Building earthquake early warning for the west coast

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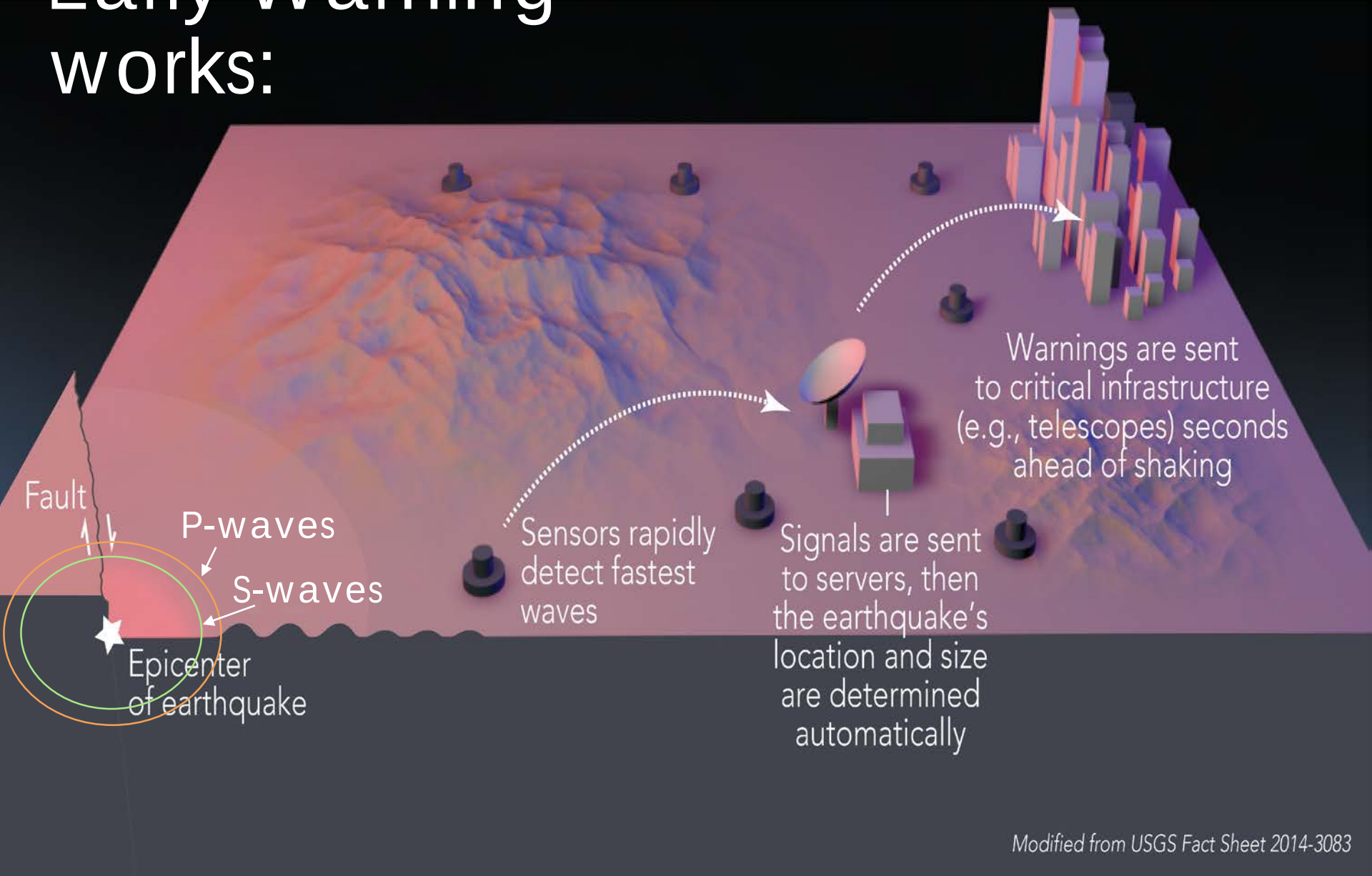
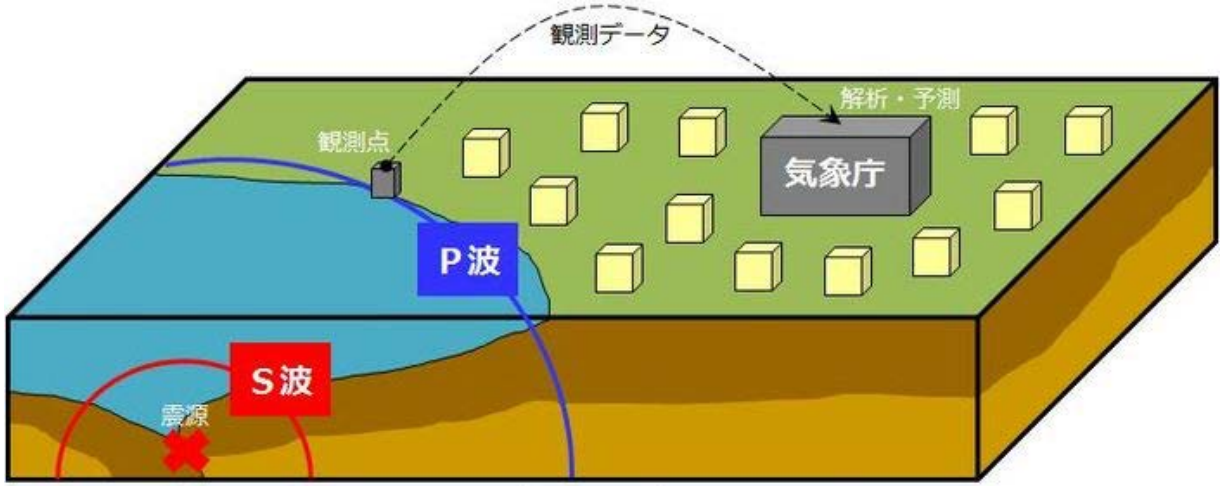
How Earthquake Early Warning works:



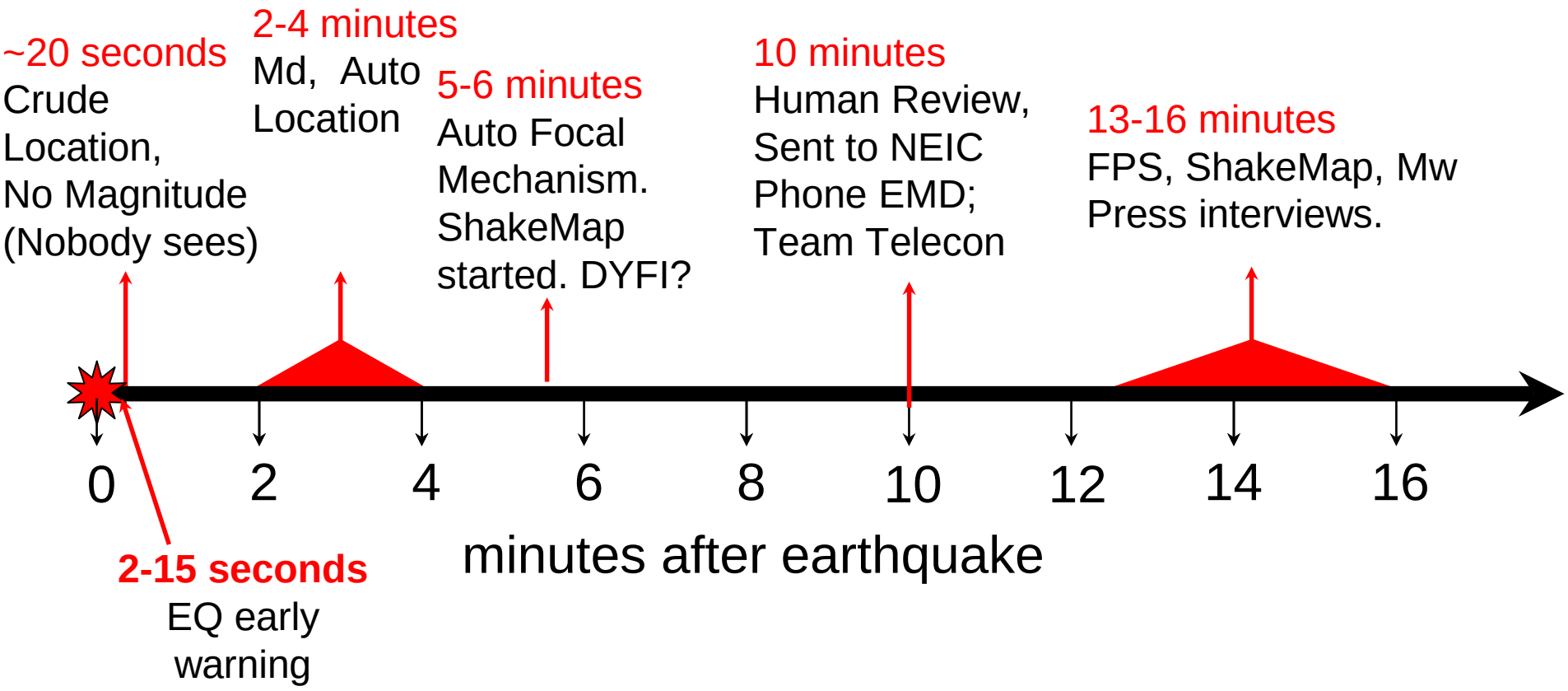
Modified from USGS Fact Sheet 2014-3083

3-fold way of Earthquake Early Warning

- 1. P waves arrive faster and are used to detect, locate and determine size of earthquake
- 2. Stations can be closer to rupture initiation than people and property to be warned
- 3. Strong shaking is from slower traveling S waves and surface waves

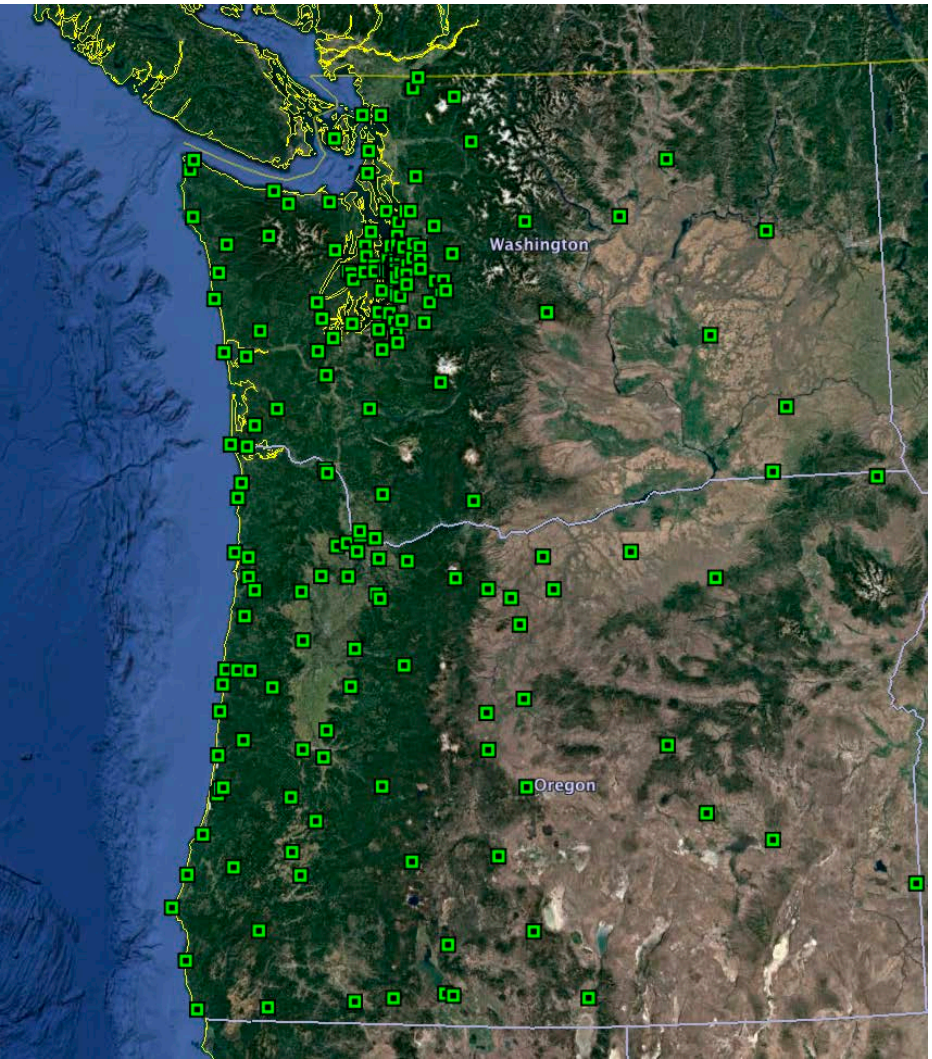


Event timeline

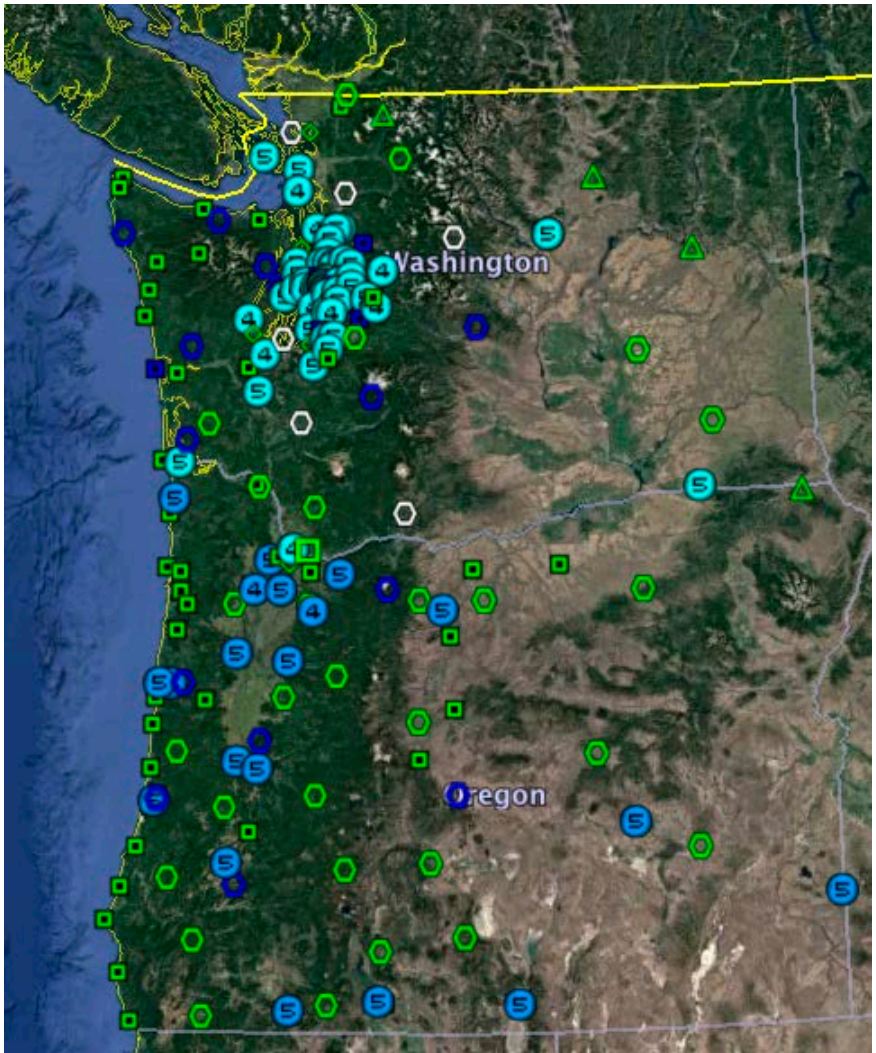


Upgrade current network – 2016 -2017

Current EEW Stations



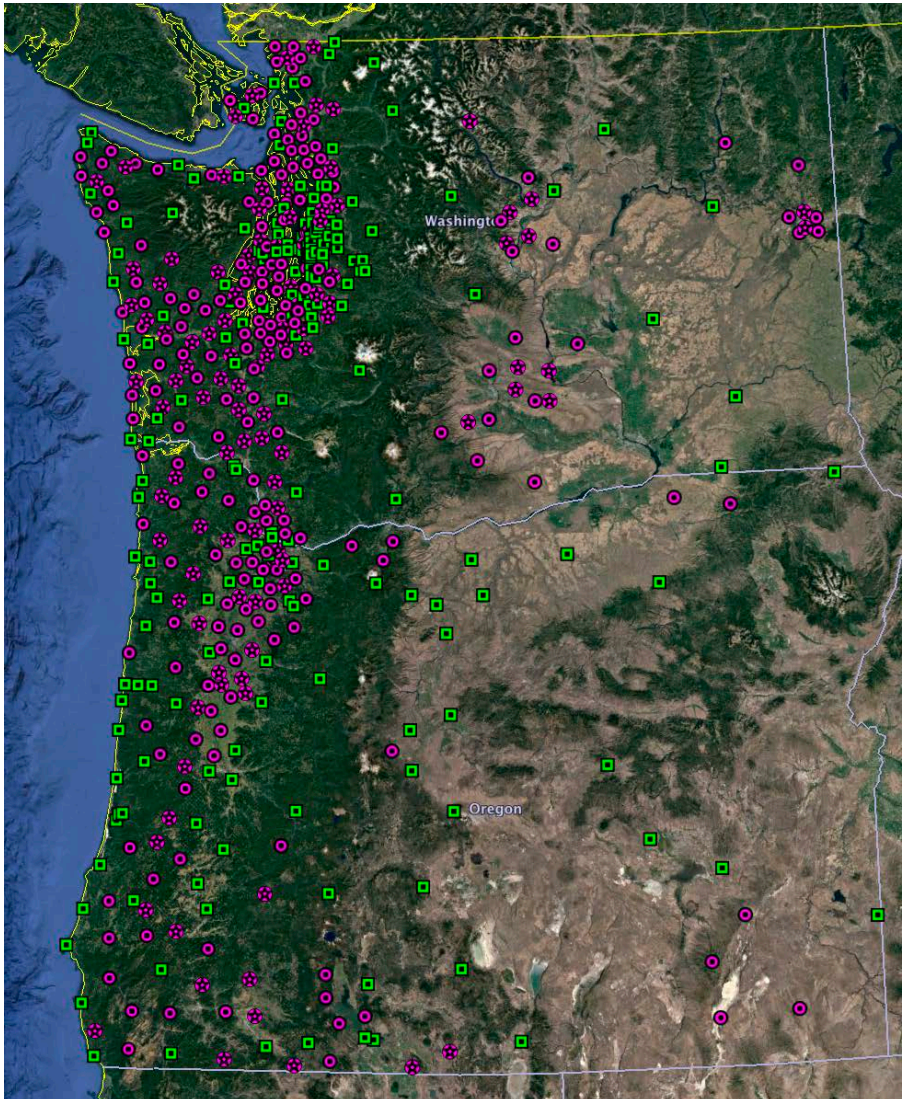
Upgraded EEW Stations



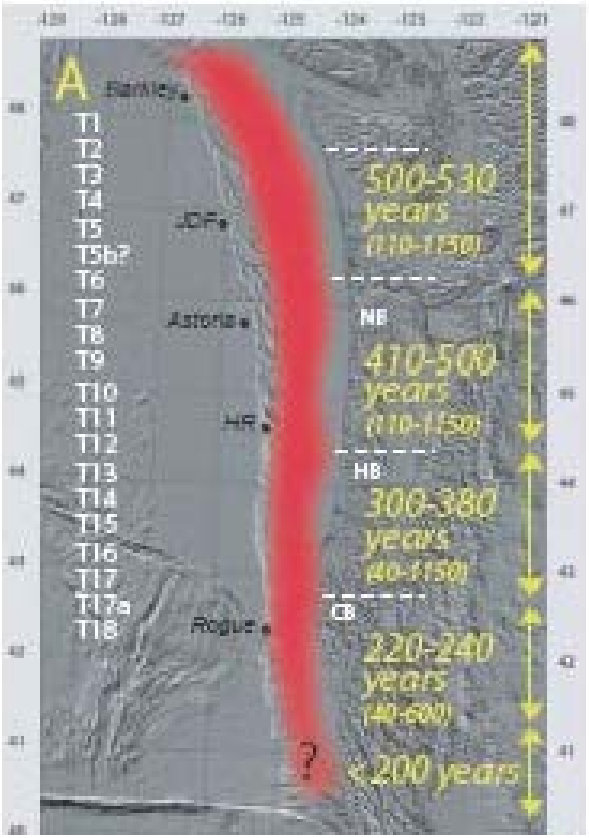
Network expansion – 2018 -->

Implementation Plan

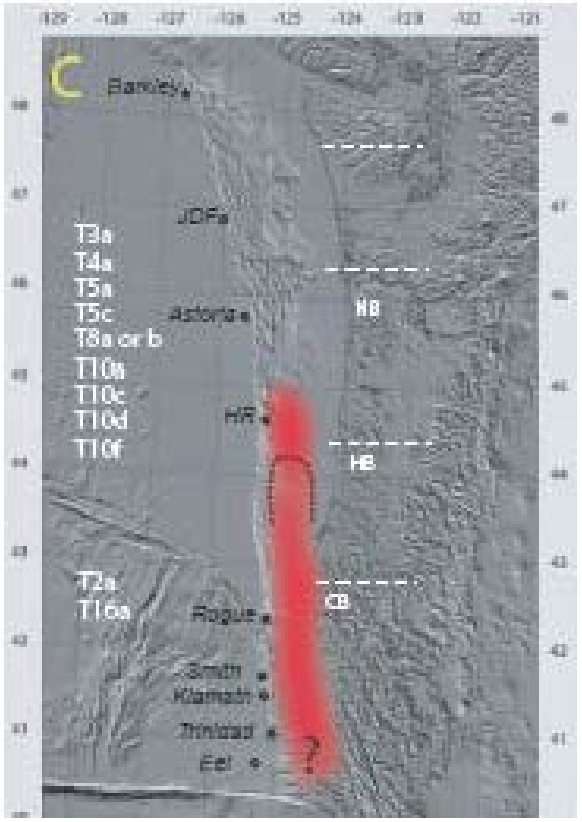
- Station upgrades (~125)
- New Stations (~309)
  - Siting
  - Permitting
  - Construction
- Data flow & operation
- Ensuring EEW data quality



Last 10,000 years of M8+ earthquakes from offshore geology – **Type 1**

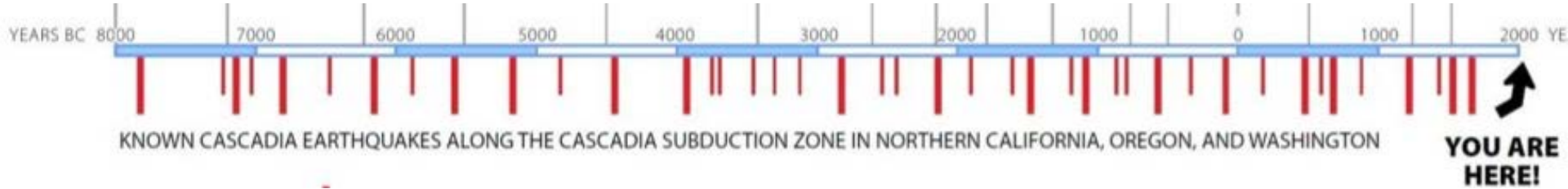


20 ~M9 events



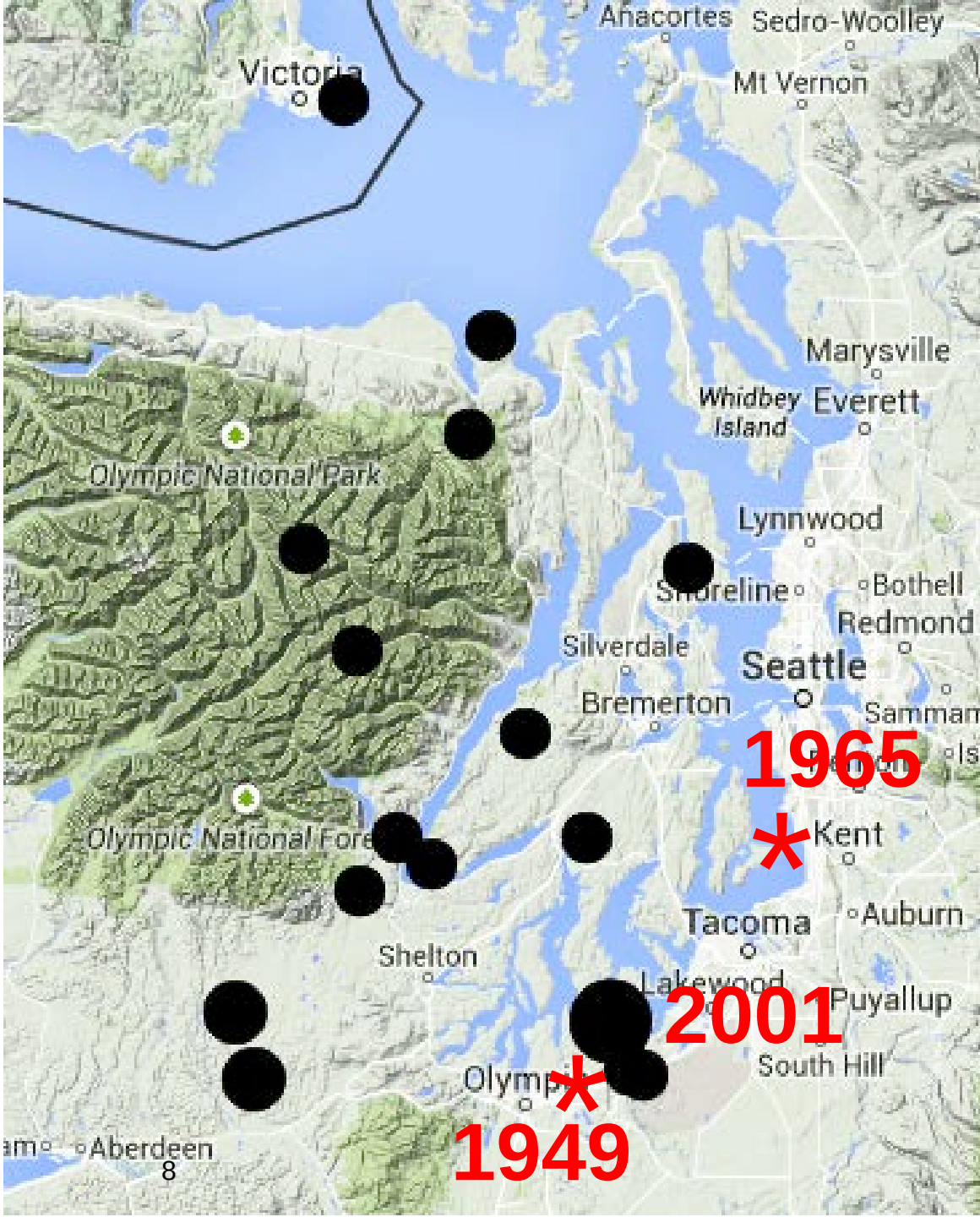
20 ~M8 to M8.5 events

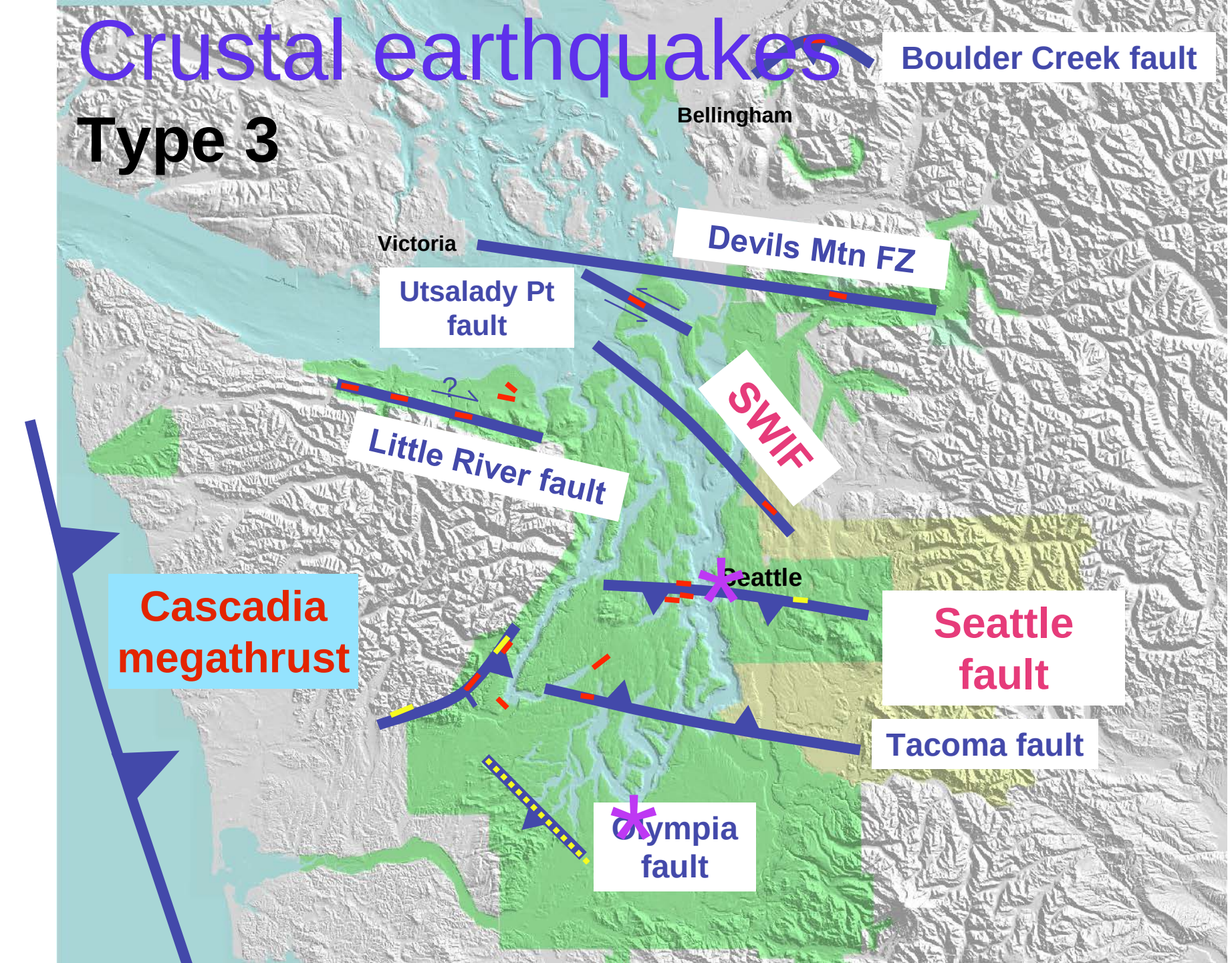
(Goldfinger et al., 2008, Bull, Seis. Soc. Amer)



Type 2
Deep Puget Sound earthquakes

Since 1969, plus
1949 & 1965,
M > 4
Depth 40-53 km




Crustal earthquakes
Type 3
Boulder Creek fault
Bellingham
Victoria
Devils Mtn FZ
Utsalady Pt fault
SWIF
?
Little River fault
Cascadia megathrust
Seattle
Seattle fault
Tacoma fault
Olympia fault

Cascadian EEW Capabilities

- Megathrust Earthquakes
  - 1/2 minute to 5 minutes warning to urban centers (depending on quake starting point and location).
  - Enhanced tsunami forecasts possible (w/ NOAA).
- Deep events
  - 10-20s easy.
- Crustal faults
  - “Blind Zones” can limit usefulness of warnings.
  - Would benefit from denser/better instrumentation.

EEW considerations

- Earthquake early warning and fast response
  - Slowing traffic, trains, airports,
  - Hospitals, jump-starting emergency operations,
  - Warning delicate industrial operations.
  - Open garage doors in fire stations
- Modest expense – our plan $16M/yr.
- Everybody that's anybody is doing it:
  - Japan (~$1B), China (~$300M+), Mexico, Korea, Romania, Taiwan, Mongolia, … are doing it now.
- It's not hard:
  - Basic physics known for more than a century.
  - Better situational awareness during chaos.

Trains

Automatically slow and stop trains – takes 24 sec

why?

Rush-hour:

- 10 car train: 1000 passengers
- 64 trains operating
- 40-45 traveling at 70 mph
- How many might derail?
- Automatic deceleration reduces risk

One 10-car train
= $33 million

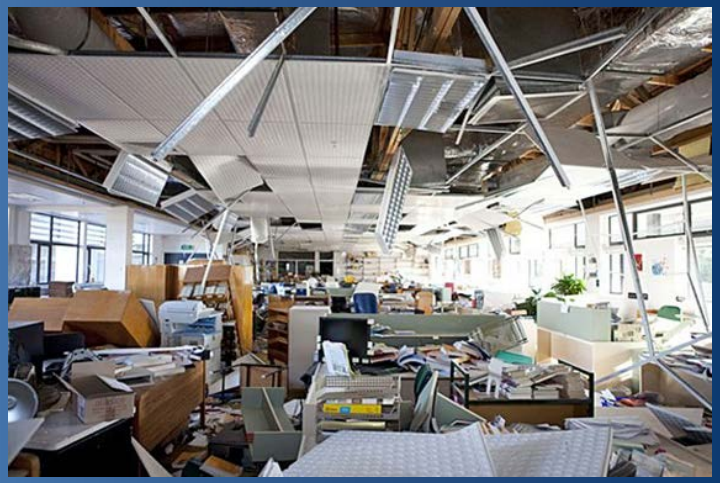
Post-earthquake recovery:

- $2.1B retrofit so BART remains operational
- Evacuate people + Bring in supplies
- Only if derailed trains are not blocking the tracks

Reducing costs

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 EEW could reduce injuries by 50%

Cost of injuries in Northridge: $2-3 billion

Shoaf et al, 1998; Porter et al, 2006

PNW ShakeAlert Beta Users

Private Sector:
- Alaska Airlines
- The Boeing Company
- Intel Corporation
- Microsoft
- PACCAR Inc
- British Petroleum
- Puget Sound Energy
- Beta Tester for OSH
- Providence Health & Services

Local Government:
- Portland Bureau of Emergency Management
- City of Seattle Office of Emergency Management
- Seattle Public Utilities (Water, Sewer, Garbage, Networks)
- Seattle City Light
- Port of Seattle
- Sound Transit

State and Provincial Government
- Emergency Management of British Columbia
- Oregon DOGAMI
- Oregon DOT
- Univ. of Washington Emergency Management
- Washington DNR, EMD
- Washington DOT

Federal Government:
- Bonneville Power Administration
- FEMA Region X
- Ocean Networks Canada
- Natural Resources Canada
- NOAA/PMEL
- Naval Air Station Whidbey Island
- USGS

NGOs:
- North West Healthcare Response Network

Our research partners:
- Hawaiian Volcano Observatory
- Central Washington University
- Caltech
- University of Oregon
- Berkeley Seismology Laboratory
- USGS
- Early Warning Labs

Washington Pilot Users

- WashDOT: Alert operators of bridges, ferries, etc.
- RH2 / Northeast Sammamish Sewer and Water District: Automatically control valves, gates and power generators

ShakeAlert Earthquake Early Warning

- California, Oregon, Washington
- Limited Public Rollout in late 2018
- Will continue to improve system:
- Software algorithms: faster alerts, reduce false alerts
- Improve speed of telemetry
- Add seismometers
- Develop beta users and pilot users
- Improve education and outreach

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