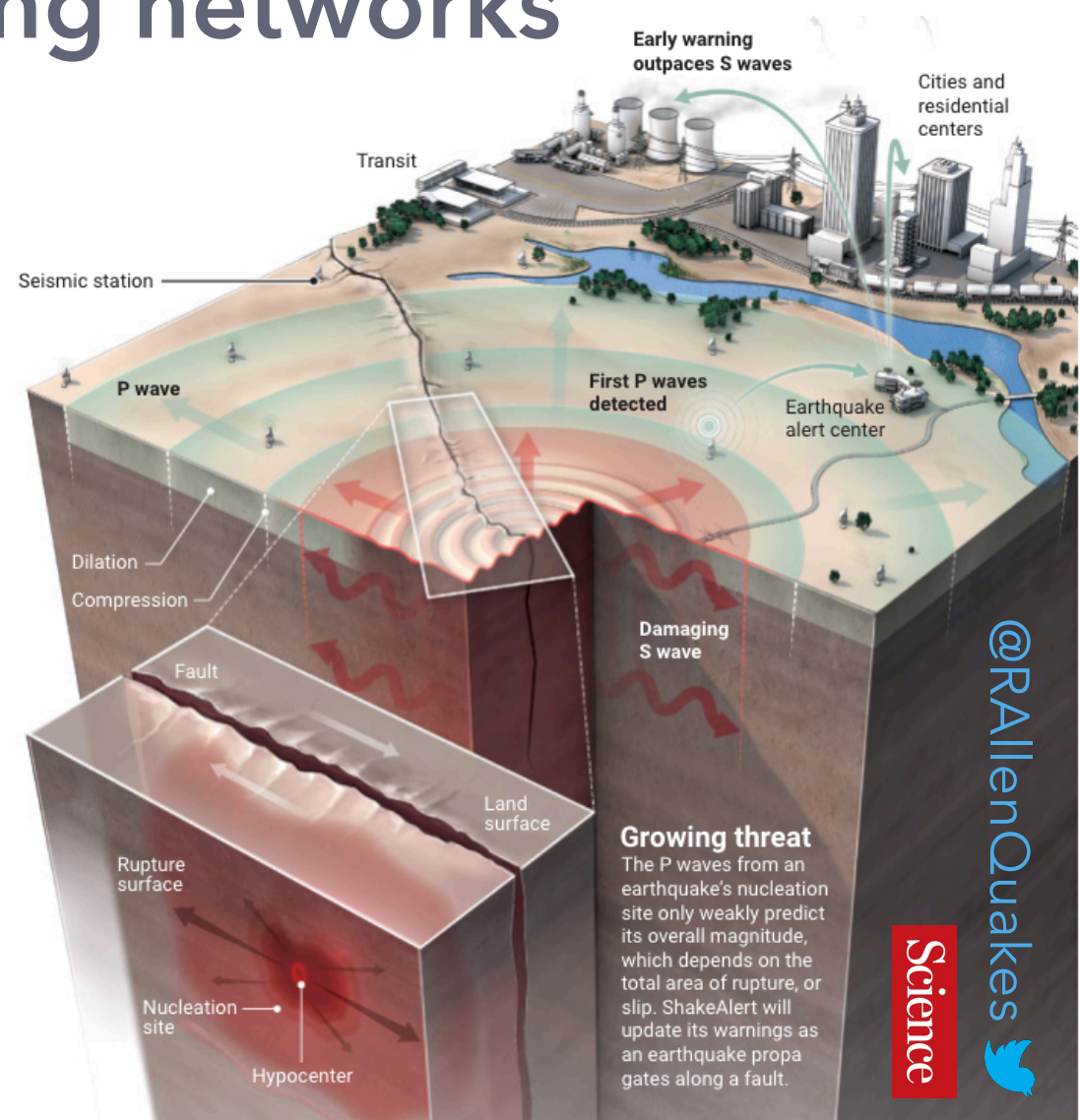


Earthquake early warning

Status and opportunities for massive sensing networks



Richard Allen



@RAllenQuakes

Science

The visible story

April 2011

Earthquake Early Warning Summit

scientists, public and private sector,
legislators and foundations



ShakeAlert™ US early warning system
using traditional sensors

Feb 2016

White House Summit

scientists, legislators, responsible
agencies and foundations



 **MyShake** Smartphone earthquake
detection and warning

Oct 2019

Public warnings in California

ShakeAlerts delivered
to MyShake phones



USGS
science for a changing world

Cal OES

Berkeley
UNIVERSITY OF CALIFORNIA

Caltech

OREGON

W
UNIVERSITY of
WASHINGTON

GORDON AND BETTY
MOORE
FOUNDATION

The other story

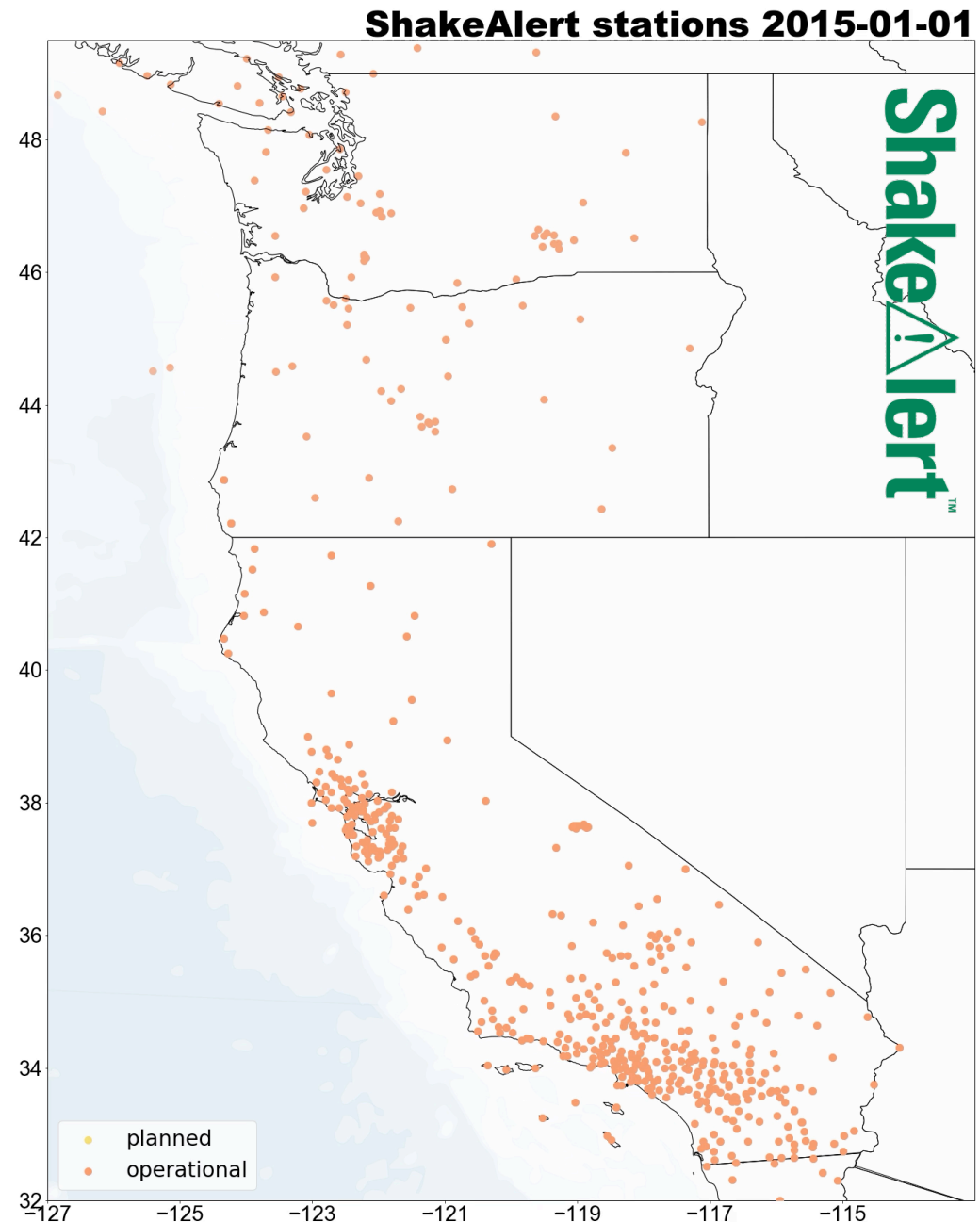
Dual-use geophysical networks

and the scientific
opportunities they
present

2014: 575 stations

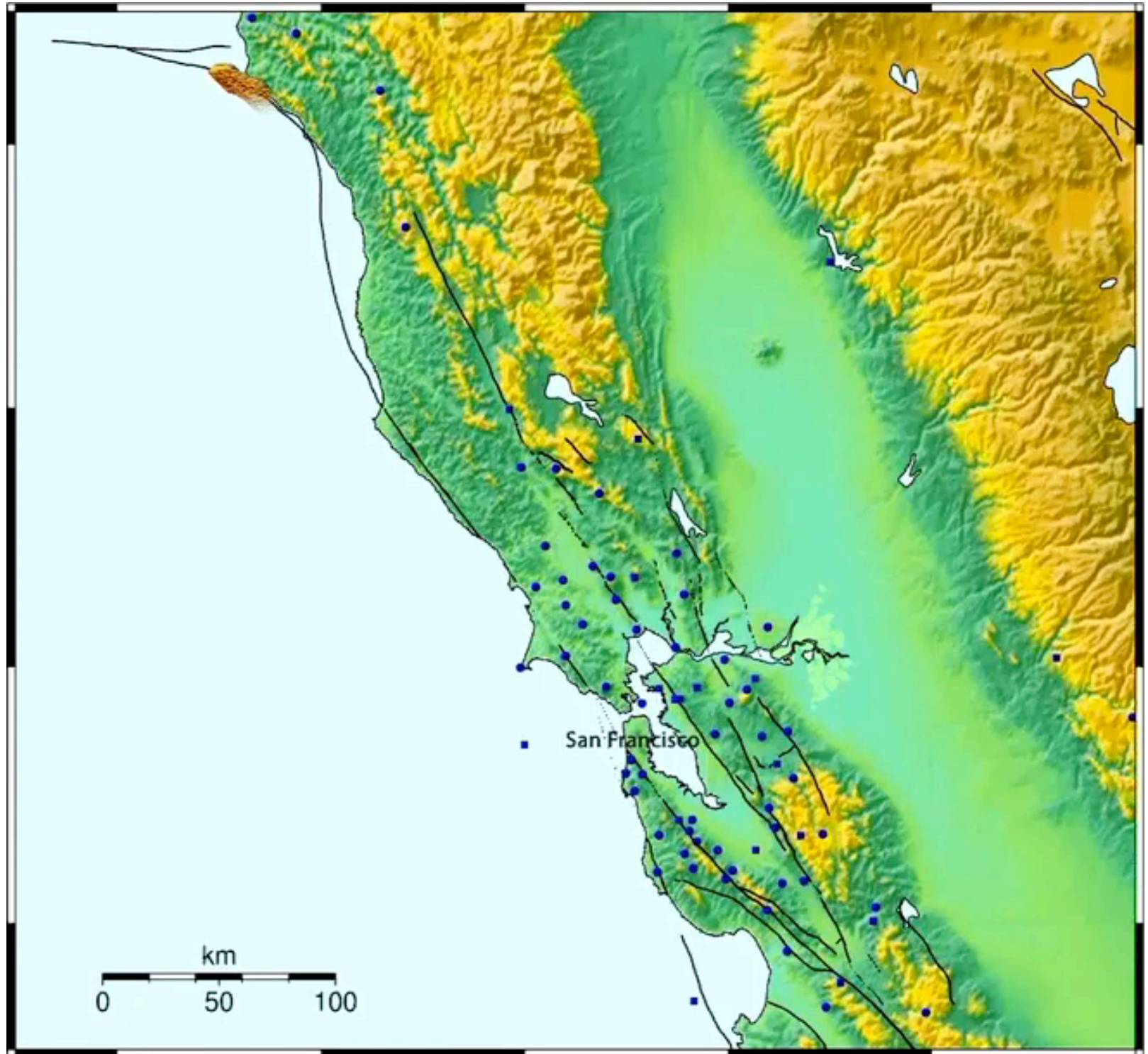
Today: 1143 stations

Planned: 1675 stations




What is
earthquake
early
warning?

Magnitude 8 on the San Andreas



Why do we need
earthquake early warning?

 **MyShake**'s goal:
Deliver earthquake
alerts around the
globe

Mexico City

M7.1 – September 19, 2017



Who could use
earthquake early warning?

Reducing Falling hazards



Loma Prieta >50% injuries
were linked to falls



Northridge

>50% injuries were
non-structural (falling)
hazards

if everyone received a few seconds warning
if everyone dropped, took cover, and held on
then early warning could reduce injuries by 50%

Cost of injuries in Northridge: \$2-3 billion

Who could use earthquake early warning?

Big-box store



Photo Eduardo Miranda / Michael Rowe
M6.3 Christchurch, NZ - Feb 22, 2011

Who could use earthquake early warning?

Santiago airport terminal



Photo Eduardo Miranda
M8.8 Maule, Chile - Feb 27, 2010

Who could use earthquake early warning?



Kawasaki Concert Hall



Photo Eduardo Miranda
M9.0 Tohoku, Japan - Mar 11, 2011

Who could use
earthquake early warning?

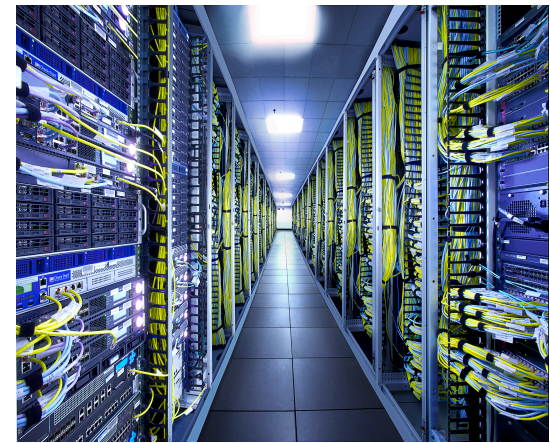
Automated control



Slowing and stopping trains



Isolating hazardous machinery and chemicals



Data security

Situation awareness

**Preventing
cascading
failures**



Elements

of an Earthquake Early Warning system

Earthquake detection

Sensor network

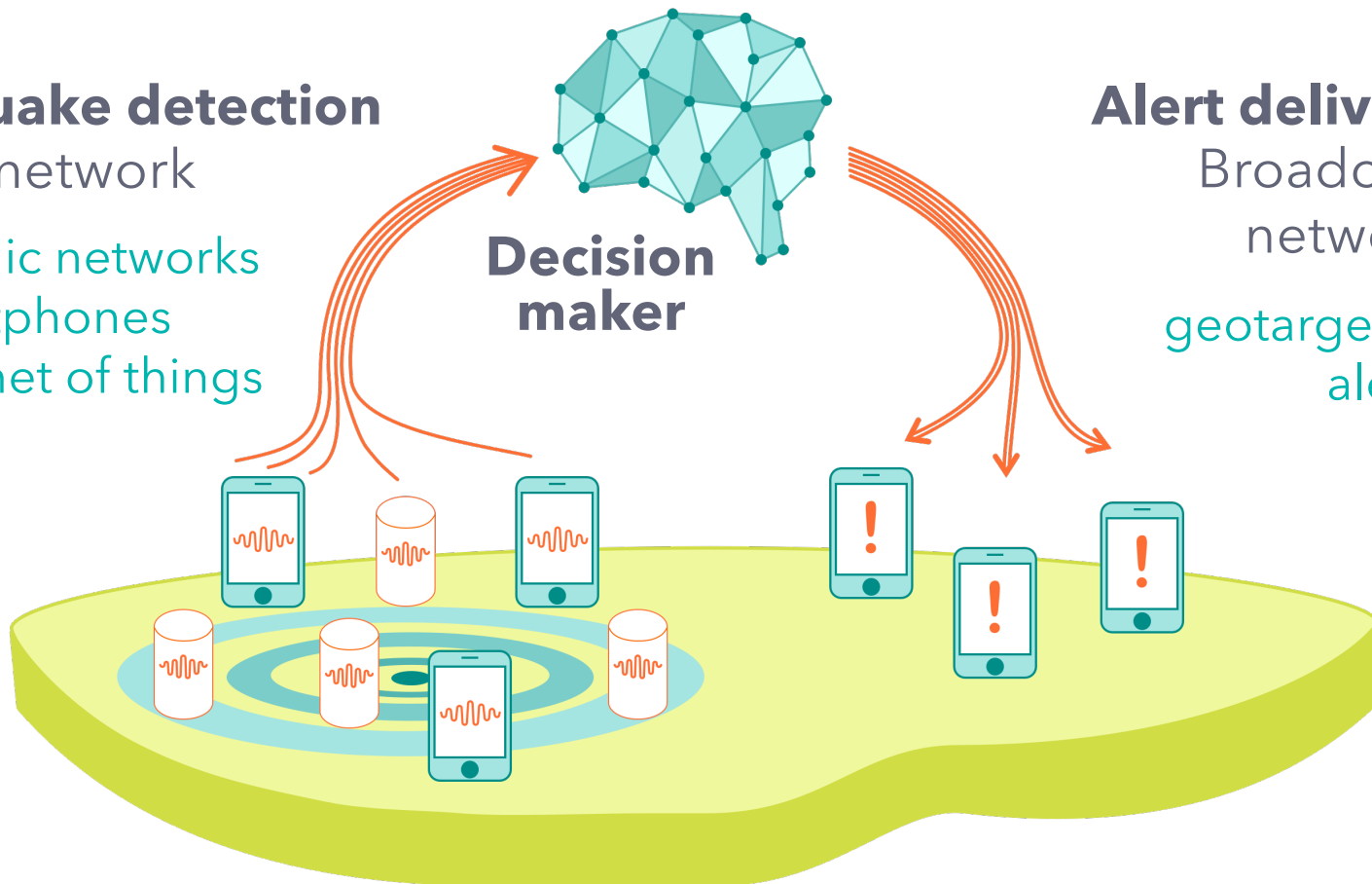
- seismic networks
- smartphones
- internet of things

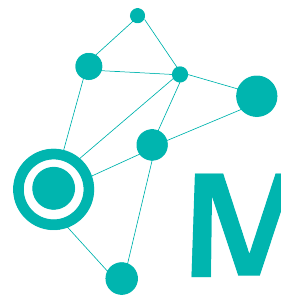
**Decision
maker**

Alert delivery

Broadcast
network

geotargeted
alerts





MyShakePlatform

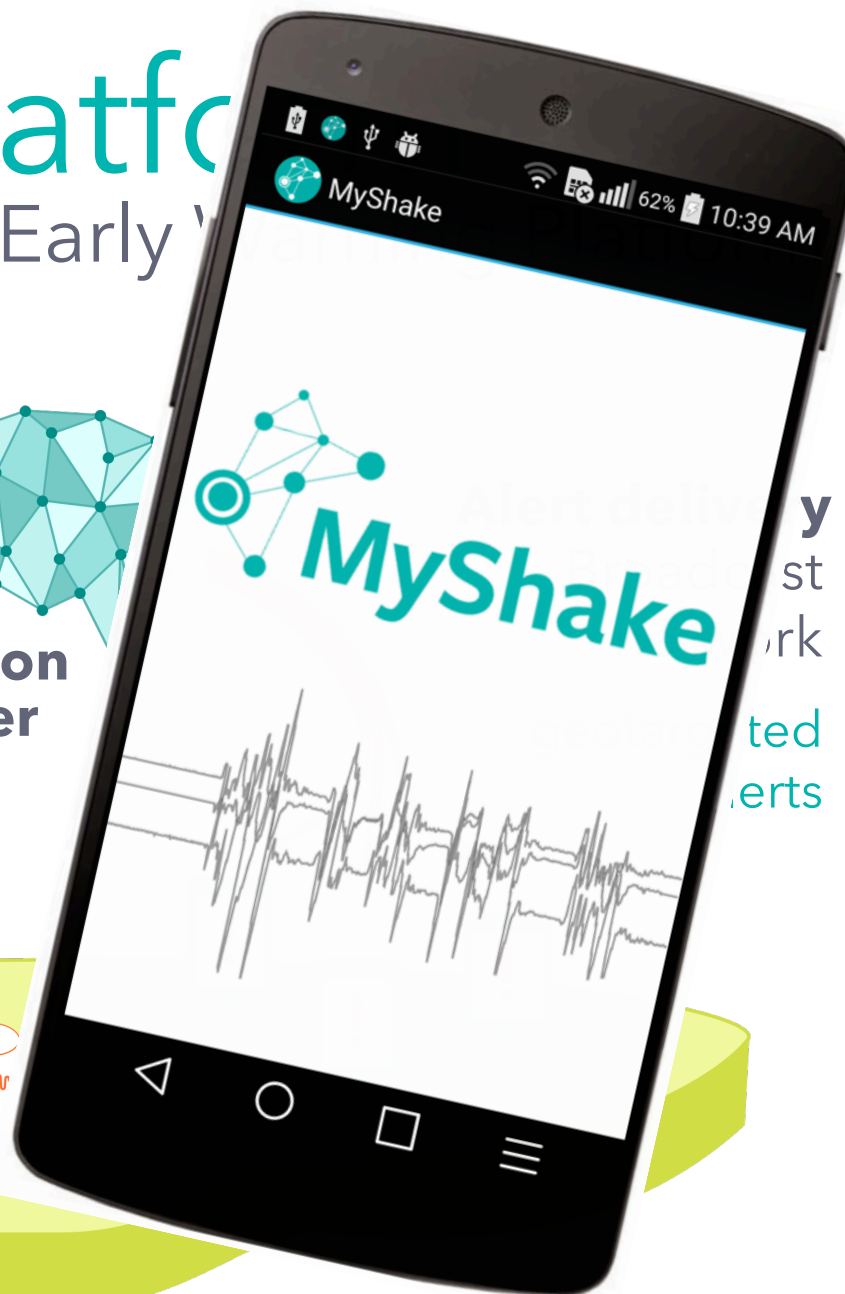
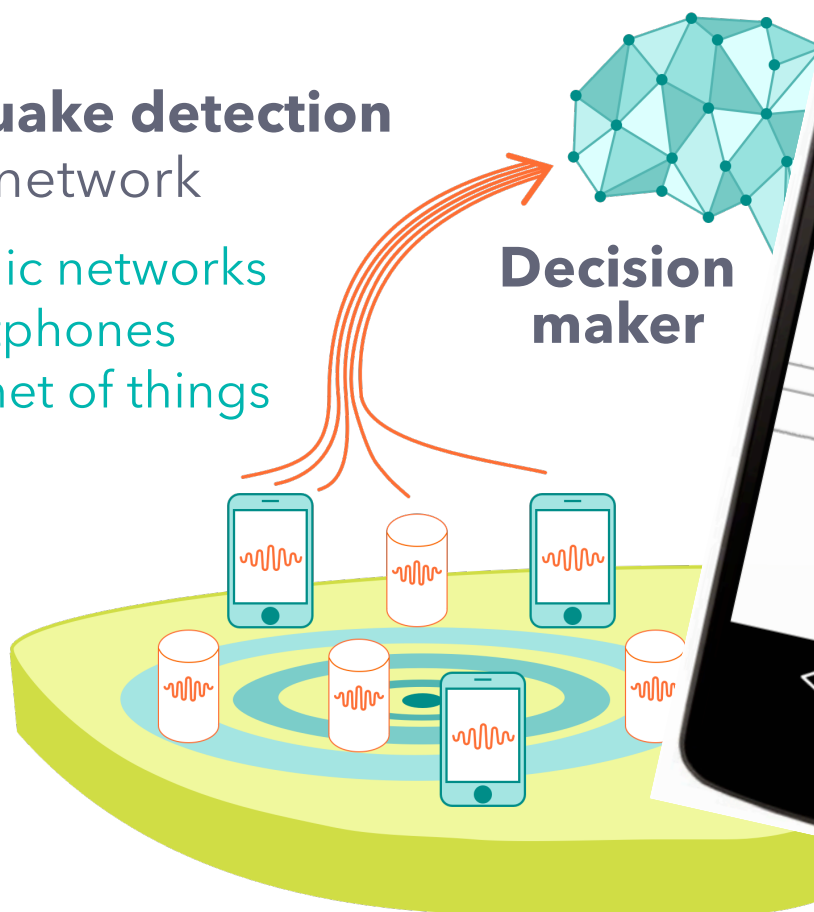
An Earthquake Early Warning

Earthquake detection

Sensor network

- seismic networks
- smartphones
- internet of things

**Decision
maker**



The MyShake team



Richard Allen
PI



Jenn Strauss
Project manager



Qingkai Kong
Researcher



Sarina Patel
PhD student



Sharon Pothan
User Experience
Designer



Stephen
Thompson



Steve
Allen



Akie Mejia

Developer team

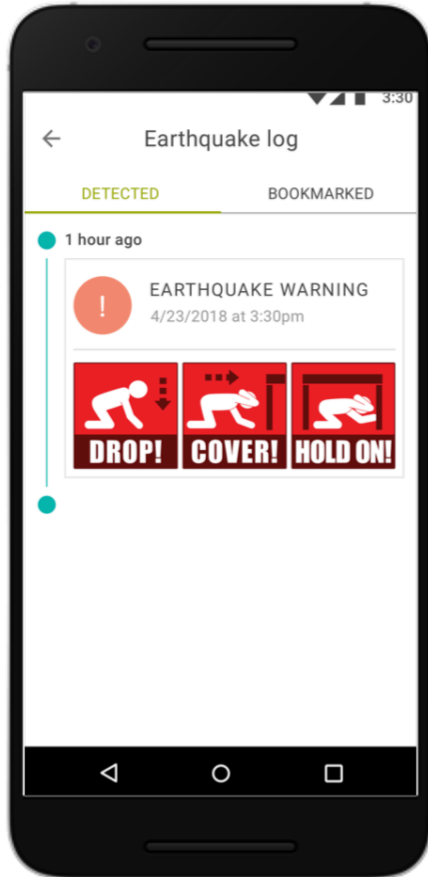


MyShake 2.0

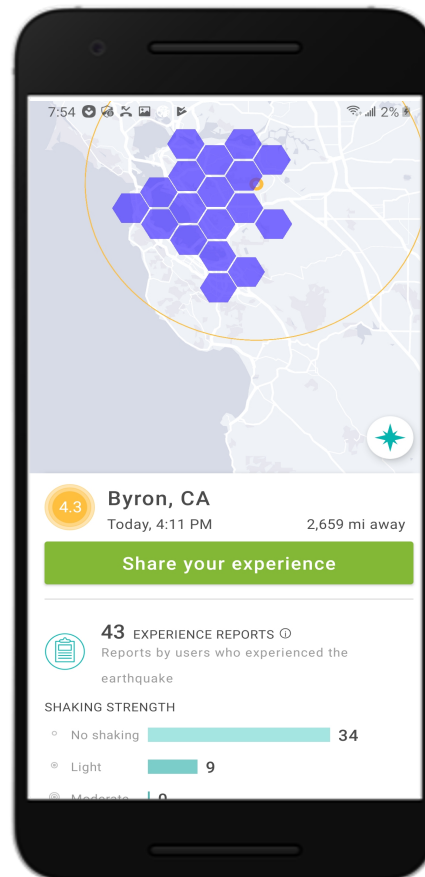
Be Quake Ready

Available on the
App Store

Available on
Google Play



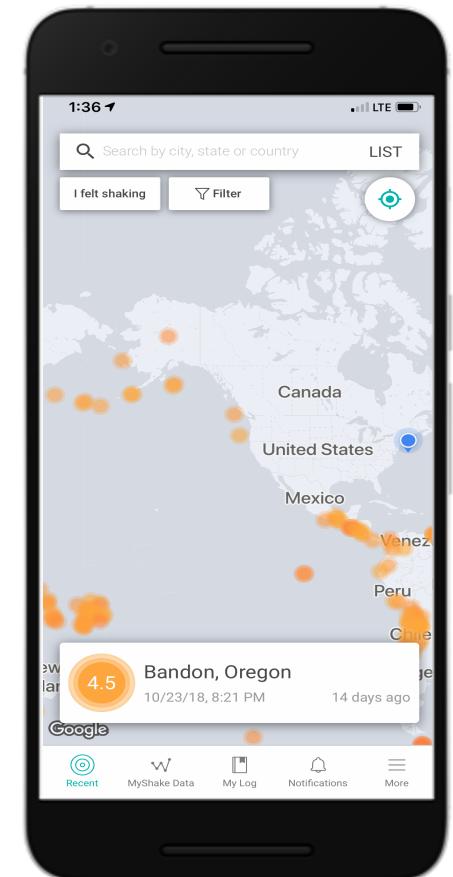
Early warning
delivery
(ShakeAlerts in CA)



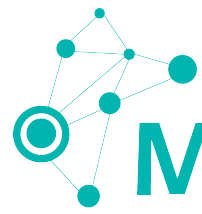
Detailed damage
information
reported by users



Preparedness
and safety tips



Realtime earthquake
information around
the globe



MyShake 2.0

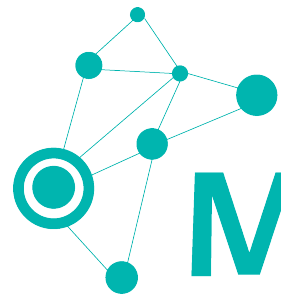
Gov. News on
release



The New York Times

***California Launches Earthquake Early
Warning System It Calls Best in World***

October 17, 2019



MyShakePlatform

An Earthquake Early Warning Platform

Earthquake detection

Sensor network

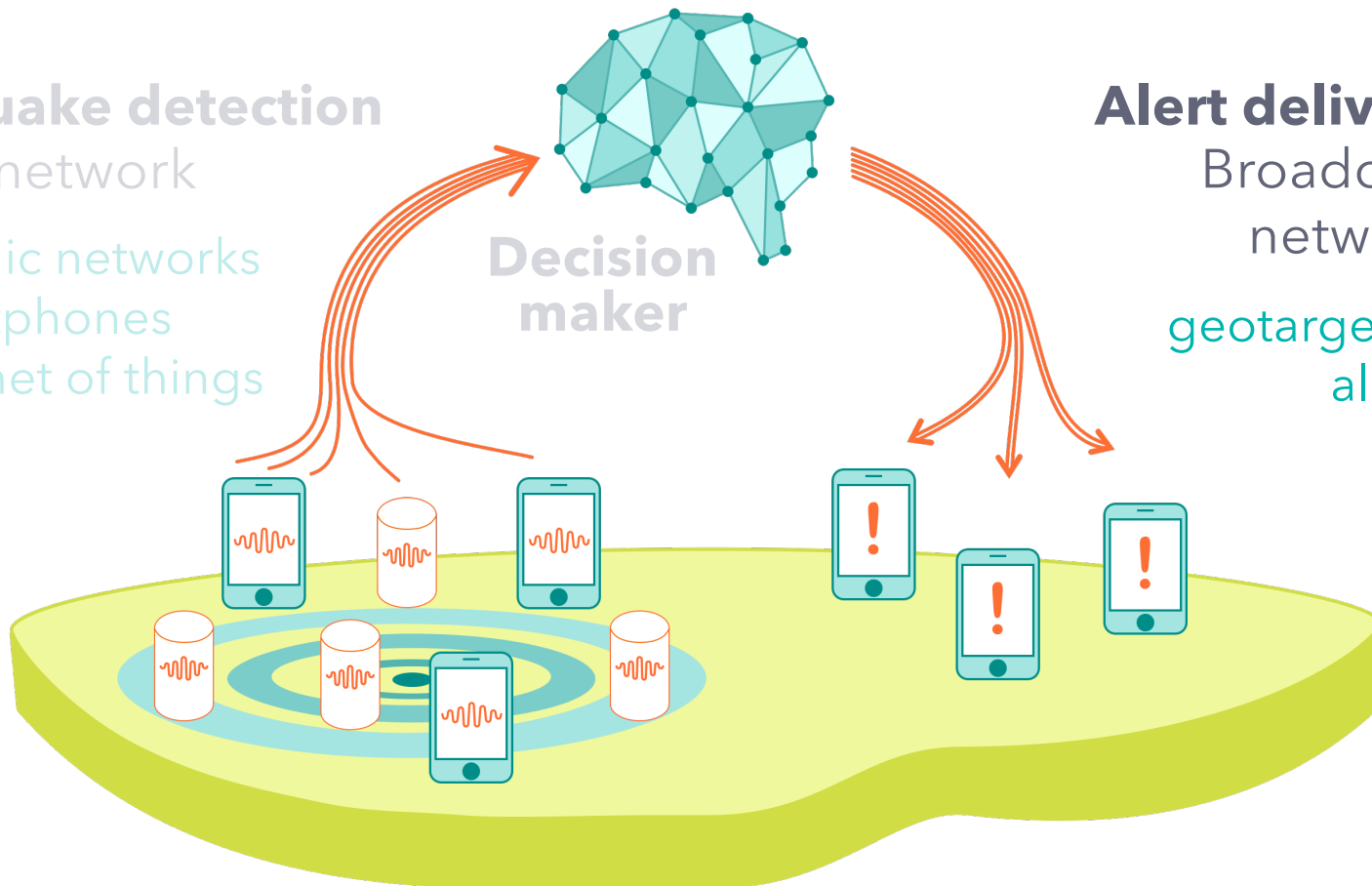
- seismic networks
- smartphones
- internet of things

**Decision
maker**

Alert delivery

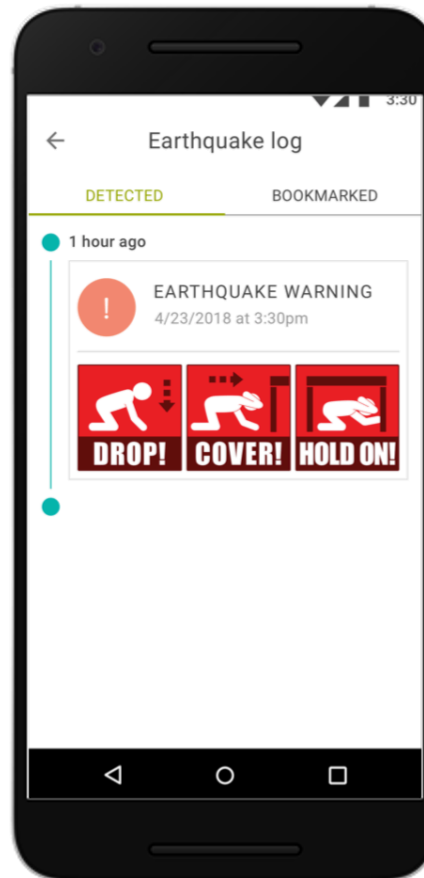
Broadcast
network

geotargeted
alerts



MyShake 2.0

Alert delivery



In specific regions as possible
depending on availability



Where do the alerts come from?

ShakeAlertTM

in California, Oregon and Washington

Alerts are available for use...

...by technical and industrial users

...the public in California - Oct 2019



Shake!lert™

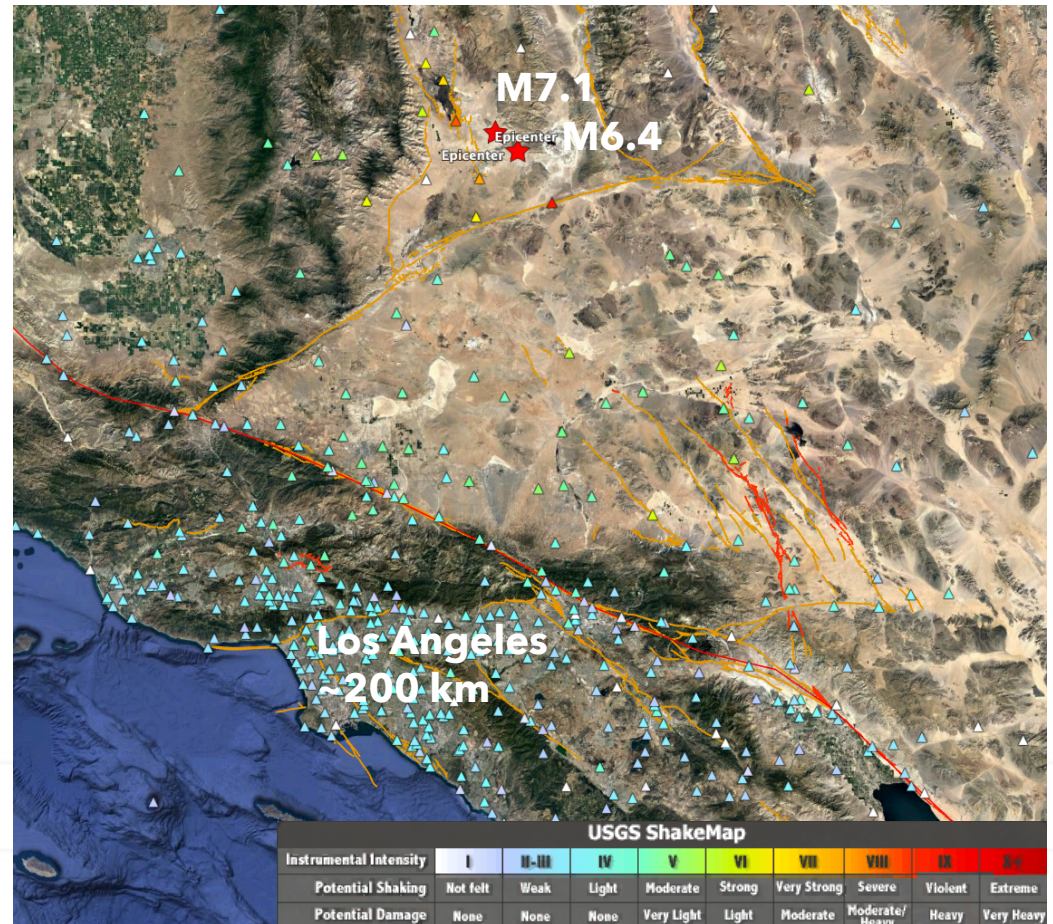
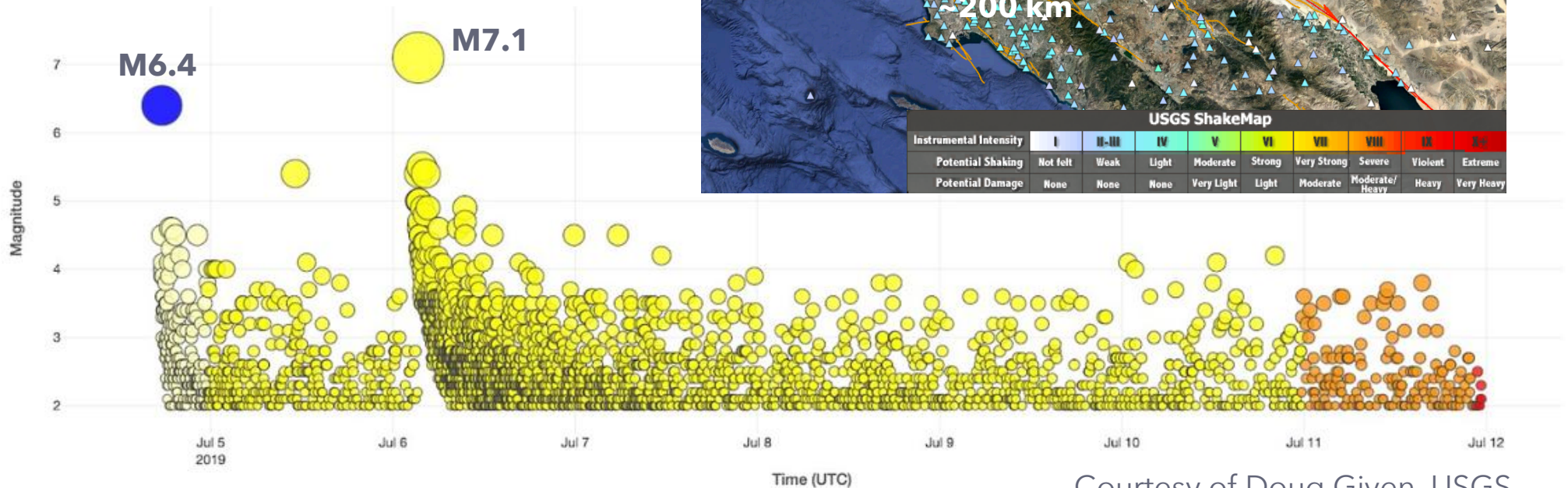
First big test

Ridgecrest sequence

M6.4 – July 4th 10:33 am local

M7.1 – July 5th, 8:19 pm local

Earthquake sequence:
Magnitude vs. time



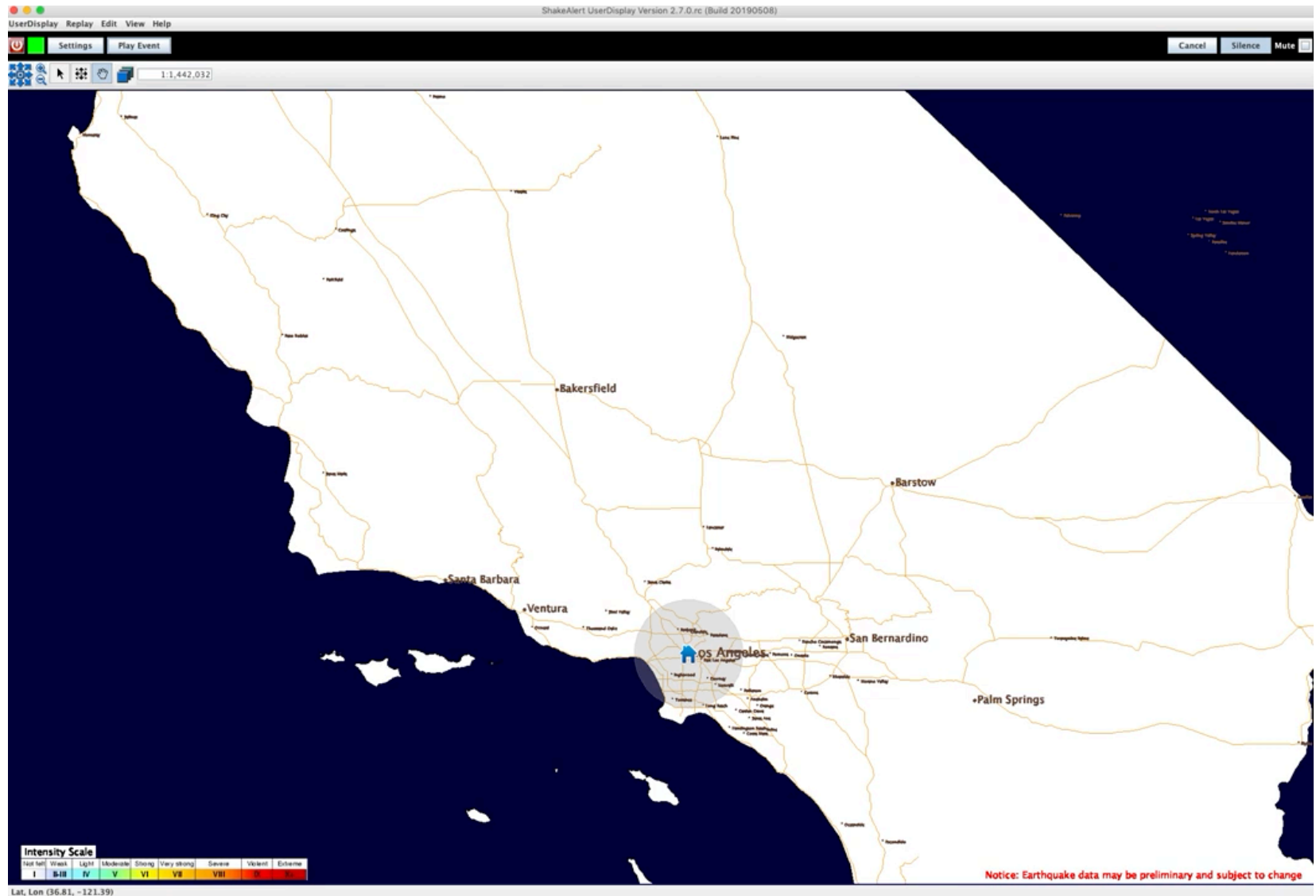
Courtesy of Doug Given, USGS

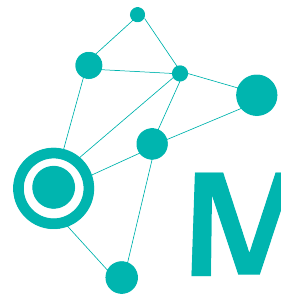
M7.1 Ridgecrest earthquake

8:19 pm – July 5th, 2019 local

ShakeAlert™

LA
City
Hall





MyShakePlatform

An Earthquake Early Warning Platform

Earthquake detection

Sensor network

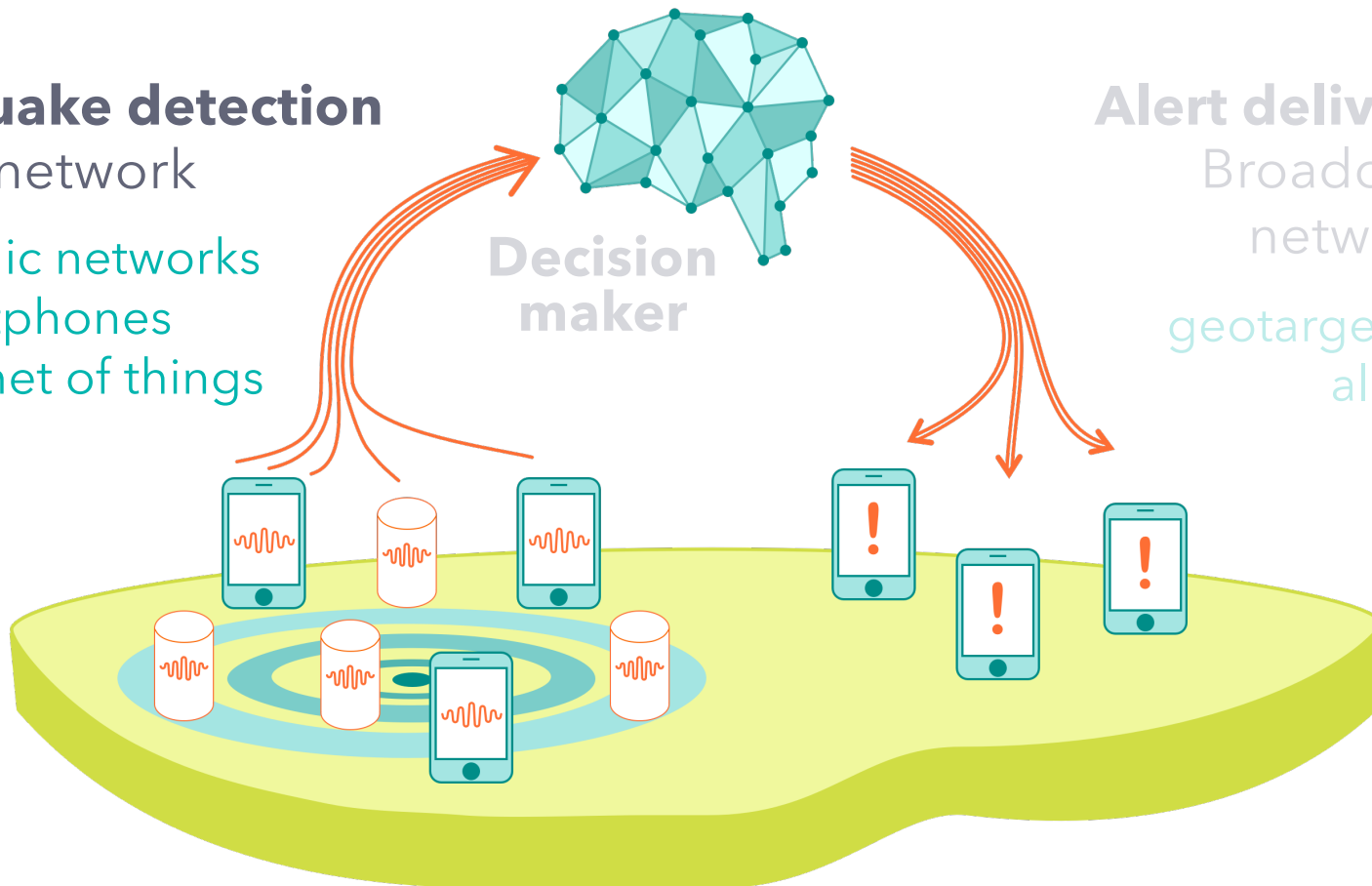
- seismic networks
- smartphones
- internet of things

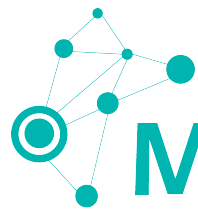
Decision
maker

Alert delivery

Broadcast
network

geotargeted
alerts

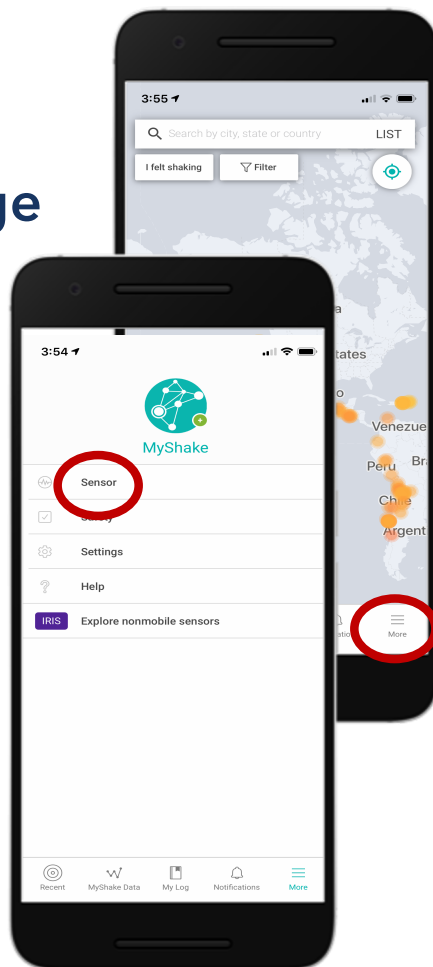




MyShake

*Also turns your phone
into a seismic sensor*

Try it out:
Open the
sensor page

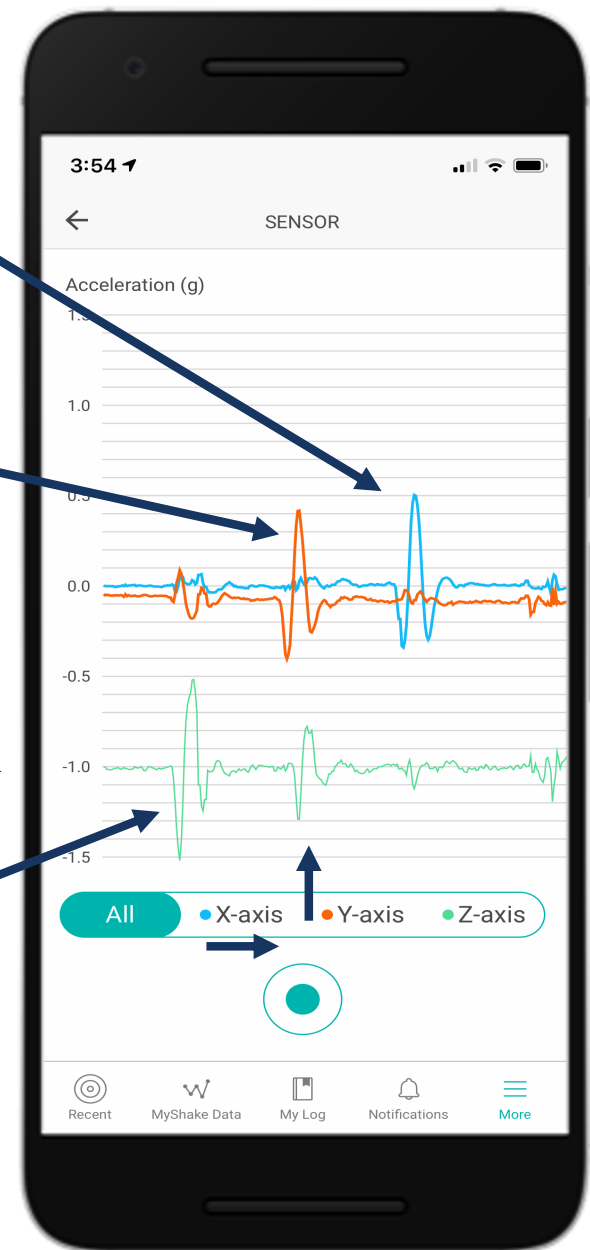


Horizontal
(x-axis: side-
to-side)

Horizontal
(y-axis: up and
down on the
desk)

-1.0g = gravity →

Vertical
vibration
(z-axis)

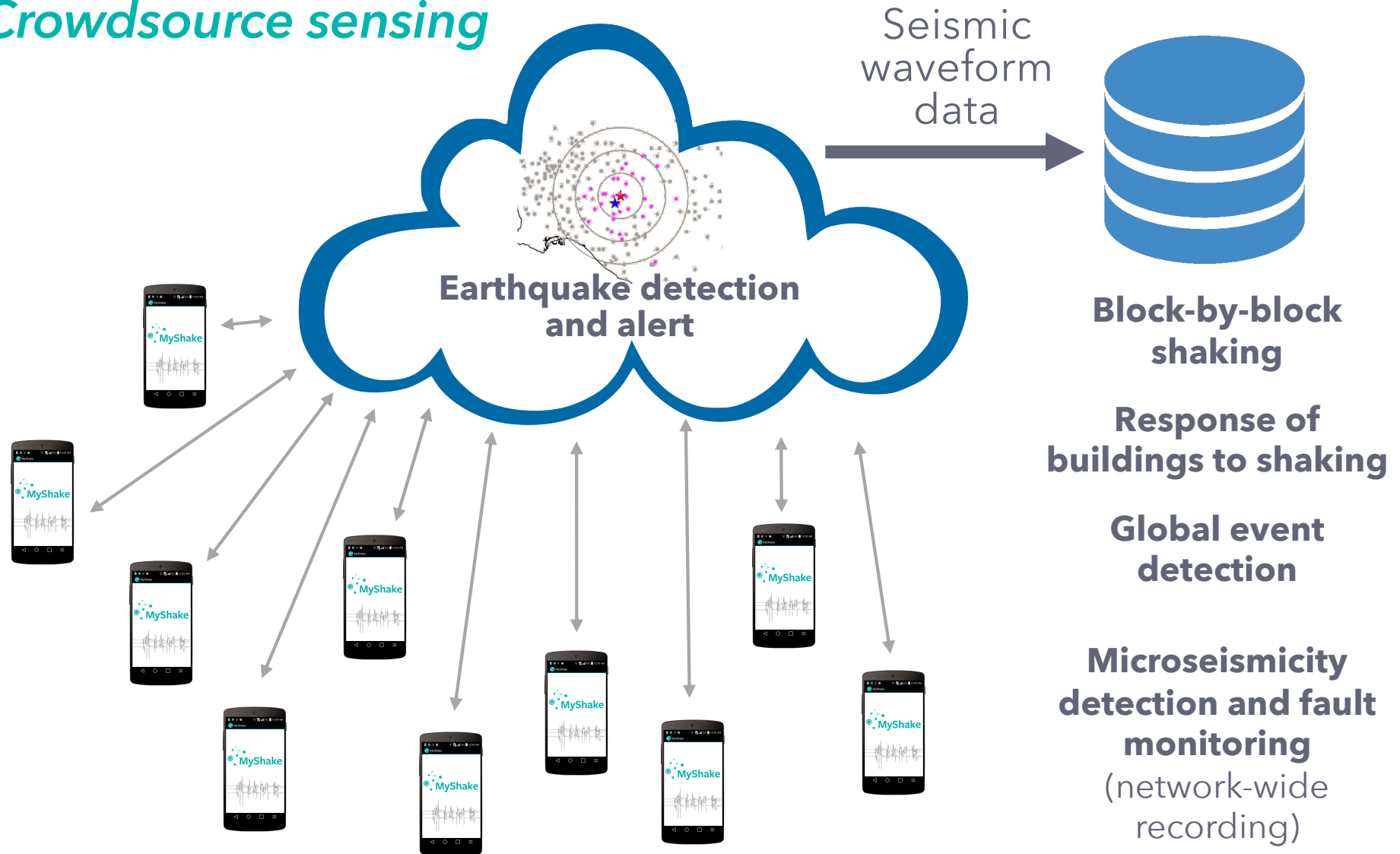


<http://myshake.Berkeley.edu>

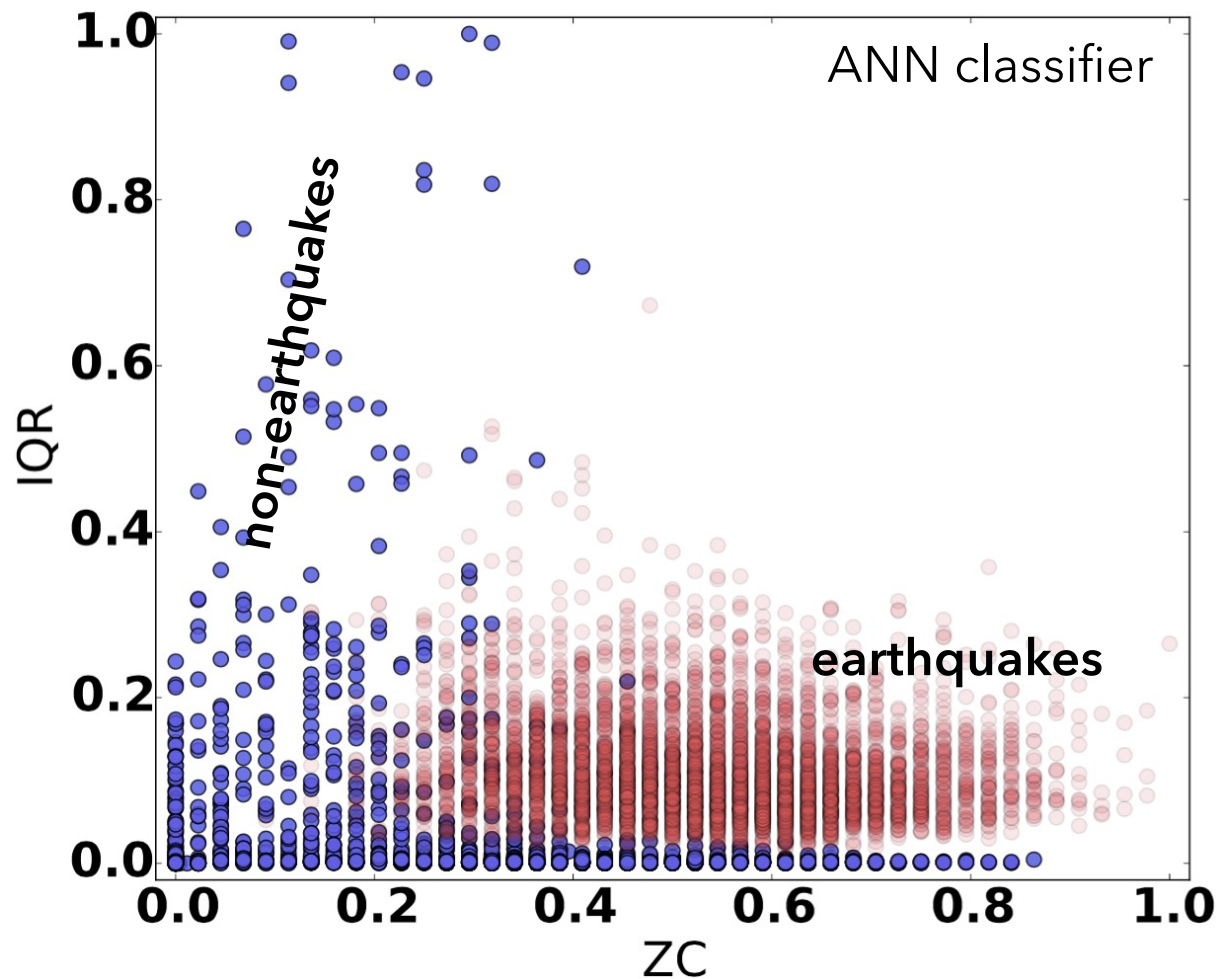


MyShake

Crowdsense sensing



Distinguishing earthquakes from other shakes *on a phone*



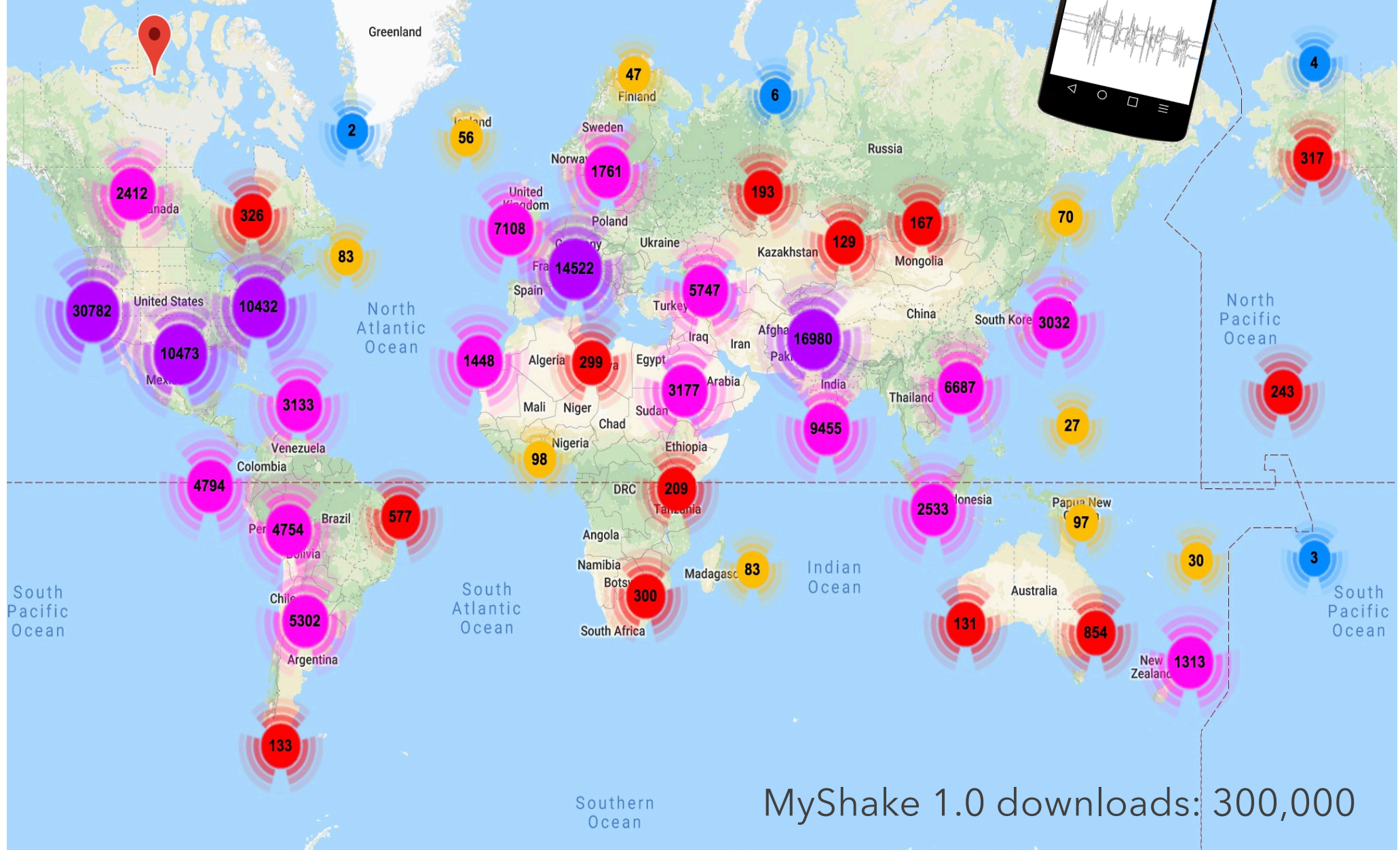
- Identify key characteristics measured from 2 second windows of data
- Neural Network trained to classify activity

**93% success rate
on the phone**

Then send earthquake
trigger into the MyShake
cloud

Before MyShake 2.0

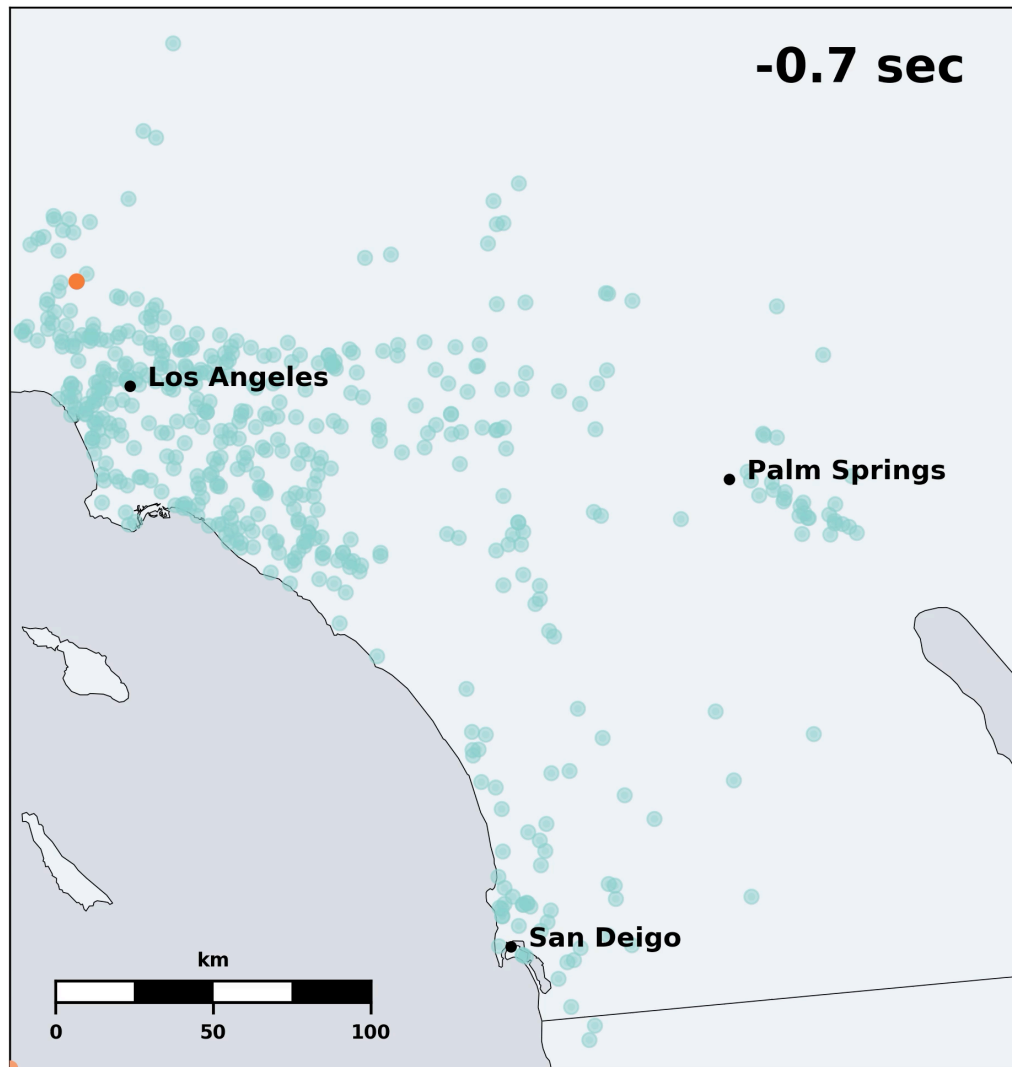
Already a global seismic network



MyShake Earthquake detection

Borrego Springs

M5.2
June 10th 2016



Time(UTC) 2016-06-10 08:04:38
Time(Local) 2016-06-10 00:04:38
Triggers 1

M5.2 Borrego_Springs
Depth 12.3 km

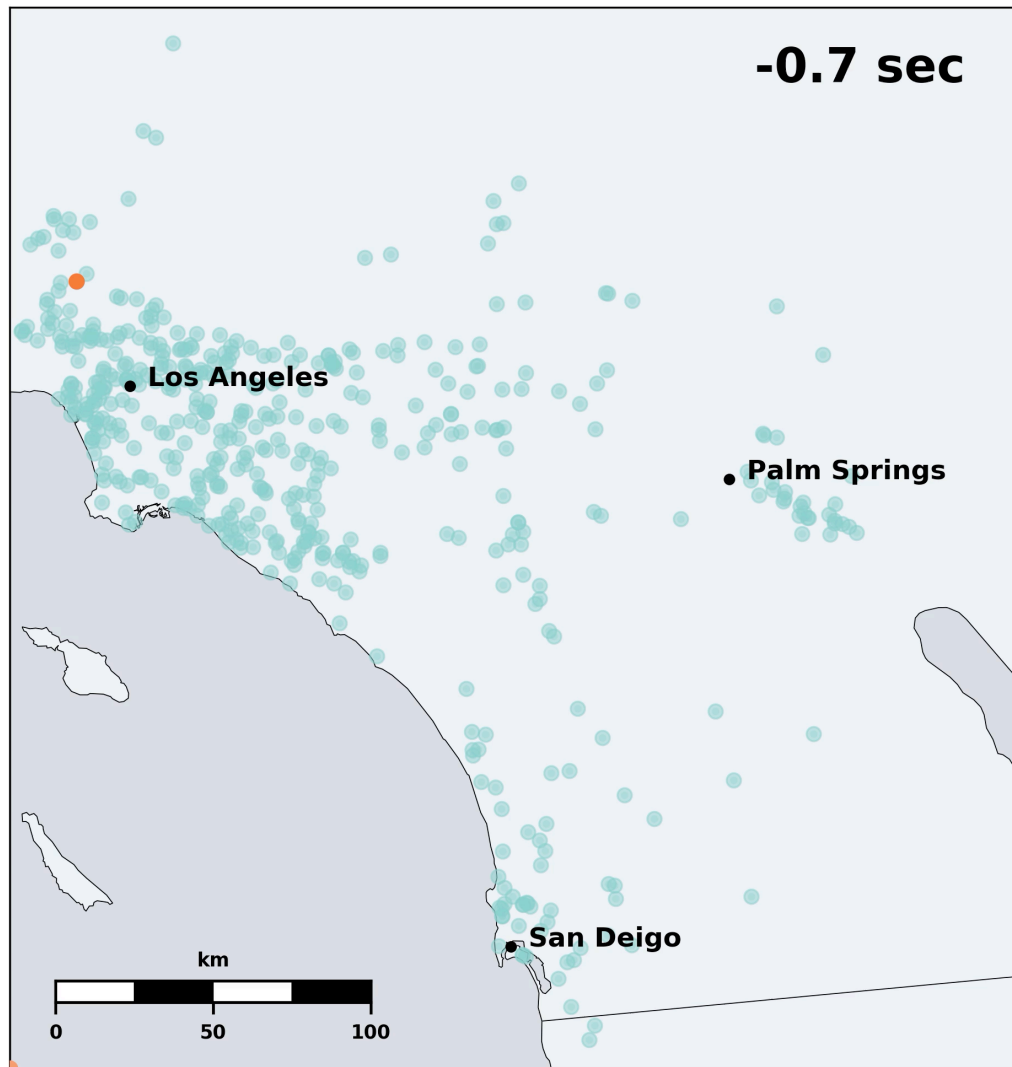
- MyShake phone
- Triggered phone
- Used for location
- True earthquake location
- Estimated earthquake location
- P-wave front
- S-wave front
- Limit of shaking intensity 4

triggers with P and S

Alert delivery: Borrego Springs

re-run using MyShake detections

M5.2
June 10th 2016



Time(UTC) 2016-06-10 08:04:38
Time(Local) 2016-06-10 00:04:38
Triggers 1

M5.2 Borrego_Springs
Depth 12.3 km

- MyShake phone
- Triggered phone
- Used for location
- True earthquake location
- Estimated earthquake location
- P-wave front
- S-wave front
- Limit of shaking intensity 4

Re-run: Warning

Some successes...



Detecting earthquakes and generating alerts in
California, Oregon and Washington

Our earthquake models (for rapid detection) are
performing well for M4 through M~7.0 earthquakes
i.e. for most quakes ...but not the biggest

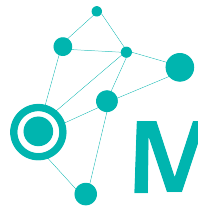


Delivering ShakeAlerts to the public in California
Oregon & Washington expected 2021

Massive new source of seismic data from around the globe

Testing MyShake-generated alerts

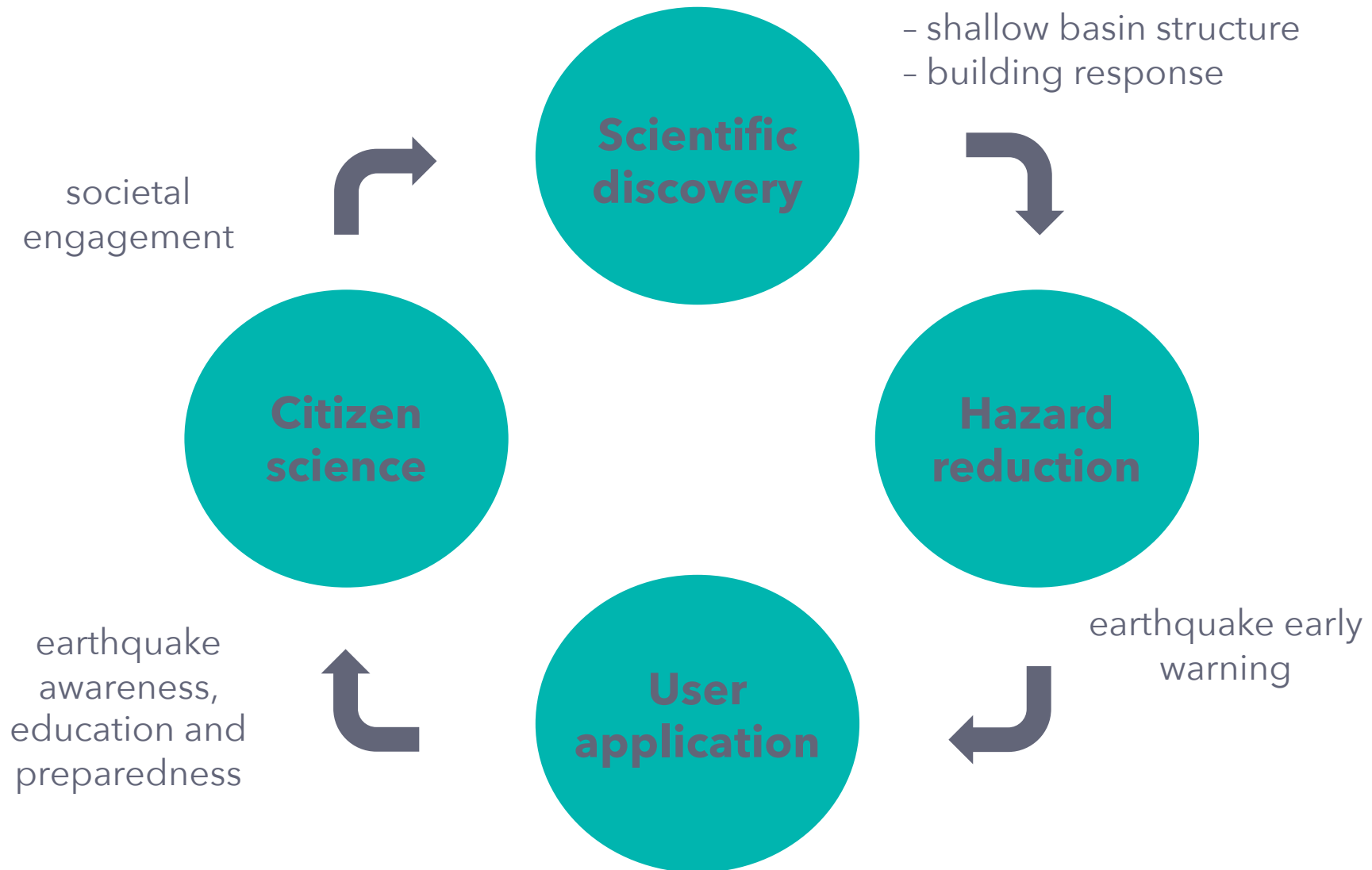
Goal: provide earthquake early warning around the globe



MyShake

A virtuous circle?

- block-by-block shaking
- earthquake rupture physics
- microseismicity
- fault detection
- shallow basin structure
- building response



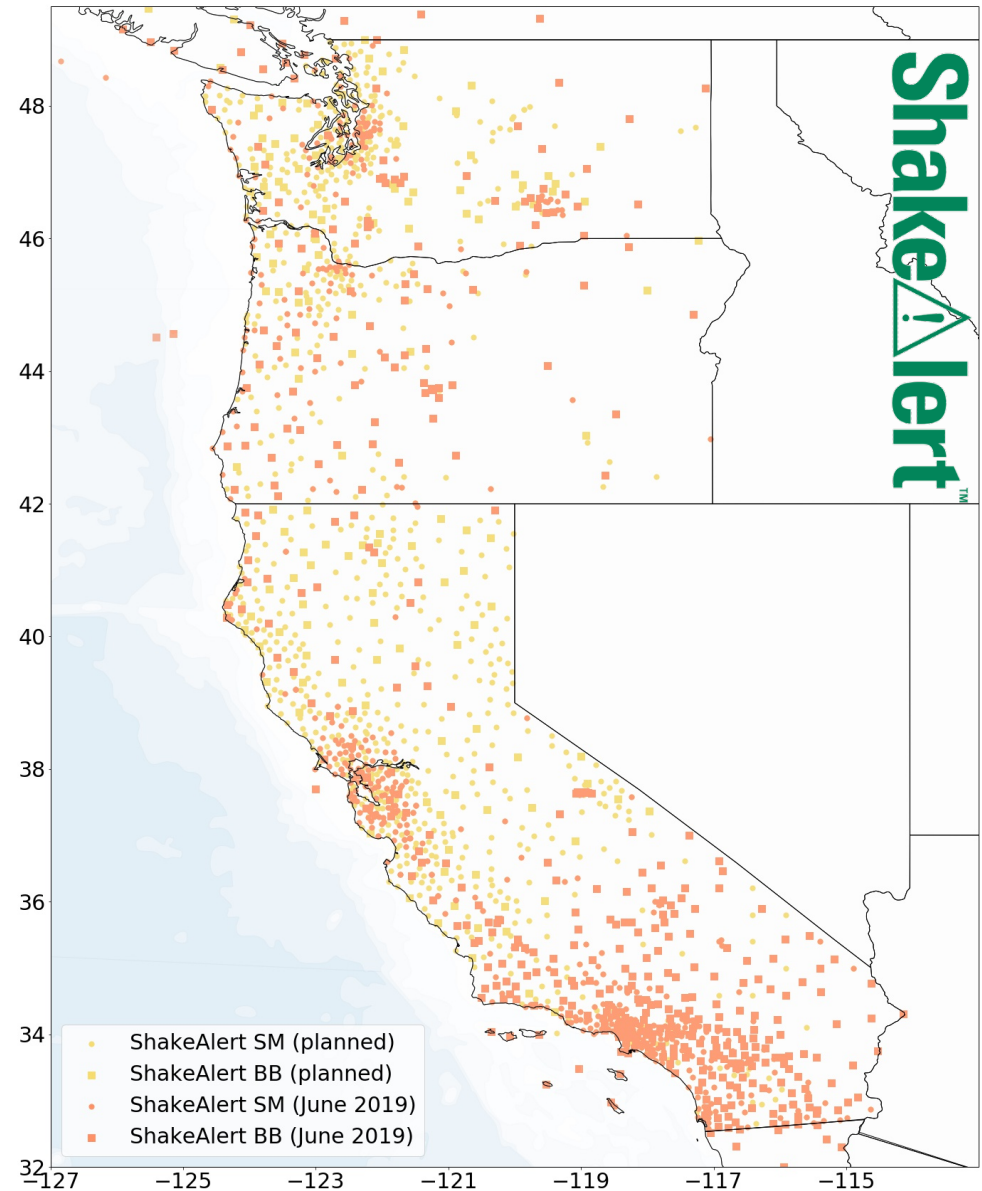
...that we hope will grow

Where might DAS/cabled observatories fit in?

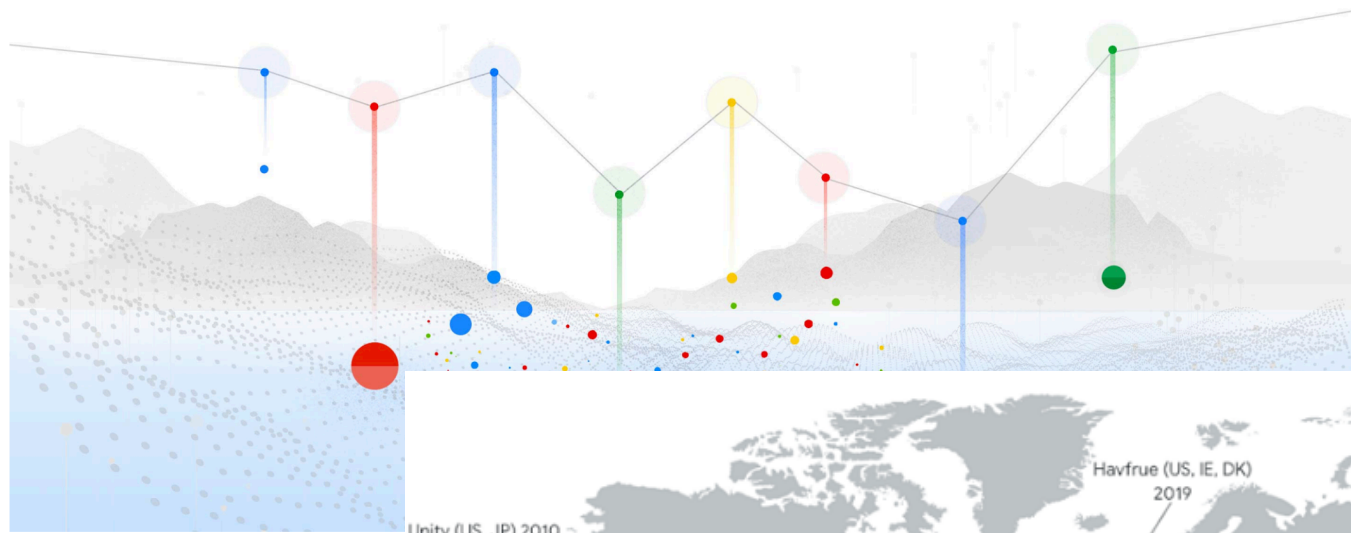
1. Earthquake detection

Lots of stations
onshore

The biggest
earthquakes are
offshore



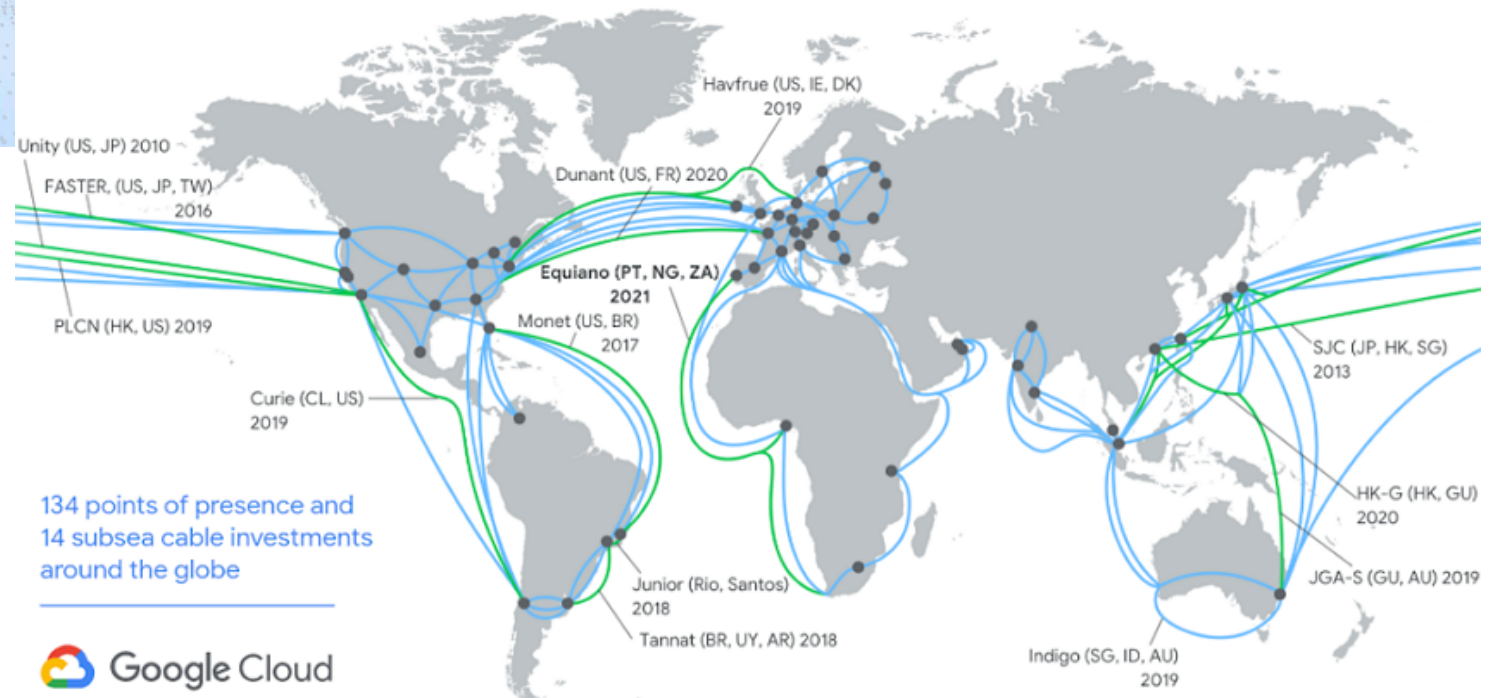
What's shaking? Earthquake detection with submarine cables



Valey Kamalov
Google Global Networking

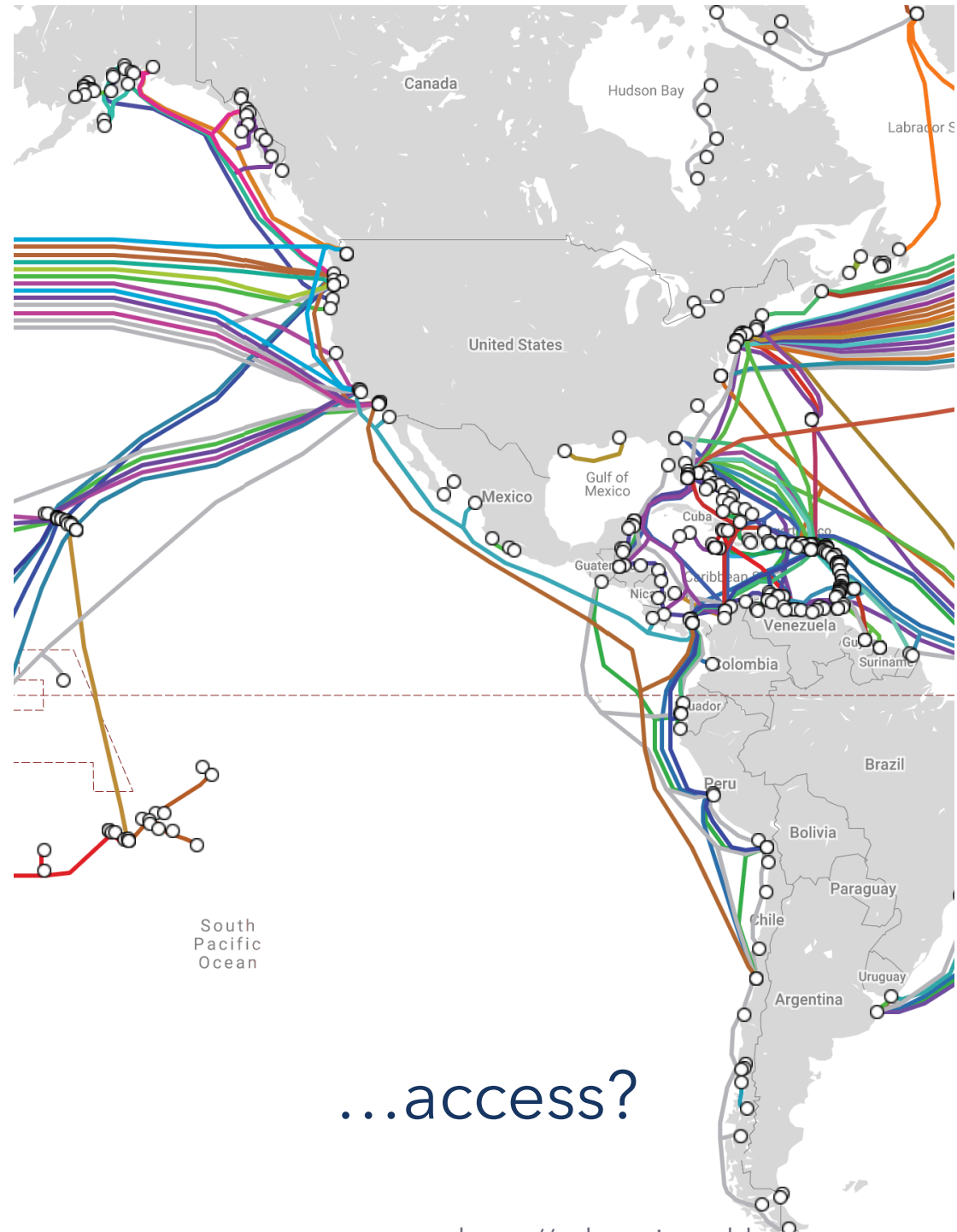
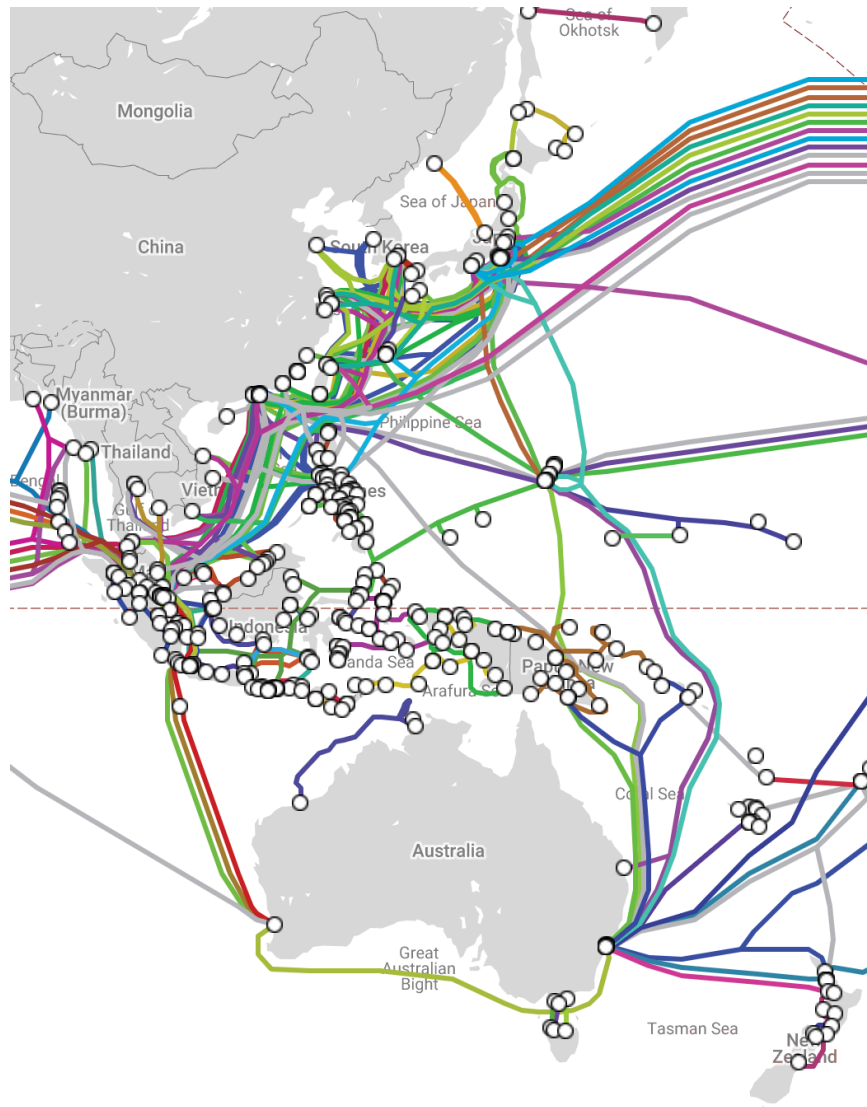
Mattia Cantono
Google Global Networking

July 16, 2020



<https://cloud.google.com/blog/products/infrastructure/using-subsea-cables-to-detect-earthquakes>

Lots of cables...



...access?

<https://submarinecablemap.com>

Where might DAS/cabled observatories fit in?

1. Earthquake detection

Few seismic sensors **offshore**
The biggest earthquakes are **offshore**

2. Ground motion prediction

Current alert region based on

- Generic ground motion prediction equations
- Estimated magnitude
- Distance to epicenter or fault

Can DAS observations in urban areas provide **better ground shaking predictions?**

Either better models ahead of time, or in real-time

