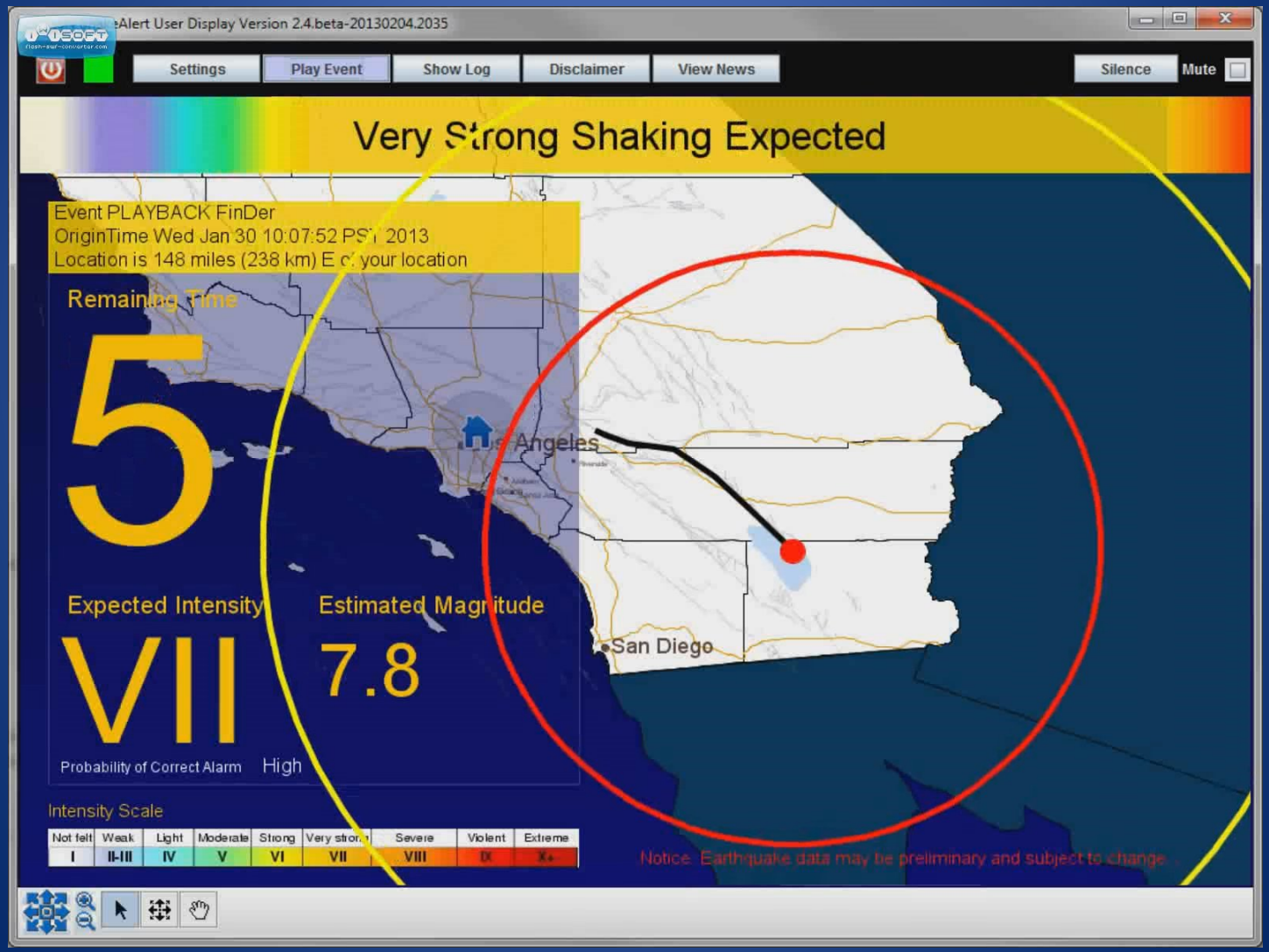


ShakeAlert: Major System Components

Sensor Networks

Field telemetry

Processing
Alert Creation

Alert Delivery

User Actions

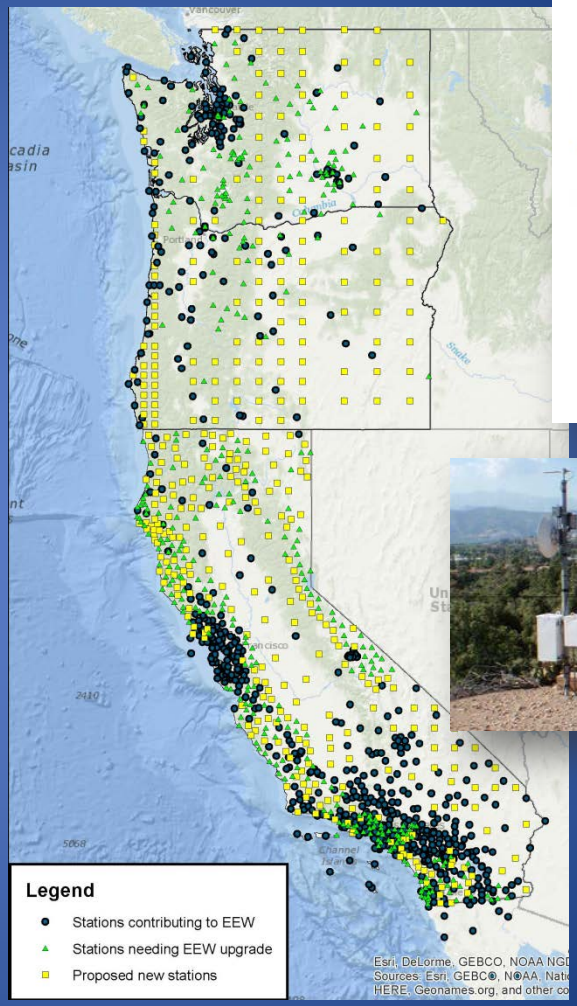
Ground Motion Sensors

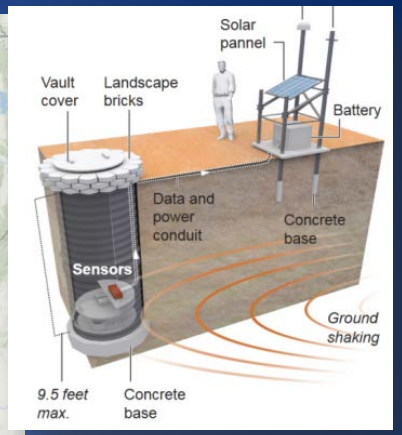
Plan

- Add or upgrade ~1,000 stations (1,675 total)
- Target station spacing
  - 10km in urban areas
  - 20km in outlying areas

Progress:

- 624 stations contributing
- Plans for ~100 upgrades this year
- Planning for GNSS





Sensor Networks → Field telemetry → Processing Alert Creation → Alert Delivery → User Actions

Network Telecommunications

Plan

- Diverse Telecomm Strategy
  - Cellular (multiple carriers)
  - IP Radio
  - Digital microwave
  - Satellite
  - DSL, cable
  - Public Internet
  - Partner systems

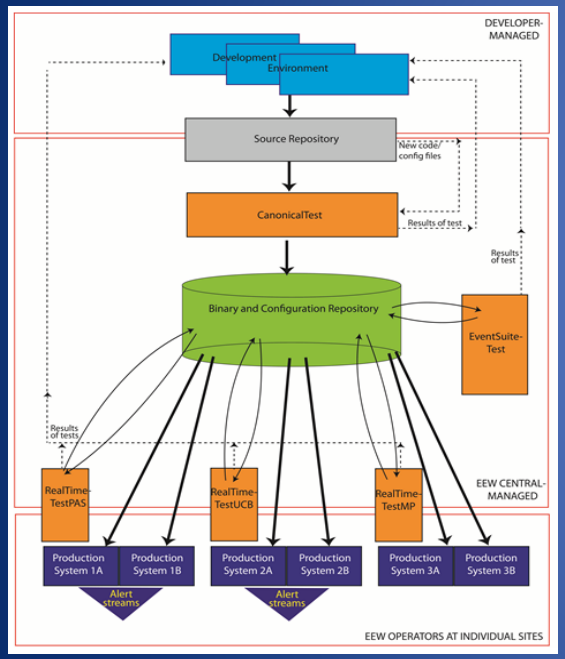
Progress

- Upgrading telemetry systems
- Exploring new technologies
- Seeking partners to share telecomm

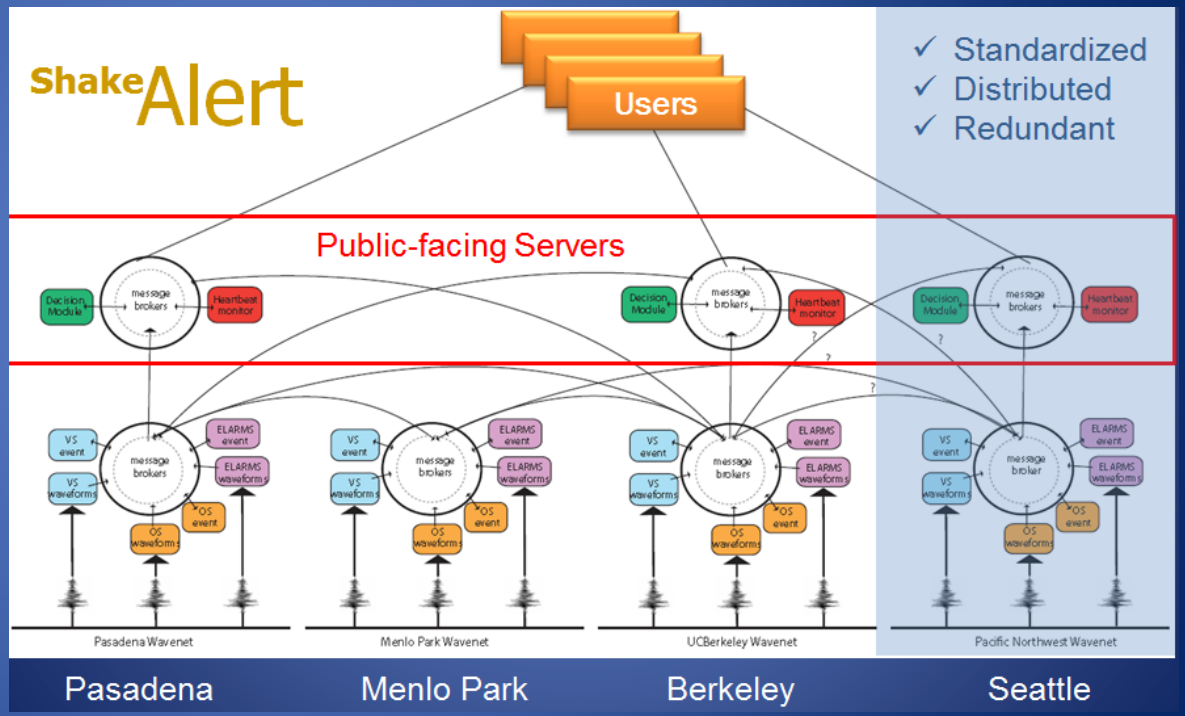
Sensor Networks → Field telemetry → Processing Alert Creation → Alert Delivery → User Actions

ShakeAlert Production Prototype V1.0

Code Management & Testing Model

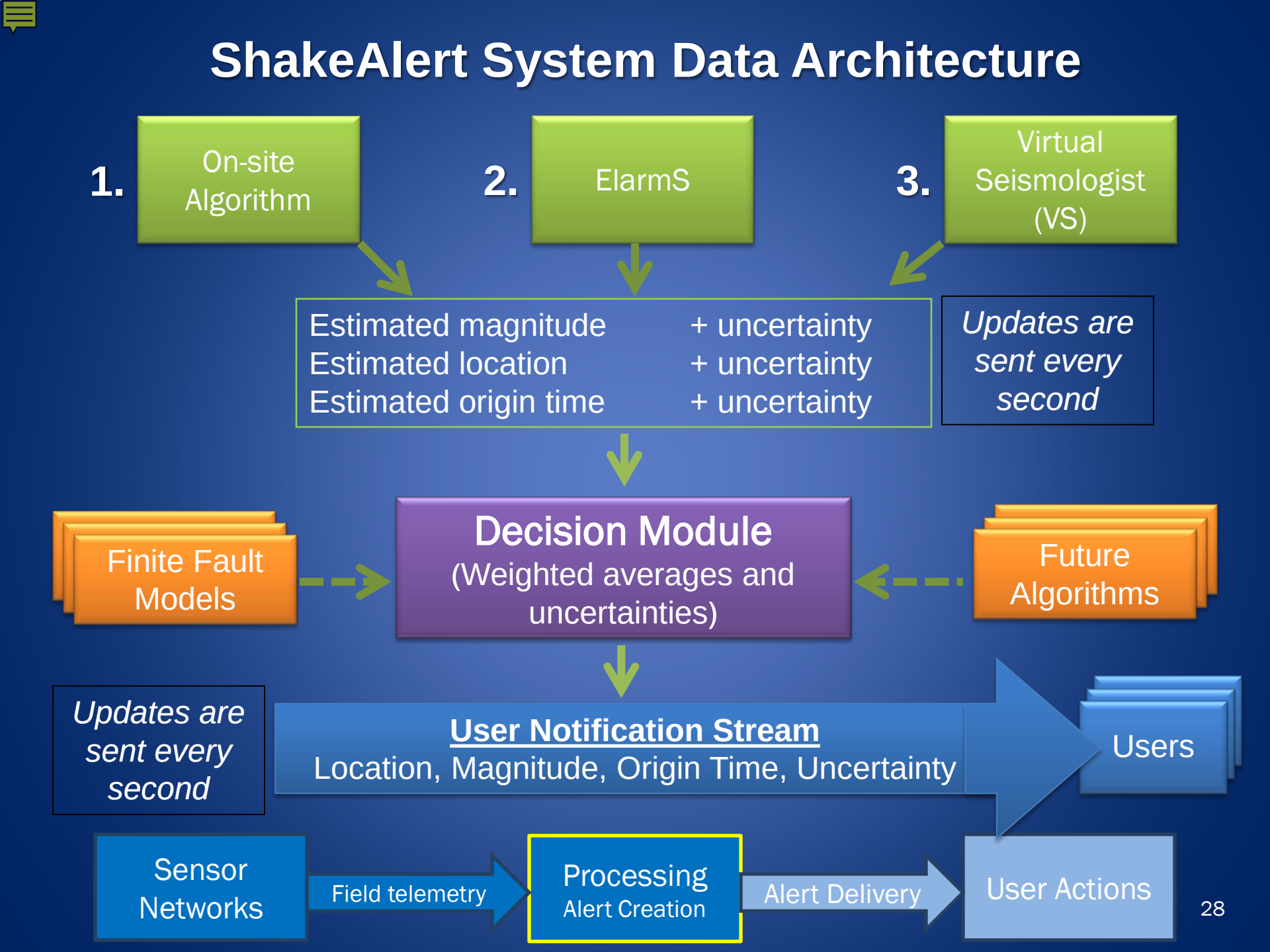


Fault Tolerant System Topology

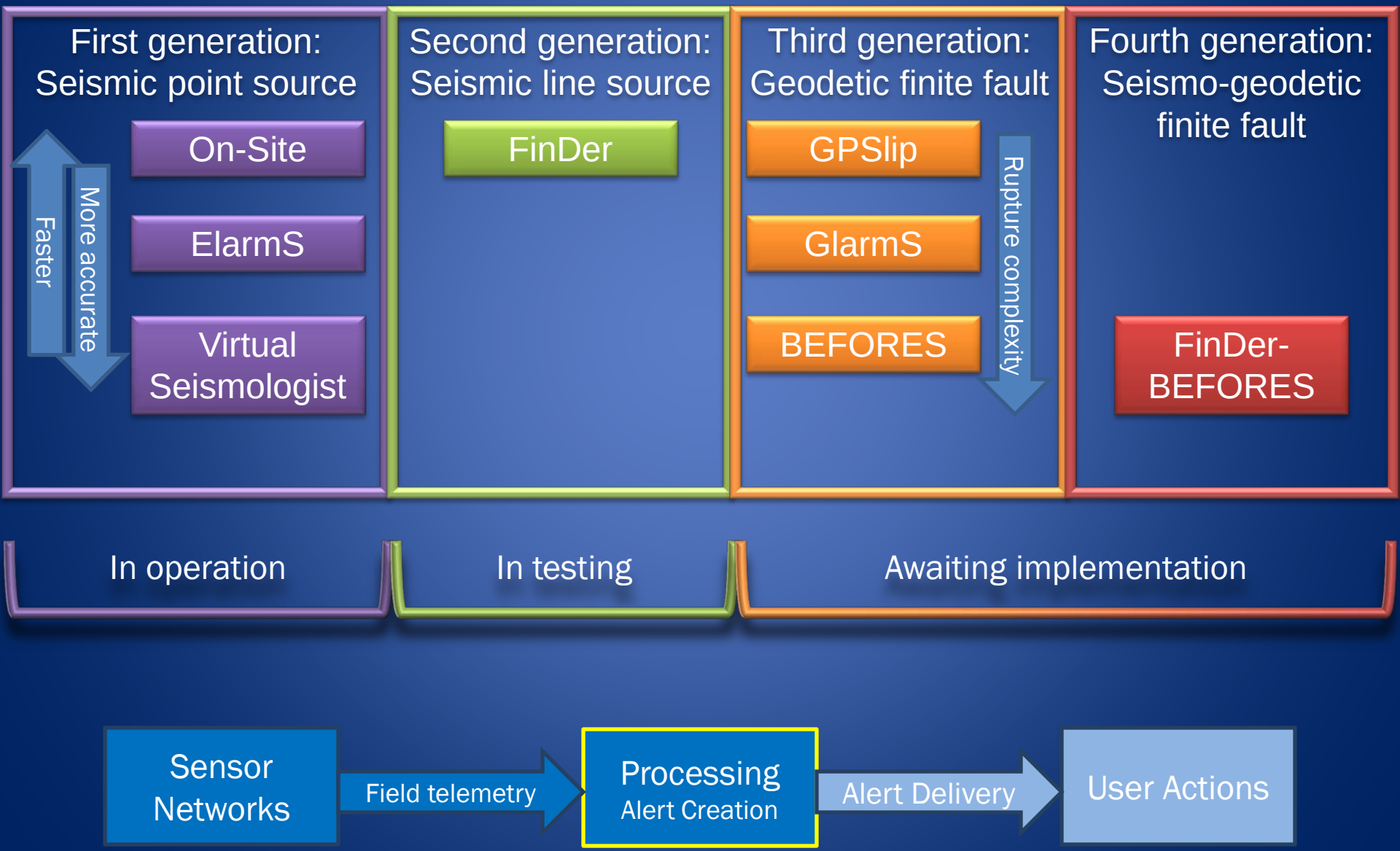


Sensor Networks → Field telemetry → **Processing** Alert Creation → Alert Delivery → User Actions

ShakeAlert System Data Architecture



ShakeAlert Algorithms are Evolving

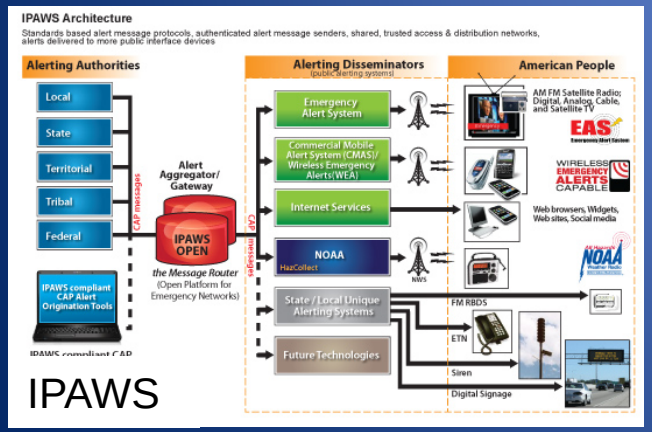


Alert Delivery: *by all available means*

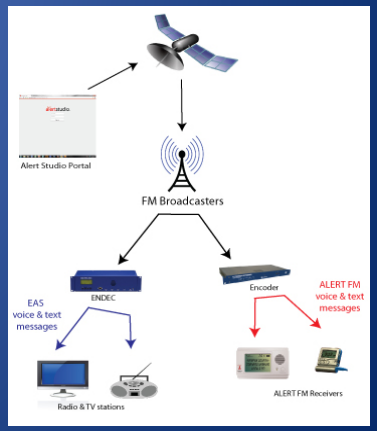
- Send alerts by all available means (redundant, robust)
  - IPAWS/WEA (FEMA)
  - TV, radio, satellite, cell network
  - Internet, social media, pubsub
  - Private & public data networks
- Encourage private sector innovation

Examples

- IPAWS "alert authority"
- Google/Android app
- Partnerships
  - GSS, FM Alert (broadcast)
  - EWL (cloud server, app, actuator)
  - More to come…



IPAWS



Sensor Networks → Field telemetry → Processing Alert Creation → Alert Delivery → User Actions

Two User Categories

People

- Need effective, consistent alerts
  - Alert content, sounds
  - Messaging, "branding"
  - Education & training

Things (automated)

- Private partner R&D
- Automated, context-specific decision-logic
- Actuators

Sensor Networks → Field telemetry → Processing Alert Creation → Alert Delivery → User Actions

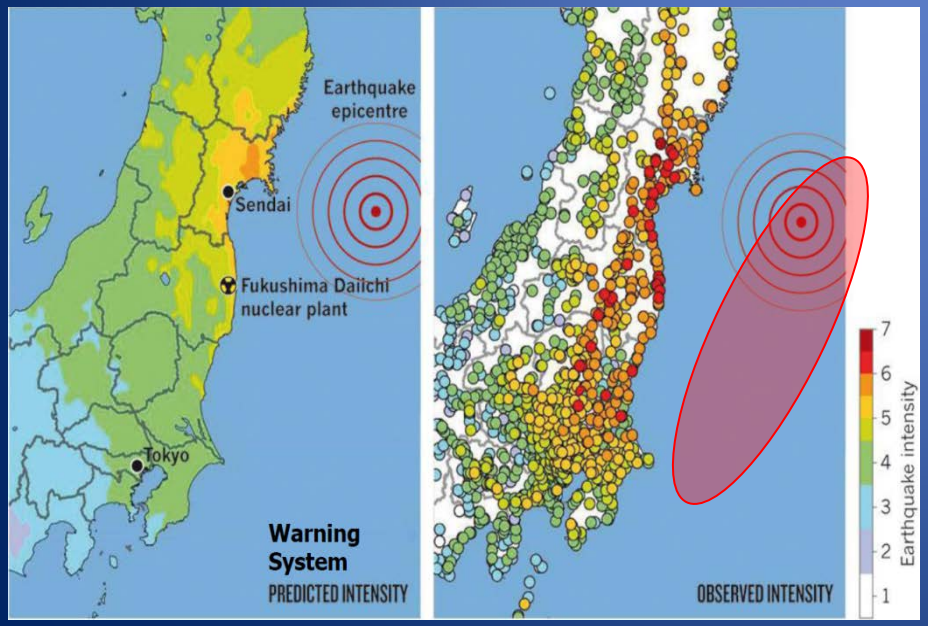
EEW Alert: Tohoku M9.0, March 11, 2011

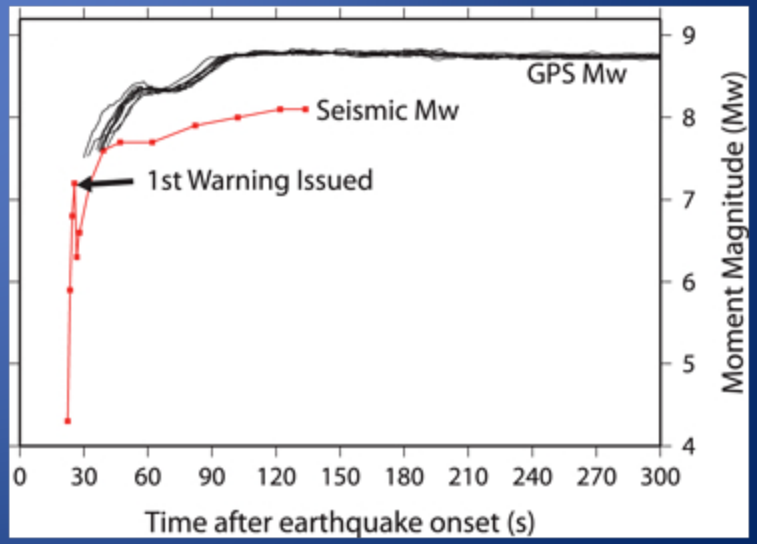
The good:

- Alert was sent
  - 8.6 sec after 1st detection
  - 31 sec after OT
- Millions received 5 – 40 sec warning

The not-so-good:

- Magnitude saturated at M8.1
- Point source assumption
  - Intensity too low
  - area affected too small
- Missed and false alerts followed
- 55 stations lost power





Future Plans

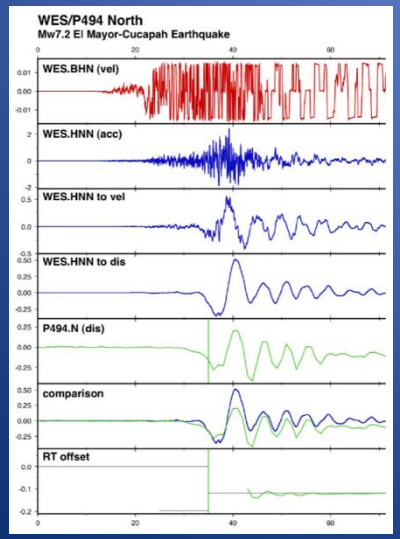
- GNSS
  - Integrate data streams
  - R&D on algorithms
- Low cost sensors
- Crowdsourcing
  - Smart phones
  - The “internet of things”
- Foster private R&D in emerging technologies
  - Sensors
  - Data communication
  - Mass alert delivery
  - Practical implementations
- Create T&E plan
- Seek full funding

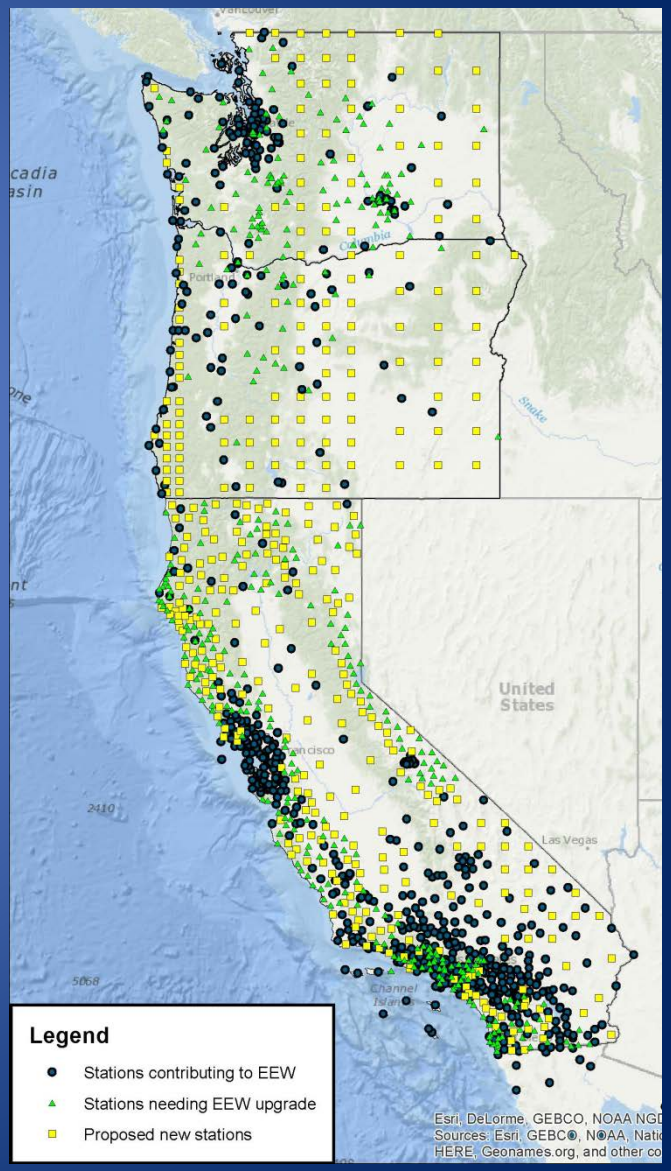
ShakeAlert & Tsunami Warning

- Public will receive ShakeAlert messages before they feel shaking
- What should the public message be if the event is potentially tsunamigenic?

ShakeAlert & Tsunami Warning

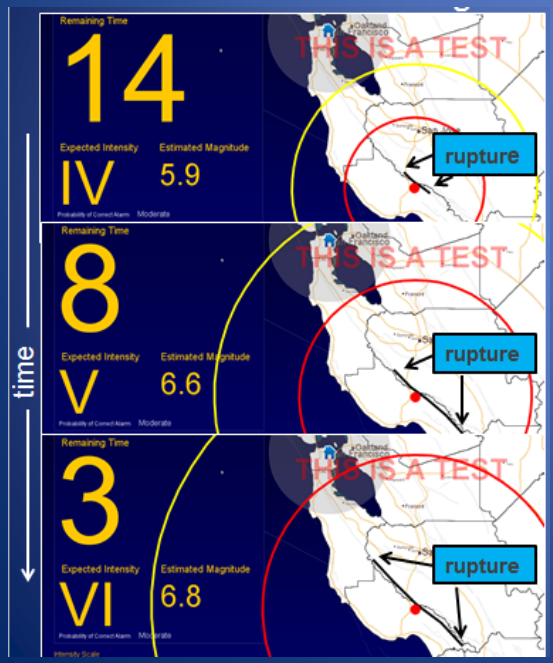
- ShakeAlert will result in much more real-time data, both seismic and geodetic
- How might that benefit tsunami warning?

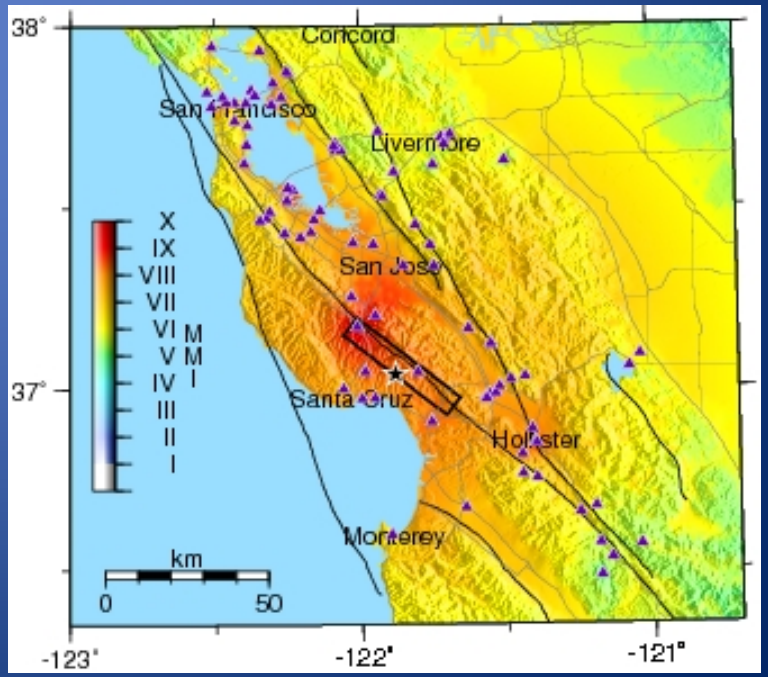




ShakeAlert & Tsunami Warning

- ShakeAlert will produce real-time source models.
- How might that benefit tsunami alerting?





ShakeAlert & Tsunami Warning

- ShakeAlert will need (drive?) changes to public alerting pathways.
- How might that benefit tsunami alerting?
  - IPAWS/WEA
  - Mass notification
  - Apps
  - Others…

ShakeAlert & Tsunami Warning

- ShakeAlert will promote public hazard education and training
- How can we best integrate this with other hazard education including tsunamis?
  - CalOES lead T&E committee
  - USGS hiring T&E coordinator

ShakeAlert

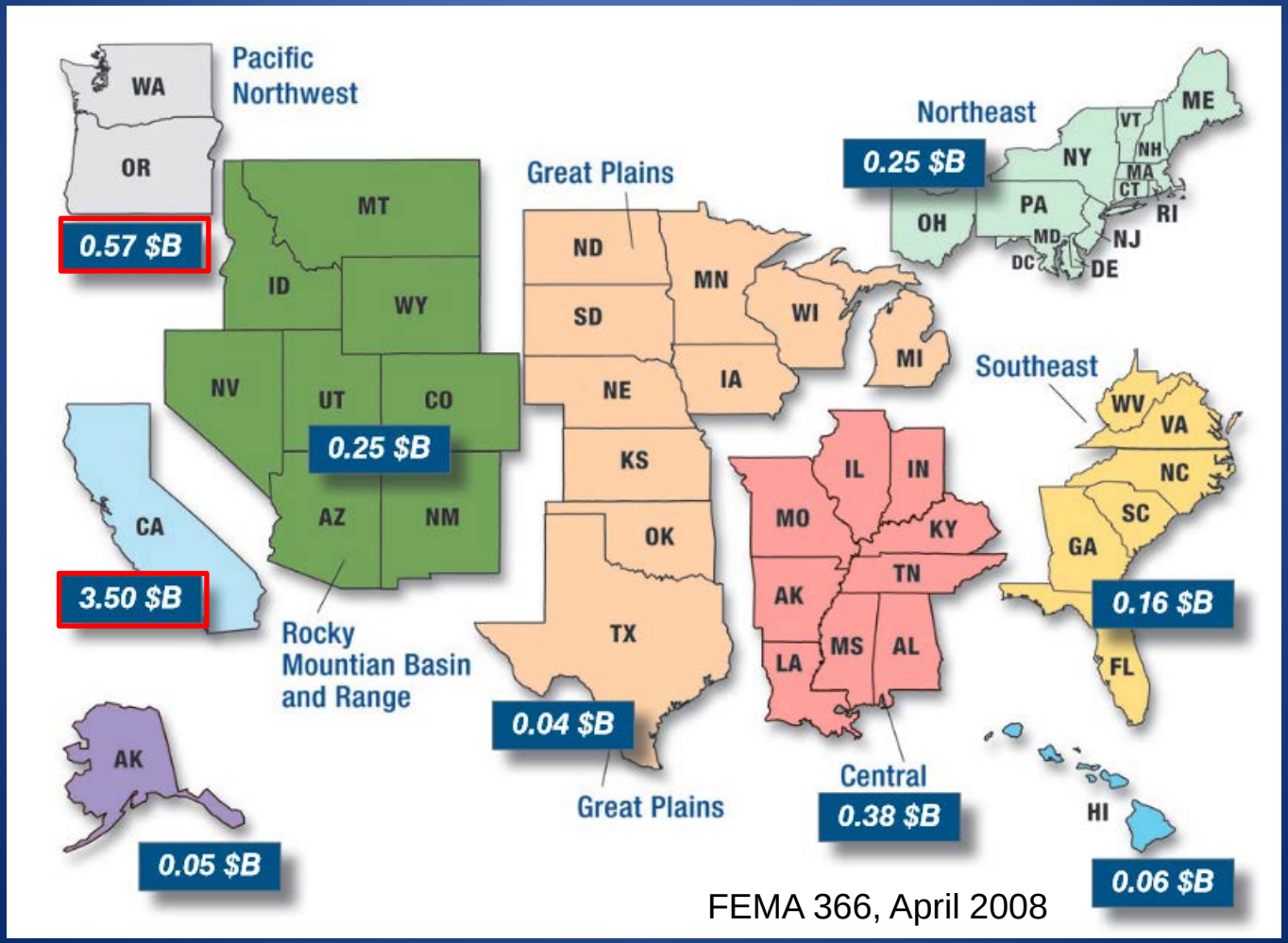
Summary

- ShakeAlert is progressing despite limited resources (V1.0)
- Pilot implementations will begin soon (in CA)
- Completing ShakeAlert will require further work, investment & coordination
- Partners will play a critical role in fully implementing ShakeAlert

Annualized Earthquake Losses = $5.3B/yr

77% on West Coast ($4.1B)

ShakeAlert only needs to prevent 0.4% of direct losses to be cost effective



FEMA 366, April 2008