COMMENT

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JUSTIN SULLIVAN/GETTY

US school children shelter under their desks during an earthquake drill.

Seconds count

The United States should install an earthquake early-warning system now — and before the next big one hits, says **Richard Allen**.

The United States will be hit by a major earthquake causing hundreds of fatalities within my lifetime. Whether it will be in 20 years, 2 years, or tomorrow, we do not know. Such an event will prompt the country to implement a public earthquake early-warning system, giving people seconds or minutes to prepare for the shaking. Rather than waiting until the next big quake galvanizes political action, I believe that we must build an alert system now.

Earthquake early-warning technology is proven. Japan leads the way. When the magnitude-9 Tohoku-Oki earthquake hit the northeast of the country in March 2011, an automatic warning was issued within seconds. Trains stopped, students took shelter under desks, sensitive manufacturing equipment was paused and hazardous chemicals were isolated. Lives and money were saved. China, Taiwan, Mexico, Turkey and Romania also issue earthquake alerts.

The US public deserves access to warnings too. For the past 2 years, California has run a successful demonstration system — providing seismic alerts to 36 organizations, including the Bay Area Rapid Transit rail network. Now, the system must be made more robust and rolled out to the public, first across the West Coast and then nationwide. The benefits for security, business and science are manifold.

The cost of an initial West Coast system is reasonable: US$120 million for the first 5 years to build and operate it, and a further $16 million a year to run it. This is roughly twice the current earthquake-monitoring budget for the region. Private enterprise could deliver the alerts and tailored services. Seismology would also benefit from the hundreds of extra sensors that would need to be installed along high-hazard faults — those most likely to slip.

The main obstacle is political will. Politicians, business leaders and agency administrators need to recognize the significance and urgency of seismic risk and implement an early-warning system before the next ▶

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big quake costs lives. Other regions, including Europe, should follow.

INEVITABLE HAZARD

The probability that a major earthquake will hit the western United States in coming decades is high. California has a 99% chance of experiencing a quake of at least magnitude 6.7 (the size of the 1994 Northridge earthquake near Los Angeles) in the next 30 years. Both San Francisco and Los Angeles have a two-in-three likelihood of such an event. There is a 50% chance that the next big Bay Area quake will be on the Hayward Fault, which is situated about 500 metres away from the seismological laboratory at the University of California, Berkeley, where I work.

The Pacific Northwest region must be prepared for even bigger earthquakes, measuring up to magnitude 9 — similar to the one that hit Japan in March 2011. The hazard across the rest of the United States is lower, but damaging earthquakes can also occur all the way to the East Coast, as illustrated by the August 2011 Virginia quake of magnitude 5.8 that rattled Washington DC and New York.

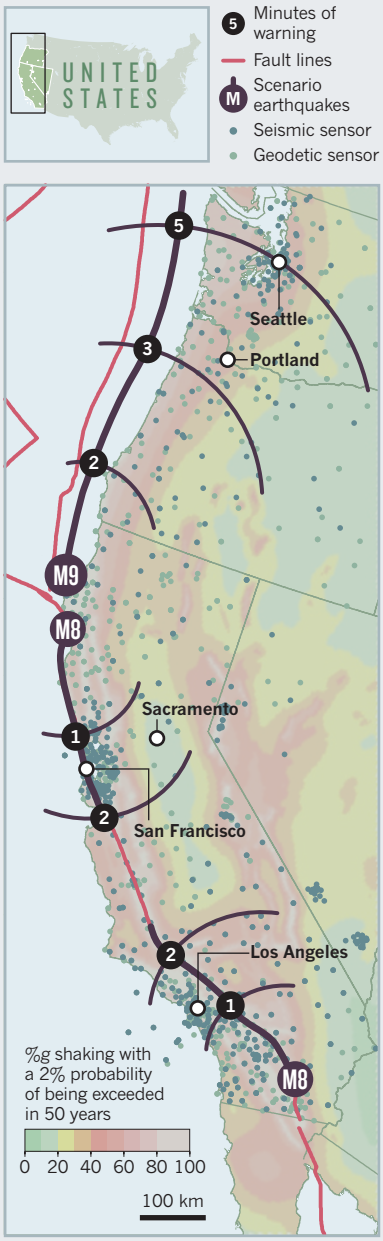
The first line of defence in the United States is a robust building code to prevent structures from collapsing. But now, the information revolution allows us to develop real-time responses to minimize casualties and damage. When seismic sensors pick up the first vibrations of a rupturing fault, automatic alerts can be issued within seconds to give people up to 5 minutes to react, depending on their distance from the epicentre[1].

Japan has pioneered such systems since the 1995 Kobe earthquake, which killed more than 6,000 people. The government invested billions of yen in seismic and geodetic networks to detect quake signals. In 2004, the Japan Meteorological Agency tested a limited earthquake-warning system. It delivered its first alert in 2005, and in 2007 the system went national and public. The first true test came in the Tohoku-Oki earthquake. Sendai, the closest major city to the epicentre, received a 15-second warning.

California's demonstration system, ShakeAlert[2], has been operating since 2011 but is yet to go public. Using existing seismic sensors, it detects earthquakes daily and, when magnitudes exceed 2.5, issues alerts to a limited group of organizations mainly involved in transport, manufacturing and emergency response. It is largely a public-sector and academic enterprise: a collaboration that includes the California Integrated Seismic Network, with researchers and funding provided by the University of California, Berkeley, the California Institute of Technology in Pasadena, the US Geological Survey (USGS), the Southern California Earthquake Center and the Swiss Federal Institute of Technology in Zurich. In 2012, the scheme expanded to include the Pacific Northwest, adding the University of Washington in Seattle, and gained support from the Gordon and Betty Moore Foundation, a private grant-making organization in Palo Alto, California.

US WEST COAST HAZARD MAP

Public alerts of large earthquakes could give the populations of major cities along the West Coast several minutes advance warning.



Although the California system has not yet been tested by a large earthquake, it successfully gave organizations in Pasadena a 5-second warning of ground shaking for a magnitude-4.2 earthquake in September 2011. In the San Francisco Bay Area, several small (magnitude-3) earthquakes located close to the epicentre of the 1989 Loma Prieta quake were detected, and alerts were provided around 20 seconds before peak ground motion in San Francisco, Oakland and Berkeley — illustrating what would be possible in a repeat of the devastating 1989 quake.

The detection algorithms have performed well so far, with few false alerts and no cases of small earthquakes being misclassified as large, dangerous ones. But before the California system can be trusted to go public, it needs more monitoring stations (using both seismic and Global Positioning System (GPS) techniques), more reliable communications and testing, multiple data paths and round-the-clock daily support. The infrastructure must be made resilient to hard shaking, to ensure that the system stays online during a big quake. More seismic and GPS stations will produce faster alerts in some regions and allow tracking of large-magnitude events as they tear along active faults.

Users can decide on the thresholds for alerts and choose whether they want to hear about only the big quakes that will cause damage, or all those that are felt. But the mechanisms to deliver the alerts in the United States — through smartphone and computer apps, television and radio — remain to be developed.

BUSINESS BOON

A public–private partnership is the most effective way to disseminate the warnings, as in Japan. There, the public sector pays for the installation and long-term operation of geophysical networks to detect earthquakes and generate basic alerts. The private sector enhances and delivers the alerts, and provides support and risk-reduction expertise to the public and to businesses.

The benefits for business are threefold. First, commercial opportunities will be created. Apps will raise the alert on mobile phones, count down the time until shaking and provide location-specific instructions of what to do: for example, get under the table, exit the building or remain inside the steel-framed, glass-clad skyscraper. Self-driving cars will slow and stop. Manufacturing plants, petrochemical facilities and biotechnology companies will need other services, including determination of money-saving actions, appropriate thresholds of when actions should be taken and devices to implement them.

Second, financial losses will be reduced. After two damaging earthquakes in 2003 caused $15 million in losses at Oki Electric Industry, a chip manufacturer in Miyagi prefecture, Japan, the company spent $600,000 on an early-warning system and improvements to its buildings. In two similar earthquakes that followed, its resulting losses fell to $200,000 because machine damage and chemical spills were reduced.

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ERIC RISBERG/AP/PA

An earthquake early-warning drill at a Bay Area Rapid Transit station in California.

In California, the Bay Area Rapid Transit system has implemented an automated train-braking mechanism that is triggered by earthquake early warnings. It takes 24 seconds to bring a train travelling at 112 kilometres per hour (70 miles per hour) to a stop. During peak commuting times, about 64 trains are in operation, each carrying around 1,000 passengers, and up to 45 trains travel at 112 kilometres per hour at any one time. Even one derailment at such a speed would be devastating.

Third, the recovery time for businesses is reduced. With its warning system installed, Oki's fabrication plant was closed after the earthquakes for just a few days, rather than for weeks. Minimizing damage to trains and tracks will result in faster resumption of service, which in turn supports the restart of regional businesses after a quake.

Seismology will benefit from the improved instrumentation. The 2011 Tohoku quake — the fourth largest since 1900 — yielded scientific advances because it occurred in one of the most densely instrumented regions in the world[3–9]. This extreme event tested the limits of early-warning systems. The size of the earthquake and the area affected were underestimated, and as a result, improvements to observational arrays are being made. Fast and accurate GPS sensor networks are needed to detect ground surface deformation, and ocean-floor observatories could closely monitor undersea faults.

Tracking fault motion in real time is key to making accurate shaking predictions, avoiding the underestimation that occurred in Japan's 2011 quake. To improve estimates of earthquake strength from the first signals, my research group is exploring how kilometre-scale seismic arrays can be deployed and tuned to track the progression of large fault ruptures.

In the future, the accelerometers that are embedded in smartphones and computers could provide a source of shaking data, thus boosting the number of magnitude sensors by thousands[10].

NEXT STEPS

By providing earthquake early warnings, everyone wins: people, businesses and science. So what is the hold-up? The answer is the allocation of money — and responsibility. Although US federal and state budgets are tight, the $120-million price tag to build and operate a West Coast system over 5 years works out at roughly $2.44 per person for the populations of California, Oregon and Washington. My morning coffee costs me $2.40.

What is needed to move forward is a partnership between leaders from state and federal politics, businesses, government agencies and science. Some individuals are making headway, but more must do so.

"By providing earthquake early warnings, everyone wins."

California State Senator Alex Padilla (Democrat) introduced a bill to build an earthquake early-warning system in the state, and successfully manoeuvred it through the legislature, where it was passed unanimously this September and was signed into law by Governor Jerry Brown. The governor's office of emergency services is charged with finding the necessary funding. Start-up funds are needed now, to maintain momentum. To cover the West Coast, governors and state legislators in Oregon and Washington will need to take similar steps.

Federal legislators must also take action. A number of California representatives, led by Congressman Adam Schiff (Democrat), have expressed bipartisan support for a warning system. However, with the House Interior Appropriations Bill now stalled, there is no prospect of funding this year. The USGS stands ready to deliver earthquake alerts, but it needs an extra $16 million a year to operate and maintain the system.

Partnerships between the USGS and other federal agencies are needed. The US National Science Foundation should fund the expansion of geophysical networks in zones of high seismic hazard. The Department of Homeland Security and its Federal Emergency Management Agency should support earthquake early warning as a public-safety issue.

Business leaders must also advocate the value of a warning system more strongly. John McPartland, a member of the board of directors for Bay Area Rapid Transit, has recognized and spoken widely about the need for it. Others should step forward in the many sectors that are affected by severe earthquakes.

Other regions should implement early-warning systems before their next big quake. European researchers are poised to do so, but are waiting for funding. The United Nations Educational, Scientific and Cultural Organization should continue to help in promoting the technology in other earthquake-prone areas around the world.

The scientific community provides information about the likelihood of earthquakes and their effects. But I believe that it is also important to use its expertise and authority to apply moral pressure on leaders. Although some researchers will prefer not to step out of their ivory towers, earthquake scientists who are keen to see progress must gain knowledge of and access to the policy-making process.

As Padilla commented to a colleague during the California Senate hearings for his earthquake bill: "I know you don't want to be sitting here with me after the next big one if we have not deployed this system." I am happy to give up tomorrow's coffee in exchange for a warning before the next big shake. ■

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