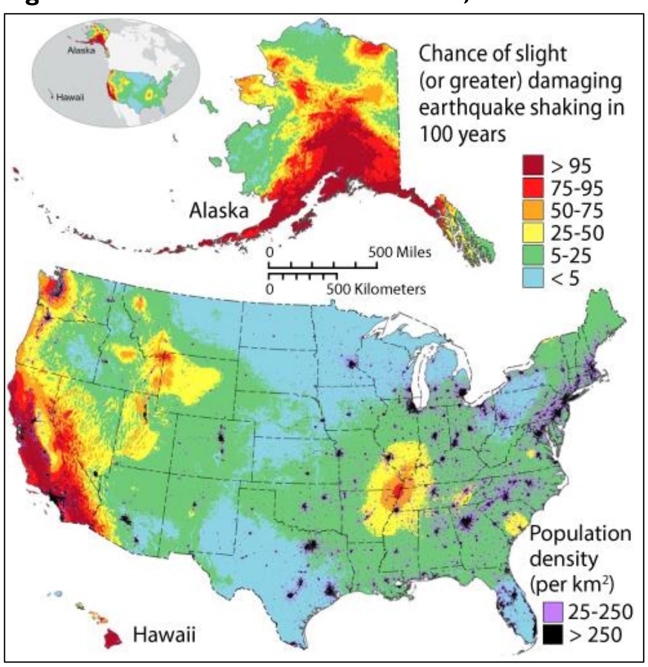
Updated April 25, 2025

The ShakeAlert Earthquake Early Warning System

Portions of all 50 states, as well as U.S. territories and the District of Columbia, are vulnerable to earthquake hazards (e.g., ground shaking) and associated risks (e.g., exposure of people or property to ground shaking) to varying degrees (**Figure 1**). Among the costliest U.S. earthquake disasters was the 1994 magnitude 6.7 Northridge earthquake in California, which caused about 60 fatalities and more than 7,000 injuries; left about 20,000 homeless; damaged more than 40,000 buildings; and caused an estimated $13-$20 billion in economic losses.

Congress established the National Earthquake Hazards Reduction Program (NEHRP), involving the U.S. Geological Survey (USGS), National Science Foundation (NSF), Federal Emergency Management Agency (FEMA), and National Institute of Standards and Technology (NIST), in 1977 to reduce earthquake risks. In the NEHRP Reauthorization Act of 2018 (P.L. 115-307), Congress directed the USGS to implement an effective earthquake early warning system to reduce risks.

Figure 1. USGS Seismic Hazard Model, 2023

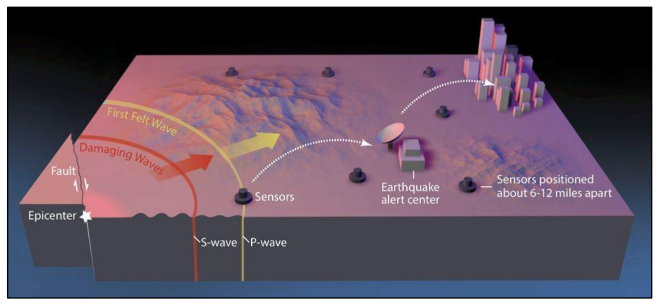


Source: Mark D. Peterson et al., "The 2023 U.S. 50-State National Seismic Hazard Model: Overview and Implications," *Earthquake Spectra*, vol. 40, no. 1 (2024), DOI: 10.1177/87552930231215428.

Notes: Map displays the likelihood of damaging earthquake shaking (equivalent or greater than Modified Mercalli Intensity VI) in the United States over the next 100 years. Earthquakes cannot be predicted, nor can the potential for an earthquake to reoccur in areas with some seismic history be ruled out. The model uses existing faults and past earthquakes to forecast the probability of future earthquakes and uses the geology to estimate how much the ground shakes during an earthquake.

Earthquake early warning (EEW) may reduce earthquake risks (i.e., reduce fatalities and injuries, as well as damage to structures and operations). EEW refers to sending a warning that an earthquake was detected and damaging ground shaking may be coming (**Figure 2**). An EEW received in tens of seconds to minutes before shaking may allow individuals to take protective actions and institutions to engage automated protective actions (**Table 1**).

Figure 2. Schematic of the ShakeAlert System



Source: ShakeAlert.

Notes: Once an earthquake starts (star labeled *epicenter* on a *fault*), the earthquake-sensing network (*sensors*) detects the P-waves (yellow curve and arrow) at sensors closest to the epicenter. The sensors transmit data to data processing centers. The centers process the data and, if the earthquake may be damaging, prepare alert messages with information about the earthquake's magnitude and location and what areas may receive intense shaking from the later-arriving, more damaging S-waves (red curve and arrow). Public and private communication pathways convert the alert messages into EEWs and send them to individuals and institutions in endangered areas.

The USGS and other federal, state, academic, and private partners began public EEW on the West Coast via the ShakeAlert Earthquake Early Warning System in California in 2019 and in Oregon and Washington in 2021. There have been some feasibility studies about implementing ShakeAlert in Alaska, Hawaii, Nevada, and Utah.

An EEW system consists of the following components (**Figure 2** and **Figure 3**):

- an understanding of earthquakes and faults to determine where to locate an earthquake-sensing network;
- an earthquake-sensing network, including seismic and geodetic sensors, to detect the start of an earthquake;
- robust and rapid telemetry;
- data analysis and alert decisionmaking;

- a targeted and clear alert message; and
- rapid mass notification through communication services to areas at risk.

ShakeAlert sent 41 public alerts for earthquakes that caused light shaking and little damage between October 17, 2019, and September 1, 2023. ShakeAlert missed 12 earthquakes (7 were mislocated and 5 had underestimated magnitudes), in part because the earthquakes were on the edges or outside (i.e., offshore) of the earthquake-sensing network. EEWs sent via FEMA's Wireless Emergency Alert (WEA) system—an alerting system sending messages to wireless mobile devices—often did not arrive before shaking started. Technical glitches caused some WEA messages to be delayed more than five seconds. EEWs sent via cell phone applications over Wi-Fi or cellular networks were generally delivered with less than five seconds delay, giving those alerted time in most cases to take protective actions before ground shaking arrived (**Table 1**).

Table 1. Examples of Individual or Automated Protective Actions

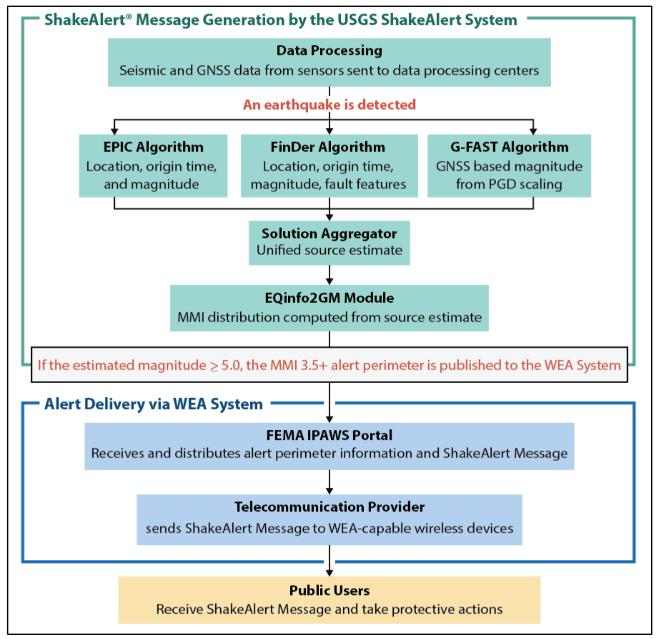
- Individuals may drop, cover, and hold on until shaking ends.
- Drivers may turn on emergency flashers (to warn others) and slow down.
- First responders in the field may temporarily retreat to safe spaces.
- Automatically opening doors for emergency vehicles and starting generators.
- Placing cranes and lifts in safe positions and moving people away from hazardous construction sites.
- Closing valves, slowing or stopping production lines and sensitive processes (may be automated), and moving people away from hazardous industrial processes.
- Halting dental, eye, and other medical procedures.
- Automatically stopping elevators at the nearest floor and opening doors.
- Moving people away from windows to interior/safer spaces in buildings.
- Turning off heat sources and securing or avoiding areas with potentially dangerous equipment, such as deep fryers in restaurants.
- Alerting students and staff in schools to take a protective action such as drop, cover, and hold on.
- Slowing or stopping trains, closing vulnerable bridges, and slowing or stopping traffic by turning traffic signals to red (may be automated). Stopping aircraft takeoffs and landings.
- Opening or closing critical valves in pipelines, shutting down systems, and rerouting power supplies (may be automated). Moving field personnel into safer positions.

Source: ShakeAlert, Modified by CRS.

Congressional Considerations

Congress may consider providing direction on policy priorities related to the authorities and mandates of the NEHRP Reauthorization Act of 2018. The authorization of appropriations for NEHRP expired in FY2023, although appropriators provided NEHRP funding in FY2024 for participating agencies. In considering future funding or legislative changes, Congress could seek information about ShakeAlert's effectiveness. For example, a performance review of the ShakeAlert system made recommendations to reduce the earthquake miss rate, such as adding sensors to the network and improving the algorithms (**Figure 3**). Congress may seek information about the ability of FEMA's alerting technology to provide rapid and targeted mass notification for earthquakes.

Figure 3. ShakeAlert Message Generation and Alert Delivery



Source: USGS, December 12, 2024. Modified by CRS.

Notes: GNSS is Global Navigation Satellite Systems. EPIC is Earthquake Point-Source Integrated Code. FinDer is Finite Fault Detector. EPIC and FinDer use seismic data gathered by the seismic network. G-FAST is Geodetic First Approximation of Size and Timing, and PGD is Peak Ground Deformation. G-FAST uses geodetic data gathered by the geodetic network. EQ is earthquake. GM is ground motion. MMI is Modified Mercalli Intensity Scale (i.e., shaking intensity). M is magnitude. WEA is Wireless Emergency Alert. IPAWS is Integrated Public Alert Warning System.

If Congress continues funding for EEW generally and ShakeAlert specifically, it may consider a range of options to do so, such as through annual appropriations, shared costs that are a mix of federal- and state-funded initiatives, or contributions from other federal agencies. One consideration could be whether to establish priorities for ShakeAlert vis-à-vis other NEHRP priorities. For example, in FY2024, Congress appropriated about $99.7 million for the USGS component of NEHRP and specified $28.6 million for EEW.

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