California Integrated Seismic Network

Strategic Plan: 2005 - 2010

Caltech

CGS

OES

UC Berkeley

USGS, Menlo Park

USGS, Pasadena

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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, response operations and mitigation practices are built.

This strategic plan is an assessment of the needs for and a framework of the strategy to develop and operate 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 earthquake response and 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 to speed response in the aftermath of large earthquakes. Through modernization, the CISN will provide these products on a statewide basis. In addition, many buildings and other 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, what controls where the earthquake rupture will terminate, and what are the limits on extreme ground motions. The CISN will collect, archive and provide the seismological data necessary to address these research questions as well.

The focus of the CISN is modernization and operation of a robust seismic network infrastructure statewide. During the first four years of CISN operations several important steps have been made towards integration, standardization, and improvements in robustness. It is the mission of CISN that the modern seismic 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. Before the formation of the CISN, each of the existing networks had been collecting seismic information that served some of the needs of the State, but no single network fulfilled all of the requirements. By integrating these monitoring efforts into a single system, researchers and users can access a complete and well-organized knowledgebase. The 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 a participant and client of near real-time seismic data (see Appendix A). In addition, several other seismic networks are contributing members of the CISN.

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 realizing these goals:

1. Continue integration of current monitoring networks into a statewide system with redundant data retrieval, storage and processing capabilities through improved communications systems, software, and standardized methodologies.
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 Current Products

The CISN will provide:

1. Rapid 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 via Web sites, e-mail and other modern 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, which sometimes is referred to as early warning.
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., Internet Quick Reports) will be produced rapidly for significant earthquakes to facilitate engineering use of the data. These reports will 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 access to facilitate seismological use of the data. A common earthquake catalog will be produced for online access.
5. Improved 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 response and mitigation. 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 New 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 collect and analyze seismic data an order of magnitude more quickly and accurately, which in turn opens new opportunities to improve public safety and reduce losses from future earthquakes. Success requires the coordinated effort of several organizations that have formed CISN 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?” “What are the priorities and areas for initial response?” 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 CISN management centers are responsible for generating and distributing CISN products. Current rapid products include information on location and magnitude, ShakeMaps, analysis of the source and rupture characteristics, and reports of seismological and engineering interest. The Northern and Southern California centers have primary responsibility for rapid earthquake information. 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, email, and other dedicated communications in which the CISN actively sends the information to the client, and via passive systems in which the user must seek information, such as from Web pages. Currently the CISN supports multiple distribution mechanisms, ranging from email notification (Web-based sign-up was released in 12/2003), dedicated Web servers for ShakeMap and other CISN seismological products (released 9/2003), and a new software package called “CISN Display” (released 12/2004).

CISN Display is a software package that rapidly receives earthquake information via the Internet distributed by seismic networks operating in the United States. The application was designed primarily for emergency management 24/7 operations centers.

It provides map displays of earthquake locations, magnitudes, and time of occurrence and can notify users of the occurrence of an earthquake. For larger quakes CISN Display may also display ShakeMaps. The software provides links to available earthquake products on the web, such as loss estimates from HAZUS, special reports on the earthquake prepared by seismologists, tsunami warnings, focal mechanisms, images of seismograms, maps of "felt" reports, and reports on damage and casualties from emergency services agencies. CISN Display offers an open source GIS mapping tool that allows users to easily customize the display by importing GIS layers of public highways, roads and bridges, as well as private layers of organizational-specific infrastructure and other private facilities information. The software is written in Java and runs on all popular operating systems.

Tools such as CISN Display and the Recenteqs Web pages depend on earthquake information distributed using the Quake Data Distribution System (QDDS). QDDS transmits information in near real-time to clients from redundant hubs in Menlo Park, California and Reston, Virginia. The CISN is working with the ANSS to develop a replacement for QDDS, known as EIDS (Earthquake Information Distribution System). The CISN is also working with the ANSS on “ShakeCast”. The ShakeCast system is designed to be a software tool for the rapid distribution of ShakeMaps. In addition to delivering ShakeMaps, the software allows users to define locations of interest and set shaking levels to trigger automatic notification, provide electronic notification of events and projected intensity levels, and integrate with in-house GIS systems.

In the advent of a significant earthquake, the CISN must be concerned about the reliability of communications links. For example, 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.

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 ongoing activities are needed to achieve this objective:

- Operate 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 parallel earthquake processing centers;
- Exchange waveform data in real time between centers and directly from remote stations to both centers;
- Establish improved protocols and procedures for statewide earthquake reporting;
- Develop and implement software to monitor and exchange "state-of-health" for each center.

3.2 Deploy New Stations

To accomplish the CISN goals, we plan to continue to deploy and operate 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 triaxial strong motion accelerometer;
4. Regional short-period analog stations;
5. Stations with sensors installed in boreholes for enhanced monitoring in urban areas, in near-fault regions, and other regions of seismic interest; and
6. Seismic instrumentation of selected buildings, structures, and lifelines.

Table 1. CISN Instrumentation Plan

	Southern California		**Northern California**		**Statewide**
	Existing	Additional Needed	Existing	Additional Needed	Total
Urban Strong Motion (SM)	602	698	372	588	2260
Broadband + SM[1]	170	60	38	212	480
Short Period (SP) + SM	16	90	61	119	286
Analog SP [2]	133	0	367	0	291[3]
Borehole	15	35	36	24	110
Geotechnical Arrays	14	20	8	18	60
Buildings					221
Bridges					70
Dams					26
Others					13

1 Includes Anza stations
2 Includes UNR, DWR, and PG&E stations
3 Includes existing UNR, DWR SP stations and CI and NC stations after upgrade to digital short-period and strong motion capability. The number of these stations is expected to decrease as the equipment is upgraded to digital.

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 building and potential value of the resulting data. ANSS has prepared its Guideline for ANSS Seismic Monitoring of Engineered Civil Systems, and will use it to carry out this major portion of the ANSS goal. ANSS and SMIP will coordinate the selection and instrumentation of structures in California to best achieve the goals of the programs and serve the public need. 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 buildings and other structures during large earthquakes, it is necessary to record shaking both within the structures and on the ground nearby. There are currently approximately 974 modern urban strong ground motion instruments in the state (Table 1), and 1286 “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 further densified 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 planned 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 (Table 2).

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

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 200 stations consisting of vertical, short-period seismometer and a tri-axial accelerometer.

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 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 explicitly address borehole installations, we recommend that about 110 stations be installed in boreholes across the entire state. Borehole stations record data that enable seismologists to record much smaller earthquakes than observable from surface stations. Because the number of earthquakes increases by a factor of 10 for each unit change in magnitude, the greater number of quakes provides a rich data source to investigate the interval of time between repeating earthquakes that reflects the strain rate in the fault zone. Seismograms recorded in boreholes are simpler because the signal is not influenced by the free-field effect at the surface, and thus are invaluable for research on source properties and predicting ground motions. Finally, borehole stations are much quieter, and thus collect essential data for detecting the possible presence of fault zone seismic tremor and other subtle geophysical signals.

It is important to note that the plan in Table 1 does not include the instrumentation needed to provide reliable early warning uniformly in California. While the current infrastructure provides certain capabilities, additional instrumentation – both broadband and strong-motion sensors – will be needed to support and facilitate development of early warning uniformly across the state.

The following specific activities have been identified:

- Deploy instruments to achieve the estimated numbers shown in Table 1 for California;
- Coordinate the SMIAC and ANSS structural instrumentation advisory group activities to help locate and design instrumentation for buildings and other structures 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 one of the CISN processing centers do not affect the monitoring or reporting capabilities of the entire system.

Achieving 100% redundant or duplicated capabilities, which is the long-term goal of CISN, 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 not cost effective with the present generation of telemetry and seismic instrumentation.

As an initial step in this direction, the CISN has implemented data sharing directly from the field based on a core group of seismic stations that 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, a few types of telemetry protocols, and in areas where such protocols are offered. To complement this sparse set of stations, the CISN has implemented the statewide sharing of parametric data such as picks and amplitudes. The combination of center-to-center and station-to-center data exchange provides 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.

A first step in the direction of establishing statewide processing and reporting at both centers has been implemented by the CISN through the sharing of parametric data such as picks and amplitude data. These new capabilities will allow all three centers to produce ShakeMap and the two centers to notify about statewide earthquake activity. To increase the reliability of statewide operation, the CISN will investigate the feasibility of establishing a simultaneous exchange of parametric data via satellite using either a commercial ISP or using the state OASIS replacement. A satellite link will presumably remain functional even if an earthquake disrupts terrestrial telecommunication links in the state.

In addition to the effort to establish reliable reporting within the processing centers of the CISN, the CISN will exchange data with ANSS partners, including the USGS National Earthquake Information Center (NEIC) so that this national facility can serve as an additional resource for reliable reporting capability. The NEIC will have a subset of CISN data from California and thus have limited ability to respond, in case the CISN centers are incapacitated. Both centers also provide real-time seismic data feeds to other seismic network operators such as the Pacific Northwest Seismic Network, the University of Nevada Reno, the California Department of Water Resources, Lawrence Livermore National Labs, University of California San Diego, and the tsunami warning centers in Alaska and Hawaii.

The CISN is also working with the NSF-funded Earthscope project in order to incorporate seismic data from the USArray, SAFOD, and PBO projects in their routine processing. In particular, the temporary deployment of USArray stations over 2004-2008 in northern California will enhance the CISN monitoring capabilities as well as provide an opportunity to leverage the NSF investment into permanent stations. The permanent deployment of borehole seismometers in PBO and the SAFOD borehole will provide new opportunities to study seismicity in selected areas in California. A total of about 60 CISN stations statewide also report real-time seismic data to the USArray data processing center in San Diego and to the IRIS data center in Seattle (IRIS/DMC).

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 backup copies of data of engineering interest at the seismic stations with accelerometers, in the case data communication links fail;
- Exchange real-time data streams with ANSS partner networks, including NEIC and tsunami warning centers in Alaska and Hawaii.
- Improve protocols for exchanging data and backup product distribution with NEIC in Golden, Colorado.
- Collaborate and exchange data with Earthscope to improve earthquake-monitoring coverage.

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 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;
- Improve 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 in the California Geological Survey will operate the Engineering Management Center in cooperation with the USGS/National Strong Motion Program and ANSS. The Engineering Management Center will provide raw and processed 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, along with the longer-term development of improved building code provisions and engineering design practices. 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:

- Operate the CISN Engineering Data Center, producing the Internet Quick Reports web site, organizing and delivering the suite of processed strong motion records generated by each new earthquake within a few hours;
- Complete documentation of the geologic, geotechnical and topographic details of free-field strong motions sites, and the structural details (metadata) 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, and provide Web interfaces for selecting and downloading data of user interest;
- Continue annual review meetings that summarize progress in analysis of engineering data for ground and structural response;
- Provide data input to code developers and performance-based engineering

researchers for new seismic response models.
- Work toward integration of CSMIP and NSMP/ANSS in California consistent with the goals of Sections 3.3 and 3.4; and
- Explore and develop efficient means to conduct effective, practical continuous real-time data collection from instrumented structures.

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, relevant data from distant earthquakes, and other data need to further the goals of CISN;
- Provide new automated paths such as web services for entry into the data sets;
- Maintain a uniform statewide earthquake catalog with world wide web access;
- Maintain a 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 co-existence of operations and research. The research tools and results 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. As new algorithms become available, new software will be developed by the CISN for improved data processing and information distribution. As an example, these algorithms will be used to provide faster and improved near real-time earthquake source parameters, ground motion maps, and other earthquake-related products. For example:

Early warning may in some instances provide users with notification of impending ground shaking a few to 20 seconds before the shaking arrives at the users site. Further, very rapid reliable determinations of magnitude are crucial for providing quick tsunami warnings. The CISN facilities are an ideal test bed to develop such algorithms and to demonstrate if useful warning times can be achieved with the current CISN technology.

There are not enough instruments deployed in California to produce a reliable ShakeMap for every region. Site response data such as detailed geology maps, soil data, 3D velocity models, or borehole measurements can be used to improve the interpolation of ground motion data between instrumented sites, and thus make more useful ShakeMaps for these regions. The CISN will continue to develop innovative methodologies to include site response data, which will increase the reliability of ShakeMaps.

The powerful data set that is being generated by CISN leads to several opportunities for development of 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:

- Develop and test early warning methods to provide ultra-rapid notification to users 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;
- Provide synthetic ShakeMaps based on 3D velocity models and source parameters for regions where such models are available;
- Develop new waveform-based methods for hypocenter and moment tensor determination;
- Develop maps to accompany ShakeMaps reflecting the uncertainty in mapped shaking estimates;
- Develop innovative visualizations of earthquake shaking in buildings and other structures to further engage the interest of engineer and emergency managers.
- Develop new methods to incorporate site response data into ShakeMap to compensate for lack of instrumentation.

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 and Engineering Design Practices

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 and engineering design practices.

3.8.3 Public Information and Education

Public information efforts will build on existing successes of CISN that have included 1) developing long-term relationships with local and county government agencies, emergency responders and regional utilities (such as the ERA/CUBE program); and 2) the CGS strong motion data utilization workshops and research element. In both approaches, long-term interaction through regular informational workshops has 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 Association 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;
- Provide information about tsunamis as part of earthquake education outreach;
- Conduct seminars and workshops with various user communities to train emergency professionals on CISN products;
- Maintain high-capacity web sites that can be easily accessed by professionals and the public alike, to provide data, information products, and educational materials developed by CISN.
- Participate with electronic media in developing enhanced graphic displays of ShakeMap and other data

4 Organization of CISN

The CISN 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 a participant (see Appendix A). 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 and USGS 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 Chief Scientist, Earthquake Hazards Team, USGS in Menlo Park will also be a member of the CISN steering committee.

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 among the five institutions. There will be a vice chair who will be the chair in the following term. 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 National 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 and geotechnical 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. These funds are used for core operations of earthquake monitoring in southern and northern California. The USGS office in Menlo Park works with UC Berkeley to maintain a comprehensive program of monitoring and archiving in northern California. The USGS office in Pasadena is located on the Caltech campus and shares responsibilities with Caltech in operating the seismic network in southern California. The USGS external program also provides funds to Caltech, UC Berkeley, 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). The USGS through the ANSS funds expansion and modernization of 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, through the Governor's Office of Emergency Services provided significant funds to increase the capability of the CISN. Funds are being used to support the operations of CISN, 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. Additional funding has been provided by the Federal Emergency Management Agency's Emergency Management Performance Grants (EMPG) and the Hazard Mitigation Grant Program (HMGP) through California OES for emergency response enhancements to CISN.

In addition to the core members, several organizations contribute data that enhances the capabilities of the CISN. Contributing members of the CISN include: University of California, Santa Barbara, University of California, San Diego, University of Nevada, Reno, University of Washington, California Department of Water Resources, Lawrence Livermore National Lab, and Pacific Gas and Electric.

4.3 Management Centers

To facilitate coordination of activities between institutions the CISN has formed 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 operate as twin earthquake processing centers. Both centers acquire data from remote stations for statewide earthquake monitoring. Each center has 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 among the California Department of Conservation, California Geological Survey (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. The Governor's Office of Emergency Services (OES), as the primary Emergency Management organization in California and user of emergency management information in providing for public needs in mitigation and emergency response, serves as a partner with the network operators in the CISN. OES and the 5 core members constitute the 6 founding members of CISN.

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 represent California as a designated region of the Advanced National Seismic System (ANSS). The institutions will cooperate in raising funds to achieve modernization of the instrumentation and reliable operations. The extent to which the CISN can achieve these goals will be dependent on adequate funding.

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.

5.2 CISN Products and Distribution

The products of CISN will include:

1. 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.
2. 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.

3. 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.
4. 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.
5. 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 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). OES will participate as a primary user of CISN product 2 and as a representative and facilitator of emergency management user communities for product 5.

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 six institutions signatory to this memorandum are the founding 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, and, in addition, a representative of California Governor's Office of Emergency Services, the chair of an Advisory Committee to the CISN, and the Chief Scientist for the USGS Earthquake Hazards Team. 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 the PMG. The Advisory Committee will have at least ten members, including three representing the constituency of each management center and one representing OES, and will elect a chair from its membership. The chair of the Advisory Committee will serve a one-year term, renewable. The Advisory Committee will also elect a vice chair. 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 among the five core institutions. The term of the chair shall be one year, renewable for an additional year. There will be a vice chair who will be the chair in the following term. 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 shall not 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 interest 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.

CISN institutions, approved**:**

Dr. William Ellsworth
____________________________________Date_____________
Chief Scientist, Earthquake Hazards Team
US Geological Survey

Dr. Lucile Jones
____Date_____________
Scientist-in-Charge for Southern California
US Geological Survey

Dr. Michael Reichle
_____________________________________Date_____________
Acting California State Geologist
California Geological Survey

Dr. Barbara Romanowicz
_________________________________Date_____________
Director, Seismological Laboratory,
University of California at Berkeley

Dr. Jeroen Tromp
_______________________________________Date_____________
Director, Seismological Laboratory,
California Institute of Technology

Mr. Henry Renteria
_____________________________________Date_____________
Director, Governor's Office of Emergency Services,
State Of California

6 Appendix B: Glossary

ABAG	Association of Bay Area Governments
ANSS	Advanced National Seismic System
CISN	California Integrated Seismic Network
CGS	California Geological Survey
CSMIP	California Geological Survey Strong Motion Instrumentation Program
CUBE	Caltech/USGS Broadcast of Earthquakes
EIDS	Earthquake Information Distribution System
EMPG	Emergency Management Performance Grants
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HAZUS	Hazards US
HMGP	Hazard Mitigation Grant Program
IRIS	Incorporated Research Institutions in Seismology
ISP	Internet Service Provider
NOAA	National Oceanic and Atmospheric Administration
NEIC	National Earthquake Information Center
NSF	National Science Foundation
NSMP	National Strong Motion Program
OES	Office of Emergency Services
PBO	Plate Boundary Observatory
PMG	Program Management Group
QDDS	Quake Data Distribution System
SAFOD	San Andreas Fault Observatory at Depth
SCEC	Southern California Earthquake Center
SMIAC	Strong Motion Instrumentation Advisory Committee
USGS	United States Geological Survey

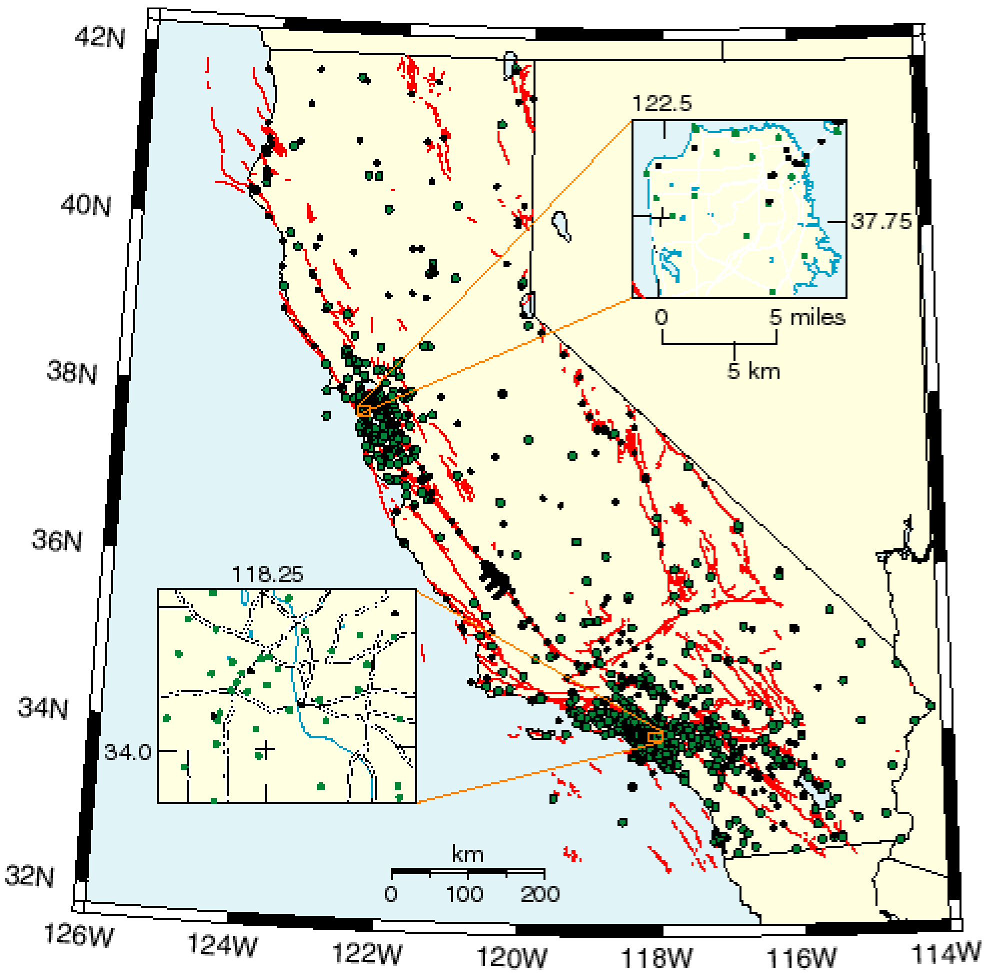

Figure 1. Distribution of strong motion instrumentation in California. Green symbols depict recorders with telemetry and which are suitable for use in ShakeMap. Black symbols depict recorders that are either instruments that are analog and/or do not have telemetry, or are located in structures. Insets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

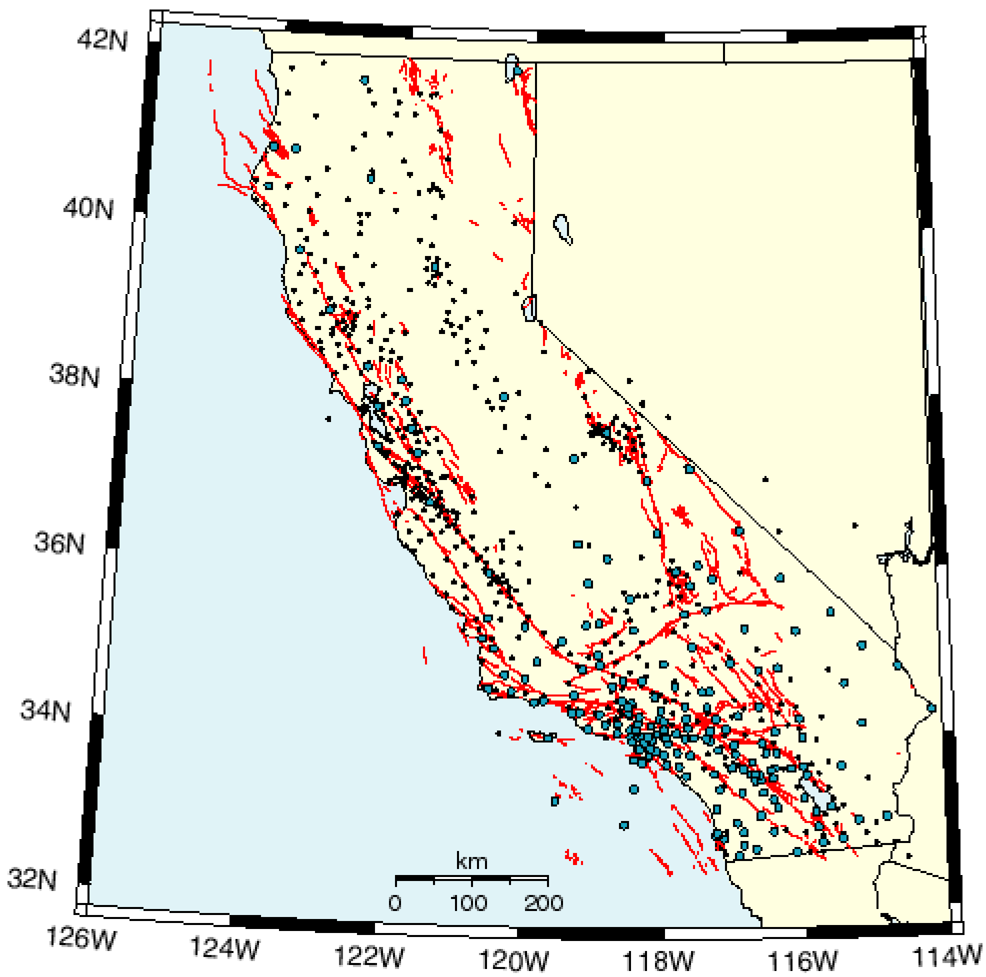

Figure 2. Distribution of weak motion instrumentation in California. Blue symbols depict stations with tri-axial broadband instruments with 24-bit digitizers and continuous digital telemetry. Black symbols depict stations with short-period seismometers using continuous analog telemetry.

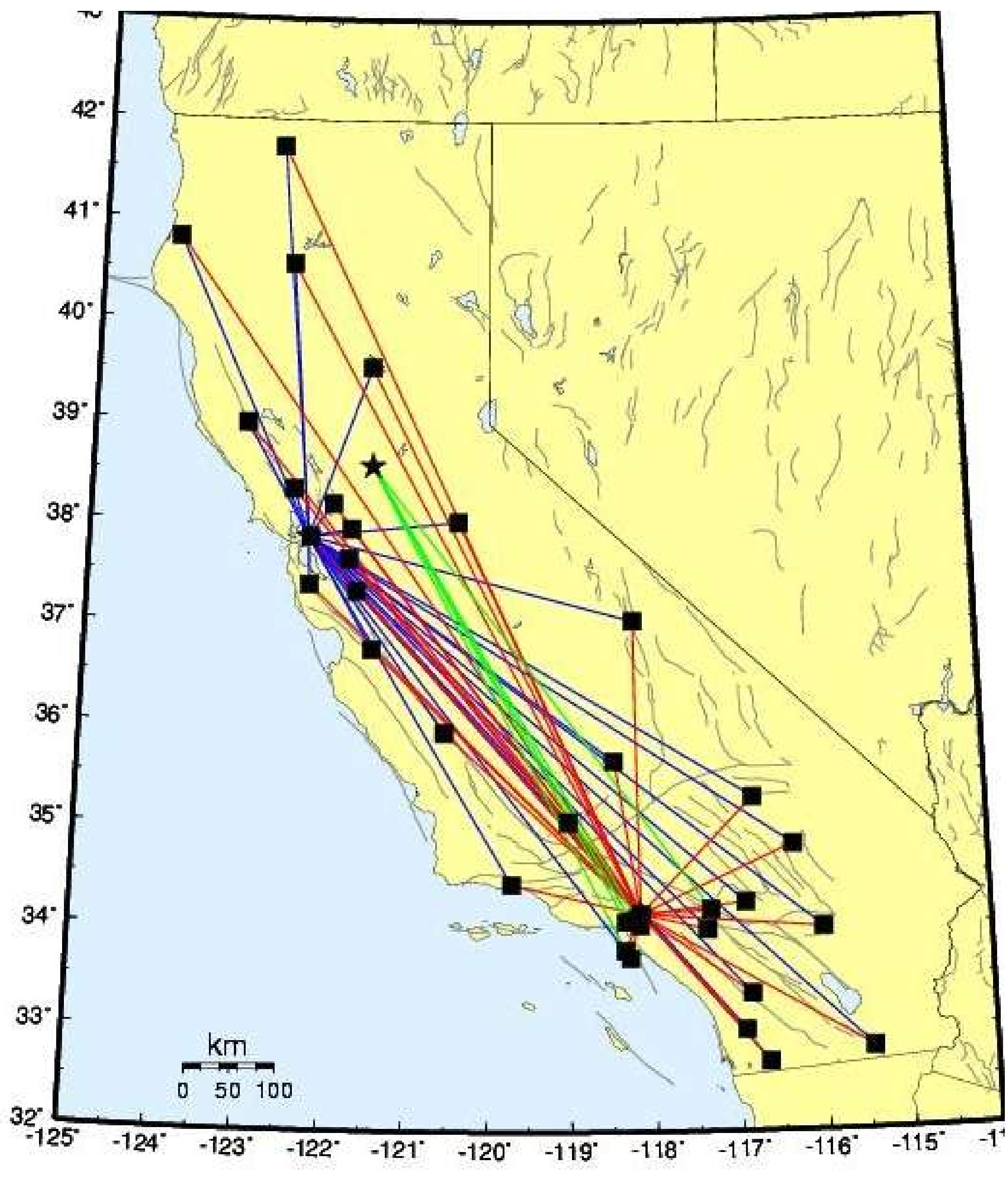

Figure 3. Diagram illustrating dual station data feeds to improve robustness.

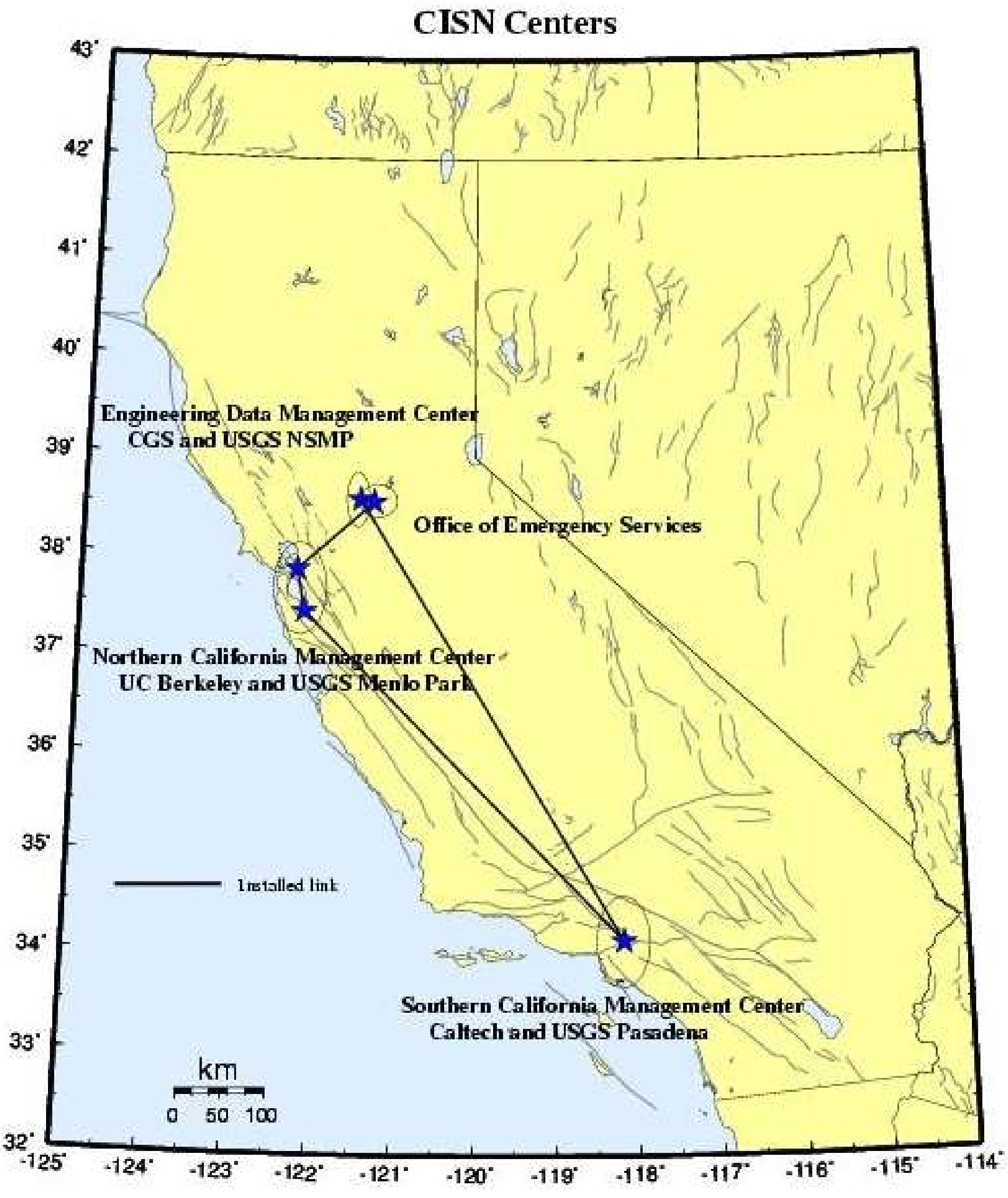

Figure 4. Diagram of the CISN backbone.