Executive Summary

This proposal requests five years of funding for the Southern California Earthquake Center (SCEC). The Center is a regionally focused organization with the mission to gather new information about earthquakes in Southern California, integrate knowledge into a comprehensive and predictive understanding of earthquake phenomena, and communicate this understanding to engineers, emergency managers, government officials, and the general public.

Rationale and Transition Objectives

Although SCEC will graduate from the NSF Science and Technology Centers (STC) Program in January, 2002, it should continue as a major center for earthquake science for three compelling reasons:

- Nearly half of the national earthquake risk is located in Southern California, with one-quarter concentrated in Los Angeles county alone. SCEC serves a population of 20 million people as its regional center for earthquake information.
- With many active faults and diverse tectonic regimes astride the rapidly moving Pacific-North America plate boundary, Southern California is a superb natural laboratory for understanding the fundamentals of earthquake processes. Data on earthquakes in this part of the world are outstanding. The integration of this information into a comprehensive and predictive understanding of earthquake behavior requires the resources of a multidisciplinary consortium capable of system-level research.
- Coordination of earthquake science in Southern California is critical to the development of the comprehensive data sets, consensus models, and consistent scientific judgements needed for public policy in earthquake risk management and mitigation.

The transition from the original STC (SCEC1) to the new, free-standing center (SCEC2) will be guided by five objectives: (1) to develop a prototype, interdisciplinary research center for NSF's EarthScope program, (2) to align SCEC2 more closely with the USGS, (3) to employ advanced information technology in system-level studies of earthquake phenomena, (4) to enhance the application of basic research to earthquake risk reduction, and (5) to facilitate the participation of a broader group of experts interested in the Southern California natural laboratory.

SCEC Accomplishments

For nearly a decade, SCEC has been the primary organization in Southern California for coordinating earthquake research. Among the most significant scientific accomplishments attained by scientists within this extended collaboration are the following:

- *Seismic hazard science:* Synthesis of seismic, geologic, and geodetic data to estimate earthquake potential. Procedure for balancing seismic and tectonic moment rates, including allowance for blind thrusts and off-fault earthquakes. Recognition of hazard-estimate sensitivity to magnitude distribution and non-Poissonian recurrence.
- *Los Angeles Basin hazard:* Fundamental reformulation of tectonics and seismic hazard of the L.A. Basin, including recognition of blind thrusts and the potential for very large (magnitude 7+) earthquakes.
- *Strong ground motion:* Improved understanding of how sedimentary basins influence earthquake ground motion—focusing effects in Santa Monica, sediment nonlinearity from the Northridge earthquake, and basin-depth effects—and the effects of surface deposits on ground shaking. Matching of low-frequency ground-motion amplitudes from Northridge using three-dimensional wave-propagation simulations.
- *Landers earthquake:* Joint inversion of multiple data sets to determine rupture history of a large earthquake. Demonstration of rupture propagation by dislocation pulse, rather than expanding crack. Detailed observations and physical modeling of post-seismic relaxation and the effects of fault segmentation during large-scale rupture.
- *Fault systems:* Paleoseismic fieldwork, geodetic observations, and integrative studies showing clustering of large earthquakes, prolonged earthquake interactions, large cascading ruptures, and general consistency with the historical record.
- *Deformation map:* Development of a detailed crustal deformation map, combining all available geodetic data, and use of this map to investigate tectonic loading of faults and post-earthquake response. Recognition from geodetic data of rapid strain accumulation in the eastern Ventura basin prior to the Northridge earthquake.
- *Evolution of stresses and slip deficits:* Modeling of stress evolution due to earthquakes, tectonic motions on faults, and stress relaxation. Demonstration that some earthquake sequences are consistent with triggering by stress interactions. Recognition of seismic slip deficits on faults in the Ventura and Los Angeles basins.
- *Los Angeles Basin structure from LARSE:* Discovery of a mid-crustal reflector (possible detachment zone) under the San Gabriel Mountains, apparent offset of the crust-mantle transi-

tion under the San Andreas Fault, and the displacement of the crustal root north of the topographic maximum. Revision of the depths of the San Gabriel and Los Angeles sedimentary basins.

- *Fault-zone waves:* Demonstration of the existence of waves trapped by fault-zone low-velocity waveguides and use of these waves in determining fault-zone properties and observing the fault-zone healing after earthquakes.
- *3D seismic velocity model:* Development of a 3D velocity model that includes geologic constraints, sedimentary basins, tomographic background velocities, a detailed geotechnical surface layer, and topography on the crust-mantle boundary. Demonstration that this model is consistent with independent gravity measurements.

These and other scientific results have been published in more than 500 scientific articles and special publications. The results have been synthesized into a "Master Model" of probabilistic seismic hazard in the Los Angeles region through a series of integrative reports:

- **Phase I**: Future Seismic Hazards in Southern California, Implications of the 1992 Landers Earthquake Sequence.
- **Phase II**: Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024.
- **Phase III**: Accounting for Site Effects in Probabilistic Seismic Hazard Analyses of Southern California.
- **Phase IV**: RELM: Regional Earthquake Likelihood Models.

SCEC organized and obtained funding for major new facilities in Southern California. The 250-station Southern California Integrated GPS Network (SCIGN) is the world's second-largest (behind Japan), making continuous, densely spaced geodetic measurements of strain accumulation and release in the L.A. Basin and surrounding regions. The Southern California Earthquake Data Center (SCEDC) is the primary data repository and distribution center for seismic networks in the region. The Portable Broadband Instrument Center (PBIC) provides high-performance seismic instrumentation for field experiments and post-seismic response.

Along with these facilities, SCEC developed a new infrastructure that allows researchers to share data, instruments, expertise, and effort. It developed on-line data archives for all available seismic records, geodetic data, and satellite radar images for Southern California, and established the first on-line, web-based relational database for retrieving strong-motion data. It coordinated the field observations and science analysis following the 1992 Landers, 1994 Northridge, and 1999 Hector Mine earthquakes, and provided much of the expertise for post-event response to the damaging 1999 Turkey earthquakes. Indeed, SCEC's most enduring accomplishment may be the demonstration that an effective, organized collaboration among disciplines is the best way to make progress in understanding earthquakes and communicating this understanding to others.

Science Plan

The proposed science plan is based on a fundamental research goal—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. It also addresses the application of this understanding to the practical problems of improving seismic hazard analysis and reducing earthquake risk. Five-year objectives have been formulated for each of the major research areas:

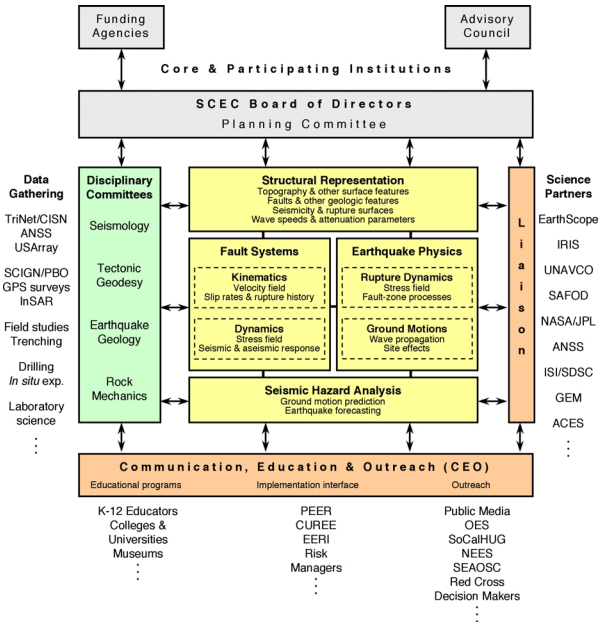
- *Plate-boundary tectonics:* to determine how the relative motion between Pacific and North American plates is distributed across Southern California, how this deformation is controlled by lithospheric architecture and rheology, and how it is changing as the plate-boundary system evolves.
- *Fault systems:* to understand the kinematics and dynamics of the plate-boundary fault system on interseismic time scales, and to apply this understanding in constructing probabilities of earthquake occurrence in Southern California, including time-dependent earthquake forecasting.
- *Fault-zone processes:* to understand the internal structure of fault zones and the microscale processes that determine fault-zone rheologies in order to formulate more realistic macroscopic representations of fault-strength variations in time and space.
- *Rupture dynamics:* to understand the physics of rupture nucleation, propagation, and arrest in realistic fault systems, and the generation of strong ground motions by earthquakes.
- *Wave propagation:* to determine the structure of urbanized Southern California well enough to predict deterministically the surface motions from a specified seismic source at all frequencies up to at least 1 Hz, and to formulate useful, consistent, stochastic representations of surface motions up to at least 10 Hz.
- *Seismic hazard analysis:* to incorporate time dependence into the framework of seismic hazard analysis in two ways: (a) through the use of rupture dynamics and wave propagation in realistic geological structures, to predict strong-motion seismograms (time histories) for anticipated earthquakes, and (b) through the use of fault-system dynamics, to forecast the time-

dependent perturbations to average earthquake probabilities in Southern California.

The SCEC2 framework proposed for achieving these long-term goals is a matrix of four components. *Disciplinary committees* in seismology, geodesy, geology, and rock mechanics will be responsible for planning and coordinating data gathering and disciplinary infrastructure, including field programs, centralized data processing, and the distribution of data products. Project-oriented *focus groups* will conduct interdisciplinary research in four primary areas: (1) structural representation, to unify geologic and seismic information into a coherent picture of subsurface structure, (2) fault systems, including both their kinematical and dynamical behaviors, (3) earthquake physics, including rupture dynamics, wave propagation, and site effects, and (4) seismic hazard analysis. Much of this research will be coordinated through the development of Community Models—on-line, documented, maintained resources that can function as virtual collaboratories for knowledge quantification and synthesis, hypothesis formulation and testing, data conciliation and assimilation, and prediction.

The advanced IT infrastructure needed for this type of system-level earthquake science—computational algorithms for exploiting massively parallel computers, access to distributed computing and collaborative environments, advanced methods for code development and sharing, software libraries, distributed visualization tools, and data-management capabilities—will be developed through an *information technology partnership*. In addition to the SCEC2 institutions, the partnership will comprise USC's Information Sciences Institute (ISI), UCSD's San Diego Supercomputer Center (SDSC), the Incorporated Institutions for Research in Seismology (IRIS), and the Generalized Earthquake Models (GEM) project.

A strategically designed, outcome-oriented *Communication, Education and Outreach* (CEO) program will continue SCEC1's successful outreach efforts with two significant enhancements: there will be a much closer collaboration with the USGS outreach program in Southern California, and the knowledge-transfer activities will be restructured to include an "implementation interface," designed to foster two-way communication with SCEC2 partners in earthquake engineering and risk management.



The SCEC2 matrix of activities. Disciplinary committees will coordinate data-gathering activities and infrastructure. Focus groups will organize project-oriented interdisciplinary research. Interfaces to SCEC partners will include scientific liaison and the CEO Program. Scientific planning will be the responsibility of the Planning Committee, which will prepare annual budgets for the Board of Directors.

Management Plan

SCEC2, like the current Center, will be an institutionally-based organization governed by a Board of Directors. The structure of SCEC2 will recognize both *core institutions*, which are research organizations with major, sustained commitments 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. Currently, 14 core and 26 participating institutions are enrolled in the SCEC2; however, this listing may change, because the Center will be an *open consortium*, available to any individuals and institutions seeking to collaborate on the science of earthquakes in Southern California. The administrative staff will include a Center Director, who will act as the chief executive officer of the Center and will bear ultimate responsibility for the Center's programs and budget. The Center will establish an external Advisory Council to serve as an experienced advisory body to the Board of Directors. The annual budget cycle will begin with the articulation of the research plan, coordinated through a Joint Planning Committee with the USGS and approved by the Executive Committee. This research plan will form the basis for the solicitation and evaluation of "miniproposals" from SCEC2 participants, which will guide the preparation of an annual Center budget; once approved by the Board and signed by the Center Director, this budget will be submitted to the sponsoring agencies for final approval and funding.