Topic	California Integrated Seismic Network (CISN)
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1 How earthquake monitoring is organized in the United States

Earthquake monitoring in the US is organized under the Advanced National Seismic System (ANSS), a program operated by the US Geological Survey. The mission of the ANSS is to provide timely and accurate earthquake information products, including rapid estimates of their effects on the built environment across the Nation. The United States is divided into eight ANSS regions to facilitate monitoring on a regional scale and to foster partnerships with local universities and other seismic network operators. The California Integrated Seismic Network (CISN) is the umbrella organization for earthquake monitoring in the California region of ANSS (Figure 1).

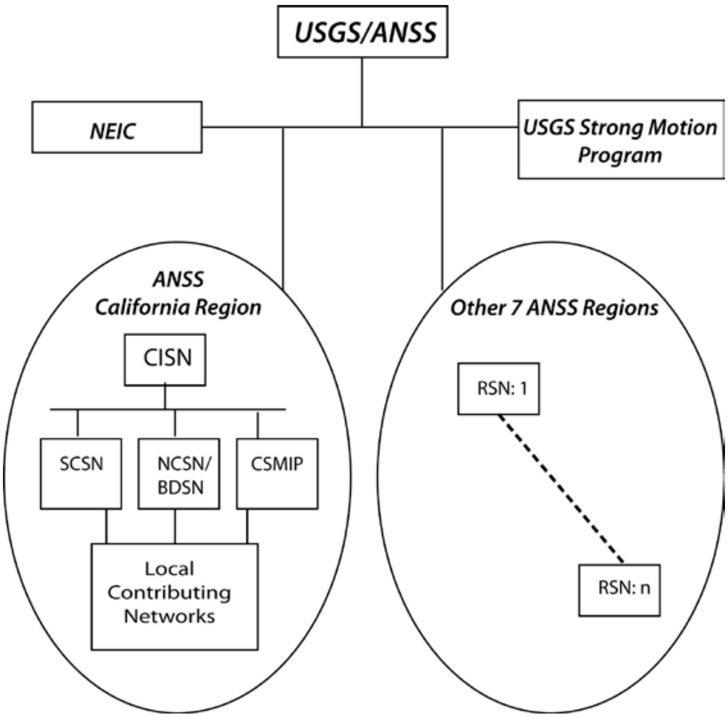

Figure 1 Schematic organizational diagram illustrating how the ANSS, and as an example the CISN and other regional networks (RSNs, numbered 1 through n) form a system. **Bottom left:** The main components of the CISN; **Bottom right:** Summary diagram to indicate the other seven regions of ANSS; BDSN – Berkeley Digital Seismic Network; CISN – California Integrated Seismic Network; CSMIP – California Strong Motion Instrumentation Program; NCSN – Northern California Seismic Network; NEIC – USGS National Earthquake Information Center; and SCSN – Southern California Seismic Network.

2 California Integrated Seismic Network (CISN)

There are more than 15 seismic network operators in California that share data real-time as part of CISN operations. The CISN consists of three management centers. First, the California Geological Survey (CGS) operates the California Strong Motion Program, and provides near real-time strong motion data and associated products from all CISN partners to earthquake engineers. Second, the Northern California Seismic Network (NCSN) in Menlo Park and the Berkeley Digital Seismic Network (BDSN) at UC Berkeley provide real-time reporting for northern California. Third, the Caltech/USGS Southern California Seismic Network (SCSN) provides real-time reporting for southern California. The CISN partners also contribute data to the USGS/NEIC, develop standards, and carry out joint development and implementation of new technologies.

Extensive real-time data sharing takes place within the CISN. Subsets of real-time waveforms are shared automatically for processing by partner networks between central processing sites. In addition, about 12 broadband and strong motion stations operated by the SCSN transmit data real-time to both the SCSN in Pasadena and the BDSN in northern California, and comparable 12 BDSN stations are also recorded in Pasadena for backup purposes. Also, several strong motion stations provide simultaneous real-time data feeds to the SCSN Pasadena and the CGS in Sacramento (Figure 2).

Amplitudes are produced at all three CISN processing centers and shared automatically to facilitate seamless production of ShakeMap. Most recently, proxy wave-servers are used in post-processing to access waveforms in remote data archives, and improve earthquake locations and magnitudes. All products are transmitted via the USGS operated middleware Earthquake Information Distribution System (EIDS) for publishing on the USGS/ANSS web pages. To ensure high availability of earthquake information following major earthquakes, the USGS contracts with a commercial Internet provider to host the ANSS/USGS web pages.

The CISN partners have developed and operate the ANSS Quake Monitoring Software (AQMS) for their earthquake monitoring needs. In 2009, the ANSS began deploying the AQMS software at five other major ANSS data processing centers across the US. The AQMS software is based on the Oracle database, Earthworm modules, a variety of CISN developed software modules, and open source IT software modules for state of health monitoring. A CISN working group curates the Oracle CISN schemas to maintain standardization. The AQMS software includes data acquisition modules, broadcast and capture modules, data analyst and duty-seismologist review modules, and modules for various processing threads such as generation of earthquake locations, magnitudes, moment tensors, and alarming functionality. The AQMS software also has various facilities for data archiving. Recent additions to the software include incorporation of QuakeXML and StationXML to facilitate catalog data and station metadata exchange.

Today the USGS National Earthquake Information Center (NEIC) is the backup for the CISN. The CISN partners share waveforms from selected seismic stations, as well as parametric products such as arrival time picks, hypocenters, and magnitudes in real-time with NEIC. If the CISN does not report within several minutes on an earthquake that just occurred, the NEIC will release available information to ensure timely and accurate reporting. Once CISN has recovered from a failure or significant new information is available, it may update the information previously posted to the USGS hosted and other web sites.

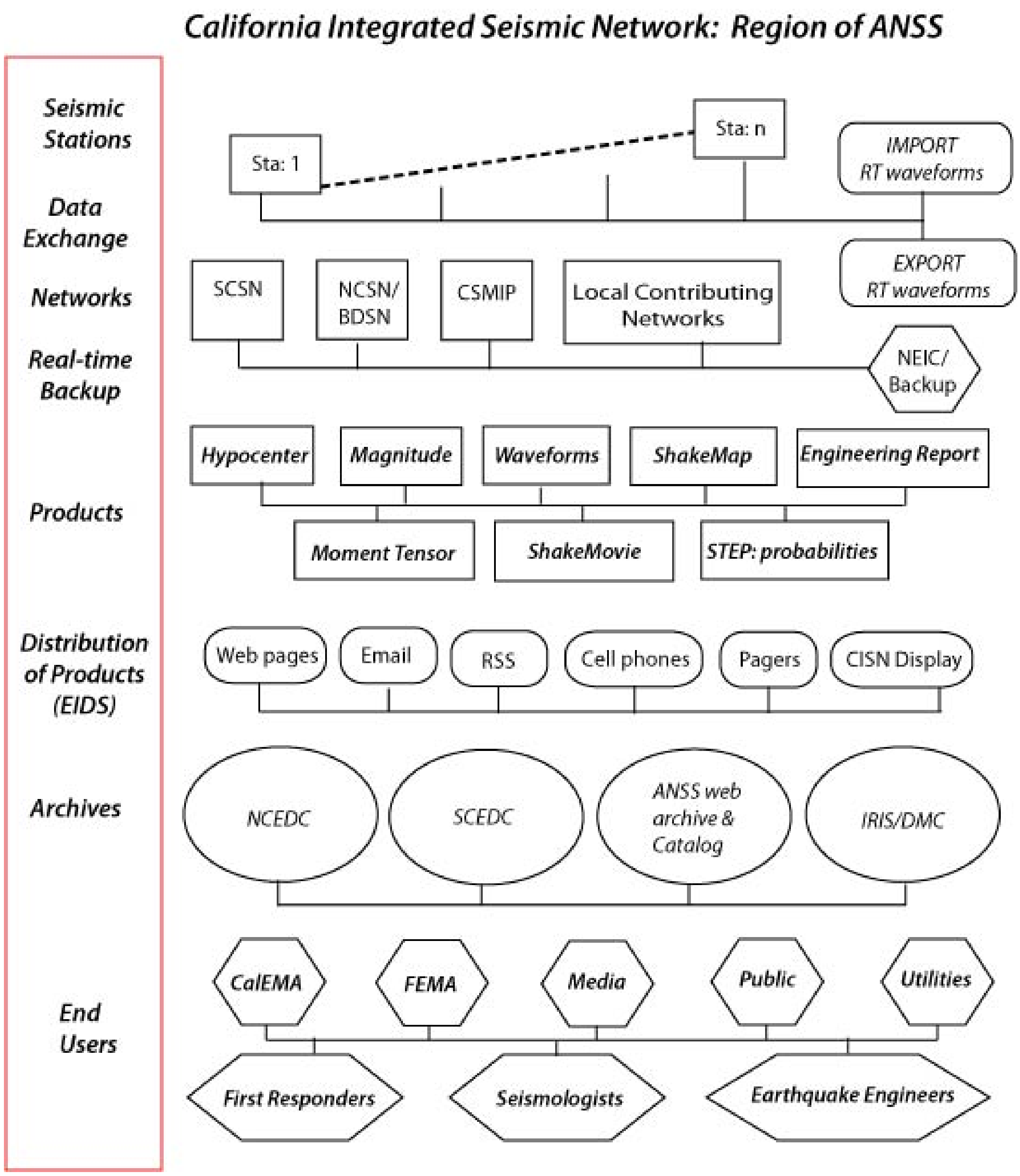

Figure 2 Schematic diagram showing the major elements and components of the CISN. (Left) list of major elements; (right) the various components of the CISN; CalEMA – California Emergency Management Agency; FEMA – Federal Emergency Management Agency; IRIS/DMC – IRIS Data Management Center; NCEDC – Northern California Earthquake Data Center; RSS- Real Simple Syndication; SCEDC – Southern California Earthquake Data Center; STEP – short-term earthquake probabilities.

3 Southern California Seismic Network (SCSN)

The authoritative earthquake-monitoring region of the Southern California Seismic Network (SCSN) extends across southern California, from the US-Mexico international border to Coalinga and Owens Valley in central California. The SCSN also reports on earthquakes in northern Baja California, Mexico because these could possibly cause damage in the United

States. The region is home to almost 20 million inhabitants, including two of the ten largest cities in the United States (Los Angeles and San Diego) and the two largest harbors (Los Angeles and Long Beach) in the Nation. Emergency managers use SCSN information to coordinate rescue operations, guide inspectors in the search for damage, and to facilitate disaster recovery. The media broadcasts the earthquake information to satisfy public need for information.

The SCSN processes and records real-time data from about 425 seismic stations (station map shown in Chapter 8.7). It operates about 300 seismic stations and receives real-time waveform data from an additional 125 stations operated by partner networks. The SCSN seismic stations can be divided into three groups. First, the most modern group of 167 SCSN stations consist of broadband sensors, strong motion sensors, and high resolution dataloggers for digitization and data communications. The data from these stations are used for real-time determination of earthquake locations, magnitudes, moment tensors, and amplitudes for ShakeMap. The second group consists of about 35 stations that are equipped with only strong motion sensors and a datalogger. These stations provide amplitudes for ShakeMap and occasional arrival-time picks. The third group consists of 125 short-period stations that use legacy analog, frequency-modulated (FM) audible tone technology and Earthworm digitizers for data acquisition. These stations are low-cost and can be installed at seismically quiet sites with minimal security. The waveform data can be transmitted for long distances using analog FM radio with very low bandwidth. Although, the amplitude data have limited dynamic range and are often only calibrated using nominal response values, these stations provide arrival-time picks for improved location and depth determination as well as coda duration for determining magnitudes of small earthquakes. Eight Earthworm hubs that are spread across southern California aggregate the SCSN short-period stations and transmit digital waveform data to the central site in Pasadena.

We use SeisNetWatch, initially developed by Caltech and later adopted by ANSS, to track the state of health of the stations. Various tools are used to check delivery and the presence of current waveform data within the processing systems. The tracking of mass centering and issuing of recentering commands is semi-automated. In addition, firmware upgrades on dataloggers are done remotely using command and control tools.

The data flow path from the remote seismic stations includes the on-site equipment, the data communications path, and a data acquisition computer at the central recording site. The last mile data communications to each site may use copper wire, spread-spectrum radios, or optical fiber. The main long-haul data communications include digital phone lines (frame relay or T1 lines) and digital microwave circuits. The waveform data are acquired by front-end processors that broadcast the data on a private local network. Many computers that are connected to this network capture and process the waveforms or capture the data for archiving. For instance, a processing thread of Earthworm modules carries out the real-time picking of arrival-times, association, and hypocenter determination. A different thread harvests amplitudes and determines local magnitudes. Similarly, an earthquake-early-warning processing thread captures the waveform data to facilitate testing of algorithms for ultra rapid determination of source parameters.

The AQMS software provides various buffers to allow for intermittent failure or maintenance of the acquisition and processing system. The dataloggers at broadband and strong motion stations can store several months worth of waveform data on site. In addition, each import server has some amount of waveform data storage as a backup feature. At the central recording site in Pasadena, wavepools that are populated with waveform data in real-time provide redundant storage for up to four months. These wavepools are accessed by many processes including the processes that perform final data archiving.

The Southern California Earthquake Data Center (SCEDC) archives all the SCSN data and distributes the products of the SCSN. The waveform archiving is done within minutes of the occurrence of the earthquake using a system of request cards. The data center issues request cards for both event triggered waveforms where each request card specifies a time window of waveform data for a selected station channel of data. It also issues request cards for six hour windows of continuous data to the wavepool that is operated as part of the real-time systems. All parametric data determined by the real-time systems are stored in the database. During post-processing, data analysts use tools to display the waveforms, modify or add arrival time picks or amplitudes. They can also relocate the earthquake and update the magnitude. All of these actions result in updates in the database for that particular event. As the SCSN processes the data for detected earthquakes, outside researchers can also access all the data in the database, within minutes or as soon as the data are entered into the archive.

The SCSN products include the southern California earthquake catalog, event gathers (triggers) of waveforms for nearly all events back to 1981 and for some events extending back to 1976, continuous broadband waveforms from 1999 to present, continuous instrumental record of earthquake occurrence in southern California that includes four earthquakes of M>7 extends back to 1932. The SCSN and the SCEDC have maintained and published a catalog of earthquakes with magnitude of completeness above magnitude 3.25 since 1932 and above magnitude 1.8 since 1980 with consistent magnitudes over the whole time (Hutton, *et al.* 2010). The catalog is used to produce societally useful products such as USGS earthquake hazards maps as well as by seismologists for research.

Subsets of SCSN waveforms are also archived at the IRIS/DMC. In the 1990s Caltech started collecting broadband data using a new seismic network called TERRAscope (network code: TS). These data were at first only archived at the IRIS/DMC. In the late 1990s TERRAscope was merged with the SCSN under the network code CI. In 2004 the SCSN began data sharing with Earthscope/USArray and those data are also archived at the IRIS/DMC. At present, continuous waveform data from a subset of about 65 SCSN broadband and strong motion stations are being archived at the IRIS/DMC.

For more information see related web sites:

http://earthquake.usgs.gov/monitoring/anss; http://www.strongmotioncenter.org

http://www.cisn.org; http://www.scsn.org; http://www.data.scec.org

http://www.ncedc.org; http://www.iris.edu

References

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