Real-Time Emergency Management Decision Support: The California Integrated Seismic Network (CISN)

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Introduction

Recent deployment of modern digital seismic instrumentation in California in combination with faster computing and sophisticated analysis software, has produced new capabilities with significant implications for public safety in earthquakes. Currently, magnitude and location of an earthquake are available in a few seconds, ShakeMap provides shaking intensity and other ground motion parameters within 5 minutes on the Internet and GIS-based software provide loss estimates in near real-time. One of the greatest challenges faced by those concerned with dissemination of information from these new networks and associated technologies is how to ensure that potentially beneficial information is effectively transferred to groups that can utilize it to improve emergency response, public information, preparedness and hazard mitigation.

A concerted outreach effort is being made to transfer new real-time information from the California Integrated Seismic Network (CISN) to the emergency services community, particularly first responders who need rapid information for situation assessment, search and rescue, shelter and mass care, mobilizing resources and initiating mutual aid. This effort involves the cooperation of the California Governor's Office of Emergency Services, the United States and California Geological Surveys, the University of California, Berkeley and the California Institute of Technology.

The objective of this paper is to describe new technologies for earthquake response and several strategies for scientific outreach in California directed to specific target groups, particularly emergency managers and news organizations. These strategies include the use of ShakeMap and HAZUS loss estimates to produce detailed exercise scenarios, focused workshops to tailor new information products for specific target audiences, and the integration of new information technologies in formats that maximize their value in responding to significant earthquakes.

The California Integrated Seismic Network (CISN)

In both the Northridge (1994) and Loma Prieta (1989) earthquakes, emergency response was delayed because the location and pattern of damage could not be immediately assessed. In the Northridge event, it required nearly an hour to obtain an accurate magnitude and epicenter location, parameters that, for smaller earthquakes had been available within a few minutes. In Loma Prieta, the extent of damage in Santa Cruz was not determined for nearly ten hours. In Northridge, the pattern of damage in Santa Monica and more remote areas was not reported for several hours.

In the aftermath of the Northridge earthquake, a partnership was formed among the Governor's Office of Emergency Services (OES), the Federal Emergency Management Agency (FEMA), the California Geological Survey (CGS) (formerly the California Division of Mines and Geology), the United States Geological Survey (USGS) and the California Institute of Technology (CalTech) to build a modern digital seismic and strong motion network in southern California that would provide real time reporting of ground motions. The TriNet system (Caltech, CGS and USGS) was the proof of concept that strong motion networks could be used to provide near real time maps of ground motions. TriNet was a significant advance over older analog systems and made possible a suite of products that superceded the earlier programs in which magnitude and location of earthquakes in California were broadcast to users over belt pagers.

In 2000, California OES proposed to the Governor that funding be provided to expand TriNet to provide coverage to northern and central California. Base line funding of $3.9 million was included in the Governor's budget for 2002 for expansion and operations of the California Integrated Seismic Network (CISN) that now includes Caltech, USGS (Menlo Park and Pasadena), UC Berkeley, the California Geological Survey and OES. Funding is expected for a minimum of five years to expand and operate the state wide network and provide outreach to engineers, emergency managers, utility companies, police and fire agencies, schools, the news media and other potential users of near real time earthquake ground motion data.

Priorities for CISN include robust data notification and archiving, delivery of ShakeMap and other earthquake information to emergency managers, the provision of statewide ShakeMap input files to HAZUS, and the creation of an online CISN Engineering Data Center. In cooperation with the USGS Pasadena and with funding from FEMA, OES is currently developing software and technology to provide ShakeMap input for automated earthquake loss estimation using HAZUS. This innovation promises to provide state and federal emergency managers with early estimates of damage, casualties and the number of displaced persons needing care and shelter, and their demographics. CISN, as a Region of the Advanced National Seismic System (ANSS) initiative of the United States Geological Survey, ensures that the CISN and ANSS activities in California are coordinated and are consistent with state and national priorities.

CISN Products and Strategies for Dissemination

Shakemap

ShakeMap (See Figure 1) is available very quickly following a significant earthquake (Wald, et al, 1999). Given that ShakeMap is an Internet based product, one of the first efforts to raise awareness of the availability of ShakeMap and promote its utilization was a postcard campaign that encouraged carefully selected users to "bookmark" ShakeMap on their computer or list it as one of their "favorites." The target audience for the postcard campaign included first responder groups summarized under the title of emergency managers. This category included police, fire services, emergency planners, building officials and others who have a primary role in responding to an earthquake. Several thousand postcards have been distributed since 1998.

Both USGS scientists involved in the creation of ShakeMap and outreach personnel took part in the development of presentational material and sought opportunities to speak at conferences, workshops, seminars and meetings attended by the target groups identified above. In California, the California Specialized Training Institute provides in-service training for first responders and ShakeMap has been prominently featured through a lecture offered on a monthly basis at CSTI entitled "Using New Technologies in Managing Earthquake Emergencies." In addition, ShakeMap was featured in three regional earthquake conferences staged in southern California entitled the "Emergency Operations Center in the 21st Century."

In recognition of the fact that members of the public obtain emergency period information and instructions from the news media, particularly television news, ShakeMap was modified for presentation on television (Goltz, 2000). A simple format was adopted in which acceleration and velocity, measures of ground motion unfamiliar to most people were eliminated and a simple color-coded chart describing intensity as "weak," "moderate," "strong" and so forth was adopted. The only number that remained on these TV ShakeMaps was the magnitude. The TV ShakeMaps are available to download by news organizations in several formats. Members of the computer-using public may also participate in creating an intensity map by linking to the Community Internet Intensity Map (Wald, et al, 1999) website and filling out a brief questionnaire. Responses to this "Did you feel it?" intensity map are tabulated by zip code and displayed on the CIIM site (See Figure 2) operated by the US Geological Survey.

ShakeMap and HAZUS

HAZUS is a term for Hazards USA and is a nationally applicable loss estimation methodology for earthquake, flood and wind hazards. It provides estimates of direct damage including estimated damage to buildings, critical facilities and utilities and transportation lifelines. Estimates are also calculated for induced damage including fire following an earthquake and debris generation. HAZUS provides estimates of losses based on building damage, outage and damage to transportation and utility lifelines and long-term economic impacts. Finally, HAZUS generates estimates of population impacts in terms of the number of casualties, both deaths and various degrees of injury, and the number of households likely to require shelter and mass care.

HAZUS is GIS-based and the data inputs for loss estimation include geological information, building and lifeline inventories and census data (FEMA/NIBS, 2000). Although HAZUS was not originally designed to be a response tool, some in the hazards research community recognized the potential utility of loss estimates as a supplement to other real-time information technologies in providing decision support following a damaging earthquake. Over the past year, methods have been devised to reduce the run time required for loss estimates to be generated from 4 hours or more to just 10 minutes. Thus, HAZUS is a versatile planning and response tool that, in combination with other technologies, can provide valuable decision support from the immediate aftermath of a damaging earthquake to the recovery and reconstruction period that follows.

Developing an interface between ShakeMap and HAZUS had several advantages. When first introduced, the HAZUS methodology relied upon the magnitude of the earthquake and location to generate loss estimates. This arrangement required that a number of assumptions be made regarding direction of rupture, the distribution of ground shaking and other parameters. When based on actual ground motion records from instruments responsible for generating ShakeMap, HAZUS loss estimates were freed of dubious assumptions about the distribution of ground motion, providing a sound basis for estimates. The capability to rapidly calculate loss estimates in California make this ShakeMap/ HAZUS interface a more useful and robust emergency response tool by facilitating a suite of geological, economic and societal impact information for emergency planners in real-time.

The availability of ShakeMap/ HAZUS has been promoted through workshops and training for emergency managers as well as use of these technologies to generate very realistic scenarios for earthquake exercises and drills. In addition, a system has been established for the California Governor's Office of Emergency Services to receive and rapidly process ShakeMap shapefiles from the seismic network, use these data to rapidly and automatically process HAZUS and produce maps and reports that are shared with local government via a hardened communications network called the Response Information Management System or RIMS. Thus, the ShakeMap/HAZUS interface provides a rapid, accurate and useful set of data for response and is available by the time the first responder arrives at the emergency operations center. Another obvious advantage of this system is that all response agencies are responding to the same information.

Rapid Assessment of Critical Infrastructure

An important milestone in the expanded utility of strong ground motion data was the integration of the California Strong Motion Instrumentation Program (SMIP) with the California Integrated Seismic Network (CISN) and the addition of near-real time telemetry to all strong motion stations under the TriNet Project. The availability of rapid strong motion data facilitated the development of a more accurate and robust ShakeMap and opens the possibility for rapid assessment of infrastructure with major potential benefits for emergency response following a major earthquake.

The California Geological Survey anticipated that an expanded strong motion network and near real-time availability of these data would have utility for an expanded set of user groups. In 2000, the CGS awarded a contract to the Applied Technology Council (ATC) to develop guidelines for using strong motion data and ShakeMaps in post-earthquake response. ATC presented a draft of the guidelines at a workshop held in Oakland on June 14, 2002. The ATC –54 Guidelines envision the interpretation of strong motion data in a time frame of minutes to hours following the occurrence of a significant earthquake

(ATC, 2002) opening the possibility that such data could be used for rapid damage assessment of buildings and critical infrastructure.

In addition, CGS has made strong motion data for significant earthquakes (M≥4) publicly available through the creation of Internet sites for rapid access by users. These sites include the CISN Engineering Strong Motion Data Center http://docinet3.consrv.ca.gov/csmip/cisn-edc/default.htm the Internet Quick Report http://docinet3.consrv.ca.gov/csmip/cisn-edc/iqr1.htm and Internet Data Report http://docinet3.consrv.ca.gov/csmip/cisn-edc/idr/idr.htm. The purpose of these sites is to "provide rapid information after an earthquake, ranging from ShakeMap to distribution of the data and calculated parameters"

Integrating Real-Time Information

The rapid evolution of real-time seismic information has raised an issue of effective delivery of this information through mechanisms that are available to all users and in formats that are readily accessible. Currently, in beta-testing mode is the CISN Display, a web-based application which promises to become a vehicle for delivery of real-time seismic information from multiple sources. These data include: source data such as magnitude, location, and focal mechanism, ShakeMap and the Community Internet Intensity Map; loss estimates from HAZUS; ground displacement information from the GPS network; and various reports from OES and commentary from seismologists.

In addition to providing a platform for the delivery of information from multiple real-time sources, it also has the potential to select certain information of particular interest to the user, thus allowing some customization. The CISN Display features the OpenMap GIS mapping tool that can be used to plot organizational assets and facilities on the Display's map base, thus providing a quick reference to potentially impacted resources.

While the technologies outline in this paper are promising, the effort to develop decision support systems presents significant challenges. The technologies and the networks, agencies and institutions that support them are independent and integration must overcome organizational and disciplinary barriers. Clearly, funding must be secured to support the development of models, software and pilot testing. In addition, new technologies must be effectively transferred through outreach programs that can bridge the gap between science and practical application in an environment in which the products of science are often poorly understood.

Nevertheless, the development of ShakeMap, its interface with the HAZUS loss estimation software, and the new CISN Display are welcome advances that have strong potential to increase the efficiency and timeliness of emergency response and recovery. Despite the barriers that must be overcome, the advantages in life safety and property damage reduction make the challenges worth confronting.

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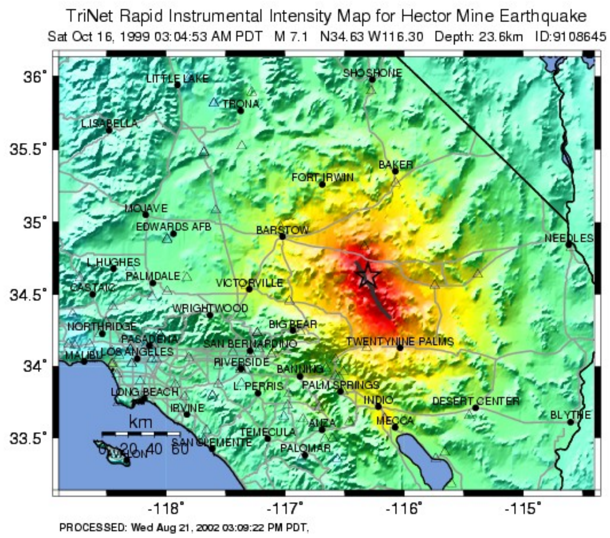
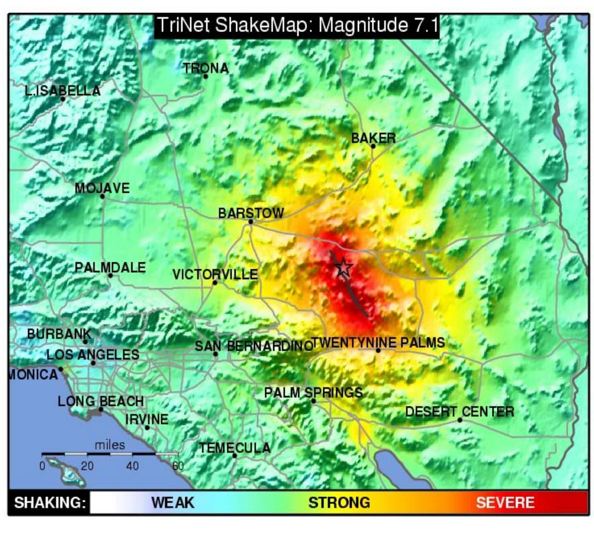
Figure 1



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

ShakeMap for the Hector Mine earthquake
of October 16, 1999

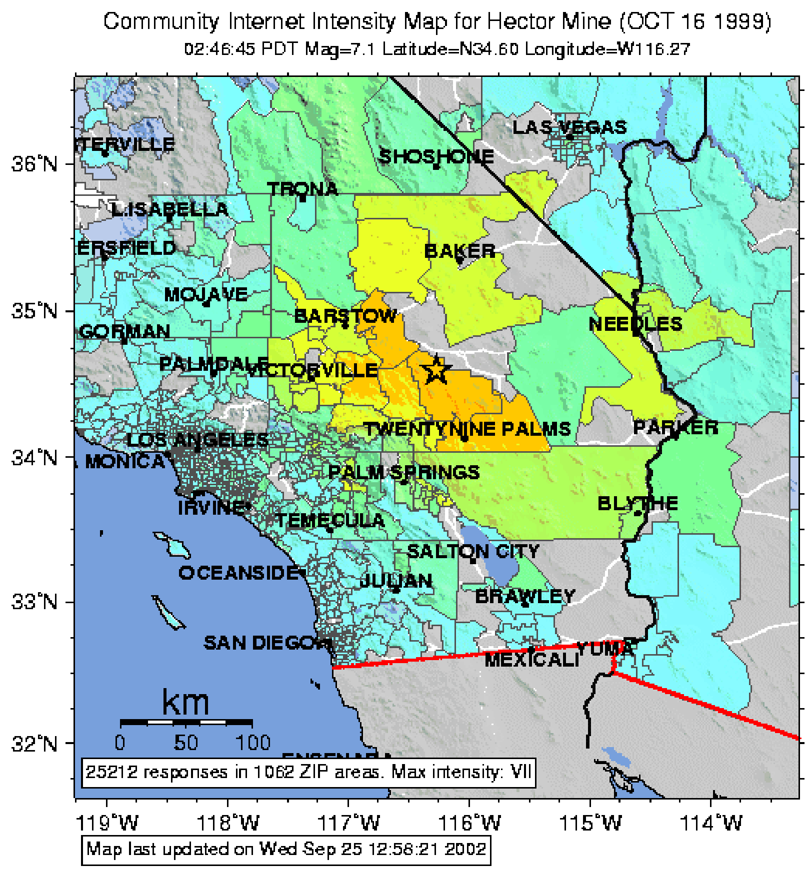
Figure 2



Media ShakeMap for the Hector Mine earthquake of October 16, 1999

Figure 3

Event Hector_Mine: **ZIP Map** | Additional Maps and Data | Did you feel it? Tell us! | Statistics



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

Community Internet Intensity Map for the Hector Mine Earthquake of October 16, 1999.