Transforming Earthquake Detection?

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Earthquakes are a collective experience. Citizens have long participated in earthquake science through the reporting, collection, and analysis of individual experiences. The value of citizen-generated status reports was clear after the 1995 Kobe, Japan, earthquake (1). Today’s communications infrastructure has taken citizen engagement to a new level. Earthquake-related Twitter messages can outrun the shaking (2), Internet traffic detects earthquakes (3–7) and maps the distribution of shaking in minutes (8–10), and accelerometers in consumer electronic devices record seismic waveforms (11–16). What are we learning from this flood of data, and what are the limitations? How do we harness these new capabilities for scientific discovery, and what is the role of education?

Modern geophysical instruments can record a magnitude 5 (MS) earthquake from the other side of the world. However, to map, track, and analyze the details of large destructive earthquake ruptures, and to elucidate how the rupture process links to earthquake impacts, requires detailed data from close to the event. Currently, the best traditional geophysical networks only have stations every ~10 km and cover limited areas. Contributions of citizens have the potential to provide much higher resolution, especially in residential areas.

The best-developed citizen-based earthquake science project today is the U.S. Geological Survey’s (USGS) “Did You Feel It?” (DYFI) (8–10). After an earthquake, individuals can go online and answer questions designed to capture the data necessary to estimate shaking intensity. The location information of each report is converted to latitude-longitude coordinates and the data are mapped. Online tools allow users to explore the data set that includes their contribution. The project also has an educational component explaining earthquake phenomena.

The DYFI database now contains nearly 2 million entries available for download (8–10). The DYFI data are used to complement the traditional network data. Combined with reports of building damage, they can also help to determine how well building infrastructures withstand earthquake shaking in different locations.

An individual’s reaction to an earthquake can also be tracked for scientific purposes without that individual’s active participation. The European-Mediterranean Seismological Center (EMSC) tracks the hits on its Web site and uses the hit rate and Internet protocol (IP) addresses to extract information about earth-
The value of citizen science. New networks allow citizen-scientists to host seismic stations and provide detailed waveform recordings. This instantaneous view of ground shaking looks like ripples on a pond propagating away from the earthquake source. In the future, such data may provide detailed observations of seismic wave propagation and earthquake source processes. The challenge is to maintain data quality and ensure that citizen networks are still active when the next big earthquake occurs.

The sensor can be glued to a basement or the wall of a building, providing better coupling to ground or building motion and allowing detection of M3 earthquakes. Both the Community Seismic Network (CSN) and the QCN deploy such sensors in citizens' homes in earthquake-prone regions (11–14). The USGS NetQuakes project uses a more robust system with a higher-quality sensor. An engineer bolted the ~$6000 sensor package to the concrete basement of a home: the instrument is largely autonomous, needing only periodic connections to the citizen-host’s wireless Internet. Online tools allow the citizen-scientist to look at the recorded data and compare recordings across the region (17).

This new age of networks has the potential to increase the density of instruments by an order of magnitude or more. Data from a recent deployment of 5000 sensors in a 5 km by 7 km area in Long Beach, California, by NedaSismos Inc. show that seismic energy from nearby earthquakes radiates across the array, it deviates from the simple waves-on-a-pond pattern, indicating the complexities of the subsurface structure (18). Dense data like this across swaths of earthquake-prone regions could substantially advance understanding of wave propagation effects and the earthquake source (see the figure). In addition, sensors can be placed in different types of locations, such as multiple stories of different types of buildings.

Finally, this approach provides one of the best opportunities to engage citizens to learn about earthquakes.

However, the challenges are substantial. First, how good are the data? Some sensors may record true ground or building motion, whereas others record the oscillations of a wobbly tabletop. Second, how robust will the networks be? How much will lose power or could a large earthquake damage or still be running by the time a large earthquake occurs? Long-term operation requires continued interest of the citizen-hosts to ensure that both hardware and software remain operational. Finally, privacy concerns may limit data use if individuals are not prepared to release precise sensor locations.

Despite these challenges, citizen-based projects have the potential to transform earthquake science if two conditions are met. First, amateur scientists must be able to explore the data and draw conclusions. Online educational tools such as those at DYFI allow individuals to see how their data are used and how they contribute to scientific discovery. This is crucial for maintaining sustained participation. Second, the citizen-generated data must conform to high data management standards with accurate location and instrument type information. It must also be archived alongside traditional data in order to be useful to professional scientists and thereby drive fundamental discovery.

References and Notes
2. See www.youtube.com/watch?v=5j12xknel_LQ.
5. To follow the USGS text-based earthquake information, subscribe to @USGS and twitter.

Supporting Online Material
www.sciencemag.org/cgi/content/full/331/6046/297/DC1
Note S1.