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The TriNet Project

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ABSTRACT

TriNet is a collaborative project of the California Institute of Technology, the California Division of Mines and Geology, and the U.S. Geological Survey to develop a digital seismographic network in southern California. TriNet will provide ground motion data having unprecedented frequency bandwidth and dynamic range throughout southern California, including urbanized areas. All stations will have 3-component, high-dynamic-range, strong-motion force balance accelerometers. In addition, all stations will have either real-time or dial-up digital telemetry. Many stations will have high-gain seismometers, many of which will be of the force-balance type with broad frequency responses. TriNet will enhance the traditional products of the existing regional seismographic network and strong-motion networks, and important new products will be developed. Major products of the TriNet project are: 1) near-real-time monitoring and cataloging of earthquakes in southern California, 2) broad-band ground motions from teleseismic earthquakes and other seismic sources, 3) strong-motion recordings from significant earthquakes, 4) near-real-time shaking intensity maps for emergency management, and 5) a pilot system for early warning of seismic shaking. Many other agencies (e.g., lifeline operators, emergency management agencies, etc.) are being included in the TriNet development.

KEYWORDS

Accelerograph; seismic; strong motion; network; California; early warning.

INTRODUCTION

In the past, several very different seismographic networks have been developed in southern California to meet different critical functions. The California Institute of Technology (Caltech) and the U.S. Geological Survey (USGS) jointly developed the Southern California Seismographic Network (SCSN). The primary function of this 250-station network has been to monitor and catalog seismic activity in southern California (Wald *and others*, 1995a and 1995b; see also). More than 200,000 earthquakes have been documented with this system which is comprised primarily of 1-second, vertical-component seismometers with continuous analog FM telemetry to the Caltech campus in Pasadena, California. While this system has successfully achieved its goal of monitoring seismicity in southern California, it does not record horizontal ground motions which are of primary interest for earthquake engineering. Furthermore, stations are operated at high amplifications and they are generally located at seismically quiet sites away from urbanized areas. Most of the data streams from this network are clipped when ground accelerations exceed 10^{-5} g.

In contrast, strong-motion accelerograph networks have been independently developed in southern California by the California Strong Motion Instrumentation Program (CSMIP; Shakal *and others,* 1988) and by the USGS National Strong Motion Program (USGS/NSMP). CSMIP operates more than 300 stations and the USGS/NSMP operates nearly 200 stations in southern California. The primary mission of these networks is to record strong shaking from significant earthquakes. Since strong shaking is infrequent, there was no reason to continuously telemeter data, and all stations are triggered only by strong shaking. Most stations record motions only at the accelerograph site and most of those recordings are on photographic film which must be collected and processed before ground motions can be analyzed. Furthermore, accelerations less than 10^{-3} g cannot be resolved by these networks. Strong motion accelerographs are commonly placed in urbanized regions to record damaging ground motions.

The primary functions of the regional seismographic network (SCSN) and the strong motion networks have been so disjoint that there has been little need for coordination in the development and operation of these different types of networks. However, recent advances in seismographic recording and telemetry systems are expanding the capabilities and missions of these networks so that it is now advantageous to coordinate their operations. In particular, advanced digital seismographic stations have digital communication capabilities and they record individual channels with 120 to 140 dB of dynamic range. As a result, both the regional seismographic network and the strong-motion networks are deploying stations that can record both weak and strong motions. Furthermore, data from advanced digital stations in the strong motion networks are now electronically retrieved within minutes of a significant earthquake. As a result of these advances, the SCSN has begun recording strong motions from significant earthquakes, and CSMIP has begun retrieving data from earthquakes in near real time.

The TriNet project will provide the overall coordination between the different networks so that data can be shared to better achieve traditional functions (earthquake monitoring and strong motion recording), and to also provide new functions that were previously unattainable. The most important new functions are the 1) near-real-time dissemination of the geographic distribution of shaking intensity to help coordinate emergency services, 2) development of a pilot early warning system for strong shaking, and 3) comprehensive recording of ground motions from relatively numerous moderate-sized earthquakes to better predict the characteristics of ground shaking in future damaging earthquakes.

This paper describes the general plan and objectives of the TriNet project. However, since overall funding for this project is currently uncertain, the number of stations and the schedule for their deployment is currently tentative. A more complete discussion of scientific goals and potential applications of seismic networks can be found in the National Seismic System Science Plan (Heaton, *and others*, 1989) and in a report from the National Research Council (Panel on Real-Time Earthquake Warning, 1991).

TriNet

The TriNet project plan currently calls for 700 remote stations (contingent on funding) and two data processing and distribution facilities located in Pasadena and Sacramento.

CSMIP would deploy 400 stations with three-component force-balance accelerometers recorded by 20-bit digital data loggers. In the interests of economy, only about 10% of the CSMIP stations will have dedicated telemetry, while about 90% of the CSMIP stations will have near-real-time dial-out digital telemetry. Data loggers at the CSMIP stations will have the capability of real-time telemetry if future funding becomes available for that function. As is usual for strong motion instruments, a copy of the data will be kept at the station and can be retrieved manually if the communications fail.

The Southern California Seismographic Network (SCSN), jointly operated by Caltech and the USGS Pasadena Office, will deploy 200 stations with continuos real-time digital telemetry. Each station will have 24-bit data loggers recording both strong-motion force balance accelerometers and high-gain force-balance seismometers with broad-band velocity outputs. Each station will be networked to the Caltech campus using dedicated digital telecommunications links with error correction.

In addition, the USGS/NSMP will deploy approximately 100 stations with three-component force-balance accelerometers recorded by 20-bit digital data loggers. At least half of these stations will also record high-gain seismic channels. These stations will be configured for either continuous real-time digital telemetry or for automated dial-out telemetry, depending on the availability of continuous digital telemetry lines.

The combination of digital telemetry together with the large dynamic range of the digital data loggers means that stations operated by CSMIP and USGS/NSMP can operate with substantially more sensitive event triggers than has been previously possible. Therefore, a large volume of data will be recorded by this new system (more than 2,500 individual channels of seismic data) from the relatively numerous moderate sized earthquakes in southern California. Data from smaller earthquakes will be sent to the SCSN data processing center at Caltech where they will be automatically processed and archived in the Southern California Earthquake Center's (SCEC) Data Center. This data will be stored on an optical jukebox (600 Gbyte), and data can be retrieved through the Internet.

When significant earthquakes happen, a multi-agency data reporting approach will be used. Early warning and initial strong motion information during the first few minutes after large earthquakes, and all information for smaller earthquakes, will come from the 200 real-time Caltech/USGS stations (SCSN) and from the CSMIP and USGS/NSMP stations with real-time telemetry. Early warning information will be produced and released by the data analysis center of the SCSN located on the Caltech campus. For the larger events, the approximately 400 near-real-time dial-out stations of the CSMIP will automatically transfer their data to Sacramento. As part of TriNet, all agencies will electronically exchange data. This will allow both Caltech/USGS in Pasadena and CSMIP in Sacramento to process the data independently, thus providing overall system reliability. Traditional products of Caltech, USGS, and CSMIP for their respective users will continue to be provided by these institutions as they are today.

Partnerships with other southern California agencies are currently being solicited. In particular, potential sites for stations located at critical facilities (major lifelines, dams, etc.) are being sought. Currently, the Pacific Bell Telephone Company (PacBell), General Telephone (GTE), the Southern California Gas Company, and the Metropolitan Water District (MWD) are actively participating in the project by providing either sites, digital telemetry links, or both.

Existing Projects supporting TriNet Development

Much of the seismic and communications technology that is proposed for the TriNet project has already been developed and demonstrated in smaller scale projects. In particular, Caltech has developed the 20-station TERRAscope broad-band digital network. Stations in this network have 3-components each of force-balance strong motion accelerometers (Kinemetrics FBA-23's) and force-balance broad-band velocity seismometers (Streckeisen STS-1's and STS-2's). 24-bit data loggers (Quanterra) provide these systems with a combined dynamic range of more than 180 dB between frequencies of 20 and .005 Hz. An additional 8 TERRAscope stations are planned for installation within the next 2 years. Currently about half of the TERRAscope stations have dial-up telemetry that is automatically triggered by the SCSN after detecting an event. The other TERRAscope stations have continuous digital telemetry. Two of these stations use satellite telemetry operated by the U.S. National Seismic Network of the USGS (Golden). The remaining stations use frame relay lines provided by a California Research and Education Network grant (CalREN) from Pacific Bell Telephone and GTE. The frame relay telemetry allows the TERRAscope stations to be networked to the Caltech campus using standard protocols such as TCP/IP, which is presently supported by the Quanterra data loggers. In addition to the TERRAscope network, Caltech and Kinemetrics Inc. have also developed a pilot network for automated real-time reporting of strong motion. There are currently 15 K-2 digital accelerometers located in Pacific Bell telephone office distributed in the greater Los Angeles metropolitan area and linked to the Caltech campus by frame relay lines. Many of these stations also record a vertical-component, 1-second seismometer. The K-2 data loggers can simultaneously telemeter continuous data and also store triggered strong motion data onsite for failsafe data recovery in the event of a telemetry failure.

The USGS is providing support for TriNet in several key areas. The hardware for 50 new stations funded by the USGS is on order. These stations have 6-channel 24-bit Quanterra data loggers with TCP/IP networking capability. In addition, 50 broad-band 3-component force-balance seismometers (Guralp CMG-40) and 50 3-component strong motion accelerometers (Kinemetrics FBA-23) have been ordered. These stations will be integrated into the SCSN. In the near future, data from these digital networks will be integrated into the Caltech/USGS Seismic Processing system (CUSP) that has been developed over the past 15 years to analyze and archive seismic data streams from the SCSN. The USGS/NSMP has also ordered 42 digital accelerographs (6-channel Kinemetrics K-2's) that can be configured for either real-time or dial-out telemetry capabilities.

CSMIP has also begun to develop near real-time dial-out telemetry systems in California. There are currently about 40 accelerographs that automatically download their data to Sacramento over standard modems. These stations are used to generate very rapid data reports on significant earthquakes.

There have also been significant progress towards development of a system to broadcast earthquake information rapidly during earthquake crises. In particular, the Caltech/USGS Broadcast of Earthquakes project (CUBE) has been in development for the past 5 years and currently 18 agencies are participating. The goal of this project is to promote the use of seismic information in real time. Currently, epicenters and magnitudes are broadcast on alpha-numeric pagers throughout the United States. One group of pagers is intended to be carried by emergency management personnel, and a second group of pagers feeds data through serial lines into personal computers operating under Microsoft Windows. Software is provided to display the location of the events. The CUBE project has also begun to transmit the peak accelerations from individual stations within minutes of an event. These real-time accelerations are also displayed on a map.

Discussion

Although funding uncertainties prevent us from presenting a detailed look at the future of seismic networks in southern California, the formation of the TriNet project is a major turning point for earthquake studies. New technologies for recording seismic data and for networked communications have opened a door into new applications for seismic networks, and they are enhancing the ability for seismic networks to perform their traditional functions. These new technologies are making data from regional seismographic networks valuable to those that have traditionally been concerned only with strong motion networks, and data from new strong motion networks is now valuable to those who have traditionally been concerned only with regional seismic networks.

Although the cooperation that is proposed in TriNet may seem to be an obvious direction for the development of seismic networks in southern California, TriNet planning has been and will continue to be a complicated process. The strong-motion and regional seismographic communities have fundamentally different roles that must be served by this project. Furthermore, the primary agencies involved (a Federal agency, a State agency, and a private university) have distinctly different management structures and overall missions. The involvement of many other agencies (such as railroads, telecommunications companies, State agencies, County agencies, etc.) is also essential for the successful development of the TriNet project. TriNet is providing a framework for how all these agencies can work together to provide seismic information that will greatly enhance our ability to plan for future earthquakes and to respond to them when they happen.

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