CISN Caltech UC Berkeley ETH Zurich SCEC USGS

CISN ShakeAlert

An Earthquake Early Warning Demonstration System for California

Earthquake Early Warning Project

Frequently Asked Questions

What is Earthquake Early Warning?

When an earthquake occurs seismic waves radiate from the epicenter like waves on a pond. It is these waves we feel as earthquake shaking and cause damage to structures. The technology exists to detect moderate to large earthquakes so quickly that a warning can be sent to locations outside the area where the earthquake begins before these destructive waves arrive.

How do Earthquake Early Warning systems work?

Currently, there are two approaches to earthquake early warning (EEW): the "single station" ("on-site") approach and the "network" approach.

Single-station approach: In this approach a single sensor detects the arrival of the faster but weaker P-wave and warns before the arrival of the slower, more destructive S-wave. This approach is relatively simple, but it is less accurate and more prone to false alerts compared to the network approach.

Network approach: The network approach utilizes many seismic sensors that are distributed across a wide area where earthquakes are likely to occur. This network of sensors sends data to a central site where ground motion signals are analyzed, earthquakes are detected and warnings are issued. The network approach is considered to be slower, but more reliable than the on-site approach. This is because it uses information from many stations to confirm that the ground motion detected is actually from an earthquake and not from some other source of vibration. Using a network of seismic sensors has the advantage that these stations are used constantly for monitoring daily small earthquakes so the system will be maintained and exercised routinely. Only a regional network of sensors is capable of characterizing large, complex earthquakes as they evolve. Thus, forecasts gain accuracy as more data are recorded and analyzed.

California routinely experiences small and moderate earthquakes that do little or no damage. In the vast majority of cases, EEW will alert users that although the ground is about to shake, the expected shaking will be predicted to be slight or moderate. Only in the rare case of a large earthquake will there be a warning of strong shaking.

Why not just use on-site seismometers instead of a networked system?

Earthquake early warning can be based on data from a single station or from a network of stations, or a combination of the two. In a "single station" warning system, data does not need to be sent to a central processing site. However, using only one station to detect ground motion and provide an alert is more prone to false alarms. Accuracy and warning time are maximized when using a combination of warnings from single stations and a regional seismic network. For the optimum performance during a moderate to large earthquake, we combine on-site and regional warning approaches in the CISN ShakeAlert demonstration system.

How does California's current earthquake monitoring system support EEW?

The California Integrated Seismic Network (CISN) is a collaborative effort between Caltech, UC Berkeley, USGS, CalEMA and California Geological Survey (CGS) and currently operates a network of hundreds of seismic sensors in California. The CISN that is mainly funded by USGS, CalEMA, and CGS monitors and notifies about earthquake activity in California. The CISN generates and distributes ShakeMap and other products for emergency response, post-earthquake recovery, earthquake engineering, and seismological research. Although not sufficient for a robust EEW system, the CISN network provides the backbone on which to efficiently and cost-effectively build a regional early warning system. Leveraging the existing investment in earthquake monitoring has several advantages. First, it reduces the startup costs of an EEW system by using sensors and other infrastructure that already exists. Second, by being integrated with current earthquake monitoring the system will be supported, tested, and developed by the nation's experts in the field. Finally, building on the existing CISN network means that all the improvements for EEW also result in improved information for emergency response and aftershock forecasting.

How much warning time will there be?

The amount of warning time at a particular location depends on its distance from the earthquake epicenter. Locations very close to the earthquake epicenter that are within the 'blind zone' will receive no warning. Locations far removed from the earthquake epicenter would receive lots of warning time but may not experience damaging shaking. For locations in between, the warning time could range from seconds to minutes. The benefits of EEW are greatest for earthquakes greater than magnitude 7 where the area of strong shaking is large. EEW would be most effective in a case where the earthquake begins on a fault far from your location and the rupture propagates toward your location. This would be the case for an earthquake beginning at the northern end of the San Andreas Fault and rupturing south towards the San Francisco Bay Area, or an earthquake starting near the Salton Sea and rupturing north toward Los Angeles, which was the scenario event in the 2008 ShakeOut exercise. The chart below explains the distance dependence of warning times.

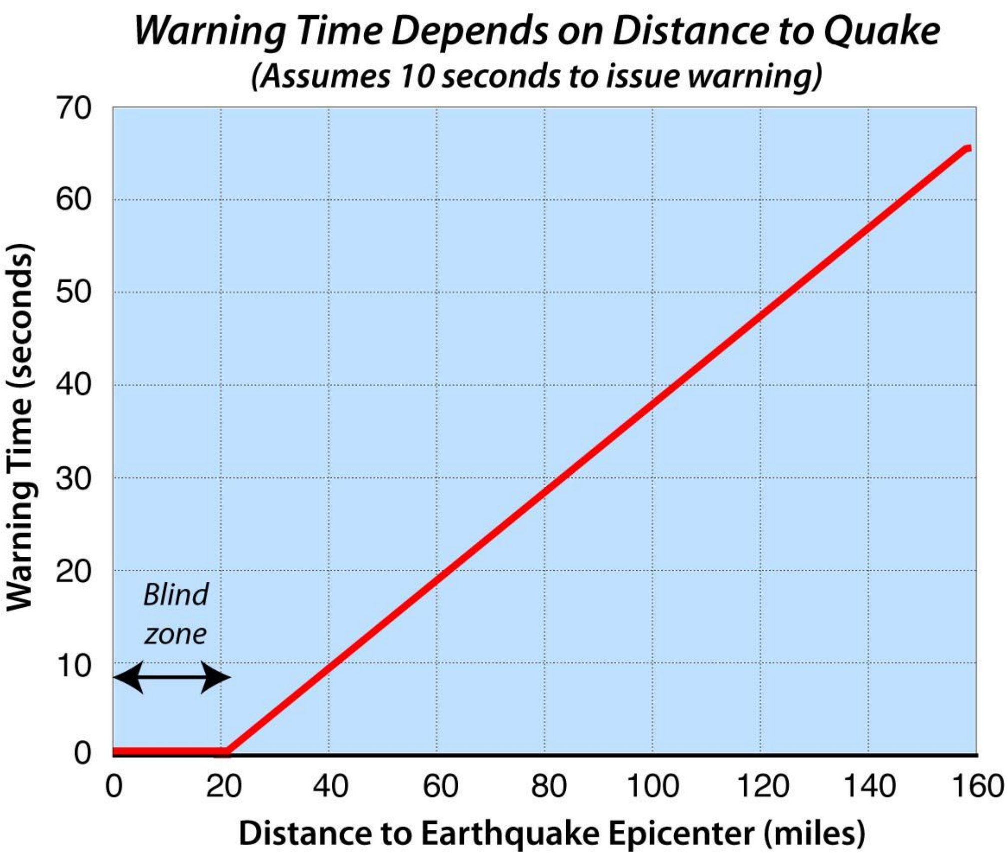

Figure 1: Warning time depends on your location's distance from where the earthquake begins. The slanted red line shows how warning time increases with distance from the epicenter. In this case, warning time increases beyond the 21 mile-radius blind zone with, for instance, approximately 10 seconds warning at 40 miles distance. Ongoing research is focused on reducing the size of the blind zone.

How realistic is a government-run EEW system? Are there systems in operation now?

EEW systems are now either operational or are being implemented in several countries. Mexico City has had a system since 1991. Japan has had a nationwide public warning system since 2007. There are also systems in Istanbul, Turkey, Bucharest, Romania, China, Italy, and Taiwan. All of these systems are tailor made for the local system of faults and thus cannot easily be adapted to California.

In the United States, USGS is funding research into earthquake early warning in California with several research partners: UC Berkeley, Caltech, the Southern California Earthquake Center (SCEC) and Eidgenössische Technische Hochschule (ETH), Zürich. With these partners, and by leveraging federal and state investments already made in the Advanced National Seismic System to monitor earthquake activity, an EEW system in the US administered by the USGS is a realistic expectation of leaders and the community. By being part of an existing, active seismic network, the early warning system will be tested and monitored daily through existing operations. Additionally, building on the existing National System means all the infrastructure improvements for EEW will also result in improved information for emergency response and aftershock forecasting.

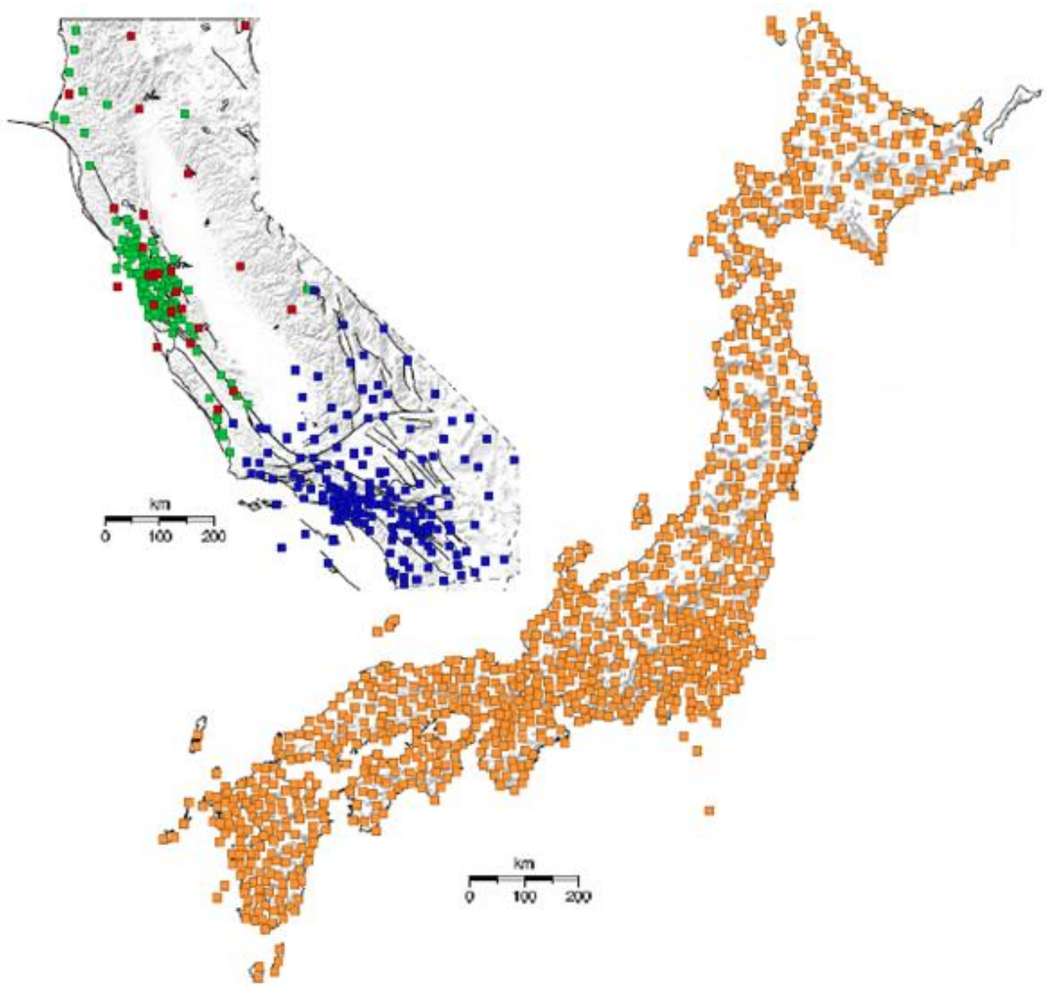

Figure 2: Earthquake sensor density: California versus Japan. New sensors need to be added in California to shorten the CISN sensors spacing to approximately 12 miles to facilitate timely EEW. The shorter the station spacing, the smaller the blind zone will be because warnings can be issued faster.

Who will issue the warnings?

Under the Disaster Relief Act of 1974, popularly known as the Stafford Act (P.L. 92–288), the USGS has the Federal responsibility to issue alerts for earthquakes, to enhance public safety, and to reduce losses through effective forecasts and warnings. USGS already issues rapid, automatic earthquake information via the Internet, email, text messages, and social media.

How will warnings be delivered?

Every available technology will be used to insure that EEW messages reach as many people and as quickly as possible. Most currently available mass messaging technologies are too slow for EEW. However, many promising technologies are on the horizon like broadcast text messaging, smartphone apps and recent upgrades to the national Integrated Public Alert and Warning System. EEW uses will open the door to many public/private partnerships.

The EEW system must be connected with users of the warning ahead of time, and therefore requires a public outreach effort upon implementation to make people aware of the system and how to respond to it. Responses are most effective when automated and pre-established so the recipients know what action to take when they get a warning.

How can an earthquake early warning be used?

The uses for EEW fall into two major categories: warning people to take protective action and triggering automatic responses in places like factories.

EEW uses range from the simple to the complex. Here are some examples:

- <u>Transportation</u>: Slowing or stopping trains, stopping airport take-offs and landing, closing vulnerable bridges, slowing or stopping traffic by turning all signals red, including freeway entrances
- <u>Utilities</u>: opening/closing critical valves in pipelines; shutting down systems, reroute power, securing field personnel in safe positions
- <u>Construction</u>: Placing cranes and lifts in safe positions, moving people from unsafe locations
- <u>Office</u>: Stopping elevators at the nearest floor and opening the doors, moving away from windows to interior/safer spaces
- <u>Industrial</u>: Closing valves, slowing or stopping production lines and sensitive processes, moving employees away from hazardous materials
- <u>Medical</u>: Halting dental operations, surgery, laser procedures, etc.
- <u>Restaurants</u>: Shutting off heat sources, securing/avoiding dangerous areas like deep fryers
- <u>Schools</u>: Warning school children to drop, cover and hold on
- <u>Emergency</u>: Alert first-responders in the field to temporarily retreat to safe spaces, triggering doors to open for emergency vehicles, start generators
- <u>Cars & trucks:</u> Instruct alerted drivers to turn on emergency flasher (to warn others) and to slow down
- <u>General</u>: Alerting the public to prepare physically and psychologically for the impending shaking

Are there any limitations to the system?

No system is perfect. No warning will be possible in a "blind zone" within 15-20 miles of the epicenter that is shaken in the first few seconds of the quake. It is also possible the system might send warnings for earthquakes too small to cause damage or when there is no earthquake at all. Finally, the system could fail to send warnings or send them too late to be acted upon. While all these "failure modes" are possible, rigorous planning and testing should minimize them. In many situations automatic systems can use information about time, location, magnitude and certainty in the warning notification to make decisions about the appropriate action to take in a particular context.

How long before a full system will be operating and sending messages to the general public?

In order to have a fully developed system, three steps are necessary: the development of the technology to provide warnings to the public, education about the meaning of the warnings, and investment in the seismic infrastructure to improve the rapid detection of earthquakes.

In late 2011 a demonstration project began sending live notifications to a small number of selected test users in the business, utility and transportation sectors of California. *Public warnings will not be sent as part of this demonstration project*. Additional investment in sensors, communications infrastructure, software development and operations personnel will be required to create a robust public system. There is currently no commitment to fund such an effort.

How much will a fully developed and operational system cost?

The CISN that operates the statewide infrastructure for earthquake monitoring will also be the backbone of a future EEW system. Currently, the annual budget for the CISN that is funded by the USGS/ANSS, CalEMA, and others is about $15M/yr.

Additional sensor sites, upgraded data communications, algorithm development, new software systems, and robustness features are needed before EEW can be made fully operational. The cost of a robust, fully operational EEW-capable CISN system in California is estimated to be about an additional $80M over 5 years. However, detailed budget and implementation planning has not been made yet. A similar capability in the Pacific Northwest is estimated to cost $65M over 5 years. Not included in these budget numbers are costs associated with user implementation of EEW. Today, the EEW effort benefits from smaller increments of funding, such as provided by the USGS and the Betty and Gordon Moore Foundation, which are being used to continue the EEW research, develop proto-type distribution systems, and working with early adopters.

What is the role of the private sector, and will jobs be created?

In Japan jobs have been created in the private sector. These advanced technology companies evaluate the needs of each EEW user and provide value-added application technology to the EEW signals from the Japanese Meteorological Agency (JMA). Such private-sector products also tailor the EEW signal for use in specific applications such as for equipment protection and safety in semi-conductor factories.

We envision such private companies in the US will develop smart EEW-user technology to take automated action based on the EEW signals generated by the CISN. Such technology may safeguard the energy grid, water systems, high-speed rail, open firehouse garage doors, move elevators to the nearest floor, warn doctors treating patients, sound alarms via paging systems in schools, as well as have numerous smart industrial applications. In particular, the power utilities can re-route power around areas of intense shaking. Possible damage to pumping stations in the water system could be mitigated with EEW signals. Also, people working on power systems or on water systems can be warned to enable them to move to safety before shaking arrives.

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