California Integrated Seismic Network

Strategic Plan: 2002-2006

Caltech

CGS

OES

UC Berkeley

USGS, Menlo Park

USGS, Pasadena

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Table of Contents

1 Executive Summary

Large earthquakes in California are inevitable. The degree to which future losses of life and property in the State from these earthquakes can be mitigated depends on our collective understanding of the earthquake problem and our investment in learning how to mitigate the earthquake effects. Seismic monitoring is the foundation upon which earthquake understanding and mitigation practices are built.

This report is an assessment of the needs and an outline of the strategy for developing an integrated seismic network for the State of California. A modern statewide earthquake monitoring and reporting system is fundamental to obtaining timely and accurate seismic information, the cornerstone of an effective mitigation strategy for the State. This California Integrated Seismic Network (CISN) will organize and manage the collection and distribution of seismic information and develop and provide new products and services. The CISN also constitutes one of the eight regions within the Advanced National Seismic System (ANSS) structure, and it participates fully in ANSS activities.

Rapid earthquake notification and automatically generated maps of the distribution of damaging shaking levels (ShakeMap) provide critical information in the aftermath of large earthquakes. Through modernization, the CISN will provide these products on a statewide basis. In addition, many structures throughout California were designed without adequate knowledge of the level of strong ground motions to be expected from a major earthquake. The CISN will collect and distribute strong-motion information that will enable the engineering community to monitor how structures actually perform during strong earthquakes. Finally, many fundamental scientific questions about earthquakes remain unanswered: for example, what controls the magnitude of an earthquake, and what controls where the earthquake rupture will terminate. The CISN will collect, archive and provide the seismological data necessary to address these research questions as well.

The focus of the California Integrated Seismic Network (CISN) is modernization and operation of a robust seismic network infrastructure statewide. The TriNet project, primarily funded by the Federal Emergency Management Agency (FEMA) through the California Office of Emergency Services (OES) and the U.S. Geological Survey following the 1994 Northridge earthquake, provided the basis for modernizing the seismic network infrastructure in southern California. It is the mission of CISN that this network infrastructure be extended statewide, streamlined, and integrated into a coherent network, and that this network be supported and operated in the long term in a way that improves the safety of the people of the State of California during and after future earthquakes.

2 Defining the California Integrated Seismic Network (CISN)

Advances in technology have made it possible to integrate existing, separate earthquake monitoring networks in California into a single seismic monitoring system. Each of these networks has been collecting seismic information that serves some of the needs of the State, but no single network fulfills all of the requirements. By integrating these monitoring efforts into a single system, researchers and users can access a complete and well-organized database. The California Integrated Seismic Network (CISN) provides the organizational framework to coordinate these earthquake-monitoring operations. The CISN constitutes the California region within Advanced National Seismic System (ANSS). It is governed by a memorandum of agreement (MOA) among the core members (USGS Menlo Park, USGS Pasadena, Caltech, CGS, and UC Berkeley) with the Governor's Office of Emergency Services as an ex officio participant (see Appendix 2).

2.1 Mission of the CISN

The mission of the California Integrated Seismic Network is to operate a reliable, modern, statewide system for earthquake monitoring, research, archiving, and distribution of information for the benefit of public safety, emergency response, and loss mitigation. Further, the CISN seeks to mitigate the impact of future earthquakes by collecting, processing, and disseminating critical earthquake information in a timely way.

2.2 Goals

To achieve this mission, the CISN has identified the following primary goals:

1. Operate and maintain a reliable and robust statewide seismic monitoring system to record earthquake ground motions over the relevant range of frequencies and shaking levels.
2. Distribute information about earthquakes rapidly after their occurrence to a broad spectrum of knowledgeable users to improve the State’s emergency response capability and to better inform and educate the public.
3. Create and maintain an easily accessible archive of California earthquake data, including waveform data and derived products, to stimulate engineering applications and further the seismological understanding of the locations and causes of future earthquakes throughout the State.
4. Develop new algorithms for analyzing earthquake data and creating new user products by applying the latest research and technological discoveries.

2.3 Objectives

The CISN has identified the following specific objectives for achieving these goals:

1. Integrate current monitoring networks into one statewide system with redundant data retrieval, storage and processing capabilities through improved communications systems, software, and standardization.

2. Expand the capabilities of the statewide, integrated seismic network by increasing station density, improving instrumentation, enhancing data processing systems, and increasing the speed of reporting.
3. Improve robustness of data retrieval, processing, and uniform reporting capabilities at each processing center so that there is no single point of failure in the statewide network, especially after a major earthquake in any part of the State.
4. Develop and incorporate new seismological algorithms and technologies that utilize improved data fidelity and spatial density in the network to provide more user-relevant products.
5. Implement a statewide, virtual, seismic data center to provide seamless data access for technical researchers, emergency professionals, and the public in formats suitable for each group.
6. Identify and train potential users in the use of new products from the CISN.

2.4 Products

The CISN will:

1. Rapidly available reports of key technical parameters for all significant earthquake activity in California. Earthquake source parameters will be issued within minutes of the occurrence of an earthquake. These will be distributed electronically, via Web sites, e-mail and robust communication pathways for emergency responders. As technology improves, rapid notification may advance to rapid alerts that precede the arrival of strong shaking at more distant sites.
2. Maps depicting the distribution of ground motion and shaking intensity (e.g., ShakeMap), to guide emergency response operations and damage assessments immediately following a significant earthquake in California. The maps, based on ground motion parameters from seismic stations, will be distributed electronically within minutes following the occurrence of the earthquake.
3. Reports and archives of strong motion records of engineering interest. Reports of strong ground motion records (e.g., Quick Reports) will be produced rapidly for significant earthquakes to facilitate engineering use of the data. These reports may also include data from structures, response spectra, and other relevant information. Archives of strong motion records from all the CISN partners will be produced and made available online, for access by the engineering community and the public alike.
4. An archive of seismological data for all recorded earthquakes. Ground motion records from all CISN partners, including strong motion stations, will be analyzed and archived for easy retrievability to facilitate seismological use of the data. A common earthquake catalog will be produced for online, public access.
5. Imporved seismological algorithms for characterizing ground motions and rapid reporting of near real-time earthquake parameters, including mechanisms, seismic

moment, depth, rupture information, and other source parameters for moderate-sized to major earthquakes.

6. Training documents and workshops covering the uses of the CISN products for disaster reduction. This outreach effort focuses on emergency responders, contingency planners, public information media representatives and others. The CISN will also provide a unified, simple means of access to all the data in all CISN-sponsored databases.

3 Developing and Delivering CISN Products

The CISN consists of a group of institutions with recognized capabilities and experience in improving the delivery of critical seismic information to decision-makers and direct users throughout the State of California. With the advent of a new generation of recording instruments and new data transmission and processing tools, we have the opportunity to measure, collect, and analyze seismic data an order of magnitude more quickly and accurately, which in turn opens some unique new ways to improve public safety and reduce losses from future earthquakes. Success requires the coordinated effort of several organizations, who have formed CISN in order to systematize the handling of seismic data in near-real time immediately after the earthquake strikes. The scope of the effort, and an overview of the specific action items to be undertaken by CISN in the coming five years are described in this section of the Plan.

3.1 Provide Rapid Reports for Public Safety

Rapid earthquake notifications are an essential tool for post-earthquake response. Information about the location and magnitude of an event - typically available less than 2 minutes after an event - answers the initial questions of "Where?" and "How large?". When coupled with maps of strong ground shaking, which can be available within 5 minutes of the end of shaking, the seismic information allows the emergency response manager to begin to answer the questions related to overall impact: "What facilities need to be inspected?", "Where should resources be concentrated?", and "What additional assistance is required?" Seismic information about the earthquake location, size, and area(s) of greatest impact is critical to improving emergency response. It is necessary for estimating the probabilities of large aftershocks. And it has a primary role in informing (and thus reassuring) a generally traumatized public about what has just happened, how bad it is (in a qualitative way), and what may or may not happen next.

The advent of digital communications and the development of reliable real-time systems to compute information about earthquakes have revolutionized the manner in which seismic networks now distribute data. In the early-1990s the Caltech-USGS Broadcast of Earthquakes (CUBE) system was a major advance in the robust distribution of earthquake information. This CUBE system integrated the information received by an alphanumeric pager with dedicated DOS display software, but it only met the needs of a few hundred clients. However, within a few years earthquake information was distributed to tens of thousands of users via the Web. Anticipating future developments in the communications industry is difficult, but the CISN must design a flexible system to take advantage of changes in technology..

The CISN management centers are responsible for generating and distributing CISN products. A near real-time earthquake catalog will be generated and distributed by the southern and northern management centers with primary and secondary reporting areas. All three centers will generate ShakeMaps routinely and the north and south centers have primary responsibility for their distribution, while the engineering center provides a backup capability. The engineering center has responsibility for quality control and distribution of data and products of engineering interest.

Product distribution can occur via "push" mechanisms, such as pagers, ftp, and email, in which the CISN actively sends the information to the client, and via passive systems in which the user must seek information from Web pages (Figure 4). Likewise, the way that the information is released will vary with the needs of the recipient. Users accessing the information over the Internet might see a ShakeMap portrayed as a map that can be easily understood, whereas as the emergency response community may require that the same ShakeMap be pushed to them as a GIS file. In all cases, the issues of robust operation are criticial. The design of the distribution system must include eliminating single points of failure.

With unlimited bandwidth and resources, all information could be mirrored across the State, so that information distribution would not be impeded during disruptions to communication infrastructure. However, only a subset of the CISN user community requires access to robust and reliable delivery of earthquake information in near real-time. The emergency response community needs rapid delivery of the earthquake location, magnitude, and distribution of shaking to be able to assess the impact of earthquake and issue an appropriate response. The CISN makes extensive use of the Internet to distribute real-time information, but it is unlikely that the Internet will be fully functional in the area impacted by the earthquake. For CISN clients who require reliable delivery of earthquake information (e.g., OES, FEMA, and NOAA), the CISN will also transmit information via direct radio communication if feasible, or transmit data via a satellite system. We will also take advantage of the vast communications infrastructure available to the media by providing suitable products (graphics and information) for direct television and radio broadcast following significant earthquakes for achieving more general distribution.

Even when there has not been a devastating earthquake and the communication infrastructure is functional, the CISN management centers will distribute earthquake information via robust methods to avoid single-point-of-failures and saturation of Internet/server bandwidth. Currently, the CISN northern and southern California management centers distribute earthquake information using the Quake Data Distribution System which transmits information in near real-time to clients from redundant hubs in Menlo Park, California and Reston, Virginia. The CISN also "mirrors" information on multiple web sites in Reston, Virginia, and in Menlo Park, Berkeley, and Pasadena, California.

The forms of these reports are currently the ShakeMaps, the television versions of ShakeMaps (which are pushed automatically to television networks requesting the feed), the seismological and engineering versions of Quick Reports, and an input data set or HAZUS calculations. Additional reports are likely to be developed during the next five years, as better data recovery and handling procedures generate new opportunities.

The Northern and Southern California Management Centers have the lead responsibility for providing input to the rapid notification process, and for issuing the notifications themselves. They must work together to re-design their earthquake monitoring systems to process and report data consistently, and to provide adequate overlap so the notifications can be issued for any part of the State, as needed. Several steps are needed to achieve this objective:

- Install high-speed robust data communication links among the CISN partners, and between CISN and OES and other key emergency responders;
- Operate the Northern and Southern California Management Centers as twin earthquake processing centers.
- Exchange waveform data in real time between centers and directly from remote stations to both centers.
- Establish protocols and proceedures for statewide earthquake reporting.
- Develop and implement software to monitor "state-of-health" for each center.

3.2 Deploy New Stations

To accomplish the CISN goals, we plan to deploy a new generation of modern seismic instrumentation. Our planned deployment is consistent with the requirements set forth in the ANSS planning document (USGS Circular 1188, 1999), with several enhancements as discussed below. Our California plan, shown in Table 1, considers the need for six classes of seismic stations and structures instrumentation across the State:

1. Urban stations with strong motion accelerometers (Figure 1);
2. Regional stations with broadband sensors and strong motion accelerometers (Figure 2);
3. Regional or urban short-period seismic stations with a single component vertical seismometer and a strong motion accelerometer;
4. Regional short-period stations;
5. Urban stations with sensors installed in boreholes; and
6. Seismic instrumentation of selected buildings, structures, and lifelines.

Table 1. CISN Instrumentation Plan

	Southern California		**Northern California**		**Statewide**	**Statewide**
	Existing	New	Existing	New	New	Total
Urban SM	475	825	200	760	1585	2260

BB + SM	150	100	32	218	318	500
SP + SM	25	100	30	150	250	305
SP analog	140	0	340	0	0	200
Borehole	15	35	35	25	60	110
Structures	100	100	100	100	200	400
Total					2415	3777

In the final network layout, we intend to locate approximately one strong motion station in each zip code across the State, subject to some specific recommendations by the Strong Motion Instrumentation Advisory Committee (SMIAC) for instruments in urban buildings. SMIAC provides recommendations to the California Geological Survey Strong Motion Instrumentation Program (CSMIP) for locations of instruments in buildings, based on the engineering significance of the resulting data. The selection of zip codes as a way to distribute strong motion instruments strikes a balance between a broad geographic spread of the instruments and a concentration of instruments in urban settings where ground response and building response are especially critical to public safety.

To be able to understand and predict the performance of structures during large earthquakes, it is necessary to record shaking both within the buildings and in the ground (free field) nearby. There are currently approximately 675 modern urban strong ground motion instruments in the state (Table 1), and 2415 "new" in Table 1 need to be added to complete the coverage. Their distribution is shown in Figure 1, and at first glance, there may appear to be adequate coverage in the San Francisco and Los Angeles urban centers. However, the insets show that the inventory of urban stations needs to be still more dense if it is to meet the CISN requirements, based on the ANSS assessment for California. That assessment calls for 3020 new instruments in California, with approximately half for buildings and half for free-field stations. Our CISN plan for the number of new urban stations is slightly larger than the number proposed in the ANSS assessment (USGS, 1999). In developing Table 1, we recognize that an adequately instrumented structure will have many more strong-motion sensors than a ground station, since the structure is commonly instrumented at several different levels. Thus the number of structures will be considerably fewer than the number of instruments called for in the ANSS assessment (Figure 2).

The upgraded regional stations that in many cases will replace short period seismic instruments will provide broadband waveforms for source and wave propagation analysis. They will also capture valuable data from earthquakes that occur outside the urban areas. These stations will make it possible to monitor many regions of high seismic risk (e.g., urban areas adjacent to major late Quaternary faults), the Long Valley volcanic region, regions with active seismicity and scientific interest (e.g., Imperial Valley and Eastern California Shear Zone, creeping section of the San Andreas fault, Cape Mendocino and the Gorda plate subduction zone), and regions of perceived future risk (e.g., locked sections of the San Andreas fault). However, the number of broadband stations planned for the CISN is less than the number of analog short-period seismic stations currently operating in the state. To maintain the existing capability of seismic monitoring and to meet the above monitoring goals, the CISN plans to supplement the broadband regional stations with approximately 300 stations consisting of vertical, short-period seismometer and a tri-axial accelerometer.

Table 2. Seismic stations needed for various urban areas[a]

Urban Area	Earthquake Hazard in %g[b]	Population in Millions	Risk Factor[c]	# of Urban stations[d]
Los Angeles	88	15.4	5.12	1,300
San Francisco	99	6.5	2.43	1,000
San Diego	25	2.6	0.42	300
Santa Barbara	52	0.4	0.08	100
Salinas	43	0.4	0.07	100
Sacramento	17	1.6	0.10	100
Stockton-Lodi	18	0.5	0.03	60
Fresno	12	0.8	0.04	60
Total				3,020

[a] After Table 3 of U.S.G.S. Circular 1188
[b] Severity of ground shaking (in percent of gravity) that has a 10% chance of being exceeded in the next 50 years
[c] Relative risk factor equals the hazard (not shown) multiplied by the population
[d] Half are proposed for ground stations and half for structures

At present there are about 50 borehole stations operating in California. These sites provide valuable data on earthquakes for several reasons. In urban areas, the level of seismic noise generated by cultural activities renders most seismic stations useless except for recording only earthquakes above M3. This noise is greatly diminished in borehole installations and makes it possible to record smaller earthquakes in critical locations. In addition, recording downhole and surface motions can provide valuable information pertaining to site amplification, soil nonlinearity, and attenuation of energy. Seismic instrumentation is also installed in boreholes that contain strainmeters, such as along the Hayward fault. Although USGS Circular 1188 does not address borehole installation, we recommend that about 110 stations be installed in boreholes across the entire state.

The following specific activities have been identified:

- Deploy instruments to achieve the estimated numbers shown in Table 1 for California;

- Engage the SMIAC to help locate and design instrumentation for buildings in California;
- Locate additional sensors in available boreholes as financial constraints allow.

3.3 Achieve Statewide Integration

The CISN is committed to operating a robust system that will reliably acquire and distribute earthquake information. Reliable operation is essential if earthquake information is to be of use to the emergency response community. In addition the failure to record a significant event means that the seismological and earthquake engineering communities lose valuable data for conducting research. To achieve a highly robust system, single-points-of-failure must be addressed in the design phase. The CISN must be developed so that disruptions to a CISN processing center do not affect the monitoring or reporting capabilities of the entire system.

Achieving 100% redundant or duplicated capabilities would require the simultaneous transmission of waveform data directly from the 1000+ seismic stations in California to at least 2 of the CISN processing centers, which is prohibitively expensive with the present generation of telemetry and seismographic equipment. The CISN is developing plans where a core group of seismic stations will have the ability to transmit continuous waveform information from the seismometer to multiple centers (Figure 3). This is currently possible only with a few types of digital data acquisition systems (continuous and triggered), a few types of telemetry protocols, and in areas where such protocols are offered. This direct feed from the seismic stations will be complemented, by exchanging data between processing centers. The CISN is designing a system that will take advantage of satellite communications as well as landlines among the operations centers to ensure system robustness.

The combination of center-to-center and station-to-center data exchange will provide the capability of reliable statewide earthquake reporting at multiple processing centers. In the case of a catastrophic failure of a CISN processing center, it is the goal of CISN to provide reporting from an alternative center, to maintain full reporting capabilities of the statewide system.

In addition to the effort to establish reliable reporting within the processing centers of the CISN, the CISN will exchange data with the USGS National Seismic Network (USNSN) so that this national facility can serve as an additional resource for reliable reporting capability. The USNSN will only have CISN data from California and thus have limited ability to respond, in case the CISN centers are no longer forwarding data to the USNSN.

Specific activities required of the CISN in this area are:

- Identify single-points-of-failure issues associated with data acquisition, processing, and product distribution, and resolve these as appropriate;

- Identify and if feasible, implement redundant communications paths that would permit more robust transmission capabilities for both data and products;
- Enhance software and hardware for exchanging data between Centers;
- Expand the seismic stations reporting to multiple centers to facilitate statewide processing;
- Record copies of data of engineering interest at the seismic stations, in the case data communication links fail;
- Improve protocols for exchanging data and product distribution with USNSN Golden, Colorado.

3.4 Standardize Products

To operate as an "integrated" seismic network, the CISN must coordinate the acquisition of data, reporting activities, and products of each of the individual reporting networks so that the CISN appears seamless.

Although some of the member seismic networks utilize common software, much of the software is unique to each institution because it was developed specifically to address their program mission. Some networks acquire continuous real-time information, while others operate triggered stations that call a central site after an earthquake. Networks acquire data from different data loggers, different sensors, and digitize the data at different sample rates. Some networks archive continuous waveform data, while others archive only event waveforms. Some release data in near real-time, and others only after rigorous quality assurance. Standardization of complex and sophisticated software is necessary if the information reported by each CISN member is to be consistent.

Conflicting reports of earthquake information confuse the public, user communities, and emergency response efforts. In order that each CISN member network releases consistent information, each member network must be able to compute the same result with the same software using the same data. The implementation of common software by each CISN network will be conducted in a manner that does not compromise the real-time operations of its member networks. The effort to standardize operations will likely proceed by first adopting high-level software that computes, for example, location and magnitude, while low-level software that controls data acquisition at each institution will remain intact to ensure sustained and reliable operations. Ultimately, the CISN institutions are likely to participate in software development for the entire nation under the Advanced National Seismic System (ANSS).

Specifically, the CISN will be conducting the following activities:

- Calibrate algorithms to ensure that CISN products are standardized statewide;
- Improve exchange of parametric data and waveform data to facilitate standardized product generation at the CISN centers;
- Develop methods to report, update, and withdraw parametric information in CISN databases;

- Develop and implement approaches to exchange station meta data to ensure consistent reporting;
- Participate in the ANSS algorithm analysis and deployment program, to help assure consistency in the National program as well.

3.5 Provide Strong Motion Records for Engineering Use

The Engineering Management Center has the lead responsibility for producing engineering data products. The California Department of Conservation's Strong Motion Instrumentation Program (CSMIP) in the California Geological Survey will operate the Engineering Management Center in cooperation with the USGS/National Strong Motion Program (NSMP). The Engineering Management Center will provide data from CSMIP and NSMP stations, and assemble strong motion data sets for the earthquake engineering community from all CISN stations. In addition, the Engineering Management Center will provide strong motion records from their stations of small earthquakes, for seismological and site response studies. Finally, the Engineering Management Center will serve as a limited backup facility for the statewide earthquake notification system, including the capability for generating ShakeMaps.

An important engineering application of strong motion records is rapid post-earthquake analysis of building and infrastructure performance, in support of the longer-term development of improved building code provisions. The Center will develop innovative approaches to delivering strong motion data in user-friendly formats and interfaces to support these engineering applications.

Some of the specific work activities include:

- Complete the newly formatted Quick Reports for organizing and delivering the suite of strong motion records generated by each new earthquake within 48 hours;
- Complete documentation of the geologic and topographic details of free-field strong motions sites, and the structural details of individual buildings and other structures that have been instrumented to date;
- Direct the efforts of expert engineering teams for selecting candidate buildings and designing the arrays of instruments in the selected buildings;
- Archive engineering data in a user-friendly format, particularly designed for engineering users;
- Continue annual review meetings that summarize progress in analysis of engineering data for structures;
- Provide data input to code developers and performance-based engineering researchers for new seismic response models.

3.6 Create Seamless Archive of Seismic Data

The data produced by the CISN will be fundamental to the understanding of earthquake source processes, the cause of earthquakes, the propagation of seismic energy, and seismic hazard, for a wide variety of users. The CISN centers will create and maintain long-term archives of earthquake data for earthquake engineers, seismologists, land-use planners, and other users. These archives will expand on the strengths of the Northern and Southern California Earthquake Data Centers through the creation of a seamless statewide archive.

A state-of-the-art data archive contains complete sets of seismograms for each earthquake, all processed in a uniform (and clearly described) way, and easily accessible by researchers and other users. Complete sets of records are added to the archive quickly after an earthquake, and the sets are organized in a way that makes them easy to use. The statewide archive system that is envisioned accomplishes all of these goals using software that directs the user to the catalog quickly, then permits downloading of records and supporting data (processing information, site conditions, etc.) in an efficient way.

The CISN will undertake the following activities:

- Create a seamless, well-organized, and easily-accessed archive of seismic records on a statewide basis, for California earthquakes;
- Prepare new automated paths for entry into the data sets;
- Maintain a uniform statewide earthquake catalog with world wide web access;
- Maintain station metadata archive to facilitate the use of the data.

3.7 Generate New Seismological Algorithms for use by Others to Improve Application of Integrated Seismic Data to Loss Reduction

An important element of the CISN is the interplay between operations and research. The research tools of today often translate into the real-time earthquake data products of tomorrow. Recent examples of such migration include algorithms for the automated determination of the fault rupture parameters into ShakeMap calculations, and indeed, ShakeMap itself. New software will be developed by the CISN for data processing and information distribution. These algorithms will be used to provide faster and improved near real-time earthquake source parameters, ground motion maps, and other earthquake-related products.

The powerful data set that will be generated by CISN leads to several opportunities for new algorithms that impact directly on how and where real seismic data can be incorporated into loss reduction. A few examples that are anticipated by the CISN leadership include:

- Calibrate algorithms and provide new input formats to HAZUS calculations for rapid loss estimating;
- Develop methods to provide ultra-rapid notification to users in nearby urban centers after a large earthquake has begun;

- Improve real-time moment tensor (focal mechanism) determination and other algorithms for source characterization, including finite source algorithms for large to major earthquakes;
- Improve near real-time magnitude and location determinations statewide;
- Determine site response for CISN stations to facilitate ShakeMap generation and engineering use of the data.
- Provide automated determination and delivery of aftershock probabilities, including both spatial and temporal information.

3.8 Communicate Progress With Users and the Public

New seismological information and tools produced by CISN will require substantial outreach and education efforts. Emphasis for technology transfer will be placed in the three following sectors. In each, several primary tasks have been identified.

3.8.1 Emergency Management

Helping emergency managers work with CISN products will require collaboration with OES in a statewide effort. CISN will expand on current outreach efforts to insure delivery of products to emergency managers and responders, and to provide guidance in their use. Strong working relationships with this community developed through the ERA/CUBE program with Caltech and the USGS will be expanded statewide, benefiting from the existing OES role in statewide emergency management. The CISN will conduct workshops, give seminars, and participate in conferences to promote the use of new products and train emergency response managers in their use.

In planning and coordinating their emergency response activities, the utilities and emergency response agencies are best served by conducting training exercises based on realistic earthquake situations. The CISN will continue ongoing efforts to work with HAZUS users groups in northern and southern California to employ realistic earthquake scenarios for planning exercises and loss estimation. In addition, earthquake scenarios are used heavily in emergency response planning and loss estimation by city, county, state and federal government agencies (e.g., FEMA, the Army Corp of Engineers), emergency response planners and managers for utilities, businesses, and other large organizations. CISN will be active in generating both exercise-specific and general earthquake scenarios (ShakeMaps) and provide the necessary guidance in their use to these groups.

CISN will also integrate various real-time information products including earthquake data, ShakeMap, and loss estimation input in common user-friendly formats for use in managing earthquake emergencies and maintain a web site to distribute information about current as well as past and scenario earthquakes, for use in response planning and management.

3.8.2 Improving Building Codes

An important means to contribute to code enhancement is to ensure timely, easy access to strong-motion data to promote both rapid post-earthquake analysis of building and infrastructure performance and the long-term development of improved code provisions. The CISN Engineering Data Center will develop innovative approaches to deliver strong motion data in user-friendly formats and interfaces to ensure rapid analysis and incorporation of new data into studies pertinent to building code development. In particular, numerous recordings from instrumented buildings will require not only easy access to the recorded motions, but also detailed information about the instrument layout and structural layout and design. The CGS Data Utilization seminars discussed in Section 3.5 are a key part of the outreach to the engineering research community and to practicing engineers that is needed to improve building codes.

3.8.3 Public Information and Education

Public information efforts will build on existing successes under TriNet which included 1) developing long-term relationships with local and county government agencies, emergency responders and regional utilities (such as the CUBE/ERA program); and 2) the CGS strong motion data utilization workshops and research element. In both approaches, long-term interaction through regular informational workshops provided critical feedback and a standard avenue for introducing users to new ideas and products.

CISN will also coordinate with organizations that have existing public outreach programs (e.g., the Assoc. of Bay Area Governments (ABAG), the Southern California Earthquake Center (SCEC), etc.) to expand outreach exposure and to develop instructional materials. CISN will conduct workshops, seminars, and conference participation to raise awareness of the contributions of the CISN, and their applications to public safety. This will be enhanced through collaboration with print, radio, and television media outlets to help widely distribute rapid and accurate post-earthquake information to the general public.

By developing and maintaining easily accessible web sites with high capacity, CISN will distribute information about current and significant earthquakes, and provide educational material on earthquake hazards and personal mitigation strategies.

In summary, the outreach activities include:

- Maintain and strengthen working relationships with the emergency planning and response community;
- Develop realistic scenario earthquakes for emergency response exercises;
- Conduct seminars and workshops with various user communities to train emergency professionals on CISN;
- Maintain high-capacity web sites that can be easily accessed by professionals and the public alike, to provide educational materials developed by CISN.

4 Organization of CISN

The CISN is governed by a memorandum of agreement (MOA) (Appendix A) among the core members (USGS Menlo Park, USGS Pasadena, Caltech, CGS, and UC Berkeley) with the Governor's Office of Emergency Services as an ex officio participant (see Appendix 2). The MOA describes the CISN organizational goals, products, and management. It is anticipated that the CISN will grow to include other organizations involved in earthquake monitoring within California, both public and private, through expanded membership.

4.1 Leadership Structure and Responsibilities

The organizational aspects of the CISN address both geographical issues as well as disciplinary issues that build on the strengths of the participating institutions. For instance, the institutions in northern and southern California are best suited to monitor and report on earthquakes in their regions, while the California Geological Survey (CGS) earthquake engineering component complements these activities statewide by focusing on recording engineering data from the largest earthquakes in the state.

4.1.1 Steering Committee

The CISN Steering Committee will oversee the program. The Steering Committee will be composed of two members from each of the core institutions, a representative of California Governor's Office of Emergency Services, and the chair of an Advisory Committee to the CISN. One of the USGS Menlo Park representatives will be the National Strong Motion Program Coordinator.

The Steering Committee will be responsible for policy decisions about data exchange and distribution, and for developing guidelines and spending priorities to be used in joint applications for funding. The CISN Steering Committee will review the program annually to assess the progress, organizational structure and the contribution of the member institutions, and to recommend adjustments where necessary. The Steering Committee will approve the formation and dissolution of standing committees to address specific CISN activities. The Steering Committee will have the authority to amend the Memorandum of Agreement. The chair of the Steering Committee will rotate annually among the five institutions. In each year there will be a vice chair who will be the chair in the following year. The chair and vice chair of the Steering Committee will never be from the same management center or same sector (e.g. academic, federal or state).

The Steering Committee will select one member to be the Regional Coordinator to ANSS and another as the Alternate Coordinator. The Regional and Alternate Coordinators will never be from the same management center or same sector. The Regional Coordinator will be responsible for the interaction of the CISN with other regions of the ANSS and to represent the interests of the CISN. The terms of the Regional Coordinator and the Alternate Coordinator will be one year and can be renewed. The Alternate Coordinator will be an ex officio member of the ANSS Implementation Committee if permitted by the ANSS.

4.1.2 CISN Program Management Group

A CISN Program Management Group (PMG), consisting of five members of the Steering Committee, one from each core institution, will meet regularly to coordinate the implementation of the CISN tasks by the member institutions. The PMG will have authority within its agency to carry out the goals of the CISN, and will report to the Steering Committee on a regular basis, no less than quarterly, on the progress of the CISN.

The PMG will oversee efforts to integrate and standardize operations through the activities of the CISN Standards Committee, which is tasked with examining issues related to implementing common software, such as waveform and parametric exchange, station naming conventions, and robust recovery of information following network interruptions. The PMG will coordinate with the ANSS to ensure that CISN efforts contribute to the goals of the ANSS, while also meeting the immediate needs of the CISN (Appendix A).

4.1.3 CISN Advisory Committee

The CISN Advisory Committee is composed primarily of users of CISN data and services to provide advice to the Steering Committee and Program Management Group on directions and goals. The Advisory Committee represents the interests of structural engineers, seismologists, emergency managers, industry, government, and utilities. The Steering Committee approves the members of this Advisory Committee from nominations made by each management center or OES. The Advisory Committee will have fifteen members, representing the constituency of each management center, OES, USGS, and FEMA. The chair of the Committee is elected by the membership, and serves a one-year term, renewable. The term of membership on the Advisory Committee will be three years, renewable.

4.2 Partnerships and Funding

Existing sources of funding provide many of the infrastructure items needed by CISN. The core members of the CISN have agreed to cooperate in this effort because of the obvious benefit to the State and the Nation. Because of this agreement, any new sources of funding for the CISN will have increased effectiveness because they will be directed to the area of most critical need.

The Federal Government through the USGS provides funds for seismic monitoring in California both through internal and external programs (Appendix B). These funds are used for core operations of earthquake monitoring in southern and northern California. The USGS office in Menlo Park works with UCB to maintain a comprehensive program in northern California. The USGS office in Pasadena is located on the Caltech campus and the USGS share responsibilities with Caltech in operating the seismic network in southern California. The USGS external program also provides funds to Caltech, UCB, and UCSD for operations and earthquake catalog production. The USGS and NSF fund the Southern California Earthquake Center (SCEC), which in turn provides funding for the Southern California Earthquake Data Center (SCEDC) for TriNet. The USGS through the Advanced National Seismic System (ANSS) funds improvements in seismic instrumentation throughout the state.

The State of California provides core funding for the CGS/CSMIP program. The State, through the University of California at Berkeley, provides core support for the Berkeley Seismological Laboratory, including partial support for the operation of the Berkeley Digital Seismic Network. Recently the State of California provided significant funds to increase the capability of the CISN. Funds are being used to support the operation of TriNet in southern California, expand broadband instrumentation throughout northern California, and increased the number of strong motion instruments in urban regions of northern California including the San Francisco Bay area.

4.3 Management Centers

To facilitate coordination of activities between institutions the CISN will form three management centers located in Pasadena, San Francisco Bay Area, and Sacramento. These centers are referred to as:

- **Southern California Management Center:** (Caltech/USGS-Pasadena)
- **Northern California Management Center:** (UC Berkeley/USGS Menlo Park)
- **Engineering Management Center**: (CGS CSMIP/USGS NSMP)

4.3.1 Northern and Southern California Management Centers

These centers will operate as twin earthquake processing centers. Both centers will acquire data from remote stations for statewide earthquake monitoring. Each center will have a reporting region for which it is the primary source of data. Each center will also have a statewide reporting capability and be able to report in case of failure on earthquake activity in the adjacent region. Each center operates facilities for archiving and public distribution of data. Data users will be able to obtain all data from either center based on the concept of virtual data centers.

The centers will exchange waveform data in real-time directly from select remote stations as well as from center to center. In addition, the centers will exchange parametric data in near-real time from center to center. The goal will be to maintain adequate coverage in the boundary regions between the reporting areas and to provide backup over the whole region by recording subsets of stations.

4.3.2 Engineering Management Center

The Engineering Data Management center has the responsibility for producing engineering data products. The California Department of Conservation's Strong Motion Instrumentation Program (CSMIP) in the California Geology Survey will operate the engineering management center in cooperation with the USGS/National Strong Motion

Program (NSMP). The Engineering Management Center will provide data from CSMIP and NSMP strong motion stations. It will also assemble strong motion data sets for the earthquake engineering community using data from all CISN stations. Further, the Engineering Center will provide strong motion records, from their stations, of small earthquakes for seismological and site response studies. The engineering center will serve as limited back up for the statewide earthquake notification system. By using data from its own stations combined with strong motion parametric data from both northern and southern California centers it will be able to produce ShakeMaps coordinated with and in parallel with the other centers.

5 Appendix A: CISN Memorandum of Agreement:

Memorandum of Agreement for the California Integrated Seismic Network

5.1 Goals of the CISN

The California Integrated Seismic Network (CISN) is a collaborative program between the California Department of Conservation, California Geology Survey will (CGS), the U.C. Berkeley Seismological Laboratory (BSL), the Caltech Seismological Laboratory (Caltech) and the Menlo Park and Pasadena Offices of the United States Geological Survey (USGS), (hereafter the CISN core institutions) to develop and operate a statewide seismic monitoring and reporting system.

CISN institutions will build upon their existing facilities to cooperatively improve seismic instrumentation, its spatial distribution throughout the state, its effectiveness in meeting public needs, the software for processing, archiving and distributing seismic data and information, and training for users. The CISN will be the designated region for California of the Advanced National Seismic System (ANSS). The institutions will cooperate in raising funds to achieve modernization of the instrumentation and reliable operations.

This agreement is based on the value the organizations place on their own institutions receiving appropriate credit, and their understanding that the long-term health of an organization depends on the recognition of its value to the community and state. Releases by CISN will identify the contributing institutions and incorporate a logo to be developed which will clearly identify the member institutions. The extent to which CISN can achieve these goals will be dependent on adequate funding.

5.2 CISN Products and Distribution

The products of CISN will include:

- Reliable monitoring and continuous reporting of all significant earthquake activity in California. Earthquake source parameters will be issued within minutes of the occurrence of an earthquake. These will be distributed electronically, including Web sites, e-mail and robust pathways for emergency responders. The earthquake information will be corrected as needed in post processing and maintained as a permanent archive. As technology improves, rapid notification may advance to rapid alerts that precede the arrival of strong shaking at distant sites.

- Maps depicting the distribution of shaking intensity of ground shaking (e.g., ShakeMap) to guide emergency response operations and damage assessment immediately following a significant earthquake in California. The maps will be based on shaking parameters from stations in the combined seismographic networks and also be distributed electronically within minutes of the occurrence of the earthquake.

- Distribution and archiving of strong motion records of engineering interest. Reports of strong ground motion records (e.g., Quick Reports) will be produced rapidly for significant earthquakes to facilitate engineering use of the data. These reports may also include data from structures, response spectra, and other relevant information. Super datasets of strong motion records from all the institutions will be produced for online, public access.

- Distribution and archiving of seismological data for all recorded earthquakes. Ground motion records from all CISN networks, including strong motion stations will be analyzed and archived to facilitate seismological use of the data. A common earthquake catalog will be produced for online, public access.

- Outreach and technology transfer for education, mitigation and emergency response. Training in the uses of seismological information for disaster reduction will be provided to emergency responders, contingency planners, public information media representatives and others. CISN will also provide a unified, simple means of access to all the data in all CISN-sponsored databases.

5.3 CISN Structure

The CISN will be comprised of three management centers to represent the respective needs of northern California, southern California, and the engineering community. The responsibilities of these centers will include installation and operation of seismic instrumentation, data acquisition and processing facilities, archival data centers, and outreach and educational facilities. UC Berkeley and the USGS in Menlo Park will cooperatively operate a management center for seismological information in northern California. These institutions will have primary responsibility for products 1, 4 and 5 above in northern California. The California Institute of Technology and the USGS in Pasadena will cooperatively operate a management center for seismological information in southern California. These institutions will have primary responsibility for products 1, 4 and 5 above in southern California. A management center for statewide earthquake data of engineering interest will be operated by CGS with the USGS. They will have responsibility for product 3 above. All three management centers will provide product 5, outreach and technology transfer, with emphasis on meeting the needs of their respective constituents (northern California, southern California and the engineering community).

Data from all institutions will be transmitted to and archived in all the data centers as appropriate to the goals of that data center. All institutions will contribute data to create product 2, real-time ground-shaking maps. Real-time and archived data will be distributed through a single, virtual system that provides seamless access to all California earthquake data to both the seismological and the earthquake engineering communities.

The CISN institutions will continue to refine their products to be of optimum use to their constituency. CISN institutions will distribute earthquake data to the public via web sites and email. They will also distribute data to the California Office of Emergency Services (OES) and the Federal Emergency management Agency (FEMA) for emergency response and for use in its post-earthquake damage estimation program. Member institutions that distribute CISN information will acknowledge CISN as a source of the data and the contributions of other institutions as appropriate.

The five institutions signatory to this memorandum are the founding core members of the CISN. Core members have primary responsibility for the recording and monitoring of earthquakes, and creation of CISN products. Other entities involved in seismological monitoring in California are invited to participate as members of CISN. Members will support the goals of CISN, contribute to the creation of CISN products, and agree to abide by practices and standards endorsed by the CISN Steering Committee. Members will have a primary affiliation with one of the management centers.

5.4 CISN Management

The CISN will be governed by a Steering Committee. The Steering Committee will be composed of two members from each of the core institutions, a representative of California Governor's Office of Emergency Services, and the chair of an Advisory Committee to the CISN. One of the USGS Menlo Park representatives will be the National Strong Motion Program Coordinator.

The CISN will create an Advisory Committee composed primarily of users of CISN data and services to provide advice to the Steering Committee and Program Management Group on directions and goals. The Steering Committee will approve the members of this Advisory Committee from nominations made by each management center. The Advisory Committee will have ten members, three representing the constituency of each management center and one representing OES. The chair of the Committee will be elected by the membership, and serve a one-year term, renewable. The term of membership on the Advisory Committee will be three years, renewable once.

The Steering Committee will be responsible for the governance of the CISN. This will include policy decisions about the level of data exchange and about the distribution of data. The Steering Committee will develop guidelines and spending priorities to be used in joint applications for funding. The CISN Steering Committee will review the project annually to assess the project, organizational structure and the contribution of the member institutions, and to recommend adjustments where necessary. The Steering Committee will have the authority to amend this Memorandum of Agreement. The chair of the Steering Committee will rotate annually between the five institutions. In each year there will be a vice chair who will be the chair in the following year. The chair and vice chair of the Steering Committee will never be from the same management center or same sector (e.g. academic, federal or state).

The Steering Committee will select one member to be the Regional Coordinator to ANSS and another as the alternate coordinator. The primary and alternate coordinators will never be from the same management center or same sector. The Regional Coordinator will be responsible for the interaction of the CISN with other regions of the ANSS and to represent the interests of the CISN. The term of the Regional Coordinator and the alternate will be one year and can be renewed. The alternate representative will be an ex officio member of the ANSS Implementation Committee if permitted by the ANSS.

A CISN Program Management Group (PMG), consisting of one member of the Steering Committee from each core institution, will meet regularly to coordinate the implementation of the CISN by the member institutions. The PMG will have authority within their agency to carry out the goals of the CISN and will report to the Steering Committee on the progress of the CISN. The Steering Committee will approve the formation and dissolution of standing committees to address specific CISN activities. The PMG will appoint members to standing committee activities with the approval of the Steering Committee and oversee subcommittee activities. Each core institution will provide one or two members for each of the standing committees.

6 Appendix B : Background Information

6.1.1 TriNet

The TriNet project, primarily funded by the Federal Emergency Management Agency (FEMA) through the California Office of Emergency Services (OES), the U.S. Geological Survey, and CGS following the 1994 Northridge earthquake, provided the basis for building the necessary seismic network infrastructure in southern California.

The TriNet project was named for the three organizations that have collaborated to build this network, the California Institute of Technology, the California Geological Survey, and the US Geological Survey through its Pasadena Office. The five-year project was completed in 2001 and operated with a budget of approximately $21 million, which included matching funds. The TriNet funds were invested in hardware, software development, data communications and an outreach program, which seeks to move technology from the laboratory to the emergency operations center. The "real-time information products" from TriNet are direct results of the new digital seismic and strong motion networks. They include: the rapid broadcast and web posting of accurate and reliable information on magnitude, location, fault configuration, and ground shaking for all earthquakes in the region; maps showing the distribution of ground motion expressed as intensity, peak acceleration and velocity; and, a prototype earthquake early warning system. TriNet also provides ground-shaking data for regional loss estimation software including HAZUS and the Early Post-Earthquake Damage Assessment Tool (EPEDAT). In addition TriNet meets the needs of other user groups by providing data for seismological and earthquake engineering research and improvements of building codes, led by CGS.

6.1.2 Berkeley Seismological Laboratory (BSL)

Since 1991 the BSL has been involved in a systematic program to upgrade and improve the geophysical monitoring facilities at UC Berkeley. With one-time funding from the University, complemented with matching funds from various federal and private sources, the Berkeley Digital Seismic Network has been upgraded and expanded to a modern network with broadband sensors collocated with strong-motion instrumentation and digital dataloggers. As of 2001, the BSL operates and acquires continuous, real-time data from over 40 digital seismic stations (BDSN, HFN, HRSN), 18 geodetic GPS stations, and 2 electromagnetic sites. These data are fed into the BSL real-time processing and analysis system and used as part of the joint USGS-UC Berkeley earthquake monitoring system. These data are archived and available to the public, along with data from other institutions, at the Northern California Earthquake Data Center, which is jointly operated by the USGS and UC Berkeley and located at the BSL.

6.1.3 Advanced National Seismic Research and Monitoring System (ANSS).

While TriNet was developing a modern seismic network in southern California, the U.S. Geological Survey, as required, undertook a review of the state of seismic monitoring in the US. A report was drafted based on this review and published in USGS Circular 1188, "An Assessment of Seismic Monitoring in the United States" (USGS

1999). In addition to a review of the current monitoring status, this review provides recommendations for the modernization of seismic networks and their infrastructure.

This report emphasized that the seismological research and earthquake engineering communities have recognized for years the need for modern seismological instrumentation in order to understand better the nature of earthquakes and to improve building design. During the1980s and 90s numerous reports and articles provided justification for modernizing different components of existing seismic monitoring systems. Critical to the success of the ANSS is the need to upgrade national, regional and urban components of the system. The ANSS report recommended increasing the national seismograph network to 100 stations from 56 stations; adding or replacing 1,000 modern seismographs in regional networks in areas of greatest risk; installing 6,000 strong-motion recording systems in urban areas at risk of damaging earthquakes; and linking seismographs to monitoring centers with modern, robust telecommunications equipment.

In the reauthorization act for the National Earthquake Hazard Reduction Program (NEHRP), Congress responded to the receipt of the report by requiring the USGS to provide them with a management and implementation plan for an "Advanced National Seismic Research and Monitoring System" (ANSS). Representatives of a dozen different seismological organizations outlined such a management plan. An over-riding theme of this plan is that seismic monitoring of the US should be implemented within regions representing the major physiographic and tectonic parts of the country. No more than six to ten regions or groups should be so defined, one of which is a national group to provide linkages between the regions as well as to provide broad coverage of the whole US and include global monitoring.

Although funds for the ANSS have not been fully authorized, some preliminary funding has been made available. In FY2000, the USGS began installation of approximately 100 digital seismic stations in the San Francisco Bay region. The sites were chosen to address two critical seismic-monitoring needs in the region: construction of real-time ShakeMaps, and monitoring of strong shaking in urban areas. To improve the ability of the CISN to create ShakeMaps, the USGS Northern California Seismic Network (NCSN) replaced obsolete analog seismic equipment at 27 regional network sites throughout the region with data loggers digitizing output from a tri-axial accelerometer (for strong motion) and a vertical seismometer (for monitoring microearthquakes). The remaining sites were newly installed by the USGS National Strong Motion Program in fire stations and schools located in metropolitan regions of the Bay Area where there were few other strong motion stations.

It was natural that one of the regions of the ANSS would be the state of California, and CISN is the regional body of ANSS to play that role. Due to the combination of seismic hazard and population at risk, the CISN serves the Advanced National Seismic System (ANSS) region with the highest expected long-term losses (FEMA, 2000). With its collective experience in designing TriNet, NSMP, BDSN, NCSN and the CSMIP, and it's central part in the ANSS, the CISN plays a pivotal role in determining future scientific and technological directions of the larger, nationwide system.

6.1.4 The California Seismic Safety Commission (CSSC).

The strong-motion aspect of the CISN project, like the TriNet project, responds to key recommendations outlined in the California Seismic Safety Commission's (CSSC) report on lessons of the 1994 Northridge earthquake, "Northridge Earthquake, Turning Loss to Gain." The Commission concluded that the instrumentation by the California Geology Survey (CGS) Strong Motion Instrumentation Program, is a valuable part of California's effort to reduce the risk from earthquakes. It recommended that a high priority should be given to "establishing a network of reference stations to measure ground motion in major urban areas of California." The reference station network should provide ground-shaking data for use in the evaluation of the performance of buildings and structures after damaging earthquakes. Instruments deployed in this network should provide data that require a minimum amount of processing and will be available to building officials and engineers on an urgency basis.

The Commission endorsed the TriNet project as an element of that goal. In addition to structural engineering and geotechnical engineering communities, government agencies such as OES, the California Department of Transportation, the California Department of Water Resources and the City of Los Angeles also supported the goals of TriNet. They recommended that these goals be extended to northern California provide statewide coverage.

The Strong Motion Instrumentation Advisory Committee (SMIAC), a subcommittee of the CSSC, provides a Legislatively mandated advisory role to the California Strong Motion Instrumentation Program (CSMIP). The SMIAC emphasized the usefulness of more stations in urban areas to obtain the data needed to understand the relationship of earthquake shaking to structural damage. They recommended that CSMIP seek funding to accelerate installation of these stations. The Advisory Committee recommended a goal of one strong motion station in each zip code throughout California. The TriNet project provided an effective program to nearly accomplish that goal in southern California. However, since TriNet was limited by the nature of its funding to southern California, the CISN project is critically needed to move toward that goal in the rest of the state.

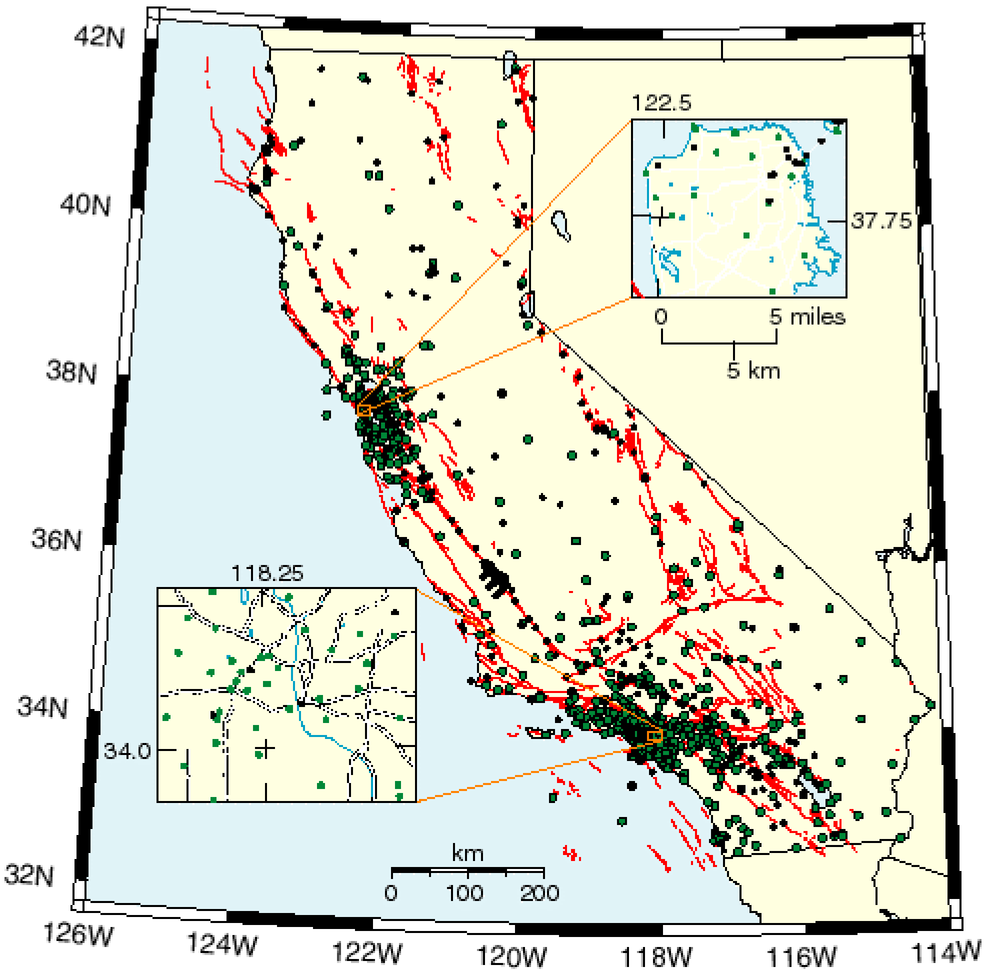

Figure 1. Distribution of strong motion instrumentation in California. Green symbols depict recorders with telemetry and which are suitable for use in ShakeMap. Black symbols depict recorders that are either instruments that are analog and/or do not have telemetry, or are located in structures. Insets show distribution of instrumentation in central Los Angeles and San Francisco. Major roads are shown in insets.

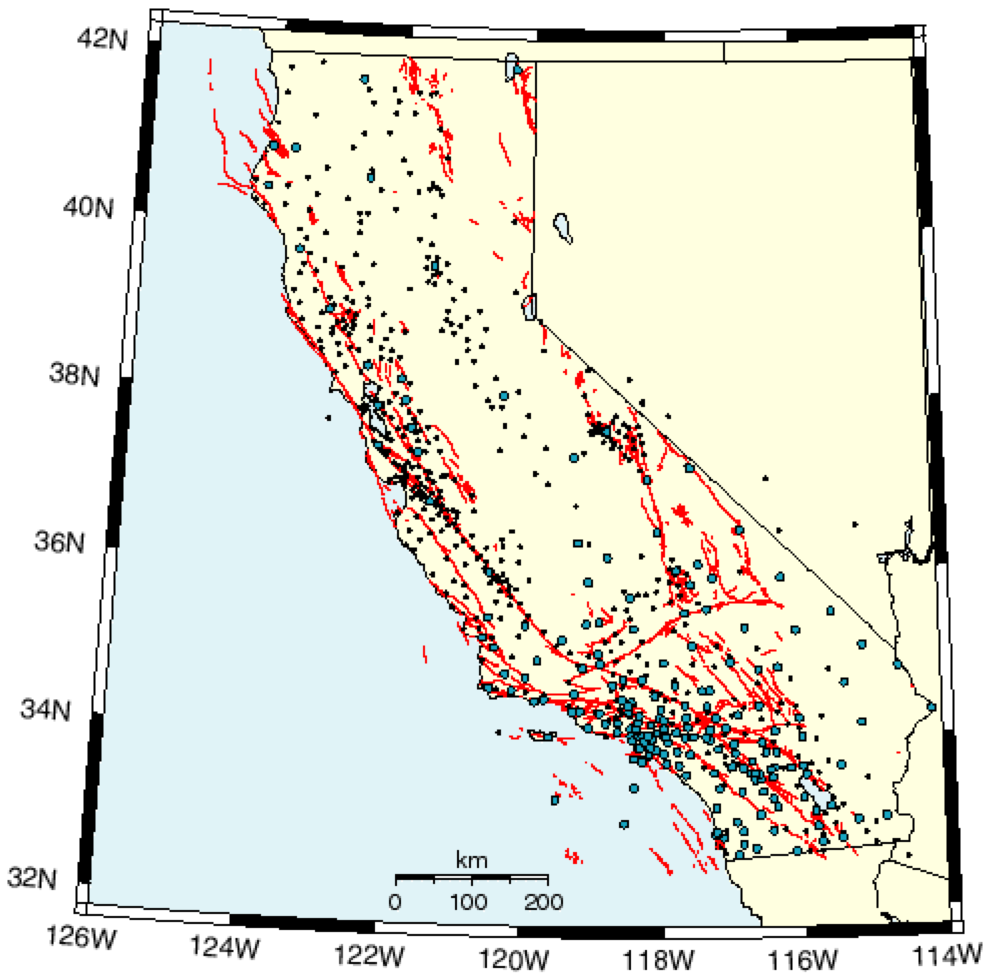

Figure 2. Distribution of weak motion instrumentation in California. Blue symbols depict stations with tri-axial broadband instruments with 24-bit digitizers and continuous digital telemetry. Black symbols depict stations with short-period seismometers using continuous analog telemetry.

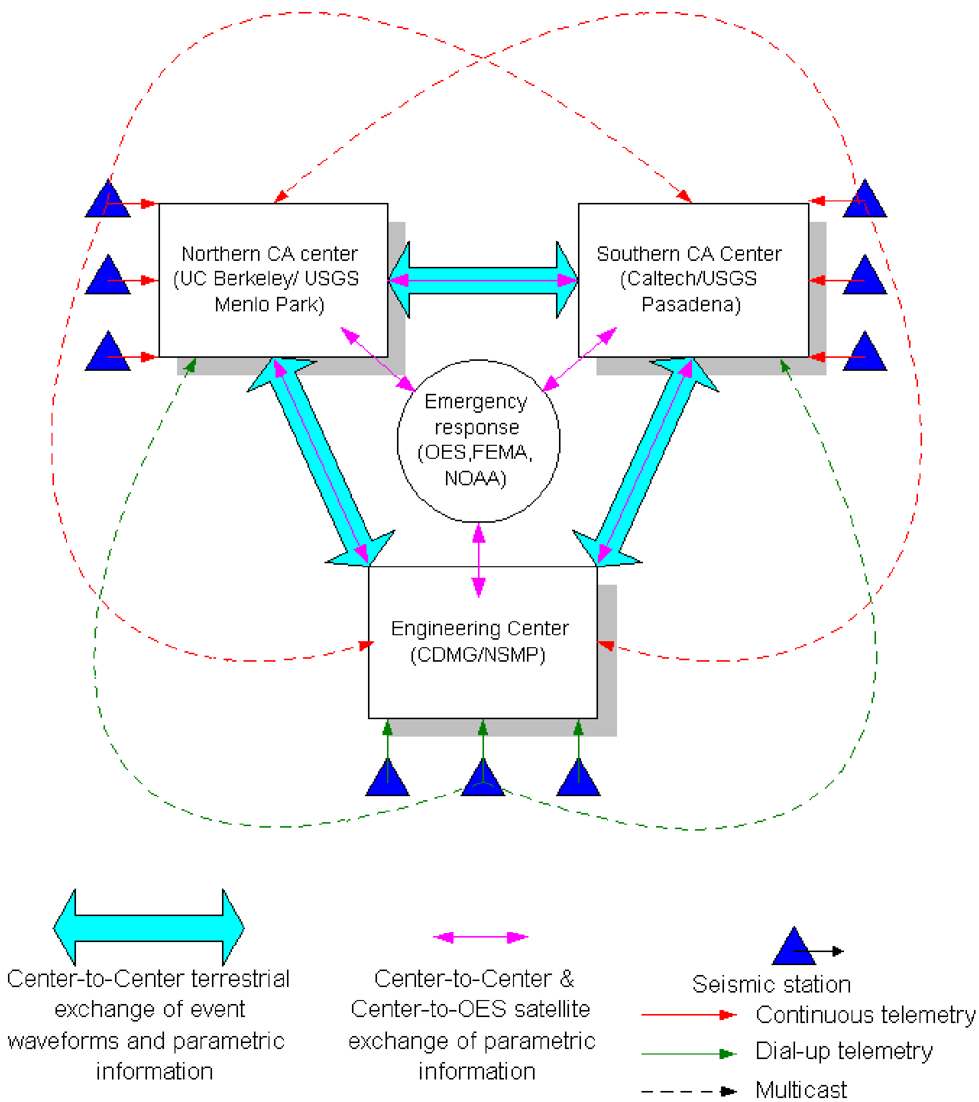

Figure 3. CISN products and distribution channels.

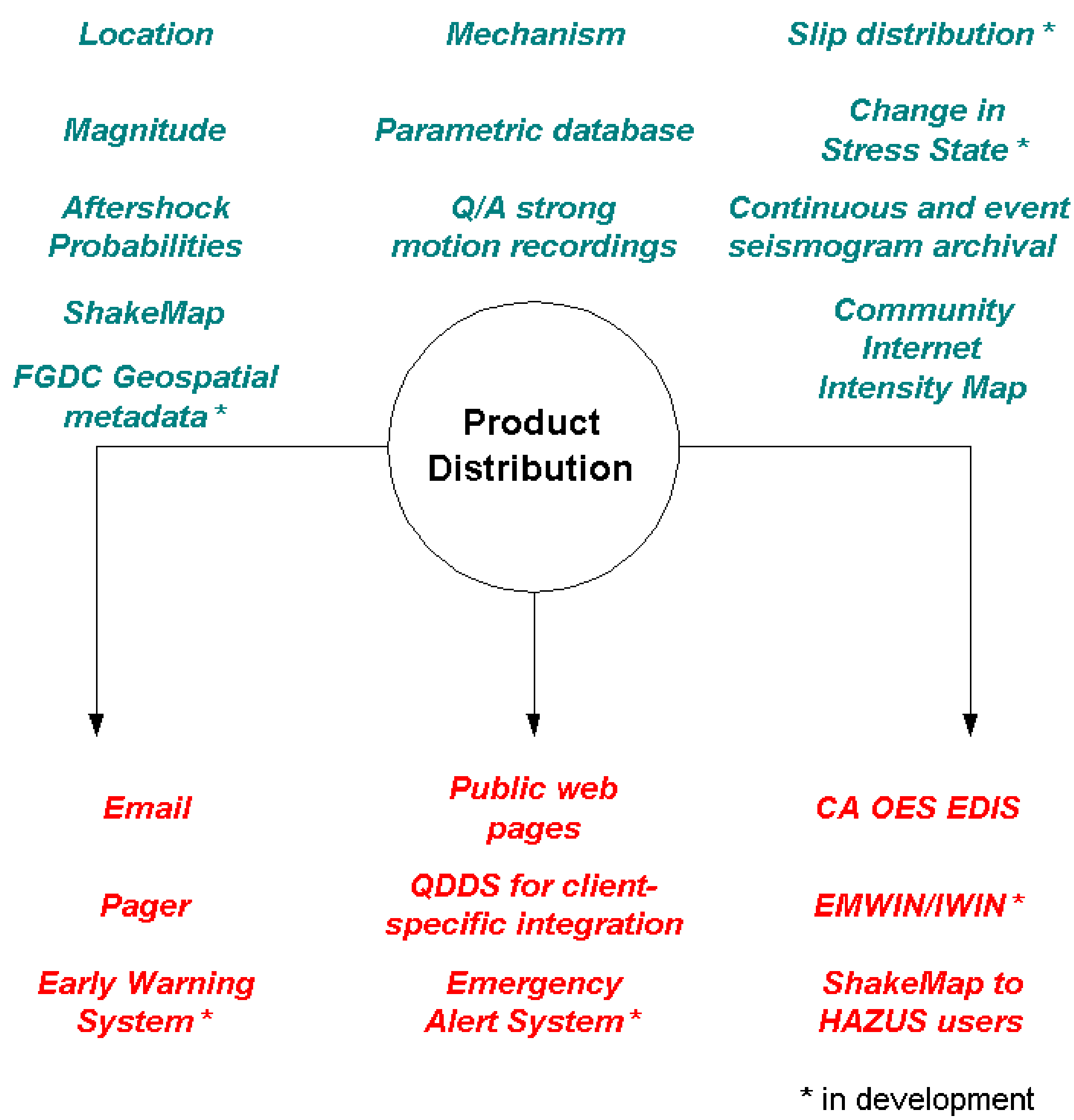

Figure 4. CISN products and distribution channels.