A Proposal to NSF and USGS for Sponsorship of the Southern California Earthquake Center

I. Introduction and Overview

This proposal requests five years of funding from the National Science Foundation and United States Geological Survey for the Southern California Earthquake Center (SCEC). The Center was founded in January, 1991, to coordinate the activities of experts in academia, government, and the private sector on the scientific study of earthquakes in Southern California. SCEC is currently sponsored by NSF and the USGS under NSF's Science & Technology Centers (STC) program. In 1999, the base funding provided to SCEC by these federal agencies was about $5 million.

A. Rationale for the Center

The STC program supports individual centers for a maximum of 11 years, so SCEC is entering its last year of STC funding. There is, however, a compelling rationale and a strong consensus that SCEC should continue as a major center for earthquake science.

1. Earthquake Risk in Southern California

The need for SCEC was underscored in a report released last September by the Federal Emergency Management Agency (FEMA), which apportioned California about three-quarters of the national earthquake risk (Fig. 1.1). Nearly half of this national risk is located in Southern California, with one-quarter concentrated in Los Angeles county alone.[1] A parallel study by the California Division of Mines and Geology (CDMG) estimated that the direct economic losses due to earthquakes in six high-risk Southern California counties (Los Angeles, Orange, San Bernardino, Riverside, San Diego, and Ventura) will average $2.7 billion dollars per year.[2]

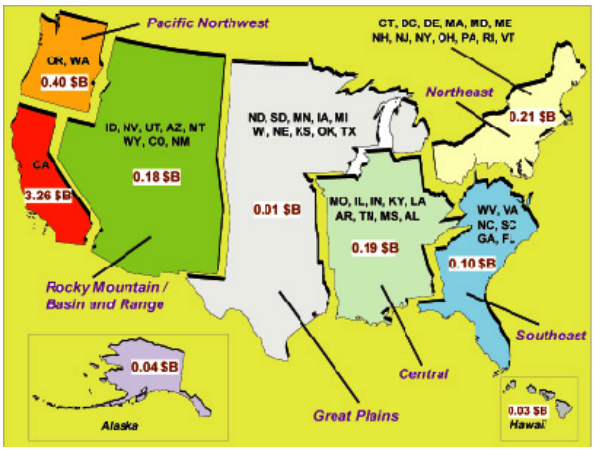

Figure 1.1. Annualized earthquake loss (AEL) for regions of the United States, estimated by FEMA using the HAZUS methodology. The total AEL for the United States is $4.4 billion/yr; 74% of this total is in California. Owing to its high urban population and dense network of active faults, Southern California accounts for nearly 50% of the national AEL. 25% is concentrated in Los Angeles county alone.

The high earthquake risk in Southern California is the product of a dense network of active faults (high hazard) and a large urban population (high exposure). This population currently exceeds 20 million and is expected to reach 24 million by 2010.[3] Southern California's gross regional product is approaching $600 billion per year—it is now one of the world's largest economies and contains a number of rapidly growing urban centers with extensive infrastructures: major harbors, airports, freeways, lifelines, heavy and light industry, and all building types.

The people in Southern California know they are at risk, and they are eager to improve their understanding of earthquake hazards. SCEC serves this public as a distributed, regional organization with the mission of discovering, integrating, and communicating knowledge about earthquakes.

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[1] *HAZUS®99 Estimated Annualized Earthquake Losses for the United States*, Federal Emergency Management Agency Report 366, Washington, D.C., September, 2000, 32 pp (http://www.fema.gov/pdf/FEMA366.pdf).

[2] *An Evaluation of Future Earthquake Losses in California*, California Division of Mines and Geology, Sacramento, California, September, 2000, 16 pp (ftp://ftp.consrv.ca.gov/pub/dmg/pubs/Future_EQ_Losses.pdf). This estimate does not include losses associated with damage to transportation lifelines or critical facilities such as hospitals and power plants.

[3] *A Landscape Portrait of Southern California's Structure of Government and Growth*, W. Fulton, M. Glickfield, G. McMurran, and J. Gin, Claremont Graduate University Research Institute, California Planning and Development Report, 2000, 36 pp. (http://www.cp-dr.com/landscape_port/landport.html)

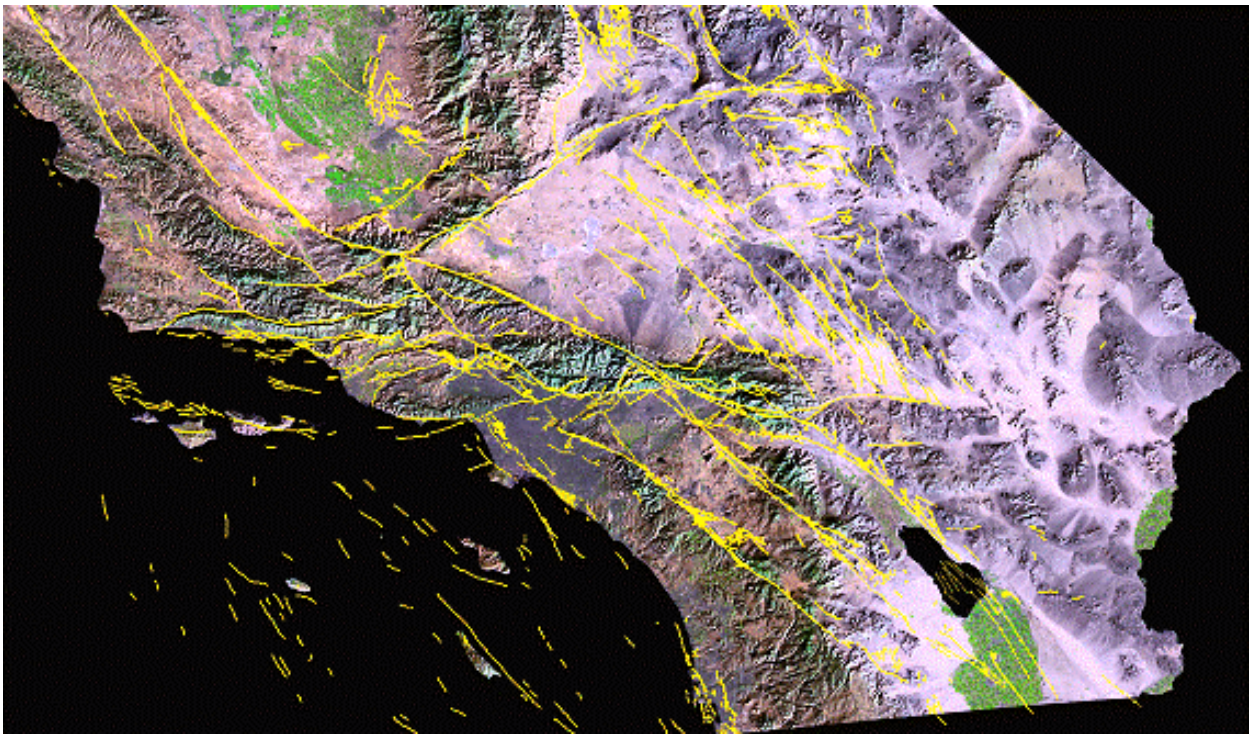

Figure 1.2. With its numerous active faults and diverse tectonic regimes astride the rapidly moving Pacific-North America plate boundary, Southern California is a superb natural laboratory for the system-level earthquake science proposed by SCEC.

2. Southern California: a Natural Laboratory for Earthquake Science

SCEC's role as a public-oriented center is complemented by its scientific mission, which is to investigate the fundamentals of crustal deformation in Southern California (Box 1.1). Many factors combine to make this natural laboratory ideal for basic earthquake research:

- Tectonic diversity. The setting comprises a wide range of tectonic styles and transitions, from extensional deformation in the Salton Trough to compression in the Transverse Ranges, and it contains a great variety of geologic structures, from granitic batholiths and core complexes of ancient metamorphic rocks to deepening basins filled with kilometers of Neogene sediments (Fig. 1.2).
- Fault-system complexity. Its geologic heterogeneity and position astride the rapidly moving (~50 mm/yr) Pacific-North America plate boundary have combined to generate a dense network of active faults (> 300), dominated by the San Andreas Fault (SAF) system. This natural laboratory has appropriate geographic dimensions for system-level studies—big enough to contain the largest SAF earthquakes (the dynamical outer scale), but small enough for a detailed analysis of seismicity and fault interactions.
- Excellent exposure. Onshore, the plate boundary deformation zone is particularly well exposed for geologic field mapping and satellite-based remote sensing. Offshore lies the California Borderlands, one of the few areas of continental wrench tectonics easily accessible to the increasingly powerful subsurface imaging methods of marine geophysics.[4]
- High seismic activity. Seismic activity in Southern California is as diverse as its geology. Young, rough faults such as the San Jacinto generate lots of small-magnitude seismicity, conforming to Gutenberg-Richter statistics,

[4] On the order of 10% of the earthquake potential in southern California may be due to offshore thrust and strike-slip faults. SCEC scientists have mapped active offshore structures from Santa Barbara to San Diego, including two large blind thrust faults between Los Angeles and San Diego that are believed to be reactivated low-angle normal faults with the potential for large (M 7.1-7.6) earthquakes; see C. Rivero, J. H. Shaw & K. Mueller, *Geology*, **28**, 891-894, 2000.

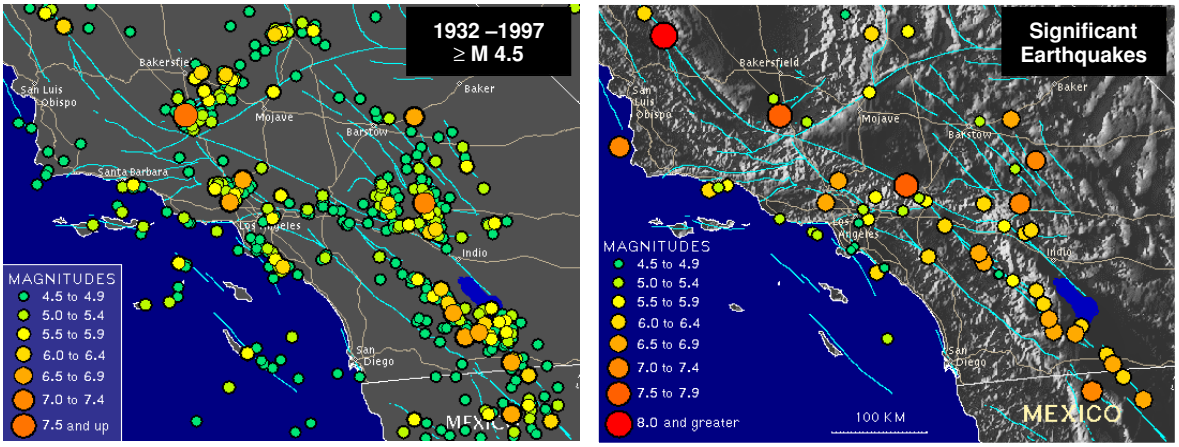

Figure 1.3. The instrumental and historical records of Southern California earthquakes document a wide variety of fault behaviors. The left panel displays the larger (M ≥ 4.5) earthquakes from a 65-year catalog of the Southern California Seismic Network; the right panel plots a selected set of epicenters for large, destructive, or unusual earthquakes since 1812.

while the more mature, smoother faults, including the San Andreas itself, release proportionately more of the strain in large-magnitude events (Fig. 1.3). Three major earthquakes have occurred in Southern California during SCEC's first decade: 1992 Landers (M7.3), 1994 Northridge (M6.7), and 1999 Hector Mine (M7.1). These are now among the best studied of all earthquakes; Northridge, the most costly natural disaster in U.S. history, yielded crucial information about earthquake damage in the urban environment.

The data on earthquake phenomena in Southern California are outstanding by all measures of quantity, quality, and variety. The 69-year catalog of the Southern California Seismic Network (SCSN) now comprises almost 500,000 instrumentally located events. For the last decade, local and regional earthquakes have been captured on digital, broadband arrays, and these records are readily available to researchers through the Southern California Earthquake Data Center at Caltech. Catalog parameters are being improved and expanded through new data analysis techniques; for example, focal mechanisms have now been determined for over 30,000 events. Strong ground motions have been recorded at hard-rock and soft-sediment sites for a series of major events, beginning with the Long Beach earthquake in 1933, and the densification of seismic instrumentation through the TriNet program will lead to further improvements in the strong-motion data base. The surface ruptures and secondary deformations of earthquakes have been carefully mapped, and the paleoseismicity of many active faults has been studied at many (177) trenching sites. Campaign GPS measurements have been collected across Southern California since 1985, and the Southern California Integrated GPS Network (SCIGN), formed in 1995 under the auspices of SCEC, is now providing continuous recording at over 235 permanent stations. The region's arid climate and low vegetation have allowed extensive mapping of fault structures and deformations by multi-spectral imaging, lidar, and interferometric synthetic aperture radar (InSAR).

SCEC provides the organizational structure for an outstanding scientific community nationwide. Some of the most accomplished researchers in earthquake science, and some of its most promising students, reside in Southern California—home to more than a dozen universities with geoscience programs, as well as the Jet Propulsion Laboratory, offices of the USGS (Pasadena) and CDMG, and respected private-consulting groups. Moreover, SCEC extends beyond Southern California. The core institutions in this proposal, listed in Table 1, include USGS offices in Menlo Park and Golden, as well as universities in Northern California (Stanford), other western states (University of Nevada at Reno), and the eastern U.S. (Columbia, Harvard, MIT). Another 18 geoscience organizations outside of Southern California have enrolled in SCEC2 as participating institutions (Table 2). A much larger, worldwide scientific community looks to the Center for collaborations in earthquake research.

3. Coordination of Earthquake Research

Understanding Southern California earthquakes and mitigating their impact is the focus of many organizations and individuals in government, academia, and the private sector. No single government agency can direct these diverse groups to implement a comprehensive research plan; coordina-

Box 1.1. SCEC Mission Statement and Science Goal

While the new center will differ significantly from the old in terms of scientific focus and management structure, SCEC will remain a regionally focused organization with a tripartite mission:

❶ To gather new information about earthquakes in Southern California.

❷ To integrate this information into a comprehensive and predictive understanding of earthquake phenomena as a scientific basis for seismic hazard analysis.

❸ To transfer this understanding to other communities in Southern California and elsewhere by communication with scientists, engineers, emergency managers, and government officials, and through education of the general public.

SCEC's primary science goal follows directly from statement ❷: To develop a physics-based understanding of earthquake phenomena in Southern California through integrative, multidisciplinary studies of plate-boundary tectonics, history and behavior of active fault systems, fault-zone processes, dynamics of fault ruptures, wave propagation, and strong ground motions.

tion requires a voluntary consortium. This coordination is critical to the development of (a) comprehensive data sets, (b) consensus models, and (c) consistent scientific judgements for public policy. Moreover, a broadly based consortium is well suited to the nature of the earthquake problem itself. Crustal faulting at seismogenic depths cannot be easily replicated in the laboratory and is nearly inaccessible to direct observation. The fundamental interactions are distributed over an enormous range of spatial and temporal scales. Progress in earthquake science, as in the study of many other complex natural systems (e.g. climate), requires the integration of a wide variety of observations into physics-based models capable of describing the contingent behaviors of individual events as well as the universal behaviors of many events. A primary objective of the proposed SCEC activities will be to achieve such integration.

Information technology is now furnishing the means to process massive streams of observations and, through numerical simulation, to elucidate and quantify many aspects of earthquake phenomena that have been completely resistant to standard theoretical analysis. As discussed in subsequent sections, the requirements for system-level modeling of earthquakes in Southern California lie well beyond the resources available to a single scientist or research group. The proposed SCEC effort has the twin purposes of (a) facilitating collaborations among large groups of investigators from a variety of disciplines and (b) providing an appropriate infrastructure for system-level modeling and integration. These activities are the basis for the science plan of this proposal.

B. The SCEC Transition

SCEC's graduation from the STC program presents an opportunity to reformulate its structure and improve its effectiveness. The transition from the original STC (here called SCEC1) to the new, free-standing center (SCEC2) will be guided by five tasks:

1. Develop a prototype, interdisciplinary research center for the EarthScope program.[5] Together with the many other organizations participating in EarthScope, SCEC2 will promote the integration of the various types of data into a comprehensive understanding of active deformation within the Southern California part of the Pacific-North American plate boundary zone.
2. Align SCEC2 activities more closely with those of the U.S. Geological Survey, which is planning to expand its programs related to earthquake hazards and loss mitigation in Southern California. The USGS has reiterated its support of the Center as a major partner in its scientific and public-outreach efforts.
3. Employ advanced information technology (IT) in system-level studies of earthquake phenomena. Through a partnership with several Earth-science and IT organizations, SCEC2 will develop an IT framework for research collaboration among widely distributed institutions and the dissemination of scientific results.
4. Enhance the application of basic research to earthquake risk reduction. The transfer mechanisms will include an Implementation Interface with the earthquake-engineering and risk-management communities and enhancements to SCEC1's successful Education and Outreach program.
5. Structure SCEC2 as an effective organization that can facilitate the participation of a broader

[5] EarthScope is an NSF initiative to employ new technologies for synoptic observation of the active tectonics and structure of the North American continent.(http://www.earthscope.org).

group of experts interested in the Southern California earthquake problem.

SCEC1 has been, and SCEC2 will continue to be, open to any individuals and institutions seeking to collaborate on the science of earthquakes in Southern California. The structure of SCEC2 recognizes both *core institutions*, which are research organizations with a major, sustained commitment to SCEC2 objectives, and a much larger number of *participating institutions*, which are self-nominating through the involvement of individual scientists or groups in SCEC2 activities. The nine core institutions of SCEC1 will be augmented by three universities (Stanford, Harvard, and MIT) and two additional offices of the USGS (Menlo Park and Golden). The number of core and participating institutions in SCEC2 now stands at 40 (Tables 1 & 2). For the five-year performance period of this proposal, the 11 academic core institutions have pledged over $5.5 million in direct matching funds (including overhead), as well as other valuable support such as faculty release time and space/facility usage. The commitment of University of Southern California, which will act as the managing institution for SCEC2, is especially impressive: $2.3 million in matching funds plus 11,000 square feet of renovated space in North Science Hall.[6] The new SCEC2 facility at USC will include a media center, conference room, a training center, advanced IT facilities, laboratories, office space for visitors, and the SCEC2 administrative center. This high level of commitment demonstrates that SCEC2 will be a true partnership between the core institutions and the sponsoring agencies.

C. Proposal Organization

This proposal is organized into five sections. Section II reports on the results of previous research funded by NSF and the USGS through a narrative that highlights SCEC1 accomplishments during its first decade, 1991-2000. This summary is followed by the Science Plan (§III), which discusses the major scientific issues and the proposed organizational framework. The remaining two sections describe the management plan (§IV) and the five-year budget (§V).

Table 1.1. SCEC2 Core Institutions

California Institute of Technology
Columbia University
Harvard University
Massachusetts Institute of Technology
San Diego State University
Stanford University
U.S. Geological Survey, Golden
U.S. Geological Survey, Menlo Park
U.S. Geological Survey, Pasadena
University of California, Los Angeles
University of California, San Diego
University of California, Santa Barbara
University of Nevada, Reno
University of Southern California

Table 1.2. SCEC2 Participating Institutions

Arizona State University
Brown University
Cal-State, Fullerton
Cal-State, Northridge
Cal-State, San Bernardino
California Division of Mines and Geology
Carnegie Mellon University
Central Washington University
Florida State University
Jet Propulsion Laboratory
Lawrence Livermore National Laboratory
Oregon State University
Pennsylvania State University
Rice University
Texas A&M University
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Riverside
University of California, Santa Cruz
University of Colorado
University of Massachusetts
University of New Mexico
University of Oregon
URS Corporation
Whittier College

[6] The North Science Hall renovation (45,000 sq.ft.) will cost USC about $32 million, with the 11,000 sq.ft. allocation for SCEC2 representing a commitment of nearly $8 million. Phase-I construction of this facility (6,600 sq.ft.) will begin in May, 2001, and Phase-II construction (4,400 sq.ft.) will be completed by September, 2002.