Southern California Earthquake Center

2003 Annual Report

NSF Cooperative Agreement EAR-0106924 and USGS Cooperative Agreement 02HQAG0008

I. Introduction

The Southern California Earthquake Center (SCEC) is a regionally focused organization with a tripartite mission to

- gather new information about earthquakes in Southern California,
- integrate this information into a comprehensive and predictive understanding of earthquake phenomena, and
- communicate this understanding to end-users and the general public in order to increase earthquake awareness and reduce earthquake risk.

SCEC was founded in 1991 as a Science and Technology Center (STC) of the National Science Foundation (NSF), receiving primary funding from NSF's Earth Science Division and the United States Geological Survey (USGS). SCEC graduated from the STC Program after a full 11-year run (SCEC1). It was reauthorized as a free-standing center on February 1, 2002 (SCEC2) with base funding from NSF anD USGS. In addition, the Center was awarded major grants from NSF's Information Technology Research (ITR) Program and its National Science, Technology, Engineering, and Mathematics Digital Library (NSDL) program.

This report summarizes the Center's activities during the second year of SCEC2. The report is organized into the following sections:

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II. Planning, Organization, and Management of the Center

The transition from SCEC1 to SCEC2 involved considerable planning and restructuring. A five-year planning document, *The SCEC Strategic Plan 2002-2007*, was submitted to the sponsoring agencies in October, 2001. This plan articulates the Center's long-term research goals, which are reproduced here in Appendix A. The current organization chart of the Center is presented in Figure II.1.

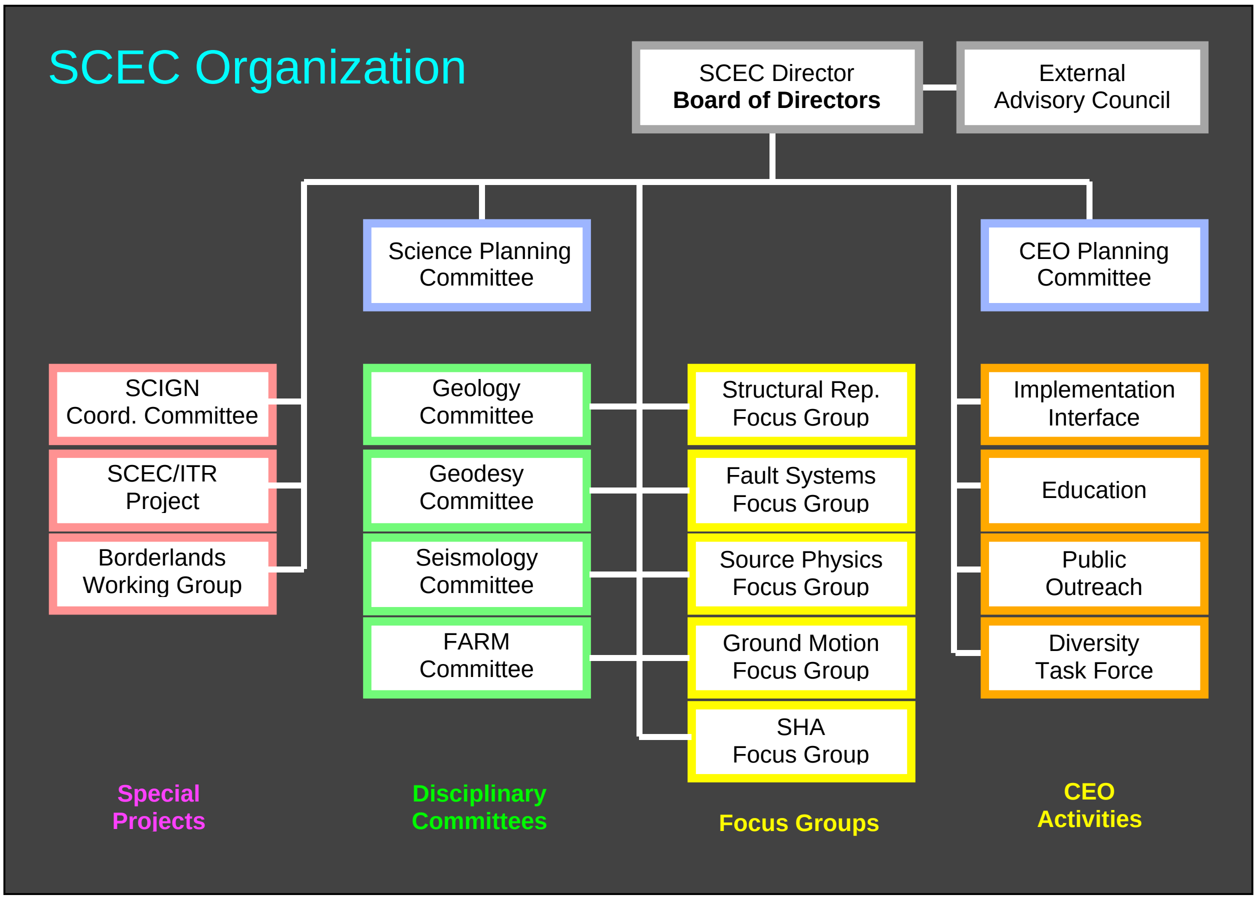

Figure II.1. Organization chart of the Southern California Earthquake Center

SCEC is an institution-based center, governed by a Board of Directors who represent its members. During the past year, the Board approved three new U.S. participating institutions (Boston University, Utah State University, SUNY Stony Brook) and two foreign institutions (ETH Zürich and Centro de Investigatión Cientifica y de Educatión Superior de Ensenada). The SCEC membership now comprises 14 core institutions and 30 participating institutions. One measure of the growing size of the SCEC community is the attendance at its Annual Meeting (September 7-10, 2003), which rose to 360 people—the largest group in the history of the Center.

Board of Directors

Under the SCEC2 by-laws, each core institution appoints one board member, and two at-large members are elected by the Board from the participating institutions. Dr. Bill Ellsworth, who was recently appointed as the leader of the USGS Western Region Earthquake Hazards Team, has replaced Dr. Jim Dieterich as the board member from the USGS-Menlo Park office. (Jim is not about to disappear, however; he will continue his effective leadership as the co-chair of the Fault and Rock Mechanics disciplinary committee.) The other 15 members of the Board are listed in Table II.1. *Ex officio* members include the SCEC Deputy Director, Prof. Ralph Archuleta, who replaced Prof. Tom Henyey on September 1, 2003; the Associate Director for Administration, Mr. John McRaney, who also serves as Executive Secretary to the Board; and the Associate Director for Communication, Education and Outreach, Mr. Mark Benthien.

Table II.1. SCEC Board of Directors

Institutional and At-Large Representatives	
Thomas H Jordan* (Chair)	University of Southern California
Gregory C. Beroza* (Vice-Chair)	Stanford University
James N. Brune	University of Nevada Reno
Douglas Burbank*	University of California Santa Barbara
Steven M. Day	San Diego State University
Bill Ellsworth	USGS-Menlo Park
Lisa Grant (At-Large)	University of California Irvine
Thomas Heaton	California Institute of Technology
Thomas A. Herring	Massachusetts Institute of Technology
David D. Jackson	University of California Los Angeles
Lucile Jones*	USGS-Pasadena
J. Bernard Minster*	University of California San Diego
James Rice	Harvard University
Bruce Shaw	Columbia University
Terry Tullis (At-Large)	Brown University
Robert Wesson	USGS-Golden
Ex-Officio Members	
Ralph Archuleta (Deputy Director)	
John McRaney* (Executive Secretary)	
Mark Benthien (Associate Director, CEO)	

* Executive Committee members

External Advisory Council

SCEC's Advisory Council (AC) is an external group charged with developing an overview of SCEC operations and giving advice to the Director and the Board. Dr. Sean Solomon of the

Carnegie Institution of Washington joined the AC in 2003, bringing its membership to 10. The current members are: Robert Smith (Chair/ U. Utah,), Jeff Freymueller (U. Alaska), Raul Madariaga (Ecole Normale Superieure), Jack Moehle (PEER), Farzad Naeim (John A. Martin & Associates), Garry Rogers (Geological Survey Of Canada), Chris Rojahn (Applied Technology Council), Haresh Shah (RMS, Inc.), Sean Solomon (Carnegie Institution of Washington), Ellis Stanley (LA Emergency Preparedness Department), and Susan Tubbesing (EERI). Prof. Smith will step down as chair when his term ends in January, 2004, although he will remain a member of the AC. The Advisory Council's second report is reproduced verbatim in Section VI.

Organization of Research

A central organization within SCEC is the Science Planning Committee (PC), which is chaired by the Deputy Director and has the responsibility for formulating the Center's science plan, conducting proposal reviews, and recommending projects to the Board for SCEC funding. The PC was very capably chaired by Tom Henyey through the 2003 SCEC annual meeting. Prof. Henyey resigned as SCEC Deputy Director in the summer of 2003 to assume the chair of the Earth Sciences Department at USC. Prof. Ralph Archuleta of UC-Santa Barbara was appointed Deputy Director and Chair of the PC in September, 2003.

The PC membership includes the chairs of the major SCEC working groups. There are three types of working groups—disciplinary committees, focus groups, and special project groups. The Center is fortunate that some of its most energetic and accomplished colleagues participate as group leaders (Table II.2). During the past year, Dr. Craig Nicholson of UCSB replaced Dr. Monica Kohler of UCLA as chair of the Borderland Working Group, and Prof. Tom Herring of MIT was elected as the chair of the SCIGN Coordinating Committee, replacing Dr. Ken Hudnut of the USGS.

Table II.2. Leadership of the SCEC Working Groups

Disciplinary Committees	
Seismology:	John Vidale (chair)*
	Peter Shearer (co-chair)
Geodesy:	Duncan Agnew (chair)*
	Mark Simons (co-chair)
Geology:	Tom Rockwell (chair)*
	Doug Burbank (co-chair)
Fault & Rock Mechanics:	Terry Tullis (chair)*
	Jim Dieterich (co-chair)
Focus Groups	
Structural Representation:	John Shaw (leader)*
	Rob Clayton (co-leader)
Fault Systems:	Brad Hager (leader)*
	Charles Sammis (co-leader)
Earthquake Source Physics:	Ruth Harris (leader)*
	Greg Beroza (co-leader)
Ground Motions:	Paul Davis (leader)*
	Steve Day (co-leader)
Seismic Hazard Analysis:	Ned Field (leader)*
	John Anderson (co-leader)
Special Project Groups	
Implementation Interface:	Paul Somerville (leader)*
	Rob Wesson (co-leader)
SCIGN Steering Committee:	Tom Herring (chair)*
SCEC/ITR Project:	Bernard Minster (liaison)*
Borderland Working Group:	Craig Nicholson (chair)*

* Science Planning Committee members

The Center sustains disciplinary science through standing committees in *seismology*, *geodesy*, *geology*, and *fault and rock mechanics*. These committees are responsible for planning and coordinating disciplinary activities relevant to the SCEC science plan, and they make recommendations to the Science Planning Committee regarding the support of disciplinary infrastructure. Interdisciplinary research is organized into five science focus areas: *structural representation*, *fault systems*, *earthquake source physics*, *ground motion*, and *seismic hazard analysis*. The focus groups are the crucibles for the interdisciplinary synthesis that lies at the core of SCEC's mission.

In addition to the disciplinary committees and focus groups, SCEC manages several special research projects, including the Southern California Integrated GPS Network (SCIGN), the Borderland Working Group, and the SCEC Information Technology Research (SCEC/ITR) Project. Each of these groups is represented on the Science Planning Committee by its chair, with the exception of the SCEC/ITR Project, which is represented by Bernard Minster, a Co-P.I. of the project (the P.I. is the Center Director, Tom Jordan).

SCEC continues as the parent organization for the Southern California Integrated GPS Network (SCIGN), which has now has > 260 continuously monitoring GPS stations. We are now working with UNAVCO to coordinate future SCIGN work with those of the Plate Boundary Observatory (PBO) of the EarthScope Project.

The Borderland Working Group represents SCEC researchers interested in coordinating studies of the offshore tectonic activity and seismic hazards in California Borderland.

The goal of the SCEC/ITR Project is to develop an advanced information infrastructure for system-level earthquake science in Southern California. Partners in this SCEC-led collaboration include the San Diego Supercomputer Center (SDSC), the Information Sciences Institute (ISI), the Incorporated Research Institutions for Seismology (IRIS), and the USGS. In many respects, the SCEC/ITR Project presents a microcosm of the IT infrastructures now being contemplated in the context of EarthScope and other large-scale science initiatives, so the opportunities and pitfalls in this area need to be carefully assessed. The SCEC/ITR annual report has been submitted as a separate document to NSF.

The long-term goals and short-term objectives laid out in the SCEC Strategic Plan provided the basis for the SCEC Program Announcements, which are issued annually in October. This proposal process is the primary mechanism through which SCEC recruits scientists to participate in its research collaborations. The process of structuring the SCEC program for 2003 began with the working-group discussions at the annual meeting in September, 2002. An RFP was issued in October, 2002, and 187 proposals (140 projects, considering collaborations) requesting a total of $5,663K were submitted in November, 2002. The 2003 RFP is reproduced in Appendix C.

All proposals were independently reviewed by the Director and Deputy Director. Each proposal was also independently reviewed by the chairs and/or co-chairs of three relevant focus groups or disciplinary committees. (Reviewers were required to recuse themselves when they had a conflict of interest.) The Planning Committee met on January 20-21, 2003, and spent two long days discussing every proposal. The objective was to formulate a coherent, budget-balanced science program consistent with SCEC's basic mission, short-term objectives, long-term goals, and institutional composition. Proposals were evaluated according to the following criteria:

a. Scientific merit of the proposed research.

b. Competence and performance of the investigators, especially in regard to past SCEC-sponsored research.
c. Priority of the proposed project for short-term SCEC objectives.
d. Promise of the proposed project for contributing to long-term SCEC goals.
e. Commitment of the P.I. and institution to the SCEC mission.
f. Value of the proposed research relative to its cost.
g. The need to achieve a balanced budget while maintaining a reasonable level of scientific continuity given very limited overall center funding.

The recommendations of the PC were reviewed by the SCEC Board of Directors at a meeting on February 3-4, 2003. The Board voted unanimously to accept the PC's recommendations, pending a final review of the program by the Center Director, which was completed on February 14. Section III outlines the progress achieved in the 2003 research program.

In June, the Planning Committee met jointly with the Board of Directors and agency representatives for two full days to conduct a comprehensive review of the entire SCEC program. The leaders of all of the working groups summarized their accomplishments and plans, and there were vigorous discussions of how the current mix of science projects and other activities might be adjusted to better attain SCEC's five-year goals. Out of those sessions came the draft 2004 RFP that was put up for scrutiny at the 2003 annual meeting.

SCEC is coordinating its research program with the USGS through a Joint Planning Committee (JPC). For example, the USGS members of the JPC attended the proposal review meeting of the SCEC Planning Committee as non-voting participants, and they also attended the joint Board/PC meeting in June.

Communication, Education, and Outreach

SCEC is committed to applying the basic research in earthquake science to the practical problems of reducing earthquake losses. To accomplish this aspect of its mission, SCEC maintains a vigorous Communication, Education, and Outreach (CEO) Program that receives 10% of its base funding plus other funds from special projects, such as the Electronic Encyclopedia of Earthquakes. CEO activities are managed by the Associate Director for CEO, Mark Benthien. The programmatic elements include structured activities in education and public outreach and two new structures: an *Implementation Interface*, designed to foster two-way communication and knowledge transfer between between SCEC scientists and partners from other communities—in particular, earthquake engineering, risk analysis, and emergency management, and *a Diversity Task Force*, responsible for furthering the goal of gender and ethnic diversity in earthquake science. A report on the second-year CEO activities is given in Section IV.

III. Research Accomplishments

This section summaries the main research accomplishments and research-related activities organized by the disciplinary committees, focus groups, and special project working groups during 2003.

Disciplinary Activities

During this past year, the disciplinary committees reviewed the infrastructure elements in their disciplines that have been historically supported by SCEC and to assess how SCEC resources should be allocated to the disciplinary infrastructure in the future. The chairs and co-chairs of the disciplinary committees also participated in developing the program announcements and in the proposal review process to insure that the disciplinary elements of SCEC research remain strong. The following reports summarize the infrastructure activities and the discipline-oriented research.

<u>Seismology</u>. In 2003, SCEC has supported four activities to maintain and improve seismic infrastructure. Two projects are managed by UCSB, one is a joint effort between Caltech and UCSD, and the largest is run from Caltech.

Portable Broadband Instrument Center. The SCEC portable instrument program at UCSB, managed by Jamie Steidl, provides a valuable resource for focused experiments in southern California, and it has contributed to a number of important results, including analyses of fault-zone guided waves, aftershock seismicity studies, and detailed images of crustal velocity structure derived from the LARSE refraction profiles. These experiments promote student involvement and can be conducted with greater flexibility and shorter lead times than is possible through the IRIS PASSCAL program.

In the past year, SCEC support for the PBIC covered maintenance of instrumentation (including DAS firmware upgrades, battery maintenance, and sensor calibrations) and continued support of several projects. These include a project run by UC Santa Cruz to examine shoreline wave energy and cliff erosion using the PBIC broadband CMG-40T sensors and RefTek DAS systems. This project is a continuation of previous work by Pete Adams that has resulted in a 2002 publication in Geology. UCSD and SDSU researchers Frank Vernon and Steve Day continue to collaborate on a Northern Baja experiment using the PBIC broadband CMG-40T sensors. UCSB researcher Ralph Archuleta along with undergraduate student assistants finished up the Santa Barbara Array deployment in summer 2003, and the students are now learning how to process and analyze the data. Education of the undergraduates as well as outreach to local K-12 schools in the Santa Barbara area have always been an integral part of the PBIC program at UCSB.

The PBIC is currently seeking future funding opportunities to upgrade the existing instrument pool with new data-logger and telemetry technology. This upgrade would enable the portable instrument pool to be deployed and integrated into local regional networks. These upgrades would facilitate routine data processing and archival, as well as provide real-time access to data from individual PBIC projects and major earthquake deployments. Cost sharing is required by the two NSF programs that are being considered, the MRI and IF programs. An MRI pre-proposal was submitted to UCSB administration on October 24, 2003 and, if approved to be one of the two campus proposals targeted for this program, UCSB with help from SCEC will need to come up with approximately $150K of matching funds to support this program. The IF program has slightly lower cost sharing requirements, but proposal for instrumentation upgrades are only allowed in the annual July deadline. This will be the backup target for the new proposal.

Borehole Instrumentation Program. Borehole seismic instruments, installed by Jamie Steidl at UCSB, have advantages over surface installations owing to their generally lower noise levels and ability to record signals below highly attenuating near-surface layers. They provide valuable constraints on seismic structure and earthquake source processes, as well as motions for nonlinear soil behavior during strong shaking. Boreholes are expensive, however, and the seismic community cannot afford to drill many new holes. Hence, the SCEC borehole instrument program is taking advantage of the opportunities provided when pre-existing boreholes become available for research purposes.

The SCEC borehole instrumentation program maintained its close collaboration with CISN this past year with the long term goal to increase the number of borehole channels while leveraging resources from the variety of agencies within CISN. Cost sharing and collaboration are the biggest success stories for the borehole program which takes advantage of the network infrastructure resources to ensure that the borehole data flow real-time into the regional CISN networks and are integrated into the Southern California Earthquake Data Center. This involves a significant and active role in the maintenance of network and data center operations.

The majority of efforts in the past year have been focused on upgrades and maintenance of existing stations, and planning for new borehole channels from the San Fernando Valley, the Imperial Valley, and the Keenwild and Pinon Flat ANZA sites. The San Fernando Valley is a collaboration with the LADWP at the Rinaldi sub-station where the USGS has provided a cased borehole from site characterization studies of the site. This station recorded one of the most important strong motion records from the Northridge earthquake. The Imperial Valley site is a collaboration with USGS NSMP program at a previously drilled strong motion station, Bonds Corner, that has a history of recording important strong motion records. The SCEC community, especially the earthquake source physics and rock mechanics groups, have requested deep bedrock borehole data in active fault regions. The Keenwild and Pinon boreholes will be re-instrumented with new sensors over the next two years and integrated into CISN through the ANZA network.

Southern California Earthquake Data Center (SCEDC). The USGS/Caltech/SCEC data center for SCSN/Trinet/Terrascope, overseen by Rob Clayton, plays a key part of seismic network operations and facilitates both routine and innovative analyses of seismic data. It has continued to maintain and update the primary online, near "real-time" searchable archive of seismological data for Southern California.

The SCEDC has continued converting the remainder of the historic seismic data, so there will be a single source of seismic data from 1932-present. The data sets from 1932-1976 have been compiled and converted into the modern archival format. This era of seismic data were key-punched from the original phase cards into CUSP format. The data were then imported into the SCEDC Oracle database, so phase and epicenter data is available for direct retrieval by users via STP. Quality control verification of 1981-2000 historic parametric and waveform data that had previously been converted into the modern archival format has progressed using a detailed examination and verification of magnitudes. The remaining data to be converted are a problematic four-year span of 1977-1980, which still exists in CUSP format on a VAX system, but will be complete by the end of July. The Data Center has made significant progress to enhance and expand an interface to search all available catalogs via a single, uniform search engine spanning 1932-present.

The Data Center archived a continuous time-window of high sample-rate data from all stations for 6 hours before and 12 hours after the Feb. 22, 2003 M 5.4 Big Bear event. In standard data-collection mode, the SCSN broadband instruments are recorded continuously and the higher sample-rate short-period instruments of the network are only recorded in triggered mode. This data set will aid researchers in foreshock/aftershock studies. The alternative earthquake locations of Hauksson and Shearer-Dinger are being added to the database catalog and will be available for retrieval via STP. The Data Center continued to further develop the programmatic interface to the Data Center to allow users to directly query the archive at the SCEDC for data that serve their individual research needs. This interface will provide a virtual gateway to the archive where programmers can write their code to access, retrieve, and process on-line, machine-readable data. The SCEDC is putting significant effort into making waveform data available via the NetDC data exchange interface used by IRIS centers.

Progress has been made to establish a Data Center Advisement Committee. Greg Beroza, Bob Nigbor, Jamie Steidl, Tim Ahern, and John Vidale agreed to serve and will participate in establishing and prioritizing Data Center goals and improving feedback methodology. The Data Center has continued integration efforts with other data centers, specifically the NCEDC via the California Integrated Seismic Network (CISN), and continues to act as a backup for the northern California archive.

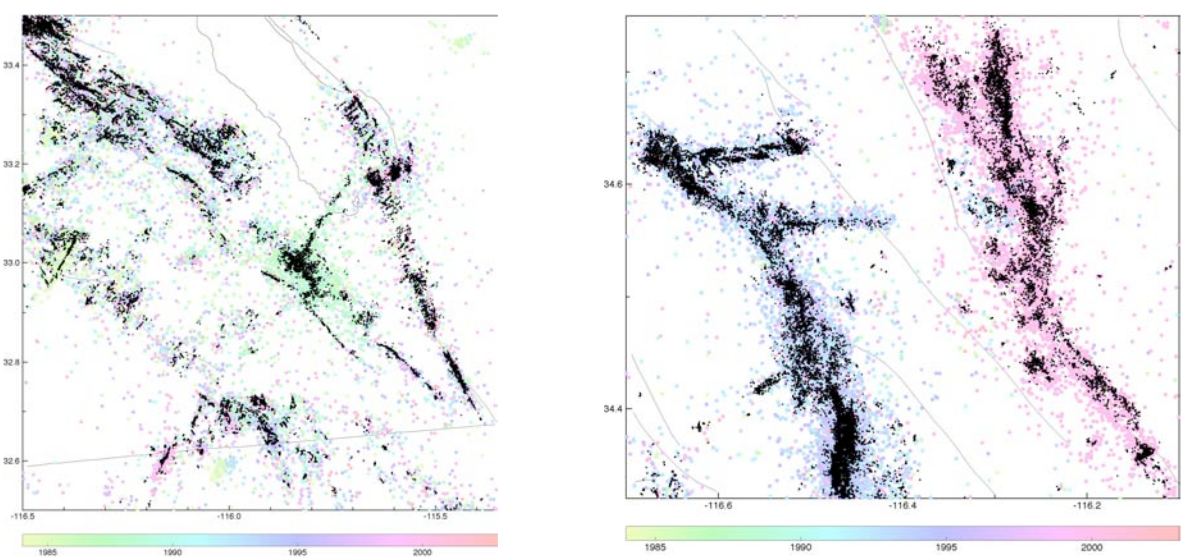

Figure III.1. Egill Haukkson and Peter Shearer have relocated more than 340,000 earthquakes that occurred between 1984 and 2002 by waveform cross-correlation. The improved seismicity maps show many conjugate faults and other fine-scale structures. These plot shows relocated similar event clusters in black for southernmost California (left) and in the region of the 1992 Landers and 1999 Hector Mine earthquakes (right).

Waveform cross-correlation relocation of Southern California seismicity. Caltech and UCSD researchers (Hauksson, Shearer and co-workers) collaborated on a jointly funded SCEC project to perform waveform cross-correlation on southern California seismograms for over 380,000 events between 1984 and 2002. Waveforms recorded by the SCSN are first extracted from the SCEDC data center in 50 s windows that include both P and S waves. The resulting online waveform archive uses about 0.5 TB on a RAID system. To simplify the computation, southern California is divided into five polygons, such that there are ~100,000 events or less in each region. Polygon boundaries are chosen to lie in regions of sparse seismicity. The traces are then re-sampled to a uniform 100 Hz sample rate and band-pass filtered to between 1 and 10 Hz. Next, time domain waveform cross-correlation times are computed for P and S waves between each event and 100 neighboring events (identified from the catalog based on a 3-D velocity model of Hauksson, 2000). The algorithm identifies and saves differential times from the peaks in the cross-correlation functions and uses a spline interpolation method to achieve a nominal timing precision of 0.001 s. The Caltech/UCSD group used these differential times as input to two different relocation methods: (1) the double-difference program (HypoDD) of Waldhauser and Ellsworth (2000), and (2) the cluster analysis approach of Shearer (2003).

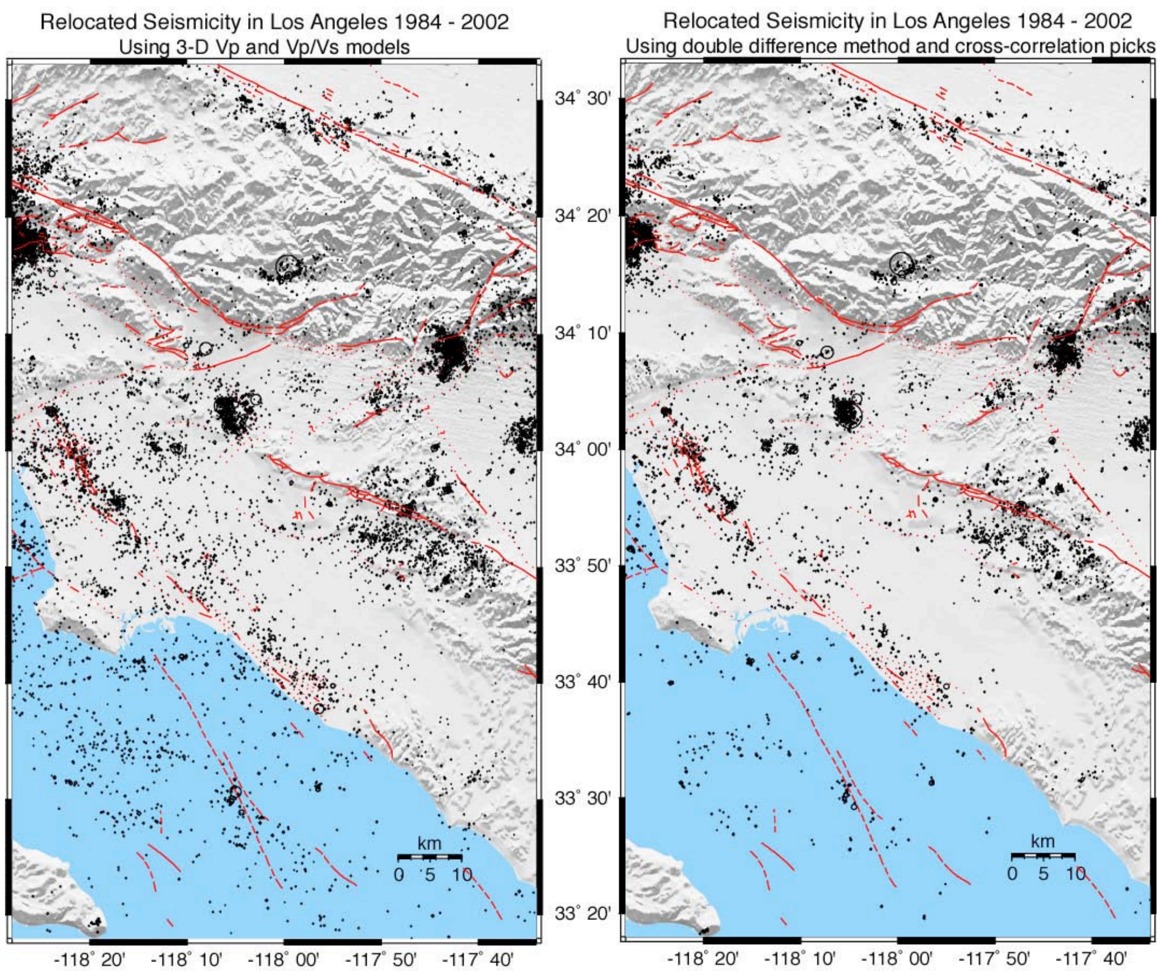

Figure III.2. Improved maps of seismicity in the Los Angeles area from the Hauksson-Shearer relocation study.

The resulting HypoDD hypocenters show improved clustering both horizontally and vertically, creating a more focused picture of the previously identified, spatially complex distributions of seismicity. In many cases, the late Quaternary faults, such as the Elsinore and

Hollywood-Santa Monica faults appear to bracket the seismicity distributions; in other cases, the faults trace the median within a symmetric distribution of hypocenters. The depth distribution of the seismicity shows sudden changes across some of the major strike-slip faults, while regions of dip-slip faulting are often bound by dipping surfaces that are clearly defined by the deepest hypocenters. The seismicity around the southern San Andreas fault shows clear alignment along the Carrizo Plain segment while both the Mojave and Coachella Valley segments are dominated by off-fault hypocenters. A prominent horizontal boundary striking a few degrees north of west with a prominent depth change in the seismicity cuts across Banning Pass towards San Bernardino. Earthquake swarms in the Salton Sea at the south end of the San Andreas fault suggest the presence of two north-northwest striking seismic zones at the south end of the San Andreas fault. In the Los Angeles basin, the major aftershock sequences appear as densely focused clusters within a cloud of scattered background seismicity. The seismicity along the Newport-Inglewood fault forms a sharp alignment to the north and a diffuse distribution to the south, where the 1933 Long Beach earthquake occurred. Similarly, several clusters as well as scattered background seismicity extending from east to west across the basin illuminate the blind thrusts beneath the north edge of the basin. The major aftershock sequences such as 1992 Landers, 1994 Northridge, and 1999 Hector Mine form clusters, with distinct internal structures, illuminating secondary faults and a heterogeneous main fault rupture surface. Some of these alignments suggest that high angle cross-faults were activated by the mainshock.

The cluster analysis approach obtains precise relative locations for the earthquakes by applying the source-specific station term (SSST) method to existing P and S phase picks and a differential location method to about ~150,000 events within similar event clusters identified using waveform cross-correlation. The entire catalog is first relocated using existing phase picks and the SSST method of Richards-Dinger and Shearer (2000). Next, cluster analysis is applied to the waveform cross-correlation output in order to identify similar event clusters. Because cross-correlation results are obtained for only some of all possible event pairs, some modifications to standard cluster analysis algorithms were necessary to achieve a suitable method. Earthquakes are then relocated within each similar event cluster using the differential times alone, keeping the cluster centroid fixed to its initial SSST location. Standard errors are obtained for the relative locations from the internal consistency of differential locations between individual event pairs; these errors are often as small as tens of meters. In many cases the relocated events within each similar event cluster align in planar features suggestive of faults. There are a surprising number of conjugate faults at small scales that strike nearly perpendicular to the main seismicity trends. In general, the fine-scale details of the seismicity reveal a great deal of structural complexity in southern California fault systems.

These relocated event catalogs are still preliminary but are planned to be released to the SCEC community by the end of the year. Future work will concentrate on comparisons between the methods and detailed assessments of location accuracy and strategies for further improvements. A long term goal is to integrate an improved location method into routine network processing.

<u>Geodesy</u>. The SCEC2 geodesy program continued to produce important data, and analyses to improve our understanding of earthquake physics in Southern California. Among the highlights of the last year have been the following:

- Release, in August 2003, of Version 3.0 of the SCEC Crustal Motion Map, available on the Web at http://epicenter.usc.edu/cmm3. This set of velocities for geodetic sites in Southern California rests on a substantial base of data-collection and analysis efforts which have given this area the longest and most spatially dense set of crustal deformation measurements anywhere in the world outside Japan. The final product includes 833 estimates of current station velocities (relative to North America) at 762 points in Southern California and northern Baja California, together with coseismic offsets for the Landers earthquake (at 353 locations), Northridge earthquake (97 locations), and Hector Mine earthquake (250 locations). The velocities are derived from EDM data between 1973 and 1991, and GPS data from 1986 through 2001, with as much care as possible taken to avoid contaminating them with post-earthquake transients.

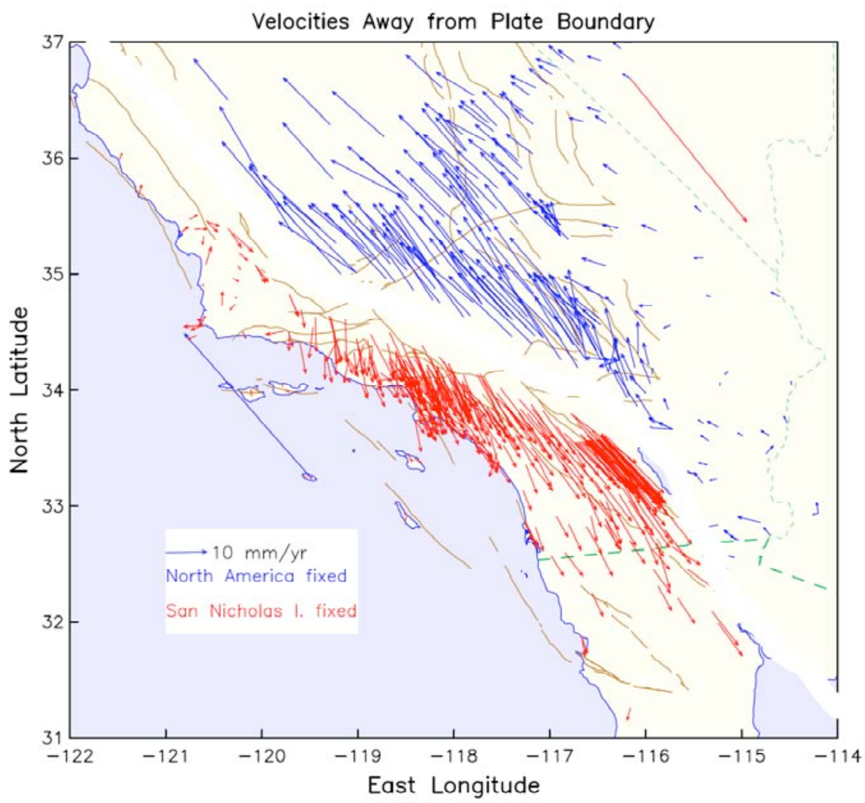

Figure III.3. Map derived from CMM3.0, showing velocities of sites away from the plate boundary, with each velocity referenced to its own plate. The effect of the Big Bend of the San Andreas is evident, in causing the velocities along the southern edge to be larger to the west of the boundary (the Borderlands faults and the Elsinore/San Jacinto system). Along the northern edge, the velocities are larger east of the boundary (the Eastern California Shear Zone).

- Recording of large dynamic strains from a teleseismic event (the Denali earthquake) as these propagated through the Los Angeles basin. One recording (Figure III.4) was made by the SCEC-sponsored strainmeter in Glendale, which has been operating since August 2002, and providing a continuous record of strain change in the area. A much more novel result came from processing of the 1-second GPS data collected by stations of the SCIGN network in Orange County. Stacking of the relative displacements between stations of this network also showed the seismic strains, at a distance greater than these had previously been recorded. Between them, these two methods offer essentially unlimited dynamic range for the recording of strains from seismic waves.

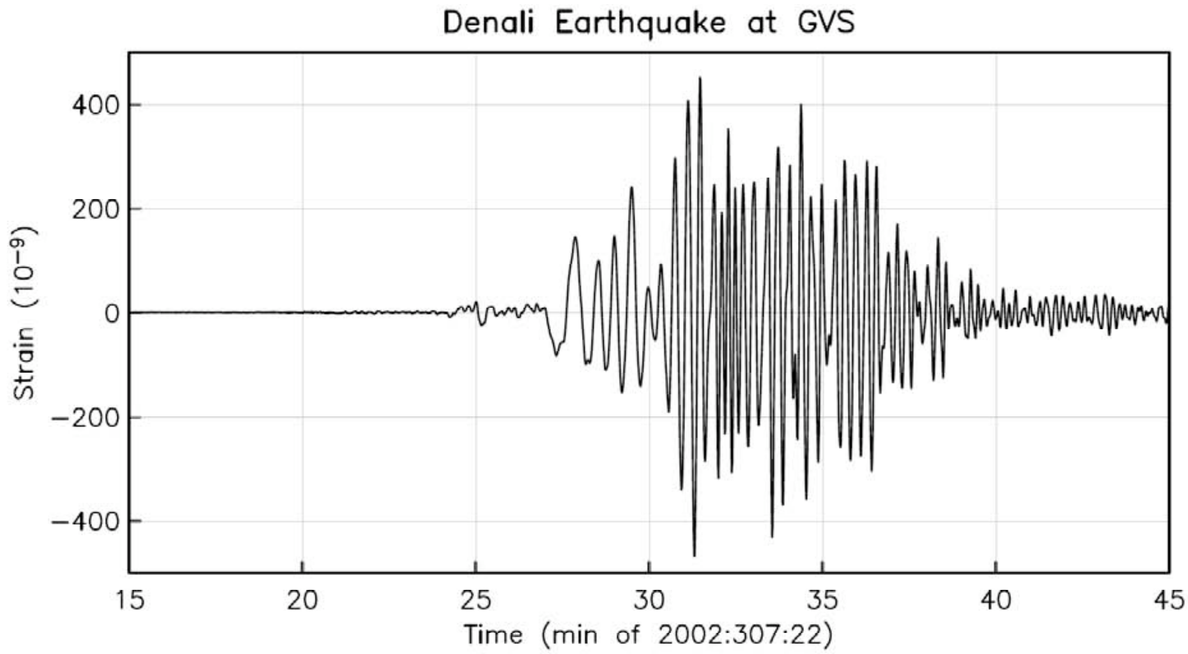

Figure III.4. Recording of large dynamic strains from the teleseismic Denali earthquake (M 7.9) at the SCEC-sponsored strainmeter in Glendale, California (GVS), which has been operating since August 2002.

- Joint analysis of InSAR and continuous GPS data from the Los Angeles area continues to provide new information about the deformations caused by groundwater pumping and withdrawal. These are of interest in themselves to water agencies; for the SCEC mission of measuring fault-caused deformations in this important area they are a source of systematic error to be removed. This is a very active area of research, but some of the latest analyses suggest that when the corrections needed are applied to the SCIGN data, the pattern of deformation from faults in the basin is concentrated in the 20 km south of the San Gabriel mountains.

- Another integration of InSAR and other data types has been the joint study of compliant fault zones using geodetic methods (anomalous deformation triggered by nearby earthquakes) and seismic data (fault-zone trapped waves). A number of faults showed triggered slip on InSAR data from the time of the Hector Mine earthquake, and detailed analysis suggests a reduction in rigidity of a factor of two within the fault zone: a surprising result for faults with relatively little total slip, but one supported by the existence of trapped waves. A group of SCEC scientists have submitted a proposal to the PBO program to make a systematic survey of the seismic velocity structure around several of these faults, since a systematic reduction in shear modulus near the fault zone will clearly be important to modelling how faults slip and what radiation this slip produces.

Scripps Orbit and Permanent Array Center (SOPAC). This center maintains the largest and most comprehensive archive of continuous GPS data, metadata, and data products serving 1-1.5 million data files per month to 2000-3000 users around the world. All data operations at SOPAC are controlled by an Oracle 8.1 RDBMS, which is continually improved and expanded to ensure data completeness, reliability, accuracy, and accessibility. SCEC investigators benefit most directly from SOPAC's contributions and responsibilities to the SCIGN project. Specifically, SOPAC maintains and downloads 20% of the SCIGN stations, is the central archive for all SCIGN data and metadata, and analyzes daily all SCIGN data to produce position time series. SOPAC maintains an active and heavily used home page (http://sopac.ucsd.edu) with a variety of Web-based tool, as well as an ftp server (ftp://garner.ucsd.edu). SOPAC analysis of SCIGN data is critical for anchoring the analysis of historical and new field GPS (campaign) data and has been the cornerstone of the SCEC Crustal Motion Model, Version 3. SOPAC also participates in the SCIGN Analysis Committee, an effort that has gone a long way to reconcile site position differences between the independent SOPAC and JPL analyses. The SOPAC director is a member of the SCIGN Executive Committee and Coordinating Board. SCEC investigators also benefit from other SOPAC activities such as precise orbit generation for the IGS, the leading role SOPAC plays in UNAVCO's GPS Seamless Archive (GSAC) effort, and SOPAC's analysis of all continuous GPS data in the region covered by the PBO, including a reanalysis of all data up to the present in ITRF2000. The California Spatial Reference Center (CSRC) an important community outreach effort also leverages SOPAC's infrastructure. CSRC projects such as upgrading SCIGN sites to high-rate (1 Hz), low-latency (1-2 seconds) operations also directly benefit SCEC investigators.

WInSAR. Over the past year SCEC funds have been used to begin a series of improvements in the WInSAR archiving system. In particular, SCEC and additional NSF funds have been combined to develop identical RAID storage systems that will reside at Caltech and Stanford (UCSD already has such a system). These RAID servers will also serve as stand alone web servers for WInSAR. This system will be a considerable upgrade from the slow and volume limited existing tape system (which is being decommissioned). In addition, the consortium has begun to design improved web based user interfaces for both data ordering and data downloading. These software development activities are critical for efficient functioning of the WInSAR system as the amount of data fluxed through the system increases. In particular, the consortium is looking to the future when the ENVISAT and ALOS data streams become active.

Future Plans. Because of the time at which the data were processed, and because of the Hector Mine earthquake, about half of the stations of the SCIGN network have not yet been included in the Crustal Motion Map. An update to include these, and other recently-collected data, is planned for release as Version 3.1 in 2004. There will also be a release of a unified velocity field for Baja California. The next stage in the CMM project will be to release a set of vertical motions for those stations for which these are sufficiently precise, along with more complete descriptions of postseismic transients. The geodesy group also plans to support the collection of geodetic data to improve our knowledge of crustal motion in areas of special interest, and to work with the PBO as it begins to install stations in southern California.

Geology. SCEC efforts related to geology fall into seven principal areas: 1) directed geologic studies and compilation efforts that contribute to the Community Fault Model (CFM); 2) paleoseismic studies in the LA Basin, Eastern California Shear Zone (ECSZ), and southern San Andreas fault system; 3) activities related to the Fault Activity Database (FAD and Fault Information System (FIS); 4) development of a vertical motion database and Community Vertical Motion Map (VMM) for southern California; 5) efforts related to resolving differences between geologic and geodetic rates and the possible role of off-fault deformation in the ECSZ; 6) chronologic efforts to precisely date past earthquakes and develop a catalog of probability density functions for large prehistorical earthquakes; and 7) other geologic studies that relate to rock mechanics, issues in source physics, etc. This summary will focus primarily on those elements not covered elsewhere, which are new advances in paleoseismic studies, the vertical motion database, and the geochronologic efforts.

New Paleoseismic Results. Seven studies were funded by SCEC that deal directly or indirectly with paleoseismic issues, in addition to the funding supplied to LLNL for dating paleoseismic events. Each area is discussed briefly.

- *Eastern California Shear Zone* – Two paleoseismic studies were completed this year in the ECSZ, both of which were continuations of 2002 research. The effort to date past events on the Pinto Mountain fault was successful, although the Holocene events are currently poorly constrained due to lack of dateable material. Samples were collected for OSL dating, with results anticipated soon. A trench across the southcentral Lenwood fault at Fry Mountain playa yielded excellent stratigraphy and abundant charcoal. A suite of 20 radiocarbon samples were dated, with the result that this site has now the best-dated record of Holocene events in the entire ECSZ. Of significance is the recognition of both large surface rupturing events and triggered slip events (small displacements), as occurred with the 1992 Landers event. The Lenwood fault events show strong clustering of events, with most events in phase with clusters published for other ECSZ faults by Rockwell et al. (2000). A related effort (Oskin) is to determine the age and slip rate on the Gravel Hills fault (GHF), and to determine how much off-fault deformation may occur that could help explain the discrepancy between geologic and geodetic estimates of shear strain rate across the ECSZ. Preliminary results show that the GHF is older than 3.5 Ma and has about 3 km of total slip, indicating a long-term slip rate of less than 1 mm/yr. Basalt flows have been successfully correlated across fault, and paleomagnetic studies are in progress to test rotations and off-fault deformation.

- *San Andreas System Faults* – Five projects were funded that deal either directly with paleoseismic studies on the San Andreas fault, or with issues of improving event correlations (Arrowsmith and Young, Biasi and Weldon)) and event timing (Biasi). New samples were collected from the Salt Creek site on the Indio segment of the SAF and were dated with SCEC funding (Seitz and Williams). The SCEC funding was leveraged by applying for NEHRP funding to continue the field work and extend the late Holocene record for the site – that proposal has been funded for 2004. A project to map slip per event for the past several SAF earthquakes at Devore (Weldon) was also funded and is in progress. Substantial initial effort was expended to clear brush from offset debris flows – these burned off in the past 2 days, exposing kilometers of offsets along this stretch of fault. The San Jacinto Hog Lake project (Rockwell) continued with dating of more samples. There are now high-resolution PDF's for the past six Anza segment surface ruptures, and work continues on dating the older events. The SCEC effort was again leveraged by applying for NEHRP support, which has been granted to complete the project in 2004.

- *Los Angeles Basin* – Only one paleoseismic project was funded for the LA basin (Dolan and Gath) to expand the earthquake history of the Whittier fault. That project was delayed by access issues, but appears on track for this November.

Vertical Motion Database and Map. Understanding the vertical component of crustal motion is important in regions of complex faulting and distributed deformation such as occurs across the active Pacific – North America plate boundary through southern California. Vertical motions directly measure reverse displacement common to both exposed and blind faults that threaten the urban region (e.g. Dolan et al., 1997; Oskin et al., 2000; Grant et al., 1999; Huftile and Yeats, 1996). Moreover, documentation of distributed vertical deformation is critical to understanding kinematic compatibility of conjugate fault systems common to southern California Additionally, the ongoing revolution in satellite geodesy has progressed to the point where precise records of present-day vertical motion are within reach, while the emerging combination of GPS with radar interferometry offers tremendous spatial coverage of absolute surface motions (Gundmedsson et al., 2002). These advances in modern vertical motions will be represented in version 4.0 of the SCEC Crustal Motion Map that will incorporate vertical motions. One challenge in analyzing these new geodetic data is to deconvolve tectonic signals from non-tectonic ones. A detailed long-term geologic record of crustal deformation is invaluable to this effort.

In response to this emerging need, a working group comprising M. Oskin, N. Neimi, and T. Rockwell has designed, implemented, and partially populated a geologic vertical motion database (GVMD) and vertical motion map utility for southern California. This database and map utility will provides a long-term regional geologic vertical motion baseline centered at the 10^5 year-timescale. The database design has been purposefully left flexible to allow integration into other ongoing geo-database projects within SCEC, such as the Community Fault Model, and the Fault Activity Database, but provides a unique set of data not currently being compiled within any of the other projects. This database will be of particular interest with the implementation of the SCEC Community Block Model to analyze and interpret long-term vertical uplift rates of tectonic blocks within southern California.

Database Design - During the past year, we have successfully designed a database structure to store, query, and analyze geologic vertical uplift data, as well as a user interface to perform these functions. The design uses the concept of 'inheritance' within an object-oriented database program (discussed in greater detail below). The concept of 'inheritance' exploits the fact that many data types may share common features (for geologic data, location, age, and reference may be common features), as well as having features unique to that particular data type. A 'parent' table within the database contains all of the common features to the many data types; 'child' tables 'inherit' these features, while having unique features of their own. The end practical result is that, through an appropriate attribution of features within a 'parent' type, many data types can be simultaneously queried for calculation of vertical uplift rates, while the geological data supporting the 'parent' data can be stored within the 'children' for later analysis and observation (Figure III.5). This database design makes the vertical motion database useful both to the geodynamicist, who may wish to calculate geological vertical uplift rates across the whole of southern California in as time-efficient manner as possible, as well as the researcher interested in Quaternary uplift of marine terraces, who may wish to query the specific species of coral used to determine a U-Th disequilibrium age for a particular terrace.

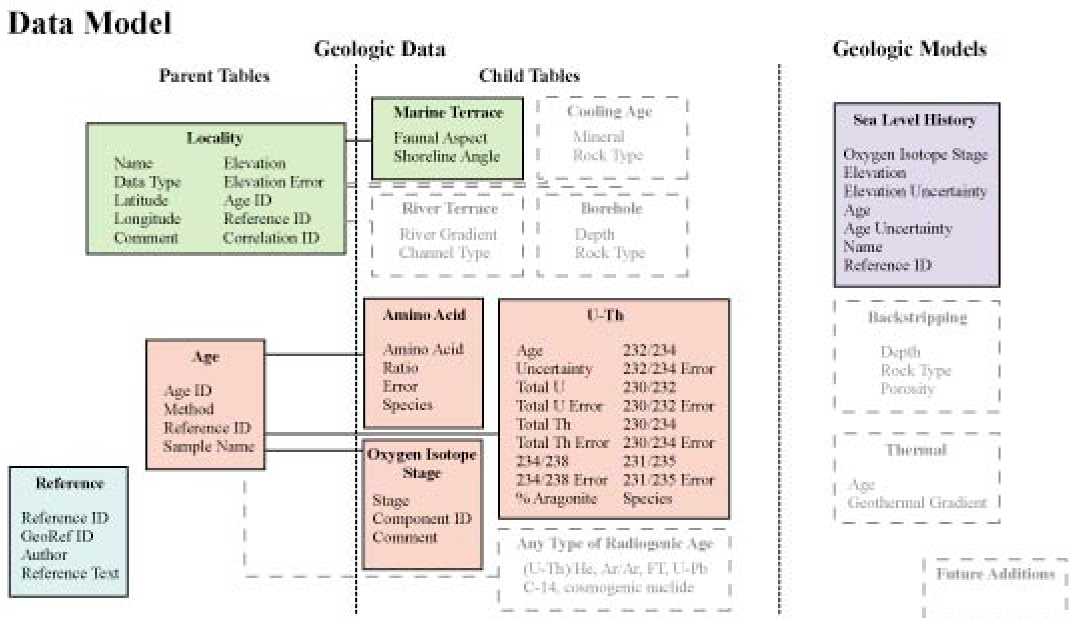

Figure III.5. Preliminary data model for the SCEC Community Vertical Motion Database. Colored tables indicate implemented portions of the database using marine terraces as an example dataset. Tables on the left, called 'parent' tables, contain information that is generic to all data types. 'Child' tables 'inherit' all of the qualities of their parents, thus they contain both generic data and type specific data. This data model thus allows a set up generic procedures to calculate uplift rates for a wide variety of geologic and geochronologic data types, will still preserving the data type-specific information that provides justification and explanation for the geologic interpretations made within the data structure. Geologic models, on the right, allow users to select various reference frames relevant to calculating uplift rates; in this example, several eustatic sea level curves are available to users for calculating marine terrace uplift rates.

In addition to this advance in geological database design, it was also determined that the vertical uplift rates should be calculated on-the-fly, when requested by the user, rather than being pre-determined results waiting for user retrieval. In part this stems from significant issues related to the selection of a vertical reference frame, and the difficulties in reliably comparing uplift rates from marine terraces, where modern sea level is the reference frame, to fluvial terraces, where some past base level is the reference frame, to thermochronologic data, where a given thermal level in the crust is the past reference. To make these issues as apparent to the user as possible, it was decided to allow the user to control the selection of reference frames for each available data type, and in cases where it was appropriate, to allow the user to select from multiple reference frames for a particular data type. A design for interactive processing of data within the vertical motion database was conceived utilizing procedural query language within the database itself (discussed below), and implemented for a set of data within the database (Figure III.6).

The implementation of this interactive processing scheme provides the end user the ability to select from two separate models of sea level history for southern California when calculating vertical uplift rates based on marine terrace data. Although this is a small step in the overall implementation of the complete vertical motion database, the effectiveness of the procedural language at processing there requests performs two important tasks; 1) the overhead in making uplift calculations is moved from the client side to the server side, thus eliminating a significant amount of communication bandwidth, and 2) effectively involves the end-user in the interpretation and analysis of the vertical motion data.

Process Model

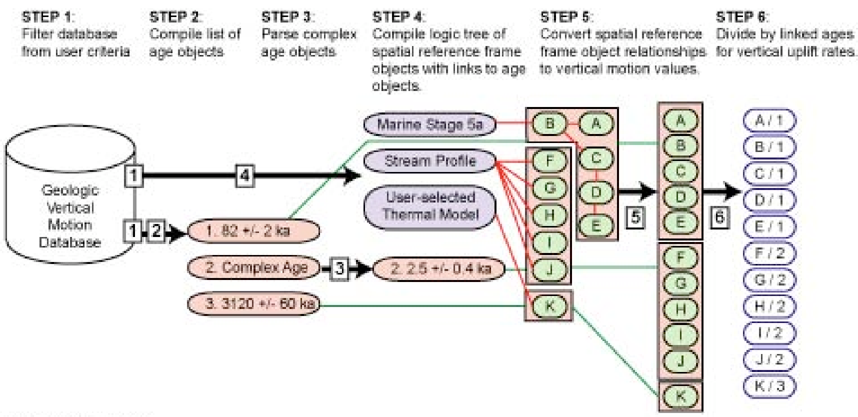

Figure III.6. Process model of the geologic vertical motion database showing how geologic relationships are processed to calculate vertical uplift rates. Lower table provides an example of the current output from the vertical motion database.

Processed Data Example

	Longitude (°W)	Latitude (°N)	Present Elevation (m)	Past Elevation (m)	Age (ka)	Uplift Rate (mm/yr)	References (GeoRef ID)
Locality 1	118.36454	34.22335	30 ± 2	+6	125	0.24 ± 0.016	1997-048251
Locality 2	118.36332	34.2243	25 ± 2	+6	125	0.20 ± 0.016	1998-056332

Model Development - Following the design portion of the project we attempted to develop the geologic vertical motion database. Based on recommendations from the Community Fault Model project, we selected PostgreSQL as the most appropriate database for our needs. This Open Source software is object-oriented, allows complicated database procedures, such as recursion and transactions necessary to our database model, offers an extension, called PostGIS to natively support geographic data objects, and supports the implementation of a variety of internal procedural languages, including native PL/PGSQL, Perl, and Python, for custom modification and development of database procedures. Within this framework, parent-child table relationships were constructed to support point data relevant to vertical uplift, age data relevant to uplift rates, and reference data relevant to the origin of the other data. Tables representing various vertical datum scenarios were also developed. Customized procedures were designed in the native PL/PGSQL language to select data and calculate uplift rates based on key identifiers for each data point stored in the database.

A web-based interface to provide the user with a graphical means to select and query the data was developed utilizing ArcIMS, a commercial Internet Map Server available from ESRI. The prevalence of ESRI products in the academic work environment, and the fact that ESRI shapefiles are a *de facto* (but not exclusive) standard in distributing geographic data made this selection a natural fit. Customized tools were added to the standard ArcIMS interface environment to provide specific capabilities related to the vertical motion database. In particular, these include the ability to extract key identifier information from user-selected objects in the graphical interface to the backend PostgreSQL database for data processing. Communication between ArcIMS and the PostgreSQL database was implemented in JavaScript and PHP (PHP

Hypertext Processor). PHP generated web pages also provide the user-interactive reference frame selection capabilities described above. The web-based interface was implemented on an Apache web server integrated with Java, Tomcat, and PHP. A 2.8 GHz Dell Pentium 4 running Windows XP provides the development environment and acts as the test server. ArcIMS was installed onto this server. PostgreSQL is installed on a Sun Ultra 60 running Solaris 8 (Figure III.7).

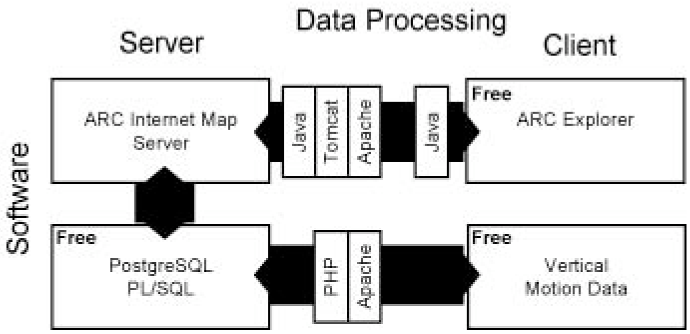

Figure III.7. Several software components were integrated to create the vertical motion database and user interface. Data tables were planned and populated in PostgreSQL, an open-source object-relational database. Custom PostgreSQL functions were programmed in PL/SQL to query complex geologic data and calculate uplift rates. A web-based user interface was created integrating ArcIMS, a java-based commercial map data server, dynamic HTML, and custom PHP scripts.

Database Population - To test the design and development of the geologic vertical motion database, we populated the database with geological data relevant to the uplift of marine terraces along the coast of southern California. Data relevant to the current elevation of the marine terrace, the age of the marine terrace, and references for this data were compiled and entered into the database. Additionally, as much data as could be retrieved was assembled for each data point; thus, all isotopic ratios for U-Th series dates were compiled; species and amino acid ratios were compiled for each amino acid racemization age determination, etc. To date, marine terrace data has been compiled for San Diego County, the Malibu Coast, the Santa Barbara and Ventura Coast, and Cayucos, as well as several of the Channel Islands (Fig. 4).

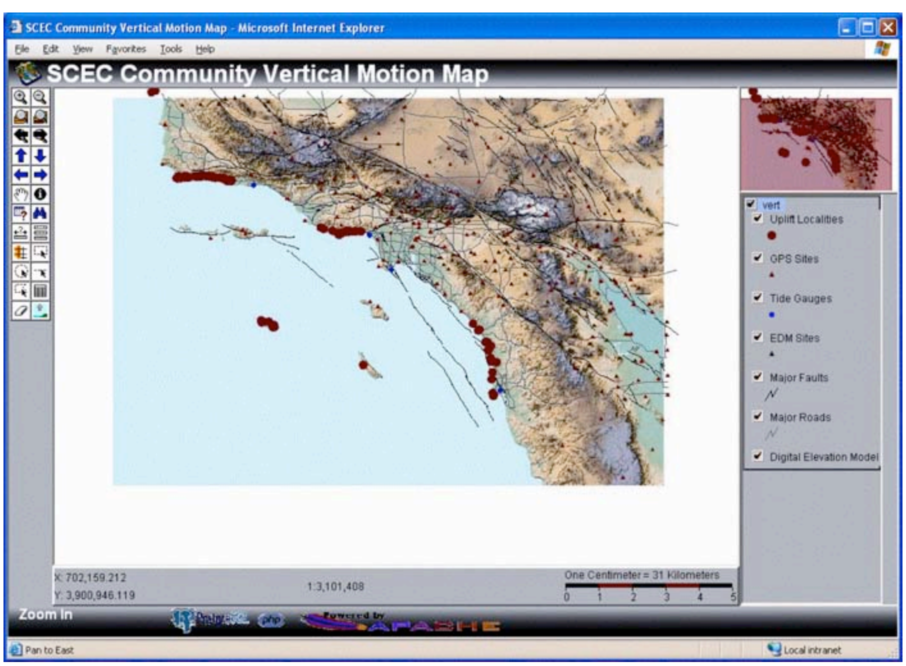

Figure 4. Screen capture of the ArcIMS graphical web interface to the SCEC Vertical Motion Database. Red dots represent marine terraces that have been populated into the database. Legend indicates the wide variety of additional data that can be incorporated into the web-based interface. Lowermost button in the right hand column at the right side of the map display is a customized to initiate calculation and display of vertical motion data.

Paleoseismic Chronologic Effort. The consolidation of geochronologic efforts, principally in radiocarbon dating, has had a dramatic affect in improving earthquake chronologies on the San Andreas, San Jacinto, Mojave, and LA basin faults. The obvious benefit is the ability to focus on dating the sections that have both the resolution of earthquake history (good stratigraphy) and the abundance of excellent, dateable material. The product has been a large increase in both accuracy and precision of paleo-earthquake events dates, with the production of probability density functions (PDF's) of many past events on the San Andreas, San Jacinto, and ECSZ faults (Figure III.7). This now allows for more formal testing of event correlations between sites, which is important in constructing earthquake rupture models for individual faults, as well as understanding long-term local and regional patterns of seismic production. The majority of radiocarbon effort in 2003 has been for the San Andreas fault (59 dates run from Wrightwood (Weldon and Scharer), 20 dates run from Salt Creek (Seitz and Williams), 20 dates pending from Burro Flats (Yule)), the San Jacinto fault (14 dates run with 24 pending), and the Eastern California Shear Zone (20 dates from the Lenwood fault (Khatib and Rockwell). Samples were also run from an offshore paleoshoreline (Goldfinger, 4 samples), and dates are pending from the LA basin (Dolan) and other studies.

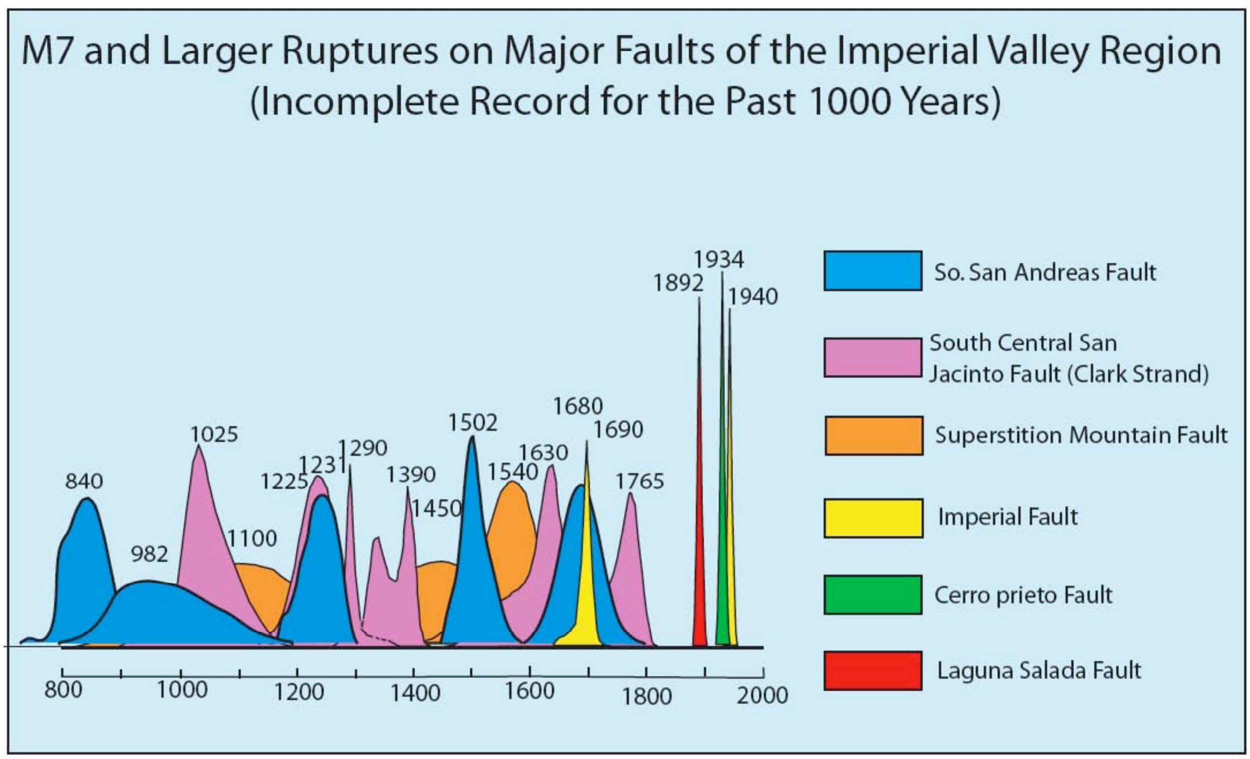

Figure III.7. Summary of event ages for the southern San Andreas fault system. Note that the southern Elsinore fault data are not included because the past two events are poorly dated at present (C-14 dates pending), but events occurred about 400 and 1000 years ago base on TL dates. The Imperial fault record only extends back the past 350-500 years and is therefore incomplete. We omitted paleoseismic evidence for smaller faults that produce earthquakes <M7. Nevertheless, this represents the majority of moment release in the Imperial Valley region for the past 1000 years.

Objectives For Next Year. The Geology group met at the SCEC annual meeting to discuss continuing efforts and new directions. Among the priorities were:

- Inclusion of more PDF's in FAD, including inclusion of the primary radiometric data that underpin the PDF.
- Inclusion of isopach time-horizons (eg., top of Mohnian, base of Quaternary, etc) in CFM
- Continued development of the Vertical Motion Database, completion of the model and its interface with the FAD
- Continued development of new methodologies to test and improve event resolution and correlations
- Foster subsurface analysis of fault systems, including blind thrusts and the role of off-fault deformation
- Compile existing information and conduct detailed studies of fault materials and structures in and adjacent to exhumed and surface faults in order to understand deformation processes and conditions, and their implications for the nucleation and propagation of earthquake ruptures
- Continue "mining" paleoseismic data to construct a 2000+ year record of large earthquakes on the San Andreas fault system, and a 10,000+ year record of earthquakes for the Los Angeles basin and the Eastern California shear zone
- Development of higher-resolution long-term slip rates on the major faults to compare to the secular GPS rate

Fault and Rock Mechanics. Research supported by SCEC during 2003 that primarily falls under the FARM disciplinary committee are shown in Table III.1: In addition to these projects, there are several others that might logically fall under the FARM description, but are being listed by one of the interdisciplinary focus groups. A small amount of money was also awarded to some people who submitted proposals in the FARM subject area to allow them to travel to the SCEC annual meeting, even though those projects were not otherwise supported. Reports on each of these projects is beyond the scope of this overview FARM report, and they have been submitted separately by the PIs. However, three highlights are examples worth mentioning.

The project headed by Vikas Prakash, "Pilot Studies to determine the feasibility of using new experimental techniques to measure sliding resistance at seismic slip rates," has shown that some interesting results on friction at high slip speeds and short displacements can be obtained using the oblique plate impact technique. This is the first time that this technique has been tried on geological materials and initial results on both glass and a novaculite show that it is possible to get meaningful data on these materials. This bodes well for further research on high speed friction on geological materials using this technique. Figure III.8 shows an example of data collected on a layer of soda-lime glass. In such experiments it is not possible to independently control the slip velocity and the shear resistance – as the resistance goes up the velocity goes down. The friction coefficient initially starts at about 0.4 with a slip velocity of a few m/s, and that as the friction drops to about 0.15 the velocity increases to about 25 m/s. There is a subsequent decrease in the slip velocity that is associated with an increase in friction. Eventually the resistance is high enough that slip stops until a release wave arrives from the rear surface of the target plate. At this point the drop in normal stress is enough to allow slip to begin again, initially with a very high friction coefficient of about 1.5, followed by a drop to about 0.8 at a slip velocity of15-20 m/s. Calculations suggest that the glass go hot enough that it welded the surfaces somewhat, probably causing the increase in friction prior to the no slip interval and perhaps causing the large friction following the no slip interval.

Table III.1 Projects of the FARM Disciplinary Group

Principal Investigators	Institutions	Project Title
V. Prakash	Case Western Reserve University	Pilot Studies to determine the feasibility of using new experimental techniques to measure sliding resistance at seismic slip rates
T. Wong, N. Beeler	SUNY Stony Brook, U.S. Geological Survey	Dc and Fracture Energy due to Friction During Dynamic Earthquake Rupture
J. Evans	Utah State University	Geochemical and structural characterization of fault-related rocks from San Bernardino and San Gabriel Mountains, Implications for Earthquake Nucleation, Rupture, and Termination Processes
J. Chester D. Goldsby	Texas A&M University; Brown University	Microscale Characterization of Natural and Experimental Slip Surfaces Relevant to Earthquake Mechanics
Z. Reches T. Dewers J. Brune	University of Oklahoma: University of Oklahoma: University of Nevada, Reno	Processes of Gouge-Formation in the San Andreas Fault Zone at Tejon Pass
T. Tullis R. Harris	Brown University, U.S. Geological Survey	Workshop on Constitutive Relations for Coseismic Slip
T. Tullis, D. Goldsby	Brown University	Laboratory Experiments on Fault Shear Resistance Relevant to Coseismic Earthquake Slip

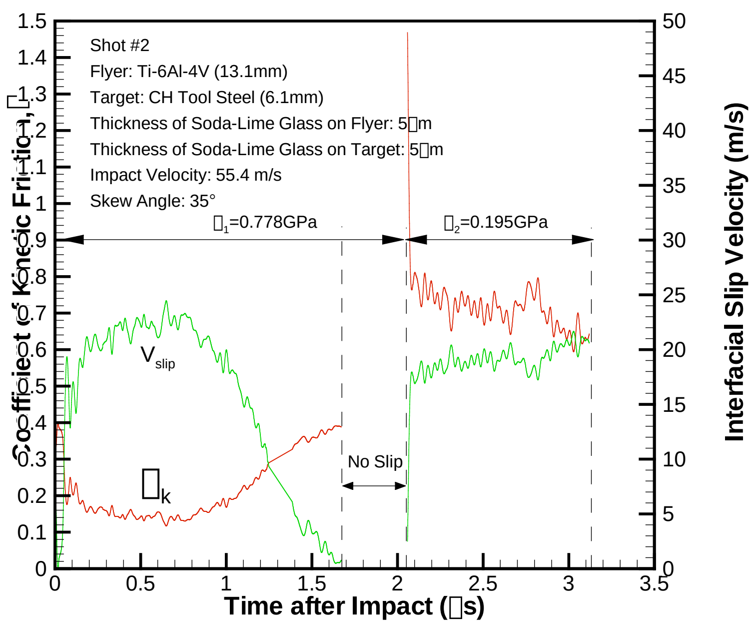

Figure III.8. Friction and slip velocity on a layer of soda-lime glass using the plate impact, pressure shear technique. See text for explanation.

The project by Terry Tullis and David Goldsby, “Laboratory Experiments on Fault Shear Resistance Relevant to Coseismic Earthquake Slip” has found weakening at slip velocities of a few hundred mm/s that appears to be due to flash heating. The weakening has been found for several rock types using a rotary shear geometry in unconfined experiments. An example for novaculite is shown in Figure 2. The agreement with the theories of *Rice* [1999]and of *Beeler and Tullis* [2003] suggests that the weakening is due to flash melting, melting that only occurs locally at the tips of contacting asperities.

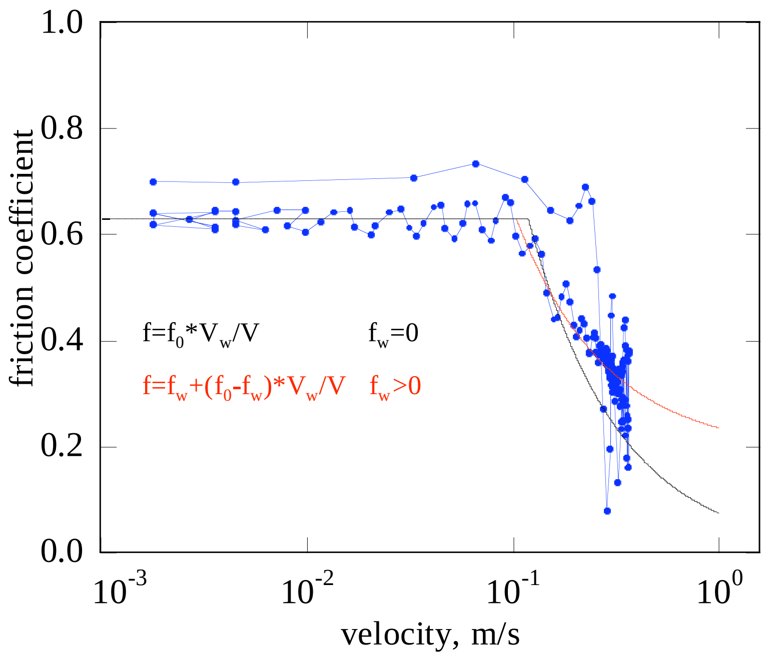

Figure III.9. Data for Novaculite. Data have been fit with the flash melting equations of *Rice* [1999] (in black) and *Beeler and Tullis* [unpublished manuscript] (in red), which describe the effect of flash melting on the friction coefficient *f* as a function of sliding velocity. The Rice analysis assumes that melted asperities have zero strength, whereas Beeler's analysis assumes melted asperities have finite strength.

Finally, it is worth mentioning the workshop entitled “Constitutive Relations for Coseismic Slip” organized jointly by Terry Tullis of the FARM disciplinary committee and Ruth Harris of the Earthquake Source Physics focus group. Many participants working in these subject areas expressed their feelings that the workshop was very stimulating and helpful. It was a workshop to assess the status of our understanding of the frictional resistance of faults during coseismic slip from the perspective of laboratory experiments and of seismic observations and modeling. Presentations were given both by modelers who addressed the question of what can be determined about frictional properties during earthquakes by modeling dynamic ruptures and comparing the model results with date from earthquakes as well as from the perspectives of laboratory rock deformation studies. It is clear that more work is needed from both perspectives. The workshop was very successful in bringing each of these communities up to date with each other’s thinking and data, and the two communities were brought closer as a result of the interactions.

Focus Group Activities

Within the new SCEC structure, the focus groups are responsible for coordinating interdisciplanary activities in five major areas of research: *structural representation*, *fault* *systems*, *earthquake source physics*, *ground motion*, and *seismic hazard analysis*.. The following reports summarize some of the year's activities in each of these areas.

Unified Structural Representation. The Unified Structural Representation (USR) Focus Area supports interdisciplinary scientific research aimed at delivering digital models of crustal and upper mantle structure in southern California for use fault systems analysis, strong ground motion prediction, and earthquake hazards assessment. These efforts include development of a Community Velocity Model (CVM), a Community Fault Model (CFM), and a Community Block Model (CBM), which integrated will comprise the USR. Activities supported by the USR Focus Area in 2003 include:

- geologic and geophysical investigations of more than a dozen fault systems to define geometries, slip rates, and paleoearthquake histories;
- construction of a new Community Fault Model (CFM), Community Block Model (CBM), supporting databases, and web interfaces;
- collaborative mechanical modeling, geodetic, and geologic studies to evaluate the CFM; and
- seismologic data collection and analysis to evaluate and enhance the Community Velocity Model (CVM).

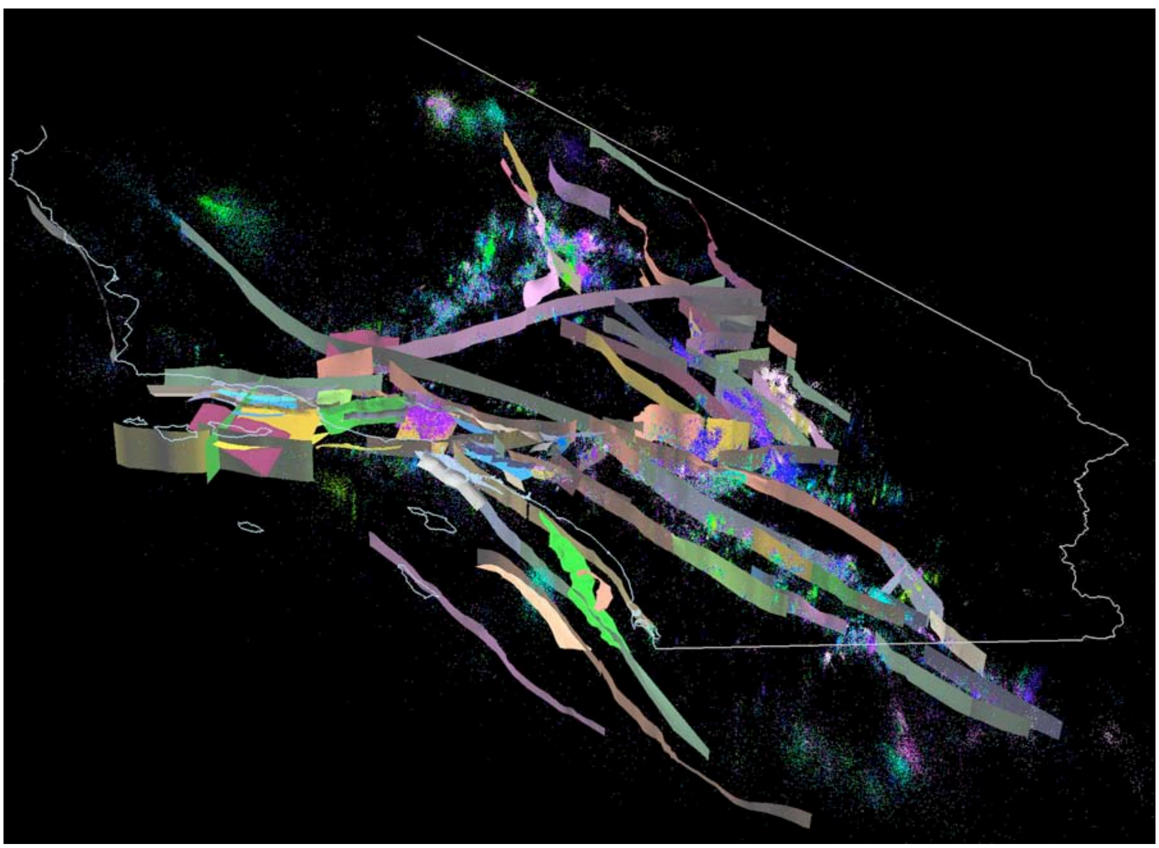

Figure III.10. Perspective view of SCEC's new Community Fault Model (CFM), which includes three-dimensional representations of more than 120 active faults in southern California (Plesch et al., 2003). The model is intended for use in strong ground motion prediction, faults systems analysis, and seismic hazard assessment. The CFM and supporting information are stored in a relational database, which can be accessed by a MapServer web interface (http://structure.harvard.edu/cfm/). Hypocentral locations are from Egill Hauksson.

USR activities this past year were highlighted by the delivery of the first Community Fault Model (CFM) for southern California (Plesch et al., 2003). The CFM (Figure III.10) is an object-oriented, 3-D representation of more than 120 active faults, defined by surface geology, hypocenters and focal mechanisms, well logs, and seismic reflection data. Many of the fault representations were derived from SCEC supported research projects (e.g., Nicholson et al., 2002; Sorlien et al., 2002; Rigor at al., 2003; Yeats et al., 2003). The model inventory reflects a comprehensive set of credible sources of moderate and large earthquake, as defined by the SCEC CFM Working Group in cooperation with the California Geological Survey and the U.S.G.S. Each fault is represented as a georeferenced triangulated surface (t-surf), in which interpolated and extrapolated fault patches are distinguished. For several of the more contentious sources, alternative fault representations are provided.

The CFM is housed in a postgresql relational database along with supporting information, including fault attributes such as fault types, slip rates, location uncertainties, blind or surface designations, and primary references. Users access the model and database through a MapServer web interface (http://structure.harvard.edu/cfm/), which can be used to download complete, versioned CFM models or to compose new models by searching the database with geographic or fault attribute criteria.

Several SCEC Focus Area and Disciplinary Groups have begun using the CFM in their efforts, which include probabilistic seismic hazard assessment, strong ground motion prediction using finite sources, and mechanical modeling of fault systems behavior over the time scales of geologic, geodetic, and seismologic observations. In turn, many of these efforts help to test and improve the CFM, by evaluating fault location and dip, fault linkages, and slip rates. For example, comparisons of geologic, geomorphic, and modeled uplift rates above the blind thrusts in the northern Los Angeles basin has helped to identify a shift of activity from the Elysian Park to Puente Hills thrust system over the past 3 Ma, and to validate CFM fault representations (Figure III.11) (Meigs et al., 2003).

A new Community Block Model (CBM) is also being constructed through collaboration between the USR and Fault Systems Focus Area Groups. The georeferenced model will consist of a subset of CFM faults, combined with topographic, bathymetric, top of basement, base of seismicity, and others surfaces, to produce volumetric descriptions of fault bounded blocks. The most immediate use for the CBM will be for finite element modeling of fault system behavior by SCEC's Fault Systems Group. However, the CBM's volumetric descriptions also provide pathways to new and alternative parameterization for SCEC's property models (including the CVM), and to integrate the CFM and CVM.

Recent efforts also centered on testing and enhancing the Community Velocity Model (CVM), and laying the ground work to integrate the CVM, CBM, and CFM into a Unified Structural Representation. The CVM3.0 was shown to yield a substantially better fit between observed and synthetic waveforms for small earthquakes in Los Angeles than was achieved using laterally heterogeneous of path-dependent 1-D models (Chen et al., 2003). This work has also illustrated regional deficiencies in the model, which can be addressed. Other efforts have focused on standardizing objects and object definitions between the CVM and CFM, such that they may be more readily combined. Combined fault and property models will serve, among other things, as the basis for a new generation of strong ground motion simulations to better address the problems of basin amplification and wave focusing.

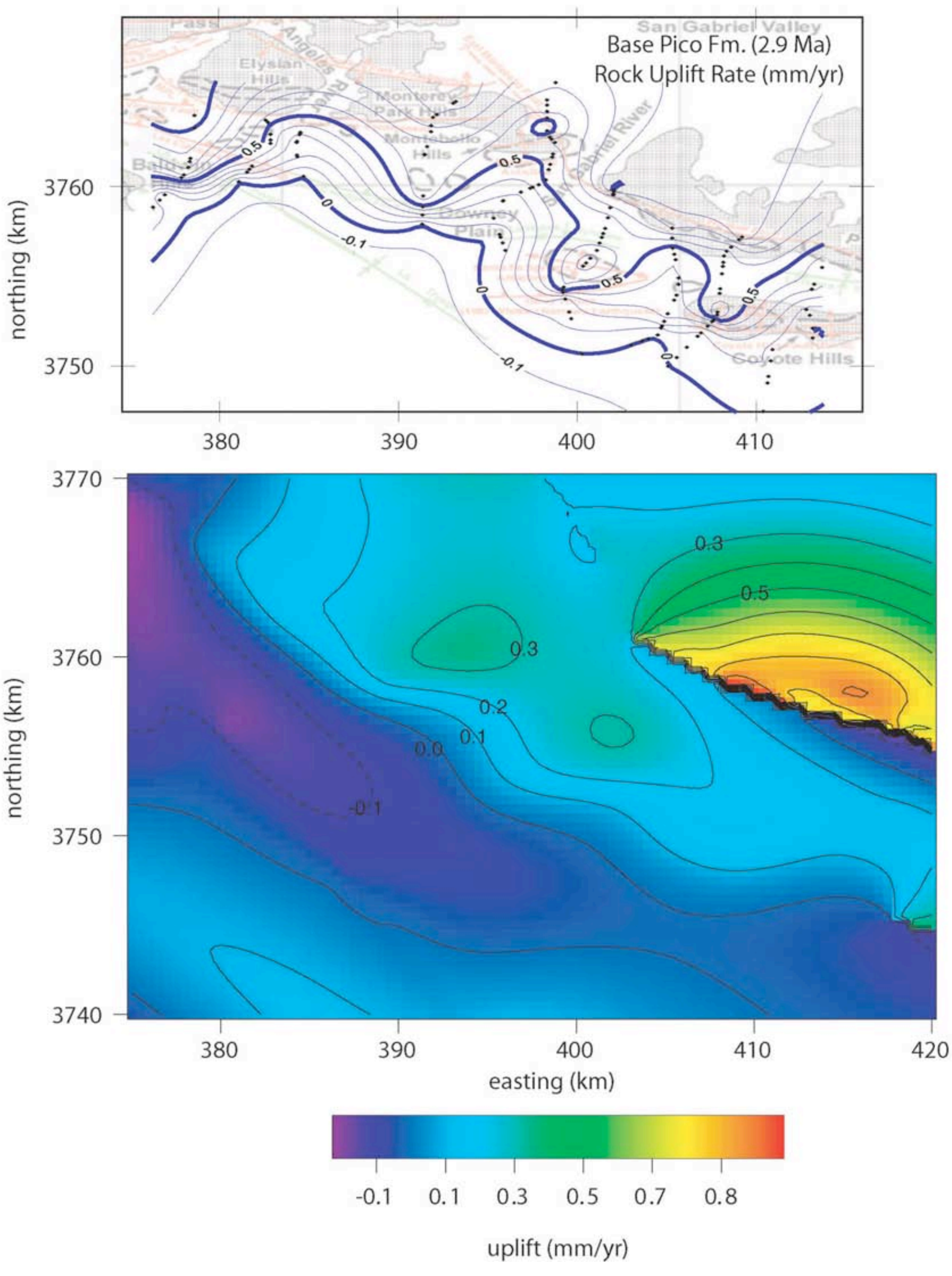

Figure III.11. Comparison of geologic (top) and modeled (bottom) uplift rates above blind thrust faults in the northern Los Angeles basin. Geologic rates are derived from structural relief of stratigraphic horizons, whereas, modeled rates are calculated using a boundary element method (BEM) with fault surfaces derived from the Community Fault Model (CFM). The discontinuity in the modeled uplift image is the Whittier fault. Areas of uplift to the southwest of the Whittier fault occur above the Puente Hills blind thrust, and correspond to areas of observed uplift based on folded stratigraphic horizons. From Meigs et al., (2003).

USR Science Plans. To best serve the science objectives of the other SCEC Focus Area and Disciplinary Groups, the USR Focus Area plans to:

- Enhance the functions of the CFM web interface, including more refined search capabilities, and to assist development of a web-based 3D model viewer by the SCEC IT Program;
- Support multi-disciplinary research to improve fault representations in the CFM;
- Compose a set of alternative source models for use by the Regional Earthquake Likelihood Models (RELM) working group;
- Refine and mesh the CBM to make it suitable for use by SCEC's Crustal Deformation Modeling Group;
- Produce a new, more flexible CVM that will accommodate alternative parameterizations, allow for ready inclusion of new data sets and constraints, and be wholly integrated with the CFM; and
- Develop a methodology for inverting waveform data to improve the CVM.

These objectives will support SCEC's primary research goals in fault systems analysis, strong ground motion modeling, and seismic hazards assessment, through provision of a Unified Structural Representation for southern California.

Fault Systems. The SCEC Fault Systems Group held two workshops during the past year. (See the respective workshop summaries for more detail.) The first, "Regional Seismicity," held December 11-12, 2002, at the University of California Davis, focused on a systems-level approach to the understanding of earthquake physics. The primary objectives of this workshop were 1) to formulate a strategy for the development of a southern-California-specific seismicity simulator and 2) to decide which problems this simulation would address. Members of both the SCEC and the NASA-sponsored Quakesim groups participated in planning for, as well as attending the workshop. The workshop was successful in strengthening the ties between "systems-level" simulations and "crustal deformation modeling" subgroups of the Fault Systems Group. Among the unifying themes that emerged from the workshop were the recommendations that both subgroups adopt a common fault system geometry (CFM-A and CBM-A) and head toward common stress transfer computations, including the effects of viscoelastic relaxation.

The second workshop, "Community Finite Element Models for Fault Systems and Tectonic Studies," hosted by Los Alamos National Laboratory in August, 2003, was the second annual workshop held by the Crustal Deformation Modeling group. The locale was chosen to enable SCEC scientists to benefit from attendance by Lab experts, particularly those with expertise in meshing. It also introduced SCEC Fault Systems efforts to LANL physics/computational groups, sowing the seeds for future collaborations. By leveraging SCEC, NASA, and LANL support, we were able to increase the number of students and senior researchers attending, as well as meet for a longer time. Because members of the NASA-sponsored Quakesim group participated in the workshop, there was significant interchange of ideas and codes. Part of the group effort is aimed at verifying code accuracy, so significant effort was spent on refining the preliminary benchmark problems that were developed at last year's workshop. Efficient and accurate meshing of complex geologic structures is a very high priority, and meshing tutorials from scientists from LANL (LAGrit) and Sandia (Cubit) were very informative. One of the important outcomes is that we are now reevaluating whether the GoCAD/Tsurf approach used by the USR group will be used to produce our final meshes (tetrahedral) or will be an intermediate step in developing hexahedral meshes. Another highlight of the workshop was a discussion of Computational Frameworks. We are heading toward integration of "Tecton," Charles Williams' community code for the Fault Systems Group, and "eqsim," Brad Aagaard's source physics and strong ground motion code, via the Pyre Framework. In addition, the Quakesim code "GeoFEST" (JPL) was impressive; a stronger integration of this project with the SCEC effort was initiated.

One of the high priorities of the Crustal Deformation Modeling subgroup is to develop a quasi-static, parallelized finite element code that will eventually be able to represent the deformation and stress fields due to all major faults in southern California as provided by the Community Block Model, using realistic rheologies and fault behavior. The code should also be relatively easy to use and should integrate well with other modeling codes as well as visualization and meshing packages. Charles Williams (RPI) has been leveraging SCEC, NSF ITR, and Caltech resources to upgrade Tecton into a SCEC Community code. The top priority has been the integration of the code into the Pyre framework (Caltech), which will immediately add several new capabilities to the code, while easing the process of adding new features. The initial version of the code is now available as a dynamic shared library, callable via python (Pyre) function calls. The groundwork has also been laid for the addition of tetrahedral elements, which are a high priority since it is relatively easy to mesh geological structures with such elements.

Fault Systems has important linkages to other SCEC Focus Groups and Working Groups. In order to develop a realistic continuum mechanics model of Southern California, it is crucial to include the fault system geometry and mechanical structure that is the focus of the USR group. The resulting Community Block Model (CBM) is not only an essential product required by Fault Systems, but also provides the natural way of combining the fault surfaces of the CFM and the volumetric properties of the CVM into a Unified Structural Representation. This year we began the task by developing a microblock model of the NW LA basin, comprised of 6 blocks, with bounding surfaces given in Tsurf format. We were able to develop a tetrahedral mesh of 4 of the blocks, but found mild incompatibilities of the Tsurf output and mesher input using for the other two that show the importance of close interaction.

Another important example is the use of predictions of Fault Systems' deformation models to evaluate, validate, and assess the consequences of SCEC Crustal Motion Map 3.0. The MIT group has developed a model that divides the crust of California into a number of blocks, with motions of the blocks described by rotation about Euler poles. Predicted geodetic velocities are then the result of the combined effects of block rotation and strain accumulation on the faults (assumed locked to depth D) with deep slip at rates determined by the relative motion between blocks. This approach can be cast as an inverse problem, with block motions and the associated fault slip rates obtained by a least-squares fir to the geodetic velocities. This allows a comparison of geodetic and geologic estimates of fault slip rates. Also, since the residual velocities are typically small, it allows an assessment of the quality of the geodetic data, simplifying the task of identifying sites with systematic errors. For example, a number of sites with motions contaminated by hydrologic conditions have been identified; also, groups of sites with velocities determined by trilateration, with weak ties to the GPS network show systematic residuals not easily identified in the original velocities. Finally, the rate of elastic strain accumulation can be quantified and compared to the elastic strain release via earthquakes in order to identify regions of seismic deficit (Figure III.12).

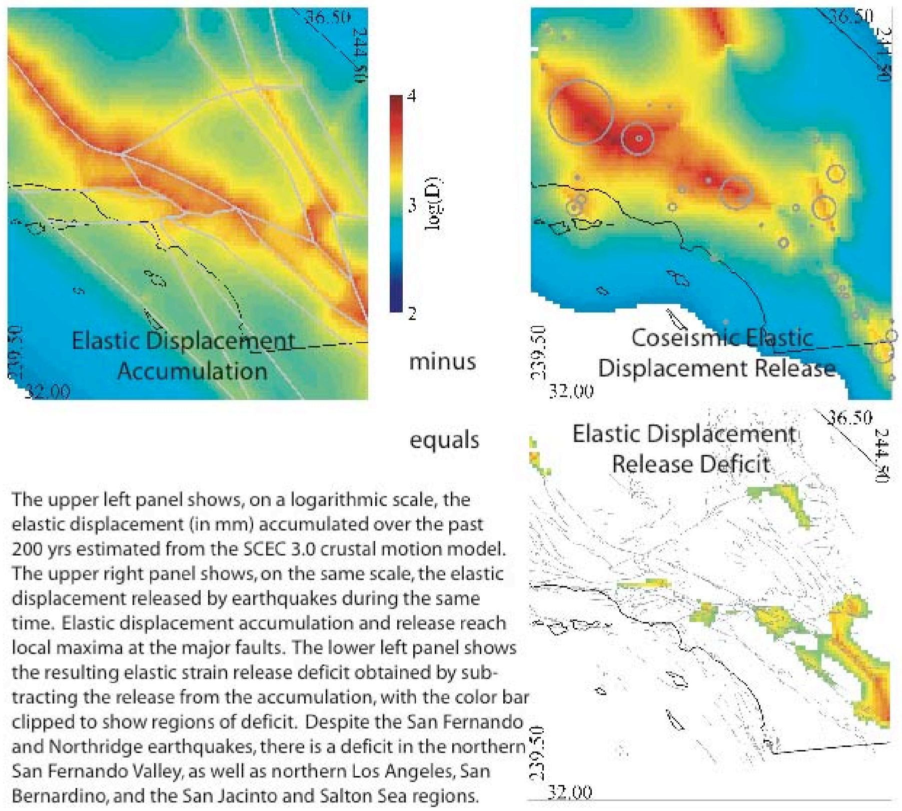

Figure III.12.

Objectives for the Upcoming Year. Compare short-term geodetic rates with long-term geologic rates and historic moment release rates and explain the differences; develop, validate, and facilitate use of modular 3D quasi-static codes for simulating crustal motions utilizing realistic, highly resolved geometries (e.g., USR fault geometry and elastic structure) and rheological properties (e.g., Burgers body viscoelasticity, rate-state friction, poroelasticity, including the time evolution of pore compaction and permeability, damage rheology); develop representations of fault system behavior on scales smaller than can be resolved on computationally feasible meshes; develop a closed volume representation of southern California (Community Block Model-A; CBM-A) that unifies the geometric representations of CFM-A and the CVM and that serves as a basis for efficient meshing and remeshing of models; assess mechanical compatibility of CFM-A and how slip is transferred between recognized fault segments, beginning with simple geometries and moving to the actual geometry; evaluate mesh generation strategies and generate realistic finite element meshes of Southern California consistent with CFM-A and CVM/USR structure; develop tectonic models that explain the rates of fault slip inferred for the southern California fault system; develop, validate, and facilitate use of codes for ensemble models simulating earthquake catalogs using CFM-A fault structure, USR and CBM-A, as well as stochastic representations of faults not included in CFM; incorporate constraints (including data assimilation) from geologic slip rates, geodetic data, realistic boundary conditions, and fault rupture parameterizations, including rate-state friction and normal stress variations.

Earthquake Source Physics (ESP). The long-term goals for the ESP group are to decipher the physics of earthquakes and the ramifications for ground motions. In FY2003 Earthquake Source Physics PI's tackled problems in 5 areas:

1. *Numerically simulating rupture dynamics to elucidate earthquake physics*
   Archuleta (energy) — Day & Harris (materials)
   Lavallee (stress) — Olsen (friction)
   Rice (geometry) — Sammis (damage-mechanics)
   Oglesby & Xu (multi-cycle) — Shaw (multi-cycle)
   Harris & Archuleta (workshop) — Tullis & Harris (workshop)
2. *Improving kinematic source models to illuminate earthquake physics*
   Heaton (stress heterogeneity) — Jordan (2nd order moments)
   Liu (resolution)
3. *Investigating large- vs. small-earthquake physics*
   Abercrombie (stress) — McGuire (directivity)
4. *Employing observations of fault zones to understand earthquake physics*
   Li (near-fault materials) — Shearer (fault geometry and focal mechanisms)
   Rockwell (geology of directivity)
5. *Using earthquake triggering observations to decipher earthquake physics*
   Beroza (pore-fluids) — Vidale & Beroza (aftershock evolution)
   Seeber & Armbruster (pore-fluids)

Some highlights from this research effort are as follows:

- On the rupture dynamics front, Jim Rice's group has found, using 2D simulations and observations from nature, that both fault geometry and stress orientation play a role in determining whether or not an earthquake will propagate around a fault bend. The speed of the rupture as it approaches the bend can also be a deciding factor.
- Daniel Lavallee examined the role of stress heterogeneity on rupture propagation and determined that the statistical form of the heterogeneity is critical in determining how or if an earthquake rupture will propagate, even on a flat fault.
- Steve Day and Ruth Harris have shown, using three-dimensional computer simulations of rupture dynamics, that material heterogeneity across a fault can affect rupture propagation. The material heterogeneity will not prevent a rupture from propagating, but it can affect its speed and amplitude.
- David Oglesby and Guanshui Xu, and, Bruce Shaw, have both ventured into the arena of two-dimensional multi-cycle earthquake simulations. Oglesby and Xu looked at multiple events on a single thrust fault plane, and Shaw examined multiple events on multiple parallel faults. These are among the first modeling efforts within SCEC (aside of former studies by Nadia Lapusta) to combine the long-term aspects of fault interaction, generally centered in the fault systems group, with the short-term aspects of fault behavior that are generally tackled by our group.
- Ruth Harris and Ralph Archuleta are holding an Earthquake Source Physics/IT workshop to validate the rupture dynamics method. The report on this workshop is not yet written because the workshop will not occur until November 10, however for an introduction I've included two figures that describe the model we're tackling. This will be the first known

effort to compare a wide range of computational methodologies commonly used to decipher earthquake physics. The problem that we're tackling initially is that of spontaneous rupture on a vertical strike-slip fault. The participants will be using computer codes that invoke methods based on finite-difference, finite-element, spectral element, and hybrid approaches.

- Jeff McGuire has been using 2nd order moment determinations to infer earthquake propagation directions of small and moderate earthquakes along the San Andreas fault and elsewhere. So far he has found that material contrast doesn't necessarily control the propagation direction.
- Peter Shearer and Egill Hauksson have put together a fantastic map of southern California that is based on relocated microseismicity. The image shows details not seen before on a large scale, including numerous cross-faults that are currently active.
- In two separate projects, Greg Beroza and John Vidale have been working on the physics of earthquake triggering by observing newly located and newly discovered small earthquakes. They are using their methodologies to infer rate-state behavior of aftershock triggering in the Los Angeles area, and the effect of pore-fluids on aftershocks in the Landers area.

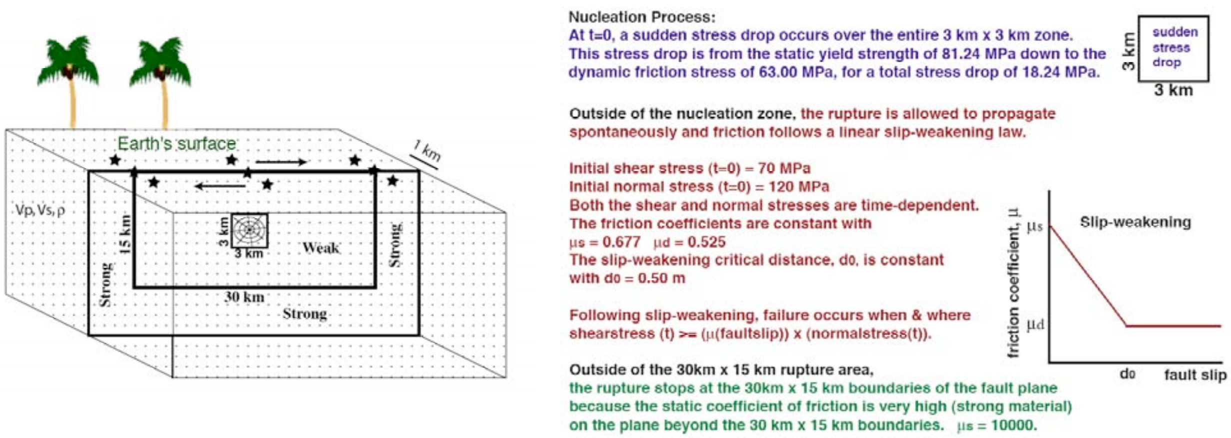

Figure III.13. The model and specifications for calculations used in the exercise for the Rupture Dynamics Code Validation Workshop.

In the coming year, FY04, the ESP group hopes to continue some of these subprojects, all with the intended goal of deciphering earthquakes physics. The biggest changes will be in the expansion of the rupture dynamics code-validation exercise, and a push to recruit a member (or members) of our community to compile a list of reference earthquake data. The goal of the former exercise is to see how close the different methods are in predicting earthquake physics behavior, with the ultimate idea of producing ground motion synthetics in the very near-fault region. The goal of this latter project is to produce a database of well-studied earthquake information, against which hypotheses proposed about earthquake physics behavior can be tested.

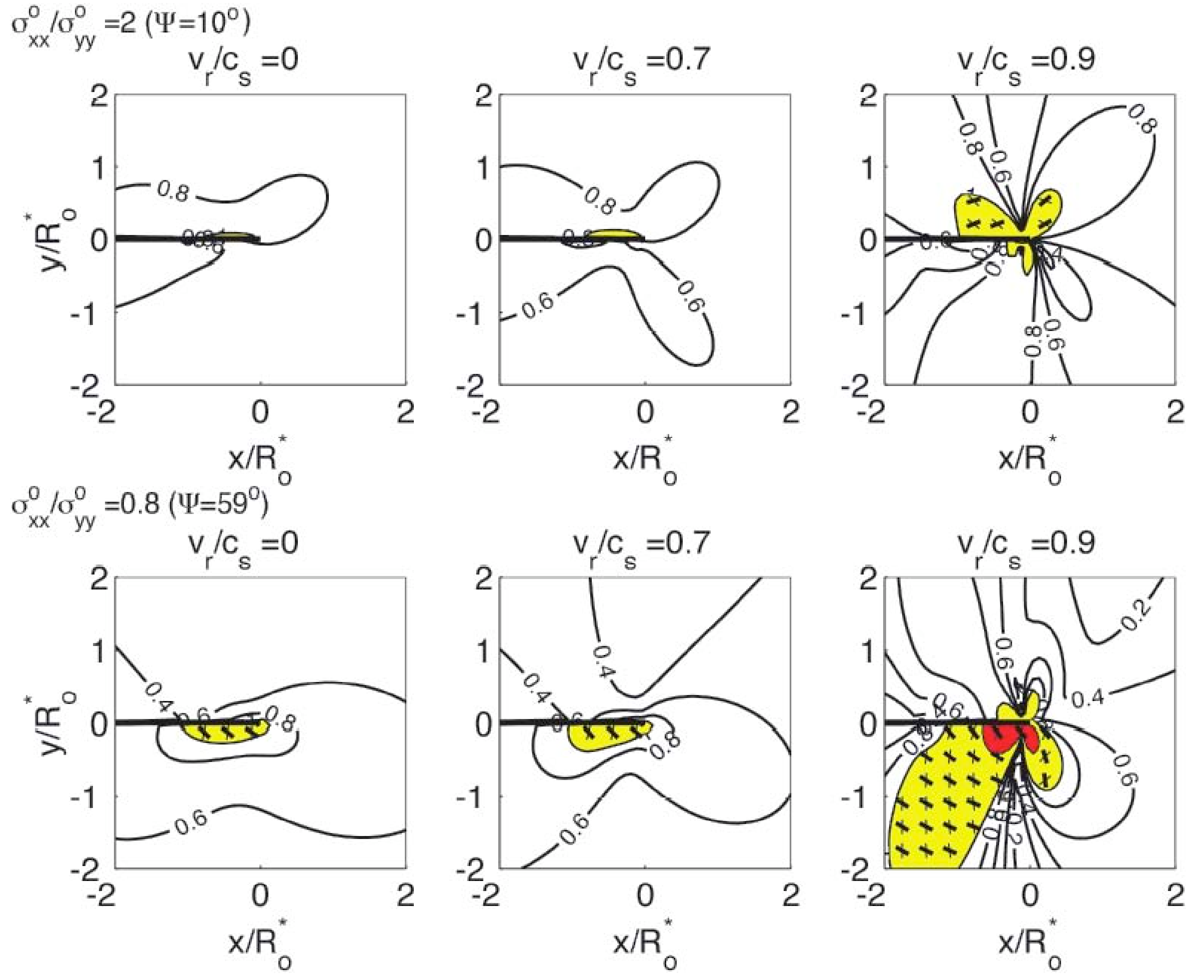

Figure III.14. Rice and Sammis have been examining where to expect off-fault damage near a strike-slip earthquake. Their model is two-dimensional and they look at the case of an incoming rupture propagating at 0 speed (the static case, left column), 0.7 times the shear-wave velocity (middle column), and 0.9 times the shear-wave velocity (right column). They look at 2 different values for the angle of the maximum principle stress direction with the fault, 10 degrees (top row), and 59 degrees (bottom row). The yellow areas on the figures show where shear failure might occur and the red areas show where tensile failure might occur. Their results show that the incoming earthquake rupture speed is quite important, as is the stress angle, for determining the pattern of near-fault damage.

Ground Motions. The Ground Motion focus group concentrated its efforts into 1) synthetic ground motion in basins, 2) determination of attenuation at low frequencies, 3) using data and synthetics to improve on the community velocity model and 4) constraints placed on peak acceleration by precariously balanced rocks.

The primary effort over the past two years has been in verification of numerical codes for computing ground motion using the SCEC 3D Community Velocity Model (CVM) in the greater Los Angeles area. This research has been collaborative with the SCEC ITR project and the Pacific Earthquake Engineering Research Center. Having verified that all of the codes produce the same results for test cases, researchers reached one of the major milestones: they computed synthetic ground motions for scenario earthquakes on 10 faults (Figure III.15a). Each fault had six different earthquake scenarios. The three-component ground motions were saved on a 1600-

node grid (the actual number of points is much larger) that uniformly covered the greater Los Angeles area (Figure III.15b) resulting in 96000 three-component time histories with an upper frequency of 0.5 Hz. These time histories provide a foundation for estimating low-frequency ground motion from some of the more hazardous faults in Los Angeles (Dolan et al, 1995). There are many positive aspects of computing the ground motion numerically: multiple scenarios, ground motions are computed on a dense grid unlike the sparse grid of real stations, and the low-frequency content is generally missing in processed data (especially from the older recordings) because of noise at long periods. Besides the inherent value of the variation in ground motion from different scenarios and the spatial variation from different faults, these time series provide an estimate of the range of ground motion that the greater Los Angeles area might expect. One of the derived quantities, spectral acceleration at 5 s period for one of the Sierra Madre simulations is shown in Figure III.16. The computed spectral acceleration is compared with one of the current attenuation relations from Abrahamson and Silva that is used in engineering practice as well as in the development of probabilistic hazard analysis.

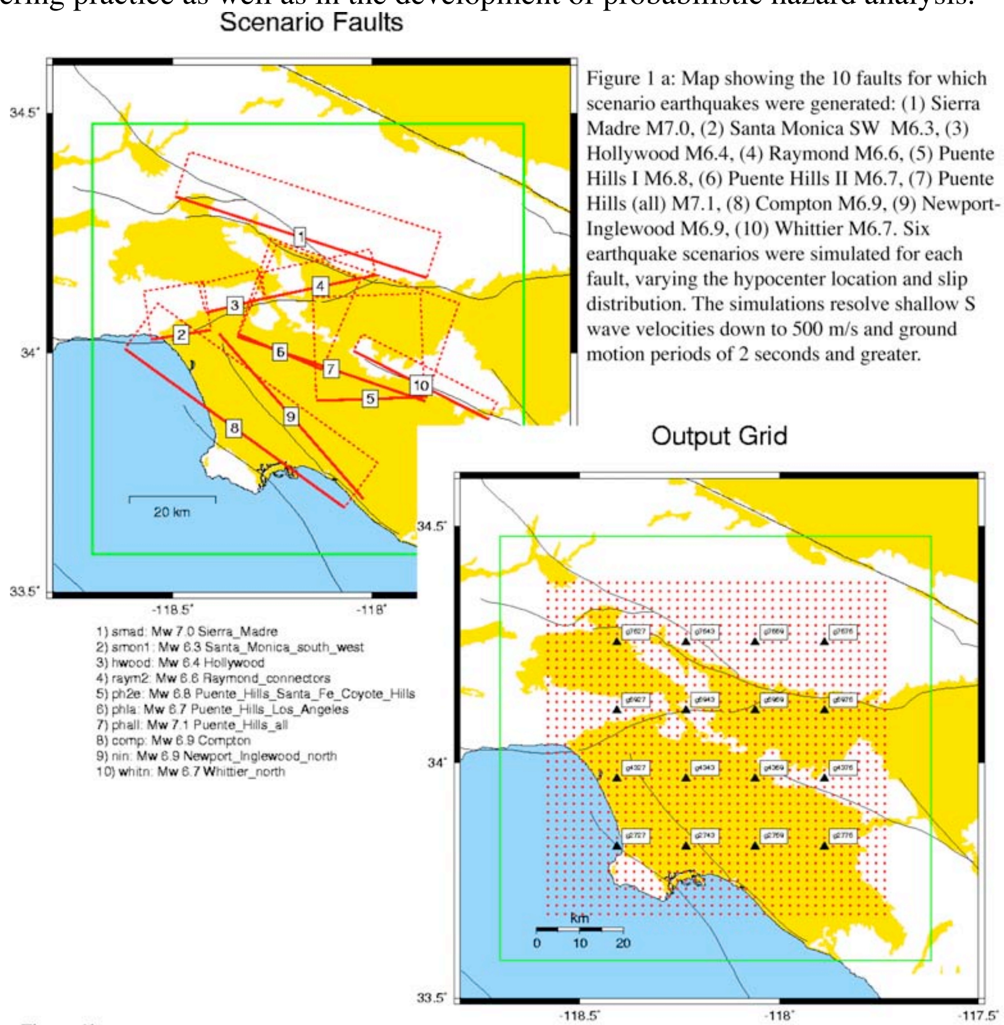

Figure 1 a: Map showing the 10 faults for which scenario earthquakes were generated: (1) Sierra Madre M7.0, (2) Santa Monica SW M6.3, (3) Hollywood M6.4, (4) Raymond M6.6, (5) Puente Hills I M6.8, (6) Puente Hills II M6.7, (7) Puente Hills (all) M7.1, (8) Compton M6.9, (9) Newport-Inglewood M6.9, (10) Whittier M6.7. Six earthquake scenarios were simulated for each fault, varying the hypocenter location and slip distribution. The simulations resolve shallow S wave velocities down to 500 m/s and ground motion periods of 2 seconds and greater.

Figure 1b:
Map of stations at which full, 3-component time histories and response spectral ordinates were computed. There are 1600 such stations for each of the 60 scenario simulations, including both basin and rock sites. The 16 numbered points were cross-check sites at which detailed comparisons were made of results from 2 different codes.

Figure III.15.

Given SCEC's continuing interest in 3D simulations, the Ground Motion focus group is maintaining a close association with the USR focus group in efforts to improve the CVM. There is progress on several different fronts.

- Estimating the attenuation structure for the low frequency simulations has been a priority. By simulating the low-frequency (less than 0.5 Hz) ground motion from the Northridge earthquake Olsen, Day and Bradley (2003) derived a shear wave attenuation model: $Q_S=0.02V_S$ for V_S < 1000-2000 m/s and $Q_S=0.1V_S$ for V_S > 2000 m/s. This attenuation model reduced the standard deviation of the residuals by a factor of 4.3.
- Incorporating this attenuation model in the CVM the group of researchers doing basin modeling then attempted to simulate the West Hollywood earthquake (M 4.2 September 9, 2001), at sites located in the Los Angeles basin and San Fernando Valley.
- However, the comparison between synthetic and data, even at low-frequency, is not perfect indicating that there are needed improvements in the velocity model. Li, Jordan and Olsen have initiated a project that will make use of the misfit between a synthetic and a recording to update the CVM. The goal is to assess and improve upon the current CVM. This involves inverting phase and amplitude data in a multi-scale fashion, starting from lower frequency and progresings to higher frequencies.

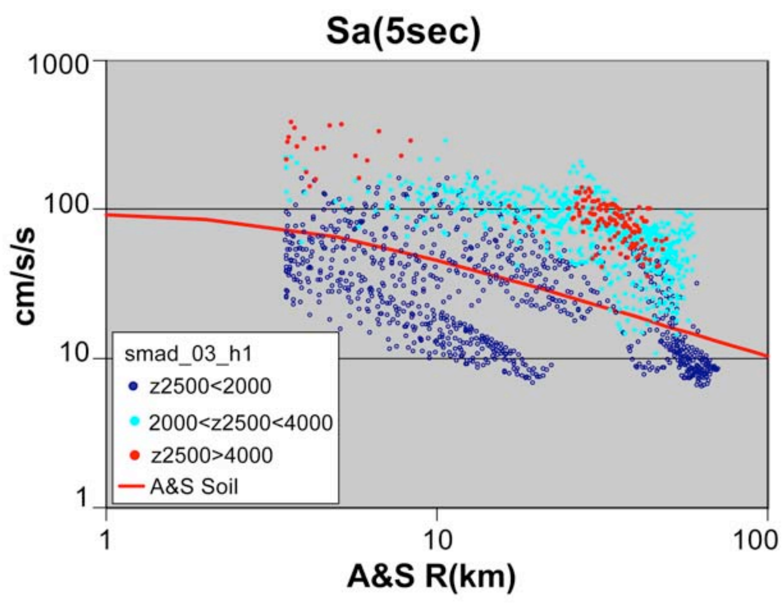

Figure 2. Spectral acceleration at 5 seconds, for one of the Sierra Madre simulations, plotted versus distance (using the Abrahamson-Silva distance definition). The synthetic Sa values are grouped by site basin depth, as represented by depth to the 2500 m/s S velocity isosurface (z2500). Note that, using this measure of basin depth, the 5 sec responses of shallow (z2500<2km), intermediate (2km<z2500<4 km), and deep (z2500>4km) sites clearly separate from one another. Analysis of the full 60 scenario synthetic data set is in progress.

Figure III.16.

For several years, the Ground Motion group has been investigating the constraint precariously balanced rocks might place on estimates of peak acceleration. Brune has recently found a number of such rocks (Figure III.17) along a 70 km line almost midway between the Elsinore and San Jacinto faults. Rockwell's paleoseismological studies indicate that these rocks would experience about 6 M 7 earthquakes every thousand years. Based on toppling acceleration models, Brune estimates a maximum acceleration of about 0.3 g which is considerably lower than the median plus 1 sigma curve from attenuation relations as well as the 2% in 50 years or 2475 year return period. Numerical studies of toppling acceleration indicate that rocks 1-2 m in length are sensitive to spectral acceleration levels in the 1-2 s period range. Thus acceleration time series with high levels of spectral acceleration in this period range may be the critical factor in destabilizing a precariously balanced rock.

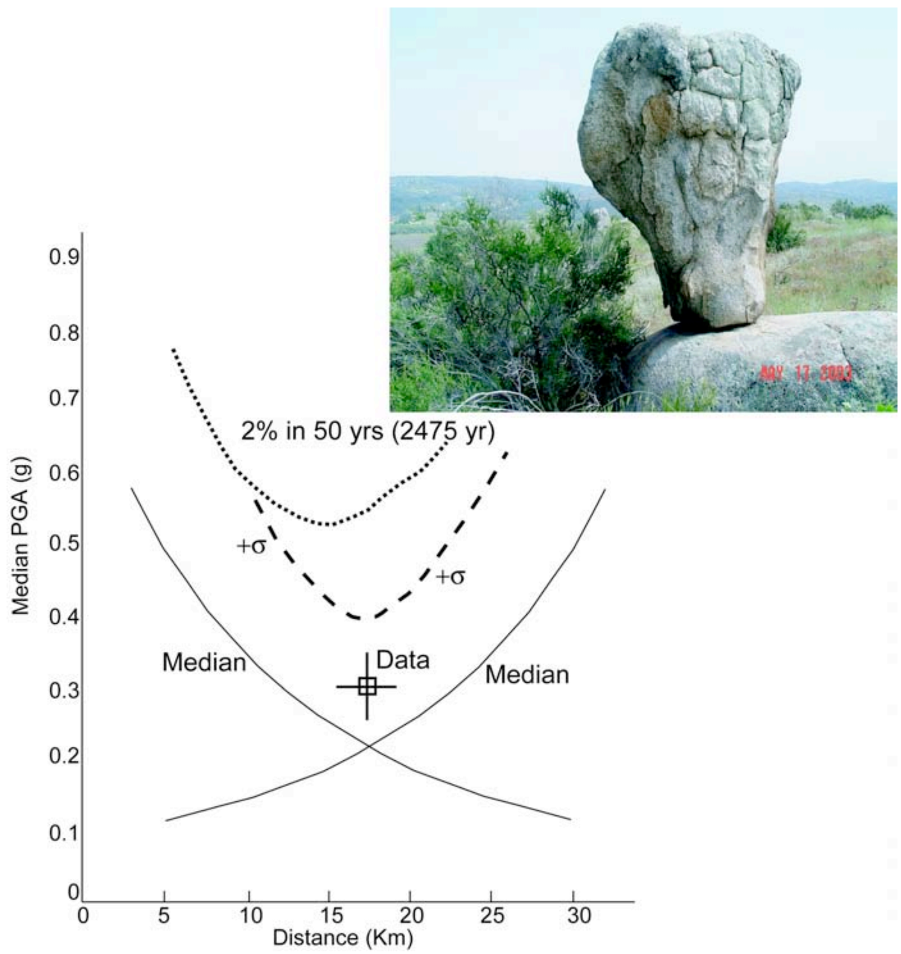

Figure 3: Estimated toppling acceleration for precariously balanced rocks along the Riverside–Aguauga line compared with attenuation relations for peak ground acceleration (PGA): the median estimate, median plus 1sigma and 2% in 50 years. About 10 precariously balanced rocks (one is shown here) have been found midway between the San Jacinto and Elsinore faults. The data point is Brune's estimate of the toppling acceleration for these rocks. The figure is modified from Brune, 2003.

Figure III.17.

Plans for the Upcoming Year. Computing realistic broadband synthetics for scenario earthquakes that can affect southern California remains as the ultimate objective. To this end the Ground Motion focus group is soliciting proposals that fall into three broad categories: deterministic modeling, improvements to the CVM and stochastic broadband synthetics. The success of deterministic modeling at low frequencies is a combination of close interaction among modelers and others developing the CVM. While successful at reproducing synthetics among various modelers, the challenge of modeling waveform data up to some maximum frequency remains. Determining the maximum frequency for which data can be modeled deterministically is predicated on how accurately the CVM represents the structure. The interaction between forward modeling and improvements to the CVM will continue to be a focus for Ground Motion.

In order to produce broadband synthetics, there must be a commensurate effort in developing methods that combine the deterministic low-frequency models with stochastic representations of the ground motion at high frequencies. This effort not only requires calibrating methods against data but also developing standards that quantify the misfit between data and synthetics. As was noted in the workshop of November 2003 finding metrics that quantify the fit between data and synthetics is necessary, but without consensus, before deciding on which stochastic models are appropriate for combining with the low-frequency ground motion from scenario earthquakes.

Seismic Hazard Analysis. The goal of seismic hazard analysis (SHA) is to state the probability that something of concern related to earthquake shaking will occur over some specified time span. SHA relies on three types of models: 1) an Earthquake Rupture Forecast (ERF) that gives an inventory of all possible (and significant) faulting events in a region over a given time span; 2) a ground motion model that gives the level of shaking at a site for a given faulting event; and 3) an engineering model that predicts the amount of damage given the level of ground shaking. The latter two models are usually combined into one that predicts the probability that and engineering "Intensity Measure" will exceed a specified value at a particular site given a fault rupture event; this combined model is referred to as and Intensity-Measure Relationship (IMR). Traditional IMRs have been based on empirical regression of observed data (so-called attenuation relationships), although IMRs could also be based on full-waveform modeling from first principles of physics.

A strong motivating force within SCEC is the belief that improvements in SHA will require a more physics-based approach to modeling. For example, SCEC's Phase III report (e.g., Field et al., 2000) demonstrated that traditional IMRs (empirical attenuation relationships) have inherent limitations with respect to precision (i.e., there will always be significant uncertainty). The Yucca Mountain Repository project also demonstrated that a lack of physics in attenuation relationships can lead to ground-motion predictions that far exceed actual strength of rock (McGarr, 2003). Thus, the key to improved IMRs is to utilize waveform modeling from first principles of physics.

Similarly, while the ERF applied in our National Hazard Maps is a time-independent Poisson model, where the likelihood of each faulting event is completely independent of all others, there presently exists a flood of papers and meeting abstracts on stress-interaction and time-dependent earthquake effects. In other words, there is clear consensus that the time-independent model is inadequate, but no consensus on what type of model should replace it. In fact, the range of views is so wide that it's highly unlikely that consensus will be reached anytime soon. Should we continue to use the time-independent Poisson model until consensus is reached? The scientific approach might say yes – keep the model simple until and alternative is proven to be superior. However, proper SHA actually requires that all *viable* models be considered in the analysis (SSHAC, 1995). Therefore, what we need is a suite of alternative, perhaps physics-based models to be developed and applied. This is the primary goal of SCEC's working group for the development of **R**egional **E**arthquake **L**ikelihood **M**odels (RELM; http://www.relm.org), This project, which constitutes the lead activity of the SHA focus group, is discussed more below.

The need to consider all viable models in SHA applies to IMRs as well. This is why the NGA project that SCEC is involved with is developing multiple attenuation relationships, some of which will utilize waveform modeling to fill in where empirical data are lacking. In addition, part of SCEC's CME project (Pathway 2) is developing a more routine, community-accessible waveform modeling capability, and there will certainly be multiple ways of doing these simulations as well.

One problem we faced was the lack of a SHA computational infrastructure capable of handling the wide range of models currently under development. As discussed more below, our solution to this potential dilemma is OpenSHA – an emerging community-modeling environment for SHA.

It's import to note that almost all activities taking place in SCEC's SHA focus group are coupled with activities in the other focus and interdisciplinary groups, What's given below, therefore, is merely outline of the two main projects (RELM and OpenSHA).

RELM. RELM is the working group for the development of **R**egional **E**arthquake **L**ikelihood **M**odels. The goal of RELM is to develop, evaluate, and test a variety of more physics-based ERFs than that currently applied in the National Hazard Maps. This will help define existing uncertainties in seismic hazard analysis, identify the research topics needed to reduce these uncertainties, and identify which models are exportable to other regions where the options are fewer. We plan to publish our results as a special issue of a peer-reviewed journal (such as BSSA). Perhaps the best overview of this project is the list of anticipated publications:

Table III. 2 RELM Papers in Preparation

Papers on Models

Blanpied et al.	The Working-Group 2002 forecast model for the San Francisco Bay area
Ward	Different models based on geologic, seismic, and geodetic constraints.
Ward	Standard Physical Earthquake Model for so. California (simulation based model).
Tiempo et al.	A Earthquake Forecast Based on Pattern Informatics (previously known as PDPC)
Jackson et al.	Different models based on geologic and geodetic constraints
Gerstenberger et al.	Short-Term Earthquake Probability (STEP) model
Helmstetter et al. ????	Epidemic Type Aftershock Sequence (ETAS) model
Anderson	Southern California regional earthquake probability estimated from geodetic data
Petersen et al.	The California model used in the 2002 USGS/CGS National Hazard Maps
Schorlemmer, Jackson, et al.	Seismicity based forecasts w/ spatial & temporal variability in mag-freq dist. params.
Rundle et al.	The Virtual California earthquake simulation model
Bowman et al.	A model that incorporates accelerating moment release and coulomb stress change
Field et al.	The SCEC system-level, CFM-based ERF

Papers on Supporting Developments

Plesch et al.	The Digital 3D SCEC Community Fault Model (CFM) of Southern California
Plesch et al.	Formalization of alternative source models from the SCEC CFM
Perry et al.	The SCEC/USGS Fault Activity Database (FAD) and the Fault Information System (FIS)
Gould et al.	A method for populating paleoseismic databases using non-expert readers
Maechling et al.	The SCEC, distributed community modeling environment and its support of RELM

Papers on Evaluations/Implications of the Models

Schorlemmer, Jackson, et al.	Standardized tests for any ERF and their application to RELM models
Field et al.	Evaluation of hazard implications of the various RELM models using OpenSHA
Campbell et al.	Risk/Loss implications of the RELM models
Stirling et al.	Use of the historical intensity data to test probabilistic seismic hazard models
Bowman et al.	Testing arbitrary RELM forecast scenarios for accelerating moment release
A panel of independent, authoritative experts	Evaluation of RELM models for practical use (independent evaluation of the complete suite of models)

Our goals for the next year are to get most of the above submitted for publication. Particular effort will be devoted to SCEC's system-level, Community-Fault-Model-based ERF, both because we now have the ingredients necessary to build it, and because it will be the closest thing to a logical extension of previous Working Group on California Earthquake Probability models (WGCEP, 1988, 1990, 1995, 2002). Significant effort will also be devoted to assembling the panel of independent experts needed evaluate the RELM models and to make recommendations for potential users and public policy officials (and perhaps forming the basis of a WGCEP-200X report).

OpenSHA. As discussed above, SHA requires two types of models – an Earthquake Rupture Forecast (ERF) and an Intensity-Measure Relationship (IMR). OpenSHA is an effort to build a computational infrastructure, or community-modeling environment, capable of handling the wide range of ERFs and IMRs currently under development. The goal is to enable any such model to plug in for analysis without having to change what's being plugged into. We also want to accommodate the rapidly evolving needs of the engineering community and other user groups.

Figure III.18 shows the basic elements of the OpenSHA framework. The output of the analysis is the probability that an intensity-measure type, which represents any functional of ground motion found by engineers to correlate with earthquake damage, will exceed a specified intensity-measure level.

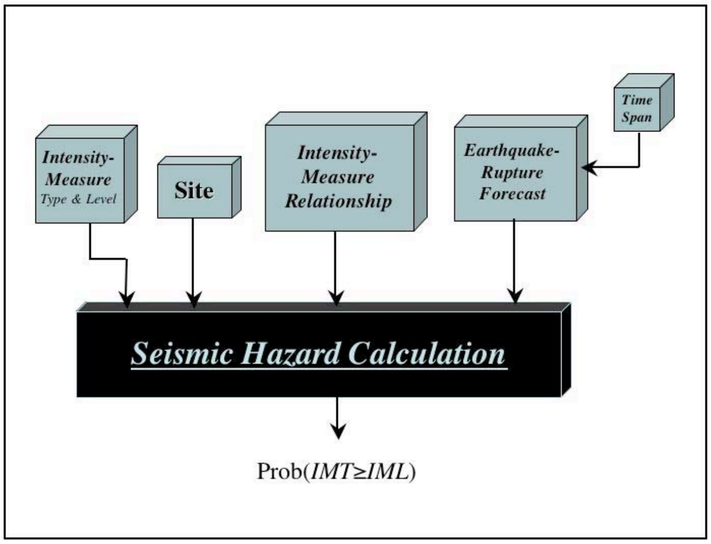

Figure III.18. The fundamental elements needed for a hazard calculation in OpenSHA. Although the figure portrays computing the exceedance probability of a single *Intenity-Measure Level (IML)*, the analysis can be repeated over different *IML*s to generate a hazard curve, over different *Intensity-measure Types (IMT*s) to generate a hazard spectrum (if considering spectral acceleration), or over different *Sites* to generate a hazard map.

The computational framework is object oriented, web and GUI enabled, platform independent, open source, and freely available. We also have a thorough and aggressive code evaluation and testing process (e.g., we are participating in a code validation exercise initiated by PEER). Although most of the code is written in Java, the overall framework is programming-language independent, and some of the existing components are legacy code (e.g., written in Fortran) with a Java wrapper.

We have thus far implemented nine different attenuation-relationship-type IMRs that are applicable to southern California. We have also implemented a variety of ERFs, including: 1) a generic single-fault forecast; 2) the ERF used in the current National Hazard Maps; 3) a variety of ERFs needed to implement the code-validation test cases defined by a PEER working group; 4) the Short-Term Earthquake Probability (STEP) model for southern California which makes a real-time forecast based on recent seismicity and foreshock/aftershock statistics; and 5) the Working-Group 2002 forecast model for the San Francisco bay area (WGCEP, 2002), which is the most sophisticated time-dependent ERF ever developed and one for which no other code can currently handle.

We presently have applications that allow the calculation of hazard curves (Figure III.19), hazard spectra, scenario ShakeMaps (Figure 3), and full hazard maps. It's important to note that none of these applications have been hard coded for any particular IMRs or ERFs (new ones can be added, or old ones removed, without rewriting any code).

A study following the November 3, 2002 Denali earthquake exemplifies the current capability and flexibility of the OpenSHA framework. During the main shock, the Alaskan oil pipeline was offset where it crosses the fault to within a few feet of its design limit. The USGS was asked to assess the likelihood that aftershocks would threaten the structure, given its diminished capacity to accommodate additional offset and the time lag in making repairs. The aftershock-forecast technique of Wiemer and Katsumata (1999) was used to build an appropriate ERF, and a new IMR based on a new intensity-measure type (fault displacement) was developed and quickly implemented in the OpenSHA (Figure III.19). This study demonstrates the extensibility of OpenSHA with respect to accommodating arbitrary model components.

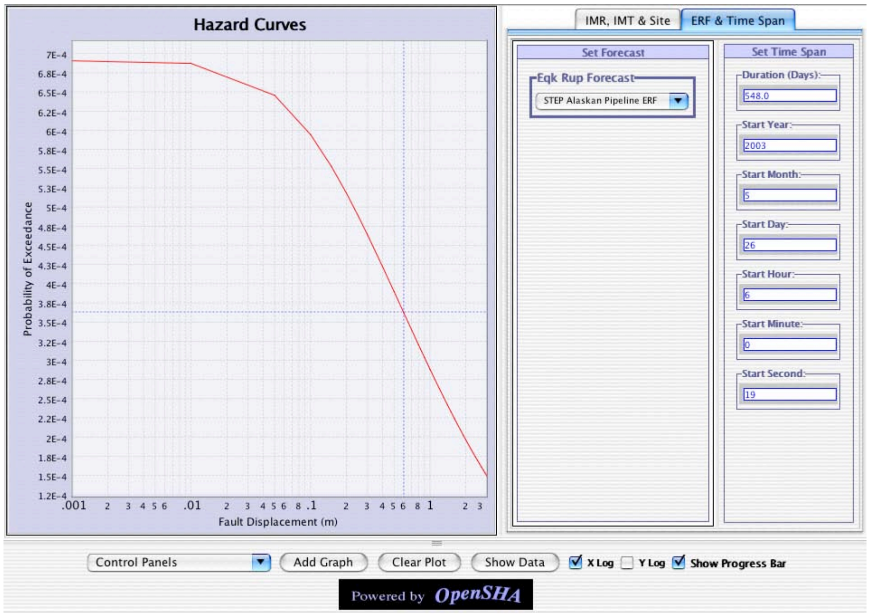

Figure III.19. A screen-shot of the OpenSHA GUI, giving the probability of exceeding a given displacement in meters on the Denali fault at the site of the Alaska pipeline in the 540 days from May 26, 2003 (Jones et al., 2003).

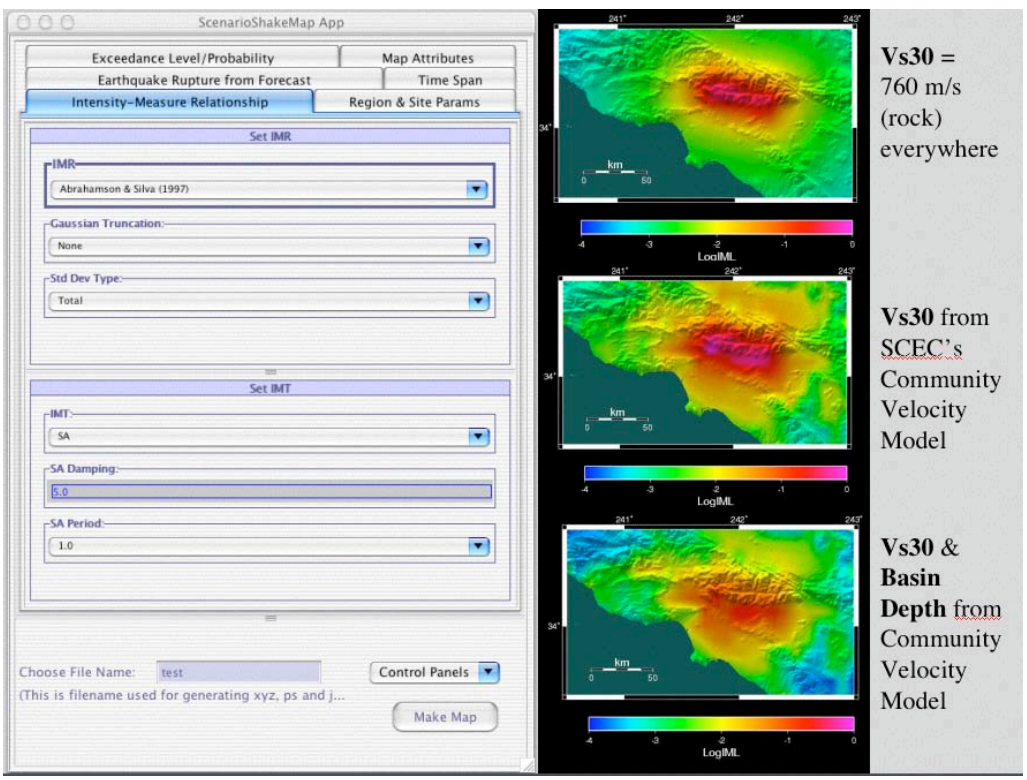

Figure III.20. Snapshot of the *OpenSHA* application for computing scenario earthquake maps. This example is for the Sierra Madre fault rupture as defined by the ERF used in the 1996 National Hazard Maps. The three images show results for different assumption regarding site conditions (the average 30-meter shear-wave velocity ("Vs30") and depth of sediments to basement rock ("Basin Depth").

Collaboration with SCEC/CME Project. We anticipate a large number of potentially complex IMRs and ERFs, almost all of which will evolve over time as assumptions change and new data become available. We also anticipate that some models will be implemented in programming languages (e.g., Fortran) that are not easily ported across platforms. To make this infrastructure manageable, therefore, a high priority is to enable the ERFs and IMRs, as well as any data resources upon which they depend, to be geographically distributed and run-time accessible over the Internet as "web services". Thus, rather bundling each ERF inside an application, for example, we instead access each ERF over the Internet at runtime. This has the added convenience of making our applications relatively lightweight and putting the maintenance onus directly on the host of each model.

Elements that have thus far been implemented as web services include: 1) several ERFs, including the WGCEP-2002 model where their Fortran code is configured and run in real time during a hazard calculation; 2) access to the SCEC community velocity model (CVM) for the purpose of defining site attributes for an arbitrary latitude and longitude; and 3) the making of GMT maps (written in the C programming language). These latter two were utilized in making the maps in Figure 3.

We are also beginning to utilize GRID computing, where the computational burden is distributed among any idle computers that are available during the calculation. Our first tests of this reduced the time needed to make a hazard map from about 7 hours to about 30 minutes. This is a very significant achievement, as it effectively means we will be able to consider more alternative models in our analysis, as required for "proper" SHA (SSHAC, 1995).

Our goals for the next year are to continue implementing and optimizing these capabilities in order to make them routine and automatic in the community modeling environment. We also want to implement the other ERFs being developed by the RELM working group, not the least of which is SCEC's system-level ERF. Finally, we will be adding the new IMRs (attenuation relationships) coming out the NGA project, and any other IMRs such as the vector-valued intensity-measure type being pursued by some SCEC researchers.

Special Projects

Southern California Integrated GPS Network (SCIGN). Installation of the primary network of the Southern California GPS Network (SCIGN) was completed in July 2001 when the 250th GPS site was installed. Since that time 20 additional sites have been installed and others have been upgraded mainly through the addition of real-time telemetry links to some of the stations. Of the 277 GPS sites in the SCIGN array (http://sopac.ucsd.edu/cgi-bin/dbShowArraySitesMap.cgi?array=SCIGN&array_option=siteList), seven have been destroyed either through vandalism or nearby construction. In addition, five of the sites are remote and are manually downloaded during site visits. During 2003, daily GPS position estimates are available from an average of 273 sites in Southern California (Latitude 28 ° to 39 °, Longitude 239 ° to 250°) with a peak of 286 sites. About 30 of these sites included in the SCIGN data analysis come from the Basin and Range Geodetic Network (BARGEN http://cfa-www.harvard.edu/space_geodesy/BARGEN/). These sites help to define the motion of the SCIGN array in a North American fixed frame. Thirty-three SCIGN sites now telemeter data in real-time instead of hourly or daily downloads of the data. The sites are located in Parkfield area (12), Orange County (13) and around the Diamond Valley Lake (8). The Orange County sites serve not only the geophysical community but also the local surveying community. All of the real-time stations collect data 1-second intervals compared to the 30-second collection interval at most of the SCIGN stations. Interaction between SCIGN and the Southern California surveying community is coordinated through the California Spatial Reference Center (CSRC http://csrc.ucsd.edu/).

Current network maintenance is focused on the replacement of failed or destroyed equipment. The costs, funding sources, and priority for the conversion of more of the network to real-time operation and to higher sampling rates are being debated. Resolution will be based on costs, multiple uses of data from the network, and on ensuring that data is preserved in the receivers in the case of telemetry failure. Addition of stations to the network will be based on analysis of existing data and the need to fill regions where coverage is currently insufficient to address tectonic questions. Much of the efforts of the SCIGN principals, JPL/SIO/USGS, will now focus on the generation of products from the SCIGN data.

SCIGN Results. SCIGN data have always been freely available. The recent focus in SCIGN has been to make the results from the analysis of the data in the form of verified and validated time series of position estimates, estimates of secular motion, and site characterizations more readily usable by the geophysics communities. The SCIGN solutions are based on the independent processing by three different organizations within SCIGN. The USGS is responsible for near real-time analysis of data and rapid dissemination of results when there is a major earthquake in Southern California (http://pasadena.wr.usgs.gov/scign/Analysis/); JPL and SOPAC generate "final" results based on precise GPS satellite orbits obtained from the analysis of data from the International GPS Service (IGS) global network of GPS sites (http://sideshow.jpl.nasa.gov/mbh/series.html/ and http://sopac.ucsd.edu/cgi-bin/dbShowArraySitesMap.cgi?array=SCIGN). The results from the JPL analysis are updated every few months while the SOPAC analyses are updated weekly. All of the time series from these three analysis can by downloaded as tar files from the SCIGN web site (http://www.scign.org/). MIT generates a combined analysis product from the JPL and SOPAC results and makes available the results from JPL and SOPAC in a common format (http://www-gpsg.mit.edu/~tah/SCIGN_MIT). MIT also makes available Matlab based tools for interactively viewing and analyzing the secular motion estimates and time series (http://www-gpsg.mit.edu/~tah/GGMatlab). Both USGS and SOPAC have web sites that allow interactive viewing of time series and either daily site displacements (USGS) or secular motion estimates (SOPAC). At both web sites, the time series plotting tools allow time series from different sites to be overlaid. JPL and SOPAC provide secular motion estimates. For the SOPAC estimates non-secular terms are included and a correlated noise model is used to compute the uncertainties of the estimates (http://sopac.ucsd.edu/processing/refinedVelsDoc.html).

Steady progress has been made on the generation of a combined SCIGN product based on the JPL and SOPAC analyses. The SCIGN combined products are generated for a geographical region and include sites from other networks such as BARGEN. Also GPS sites from North America and the Pacific plates that are parts of other networks are included from the SOPAC results to define a North America fixed reference frame for the SCIGN results. During the generation of the combined products, correlated noise models are developed and the sites characterized into three classes based on the level of the correlated noise. In the current combined solution, there are 315 GPS sites of which 273 sites have sufficiently small correlated noise to be included in the secular motion estimates and 214 have noise levels such that they are used to realize the reference frame for the time series. Included in motion estimates are logarithmic temporal variations after the Hector Mine earthquake. Figure III.21 shows the details of the secular motions in the Los Angeles basin from the analysis of GPS data between 1996 and September 2003, and Figure Figure III.22 shows estimates of the postseismic variations after the Hector Mine earthquake.

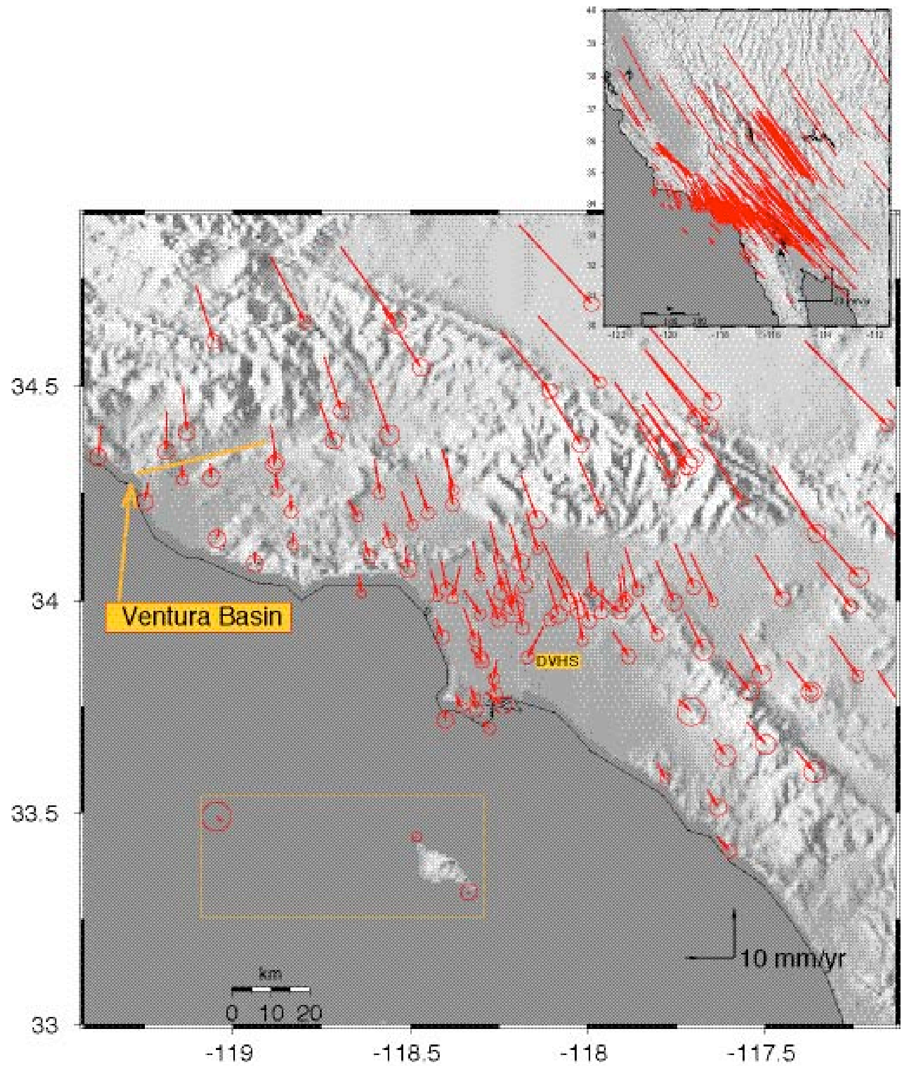

Figure III.21: Secular motion estimates in the Los Angeles shown as horizontal velocity estimates with 95% confidence error ellipses based on a correlated noise model. The median horizontal and vertical velocity uncertainties are 0.5 mm./yr and 0.6 mm/yr, respectively. The motions are shown relative to the three island sites in the light brown box. The insert, at the top of the figure, shows the velocities relative to the Pacific Plate for all the sites with regular motions in Southern California. The motion of the three island sites relative to the Pacific Plate is –4.7±0.4 N, 4.4 ±0.4 E and –2.4±0.7 U mm/yr. Convergence across the Ventura Basin is clear in the figure. At the eastern end of the basin, 4.0±0.7 mm/yr of convergence is accommodated between sites separated by 6 km. Although, the correlated noise characteristics of the sites shown suggest that ground water effects should be small for these sites, the motion of sites such DVHS shown on the figure may reflect local deformation of the sediments (see characterization of ground water effects on SCIGN sites http://quake.wr.usgs.gov/research /deformation/modeling/socal/la.html). Much of the motion shown in this figure can be attributed to strain accumulation on the San Andreas Fault. A consensus model for the effects of the San Andreas would be useful for removing its effects and to better see the effects of strain accumulation on other faults in the region.

In addition to GPS measurements, SCIGN also includes a long baseline laser strainmeter at Glendale-Verdugo (http://jacinto.ucsd.edu/gvs/) and partially supports long baseline strainmeters at Piñon Flat Observatory and Durmid Hill. Results from and descriptions of the strainmeters in Southern California can be found at http://jacinto.ucsd.edu/.

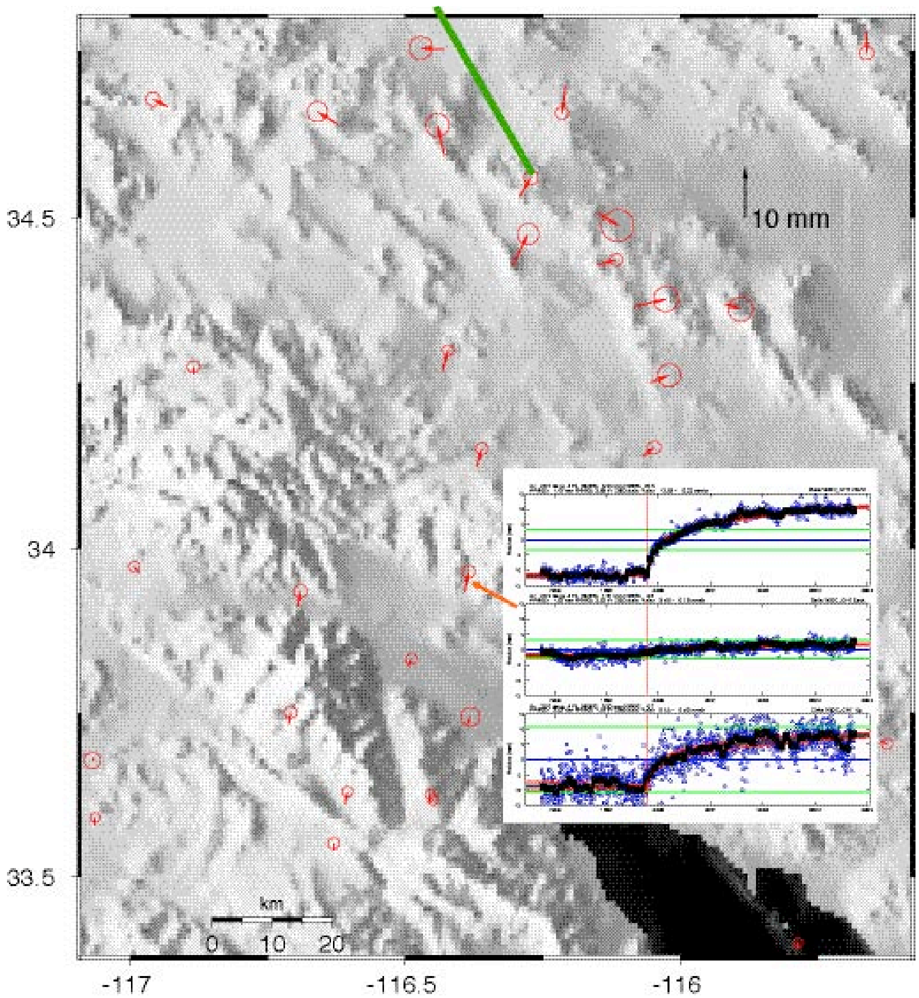

Figure III.22. Horizontal postseismic deformation after the Hector Mine earthquake parameterized by the amplitude of the logarithmic variations of the form $\log(1+\Delta t/\tau)$ where Δt is the time after the earthquake and τ is time constant. Analysis of the SCIGN data shows that τ=10 days provides a good match to the data. The thick green line shows the single fault plane solution that matches the geodetic co-seismic displacements (Hudnut, K. W., N. E. King, J. E. Galetzka, K. F. Stark, J. A. Behr, A. Aspiotes, S. van Wyk, R. Moffitt, S. Dockter, and F. Wyatt, Continuous GPS Observations of Postseismic Deformation Following the 16 October 1999 Hector Mine, California, Earthquake (Mw 7.1), *Bull. Seis. Soc. Amer.*, v. 92, No. 4, pp.1403-1422, 2002). In the insert, a typical time series is shown for a site ~80km south of the rupture. Co--seismic offsets of 51 mm North, 1 mm East and 3.6 mm Up have been removed to allow the postseismic signal to be seen. The light symbols in each of the frames for North, East and Up components are the daily position estimates. The dark squares are 30-day averages of the daily values and the solid line is the logarithmic model fit to the data. For this site, the North component, which shows the largest postseismic motion, is not well modeled by an exponential decay. The root-mean-square (RMS) scatter after an exponential fit (80-day 1/*e* time constant) is 1.4 mm compared to 1.1 mm with the logarithmic fit. Even with a velocity change after the earthquake, the RMS scatter is still 1.2 mm for the exponential decay model. Similar results are seen at all the sites with large postseismic signals although for some of the sites close to the rupture different logarithmic decay times may be needed.

Future activities. Maintenance of the network needs to be continued because of equipment failure and damage. There will be discussions within the SCIGN coordinating committee and the Plate Boundary Observatory about additions to the network to address specific tectonic questions. Much of the on-going development in SCIGN will be associated with the development of products and characterization of the sites in terms of their utility in addressing tectonic questions and other non-tectonic questions such as groundwater effects.

SCEC/ITR Project. Geoscientists and Information Technology (IT) researchers are working together on the SCEC Community Modeling Environment (SCEC/CME), a Information Technology Research (ITR) project sponsored by the NSF. On this project, we are developing physics-based models of earthquake processes and are integrating these models into a new scientific framework for seismic hazard analysis and risk management. SCEC/CME geoscience and IT research is performed by a number of collaborating organizations including University of Southern California (USC), USC Information Sciences Institute (USC/ISI), University of California at Santa Barbara (UCSB), University of California at San Diego (UCSD), Carnegie Mellon University (CMU), Incorporated Research Institutions in Seismology (IRIS), and the United States Geological Survey (USGS).

The geophysical computational capabilities of the system are organized along the lines of what we have termed "computational pathways". The first three of these pathways are increasingly complex, and computational expensive, geophysical models for simulating ground motion intensity measures. The fourth computational pathway aims to improve our knowledge of geological structures using data inversion techniques.

Appropriate IT technologies are applied to support this geophysical modeling. Technologies such as grid computing, knowledge representation and reasoning, and digital libraries are under active research and development as a part of the SCEC/CME project.

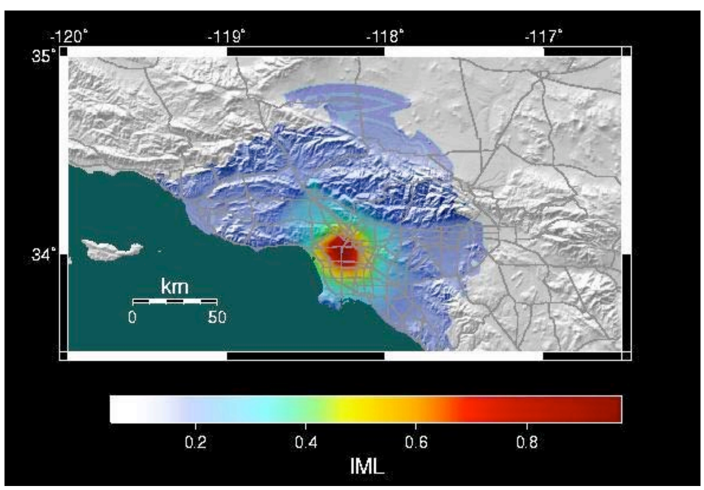

Figure III.23. Scenario Peak Ground Acceleration (PGA) Hazard Map for a hypothetical Ml 6.7 earthquake in Los Angeles using Field-2000 Attenuation Relationship and SCEC CVM 3.0 (Image: Vipin Gupta, Nitin Gupta (USC/SCEC), Ned Field (USGS))

The SCEC/CME project has adopted a development process designed to establish a rapid feedback cycle between system users and system developers. New versions of the SCEC/CME system are released to the SCEC community at the end of each calendar quarter. This provides users with rapid access to new features and capabilities. User response to the system provides rapid feedback to the developers. The project performed three publicly-released Builds during this project year. Each Build contained new geophysical and IT developments.

Key project accomplishments during this year include:

- A collaboratory infrastructure was established at SCEC including computer hardware and software. A number of SCEC/CME servers were deployed to support the software development and software integration required by the project. Collaborative project tools were developed and deployed including project web sites (http://www.scec.org/cme), email distribution lists, and document archives.
- A computational testbed was developed that provides a Web Browser-based user interface to seismological modeling software. This web-based system utilizes OpenSHA software running on the SCEC/CME servers. As one example, the system can generate Peak Ground Acceleration maps for "scenario" earthquakes located anywhere in southern California.
- A Web-browser based query system was implemented to provide SCEC researchers with access to the SCEC Fault Activity Database (SCEC/FAD).
- The SCEC/CME system established secure, high performance, data transfers between Pittsburgh Supercomputer Center (PSC), University of Southern California High Performance Center (USC HPCC), SCEC/CME servers, and San Diego Supercomputer Center (SDSC) using National Middleware Initiative (NMI) Release 3.0 software including the Globus toolkit. Job submission capability was established from SCEC to USC, and SDSC, using NMI Release 3.0 software.
- A SCEC digital library was established that provides researchers with the ability to store data sets locally or on SCEC/CME disk systems. This digital library technology helps maintain the association between the data sets and the metadata that describes the data sets. It also provides replication of data sets, and provides the user with access to the most local copy of

the data.

Figure III.24. P-Wave Velocities retrieved from the SCEC/CME Velocity Model Server for Longitudes from -119.00 to -116.0 at 34.00N Latitude for 0 to 30 KMs depth. From Left to Right: PREM Model, Hadley-Kanamori Model, SCEC CVM 2.2, SCEC CVM 3.0. (Images: Linus Kamb (IRIS), Vipin Gupta, David Okaya (USC/SCEC)).

- Several computational programs, including a velocity model server, a GMT map making service, and a coordinate conversion utility service, were implemented on the SCEC/CME system using an Internet-standard Web-Service software architecture. These computational programs can be called programmatically, or accessed via Web-Browser based applications, by members of the SCEC community.
- The Pathway 1 working group deployed a new, time-dependent, earthquake rupture forecast as a web service on a SCEC/CME server. They also established routine calculation of Short Term Earthquake Probability (STEP) maps to support USGS development in this area.

- A standardized, web-service based, programmatic interface to the SCEC Community Velocity Model was developed. This service provides access to the SCEC CVM 3.0 as well as to alternative velocity models including SCEC CVM 2.0, the Hadley-Kanamori Model, and the Preliminary Reference Earth Model (PREM).
- The SCEC/CME project collaborated with the SCEC IT Intern program in the development of the LA3D visualization software program.
- The SCEC/CME Pathway 2 working group participated in a SCEC sponsored effort that ran a series of approximately 70 earthquake wave propagation simulations for historic and scenario earthquake in the Los Angeles Basin.
- A pathway validation effort was performed showing PGV maps created using Pathway 1 and Pathway 2 simulations for historic earthquakes. These maps were compared against PGV maps generated from observed Southern California Seismic Network (SCSN) data for the same events.

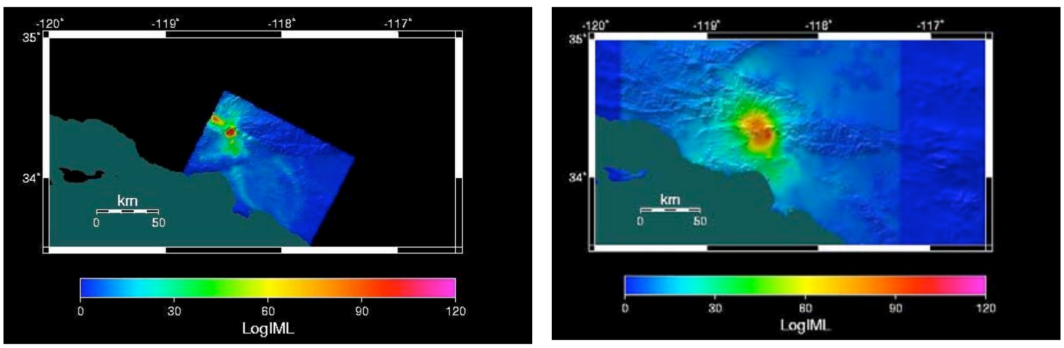

Figure III.25. Peak Ground Velocity (PGV) Maps for Northridge. On the left, the PGV values were produced using Kim Olsen's Anelastic Wave Model (AWM) wave propagation software and the SCEC Community Velocity Model (SCEC/CVM) 3.0. On the right, the PGV values were recorded by the Southern California Seismic Network (SCSN) for the same event. (Images: Nitin Gupta, Vipin Gupta, David Okaya, Kim Olsen)

- The Knowledge Representation and Reasoning working groups have developed a Composition Analysis Tool (CAT). CAT is a framework for interactive composition of computational pathways. The CAT system assists users in assembling valid computational pathway by analyzing semantic descriptions of the services and data types specified in the pathway.
- The SCEC/CME Pathway 3 working group ran simulations that coupled a Rupture Dynamic Model to an Anelastic Wave Model using an MPI interface. This simulation generated a wavefield data set. Visualizations of the data set were produced.
- The SCEC/CME Pathway 4 group is calculation and visualizing Fréchet kernels using the SCEC CVM 3.0 and Olsen's AWM wave propagation software.
- Data Visualization software that can display 3D and 4D data sets was developed to show 3D velocity models, and to display time varying 3D wave propagation data sets.

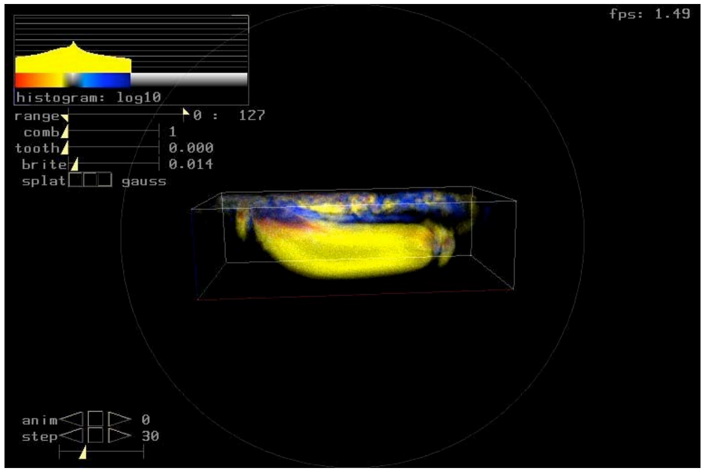

Figure III.26. Travel-Time Fréchet kernel for east-west component seismogram at DLA from Yorba Linda Event. Source is on lower right. Receiver is on the surface at upper left. (Image: Li Zhao, Tom Jordan (USC/SCEC), Marcus Thiebaux (USC/ISI))

Summary. During this past year, the SCEC/CME project made progress on each of the computational pathways and in each of the key IT technological areas.

A flexible software architecture was developed for the SCEC/CME system that includes a Web-Browser based User Interface, and a Web Services-based computational framework. The project has successfully performed integration of seismological software and data sets with complex, leading edge technology including grid-computing, digital library, and knowledge representation and reasoning systems.

In order to establish which technologies and approaches are most appropriate, much of the work done this year was prototyping. During the upcoming year, SCEC/CME system capabilities that were prototyped, such as grid-computing, and use of a digital library system, will go into routine use. Our grid-based connection to high performance computing centers such as USC HPCC, and SDSC will be used to run our computationally expensive programs. In addition, the SCEC/CME system's ability to script a sequence of computing tasks will be used by researcher to increase the efficiency of performing computational and data intensive seismological research.

The SCEC/CME system that currently provides access to Pathway 1 codes will be expanded to provide access to Pathway 2 codes including wave propagation simulations. Data sets of particular interest, such as ground motion data produced by SCEC Anelastic Wave Modelers, and Rupture Dynamic Modelers will be stored in a SCEC digital library that is accessible to the SCEC Community. In addition, we anticipate that the computational and data handling capabilities of the system will be applied by researchers to assist with the highly data and computationally expensive Fréchet kernel calculations and the data inversion processing required to generate new geological models such as an improved shear wave velocity model for southern California.

This collection of capabilities, the community standard data sets, the computational codes, the connectivity to computational resources, and the ability to facilitate research computing, will demonstrate the value of a community modeling environment for SCEC and for other systems-level geoscience research efforts.

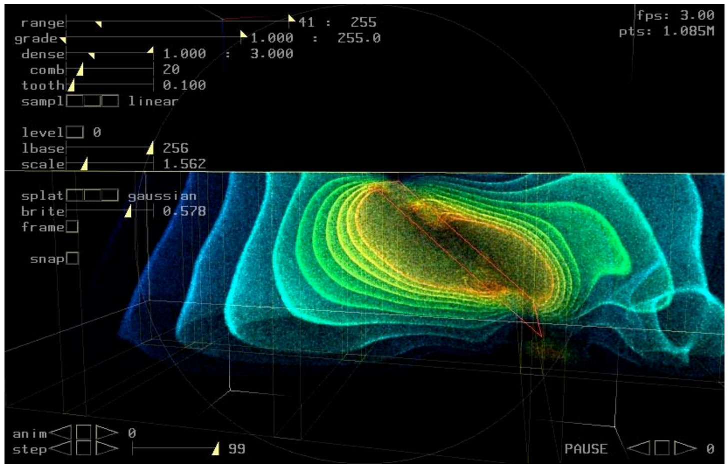

Figure III.27. Wave propagation visualization showing the position of a slipping fault plane and the resulting wave field. The wave field was generated using Kim Olsen's AWM software and the SCEC Community Velocity Model 3.0. (Image: Marcus Thiebaux, Hongsuda Tangmunarunkit (USC/ISI), Kim Olsen (UCSB)

Borderland Working Group. The offshore California Continental Borderland is a critical element in terms of understanding the tectonic evolution, active fault systems, and seismic hazard of Southern California. As a result, SCEC created the Borderland Working Group and made it an official part of the organizational structure of SCEC in June 2002. Its purpose is to focus and integrate research activities within the offshore Continental Borderland that relate to the scientific mission of SCEC. This includes the coordination of cooperative and collaborative research projects, helping to assess, archive and analyze existing offshore geologic and geophysical data, and helping to plan new research activities including future experiments within the Continental Borderland. An extended white paper on the objectives, goals, and research priorities of the SCEC Borderland Working Group can be found at the website (http://www.scec.org/borderland) and is based largely on the results of a workshop held in March 2002 on Catalina Island.

The Borderland Working Group recognizes that much of the support, data and facilities needed for offshore research must come from external sources and funding agencies, such as NOAA, NSF, NURP and ONR. Thus, much of the effort spent in 2003 by the Borderland Working Group focused on identifying appropriate funding agencies for specific research projects, developing optimal funding strategies, and coordinating and leveraging projects among different research and funding organizations. A workshop was held in late June 2003 to explore research problems in the Borderland that could be specifically targeted to NSF Ocean and Earth Science. These problems were mostly tectonic issues for which the offshore Borderland provided an unusual or outstanding natural laboratory to study. Data resources needed for these offshore studies, including existing datasets and additional new data required were also discussed. As a result of this workshop and other collaborations within SCEC, several Borderland research proposals were submitted to NSF. These include: 1) a passive long-term ocean-bottom seismometer (OBS) deployment to investigate the transition from oceanic to continental lithosphere (UCLA, Caltech, UCSB, Scripps); 2) a high-resolution study of late-Quaternary transform tectonics in thinned submerged continental crust (UCSB, LDEO); and 3) a high-resolution stratigraphic study of late-Quaternary climate and deformation in the Santa Barbara Channel (UCSB, USGS).

In 2003, SCEC helped support continued analysis of active fault systems in Santa Monica Bay. This included the Malibu Coast and Santa Monica-Pt. Dume faults, and led to the identification and preliminary mapping of a low-angle fault that may be responsible for the Shelf Projection-Palos Verdes anticlinorium (*Sorlien et al.,* 2003). Figure III.28 shows a multichannel seismic reflection profile (USGS-43) that exhibits northeast-dipping fault-plane reflections from this inferred low-angle fault where it interacts with the near-vertical San Pedro Basin fault. In addition, SCEC provided support for age-dates of recovered marine fossils to help investigate a series of submerged marine terraces and Pleistocene lowstand shorelines (*Goldfinger et al.,* 2003), thereby helping to quantify rates of offshore vertical tectonic deformation.

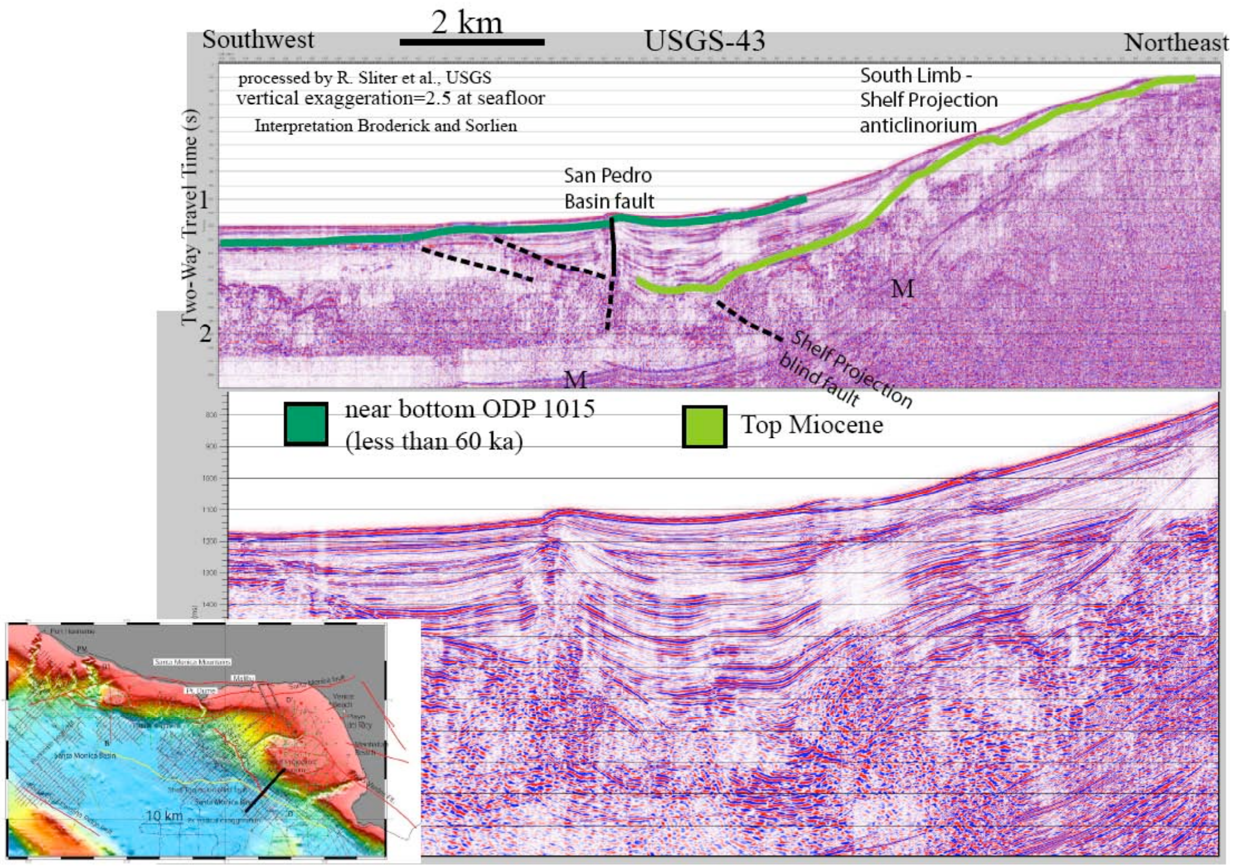

Figure III.28. Interpreted (top) and uninterpreted (bottom) multichannel seismic line USGS-43 acquired in Santa Monica Bay (black line - inset). Data exhibit NE-dipping reflections in the vicinity of the near-vertical San Pedro Basin fault that are inferred to be the Shelf Projection blind thrust responsible for the Shelf Projection–Palos Verdes anticlinorium (*Sorlien et al.,* 2003). This low-angle fault would project under Los Angeles.

Besides these major proposed and on-going projects, a substantial effort was made to identify and obtain extensive grids of existing high-quality proprietary industry seismic data as a means of providing an important community research tool and effectively jump-starting much of the needed Borderland research at minimal cost. This effort was headed primarily by Chris Sorlien (UCSB) and Jon Childs (USGS), and focused on the public release of mostly marine multichannel seismic (MCS) reflection data collected by the industry for hydrocarbon exploration. Figure III.29 shows a basemap of one such dataset available from Western GeCo. These data are high-quality and, in some cases, irreplaceable as the data extend into areas (National Marine Sanctuaries, State Water, etc.) where such marine seismic acquisition is now precluded by law. Although this particular basemap shows just the Western GeCo data available offshore of Southern California, the complete dataset and others (like Chevron-Texaco) extend along the entire western margin of the continental Unites States, making them excellent data resources for use by both SCEC and EarthScope. Negotiations with Chevron-Texaco, Western GeCo, Venoco, and Heck-Ogle Petroleum have begun and preliminary agreements made to transfer and archive the offshore MCS data with USGS, IRIS, and SCEC, if funding sources for the tape transcription costs can be found. Jon Childs is currently negotiating contracts for the data transfer and tape transcription with Western GeCo and Chevron-Texaco, and the USGS has some initial funding to begin this data rescue and archiving process. A subsequent UCSB proposal was submitted to NSF-EarthScope to provide matching support for the USGS effort, and to support an initial analysis of the MCS data to look at issues of plate boundary evolution, large-scale crustal rotations, and the interaction of high- and low-angle faults to accommodate oblique plate boundary strain. Should these pending research proposals be funded, substantial progress can be made in investigating the active deformation and hazard potential of the offshore Continental Borderland.

Figure III.29. Basemap of existing high-quality multi-channel seismic reflection lines acquired by Western GeCo offshore of Southern California and which can be made available for Borderland research, if funds for tape transcription costs can be found. The entire dataset available from Western GeCo extends from Mexico up to Washington, Oregon and Alaska. Figure provided courtesy of Jon Childs (USGS).

Fault Activity Database (FAD) and Fault Information System (FIS). In 2003, a decade-long goal became a reality, when dynamic access to a fault activity database (FAD) came on-line. Concurrently, a new need was recognized, to provide the CME with a Fault Information System (FIS), a single point of access to multiple, fault-related datasets. The FIS was designed and implemented this year, and already provides access to:

- paleoseismic data from the prototype FAD and the National Quarternary Fault and Fold database;
- well over 100 new submissions added this year, using a new, user-friendly Web form, which puts submissions in a dummy database pending review by the FIS manager;
- the 3D fault model and hazard parameters used in the state and National PSHA maps;
- data keyed to CFM fault representations;
- browser and programmatic access with query results in html tables or xml-encoded text.

In 2004, the FIS will add fuller access to CFM faults and parameters, integration with SCEC's Vertical Motion database, new data tables to provide paleo-event date probability density functions needed for Ned Field's ERF project, and a GIS-based mapping interface, as well as additional fault studies.

EIT Intern Program. Over the last year, the EIT Intern Program has introduced 22 undergraduates to cutting edge earth science and IT technologies, cross-training them to create a new generation of computer-savvy geoscientists. and citizens well-informed about earthquake issues. In their team-based projects they solve problems far more challenging than a classroom can provide. They also participate in tutorials, seminars, a field trip, and a technical writing symposium. The EIT Interns have presented their work in posters and talks at the annual meetings of SCEC, AGU, and GSA, as well as USC's undergraduate research symposium. Program participants are from a variety of disciplines, including computer science, engineering, communication, pre-law, and cinema. Already, this young program has changed the career paths of three students, bringing talented newcomers to the earth sciences. Recognizing the program's value, funding is now provided by NSF, USC, and the USC School of Engineering.

The intern program is foremost a top-notch educational experience, and also bolsters numerous SCEC research efforts. The EIT Interns have created LA3D, a scientific visualization package that provides open source, 3D visualizations of southern California's faults, earthquakes, landforms and cultural features. LA3D is also fashioning a visual ontology, with extensible earthquake, fault, and map objects. Furthermore, the code is capable of scripting movies in a variety of output formats.

During the coming year, LA3D will be expanded to enable visualizations outside southern California. An executable distribution of the code will also be released. The first user group will be SCEC scientists in need of a free viewer of Community Fault Model faults.

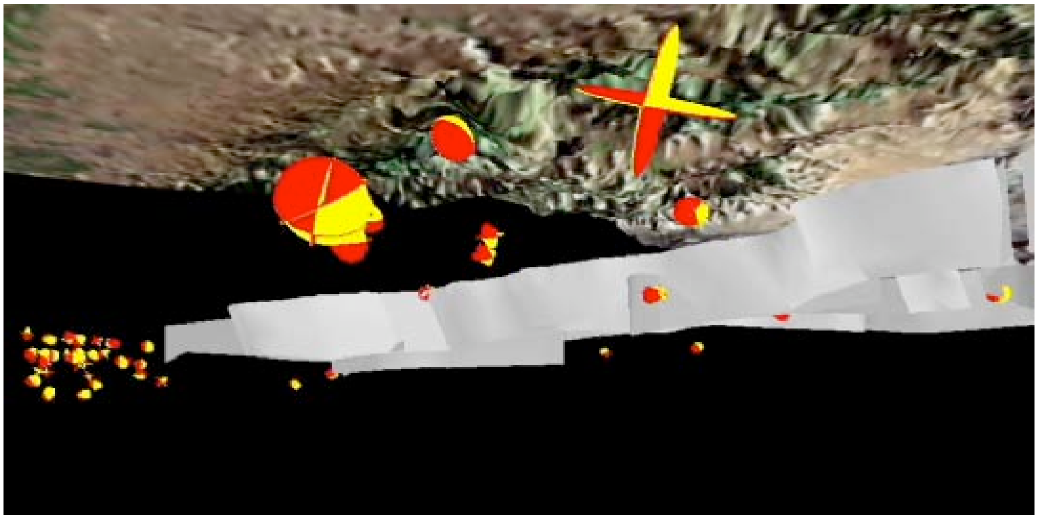

Figure III.30. A snapshot from LA3D, looking up at the surface of the earth, showing CFM faults in the distance and focal mechanisms of earthquakes larger than magnitude 4.0.

Workshops

Eight workshops on a variety of topics central to the SCEC research program were convened during the past year. Brief reports on each are given below.

SCEC Fault Systems Workshop, December 11-12, 2002, University of California Davis.
Participants: Charles Sammis, Brad Hager, John Rundle, Bill Klein, Don Turcotte, and Louise Kellogg

The primary objectives of this workshop were to formulate a strategy for the development of a southern California specific seismicity simulator and to decide which problems this simulation would address.

Model. We decided that this project should be synergistic with the kinematic block-modeling program being pursued by Hager and others in the SCEC fault systems group. In that program, the major faults in southern California are used to define the boundaries of blocks that are allowed to rotate about independent Euler poles. The blocks deform elastically in response to strain accumulation at locked faults at block boundaries. These block motions are made consistent with the SCEC GPS strain field and the resultant slips on the boundary faults are compared with geological slip rates.

This fault network and associated slip vectors will be used as the starting point for a "back-slip" seismicity model of the type developed by Rundle and others. In these models, each of the faults is divided into segments and the slip-rate is specified on each. They are called back-slip models because the stress accumulation on and around each segment is calculated by slipping the segment in the reverse direction at its prescribed velocity. Once the stress on the fault satisfies some prescribed failure criterion, slip occurs, the accumulated back slip reverses as an earthquake, and the accumulated stress field is relaxed. What makes this model interesting is that the stress accumulation before an event and reduction afterwards changes the state of stress on all the other fault segments in the network, either accelerating or retarding their failure.

Improving the model. From the outset there are some obvious shortcomings of this model. First, all events must occur on the prescribed fault network which contains only the major faults. This assumption may be appropriate for geodesy since most of the slip occurs during large events on the large faults. However, it is probably a poor assumption for seismicity, where small events appear to play an important role in stress transfer patterns leading to large earthquakes. This is certainly the implication of recent generalized aftershock models in which a large earthquake is equally likely to be triggered by a foreshock of any magnitude. The problem here is analogous to the weather forecasting problem where most of the energy is in the largest storms, but the weather is controlled by fluctuations at much smaller scales.

The challenge here is to devise a method to incorporate the effects of smaller events on the evolution of the system. The brute-force approach of including all faults at all scales is clearly impractical. Possibilities are to include a fractal network of smaller scale faults or some sort of damage rheology, which would react to off-fault stresses by generating small events with their associated stress transfers. Such a modification will clearly be necessary if we are to simulate aftershock sequences and, more importantly, foreshock sequences such as accelerating moment release that may have some predictive power.

A second shortcoming of the simple back-slip model as currently formulated is that it does not include time-dependent effects such as viscous relaxation of the lower crust or time-dependent nucleation which appears to be the physical basis for Omori's aftershock law. Techniques will have to be devised to incorporate such effects. One interesting test that could be performed would be to compare the output of the current model that assumes an elastic half-space with a parallel model that uses the Greens functions for an elastic plate, the latter being appropriate for the long-time behavior of a viscous lower crust.

Interpreting the output. There are a few obvious requirements for a viable seismicity simulator:

- It must produce a Gutenberg-Richter frequency magnitude distribution. This requirement may determine how we handle the smaller scales in the problem.
- It should produce an Omori's law distribution of aftershocks, although this may not be crucial if we are willing to consider only time scales longer than those of the aftershock sequences.

Having achieved those goals, the next question is how we interpret and use the output of the simulator. There are several possibilities:

- Ensemble Forecasting – where we run a large number of cases and identify high-probability patterns. In particular we look for patterns of accelerating precursory seismicity and precursory quiescence.
- Data Assimilation – where we force the model to simulate the known historical seismicity catalog and then continue to run it into the future in a forecasting mode.

The statistical physics of regional seismicity. Another important reason to develop the seismicity simulator is to have a more realistic test-bed for the many techniques and concepts that have been borrowed from statistical physics and applied to the spatial-temporal-magnitude patterns of regional seismicity. Examples include criticality, correlation length, fluctuations, and the renormalization group. Typically, these ideas have been illustrated using “toy models” such as cellular automata or slider-block arrays, which are at best simplified analogs of the crust. Although the proposed simulator is not a perfect mechanical model of southern California, it does contain the major faults and is faithful to the geodetically determined kinematics. This represents a significant improvement over the analog toy models, while keeping a model that is simple enough to be understood.

<u>Borderland Initiative Workshop, June 25-26, 2003, SCEC Headquarters, USC.</u>

Organizers: Craig Nicholson and David Okaya

The California Continental Borderland offshore of southern California is one of the most active continental margins of the late Cenozoic in the world. The region experienced significant elements of Paleogene subduction and Neogene extension, in addition to accommodating major strike-slip components associated with the evolving Pacific-North American (NAM) transform system. The Borderland was the locus of Pacific-NAM plate motion in southern California for about 70% of its tectonic history (from ~19 Ma to ~6 Ma), and recent GPS and VLBI data suggest that as much as 20% of the current plate boundary motion may still be located offshore. This has resulted in both mature and relatively young fault structures offshore that pose a serious but as yet unresolved seismic and possible tsunami hazard to large coastal populations of southern California. Thus, understanding the tectonic evolution of the plate boundary and the current tectonic architecture of the San Andreas fault system, as well as the tectonic history and seismic hazards of southern California necessarily requires a fundamental understanding of the offshore California Borderland.

In recognition of the importance and significance of the offshore Continental Borderland, SCEC recently created the SCEC Borderland Working Group. Its purpose is to initiate, foster, and coordinate activities in the California Borderland relevant to SCEC’s mission of understanding the tectonic evolution, earthquake dynamics and seismic hazards of southern California. Because SCEC itself has limited resources to conduct offshore research, a 2-day workshop was held to develop integrated, multi-disciplinary studies of the offshore Borderland for possible submission to appropriate NSF programs. The workshop was held on June 26-27, 2003 at the SCEC office on the USC campus in Los Angeles. There were 16 attendees (see list below). Talks were given on: 1) Regional tectonic models for Borderland evolution, rifting and rotation (Nicholson); 2) Influence of slab gaps on Inner Borderland structure (Okaya on behalf of Uri Ten Brink); 3) Models for Outer Borderland structure and evolution derived from seismic and gravity data (Miller); 4) The nature of oblique rifting and possible seafloor spreading in South San Clemente Basin (Legg); 5) Possible interactions between the Continental Borderland and the rotating Western Transverse Ranges province (Sorlien); 6) Constraints on plate motions and California margin evolution from marine magnetic data and regional volcanism (Wilson); 7) Lessons learned on Southern California crust and upper mantle structure from passive deployments (Davis); and 8) Distribution of existing industry seismic data sets in the offshore Continental Borderland (Piper).

A wide range of various science issues and tectonic problems were discussed, with specific emphasis on those questions of global significance that could best be addressed in the offshore Borderland, or with onshore-offshore experiments This included those issues that could best utilize the extensive grids of existing industry seismic reflection data that may soon become available (see Borderland Working Group report). It was clear from these discussions that the Borderland does indeed represent an ideal natural laboratory to study many types of fundamental processes. Most of these are related to the general question of: How does an oblique continental transform system initiate and evolve? Four major science issues were identified:

- What happens when a spreading ridge obliquely subducts and initiates forearc rifting? Why is the Borderland offshore Southern California different from Northern California? Multiple regional transects at Viscaino, San Quintin and the US-Mexico border could elucidate the differences between where the spreading ridge did not subduct and the margin is unrifted *versus* where the ridge did subduct and the margin did rift, thus allowing a systematic evaluation of this evolutionary process.
- How is mantle flow distributed along a continental transform boundary? Is plate boundary shear distributed or discrete, and are there differences in how the lower crust and upper mantle behave? Models for plate boundary shear make different predictions for slip rates on large plate boundary faults that are testable. The largest discrepancy between the flow models is for faults at the edges of the plate boundary system, like the offshore San Clemente fault in the California Borderland. This issue gets at fundamental problems of estimating offshore fault slip rates, anisotropy in the crust and upper mantle, hazards, and developing new techniques for marine paleoseismology.
- What drives large-scale rotation of the western Transverse Ranges? Is it driven from below by basal tractions or from the sides? Based on geologic and geophysical evidence, the western Transverse Ranges province (which includes the Northern Channel Islands) has rotated by more than 90° clockwise since 19 Ma and, based on geodetic data, this rotation continues today. This rotation accompanied oblique rifting of the Inner Continental Borderland. This problem gets at issues of timing of Borderland deformation, rates of rotation, coupling, mantle flow (anisotropy), remnant fragments of subducted oceanic lithosphere, and how the southern boundary of the rotating western Transverse Ranges province interacts with the northern boundary of the non-rotating Outer Borderland.
- How does oblique continental rifting initiate and develop? Did continental rifting in the inner Borderland progress to seafloor spreading? How do high- and low-angle faults interact to accommodate oblique finite strain? These questions are fundamental to understanding the tectonic evolution and seismic hazards of Southern California as many of the currently active fault systems originated under this process of oblique continental rifting. Preliminary evidence suggests that South San Clemente basin underwent oblique rifting since its inception and may have reach the stage of incipient seafloor-spreading.

There are distinct advantages to working in the Continental Borderland, not the least of which is that much of it is underwater. This means that it is generally an area of ***deposition***, not erosion, so much of the deformation is preserved and a detailed syntectonic stratigraphic record is available to assess dates and rates of active faulting and fold growth. Because it is underwater, less expensive, high-resolution marine geophysical techniques can be used to image and evaluate this structure, stratigraphy, and tectonic geomorphology. Moreover, many of the most important scientific issues regarding active faults ***onshore*** in southern California also have analogs ***offshore*** in the Borderland where they are more easily imaged and evaluated in 3D. This includes such processes as strain partitioning, the interaction between faults of different orientation, and fault reactivation under different stress or strain regimes. And finally, the potential availability of extensive grids of existing (previously proprietary) high-quality industry seismic reflection data can provide substantial 2D (and 3D) subsurface imaging capability in many areas.

Discussion of the various data resources needed to investigate these important tectonic issues suggested a multiphase approach to studies of the offshore Borderland:

Phase I - *Archiving and analysis of existing offshore industry data,* including the extensive grids of high-quality 2D and 3D multichannel seismic reflection data (MCS), well and gravity data;

Phase II – *Comprehensive coverage of multibeam bathymetry and compilation of seafloor and sub-seafloor geology*, including data sets at the USGS, MMS and from industry, and filling in data gaps in existing multibeam coverage;

Phase III - *High-resolution stratigraphic, petrologic, petrophysical, and geochronological studies*, to provide a necessary framework for assessing rates, dates, lithology, material properties, and a basis for conducting marine paleoseismological studies;

Phase IV – *Passive long-term GPS and seismic monitoring,* including ocean-bottom seismometer (OBS) deployments and seafloor observatories (such as the Gumbi-moor OBS, marine strainmeters, etc.); and

Phase V – *Active-source imaging and refraction studies,* including deep-penetration MCS, and wide-angle reflection and refraction to resolve crust and upper mantle velocity and anisotropy.

These five phases are not necessarily sequential as several of these are already on-going.

As a result of this workshop and other on-going collaborations within SCEC, at least four major science proposals were submitted to NSF to investigate important, interesting problems in the offshore Continental Borderland. These include: 1) a passive long-term OBS deployment to investigate the transition from oceanic to continental lithosphere (UCLA, Caltech, UCSB, Scripps); 2) a high-resolution study of late-Quaternary transform tectonics in thinned submerged continental crust (UCSB, LDEO); 3) a high-resolution stratigraphic study of late-Quaternary climate and deformation in the Santa Barbara Channel (UCSB, USGS); and 4) an initial analysis of some of the existing, high-quality industry MCS data to look at issues of plate boundary evolution and the interaction of high- and low-angle faults to accommodate oblique plate boundary strain (UCSB, USGS). A major component of the last proposal involved matching support for an on-going USGS effort to transcribe, transfer and archive existing industry MCS data into a digital, on-line, useable community research tool. If funded, these proposed studies would augment existing, on-going projects funded by NOAA, USGS and other agencies, and provide an important framework for understanding the structure, tectonic evolution, and seismic hazard of this active region.

List of Workshop Attendees

Shirley Baher (USGS)
Paul Davis (UCLA)
Gary Fuis (USGS)
Mark Legg (Legg Geophysical)
Drew Mayerson (MMS)
Kate Miller (UTEP)
Craig Nicholson (UCSB)
Bill Normark (USGS)
David Okaya (USC)
Ken Piper (MMS)
Tom Rockwell (SDSU)
Daniel Scheirer (USGS)
Chris Sorlien (UCSB)
Joann Stock (Caltech)
Doug Wilson (UCSB)
Victor Wong (CICESE)

SCEC 2nd Annual Crustal Deformation Modeling Workshop, August 25-29, 2003, Los Alamos National Laboratory.

The Crustal Deformation Modeling subset of the Fault Systems Working Group is putting together a Community Finite Element Modeling (FEM) package for studies of crustal deformation in Southern California. Mark Simons and Brad Hager organized the second annual "Workshop on Community Finite Element Models for Fault Systems and Tectonic Studies," a four-day workshop which took place August 25 - 28 at Los Alamos National Laboratory (LANL). The objective of this workshop was to serve as a venue to discuss progress in numerical modeling of lithospheric deformation, benchmarking existing codes, and defining the challenges that need to be met for future software development. Particular attention was placed on issues associated with meshing of complex domains, computational frameworks, solution methods well adapted to MPI environments, and to the definition of rigorous benchmarks. Daily activities were partitioned between formal presentations/discussions and informal time for hands-on tinkering with algorithms. Partial financial support was provided by SCEC, LANL IGPP, and NASA. 30 scientists from 12 universities, the USGS, JPL, Los Alamos National Laboratory, and Sandia National Laboratory participated in the workshop. A summary of the most significant outcomes of the workshop is given below. The agenda, participant list, and group mission statement, are appended. Web site: http://www-gpsg.mit.edu/fe

Los Alamos National Laboratory was chosen to as the locale in order to enable SCEC scientists to benefit from attendance by Lab experts, particularly those with expertise in meshing. The workshop also introduced SCEC Fault Systems efforts to LANL physics/computational groups, sowing the seeds for future collaborations. By leveraging SCEC, NASA, and LANL support, we were able to increase the number of students and senior researchers attending, as well as meet for a longer time than at the first workshop in 2002. Because members of the NASA-sponsored Quakesim group participated in the workshop, there was significant interchange of ideas and codes. Part of the group effort is aimed at verifying code accuracy, so significant effort was spent on refining the preliminary benchmark problems that were developed at last year's workshop. Efficient and accurate meshing of complex geologic structures is a very high priority, and meshing tutorials from scientists from LANL (LAGrit) and Sandia (Cubit) were very informative. One of the important outcomes is that we are now reevaluating whether the GoCAD/Tsurf approach used by the USR group will be used to produce our final meshes (tetrahedral) or will be an intermediate step in developing hexahedral meshes.

Another highlight of the workshop was a discussion of Computational Frameworks. We are heading toward integration of "Tecton," Charles Williams' community code for the Fault Systems Group, and "eqsim," Brad Aagaard's source physics and strong ground motion code, via the Pyre Framework. In addition, the Quakesim code "GeoFEST" (JPL) was impressive; a stronger integration of this project with the SCEC effort was initiated.

Participants - Workshop on Community Finite Element Models for Fault Systems and Tectonic Studies

Name	Affiliation	E-mail	Phone	(click for statement of interest)
Yuri Fiaiko	IGPP/UCSD	fialko@radar.ucsd.edu	858-822-5028	geophysics
Frederique Rolandone	UC Berkeley	frede@seismo.berkeley.edu	510-642-8374	Fault mechanics
Elizabeth Harding Hearn	University of British Columbia	ehearn@eos.ubc.ca	(604) 822-2655	lithosphere geodynamics, faulting
Mark Simons	Caltech	simons@caltech.edu	626/395-6984	geodynamics
Shelley Jean Kenner	University of Kentucky	skenner@uky.edu	(859) 257-5506	FE modeling of postseismic deformation
Noah Fay	University of Oregon	nfay@newberry.uoregon.edu	541 346 4653	Kinematic and dynamic study of the Pacific-North American plate boundary, in particular southern California
Jay Parker	JPL	Jay.W.Parker@jpl.nasa.gov	818 354 6790	Faulted crust finite elements
Bridget Smith	University of California, San Diego, Scripps Institution of Oceanography	bsmith@igpp.ucsd.edu	858 822 4347	Deformation Modeling of the San Andreas Fault System

	Charles A. Williams	Rensselaer Polytechnic Institute	willic3@rpi.edu	(518) 276-8463	Tectonophysics
10	Christopher DiCaprio	Caltech	dicaprio@gps.caltech.edu	(626) 354-3309	Geodynamics
11	Carl W. Gable	Los Alamos Nat'1 Lab.	gable@lanl.gov	505-665-3533	Geodynamics, Mesh Generation
12	Jennifer R. Boryta	LANL	jboryta@lanl.gov	505-667-5532	numerical simulations of fluid flow and mass/energy transport
13	Mousumi Roy	University of New Mexico	mroy@unm.edu	505-277-2580	Tectonics, Geophysics
14	Andrew Newman	Los Alamos National Lab	anewman@lanl.gov	505-665-3570	Earthquake and volcano seismology and geodesy
15	David Coblentz	Sandia Labs (will be LANL at the time of the workshop)	ddcoble@sandia.gov	505-845-0376	Geodynamics, Plate- and regional-scale finite element modeling
16	Christopher R. Bradley	LANL	cbradley@lanl.gov	505-665-6713	Seismology and Strong Motion
17	Theodore C. Carney	Los Alamos National Laboratory	tedc@lanl.gov	505-667-3415	computational mechanics
18	Bradford H. Hager	MIT	bhhager@mit.edu	617-496-8283	geodynamics
19	Brad Aagaard	US Geological Survey	baagaard@usgs.gov	626-583-6804	3-D Modeling of Earthquake Ruptures

20	Pururav Thoutireddy	Center for advanced computing research, California Institute of Technology	puru@cacr.caltech.edu	(626) 395 3432	Numerical Modeling and computational mechanics (Finite element method)
21	Chris Guzofski	Harvard University	guzofski@fas.harvard.edu	617-495-0367	structural geology, 3D fault mapping
22	Marian Anghel	Los Alamos National Laboratory	manghel@lanl.gov	505-667-9470	geophysics, dynamical systems, machine
23	John R. Baumgardner	Los Alamos National Laboratory	baumgardner@lanl.gov	505-667-9102	mantle and lithosphere dynamics
•'4	Greg Lyzenga	JPL and Harvey Mudd College	Greg.Lyzenga@jpl.nasa.gov	818-354-6920	Exploration Systems Autonomony, Data Understanding Systems, viscoelastic finite element codes
25	Teresa Baker	Jet Propulsion Lab	teresab@alum.mit.edu	(818) 848-2884	Crustal Deformation
26	Eric Hetland	MIT	eah@chandler.mit.edu	617-253-8872	geodynamics
27	Velimir Vessel inov	LANL	vvv@lanl.gov	505 473 4150	computational hydrogeology
28	Wendee M. Bninish	Los Alamos National Laboratory	wb@lanl.gov	505/667-5724	hard target defeat
29	Michael Borden	Sandia National Laboratories	mborden@sandia.gov	505-844-8441	Grid Generation
30	Michael Gurnis	Caltech	gurnis@caltech.edu	626-395-6979	Geodvnamics

Workshop on Converting Advances in Seismology into Earthquake Science, September 22-23, 2003, Caltech.

We convened a workshop at Caltech September 22-23 for seismic network operators and the Southern California Earthquake Center (SCEC) user community of seismologists to discuss several seismic shifts that are occurring in regional seismology. The availability of high quality digital seismic data and modern low cost storage technology is making it possible for seismologists to work with large datasets and to perform complex measurements on millions of waveforms. As researchers assemble their datasets as soon as the shaking stops and focus on getting their results published quickly, there is a need to improve the algorithms, automation, timeliness, and quality of data products such as hypocenters, magnitudes and moment tensors. Some of these products are being improved with new algorithms provided by the research seismologists.

New seismic instrumentation is in place across southern California and significant progress has been made in improving instrumentation in northern California. Since 2001, these new field instrumentation efforts, data sharing, and software development for real-time reporting and archiving have been coordinated through the California Integrated Seismic Network (CISN). The CISN is also the California region of the Advanced National Seismic Network (ANSS). In addition, EarthScope deployments of USArray will begin deployment in early 2004 in California. The southern and northern California earthquake data centers (SCEDC and NCEDC) have new capabilities that enable seismologists to obtain large volumes of data with only modest effort.

Seismologists from Caltech, UCSD, and UCLA convened the workshop that was held at California Institute of Technology (Caltech) in Pasadena in late September 2003. A total of 60 seismologists and students participated in the workshop for two days. The focus of the workshop was aimed toward observational seismology, where seismologists analyze earthquake data and undertake a variety of seismological research to improve earthquake locations, moment tensor solutions, resolution of physical processes within earthquake clusters, and tomographic models. Many of the most successful users of the seismic network data do not reside in California because the web enabled data centers provide equal access to the seismic data, both to remote users as well as to users at the host institutions.

Federal and state agencies, and university groups all operate seismic networks in California. The USGS operates seismic networks in California in cooperation with California Institute of Technology (Caltech) in southern California and UC Berkeley in northern California. The California Geological Survey (CGS) and the USGS National Strong Motion Program (NSMP) operate dial-out strong motion instruments in the state, primarily to capture data from large earthquakes for earthquake engineering and more recently, emergency response. The California Governor's Office of Emergency Services (OES) provides leadership for the most recent project, the California Integrated Seismic Network (CISN), to integrate all the California efforts and to take advantage of the emergency response capabilities of the seismic networks. The core members of the CISN are Caltech, UC Berkeley, CGS, USGS Menlo Park, and USGS Pasadena.

The goals and implementation of strong motion networks and seismic networks have been different in the past. The strong motion networks focused on deploying many sensors in strategic locations to collect rare records with large signals. The seismic networks focused on real-time data communications and using high gain sensors. Now the two types of networks are merging because both see some benefits in real-time or near-real-time data transmission and the same sensor systems can be used to detect both large and small ground motions. Similarly, instrumentation to monitor building response is evolving to have real-time data communications to record both linear and potentially non-linear ground motions in buildings. Many of the same data processing techniques apply to both kinds of data and thus new frontiers in research for seismologists and earthquake engineers are converging on several fronts.

The core and affiliated members of CISN operate more than 500 short-period stations, 200 broadband and strong motion stations, and 1000 strong-motion stations in California. The users expressed interest in greater density of broadband and strong-motion stations in northern California. The CISN is already addressing several statewide integration issues. Products such as hypocenters, magnitudes, ShakeMaps, and moment tensors are being standardized to ensure that they are uniform statewide. In the case of a major earthquake, all the data from all the CISN members will be made available through several web sites to service many different user communities such as seismologists, earthquake engineers, and the public. The users expressed interest in saving more of the high sample rate data during unusual times. Such times could be the hours or days before and following a major local earthquake or a major teleseism. These data sets could for instance be used to test rate and state friction laws and improve our understanding of earthquake triggering.

The meeting participants clearly expressed interest in having high quality earthquake locations available within minutes following an earthquake. The common seismological practice of updating the hypocenter information in the following hours, days, or weeks, can create a "moving target" that complicates later analyses. Greater uniformity in hypocenter information would facilitate tectonic interpretation as well as the production of the derivative products that use the hypocenter as a point of reference and are generated following an earthquake. There is also a clear need for near-real-time moment tensors and first motion focal mechanisms that are an essential part of the parametric description of the earthquake. The new frontier of rapid finite source inversion was also discussed and its potential application by seismic networks. The major and potentially most damaging earthquakes have sources that may extend from tens to a few hundred miles and thus finite source descriptions are a must.

The complexity of metadata used by seismologists to describe their instruments is extreme. It requires detailed understanding of signal processing theory as well as the instruments themselves. The users expressed strong need for easy and timely access to metadata and associated documentation. In addition to the modern high fidelity seismic instrumentation there is a need to determine the ground conditions, often called the site response, where the instrument is deployed. The site response can be measured through a variety of means. The simplest measurements are the field observations done by a seismologist. The more complex measurements involve cone penetration measurements, and the most complex involve a borehole and detailed logging of the borehole. The users expressed great interest in having a database of site response to facilitate interpretation of waveforms for basic source studies, ShakeMap, and long term seismic hazards studies.

One of the many products routinely produced and maintained by seismic networks are earthquake catalogs. The catalogs contain the date and time, location, magnitude, and solution quality parameters for each earthquake that occurred within the reporting boundary of the network. The California earthquake catalogs contain more than 800,000 earthquakes recorded for the last 75 years. Seismologists use the catalogs to determine earthquake statistics to further their understanding of earthquake occurrence. They also use the catalog along with other types of geological and earthquake information to estimate seismic hazards. The discussion at the workshop about earthquake catalogs focused on several aspects that might improve the existing catalogs. There was strong consensus about the need for improved documentation of the procedures used to produce and maintain the catalog so users could track any changes.

New discoveries are often made from new data that are not easily explained with current seismological theory or practice. The users at the workshop expressed interest in having more data saved for later data mining. As part of using more of the bandwidth of the seismic signal, the workshop participants discussed the mutual benefits of improved coordination between global positioning system (GPS) networks such as the Southern California Integrated Geodetic Network (SCIGN) and the seismic networks. The GPS networks are now able to capture high amplitude seismic waves using a dense network of GPS stations that record data at high sampling rates.

The data centers have several tasks, such as, to curate legacy data, maintain various types of metadata, archive the latest data and derived products, and to provide user access to all of the data and products. The SCEDC and NCEDC store the legacy earthquake data back for 75 years in the south and almost 100 years in the north. They also provide web-enabled access to the latest data within minutes in the south, and within days in the north. The SCEDC has pioneered a network based application called Seismic Transfer Protocol or (STP). The STP provides web and command line interface to the data and allows rapid retrieval of both waveforms and parametric data. These new facilities are making possible new seismological research based on ready access to seismograms. Users strongly supported ongoing efforts to make data access more uniform at both data centers and possibly providing one virtual California data center.

The existing infrastructure of the CISN will be beneficial to the EarthScope project. For instance, the CISN will provide the USArray Big Foot deployment with sites that are spaced 70 km apart, and communication infrastructure to assist in launching USArray. The ANSS program has deployed instruments to provide improved density of free field sites and reference sites (near major buildings or structures) in the San Francisco Bay area, and assisted with operations of the new instrumentation in southern California. Plans for new building instrumentation with real-time data communications are underway as ANSS initiates the necessary user review and implementation process.

<u>SCEC–EarthScope Workshop, October 14-15, 2003, Los Angeles</u>.

SCEC hosted a workshop, October 14-15, 2003 to explore potential interactions between the Center and EarthScope in southern California, and, in particular, how EarthScope can assist SCEC with its mission to gather and integrate various datasets into a comprehensive and predictive understanding of earthquake phenomena. Specific questions addressed by the attendees were:

- What are the major scientific objectives for EarthScope in southern California as they relate to SCEC's mission?
- What EarthScope data will be needed to reach these objectives?
- What instrumental deployments are needed to acquire the necessary data?
- How can the SCEC organization help the scientific community achieve these objectives?

The workshop began with a set of reports from the EarthScope facilities managers (S. Ingate, W. Ellsworth, and M. Jackson) that dealt with planning and staffing issues, instrumentation and siting, and major timelines. E. Hauksson reported on another SCEC workshop held a few weeks earlier that explored, among other things, future USArray and/or other EarthScope projects that may supplement existing California datasets to accelerate resolution of regional scientific problems. That workshop identified several scientific priorities including:

- Comparisons of California with the rest of western U.S.,
- High resolution studies of the earthquake source,
- High resolution studies of fault zones, and
- High-resolution studies of the crust and upper mantle.

These reports were followed by a series of short presentations dealing with ongoing and proposed projects in southern California. G. Fuis described the LARSE program and proposed follow-on transects; E. Cochran described proposed experiments to understand fault zone compliance by seismic probing of InSAR anomalies in the Mojave Shear Zone; P. Davis discussed the need to accelerate our understanding of the role of the lower crust and upper mantle in the tectonics of southern California, and reported on a passive OBS study of the Pacific-North American plate boundary that has been submitted to NSF-MG&G; Y-G. Li discussed the significance of fault-zone trapped wave studies; C. Nicholson reported on efforts to acquire a vast array of industry data on the California borderland, and its significance for investigating the structure and slip rates of active faults in the offshore coastal zone; and T. Henyey and T. Rockwell described an ambitious omnibus proposal to investigate the structure and evolution of the San Jacinto fault.

The workshop was organized into three disciplinary groups that generally for the purposes of breakouts – seismology, geodesy, and general/geology. The groups were chosen to reflect EarthScope as a scientific initiative with a special set of facilities. Each group met twice. Participants were asked to address questions (a) to (d) above, and any other issues they felt were important. Following are the summaries from the breakouts.

General/Geology Breakout Group. This group made the following recommendations

- Add two boxes to SCEC Organization Chart (see Figure III.31):
    - EarthScope Working Group under Special Projects & Operations
    - Tectonophysics Focus Group under Focus Groups
- SCEC should take an active role in driving EarthScope science and outreach in southern California through community workshops to identify priority projects and targets.
- SCEC should consider funding pilot studies prior to major EarthScope projects.
- EarthScope/SCEC goals in southern California should go beyond simply earthquake hazard to include larger scale architecture of the plate boundary and its evolution over multiple time scales.
- Targeted EarthScope study areas should include integration of geology, geophysics, and geodesy.
- EarthScope/SCEC need to develop standardized IT toolsets for 3D integration of geology, geophysics, and geodesy that include interoperability between other tools such as ARC and EarthVision.
- Fault Systems Focus Group and other entities within SCEC should develop an ongoing dialogue with PBO Transform Region Siting Committee.
- Need for flexible array experiments to include telemetry for routine incorporation of data streams into network products.

- Borehole strainmeters and seismometers should be co-located for studying low magnitude events.
- Experiments to study the architecture and dynamics of the plate boundary in southern California at a variety of spatial and temporal scales should be an EarthScope priority.

Seismology Breakout Group

Data needed by SCEC that EarthScope can provide:
- Crust and upper mantle P and S wave velocities.
- Crustal rheology and Q.
- Occurrence of seismic reflection "bright spots" as evidence of fluids in the crust.
- Seismic anisotropy in the lower crust and upper mantle.
- Seismic structure of fault zones including depth extent, geometry, and physical properties (important faults include the San Jacinto fault, Eastern Mojave Shear Zone, Sierra Madre/Oakridge/San Cayetano fault system, and the San Andreas at Parkfield).
- Near-field broad-band recordings of fault rupture.
- Basin structures.

Scientifically important targets:
- Plate boundary – is it discrete of diffuse?
- Mantle flow – does it exist in southern California?
- Decollements – are they pervasive in southern California?
- Moho relief – what is its pattern in southern California and relationship to the major faults and uplifts? Is there isostatic balance throughout the region?
- Fault zone structure – at what depth are fault zone guided waves trapped?
- Aftershock studies – what can they tell us about source physics?
- Brittle-ductile transition – at what depth?

Earthquake response:
- Both short period and broad-band instruments from EarthScope pool should be available for responding to a major earthquake over the lifetime of EarthScope.
- Deployments within 24 hours should be a target for studying temporal evolution of aftershocks and crustal relaxation, and capturing near-field ground motions from larger aftershocks.
- Number of instruments and time allocated should be based on a formula that includes size of the event, focal mechanism, and location.
- Instrumentation should include real time telemetry.

Major experiments of high priority:
- Southern California Imaging Project (SCIP) that includes three active/passive crustal transects across the Santa Susana, San Gabriel, and San Bernardino mountains to map crustal structure (sequel to LARSE).
- Passive OBS deployments to study the crustal/upper mantle regional structure of the northern Continental Borderland.
- High resolution active and passive deployments to study the physical properties of the San Jacinto fault, Eastern Mojave Shear Zone, and San Andreas at Parkfield.

Geodesy Breakout Group.

Science driven issues for PBO/SCIGN

- Relationship between geodetic strain (10 yrs) and geologic strain (10^3 to 10^6 yrs).
- Effects of earthquakes on strain and strain-rate fields.
- Measuring vertical deformation rates in selected areas by integrating GPS and InSAR should be a priority .
- Detection and classification of transients (both solid earth and non-solid earth).
- Data rates must be adjusted for the different transients.

Nature of transient signals

- Post seismic deformation with durations ranging from months to years.
- Periodic transients such as seen in the Pacific Northwest having a duration of ~10 days that occur on the order of every 14 months.
- Creep on the central San Andreas with a duration of a few days.
- Seismic surface waves with periods of seconds to minutes.
- Atmospheric and ionospheric transients due to earthquakes.
- Need to classify signals (each type of signal yields insights into rheology and dynamics that address the physics of deformational processes).

System frequency bands

- Nominal frequency bands of EarthScope systems:
    - Seismic: periods less than 1000 seconds.
    - Strainmeters: 1000 to 10,000 seconds.
- GPS: daily and longer.
- There should be sufficient overlap between bands so that the signal-to-noise ratio of each system in different frequency bands can be established.

Data and products needed by SCEC from PBO/SCIGN

- Raw data:
    - GPS: 15-sec sampling, 1 sample per sec when possible.
    - Strainmeters: 1 sample per sec.
- Level 1: daily GPS position estimates; strain in strain units.
- Level 2: velocity maps and strain rate maps.
- Level 3: combined GPS + strainmeter analyses.

Issues to be addressed:

- Merging of GPS, strainmeter, seismic and geologic data streams with seamless access to each type of data – an ideal role for SCEC.
- SCEC/EarthScope development of parametric characterization of geodetic data streams (similar to phase picks, moment tensor solutions, catalogs, etc. for seismic data).
- Establishment of EarthScope data products committee with SCEC representative.
- Decomposition of data streams into components:
    - “Secular” motions for geologic comparison.
    - Earthquake transients.

- Seasonal signals.
  - Study potential uses, and impact on archives, of high-rate (1 Hz) GPS data.
  - More thought needs to be given to strainmeter siting in southern California.
  - Earthquake response:
    - PBO not intended for immediate earthquake response, but a plan will need to be in place.
    - PBO portable GPS instruments ideal for studying transients after earthquakes and testing stress transfer models.
    - GPS results should be input into focal mechanism solutions.
  - A proposal should be made to co-locate strong motion instruments at GPS sites.
  - Consider using GPS to augment seismic early warning system.
  - CISN, ANSS, USArray, and PBO do not optimally address questions in earthquake source physics; this needs to be rectified; for example, accurate maps of coseismic slip distributions require high-resolution deformation fields.
  - Explore SCEC/EarthScope/NASA connections vis-à-vis PBO products.

Proposals and studies with high priority for SCEC:

- Relationships between geologic and geodetic slip rates and earthquake history.
- Pick four locations, 2 where geodetic rates faster and 2 where geologic rates faster.
- Use community block models to isolate areas for study.
- Refine error bars on all techniques.
- SCEC geologists should guide PBO laser imaging and select areas for study in southern California, including pre-earthquake imaging of targeted active faults.
- Integrate time series from seismic, strain and GPS on a variety of time scales.
- Perform real time deconvolution of transients from merged time series.

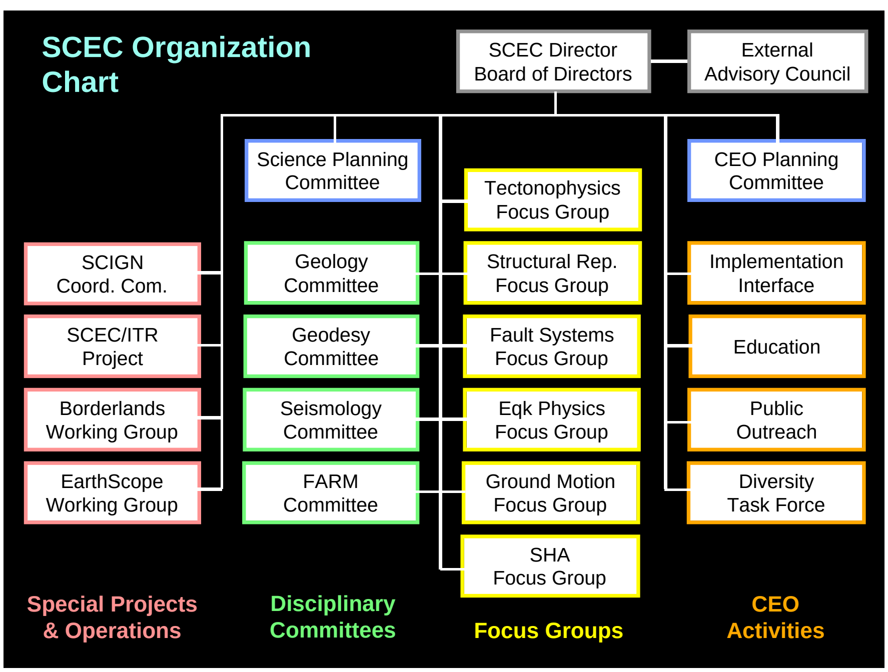

Figure III.31. Proposed modification of SCEC organizational structure to include an EarthScope Working Group and a Tectonophysics Focus Group.

Workshop on Implementation of SCEC Earthquake Hazard Research Results in Earthquake Engineering Research and Practice, October 22, 2003, Oakland, California.

Organizers: Paul Somerville and Mark Benthien.

The objective of this Workshop was to expand the interface between the Southern California Earthquake Center (SCEC) and organizations that can use SCEC knowledge in their research and practice in earthquake engineering and related disciplines. The workshop was designed to identify what kinds of scientific knowledge about earthquake hazards are useful to this community, to identify problems/ issues/ needs/ opportunities that lie at the interface, and to identify how SCEC can engage in collaborative research with this community to produce useful knowledge. Information technology is an important component of this interface.

The workshop participants included representatives of Federal and State government agencies that sponsor and use research in earthquake science and engineering (FEMA, FHWA, NSF, USGS; CEA, CGS, COES, CSSC); earthquake engineering organizations, consortia and centers (CUREE, EERI, MAE, MCEER, NEES, PEER, PEER-Lifelines), as well as practicing engineers and SCEC and USGS scientists.

The morning plenary session included presentations on key problems, issues, needs, and opportunities at the interface between earthquake science and earthquake engineering. Much of the presentation and discussion was focused on optimizing the parameters (intensity measures) that are used to describe earthquake ground motions for input into seismic response analysis of soils and structures. This discussion took place within the framework of Performance Based Seismic Engineering, whose ongoing development and application in practice were described. Interface projects that are currently underway, that have been proposed for funding, and that are solicited in the 2004 SCEC RFP, were summarized, and the OpenSHA project was described in some detail.

In the afternoon, breakout discussions focused on identification of potential collaboration projects, and on potential strategies for organizing and funding collaboration. Key issues at the interface include the optimal selection of ground motion intensity measures, and the scaling of ground motion time histories used in structural response analyses. The deployment of instruments on the ground and in structures in the ANSS (Advanced National Seismic System) was identified as a key need and opportunity for collaboration at the interface. The growing need for suites of ground motion time histories for experimentation (e.g. by NEES, the Network for Earthquake Engineering Simulation) and for design by practitioners was recognized. Analysis of the system response of spatially distributed systems such as lifelines require spatial descriptions of ground motion scenarios, providing an important computational challenge and opportunity to earthquake scientists.

One of the key suggestions for collaboration was for end-to-end simulation from the earthquake source through to structural response ("rupture to re-bar"). This would require coordination of existing simulation and information technology capabilities in earthquake science and earthquake engineering. Another key suggestion for collaboration was to use a suite of Index Buildings that would help quantify the changing levels of seismic risk that accompany real or perceived changes in the seismic hazard as represented for example in time-dependent hazard estimates and building code revisions. The SAC steel moment frame buildings and the PEER Testbed buildings and bridges are examples of such Index Buildings.

An agenda of the workshop, list of participants, presentations that were made, and summaries of the ensuing discussions, can be found on the SCEC Website, and a list of the participants and their affiliations is given in Table IV.2.

Workshop on Constitutive Relations for Coseismic Slip, September 10-11, Oxnard, California

Organizers: Terry E. Tullis, Brown University, and Ruth Harris, USGS

This was a workshop to assess the status of our understanding of the frictional resistance of faults during coseismic slip from the perspective of laboratory experiments and of seismic observations and modeling. As the agenda below shows, presentations were given both by modelers who addressed the question of what can be determined about frictional properties during earthquakes by modeling dynamic ruptures and comparing the model results with date from earthquakes as well as from the perspectives of laboratory rock deformation studies. It is clear that more work is needed from both perspectives. The workshop was very successful in bringing each of these communities up to date with each other's thinking and data.

Agenda

Wednesday, September 10

Afternoon session – The Influence of Constitutive Laws on Dynamic Rupture Models

13:30 Welcome and Introduction – Terry Tullis and Ruth Harris
13:45 Dynamic rupture models with various constitutive laws – Kim Olsen
14:30 Q&D (Questions and discussion)
15:15 Coffee Break (around posters)
15:45 Thoughts on constitutive laws and dynamic rupture models – Steve Day
16:30 Q&D
17:15 Session End
18:15 Cocktails
19:00 Dinner
20:00 Poster session

Thursday, September 11

Morning Session – Lab and Theoretical Studies of High Velocity Constitutive Laws

8:30 Recent Lab and Theoretical Results for High Speed Friction – Terry Tullis
9:15 Q&D
10:00 Coffee Break (around posters)
10:30 Dynamic interface separation: Experiments and theory – Jim Brune, Rasool Anooshehpoor, and Matt Purvance
11:15 Q&D
12:00 Lunch

Afternoon session – Observations Bearing on Coseismic Constitutive Laws

13:30 Observations from the Chi-Chi earthquake: An example of elastohydrodynamic lubrication? – Emily Brodsky
14:00 Q&D
14:45 Wrap up – Terry Tullis and Ruth Harris
15:00 Adjourn

List of Participants

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Results. In addition to the presentations listed on the agenda, there were short presentations given on Thursday morning both by Jim Rice and by Jenni Junger on the subject of what changes in pore pressure might accompany dynamic slip and thus what effect this might have on the coseismic strength. The number of interesting points made by all the participants in the active discussion is difficult to summarize, but some random points that come to mind include these: Whether there will be a reduction in dynamic shear strength due to an increase in fluid pressure depends not only on the permeability and thermal properties, but on whether dilatancy will accompany slip. Dilatancy is usually neglected in calculations of the increase in pore pressure, but the fact that fault surfaces are well mated prior to slip and that their roughness in the slip direction is significant even for mature faults suggests that it may be hard for them to slip without a significant increase in dilatancy. It was pointed out that whether faults slip via self-healing slip pulses or as a standard crack may depend on the time constant of the healing process following any dynamic weakening. If healing is instantaneous, then self healing pulses are favored, but slow healing would prevent them. Discussions made it clear that D_c has different meaning to different workers in this subject and that it is important to be clear about what one means with using this term. Different ways of trying to determine D_c for a slip weakening model from seismic data were discussed and progress is being made, but uncertainties exist in its determination for all the methods. It is clear that in the Chi-Chi earthquake there are some very interesting differences in the frequency content of the wave forms for the northern and southern parts of the event, but the exact meaning of these for coseismic resistance or its mechanism is still not clear.

summary

The participants were enthusiastic about what they learned about what everyone with interests in coseismic fault resistance is presently doing and finding out. The opportunity to discuss the state of progress and for everyone to get ideas on what needs to be done next from all perspectives made for a productive workshop. The two communities were brought closer as a result of the interactions.

<u>Workshop on Numerical Simulations of Rupture Dynamics: Validation of the 3D Method, November 10, 2003, SCEC Headquarters</u>

Organizers Ruth Harris and Ralph Archuleta.

The purpose of the workshop was to bring together the SCEC spontaneous rupture community and compare the results generated by the computer programs that are currently being used to tackle earthquake rupture dynamics problems.

Attendance: 30 members of the SCEC Community attended and participated in the workshop that had 9 invited speakers. Included in the attendance, and among the speakers were SCEC scientists whose level of expertise on the topic ranged from very senior experts with decades of experience on the topic to graduate students with 1 or 2 years of rupture modeling experience. We also had attendance from the FARM community, from the Ground Motions Focus Group, from the SCEC ITR project, and from the Implementation Interface. We started the code validation/comparison effort by casting as wide a net as possible to SCEC-affiliated scientists working in rupture dynamics. We sent out a problem (The Problem; see Figure III.13) for interested parties to tackle and gave those who chose to commit themselves to the effort 3 weeks to complete the exercise.

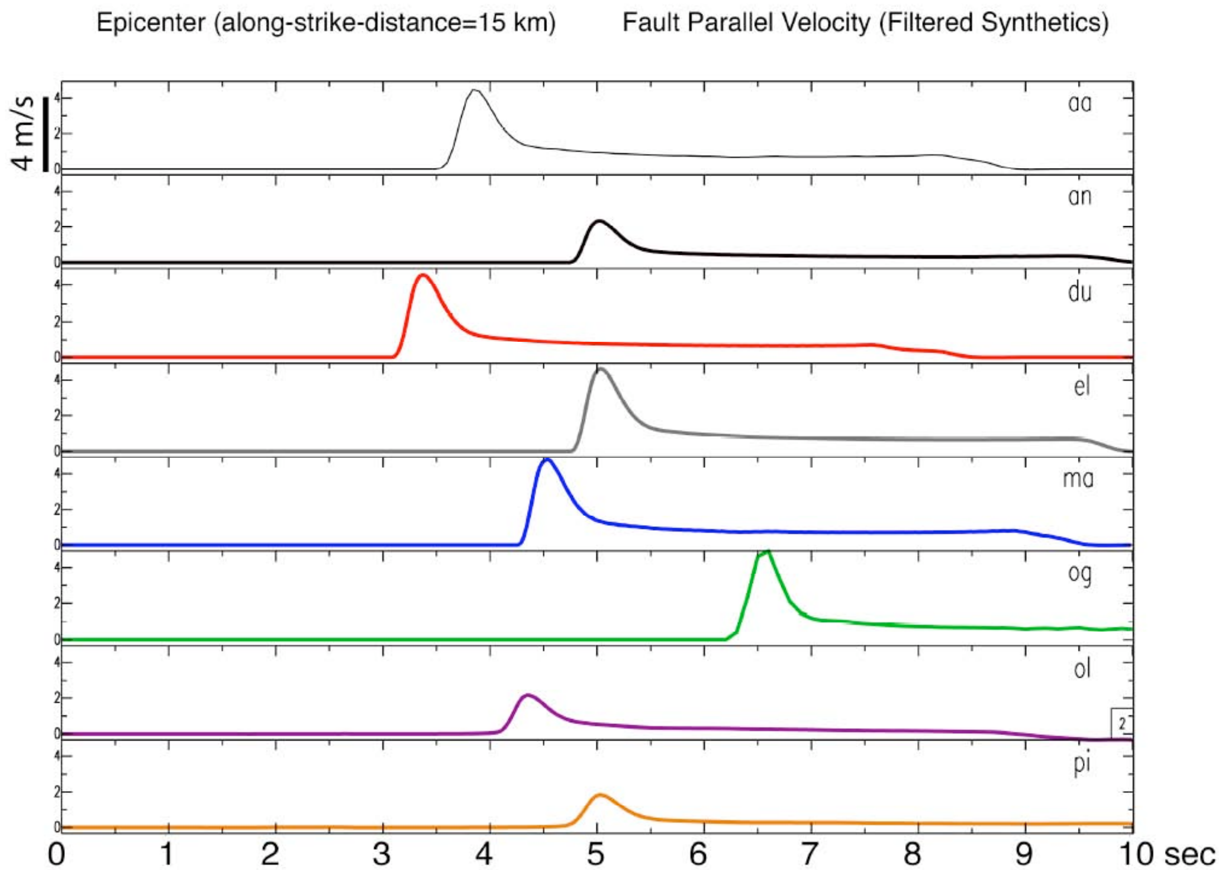

Figure III.32. Synthetic seismogram comparison (fault-parallel velocity) for The Problem (see Figure III.13, at the epicenter. Each colored seismogram was produced by a different computer program used to simulate rupture dynamics. The 2 letter labels identify the modeler/program. The seismograms are low-pass butterworth filtered with a corner at 1.5 Hz, 2 poles, 2 passes.

As in all of these types of validation exercises, we had a fairly continuous stream of communication while the researchers were performing the calculations, and the final communication about The Problem occurred just 3 days before the workshop. At the end of this report are 7 attached documents. These documents show the original invitation to participate, the description of The Problem, and a series of Questions and Answers about The Problem. These documents are also available as pdf files on the SCEC website, http://epicenter.usc.edu/rdm, set up by SCEC IT specialist Phil Maechling. At the workshop itself, we had the 9 SCEC modelers who each spent 20-30 minutes explaining their codes to the audience and providing their results to The Problem. This was quite worthwhile since everyone was able to learn more about the individual methods.

Following the individual presentations, we showed a comparison of a representative portion of the results from the computer simulations (Figure III.32). The conclusion was that although there were some similarities in the results to The Problem, there were also considerable differences that need to be understood. Therefore, based on the success of the 2003 workshop, and the clear need for continued work to arrive at convergence among the simulations, we will be proposing follow-up work. This will involve a 2004 workshop proposal to fund the 2004 workshop itself, and a collaborative 2004 proposal to fund at least a fraction of the 2004 PI/student modeler salaries.

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IV. Communication, Education, and Outreach Activities

SCEC is a community of over 500 scientists, students, and staff from 44 academic institutions across the United States, in partnership with more than 50 other science, engineering, education, and government organizations worldwide. To develop applications of the knowledge and scientific products developed by this community, SCEC maintains a *Communication, Education, and Outreach* (CEO) program with four long-term goals:

- Coordinate productive interactions among a diverse community of SCEC scientists and with partners in science, engineering, risk management, government, business, and education.
- Increase earthquake knowledge and science literacy at all educational levels, including students and the general public.
- Improve earthquake hazard and risk assessments
- Promote earthquake preparedness, mitigation, and planning for response and recovery.

Short-term objectives are outlined below. Many of these objectives present opportunities for members of the SCEC community to become involved in CEO activities. These objectives set the programmatic milestones for the Center's internal assessments, guide the development of research results needed for effective education and outreach, and identify priorities for information technology and other resources.

Management Objectives

M1. Implement CEO long-term strategic plan
M2. Establish additional collaborations with partner organizations and pursue funding opportunities
M3. Represent the SCEC Community in partner organizations, science, engineering and education conferences, etc.

CEO Focus Area Objectives

SCEC Community Development and Resources (activities and resources for SCEC scientists and students)

SC1. Increase diversity of SCEC leadership, scientists, and students
SC2. Facilitate communication within the SCEC Community
SC3. Increase utilization of products from individual research projects

Education (programs and resources for students, educators, and learners of all ages)

E1. Develop innovative earth-science education resources
E2. Interest, involve and retain students in earthquake science
E3. Offer effective professional development for K-12 educators

Public Outreach (activities and products for media reporters and writers, civic groups and the general public)

P1. Provide useful general earthquake information
P2. Develop information for the Spanish-speaking community
P3. Facilitate effective media relations

P4. Promote SCEC activities

Implementation Interface (activities with engineers and other scientists, practicing professionals, risk managers, and government officials.

I1. Engage in collaborations with earthquake engineering researchers and practitioners
I2. Develop useful products and activities for practicing professionals
I3. Support improved hazard and risk assessment by local government and private industry
I4. Promote effective mitigation techniques and seismic policies

SCEC CEO Team

Staff

Mark Benthien, Director for CEO

John Marquis, Digital Products Manager
Sue Perry, Earthquake Information Technology Intern Program Manager

Student Employees

Bob de Groot, education specialist
Ilene Cooper, education specialist
Glenn Song, education assistant
Brian Vibber, web specialist
Aleem Rana, web specialist
Jed Link, communications specialist
Eric Runnerstrom, resource application specialist

Consultant

Paul Somerville, Implementation Interface project manager

SCEC CEO 2003 Activities

The following sections include highlights of SCEC's 2003 CEO program.

Management

Recruit CEO Advisory Panel. To expand participation by partners and recipients of SCEC CEO activities, a small advisory panel will be recruited to help review progress and provide suggestions for opportunities that might otherwise be unknown. Recruitment will begin in Fall 2003.

Develop strategic plan. Continue development of long-term strategic plan, with a focus on evaluation strategies. The CEO advisory panel will be instrumental in providing guidance for evaluation priorities. Careful assessment must be conducted at every stage of program development in order to ensure that the program can be responsive to audience needs and effective in achieving its goals:

1) Stakeholder needs assessment will determine a base level of knowledge among various audiences and identify specific needs to be addressed. This information will be gathered through document reviews and interviews with representatives of the key targets audience groups.
2) Evaluation design will consider the types of evaluation methodologies and logic models SCEC CEO will employ, based on decisions of what should be evaluated (quality and/or quantity of products? Usefulness of services? Cost-effectiveness?) and why the evaluation is needed (improve the discipline of E&O? Accountability to agency management and stakeholders? Improve service delivery and program effectiveness?)
3) Performance measurement of product development and implementation will involve collecting accountability information for stakeholders, tracking intended and unintended outcomes of the program, and providing information vital to program improvement in order to achieve pre-established goals. This information can be useful for management of activities, resources, and partnerships.
4) Programmatic assessment of the overall success in achieving SCEC's stated goals and identification of what was successful, what failed, and why. This step is broader than performance measurement as it addresses the long-term, overall affect of the CEO program as a whole, and has implications for other large-scale E&O programs.

Represent SCEC as member of

- EarthScope E&O Committee
- Earthquake Country Alliance
- Western States Seismic Policy Council
- Earthquake Information Providers (EqIP) group (Benthien is Chair)
- Earthquakes and Mega Cities Initiative (Los Angeles representative)
- California Post-Earthquake Technical Information Clearinghouse (Benthien is chair of Information Technology workgroup)
- Southern California HAZUS Users Group (Benthien is project lead)
- EERI Southern California Chapter (SCEC hosts bimonthly meetings)
- EERI Mitigation Center So. Cal. Planning Committee
- Emergency Survival Program Coordinating Council
- City of Los Angeles Local Hazard Mitigation Grant Advisory Committee
- County of Los Angeles Local Hazard Mitigation Grant Advisory Committee

Document and Report on CEO activities. Each year many presentations and reports are prepared to describe the activities of the CEO program. In 2003 a paper was published in a special issue of Seismological Research Letters focused on education and outreach.

SCEC Community Development and Resources

SCEC Diversity Issues and Possible Activities for a Diversity Task Force. The participants in SCEC represent a diverse array of ethnicities and a mix of genders. Nonetheless within this array there are perceived to be certain issues related to diversity. Among these perceptions are:

- The leadership of SCEC, including the Officers and the Board, is dominantly white and male.

- The Planning Committee has significant power in SCEC II and serves as a stepping-stone to leadership. It would be desirable for the planning committee to be significantly diverse.
- Although many women and minority students are involved in intern and other programs at the undergraduate level, successively smaller numbers of women and minorities are involved at the graduate student, post doctoral, junior faculty and senior faculty levels.
- The current situation is not unique to SCEC, but reflects historical trends in the earth and physical science communities.

Possible Activities. An important first step in planning for the diversity effort at SCEC is to decide at what scale to address these perceived issues and to scope the effort. There seem to be several classes of activities that could be undertaken to address the concerns listed above. It would seem appropriate for the Board to consider which of the following classes of activities it wishes to pursue, and then to assign the responsibility for developing the activities to either a Diversity Task Force, or to specific individuals:

- Goal Setting—Does the SCEC Board want to establish a written statement of diversity goals? The goals could be cast in several ways. The goals need not necessarily be numerical, but rather could be aimed at processes.
- Analysis of statistics of past activities and maintenance of statistics on future activities—What are the actual statistics on interns, graduate students, postdocs, P.I.'s, project awards, etc.? How have these statistics changed with time? Considerable care must be taken in analyzing these statistics because the rules at some institutions (e.g. Harvard) require that a P.I. be a faculty member. This requirement may conceal a greater diversity than may be at first apparent.
- Establishing policy guidelines for the selection of individuals for "stepping stone" opportunities—SCEC could develop a policy of announcing the availability of opportunities for roles within SCEC leading to increased responsibility and/or visibility. Such opportunities might include speakers at the annual meeting, workshops and retreats, and committee assignments. By asking for volunteers and nominees for these opportunities, SCEC leadership could assure that qualified, interested individuals are not being overlooked.
- Sounding board—There may be significant diversity-related perceptions within the SCEC community that are not currently obvious to the leadership. Actions aimed at elucidating these might include the appointment of one or more diversity contacts who could serve as informal counselors, and/or holding an evening session at the annual meeting where diversity issues could be aired.
- Mentoring program—SCEC could develop a mentoring program. The program could be developed at a variety of scales, but perhaps the most critical need might be at the graduate student, post doc and junior faculty levels. The program could try to match volunteer senior faulty/researchers with younger individuals who request a mentor.
- Placement assistance—SCEC could develop a program aimed at assisting graduate students and postdocs find successor positions.
- Enhanced intern and community-based programs for involving undergraduates—SCEC I was active in involving women and minority students through internships and other activities. These programs could be continued and enhanced.

- Benchmarking—SCEC could undertake to learn what activities other large science and/or NSF-funded centers and consortia have done to achieve diversity goals and consider adoption of the most successful and appropriate of these.
- Multi-year plan—The SCEC Board could ask an individual or the Diversity Task Force to propose a 2 to 5 year plan for developing the activities the Board considers most appropriate.
- Seeking Support for Diversity Activities—SCEC could investigate additional opportunities for supporting diversity-related activities from NSF-education or other sources.
- Periodic self-analysis and reflection—The SCEC Board could hold a discussion, perhaps on an annual basis, of how SCEC is doing on diversity issues, perhaps receiving a report from the Diversity Task Force, if one is established.

SCEC Community Information System (SCECCIS). SCEC CEO has developed a new online database system, using technology developed as part of the Electronic Encyclopedia of Earthquakes project. This system was first implemented to facilitate registration for the 2002 SCEC Annual Meeting, but will soon be expanded to generate a web page for each SCEC scientist that will provide access to their past and current SCEC-funded projects, published research, outreach activities, etc. This system will also allow SCEC CEO to better track research projects with potential CEO applications. Contact information will be accessible by members of the SCEC community after signing in with a password. As a service for other communities associated with SCEC, similar interfaces have been developed. Such communities include the California Post Earthquake Information Clearinghouse, the Earthquake Country Alliance, the U.S. Educational Seismology Network, and others.

Education Activities

Electronic Encyclopedia of Earthquakes (E3). This project between SCEC, the Consortia of Universities for Research in Earthquake Engineering (CUREE) and the Incorporated Research Institutions for Seismology (IRIS), synthesizes a large and varied amount of data and information and provide broad access via the Internet in the context of the NSF-funded Digital Library for Earth System Education (DLESE). The project is supported with multi-year funding from the NSF National Science Digital Library initiative. Subject matter will feature information and resources for over 500 Earth science and engineering topics, and provide connections to curricular materials useful for teaching Earth Science, engineering, physics and mathematics. The collection supports high-quality K-12 and undergraduate education by providing educators and students with the tools and resources for instruction and research. A very sophisticated information system for building and displaying the E3 collection and web pages has been developed, and is now called the Community Organized Resource Environment (CORE). The content collection process for *E3* is underway by ten faculty-student teams (four CUREE teams, two IRIS teams, and four SCEC teams.) SCEC teams are led by Sally McGill, Sue Owen, Gerry Simila, and Jan Vermilye. (http://www.earthquake.info)

SCEC's Regional Seismicity and Geodesy Online Education Modules. These interactive online learning resources are based on seismic data from the SCEC data center, and geodetic data from the Southern California Integrated GPS Network (SCIGN). The modules are used by high school and undergraduate students and teachers, and will be integrated with the Electronic Encyclopedia of Earthquakes) (http://www.scecdc.scec.org/Module and http://scign.jpl.nasa.gov/learn). A new project is underway with Lisa Grant (UCI), Ralph Archuleta (UCSB) and Debi Kilb (Scripps) to work with SCEC staff to update functionality and content of several activities within the Seismicity module.

Seismic Sleuths Revision. SCEC is revising the AGU/FEMA Seismic *Sleuths* middle school earthquake curriculum to reflect advances in science and technology since the last update in 1995. The objectives are to promote and improve natural hazard education for students; to foster preparedness for natural hazards through empowerment and encouraging personal responsibility; to provide an updated and redesigned learning tool that can be easily integrated into a curriculum based on national standards; and to provide constant updates in science content, pedagogy, and resource information through an interactive website. Each unit has been streamlined and can stand-alone in print or on the Internet in order to be used in a variety of environments. In addition, a television special (*Earthquakes: Seismic Sleuths*) based on the series has been created and aired worldwide, made possible by funding from the California Department of Insurance, the Institute for Business and Home Safety, and SCEC. The hour-long video was first broadcast on “Assignment Discovery” in spring, 2001. The video can be used by teachers as an excellent advance organizer, or viewed by interested citizens who want to learn more about earthquakes, the destruction they can cause, the scientists and engineers who study them, and what they can do to prepare. (http://school.discovery.com/lessonplans/programs/earthquakes-gettingready/q.html)

ShakeZone. In partnership with the Riverside County Children's Museum (“KidZone”), the CUREE-Caltech Woodframe Project and UC Riverside, SCEC created an educational, family-oriented exhibit on earthquakes ("ShakeZone") that opened in January, 2002. The mission of the exhibit is to reach the local community, particularly the 20,000 elementary school children who visit KidZone each year, with positive messages about studying the Earth and preparing for earthquakes. The exhibit presents information about science, engineering, safety and mitigation. A shake table, an interactive computer display, and wall displays teach the visitors about the tools and techniques of earth scientists, engineers and emergency services personnel. (http://www.kidzone.org)

Undergraduate Internship Program. To provide hands-on experiences in the earth sciences, provide insights into career opportunities, and interest underrepresented undergraduate students in Earth science-related careers, SCEC has supported 109 students to date (including 47 women and 34 minority students) to work alongside 62 SCEC scientists over the past 10 years. In 2003 SCEC supported 32 undergraduate students (17 IT interns at USC, 8 research interns and 7 CEO interns). To begin each summer, the interns attend a Communication Workshop held jointly with interns

from the Pacific Earthquake Engineering Research Center (PEER). Mid-summer students participate in a three-day field trip with stops along faults, at field research locations, and SCEC Institutions.. Finally, students present posters at the SCEC annual meeting. (http://www.scec.org/internships)

SCEC/USEIT *proposal*. In 2003 SCEC proposes to initiate a new REU Site program, based at the University of Southern California (USC). The title of the program will be the ***SCEC Undergraduate Summer in Earthquake Information Technology***, abbreviated ***SCEC/USEIT***. The name and the acronym communicate the central goals of the program, which are threefold:

- To allow undergraduates to use, hands-on, the advanced tools of information technology (IT) to solve important problems in interdisciplinary earthquake research.
- To close the gap between two areas of undergraduate study—computer science & engineering, and geoscience—by cross-training students in the modes of understanding distinct to these disciplines.
- To engage non-geoscience majors in the application of earth science to the practical problems of reducing earthquake risk, and thereby inform students with diverse backgrounds how their classroom skills can be applied to significant social issues.

Student research will be organized around the LA3D platform, currently under development by the SCEC/ITR interns. LA3D is an object-oriented visualization system, written in Java3D, that can display earthquakes, faults, and volumetric geological structures in 3D, as well as 2D map layers. The program will be housed in the newly established and well-equipped SCEC Undergraduate Research Laboratory, where they will be challenged by high-level problems in earthquake information technology and mentored by some of the nation's most distinguished geoscience and computer science faculty. The mentorship team will be led by T. H. Jordan, the Director of SCEC, who has been teaching undergraduates for 32 years and has substantial experience in supervising individual and team-based internships.

During each summer of the 3-year grant period, a particular "grand challenge" will be put in front of the student teams. These challenges will include GIS capabilities, displaying 3D volumes that change with time, and visualization of seismic waves within the LA3D environment. Accomplishing these challenges will require well-integrated multi-disciplinary research and development.

SCEC/USEIT will bring 20 students from colleges and universities across the country to reside for twelve summer weeks at USC, where they will interact in a highly structured, team-oriented research environment. High priority will be given to women, underrepresented minority students, and others that are underrepresented in geoscience, and to students from schools with limited research opportunities. As part of their summer sessions, the students will receive formal training in how to conduct and communicate research. Through a series of field trips, they will be guided, boots-on, across the active fault systems of Southern California, and they will also visit major sites of IT research. The latter will include USC's Information Sciences Institute, the Caltech Seismological Laboratory, and the San Diego Supercomputer Center. Throughout the summer, the students will document their results in a series of team-based reports in hypertext form using the advanced SCEC Community Information System, as well as on the SCEC/USEIT webpages. At the end of the summer, they will present their results before several hundred scientists at the SCEC Annual Meeting. Many students will continue work on their projects during the academic year.

In addition to undergraduate education impacts, results of the program will have broader educational and societal impacts. For example, the challenge for the summer of 2004 will be to use LA3D to produce the high-quality 3D graphics and animations needed to support SCEC public outreach activities during all of 2004 for the 10th anniversary of the 1994 Northridge earthquake. Each year will have defined education and outreach goals.

SCEC/USEIT will be based on more than a decade of experience by SCEC in managing summer internships for undergraduates, which has involved over 100 student participants since 1994. In particular, the new program will be built upon the team-oriented internships sponsored for the last two years by SCEC's Information Technology Research (ITR) project. In this proposal, we document the success of these prototype internships in satisfying the programmatic goals stated above.

SCEC/USEIT will be highly leveraged against the SCEC core program, which will provide most of the administrative and faculty resources, as well as the research framework for student activities. In addition to providing dedicated space for the SCEC Undergraduate Research Laboratory and access to dormitories, USC will pledge over $57,500 per year for USC student participation in the program.

SCEC Student Network. Planned for 2004, this network will involve students at SCEC institutions (and elsewhere) in SCEC activities (research, seminars, workshops, annual meeting), provide educational and career resources, and encourage continuation into graduate school. The network will eventually be expanded to include high schools students through mentoring by SCEC undergraduate and graduate students.

IRIS/USGS/SCEC Teacher Workshops. CEO offers 2-3 teacher education workshops each year in partnership with the U.S. Geological Survey (USGS) Pasadena Outreach and Education office. The workshops provide a direct connection between scientists and developers of earthquake education resources and those who use these resources in the classroom.□The workshops innclude content and pedagogical instruction, ties to state standards, and materials teachers can take back to their classrooms. Many of the materials for the workshops are provided by the Incorporated Research Institutions for Seismology (IRIS). SCEC is also coordinating a college instructor version of the workshop in southern California, based on a program also designed by IRIS. In 2003 SCEC CEO began a partnership with Scripps Institute of Oceanography (SIO) Visualization Center to create a teacher workshop which takes advantage of the facilities at SIO.

USC Science Education Collaborative. In 2003 SCEC has taken advantage of the environment around the University of Southern California (USC) to form various partnerships and collaborations in order to increase earthquake awareness in the local community:

- One of our new partnerships is with USC's Joint Education Project (JEP). The JEP service learning program sends USC students into local schools to teach eight one hour lessons pertaining to what they are learning in their general education classes. SCEC has many educational resources which are made available to the USC students to take into the classrooms, they are also able to get advice from a SCEC educational specialist.
- Another partnership SCEC has begun is with the Education Consortium of Central Los Angeles (ECCLA). ECCLA funds inter-session (like summer school, but for year round schools) programs for elementary schools in the central Los Angeles region. They had an earthquake curriculum, which SCEC revised, reorganized and added to. SCEC also provided educational materials, and arranged for guest speakers and field trips for the students. The

field trips included trips to SCEC, the California Science Center, the Los Angeles Emergency Operations Center, and City Hall. A SCEC education specialist met with the teacher and maintained contact throughout the session as both a content and pedagogical resource.

- Several teachers at Weemes elementary school are coordinating a Science for Parents Night, where parents will come with their children and learn about science. SCEC has been an active participant in the planning of this event, ranging from providing the teachers with ideas for engaging activities to background content information.
- SCEC has partnered with JEP, USC Mission Science, USC Sea Grants and the Jet Propulsion Laboratory (JPL) in creating hands on workshops for teachers at schools in the neighborhood surrounding USC. These workshops focus on the interdisciplinary nature of science. Future workshops are planned to expand to include teaching science as inquiry.
- Another future project is a NSF Math Science Partnership grant. This is a mass collaboration of many science and education specialists entitled In-service Foundations for Unified Science Education Delivery (INFUSED) . INFUSED is proposed as a partnership between the University of Southern California's Rossier School of Education Program to Advance Science Education (PASE), the Los Angeles Unified School District, Hawthorne Unified School District, leading science industry companies such as NASA's Jet Propulsion Laboratory, and science based community agencies such as SCEC, California Science Center, and the LA County Museum of Natural History. INFUSED is designed to change the way in which USC has been delivering science instructional support services by focusing systematic strategic needs-based enhancement opportunities to a select group of school partners.

Teaching Aids for University and College Level Classes: Visual Objects and QuickTime Movies [managed by Debi Kilb, UCSD/IGPP]. As proposed teaching modules have been specifically designed to meet the needs of faculty members at SCEC based institutions that can be used in undergraduate and graduate classes and provide an introduction to 3D interactive exploration of data. At the 2003 SCEC meeting many of the visual objects were previewed and netted a favorable response (12 people asked for follow up information). To date Kilb has either discussed and/or ported our products to 28 people from ~20 different institutions and discussions to improve and augment these teaching tools are ongoing. Due to current space limitations only some of the end products (e.g., QuickTime movies, interactive 3D data sets, image galleries) are currently accessible through a web-based digital library interface (http://www.siovizcenter.ucsd.edu/library.shtml) at the Visualization Center at Scripps Institution of Oceanography. There have been 550 unique visitors to these page within the last 6 months. In January of 2004, space will no longer be an issue when a data streamer empowered by the OptIPuter (http://www.calit2.net/news/2002/9-25-optiputer.html) comes on line. Plans are also in place to use a 'framework' to integrate many of the images and visual objects that we developed into the Electronic Encyclopedia of Earthquakes website (http://www.scec.org/e3/)

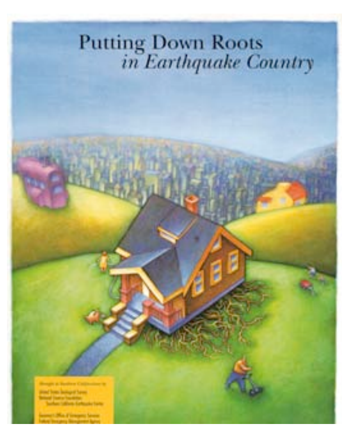
Public Outreach Activities

SCEC Webservice and SCEC News. SCEC's webservice presents the research of SCEC scientists, provides links to SCEC institutions, research facilities, and databases, and serves as a resource for earthquake information, educational products, and links to other earthquake organizations. In 2000 SCEC introduced SCEC News to provide a source of information in all matters relevant to the SCEC community – to disseminate news, announcements, earthquake information, and in-depth coverage of earthquake research, in a timely manner via the World Wide Web. Since its inception in March 2000, over 1500 people have subscribed to e-mailed news "bytes" which announce new articles. (http://www.scec.org)

EqIP. CEO participates in the EqIP (Earthquake Information Providers) group, which connects information specialists from most earthquake-related organizations. EqIP's mission is to facilitate and improve access to earthquake information through collaboration, minimize duplication of effort by sharing information through individual personal contact, joint activities and projects, group annual meetings and biennial forums, and electronic communication. SCEC's former CEO director was among the founding group members and managed the initial development of EqIP's website which provides a database of descriptions of over 250 organizations with links to their websites. SCEC's current director for CEO is now the Chair of this group. (www.eqnet.org)

Wallace Creek Interpretive Trail. In partnership with The Bureau of Land Management (BLM), SCEC designed an interpretive trail along a particularly spectacular and accessible 2 km long stretch of the San Andreas Fault near Wallace Creek. Wallace Creek is located on the Carrizo Plain, a 3-4 hour drive north from Los Angeles. The trail opened in January 2001. The area is replete with the classic landforms produced by strike-slip faults: shutter ridges, sag ponds, simple offset stream channels, mole tracks and scarps. SCEC created the infrastructure and interpretive materials (durable signage, brochure content, and a website with additional information and directions to the trail). BLM has agreed to maintain the site and print the brochure into the foreseeable future.

SCEC Publication Distribution. Copies of SCEC's field trip guides, technical reports (Phase I & II reprints, Liquefaction and Landslide Mitigation Guidelines reports, etc.), and *Putting Down Roots in Earthquake Country* general public handbook (see below) are widely distributed at workshops, earthquake preparedness fairs, and through the SCEC website. (http://www.scec.org/resources/catalog)



Putting Down Roots in Earthquake Country. To answer the growing concern regarding the implications of the Northridge earthquake and other recent seismic events in southern California, the U.S. Geological Survey and SCEC developed a graphically illustrated, 32-page color handbook on earthquake science, mitigation and preparedness Lucy Jones (USGS) wrote the handbook, and Jill Andrews (SCEC) managed the production and distribution of over 1.5 million copies. Its message is consistent and encouraging: earthquakes are inevitable, but they are understandable, and damage and serious injury are preventable. The content has also been developed into a web page (http://www.scec.org/education/public/ roots/eqcountry.html). This publication was the basis for a Nevada version, and an update is in progress.

Media Relations. SCEC has successfully engaged local, regional and national media organizations (print, radio and television) to jointly educate and inform the public about earthquake-related issues. The goal has been to communicate clear, consistent messages to the public–both to educate and inform and to minimize misunderstandings or the perpetuation of myths. SCEC CEO encourages scientists who are interested in conducting interviews with media reporters and writers to take advantage of short courses designed and taught by public information professionals.

Northridge Ten-year anniversary. SCEC is coordinating efforts to develop a set of activities to mark the ten-year anniversary of the Northridge earthquake in 2004. The activities will be coordinated and developed around a consistent theme and will commence on January 17, 2004 and continue throughout the year. The plan is to include seminars, workshops, field trips, and earthquake-related annual conferences, public awareness campaigns at multiple levels including mitigation awareness, and involvement of policy makers. To develop the plans, a new network has been formed, named the "Earthquake Country Alliance." Here is a brief overview of activities being coordinated:

- Jan. 7: "Earthquakes 101" seminar for the news media, at Caltech
- Jan. 13: SCESA special seminar at CSUN. Invited speakers: Don Manning, Lucy Jones, Tom Heaton.
- Jan. 15: City of Los Angeles Annual Emergency Response Exercise (Northridge scenario)
- Jan. 15-16: MCEER Annual Meeting (L.A. City Hall)
- Jan. 16: CEO and government decision makers luncheon (hosted by SCEC, MCEER, BICEPP and sponsored by many organizations)
- Jan. 17: Caltech/USGS anniversary fair/presentations
- Feb. 4-8: EERI Annual Meeting, Omni Hotel, downtown LA
-

Other conferences throughout the year will commemorate the anniversary, such as SSA in April (SCEC is hosting in Palm Springs) and the National Earthquake Conference (FEMA, WSSPC, CUSEC, NESEC, SCEC, USGS...) in October in St. Louis).

In addition to these activities, several products are being developed:

- Major update of "Putting Down Roots in Earthquake Country" Being revised at http://www.scec.org/roots/version2.php. USGS, FEMA, CEA and SCEC will fund the revision and artwork licenses. Copies will be purchased via a pre-order campaign.
- "Written in Stone: Earthquake Country- Los Angeles" video produced by Pat Abbott. Will feature 3D fault animations produced by SCEC's "LA3D" visualization system.
- A new website: http://www.earthquakecountry.info. This is a frequently-asked-questions driven web portal developed by SCEC using technology developed for the E^3 project (see

above). This portal will provide links to existing resources on websites of Earthquake Country Alliance members.

Implementation Interface Activities

Landslide Report and Workshops. In August 1998, a group of geotechnical engineers and engineering geologists with academic, practicing, and regulatory backgrounds was assembled to form a committee (chaired by Thomas Blake) to develop specific slope stability analysis implementation procedures to aid local southern California city and county agencies in their compliance with review requirements of the State's Seismic Hazard Mapping Act. The work of that committee resulted in the development of a relatively detailed set of procedures for analyzing and mitigating landslide hazards in California (edited by T. Blake, R. Hollingsworth, and J. Stewart), which was recently published and is available on the Southern California Earthquake Center's (SCEC) web site (http://www.scec.org/resources/catalog/hazardmitigation.html). In June 2002, over 200 geotechnical engineers, practicing geologists, government regulators and others attended a two-day SCEC workshop that explained the Landslide document. Because of the outstanding response to the sold-out workshop, a second workshop was held in February 2003 for those who were unable to attend the first. The course materials (now available for order) include extensive printed materials including all PowerPoint presentations, and two CDs with software tools and PDF files of all presentations and printed materials. As a bonus, the CD includes PDF files of the presentations given at the 1999 SCEC Liquefaction workshop and both the Landslide and Liquefaction Procedures documents.

HAZUS. CEO is coordinating the development and activities of the Southern California HAZUS Users Group (SoCalHUG) with the Federal Emergency Management Agency (FEMA) and the California Office of Emergency Services (OES). HAZUS is FEMA's earthquake loss estimation software program. SoCalHUG brings together current and potential HAZUS users from industry, government, universities, and other organizations to (a) train GIS professionals in HAZUS earthquake loss estimation software, (b) improve earthquake databases and inventories, and (c) develop and exercise emergency management protocol. SCEC is also considering how it can improve the data and models that HAZUS uses in its calculations. SCEC CEO has organized three general meetings of the user group and in July 2001, a HAZUS training was held at California State University Fullerton for 23 Geographic Information System professionals employed by local governments, utilities, universities, and corporations. Funding for the training was provided by FEMA in response to a proposal by the SCEC and the OES. SCEC is also promoting the improvement of USGS ShakeMap (to include results of SCEC Research) for use in HAZUS scenarios.

EERI Southern California Chapter. SCEC has hosted 6 meetings of the southern California chapter of the Earthquake Engineering Research Institute. These meetings include a speaker on a particular topic of interest to the attendees, typically civil, structural, and geotechnical practicing engineers. For example, on November 19, 2003, over 40 people attended a meeting with a speaker addressing new research on "Assessment and Repair of Earthquake Damage in Woodframe Construction."

Implementation of SCEC Research in Earthquake Engineering Research and Practice [managed by Dr Paul Somerville, URS Group]. The development of new knowledge about earthquakes and their effects is an important role of SCEC, but not its only role. Because earthquakes have major impacts on society, SCEC must also transfer knowledge about earthquakes and their effects for use in earthquake risk mitigation. This includes the transfer of knowledge to organizations involved in earthquake engineering research, and organizations that have special responsibilities for earthquake safety because they operate lifeline systems. The role of the CEO Advanced Implementation Interface is to implement SCEC research in earthquake engineering research and practice through information transfer and collaborative research. Table IV.1, from the 2004 SCEC Program Announcement, lists the collaborative research projects that have been developed during 2002 and 2003 between SCEC investigators and investigators from organizations involved in earthquake engineering research or practice.

Somerville's role as manager of the Implementation Interface involved participation in 32 meetings spanning 42 days. The following pages present the highlights of these activities.

Table IV.1. Current SCEC Advanced Implementation Interface Projects

THEME	PROJECT	INVESTIGATORS	SPONSORS
Ground-Motion Prediction using Rupture Dynamics	Pseudo-Dynamic Modeling Project	Beroza, Guatteri	PEER-Lifelines, SCEC
Ground-Motion Simulation Code Validation	3D Basin Code Validation Project	Day, Bielak, Dreger, Graves, Larsen, Olsen, Pitarka	PEER-Lifelines, SCEC
	Foamquake Data Interp. Project: Phase 1: Modeling of directivity Phase 2: Validation of source inversion	Day, Graves, Pitarka, Silva, Zeng	PEER-Lifelines, via SCEC
Probabilistic Seismic Hazard Analysis	Object Oriented PSHA Framework Project (Open-PSHA)	Field	SCEC
	PSHA Code Validation Project	Field used results to validate Open-PSHA	PEER-Lifelines
	Surface Faulting Hazard	Rockwell	PEER-Lifelines
	Vector-Valued Hazard Project	Somerville, Thio	SCEC, PEER
Ground-Motion Time Histories	Time Histories for PEER Performance-Based Earthquake Engineering Testbeds	Somerville	PEER, SCEC
Ground-Motion Prediction Model	Next Generation Attenuation Project	Archuleta, Anderson, Campbell, Beroza, Day, Field, Graves, Somerville, Zeng	PEER-Lifelines, SCEC
Interface	Workshop on the interface between SCEC and earthquake engineering research and practice	Somerville	SCEC
Loss Estimation	Loss Estimation Methodology for Evaluating Societal Impacts of Alternative Seismic Hazard Models	Campbell	SCEC

Workshop on Implementation of SCEC Earthquake Hazard Research Results in Earthquake Engineering Research and Practice, October 22, 2003, Oakland, California. Somerville organized this workshop with the assistance of Mark Benthien. The objective of this Workshop was to expand the interface between the Southern California Earthquake Center (SCEC) and organizations that can use SCEC knowledge in their research and practice in earthquake engineering and related disciplines. The workshop was designed to identify what kinds of scientific knowledge about earthquake hazards are useful to this community, to identify problems/ issues/ needs/ opportunities that lie at the interface, and to identify how SCEC can engage in collaborative research with this community to produce useful knowledge. Information technology is an important component of this interface.

The workshop participants included representatives of Federal and State government agencies that sponsor and use research in earthquake science and engineering (FEMA, FHWA, NSF, USGS; CEA, CGS, COES, CSSC); earthquake engineering organizations, consortia and centers (CUREE, EERI, MAE, MCEER, NEES, PEER, PEER-Lifelines), as well as practicing engineers and SCEC and USGS scientists.

The morning plenary session included presentations on key problems, issues, needs, and opportunities at the interface between earthquake science and earthquake engineering. Much of the presentation and discussion was focused on optimizing the parameters (intensity measures) that are used to describe earthquake ground motions for input into seismic response analysis of soils and structures. This discussion took place within the framework of Performance Based Seismic Engineering, whose ongoing development and application in practice were described. Interface projects that are currently underway, that have been proposed for funding, and that are solicited in the 2004 SCEC RFP, were summarized, and the OpenSHA project was described in some detail.

In the afternoon, breakout discussions focused on identification of potential collaboration projects, and on potential strategies for organizing and funding collaboration. Key issues at the interface include the optimal selection of ground motion intensity measures, and the scaling of ground motion time histories used in structural response analyses. The deployment of instruments on the ground and in structures in the ANSS (Advanced National Seismic System) was identified as a key need and opportunity for collaboration at the interface. The growing need for suites of ground motion time histories for experimentation (e.g. by NEES, the Network for Earthquake Engineering Simulation) and for design by practitioners was recognized. Analysis of the system response of spatially distributed systems such as lifelines require spatial descriptions of ground motion scenarios, providing an important computational challenge and opportunity to earthquake scientists.

One of the key suggestions for collaboration was for end-to-end simulation from the earthquake source through to structural response ("rupture to re-bar"). This would require coordination of existing simulation and information technology capabilities in earthquake science and earthquake engineering. Another key suggestion for collaboration was to use a suite of Index Buildings that would help quantify the changing levels of seismic risk that accompany real or perceived changes in the seismic hazard as represented for example in time-dependent hazard estimates and building code revisions. The SAC steel moment frame buildings and the PEER Testbed buildings and bridges are examples of such Index Buildings.

An agenda of the workshop, list of participants, presentations that were made, and summaries of the ensuing discussions, can be found on the SCEC Website, and a list of the participants and their affiliations is given in Table IV.2.

Table IV.3. List of Participants in SCEC Implementation Interface Workshop

Acronym	Name	Role	Participant
ATC	Applied Technology Council	Consensus formation for building code writing	Chris Rojahn
USBR	US Bureau of Reclamation	Dam safety	
Caltrans	California Department of Transportation	Highway infrastructure	Brian Chiou Cliff Roblee
CEA	California Earthquake Authority	Insurance	Tim Richison
CGS	California Geological Survey	Mapping seismic hazards in California	Mike Reichle Chris Wills
COES	California Office of Emergency Services	Emergency Response	Richard Eisner
CSSC	California Seismic Safety Commission	Legislation	Bob Anderson
CUREE	Consortium of Universities for Research in Earthquake Engineering	Research	Robert Reitherman Andrew Whittaker
DOE	U.S. Department of Energy	Energy	
DWR	California Department of Water Resources	Dam safety	Les Harder David Gutierrez
EERI	Earthquake Engineering Research Institute	All aspects of the impact of earthquakes on society	Craig Comartin
FEMA	Federal Emergency Management Agency	Emergency response and disaster mitigation	Mike Mahoney Jeffrey Lusk
FHWA	Federal Highway Administration	Highway safety	Roland Nimis
MAE	Mid America Earthquake Engineering Center	Research and Outreach	Amr Elnashai
MCEER	Multidisciplinary Center for Earthquake Engineering Research	Research and Outreach	Andrew Whittaker
NIST	National Institute of Standards and Technology	Building standards	
NEES	Network for Earthquake Engineering Simulation	Research facilities and collaboratory	Ian Buckle Robert Nigbor
NSF	National Science Foundation	Research	Steve McCabe Joy Pauschke
PG&E	Pacific Gas & Electric	Power Utility	Norm Abrahamson
PEER	Pacific Earthquake Engineering Research Center	Research and Outreach	Jack Moehle Greg Deierlein Allin Cornell Jon Bray Helmut Krawinkler
PEER-Lifelines	Directed Research Program on Lifelines	Sponsored by Caltrans, Cal. Energy Commission, and PG&E	Brian Chiou Cliff Roblee
SEAOC	Structural Engineers' Association of California	Professional Practice Organization	Craig Comartin Joe Maffei Charlie Kircher
SCEC	Southern California Earthquake Center	Earthquake Research and Outreach	John Anderson Ralph Archuleta Mark Benthien Greg Beroza Ken Campbell Steve Day Tom Heaton Tom Jordan Paul Somerville
USGS	U.S. Geological Survey/	Earthquake Research and Outreach	Bill Ellsworth

	SCEC		Ned Field Ruth Harris Mark Petersen Woody Savage Rob Wesson

Preparation of Proposal to NSF on the Implementation Interface. One of Somerville's major activities in 2003 was the preparation of a proposal to the National Science Foundation entitled "Implementation of SCEC Research for Seismic Risk Reduction." The objective of the proposal was to significantly expand the implementation of SCEC research results into earthquake engineering research and practice. The four proposed tasks were: Produce ground motion time histories for use in performance-based seismic engineering; Participate in the Next Generation Attenuation (NGA) project; Build a comprehensive framework for seismic hazard analysis in Southern California; and Produce ground motion and structural simulations for scenario earthquakes in Los Angeles. Somerville played a major role in preparing the work plan for Tasks 1, 2 and 4. The proposal was not recommended for funding by NSF EAR.

Participation in NGA Program. Of the projects listed in Table 1, the one with the largest SCEC involvement is the PEER-Lifelines/SCEC/USGS Next Generation Attenuation (NGA) Program. The NGA Program is a highly interactive applied research program requiring sustained focus, coordination and management. Somerville's participation in NGA management meetings, Working Group meetings, and Workshops is detailed in Table IV.3.

Table IV.3. PEER-Lifelines/SCEC/USGS NGA Program - Meeting Schedule	
Oct 24-25, 2002	NGA Program Kickoff Meeting, Richmond
Mar 24, 2003	NGA Working Group 4 Meeting #1, Menlo Park
July 2	NGA Executive Coordination Meeting, Richmond
July 23-24	NGA Workshop #2, Richmond
Sept 24	NGA Working Group 4 Meeting #2, Richmond
Oct. 23-24	NGA Workshop #3, Richmond
Dec. 2	NGA Working Group 4 Workshop, Richmond
Dec. 17-18	NGA Workshop #4, Richmond

Participation in Meetings with Engineering Research and Practice Organizations. In addition to Somerville's participation in the NGA Program, he participated in meetings with numerous engineering organizations that are involved in research and practice (Table IV.4). While Somerville's involvement in these meetings lies outside formal collaborative projects between SCEC and these organizations, his participation in these meetings provides a vehicle for communication of SCEC research results and products to these engineering organizations, and informs him of new developments in earthquake engineering research and practice, providing a basis for the planning of future collaborative projects between SCEC and these organizations.

Table IV.4. Meetings with Engineering Research and Practice Organizations	
Oct. 16, 2002.	Presentation to Department of Water and Power, Los Angeles "Ground motions – what the engineer needs to know", Los Angeles
Oct 30.	Building Seismic Safety Council. Technical Subcommittee TS1 Meeting,

	(NEHRP Code Provisions update), Oakland
Oct 31.	PEER-Lifelines / CGS Design Ground Motion Library Meeting, Oakland
Nov. 7-8.	PEER Testbeds Meeting, Oakland
Feb. 24-25, 2003	ATC-58 Workshop on Performance Based Seismic Design, San Francisco
Feb 28.	PEER Working Group on Ground Motions and Uncertainty, Stanford
Mar 7-8	PEER Annual Meeting, Palm Springs
Aug. 12	SCEC/PEER Vector Valued Hazard Project Meeting, Stanford
Sept. 4	SCEC/PEER Vector Valued Hazard Presentation, Stanford
Oct. 14-15	Meeting of the NRC Committee on the Economic Benefits of Improved Seismic Monitoring, Washington, DC.
Oct. 22	SCEC Implementation Interface Workshop, Oakland

Presentations on SCEC to Other Organizations. In addition to the informal communication between SCEC and earthquake engineering research and practice organizations that was enabled by Somerville's attendance at the meetings listed in Table IV.4, he participated in several more formal presentations of SCEC research objectives and products, listed in TableIV.5. These include meetings with California State Government organizations that have responsibilities for seismic safety, presentations at international conferences, and presentations to program directors within the Division of Civil and Mechanical Systems at NSF. The latter presentations related to the proposal that SCEC submitted to NSF EAR.

Table IV.5. Presentations on SCEC to Other Organizations	
Oct 10, 2002	California Seismic Safety Commission – Research Workshop, Long Beach
Oct 15.	California Seismic Safety Commission (SSC), Sacramento
Oct 15.	California Geological Survey (CGS), Sacramento
Oct 15.	California Earthquake Authority (CEA), Sacramento
Oct. 21-22.	NSF US-Japan Workshop on Urban Earthquake Hazard Mitigation, Kyoto
July 11, 2003	IUGG, Presentation on "Status of Strong Motion Prediction in the United States," including SCEC and NGA, Sapporo, Japan
Oct. 16	Meetings at NSF, Directorate of Engineering, Division of Civil and Mechanical Systems: Dr Galip Ulsoy, Dr Richard Fragazsy, Dr Cliff Astill, Dr Joy Pauschke, Dr Steve McCabe, Dr Priscilla Nelson, Alexandria, Virginia

Internal SCEC Meetings. Somerville participated in all of the SCEC meetings that are relevant to the Implementation Interface. These meetings, listed in Table IV.6, include Planning Committee Meetings and workshops in fields that are closely related to the Implementation Interface.

Table IV.6. Internal SCEC Meetings	
Nov. 7-8, 2002	SCEC Strong Motion Simulation Workshop, Reno
Jan 20-21, 2003	SCEC Planning Committee, USC
June 3-4	SCEC Leadership Meeting, Oxnard
Sept. 7-10	SCEC Annual Meeting, Oxnard
Sept. 10-11	SCEC FARM/ESP Workshop

Nov 10	SCEC Dynamic Rupture Workshop, USC

Effective Risk Mitigation for SCEC Target Audiences. [Lisa B. Grant (PI), with Eric E. Runnerstrom (Graduate student researcher) and Kristen Iriarte (SCEC Intern)]

Introduction. The moderate magnitude (M6.7) Northridge earthquake in 1994 was the most expensive natural disaster in U.S. history, with total losses up to $46 Billion (CDMG, 2000). Despite significant efforts by the scientific research and hazard mitigation communities, the risk from potential future earthquakes in the U.S. continues to rise as population and exposure increase in tandem. The House Committee on Science (2003) estimated that a major earthquake in a U.S. urban area could cause as much as $200 Billion in losses. Such large losses could have a significant negative impact on the U.S., especially if accompanied by casualties, and therefore seismic hazard and risk are problems of national importance.

Earthquakes, however, are *local* phenomena that have the greatest impact on specific areas or regions. *Many elements of hazard mitigation and risk reduction must be conducted at local levels to be effective* because a substantial amount of policy implementation, compliance and enforcement occurs at municipal and county levels (Mileti, 1999). Unfortunately, adoption and implementation of local seismic mitigation policies is difficult because the problem is generally perceived as a low priority for local governments (Berke and Beatley, 1992). Past research has demonstrated that technical aspects of earthquake mitigation are more advanced than implementation by governments (Berke and Beatley, 1992), and this may be especially true at the local level. Better understanding of this problem could lead to more effective seismic hazard risk communication for target audiences at the local level.

Purpose. The Southern California Earthquake Center (SCEC) is positioned to advance knowledge transfer and risk communication about seismic hazard. To strengthen risk communication between SCEC and target audiences, such as local governments, it is necessary to establish a baseline understanding of current efforts and their effectiveness at risk communication and risk mitigation In this report, we describe preliminary results of a baseline study to document the utilization of seismic hazard data and research products by local government in Orange County, one of the highest risk counties in California and the country.

Orange County Cities. Our study is focused on evaluating the effectiveness of previous SCEC activities and products in communicating seismic risk at the municipal level. Orange County is well suited for this study because it contains diverse sociologic, geologic, and seismic conditions. Orange County is one of California's geographically smaller counties, yet its population (2.8 million) and total personal income ($99.5 million) rank 2nd out of the state's 58 counties. Approximately 40% of Orange County's housing stock was built before 1970, which is prior to substantial upgrades in seismic building practices. Using HAZUS methodology, the CDMG (CGS) estimated Orange County's expected annualized total loss due to earthquake activity to be among the highest in the state.

Our study focuses on cities because they represent a key component of risk communication and mitigation. A substantial amount of policy implementation, compliance, and enforcement occurs at the municipal government level, so it is important to understand how cities utilize seismic hazard information to mitigate risk. In particular, we focus on the direct use of SCEC products by local-level policy-makers and staff. As opposed to state and federal level, we expect to find the greatest amount of variation in the use of SCEC products at the local level. By understanding this variation in the use of SCEC products, we expect that effective areas or targets within cities for risk communication should emerge.

SCEC and Research Communication. An objective of SCEC is to "…communicate the results of their research with the multiple millions of citizens who live and work in this seismically active region" (SCEC website). One mechanism designed to achieve this objective is SCEC's Communication, Education, and Outreach (CEO) program. There are multiple modes of comunication. Communication occurs among multiple stakeholder groups and at various levels of government. SCEC products, based on SCEC-funded research, can traverse multiple paths toward advancing science or improving seismic safety. These paths are not mutually exclusive. SCEC products may affect one communication node, which then impacts another node, creating a web of indirect influences. For example, empirical relationships described by Wells and Coppersmith (1994; SCEC #178) are used by HAZUS' software methodology to compute fault rupture length in order to estimate ground motions. Ground motions are used to calculate estimations of losses by social systems due to scenario earthquakes. HAZUS runs are being integrated into geotechnical background reports, which then influence policies of cities' safety elements. To track every SCEC product in order to measure direct and indirect influences on cities' seismic mitigation practices is beyond the scope of this study. We have focused on Safety Elements and related documents (Technical Background Reports, EIRs and MEAs) for Orange County's 34 cities. These documents identify hazards to public welfare and provide guidance for local decisions on zoning, subdivisions and permitting.

Planning and Seismic Safety. Within California's ~477 cities, planning is performed using three basic tools:

- the general plan
- the zoning ordinance
- the Subdivision Map Act.

These planning tools are fundamental to California's planning system. "Over the past twenty years, the general plan has emerged as the most important document in local planning in California" (Fulton, 1991). General plans were required of counties and cities by the California legislature beginning in 1937, but were not taken seriously until after a legislative milestone in 1971 that required consistency among the general plan, zoning ordinances, and subdivision procedures within a jurisdiction (§65300.5).

A general plan consists of text containing objectives, principles, standards, and plan proposals, as well as maps and diagrams. Together, these constituent parts illustrate a picture of the community's future development. Most jurisdictions select 15 - 20 years as the long-term horizon for the general plan, but are encouraged to revise every 5 years.

In statute, the general plan is organized as a collection of seven "elements" (see §65302): land use, circulation, housing, conservation, open-space, noise, and safety. The level of discussion given to each issue in the local plan depends upon local conditions and the relative local importance of that issue. Seismic hazards are included in the Safety Element.

The Safety Element establishes policies and programs to protect the community from risks associated with seismic, geologic, flood, and wildfire hazards. The safety element's identification of hazards and hazard abatement provisions are a guide to local decisions related to zoning, subdivisions, and entitlement permits. The element should contain general hazard and risk reduction strategies and policies supporting hazard mitigation measures. Policies should address hazard avoidance and risk reduction.

Geotechnical data and analyses are important to the preparation of the plan because the information establishes a context for objectives and policies, but can obscure the primary purpose of the plan (to be a statement of policies) with an abundance of pages. Consequently, the Governor's Office of Planning and Research recommends that technical background documents be provided in appendices or as separate documents.

The process of adopting or amending a general plan encourages public participation. Cities and counties must hold public hearings for such proposals. Advance notice of the place and time of the hearing must be published in the newspaper or posted in the vicinity of the site proposed for change. Prior to approval, hearings will be held by the planning commission and the city council or board of supervisors. General plans are available for anyone to study or review.

Findings. Since the founding of SCEC in 1991, 28 out of 34 Orange County (O.C.) cities have revised or created their Safety Elements. We have obtained and reviewed all available Safety Elements and supporting technical background documents for all 34 O.C. cities, and compared references with the database of over 650 SCEC publications. Directly cited SCEC products are listed below, with the citing document.

<u>Brea (Map Credit) Geotechnical Background Report 2002</u>

- Southern California Earthquake Center (SCEC) January 1932 to November 21, 2001 adapted for "Earthquake Map of the Brea Planning Area"

<u>Rancho Santa Margarita (Map Credit) Geotechnical Background Report 2002</u>

- "Earthquake Map of the Rancho Santa Margarita Planning Area" Scientists of the USGS and the Southern California Earthquake Center, 1994; Science, October 21, 1994 Figure 1

<u>San Juan Capistrano Technical Background Report 1999</u>

- Grant, L. B., K. J. Mueller, E. M. Gath, H. Cheng, R. L. Edwards, R. Munro and G. L.Kennedy, Late Quaternary uplift and earthquake potential of the San Joaquin Hills,southern Los Angeles basin, California, Geology, 27, pp. 1031-1034, 1999.
- Hauksson, E., K. Hutton and L. M. Jones, Preliminary Report on the 1992 LandersEarthquake Sequence in Southern California, Field Trip Guidebook for the LandersEarthquake, June 28, 1992, pp. 23-32, 1992.
- Jones, L. M., J. Mori and E. Hauksson, The Landers Earthquake: Preliminary Instrumental Results, Earthquakes and Volcanoes, 23, no. 5, pp. 200-208, 1993.
- Jones, L.M., 1995, Putting Down Roots in Earthquake Country, SCEC Special Publication: Los Angeles, CA.

<u>Seal Beach Safety Element 1997</u>

- McNeilan, T., T. K. Rockwell and G. Resnick, Style and Rate of Holocene Slip, PalosVerdes Fault, Southern California, Journal of Geophysical Research, 101, no. B4, pp.8317-8334, 1996.
- Shaw, J. H., Active Blind-Thrust Faulting and Strike-Slip Folding in California, Ph.D.Dissertation, Department of Geological and Geophysical Sciences, Princeton University,Princeton, NJ, 216 pp., 1993.
- Stephenson, W. J., T. K. Rockwell, J. K. Odum, K. M. Shedlock and D. A. Okaya, Seismic-Reflection and Geomorphic Characterization of the Onshore Palos Verdes Fault Zone,Los

Angeles, California, Bulletin of the Seismological Society of America, 85, no. 3, pp.943-950, 1995.

Implications. "Like other social problems, the earthquake hazard will not be addressed adequately until we understand both the social processes that produce earthquake vulnerability and the policy steps that need to be taken to reverse those processes." -- Chris Arnold, Earthquake Engineering Research Institute, Testimony before the House Committee on Science, Subcommittee on Basic Research, 2/23/1998

Our preliminary analysis of the data suggest that SCEC products are underutilized for local planning and seismic hazard mitigation. We are evaluating alternative explanations such as nested references, and other use of SCEC products without direct citation

We have also found that nearly all cities in O.C. relied on planning and/or geotechnical firms to prepare technical reports or Safety Elements. Therefore, these consultants would be excellent targets for more effective seismic risk and hazard communication by SCEC.

Looking ahead. New opportunities to establish linkages between seismic hazards and other natural hazards may emerge due to the requirements of FEMA's new Pre-Disaster Mitigation Program. On average, cities are unaware of documentation that outlines the ways SCEC can improve hazard and risk assessment by local government. In some circumstances, SCEC products and research are nested within other resources that are non-exclusive to SCEC (e.g., HAZUS). Consequently, some substantial SCEC contributions are not easily recognized by end-users. For the cities that are using SCEC for seismic hazard mitigation, we expect that the types of products and extent of usage will be better understood following our analysis of geotechnical background reports to safety elements. To date, our review of refereed literature suggests that this methodology will contribute to a better understanding of risk communication between a scientific center and non-technical government decision-makers.

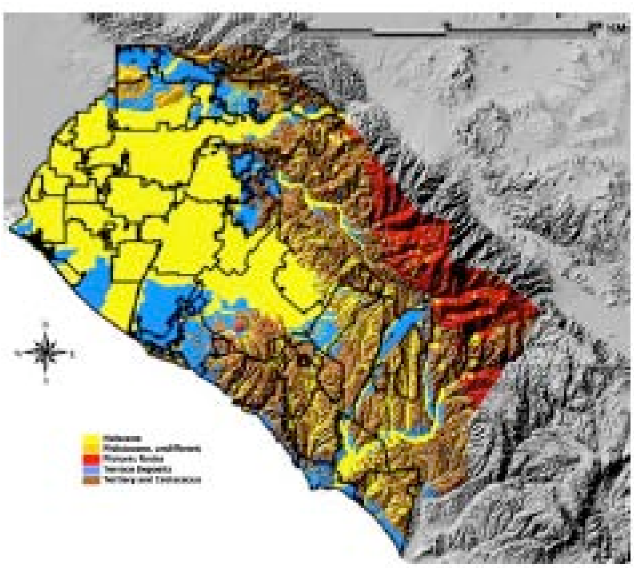


Figure IV.1. Multiple geologic, topographic, and seismic conditions are represented in the relatively small geographic area of Orange County, CA (see area of color) and vicinity (see area of grayscale). The county's 34 cities are indicated by black outlines. Orange County's physiography includes mountains, flood plains, coastal bluffs, soft soils, liquefaction and landslide hazard, surface rupture potential, and sources of potentially strong ground shaking such as the Newport-Inglewood, Whittier - Elsinore, Palos Verdes, San Joaquin Hills and San Andreas faults.

V. Director's Management Report

The following report was presented at the SCEC Annual Meeting on September 8, 2003, by the Center Director, Tom Jordan,.

The 2003 Annual Meeting is the second community-wide gathering since SCEC was reconfigured as a free-standing center a year and a half ago. The SCEC2 program is going at full tilt, and we can look forward to a series of interesting reports on our accomplishments, as well as vigorous discussions of our plans for the next year and beyond. In this brief report, I will summarize some of the major activities and touch on several issues relevant to our future.

Organization and Leadership

SCEC is an institution-based center, governed by a Board of Directors who represent its members. During the past year, the Board approved the admission of four new participating institutions: Boston University, Utah State University, SUNY Stony Brook, and Centro de Investigatión Cientifica y de Educatión Superior de Ensenada (CICESE). The institutional membership now comprises 14 core institutions and 29 participating institutions. One measure of the growing size of the SCEC community is the attendance at this meeting; as this report went to press, 335 people were signed up—the largest group in the history of the Center.

Board of Directors. Under the SCEC2 by-laws, each core institution appoints one board member, and two at-large members are elected by the Board from the participating institutions. Dr. Bill Ellsworth, who was recently appointed as the leader of the USGS Western Region Earthquake Hazards Team, has replaced Dr. Jim Dieterich as the board member from the USGS-Menlo Park office. (Jim is not about to disappear, however; he will continue his effective leadership as the co-chair of the Fault and Rock Mechanics disciplinary committee.) The other 15 members of the Board are Greg Beroza (Vice-Chair/Stanford), Jim Brune (UNR), Doug Burbank (UCSB), Steve Day (SDSU), Lisa Grant (At-Large), Tom Heaton (Caltech), Tom Herring (MIT), Dave Jackson (UCLA), Lucy Jones (USGS-Pasadena), Bernard Minster (UCSD), Jim Rice (Harvard), Bruce Shaw (Columbia), Terry Tullis (At-Large), Rob Wesson (USGS-Golden), and myself (Chair/USC). John McRaney continues to act with his supreme efficiency and effectiveness as Executive Secretary to the Board.

Planning Committee. One of our most important organizations is the SCEC Planning Committee, which is chaired by the Deputy Director and has the responsibility for formulating the Center's science plan, conducting proposal reviews, and recommending projects to the Board for SCEC support. We were fortunate that Prof. Tom Henyey, the former Director of SCEC1, was willing to get SCEC2 off to a excellent start by serving as Deputy Director. At the beginning of the summer, Tom informed the Board that he will be stepping down to assume new duties as the chair of USC's Department of Earth Science. The Board appointed a committee, led by Dr. Rob Wesson, to recommend candidates for his replacement. After a careful search, I am very happy to report that Prof. Ralph Archuleta of UCSB, the current leader of the Ground Motion focus group, has accepted the post of Deputy Director and PC chair.

The PC membership includes the leaders of the major SCEC working groups—disciplinary committees, focus groups, and special project groups. Some of our most energetic and accomplished colleagues are serving as group leaders and co-leaders (see table below). During the past year, Dr. Craig Nicholson of UCSB replaced Dr. Monica Kohler of UCLA as chair of the Borderland Working Group, and Prof. Tom Herring of MIT was elected as the chair of the SCIGN Coordinating Committee, replacing Dr. Ken Hudnut of the USGS. Both Monica and Ken deserve our thanks for the great jobs they did in these positions.

SCEC Working Group Leadership

	Disciplinary Committees
Seismology:	John Vidale (chair)*
	Peter Shearer (co-chair)
Geodesy:	Duncan Agnew (chair)*
	Mark Simons (co-chair)
Geology:	Tom Rockwell (chair)*
	Doug Burbank (co-chair)
Fault & Rock Mechanics:	Terry Tullis (chair)*
	Jim Dieterich (co-chair)
	Focus Groups
Structural Representation:	John Shaw (leader)*
	Rob Clayton (co-leader)
Fault Systems:	Brad Hager (leader)*
	Charles Sammis (co-leader)
Earthquake Source Physics:	Ruth Harris (leader)*
	Greg Beroza (co-leader)
Ground Motions:	Ralph Archuleta (leader)*
	Steve Day (co-leader)
Seismic Hazard Analysis:	Ned Field (leader)*
	John Anderson (co-leader)
	Special Project Groups
Implementation Interface:	Paul Somerville (leader)*
	Rob Wesson (co-leader)
SCIGN Steering Committee:	Tom Herring (chair)*
SCEC/ITR Project:	Bernard Minster (liaison)*
Borderland Working Group:	Craig Nicholson (chair)*

* Planning Committee members

Advisory Council. The Center's external Advisory Council, under the able leadership of Prof. Bob Smith, is charged with developing an overview of SCEC operations and giving advice to the Director and the Board. The Advisory Council's first report, which was issued in October, 2002, focused on several key issues that are now being addressed by the SCEC leadership team. At this meeting, we welcome Dr. Sean Solomon as the newest AC member. I urge all attendees to use this opportunity to communicate their views about SCEC to the Council. Current members are: Robert Smith (Chair/ U. Utah,), Jeff Freymueller (U. Alaska), Raul Madariaga (Ecole Normale Superieure), Jack Moehle (PEER), Farzad Naeim (John A. Martin & Associates), Garry Rogers (Geological Survey Of Canada), Chris Rojahn (Applied Technology Council), Haresh Shah (RMS, Inc.), Sean Solomon (Carnegie Institution of Washington), Ellis Stanley (LA Emergency Preparedness Department), and Susan Tubbesing (EERI).

Center Budget and Project Funding

The 2003 base funding for the Center is $2,630K from the National Science Foundation and $1,100K from the U.S. Geological Survey. The base budget approved by the Board of Directors for this year allocates $2,640K for science activities managed by the SCEC Planning Committee; $360K for communication, education, and outreach activities, managed by the CEO Associate Director, Mark Benthien; $170K for information technology, managed by our new Information Architect, Phil Maechling; $280K for administration and $150K for meetings, managed by the Associate Director for Administration, John McRaney; and $130K for the Director's reserve account. In addition, the Center received $2,000K from NSF's Information Technology Research (ITR) Program for continuing development of the SCEC Community Modeling Environment, and $325K from NSF's National Science, Technology, Engineering, Mathematics, and Education Digital Library (NSDL) program for the Electronic Encyclopedia of Earthquakes. The project managers for the ITR and NSDL grants are Phil Maechling and Mark Benthien, respectively.

I would like to take this opportunity to review in some detail how science projects have been funded as part of the SCEC collaboration, since this ongoing process will be a major concern of the annual meeting. The process of structuring the SCEC program for 2003 began with the working-group discussions at our last annual meeting in September, 2002. An RFP was issued in October, 2002, and 187 proposals (140 projects, considering collaborations) requesting a total of $5,663K were submitted in November, 2002. All proposals were independently reviewed by the Director and Deputy Director. Each proposal was also independently reviewed by the chairs and/or co-chairs of three relevant focus groups or disciplinary committees. (Reviewers were required to recuse themselves when they had a conflict of interest.) The Planning Committee met on January 20-21, 2003, and spent two long days discussing every proposal. The objective was to formulate a coherent, budget-balanced science program consistent with SCEC's basic mission, short-term objectives, long-term goals, and institutional composition. Proposals were evaluated according to the following criteria:

a. Scientific merit of the proposed research.
b. Competence and performance of the investigators, especially in regard to past SCEC-sponsored research.
c. Priority of the proposed project for short-term SCEC objectives.
d. Promise of the proposed project for contributing to long-term SCEC goals.
e. Commitment of the P.I. and institution to the SCEC mission.
f. Value of the proposed research relative to its cost.
g. The need to achieve a balanced budget while maintaining a reasonable level of scientific continuity given very limited overall center funding.

The recommendations of the PC were reviewed by the SCEC Board of Directors at a meeting on February 3-4. The Board voted unanimously to accept the PC's recommendations, pending a final review of the program by the Center Director, which was completed on February 14.

In June, the Planning Committee met jointly with the Board of Directors and agency representatives for two full days to conduct a comprehensive review of the entire SCEC program. The leaders of all of the working groups summarized their accomplishments and plans, and there were vigorous discussions of how the current mix of science projects and other activities might be adjusted to better attain SCEC's five-year goals. Out of those sessions came the draft RFP that is being put up for scrutiny at this annual meeting (see pp. 27-46). Based on the community input, the PC will modify the RFP, and it will be released in October, thus initiating the 2004 project-funding cycle. I urge you to participate fully in these discussions!

Accomplishments

Many of the scientific results of the SCEC collaboration are detailed in the abstracts of presentations and posters included in this volume, and others will be discussed in the working-group sessions throughout the annual meeting. Rather than attempt a summary, I will simply highlight a few examples of what you can expect to see.

Disciplinary Committees. The Center sustains disciplinary science through its standing committees in *seismology*, *geodesy*, *geology*, and *fault and rock mechanics*. These committees are responsible for coordinating disciplinary activities relevant to the SCEC science plan, and they make recommendations to the Planning Committee regarding the support of disciplinary activities and infrastructure.

A number of new results will be presented that pertain to the distribution of earthquakes, faults, and crustal motions in Southern California. An important milestone was reached by the Geodesy Committee this summer with the release of SCEC Crustal Motion Map, Version 3.0, which contains 833 crustal velocity estimates at 762 points in Southern California and northern Baja California, together with co-seismic offsets for the Landers, Northridge, and Hector Mine earthquakes. For the first time, the CMM incorporates data from the recently completed Southern California Integrated GPS Network (SCIGN).

Whereas SCEC has long sponsored activities in seismology, geodesy, and geology, the Fault and Rock Mechanics (FARM) working group is new and reflects a greater emphasis in SCEC2 on the physics of the earthquake process. The FARMers got off to a great start with a very successful workshop convened in Oxnard before last year's annual meeting. The consensus reached at this workshop led to SCEC sponsorship of several new projects. Another FARM workshop that will be held here on Wednesday and Thursday.

Focus Groups. Interdisciplinary research is organized into five science focus areas: *structural representation*, *fault systems*, *earthquake source physics*, *ground motion*, and *seismic hazard analysis*. The focus groups are the crucibles for the interdisciplinary synthesis that lies at the core of SCEC's mission. For that reason, a substantial fraction of this annual meeting will be devoted to reviewing the focus-group activities and discussing their plans. The Structural Representation group will show off the new Community Fault Model (CFM), Version 1.1, which is perhaps the most detailed 3D representation of an active fault system anywhere on the planet, and they will describe how the Community Velocity Model (CVM), Version 3.0, is being mapped into standard objects compatible with the CFM representation. These achievements set the stage for the upcoming push toward a major SCEC2 objective—a unified structural representation of Southern California incorporating both the CFM and CVM.

We will see many other examples of focus-group accomplishments: a collaboration between the Structural Representation and Fault Systems groups to erect a Community Block Model (CBM) for use in representing 3D deformations; community finite element models for fault systems and tectonic studies; new seismicity and earthquake-forecasting models from the Fault Systems group and the RELM project; new methods from the Ground Motions group for tomographic refinement of the CVM; full 3D calculations of earthquake ruptures from the Earthquake Source Physics group; the new OpenSHA platform developed in a collaboration between the Seismic Hazard Analysis group and CME project—and much more.

Special Projects. SCEC activities classified under special projects include SCIGN, the Borderland working group, and the development of the Community Modeling Environment (CME) under the SCEC/ITR project.

The time series from over 250 continuous GPS stations of the SCIGN system are being updated on a daily basis, and the archived data now comprise over 1000 station-years. NSF has recently agreed to provide substantial funding for the next 18 months to operate the regional geodetic networks in the western U.S., including SCIGN. Now that NSF's huge EarthScope program has been funded by Congress (with considerable help from the SCEC community), the challenge will be to coordinate future SCIGN developments with EarthScope's Plate Boundary Observatory (PBO).

A Borderland workshop was held in late June to identify unifying science themes and data resources for focused, inter-disciplinary studies of the offshore tectonic environment and associated seismic hazards. In collaboration with the USGS, the Borderland working group continued to make progress on the transfer of proprietary offshore industry seismic data to the public domain. A proposal has been submitted to the EarthScope program to supplement this data rescue effort as part of a broader, coordinated study of plate boundary deformation and tectonic evolution.

The goal of the CME project is to develop seismological applications and IT infrastructure to support SHA and other science activities. Standard interfaces are being developed for the full suite of SCEC community models (CMM, CFM, CVM, CBM, etc.). Significant progress has been made in setting up integrated software systems for specific computational pathways, executing jobs on the new SCEC computational grid, and managing the output using digital-library and data-grid technologies. Many of the OpenSHA capabilities are now available to SCEC community through the CME, and within the next few months, scientists will be able to generate synthetic seismograms for arbitrary source and receiver locations from the 3D CVM using a simple graphical user interface. A special symposium of the CME project will be convened on Tuesday afternoon, and the new software tools and computational environments will be demonstrated in the poster sessions.

Implementation Interface. Interdisciplinary research in risk assessment and mitigation is a primary subject for collaboration between SCEC scientists and partners from other communities—earthquake engineering, risk analysis, and emergency management. These partnerships are facilitated by an *implementation interface*, a new structure within the CEO program designed to foster two-way communication and knowledge transfer.

Over the past year, a special partnership has developed between SCEC and the Pacific Earthquake Engineering Research Center (PEER). Scientists and engineers are engaged in several projects jointly funded by the two centers; one example is research on vector-valued hazard measures for improved prediction of structural response to ground motions. Another is the Next Generation Attenuation Program (NGA), a major initiative of the PEER-Lifelines Program, SCEC and the USGS, which will develop a new set of attenuation relations for seismic hazard analysis. The first phase of this multiyear project (NGA-E, for empirical) should be completed by mid-2004. A follow-on project, dubbed NGA-H (for hybrid), will make more extensive use of SCEC's ground-motion modeling capabilities.

Representatives from a number of partnering organizations will be attending this meeting, and we should use this opportunity to discuss how our efforts toward implementing science for public benefit can be improved.

Communication, Education, and Outreach. Through its CEO Program, SCEC offers a wide range of student research experiences, web-based education tools, classroom curricula, museum displays, public information brochures, online newsletters, and technical workshops and publications.

This year, much progress has been made on the development of the *Electronic Encyclopedia of Earthquakes* (E3), a collaborative project with CUREE and IRIS. The E3 development system is now fully operational, and 165 entries are in the pipeline. When complete, E3 will include information and resources for over 500 Earth science and engineering topics, with connections to curricular materials useful for teaching Earth science, engineering, physics and mathematics.

An "Earthquake Country Alliance" has been organized to coordinate activities for the 10-year anniversary of the Northridge Earthquake in 2004, and beyond. The Alliance will present common messages, share and promote existing resources, and develop new activities and joint products, such as a new version of *Putting Down Roots in Earthquake Country*. The group includes earthquake science and engineering researchers and practicing professionals, preparedness experts, response and recovery officials, news media representatives, and education specialists. A web portal, www.earthquakecountry.info, is being established with links to web pages and descriptions of resources and services that the Alliance members provide.

SCEC's Summer Intern program has grown to a new level and now has a year-round counterpart with students working on IT projects at USC and other institutions. Since last summer, 32 students have participated in the program, including 7 students working with scientists throughout SCEC, 18 students enrolled in the USC Earthquake Information Technology (EIT) intern program, and 7 students involved in CEO projects.

Challenges

Despite the successful launching of SCEC2 and the numerous accomplishments on display at this meeting, we continue to face challenges that require us to think carefully about our future. Here are a few questions for discussion:

- As we reach the midway point of SCEC2, how should we focus our research program to achieve our key 5-year objectives?
- SCEC's base funding is about 25% lower than it was at its peak in 1999, while the size of its community has grown substantially. What are the best strategies to increase the funding for the interdisciplinary research that fuels the SCEC collaboration?
- In particular, where we will find the resources to pursue major initiatives in exciting areas like fault and rock mechanics, investigations of the southern San Andreas fault and the California Borderland, and the NGA project?
- How should SCEC activities be coordinated with EarthScope activities? What SCEC initiatives should be put forward under the banner of EarthScope?
- How can SCEC improve its interface with the NSF earthquake engineering research centers and the NEES program?

VI. Advisory Council Report

The membership of the SCEC External Advisory Council is listed in Table VI.1. Professor Robert Smith, who chaired the SCEC Advisory Council since 2000, will step down as chair in January, 2004. The Advisory Council convened at the SCEC Annual Meeting in September 2003, and their report is reproduced verbatim below.

Table VI.1. SCEC Advisory Council for 2003

Robert SMITH (Chair), University of Utah, Department of Geology and Geophysics, Salt Lake City, UT 84112-1183
Jeff FREYMUELLER, University of Alaska, Geophysical Institute, P.O. Box 757320, Fairbanks, AK 99775-7320
Raul MADARIAGA, Laboratoire de Geologie, Ecole Normale Superieure, 24 Rue Lhomond, Cedex 05, 75231 Paris, FRANCE
Jack MOEHLE, Pacific Earthquake Eng. Research Center, 1301 S. 46th St., Bldg. 451, Richmond, CA 94804-4698
Farzad NAEIM, John A. Martin & Associates, 1212 S. Flower St., Los Angeles, CA 90015
Garry ROGERS, Geological Survey of Canada, Box 6000, Sidney, V8L 4B2, BC, Canada
Chris ROJAHN, Applied Technology Council, 555 Twin Dolphin Dr., Ste. 550, Redwood City, CA 94065
Haresh SHAH, RMS, Inc., 149 Commonwealth Dr., Menlo Park, CA 94025
Sean SOLOMON, Carnegie Institution of Washington, Washington, DC
Ellis STANLEY, City of Los Angeles, Emergency Preparedness Department, 200 N. Main Street, Room 1500, Los Angeles, CA 90012
Susan TUBBESING, EERI, 499 14th St., Suite 320, Oakland, CA 94612-1902

Subject: SCEC Advisory Committee Report, SCEC Annual Meeting of 8-10, September 2003, Oxnard, California

Members present at SCEC Advisory Committee meetings of September 10, 2003:

Robert B. Smith, Chair, University of Utah
Jeff Freymueller, University of Alaska
Gary Rogers, Geological Survey of Canada
Chris Rojahn, Applied Technology Council
Sean Solomon, Carnegie Institution of Washington
Susan Tubbesing, EERI
Haresh Shah, RMS

The SCEC Advisory Committee (AC) comments are in response to the following: 1) participation in the 2003 SCEC Annual Meeting, 2) discussions with the SCEC management in both open and in executive session at the meetings, and 3) our overall perspectives of SCEC's progress.

The Annual Meeting showed continuing momentum in maintaining a successful scientific program with a strong commitment to outreach and education as guided by its new Director and management and by its Board of Directors. We compliment SCEC on maintaining an aggressive policy of involving members, outside persons, and students in SCEC programs.

It is apparent that, in this second year of SCEC-II, the organization maintains its focus on earthquake science but is clearly expanding into Information Technology (IT) and Education and Outreach (E&O) topics and is developing stronger ties with engineering organizations such as the Pacific Earthquake Engineering Research center (PEER). We nonetheless see opportunities for an even stronger focus on relations with the engineering practitioners.

A significant SCEC accomplishment has been a statewide effort of partnering with other risk management organizations including the California Seismic Safety Commission, the California Integrated Seismic Network, private engineering companies, the California Geological Survey (CGS), the U. S. Geological Survey, and PEER.

Specific Comments:

A. Advisory Committee charter

The SCEC Advisory Committee continues to operate in an informal role, without in-depth operating procedures. As SCEC-II is not part of the NSF S&T program, as it was before, we report directly to the SCEC Director. However, we suggest that our report and recommendations be conveyed to all the SCEC funding agencies. Moreover, because the SCEC-II AC operates in an advisory capacity, it does not have an official charter. To establish a more coherent guide for our advisory role, we suggest that the SCEC management consider providing us with a more formal set of guidelines and a mission statement commensurate with the new philosophy of SCEC-II. This topic is of particular interest to the new members of the advisory committee, who felt strongly that they could not respond in an advisory capacity until they knew their explicit charge.

B. Information Technology Research (ITR)

The advisory committee sees IT as playing a key in the future of the organization as well as in the success of SCEC toward setting an example for other national organizations in the Earth sciences and engineering. We strongly suggest that the SCEC's IT goals must mesh with the SCEC operating science and E&O goals, but IT can be operated separately from the core functions. This arrangement will require that SCEC IT should have enunciated programmatic goals that are clearly different from the SCEC-II science goals.

We suggest that a list of planned and delivered SCEC IT products should be placed on the SCEC web pages with web links to the products.

C. Regional Earthquake Likelihood Models (RELM)

The RELM seismic hazard analysis program is an excellent example of how scientific and engineering tools can be combined into a new user tool that crosses various domains from science to engineering. We compliment SCEC on this project.

However, we caution that the RELM product be clearly identified so that it is not seen as an official representation of earthquake hazard, but more as a guide for how the practicing user, engineer, planner, educator, or public, can learn about hazard. There needs to be a clear distinction from official earthquake hazard information such as the delivered by the CGS and USGS. These tasks and products by these organizations must be considered in SCEC RELM activities, and these agencies should be asked for advice on SCEC RELM objectives.

We note that the ITR and RELM metrics will be most visible when young SCEC scientists and engineers use the data and tools in these programs in their routine research, as this serves to multiply their productivity on related SCEC topics.

Moreover the SCEC IT and RELM programs should be clearly advertised to ancillary organizations such as Network for Earthquake Engineering Simulation (NEES), the USGS, universities, and practicing engineers.

D. Balance of applied vs. basic research

The community noted the need for keeping a balance between applied and basic research. Such products as the RELM program and the latest NSF proposal with its focus on new ground motion modeling, attenuation, scenarios, etc., are two good examples of more applied research that help carry SCEC's basic science to the practicing user.

E. Funding for SCEC

The committee notes the tight financial conditions of SCEC, with some 30% less support than in 1999. This constraint has limited the research activities of SCEC, but the management has worked hard to focus on prioritizing topics to keep operating levels of funding to those investigators who are still doing viable science that fits best within the new SCEC-II plan. The wide breadth of SCEC science and engineering and E&O projects are good examples of value-added work that should be highlighted to SCEC funding agencies.

F. E&O

E&O efforts at SCEC are at a high level of activity as well as a high level of visibility. Such topics as the Encyclopedia of Earthquakes bring SCEC expertise to the global user community. We caution, however, that this effort must contain a strong engineering contribution to the encyclopedia as well and should be coordinated and linked with the USGS Earthquake Hazards program.

Both the RELM and Encyclopedia of Earthquakes projects should be more aggressively advertised to such groups as the Applied Technology Council (ATC), Earthquake Engineering Research Institute, EERI, American Geophysical Union (AGU), and Seismological Society of America (SSA).

This brings us to an observation that while SCEC is working on active issues in engineering, it is not as well appreciated for its efforts by the engineering community. This reputation in part can be countered with more outreach and education toward engineering, but the center should also do more work to involve local partners in the SCEC geographic community.

G. Diversity

Diversity has been addressed throughout the organization of SCEC-II. Where possible women have been appointed to SCEC committees, and under-represented minorities are recruited and supported in SCEC education functions. But we caution that this effort must become a more visible component of SCEC.

H. Ten-year SCEC I Anniversary Document

A comprehensive document forming the legacy of the SCEC-I 10-year history is still not a visible product. We realize that the subjects are rapidly changing with time, and that there is a major resource commitment needed to produce and promote such a document. Nonetheless there remains a need. Given its impact and access, the web is the most promising vehicle to achieve maximum impact for such a project.

We suggest that a SCEC I Anniversary Document be completed within the next year.

If you have any questions, please feel free to call on me.

Sincerely,

Robert B. Smith
Professor of Geophysics
Advisory Committee Chair

VII. Financial Report

Table VII.1 gives the breakdown of the SCEC 2003 budget by major categories. The list of individual projects supported by SCEC in 2003 can be found on the website http://www.scec.org/research/2003research/index.html.

Table VII.1 2003 Budget Breakdown by Major Categories

Total Funding (NSF and USGS):	$3,785,000
Budgets for Infrastructure:	$ 1,035,000
Management	280,000
CEO Program	360,000
Annual, AC, Board, and PC Meetings	170,000
Information Architect	170,000
SCEC Summer Intern Program	55,000
Budgets for Disciplinary and Focus Group Activities: (including workshops)	$ 2,750,000
Geodesy	250,000
Geology	390,000
Seismology	275,000
Fault and Rock Mechanics	124,000
Earthquake Source Physics	474,000
Fault Systems	373,000
Ground Motions	211,000
Seismic Hazard Analysis	187,000
Structural Representation	336,000
Implementation Interface	130,000

VIII. Report on Subawards and Monitoring

The process to determine funding for 2003 began with discussions at the SCEC annual meeting in Oxnard in September, 2002. An RFP was issued in late October, 2002 and 140 proposals were submitted in November, 2002. Proposals were then sorted and sent out for review in mid-December, 2003. Each proposal was independently reviewed by the Center Director Tom Jordan, the Deputy Director Tom Henyey, by the chair and co-chair of the relevant focus group, and by the chair and co-chair of the relevant disciplinary committee. Reviewers had to recuse themselves where conflicts of interest existed. Every proposal had from 4 to 6 reviews. Reviews were sent to John McRaney, SCEC Associate Director for Administration, who collated and tabulated them. The SCEC Planning Committee (chaired by Tom Henyey) met on January 20-21, 2003 and spent 25+ hours over two days discussing every proposal. The PC assigned a rating from 1-5 (1 being highest) to each proposal and recommended a funding level. Proposals were rated based on quality of science and the proposed research plan, their relevance to the SCEC 2003 science goals, and the amount of money available for the overall program.

The recommendations of the PC were reviewed by the SCEC board at a meeting on February 4-5, 2003. The board voted 14-0 to accept the recommendations of the PC, pending a final review of the program by the Center Director. The director did not make any changes in the proposed plan approved by the board. The board was given two days to comment on the final plan of Jordan.

SCEC funding for 2003 is $3.73M. The board approved $280K for administration; $360K for the communications, education, and outreach program; $170K for workshops and meetings; and $170K for the information technology program. We also received a $55,000 supplement from NSF for a summer undergraduate intern program.

The Center Director did not give specific targets for funding by infrastructure and science groups. Final funding for each disciplinary and focus group is shown in Table VII.I. Most research in SCEC involves aspects of several focus groups. The funding is shown by primary review group at the Planning Committee meeting.

The Center Director also was given a small ($130,000) fund for supporting projects at his discretion. Most of the funding during the first year went into the new NGA joint project with PEER.

Following this action, individual PI's were notified of the decision on their proposals. Successful applicants submit formal requests for funding to SCEC. After all PI's at a core or participating institution submit their individual proposals, the proposals are scanned and the institution's request is submitted electronically to NSF/USGS for approval to issue a subcontract. Once that approval is received, the formal subcontract is issued to each institution to fund the individual investigators and projects.

Scientific oversight of each project is the responsibility of the Center Director, Deputy Director, and focus/disciplinary group leaders. Fiscal oversight of each project is the responsibility of the Associate Director for Administration. Regular oversight reports go to the SCEC Board. Any unusual problems are brought to the attention of agency personnel.

Subcontracts issued in 2003 are shown in the table below for both the USGS and NSF components of SCEC funding.

Table VIII.1 SCEC Subcontracts for 2003

USGS Funds

ABS Consulting	25,000	
Boston U	20,000	
Cal State-Fullerton	20,000	
Caltech	150,000	Data Center Only
ECI	15,000	
Harvard	129,000	
LLNL	55,250	
Oregon	55,000	
Oregon State	19,000	
San Diego State	68,520	
Stanford	39,000	
UCI	17,000	
University of Western Ontario	15,000	
URS	118,900	
Utah State	20,000	
WHOI	15,000	

NSF Funds

ASU	20,000	
Brown	20,000	
Caltech	117,000	Science only
Case Western	32,000	
CMU	12,000	
CWU	23,000	
Kentucky	12,500	
LDEO	55,000	
MIT	102,000	
RPI	39,000	
SDSU	137,000	
Texas A&M	17,000	
U Mass	15,000	
UCB	27,000	
UCD	24,000	
UCLA	125,000	
UCR	30,000	
UCSB	306,000	
UCSC	37,500	
UCSD	197,100	
UNR	119,000	
URS	20,000	

Report on 2003 SCEC Cost Sharing

The University of Southern California contributes substantial cost sharing for the administration of SCEC. In 2003, USC provides $280,000 for SCEC administration costs, waived $640,000 in overhead recovery on subcontracts, provided nearly $200,000 in release time to center directors to work on SCEC, and completed the renovation of SCEC space in North Science Hall at a cost of $2,000,000. USC had previously spent $5,500,000 in 2002 renovating SCEC space for a total contribution of $7.5M to space needs.

SCEC Management Cost-Sharing Report for 2002-2003

1. USC annually provides $280,000 in cost-sharing for SCEC management (Direct Costs).

Institution	Amount	Purpose
USC	$213,400	Salary Support of Jordan, T. Henyey, McRaney, S. Henyey
	$10,000	Report Preparation and Printing
	$9,000	Meeting Expenses
	$7,500	Office Supplies
	$5,000	Computers and Usage Fees
	$8,500	Administrative Travel Support for SCEC Officers
	$5,600	Postage
	$21,000	Telecommunications
	$280,000	Total

2. USC waives overhead on subcontracts. There are 41 subcontracts in 2003-2004.

$1,025,000	Amount Subject to Overhead (41 * $25,000)
0.625	USC Overhead Rate
$640,625	Savings Due to Overhead Waiver

3. SCEC Directors receive a 50% release from teaching for administrative work.

$198,000 Cost Sharing for 2002-2003 Acadmic Year

$1,118,625 2003-2004 USC Cost-Sharing to SCEC

4. USC spent $2,000,000 to remodel the second floor of North Science in 2003 for SCEC.

$2,000,000 Cost for SCEC Space

In addition to USC support of SCEC management activities, each core institution of SCEC is required by the by-laws to spend at least $35,000 in direct costs on SCEC activities at the local institution. These funds are controlled by the institution's participants in SCEC, not centrally directed by SCEC management. The following table shows how each core institution spent its funds in 2003.

Institution	SCEC Cost-Sharing for 2003-2004 Amount	Purpose
USC	$12,000	Student Support
	$3,000	Research Support/Supplies
	$5,000	Visitor Support Geoff King and Matt Holschneider
	$15,000	Research Faculty Salary Support
	$35,000	Total
Harvard	$6,412	Staff Salaries and Benefits
	$3,831	SCEC-Related Travel
	$24,487	Equipment and Research Supplies
	$34,730	Total
UCSD	$15,000	Pinon Flat Observatory Operation
	$15,000	Software Development
	$10,000	WiNSAR Archive
	$10,000	Hardware Maintenance/Supplies
	$50,000	Total
Columbia/LDEO	$1,673	Administrative Salary Support
	$1,412	Travel for James Gaherty
	$33,746	Salary Support for Leonardo Seeber
	$36,831	Total
UCSB	$2,022	Salary Support for Visiting Faculty
	$2,248	Student Salary
	$6,385	Travel Support
	$2,821	Supplies and Expenses
	$3,500	Staff Salary
	$16,000	SCEC Postdoc
	$2,000	Equipment
	$34,976	
Stanford	$35,000	Graduate Student Fellowship
	$18,190	Graduate Student/Post-Doc Travel

	$53,190	Total
UCLA	$21,774	Salary Support for Research Personnel
	$11,857	Supplies
	$1,369	Travel
	$35,000	Total
MIT	$46,711	Computer Cluster Purchase
	$24,210	Graduate Student Fellowship
	$6,900	Geophysics Field Camp
	$77,821	
SDSU	$5,118	Software Licenses and Support
	$4,041	Equipment
	$12,925	Staff Salary
	$11,774	PI Salary
	$1,142	Supplies
	$35,000	Total
UNR	$24,701	Salary for Research Faculty Rasool Anooshehpoor
	$11,262	Salary for Research Faculty Zeng Su
	$8,400	Salary for PhD Student Aasha Pancha
	$44,363	Total
Caltech	$26,058	Two Gutenberg Graduate Student Fellowships
	$47,569	Moore/Richter Graduate Student Fellowship
	$43,218	Housner Graduate Student Fellowship
	$116,845	Total
USGS/Pasadena	$350,000	Support for SCIGN (Salaries and Materials)
	$127,000	Support for RELM (Salaries and Materials)
	$477,000	
USGS/Golden	$150,000	Salary Support of RELM, OpenSHA, NGA Activities
	$10,000	Travel Support
	$160,000	
USGS/Menlo Park	$150,000	Salary Support of SCIGN, SCSN, FARM Activities
	$20,000	
	$170,000	

IX. Demographics of SCEC Participants

Center Database of SCEC Participants in 2002

	Administration/ Technical	Faculty Researcher	Graduate Student	Non-faculty Researcher	Undergraduate Student
Race					
Asian	6	12	30	10	7
Black	1	1	1	1	1
White	30	108	85	144	19
Native American	0	0	4	0	0
Ethnicity					
Latino	0	4	10	2	4
Not Latino	29	99	73	132	18
No information	7	16	28	17	1
Withheld	1	2	9	4	4
Gender					
Female	13	15	43	43	9
Male	24	106	77	112	18
Withheld	0	0	0	0	0
Citizenship					
US	30	95	66	115	24
Other	4	4	32	21	0
No information	3	8	16	6	1
Resident	0	14	3	13	1
Withheld	0	0	3	0	1
Disability Status					
None	29	96	67	126	22
No information	8	22	53	26	5
Hearing	0	1	0	0	0
Visual	0	0	0	2	0
Mobility	0	0	0	1	0

X. Report on International Contacts and Visits

1. SCEC Advisory Council. We have two international members of our Advisory Council. They are Raul Madariaga of Ecole Normale Superieure, Paris and Garry Rogers of Geological Survey of Canada, Sydney.

2. ACES (APEC Cooperative for Earthquake Simulation). SCEC and JPL are the U.S. organizations participating in ACES. Information on ACES can be found at http://www.quakes.uq.edu.au/ACES/. Andrea Donnellan of SCEC/JPL is the U.S. delegate to the ACES International Science Board and John McRaney of SCEC is the secretary general. SCEC hosted the ACES biennial meeting in May, 2002 in Maui, Hawaii. There were 50 U.S. and 55 international participants (15 from Australia, 10 from China, 1 from New Zealand, 2 from Mexico, 2 from Germany, and 25 from Japan). The next ACES workshop will be in China in 2004.

3. ETH/Zurich. Stefan Wiemar, Martin Mai, and Matt Gerstenberger of ETH are participants in the SCEC/RELM project. ETH pays the salaries of the participants and SCEC pays their travel to meetings in the U.S. Gerstenberger recently moved to IGNS, Wellington, New Zealand.

4. IGNS/New Zealand. Mark Stirling of the Institute for Geological and Nuclear Sciences of New Zealand is involved in the RELM program.

5. University of Western Ontario/Canada. Kristy Tiampo of the University of Western Ontario in London, Ontario is funded through the Earthquake Source Physics Group.

6. SCIGN. The SCIGN network has stations in Baja California and on Isla Guadalupe. Scientists from CICESE in Ensenada, Mexico participate in the SCIGN program.

7. SCEC Borderland Working Group. SCEC is developing plans to study the active tectonics of the California Borderland. Scientists from CICESE in Ensenada, Mexico are participating in this effort as the area of interest includes both U.S. and Mexican waters.

8. SCEC Annual Meeting. The SCEC annual meeting continues to attract international participants each year. There were participants in the 2003 annual meeting from China, Japan, India, Mexico, Canada, France, Switzerland, Germany, Russia, and New Zealand.

XI. Publications

Note: Publication numbers listed here are continued from the SCEC list that was initiated in 1991. This list includes on research publications that had updates between November 1, 2002 and December, 2003.

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Appendices

Appendix A. Long-Term Research Goals

This section outlines the SCEC science priorities for the five-year period from February 1, 2002, to January 31, 2007, as stated in *The SCEC Strategic Plan 2002-2007* (October, 2002). Additional material on the science and management plans for the Center can be found in the SCEC proposal to the NSF and USGS (http://www.scec.org/SCEC).

Long-term research goals have been formulated in six problem areas: plate-boundary tectonics, fault systems, fault-zone processes, rupture dynamics, wave propagation, and seismic hazard analysis. These goals delineate the general areas of research where substantial progress is expected during the next five years, and they provide the scientific context for the short-term objectives outlined in Section VI.B.

Plate-Boundary Tectonics

Goal: To determine how the relative motion between the 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.

Key Questions:

- How does the complex system of faults in Southern California accommodate the overall plate motion? To what extent does distributed deformation (folds, pressure-solution compaction, and motions on joints, fractures and small faults) play a role within the seismogenic layer of the crust?
- What lateral tractions drive the fault system? What are the directions and magnitudes of the basal tractions? How do these stresses compare with the stresses due to topography and variations in rock density? Do they vary through time?
- What rheologies govern deformation in the lower crust and mantle? Is deformation beneath the seismogenic zone localized on discrete surfaces or distributed over broad regions? How are these deformations related to those within the seismogenic zone?
- What is the deep structure of fault zones? Are major strike-slip faults such as the SAF truncated by décollements or do they continue through the crust? Do they offset the Moho? Are active thrust faults best described by thick-skin or thin-skin geometries?
- How is the fault system in Southern California evolving over geologic time, what factors are controlling the evolution, and what influence do these changes have on the patterns of seismicity?

Fault Systems

Goal: 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.

Key Questions:

- What are the limits of earthquake predictability, and how are they set by fault-system dynamics?
- How does inelastic deformation affect strain accumulation and release through the earthquake cycle? Does inelastic deformation accumulated over repeated earthquake cycles give rise to landforms and geologic structures that can be used to constrain deformation rates and structural geometries on time intervals of thousands to hundreds of thousands of years?
- Are there patterns in the regional seismicity related to the past or future occurrence of large earthquakes? For example, are major ruptures on the SAF preceded by enhanced activity on secondary faults, temporal changes in b-values, or local quiescence? Can the seismicity cycles associated with large earthquakes be described in terms of repeated approaches to, and retreats from, a regional "critical point" of the fault system?
- What are the statistics that describe seismic clustering in time and space, and what underlying dynamics control this episodic behavior? Is clustering observed in some fault systems due to repeated ruptures on an individual fault segment, or to rupture overlap from multiple segments? Is clustering on an individual fault related to regional clustering encompassing many faults?
- What systematic differences in fault strength and behavior are attributable to the age and maturity of the fault zone, lithology of the wall rock, sense of slip, heat flow, and variation of physical properties with depth? Is the mature SAF a weak fault? If so, why? How are the details of fault-zone physics such as "critical slip distance" expressed at the system level?
- To what extent do fault-zone complexities, such as bends, changes in strength, and other quenched heterogeneities control the nucleation and termination of large earthquakes and their predictability? How repeatable are large earthquakes from event to event, both in terms of location and slip distribution? How applicable are the "characteristic-earthquake" and "slip-patch" models in describing the frequency of large events? How important are dynamic cascades in determining this frequency? Do these cascades depend on the state of stress, as well as the configuration of fault segments?
- How does the fault system respond to the abrupt stress changes caused by earthquakes? To what extent do the stress changes from a large earthquake advance or retard large earthquakes on adjacent faults? How does stress transfer vary with time? Does a more realistic lower-crustal rheology affect the spatial and temporal evolution of seismicity?
- What controls the amplitude and time constants of the post-seismic response, including aftershock sequences and transient aseismic deformations? In particular, how important are induction of self-driven accelerating creep , fault-healing effects, poroelastic effects, and coupling of the seismogenic layer to viscoelastic flow at depth?

Fault-Zone Processes

Goal: To understand the internal structure of fault zones and the microscale processes that determine their rheologies in order to formulate more realistic macroscopic representations of fault-strength variations and the dynamic response of fault segments and fault networks.

Key Questions:

- Which small-scale processes—pore-water pressurization and flow, thermal effects, geochemical alteration of minerals, solution transport effects, contact creep, microcracking and rock damage, gouge comminution and wear—are important in describing the earthquake cycle of nucleation, dynamic rupture, and post-seismic healing?
- What fault-zone properties and processes determine velocity-weakening vs. velocity-strengthening behavior? How do these properties and processes vary with temperature,

pressure, and composition? How do significant changes in normal stress modify constitutive behavior?

- How does fault strength drop as slip increases immediately prior to and just after the initiation of dynamic fault rupture? Are dilatancy and fluid-flow effects important during nucleation?
- What is the explanation of the discrepancy between the small values of the critical slip distance found in the laboratory (<□00 microns) and the large values (> 100 millimeters) inferred from the fracture energies of large earthquakes? What is the nature of near-fault damage and how can its effect on fault-zone rheology be parameterized?
- How does fault-zone rheology depend on microscale roughness, mesoscale offsets and bends, variations in the thickness and rheology of the gouge zone, and variations in porosity and fluid pressures? Can the effects of these or other physical heterogeneities on fault friction be parameterized in phenomenological laws based on rate and state variables?
- How does fault friction vary as the slip velocities increase to values as large as 1 m/s? How much is frictional weakening enhanced during high-speed slip by thermal softening at asperity contacts and by local melting?
- How do faults heal? Is the dependence of large-scale fault healing on time logarithmic, as observed in the laboratory? What small-scale processes govern the healing rate, and how do they depend on temperature, stress, mineralogy, and pore-fluid chemistry?

Rupture Dynamics

Goal: To understand the physics of rupture nucleation, propagation, and arrest in realistic fault systems, and the generation of strong ground motions by earthquakes.

Key Questions:

- What is the magnitude of the stress needed to initiate fault rupture? Are crustal faults "brittle" in the sense that ruptures require high stress concentrations to nucleate, but, once started, large ruptures reduce the stress to low residual levels?
- How do earthquakes nucleate? What is the role of foreshocks in this process? What features characterize the early post-instability phase?
- How can data on fault friction from laboratory experiments be reconciled with the earthquake energy budget observed from seismic radiation and near-fault heat flow? What is explanation of short apparent slip duration?
- How much inelastic work is done outside a highly localized fault-zone core during rupture? Is the porosity of the fault zone increased by rock damage due to the passage of the rupture-tip stress concentration? What is the role of aqueous fluids in dynamic weakening and slip stabilization?
- Do minor faults bordering a main fault become involved in producing unsteady rupture propagation and, potentially, in arresting the rupture? Is rupture branching an important process in controlling earthquake size and dynamic complexity?
- Are strong, local variations in normal stress generated by rapid sliding on nonplanar surfaces or material contrasts across these surfaces? If so, how do they affect the energy balance during rupture?
- What produces the slip heterogeneity observed in the analysis of near-field strong motion data? Does it arise from variations in mechanical properties (quenched heterogeneity) or stress fluctuations left in the wake of prior events (dynamic heterogeneity)?
- Under what conditions will ruptures jump damaged zones between major fault strands? Why do many ruptures terminate at releasing step-overs? How does the current state of stress

along a fault segment affect the likelihood of ruptures cascading from one segment to the next?
- What are physical mechanisms for the near-field and far-field dynamical triggering of seismicity by large earthquakes?

Ground Motion

Goal: To understand seismic ground motion in urbanized Southern California well enough to predict the ground motions from specified sources at frequencies up to at least 1 Hz, and to formulate useful, consistent, stochastic models of ground motions up to at least 10 Hz.

Key Questions:
- How are the major variations in seismic wave speeds in Southern California related to geologic structures? How are these structures best parameterized for the purposes of wavefield modeling?
- What are the contrasts in shear-wave speed across major faults in Southern California? Are the implied variations in shear modulus significant for dynamic rupture modeling? Do these contrasts extend into the lower crust and upper mantle?
- How are variations in the attenuation parameters related to wave-speed heterogeneities? Is there a significant dependence of the attenuation parameters on crustal composition or on frequency? How much of the apparent attenuation is due to scattering?
- What are the differences in near-fault ground motions from reverse, strike-slip, and normal faulting? In thrust faulting, how does energy trapped between the fault plane and free surface of the hanging-wall block amplify strong ground motions?
- How does the structure of sedimentary basins affect the amplitude and duration of ground shaking? How much of the amplification pattern in a basin is dependent on the location of the earthquake source? Can the structure of sedimentary basins be determined in sufficient detail to usefully predict the pattern of ground shaking for future large earthquakes?
- Is the ability to model recorded seismograms limited mainly by heterogeneity in source excitation, focusing by geologic structure, or wavefield scattering?
- What role do small-scale heterogeneities and irregular interfaces play in wave propagation at high frequencies? How do they depend on depth, geological formation, and tectonic structure? How important is multiple scattering in the low-velocity, uppermost layers? Can stochastic parameterizations be used to improve wavefield predictions?

Seismic Hazard Analysis

Goal: 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 ground-motion time histories for anticipated earthquakes, and (b) through the use of fault-system analysis, to forecast the time-dependent perturbations to average earthquake probabilities in Southern California.

Key Questions:
- What factors limit fault-rupture propagation? How valid are the cascade and characteristic-earthquake models? What magnitude distribution is appropriate for Southern California?
- How can geodetic (GPS and InSAR) measurements of deformation be used to constrain short- and long-term seismicity rates for use in seismic hazard assessment? How can geologic and paleoseismic data on faults be used to determine earthquake recurrence rates?

- What temporal models and distributions of recurrence intervals pertain to faults in Southern California? Under what circumstances are large events Poissonian in time? Can PSHA be improved by incorporating non-Poissonian distributions?
- Can physics-based scenario simulations produce more accurate estimates of ground-motion parameters than standard attenuation relationships? Can these simulations be used to reduce the high residual variance in these relationships ?
- What is the nature of near-fault ground motion? How do fault ruptures generate long-period directivity pulses? How do near-fault effects differ between reverse and strike-slip faulting? Can these effects be predicted?
- What are the earthquake source and strong ground motion characteristics of large earthquakes (magnitudes larger then 7.5), for which there are few strong motion recordings? Can the shaking from large earthquakes be inferred from smaller events?
- How does the nonlinear seismic response of soils depend on medium properties, amplitude, and frequency?

Appendix B. SCEC By-Laws

The by-laws given here were approved by the SCEC Board of Directors at its March 6, 2002, meeting.

By-Laws of the Southern California Earthquake Center (SCEC)
Effective February 1, 2002

PREAMBLE

The By-Laws of the Southern California Earthquake Center (SCEC) are adopted by the Board of Directors for the purpose of conducting SCEC business in a collegial manner. They should not be construed as overriding the standard responsibilities and prerogatives of Principal Investigators or their respective institutions. However, situations and issues may arise from time to time for which resolution through standard procedures cannot be achieved. Consequently, should the Center Director and the Board of Directors not be able to reach agreement on any given issue, the Center Director, as Principal Investigator on all Center grants/contracts, will ultimately retain full authority to make and implement decisions on Center programs and policies. These by-laws supercede those adopted by SCEC upon its founding on February 1, 1991 and revised in February, 1996.

ARTICLE I

Name

Section 1. The name of the Center is the Southern California Earthquake Center.

ARTICLE II

Member Institutions

Section 1. Core Institutions. The following named institutions shall be Core Institutions:

* California Institute of Technology
* Columbia University
Harvard University
Massachusetts Institute of Technology
San Diego State University
Stanford University
United States Geological Survey, Golden
United States Geological Survey, Menlo Park

* United States 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

* The *founding* Core Institutions of SCEC.

Section 2. Obligations and Responsibilities of Core Institutions. SCEC Core Institutions are designated academic and Government research organizations with major research programs in earthquake science. Each Core Institution is expected to contribute a significant level of effort (both in personnel and activities) to SCEC programs, including the Communications, Education and Outreach Program. Core Institutions are obligated to contribute a yearly minimum of $35K of institutional resources as matching funds to Center activities. Each core institution shall appoint an *Institutional Director* to the SCEC Board of Directors, who shall represent the appropriate Dean, Office Chief, or higher officer as described in Article III.

Section 3. Addition of Core Institutions. Additional institutions that meet the requirements specified in Article I, Section 2 may become Core Institutions by a two-thirds affirmative vote of the entire Board of Directors.

Section 4. Removal of Core Institutions. Any Core Institution may resign as a Core Institution at any time by giving written notice from the appropriate Dean, Office Chief, or higher officer to the Center Director. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein. Any Core Institution may be removed by affirmative vote of N–1 Directors, where N is the total number of Directors. Any Core Institution that fails to provide a qualified Institutional Director for a period exceeding one year shall be removed as a Core Institution.

Section 5. Participating Institutions. In addition to Core Institutions, SCEC membership shall be open to *Participating Institutions*. Eligible institutions shall include any organization (including profit, not-for-profit, domestic, or foreign) involved in a Center-related research, education, or outreach activity. Participating Institutions do not necessarily receive direct support from the Center. Each Participating Institution shall appoint a qualified *Institutional Liaison* to facilitate communication with the Center. The interests of Participating Institutions shall be represented on the Board of Directors by two Directors At-Large, elected as specified in Article III, Section IV.

Section 6. Election of Participating Institutions. Election to the status of Participating Institution requires a majority affirmative vote of the entire Board of Directors.

Section 7. Removal of Participating Institutions. Any Participating Institution may resign at any time by giving written notice to the Center Director. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein. The status of Participating Institution may be withdrawn by a two-thirds affirmative vote of the entire Board of Directors.

Any Participating Institution that fails to provide a qualified Institutional Liaison for a period exceeding one year shall be removed as a Core Institution.

Section 8. Current roster of Core and Participating Institutions. The current list of Core and Participating Institutions shall be public and maintained in an accessible location, such as the Center web site.

ARTICLE III

Board of Directors

Section 1. Powers. The management of the affairs of the Center is vested in the Board of Directors. The Board of Directors shall have power to authorize action on behalf of the Center, make such rules or regulations for its management, create such additional offices or special committees, and select, employ or remove such of its officers, agents or employees as it shall deem best.

Section 2. Composition. The Board of Directors shall be composed of Institutional Directors from each of the Core Institutions and two Directors At-Large.

Section 3. Appointment of Core Institution Directors. The *Institutional Director* from each academic Core Institution shall be appointed by the appropriate Dean, or higher level officer, in a letter to the Center Director. The Institutional Director from the U.S. Geological Survey offices shall be appointed by the appropriate USGS official in a letter to the Center Director.

Section 4. Appointment of Directors At-Large. Two *Directors At-Large* shall be elected for two-year terms from a slate of three or more nominees proposed by a Nominating Committee of the Participating Institutions. The Nominating Committee will be appointed by the Center Director.

Section 5. Term of Office, Core Directors. Each Institutional Director of the Board of Directors shall continue in office until a successor is appointed; or until he or she dies, resigns or is replaced by the relevant officer of the Core Institution as specified in Article III Section 7; or until his or her institution is removed from the list of Core Institutions.

Section 6. Term of Office, Directors At-Large. Each Director At-Large shall serve a term of two years and may be reelected for up to two additional terms. The term of a Director At-Large may be terminated by a vote of N–1 of the entire board, where N is the total number of Directors.

Section 7. Resignation, Core Directors. Any Institutional Director may resign at any time by giving written notice to the Chairman of the Board of Directors and the appropriate academic dean or USGS official. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein. Upon resignation of an Institutional Director, the Core Institution shall appoint a new Institutional Director within 30 days, or resign as a Core Institution.

Section 8. Resignation, Core Directors. Any Director At-Large may resign at any time by giving written notice to the Chairman of the Board of Directors. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein. Upon resignation of an Director At-Large, the Board of Directors shall elect a new Director At-Large within 30 days.

Section 9. Alternate Members. Any Core Institution Director may appoint for a specified time interval, not to exceed one year, an Alternate Member from the same Core Institution to replace Core Institution Director in all of the activities during that interval. Such appointments must be transmitted in writing to the Center Director before taking effect.

Section 9. Salary Compensation. There shall be no salary compensation from Center funds for Institutional Directors and Directors-At-Large. The Center Director and/or Deputy Director may receive salary compensation from Center funds at a level approved by the Board and commensurate with administrative activities carried out on behalf of the Center.

ARTICLE IV

Meetings of the Board of Directors

Section 1. Annual Meeting. The Board of Directors shall hold at least one annual Board meeting at a time convenient for all members of the Board for the purpose of conducting center business.

Section 2. Special Meetings. Special meetings of the Board of Directors may be called by the Chair or Vice-Chair of the Board at any time.

Section 3. Place of Meetings. The Center Director shall designate the place of the annual Board meeting or any special meeting, which may be either within or without the State of California and which shall be specified in the notice of meeting or waiver of notice thereof.

Section 4. Notice of Meetings. Notice of such meeting of the Board of Directors shall be given to each Director by the Executive Secretary, or by an officer directed by the Chairman of the Board of Directors to give such notice by delivering to him or her personally, or by first-class mail or e-mail addressed to him or her at the address of his or her member institution, a written or printed notice not less than ten nor more than sixty days before the date fixed for the meeting. Notice of any meeting need not be given to any Director, however, who submits a signed waiver of notice, whether before or after the meeting. The attendance of any Director at a meeting without protesting the lack of notice thereof prior to the conclusion of the meeting, shall constitute a waiver of notice by him or her. When a meeting is adjourned to another place or time, it shall not be necessary to give any notice of the adjourned meeting if the time and place to which the meeting is adjourned are announced at the meeting at which the adjournment is taken.

Section 5. Quorum. Except as may be otherwise expressly required by law or these By-Laws, at all meetings of the Board of Directors or of any committee thereof, a majority of the Directors or members of such committee then serving in such position shall constitute a quorum. If a quorum is not present, a majority of the Directors present may adjourn the meeting without notice other than by announcement at said meeting, until a quorum is present. At any duly adjourned meeting at which a quorum is present, any business may be transacted which might have been transacted at the meeting as originally called.

Section 6. Executive Sessions. The Board of Directors may, at the direction of the Chairman of the Board of Directors, meet in executive session. At such executive session, the meeting will be open only to Directors, the Executive Secretary, and other persons specifically invited by the Chairman of the Board of Directors.

Section 7. Voting. Each Director shall be entitled to one vote. Except as otherwise expressly required by law, or these By-Laws, all matters shall be decided by the affirmative vote of a majority of the entire Board of Directors membership, if a quorum is then present. All votes shall be by voice vote, unless two members request a secret ballot. Votes pertaining to elections are governed by Article VII.

Section 8. Action Without a Meeting. Any action required or permitted to be taken by the Board of Directors or any committee thereof, may be taken without a meeting if all members of the Board of Directors consent in writing or by e-mail to the adoption of a resolution authorizing the action. The resolution and the written consents thereof shall be filed with the minutes of the proceedings of the Board of Directors or the committee.

Section 9. Participation by Telephone or Televideo Conference. In any meeting of the Board of Directors or any committee thereof, any one or more Directors or members of any such committee may participate by means of a telephone or televideo conference allowing all persons participating in the meeting to hear and/or see each other at the same time. Participation by such means shall constitute presence in person at a meeting.

ARTICLE V

Officers

Section 1. Officers and Qualifications. The officers of the Center shall consist of a Center Director, a Deputy Director, an Executive Secretary, and other such officers as the Board of Directors may from time to time establish, deem qualified and appoint.

Section 2. Center Director. The *Center Director* is the Chief Executive Officer of the Center and Chairman of the Board of Directors. It shall be his or her duty, insofar as the facilities and funds furnished to him or her by the Center permit, to see that the orders and votes of the Board of Directors and the purposes of the Center are carried out. He/she must be a full-time faculty member at one of the Center's Core Institutions, and shall be the Principal Investigator on all proposals submitted by the Center to external agencies. He/she shall be the board member for his/her home institution. The Center Director is the Center's official liaison to the rest of the world and, specifically, to the funding agencies. The Center Director will be the principal person for dealing with questions and concerns raised by members of the Center or from the outside. As Chairman of the Board of Directors, he/she shall call and preside at all meetings of the Board of Directors. He/she shall perform other such duties and exercise other such powers as shall from time to time be assigned by the Board of Directors. The Chairman shall have final authority for the science program, budget and financial obligations of the Center. The Chairman may appoint advisory committees or panels to assist in carrying out the business of the Center. The Center Director oversees, in consultation with the Board, the implementation of the Science Plan for the Center and will maintain day-to-day oversight of the science activities. Chairs of standing committees of the Board will report to the Chairman of the Board.

Section 4. Deputy Director. The *Deputy Director* of the Center will assist the Center Director in all his/her duties. He/she shall be nominated by the Center Director and elected by the entire Board of Directors. He/she shall serve as a non-voting *ex-officio* member of the Board of Directors. The Deputy Director will chair the Planning Committee described in Article VI, Section 4. He/she will oversee the CEO program, and will serve as liaison with SCEC partners.

Section 5. Vice-Chair of the Board of Directors. The Board of Directors will elect a *Vice-Chair* from among its members. He/she shall serve as chair of the Board of Directors in the absence of the Center Director.

Section 6. Associate Director for Administration and Executive Secretary to the Board. The *Associate Director for Administration* is the senior staff person to the Board of Directors, the Center Director, and the Deputy Director. He/she shall be nominated by the Center Director and confirmed by a vote of the Board of Directors. He/she reports to the Director and is Executive Secretary to the Board. The Executive Secretary shall give notice of meetings of the Board of Directors, shall record all actions taken at such meetings and shall perform such other duties as shall from time to time be assigned by the Board of Directors.

Section 7. Associate Director for Communication, Education and Outreach. The Center Director shall nominate an *Associate Director for Communications, Education, and Outreach* (CEO). The nominee will be confirmed by a vote of the Board of Directors. The Associate Director for CEO shall oversee the Center programs in communications, education, and knowledge transfer. He/she shall be a non-voting *ex-officio* member of the Board of Directors.

Section 8. Other Associate Directors. Other Associate Directors may be established through nomination by the Center Director for specific activities of the Center and approval by the Board.

Section 9. Resignation of Officers. Any officer may resign at any time by giving written notice to the Center Director, or the Executive Secretary of the Board of Directors. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein.

Section 10. Vacancies of Officers. Any vacancy in any office may be filled for the unexpired portion of the term of such office by the Center Director with approval of the Board of Directors.

Section 11. Removal of Officers. Any officer may be removed at any time either with or without cause by affirmative vote of N–1 Directors, where N is the total number of Directors. Removal of the Center Director also requires the consent of funding agencies.

ARTICLE VI

Committees and Advisory Council

Section 1. Establishment of Committees of the Board of Directors. Committees of the Board of Directors may be established for specified terms. Actions by the Board of Directors to create Committees shall specify the scope of Committee activity. Committee members shall be appointed by the Chairman of the Board of Directors. Committee chairs shall be appointed by the Chairman of the Board of Directors from among members of the Center. Committees may not set policy nor take binding action nor publish documents without the consent of the Board of Directors. Committees may not create or appoint Subcommittees without consent of the Board of Directors.

Section 2. Executive Committee of the Board of Directors. The Board of Directors shall establish an *Executive Committee* to take care of the day-to-day business of the Center. The powers of the Executive Committee shall be established by a two-thirds affirmative vote of the entire Board. All actions taken by the Executive Committee must be reported to the full Board with ten business days. The Executive Committee shall consist of the Chairman and Vice Chairman of the Board and three other Board members elected for staggered three-year, renewable terms. The Executive Committee shall hold a business meeting, either in person or by electronic means at least once per quarter. The Executive Secretary of the Board shall serve as Secretary of the Executive Committee, and shall be responsible for transmitting minutes and actions of the Executive Committee to the entire Board.

Section 3. Standing Committees. The Board of Directors may designate one or more *Standing Committees* for each major scientific, educational or research program of the Center. Members of each such committee shall have only the lawful powers specifically delegated to it by the Board. Each such committee shall serve at the pleasure of the Board. Members of a Standing Committee are not required to hold a Director or officer position within the Center. Standing Committees shall prepare plans for the appropriate scientific, educational, or research programs of the Center. These plans shall be modified as appropriate and approved by the Center Director with the advice and counsel of the Board of Directors.

Section 4. Planning Committee. A *Planning Committee* shall be appointed by the Center Director with approval of the Board of Directors. The Planning Committee shall be responsible for conducting the annual proposal review process and constructing annual and long-term science and budget plans for consideration by the Board of Directors. It shall be chaired by the Deputy Director, and its membership shall be constituted to provide a balanced representation of the various disciplines and focus areas of the Center. Planning Committee meetings will be called by the Deputy Director.

Section 5. Advisory Council. The Board of Directors will establish an *Advisory Council* to serve as an experienced advisory body to the Board. The members of the Council shall serve for three-year rotating renewable terms (by thirds). The chair of the Advisory Council shall be appointed for a three-year term by the Center Director in consultation with the Board and may be reappointed for two additional terms. The size and responsibilities of the Council shall be determined by the Board of Directors to reflect current needs of the Center.

ARTICLE VII

Election Procedures

Section 1. Procedure. Officers may be elected by the Board of Directors at any meeting, in accordance with the procedures established in this Article.

Section 2. Election. Election shall be by written ballot, which may be cast in person by a Director at the meeting, or may be submitted by mail, facsimile, or e-mail if received by the Executive Secretary before the meeting. The Executive Secretary will treat all electronic ballots as secret ballots. Election shall be valid if ballots are received from two-thirds of the membership of the entire Board of Directors in accordance with this Article, even if a quorum is not present for the purpose of conducting other business.

Section 3. Method of Voting. In the election of officers, a valid ballot shall contain at most one vote for each office; election shall be decided in favor of the nominee receiving a majority of votes.

Section 4. Counting of Ballots. Ballots shall be counted by the Executive Secretary and the Chairman and Vice-Chairman of the Board of Directors, unless they have cause for recusal.

ARTICLE VIII

Amendments

Section 1. Amendment. All By-Laws of the Center shall be subject to amendment or repeal by the affirmative vote of two-thirds of the entire Board of Directors at any annual or special meeting, provided the notice or waiver of notice of said meeting shall have specified the proposed actions to amend or repeal the By-Laws.

Appendix C. 2004 PROGRAM ANNOUNCEMENT

FOR THE SOUTHERN CALIFORNIA EARTHQUAKE CENTER

I. INTRODUCTION

On February 1, 2002, the Southern California Earthquake Center (SCEC) changed from an entity within the NSF/STC program to a free-standing center, funded by NSF/EAR and the U. S. Geological Survey. This document solicits proposals from individuals and groups to participate in the third year of the program.

II. GUIDELINES FOR PROPOSAL SUBMISSION

A. Due Date: November 17, 2003, 5:00 pm PST. Late proposals will not be accepted.

B. Delivery Instructions. Proposals and annual reports should be submitted as separate PDF documents via the SCEC Proposal web site at http://www.scec.org/proposals. Submission procedures will be found at this web site.

C. Formatting Instructions.

- ***Cover Page:*** Should begin with the words "2004 SCEC Proposal," the project title, Principal Investigator, institution, proposal category (from types listed in Section IV), and the disciplinary committee(s) and focus group(s) that should consider your proposal. Indicate if the proposal should also be identified with one or more of the SCEC special projects (SCIGN, Borderland, and IT) or advanced Implementation Interface projects (see Section VII.B for examples). Collaborative proposals involving multiple investigators and/or institutions should list all principal investigators. Proposals do not need to be formally signed by institutional representatives, and should be for one year, with a start date of February 1, 2004.
  - ***Technical Description:*** Describe in **five pages or fewer (including figures)** the technical details of the project and how it relates to the short-term objectives outlined in the SCEC Science Plan (Section VI.B).
  - ***Budget Page:*** Budgets and budget explanations should be constructed using NSF categories. Under guidelines of the SCEC Cooperative Agreements and A-21 regulations, secretarial support and office supplies are not allowable as direct expenses.
  - ***Current Support:*** Statements of current support, following NSF guidelines, should be included for each Principal Investigator.
  - ***2003 Annual Report:*** Scientists funded by SCEC in 2003 must submit a report of their progress to the 2004 proposals. 2004 proposals lacking 2003 reports (which may cover 2002 to mid-year 2003 results) will neither be reviewed nor will they be considered for 2004 funding. Reports should be up to five pages of text and figures.

D. Investigator Responsibilities. Investigators are expected to interact with other SCEC scientists on a regular basis (e.g., by attending workshops and working group meetings), and contribute data, analysis results, and/or models to the appropriate SCEC data center (e.g., Southern California Earthquake Data Center—SCEDC), database (e.g., Fault Activity Database—FAD), or community model (e.g., Community Velocity Model—CVM). Publications resulting entirely or partially from SCEC funding must include a publication number available at http://www.scec.org/research/scecnumber/index.html. By submitting a proposal, investigators are agreeing to these conditions.

E. Eligibility. Proposals can be submitted by eligible Principal Investigators from:
- U.S. Academic institutions
- U.S. Private corporations

F. Collaboration. Collaborative proposals with investigators from the USGS are encouraged. USGS employees should submit their requests for support through USGS channels. Collaborative proposals involving multiple investigators and/or institutions are strongly encouraged; these can be submitted with the same text, but with different institutional budgets if more than one institution is involved.

G. Award Procedures. All awards will be funded by subcontract from the University of Southern California. The Southern California Earthquake Center is funded by the National Science Foundation and the U. S. Geological Survey.

III. SCEC ORGANIZATION

A. Mission and Science Goal. SCEC is an interdisciplinary, regionally focused organization with a mission to:
- Gather new information about earthquakes in Southern California;
- Integrate this information into a comprehensive and predictive understanding of earthquake phenomena; and
- Communicate this understanding to end-users and the general public in order to increase earthquake awareness, reduce economic losses, and save lives.

SCEC's primary science goal is to develop a comprehensive, physics-based understanding of earthquake phenomena in Southern California through integrative, multidisciplinary studies of plate-boundary tectonics, active fault systems, fault-zone processes, dynamics of fault ruptures, ground motions, and seismic hazard analysis. The long-term science goals are summarized in Section VI.A.

B. Disciplinary Activities. The Center sustains disciplinary science through standing committees in *seismology*, *geodesy*, *geology*, and *fault and rock mechanics*. These committees will be responsible for planning and coordinating disciplinary activities relevant to the SCEC science plan, and they will make recommendations to the SCEC Planning

Committee regarding support of disciplinary research and infrastructure. High-priority disciplinary activities are summarized in Section VI.A.

C. Interdisciplinary Focus Areas. Interdisciplinary research is organized into five science focus areas: 1) *unified structural representation*, 2) *fault systems*, 3) *earthquake source physics*, 4) *ground motion*, *and* 5) *seismic hazard analysis*. In addition, interdisciplinary research in risk assessment and mitigation will be the subject for collaborative activities between SCEC scientists and partners from other communities including earthquake engineering, risk analysis, and emergency management. High-priority activities are listed for each of these interdisciplinary focus areas in Section VI.B.

D. Special Projects. SCEC encourages and supports several special projects including the Southern California Integrated GPS network (SCIGN), the Southern California Continental Borderland initiative, and the development of an advanced IT infrastructure for system-level earthquake science in Southern California. High-priority activities are listed for each of these interdisciplinary focus areas in Section VI.C.

E. Communication, Education, and Outreach. SCEC maintains a strong Communication, Education, and Outreach (CEO) program with four principal goals: 1) coordinate productive interactions among SCEC scientists and with partners in science, engineering, risk management, government, business, and education; 2) increase earthquake knowledge and science literacy at all educational levels; 3) improve earthquake hazard and risk assessments; 4) promote earthquake preparedness, mitigation, and planning for response and recovery. Opportunities for participating in the CEO program are described in Section VII. Current activities are described online at http://www.scec.org/ceo.

IV. Proposal Categories

A. Data Gathering and Products. SCEC coordinates an interdisciplinary and multi-institutional study of earthquakes in Southern California, which requires data and derived products pertinent to the region. Proposals in this category should address the collection, archiving and distribution of data, including the production of SCEC community models that are on-line, maintained, and documented resources for making data and data products available to the scientific community.

B. Integration and Theory. SCEC supports and coordinates interpretive and theoretical investigations on earthquake problems related to the Center's mission. Proposals in this category should be for the integration of data or data products from Category A, or for general or theoretical studies. Proposals in Categories A and B should address one or more of the goals in Section VI, and may include a brief description (<200 words) as to how the proposed research and/or its results might be used in an educational or outreach mode (see section VII).

C. Workshops. SCEC participants who wish to host a workshop between February 2004, and February 2005, should submit a proposal for the workshop in response to this RFP. Workshops in the following topics are particularly relevant:

- Organizing collaborative research efforts for the five-year SCEC program (2002-2007). In particular, interactive workshops that engage more than one focus and/or disciplinary group are strongly encouraged.
- Engaging earthquake engineers and other partner and user groups in SCEC-sponsored research.
- Participating in national initiatives such as EarthScope, the Advanced National Seismic System (ANSS), and the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES).

D. Communication, Education, and Outreach. SCEC has developed a long-range CEO plan, and opportunities for participation are listed in Section VII. Investigators who are interested in participating in this program should contact Mark Benthien (213-740-0323; benthien@usc.edu) before submitting a proposal.

V. EVALUATION PROCESS AND CRITERIA

- Proposals should be responsive to the RFP. A primary consideration in evaluating proposals will be how directly the proposal addresses the main objectives of SCEC. Important criteria include (not necessarily in order of priority):
    - Scientific merit of the proposed research
    - Competence and performance of the investigators, especially in regard to past SCEC-sponsored research
    - Priority of the proposed project for short-term SCEC objectives as stated in the RFP
    - Promise of the proposed project for contributing to long-term SCEC goals as reflected in the SCEC science plan (see Appendix A).
    - Commitment of the P.I. and institution to the SCEC mission
    - Value of the proposed research relative to its cost
    - Ability to leverage the cost of the proposed research through other funding sources
    - Involvement of students and junior investigators
    - Involvement of women and underrepresented groups
    - Innovative or "risky" ideas that have a reasonable chance of leading to new insights or advances in earthquake physics and/or seismic hazard analysis.

- Proposals may be strengthened by describing:
- Collaboration
    - Within a disciplinary or focus group
    - Between disciplinary and/or focus groups
    - In modeling and/or data gathering activities
    - With engineers, government agencies, and others. (See Section VII.B, Advanced Implementation Interface)
- Leveraging additional resources
    - From other agencies

    - From your institution
    - By expanding collaborations
- **Development and delivery of products**
    - **Community research tools, models, and databases**
    - **Collaborative research reports**
    - **Papers in research journals**
    - **End-user tools and products**
    - **Workshop proceedings and CDs**
    - **Fact sheets, maps, posters, public awareness brochures, etc.**
    - **Educational curricula, resources, tools, etc.**
- Educational opportunities
    - Graduate student research assistantships
    - Undergraduate summer and year-round internships (funded by the project)
    - K-12 educator and student activities
        - Presentations to schools near research locations
        - Participation in data collection

- All research proposals will be evaluated by the appropriate disciplinary committees and focus groups, the Science Planning Committee, and the Center Director. CEO proposals will be evaluated by the CEO Planning Committee and the Center Director.
- The Science Planning Committee is chaired by the Deputy Director and comprises the chairs of the disciplinary committees, focus groups, and special projects. It is responsible for recommending a balanced science budget to the Center Director.
- The CEO Planning Committee is chaired by the Associate Director for CEO and comprises experts involved in SCEC and USGS implementation, education, and outreach. It is responsible for recommending a balanced CEO budget to the Center Director.

- Recommendations of the planning committees will be combined into an annual spending plan by the Executive Committee of the SCEC Board of Directors and forwarded to the Board of Directors for approval.

- Final selection of research projects will be made by the Center Director, in consultation with the Board of Directors.

- The review process should be completed and applicants notified by mid-February, 2004.

VI. Coordination of Research between SCEC and USGS-ERHP

Earthquake research in Southern California is supported both by SCEC and by the USGS Earthquake Hazards Reduction Program (EHRP). EHRP's mission is to provide the scientific information and knowledge necessary to reduce deaths, injuries, and economic losses from earthquakes. Products of this program include timely notifications of earthquake locations, size, and potential damage, regional and national assessments of earthquakes hazards, and increased understanding of the cause of earthquakes and their effects. EHRP funds research via its External

Research Program, as well as work by USGS staff in its Pasadena, Menlo Park, and Golden offices. The EHRP also supports SCEC directly with $1.1M per year.

SCEC and EHRP coordinate research activities through formal means, including USGS membership on the SCEC Board of Directors and a Joint Planning Committee, and through a variety of less formal means. Interested researchers are invited to contact Dr. Lucy Jones, EHRP coordinator for Southern California, or other SCEC and EHRP staff to discuss opportunities for coordinated research.

The USGS EHRP supports a competitive, peer-reviewed, external program of research grants that enlists the talents and expertise of the academic community, State and local government, and the private sector. The investigations and activities supported through the external program are coordinated with and complement the internal USGS program efforts. This program is divided into six geographical/topical 'regions', including one specifically aimed at southern California earthquake research and others aimed at earthquake physics and effects and at probabilistic seismic hazard assessment (PSHA). The Program invites proposals that assist in achieving EHRP goals.

The EHRP web page, http://erp-web.er.usgs.gov/, describes program priorities, projects currently funded, results from past work, and instructions for submitting proposals. The EHRP external funding cycle is several months offset from SCEC's, with the RFP due out in February and proposals due in early May. Interested PI's are encouraged to contact the USGS regional or topical coordinators for Southern California, Earthquake Physics and Effects, and/or National (PSHA) research, as listed under the "Contact Us" tab.

USGS internal earthquake research is summarized by topic at http://earthquake.usgs.gov/scitech/research/ and by project at http://earthquake.usgs.gov/research/program/. Projects of particular relevance to SCEC are described under the following titles:

- Southern California Earthquake Project
- FOCUS on Quaternary Stratigraphy in the Los Angeles Region
- National Seismic Hazard Maps
- Earthquake Probabilities And Occurrence
- The Physics of Earthquakes
- Earthquake Effects
- Deformation
- U.S. National Strong Motion Program
- Earthquake Information
- Seismograph Networks

VII. RESEARCH OBJECTIVES

The research objectives outlined below are priorities for immediate research. They carry the expectation of substantial and measurable success during the coming year. In this context, success includes progress in building or maintaining a sustained effort to reach a long-term goal. How proposed projects address these priorities will be a major consideration in proposal evaluation, and they will set the programmatic milestones for the Center's internal assessments. In addition to the priorities outlined below, the Center will also entertain innovative and/or "risky" ideas that may lead to new insights or major advancements in earthquake physics and/or seismic hazard analysis.

A. Disciplinary Activities

The Center will sustain disciplinary science through standing committees in *seismology*, *geodesy*, *geology*, and *fault and rock mechanics*. These committees will be responsible for planning and coordinating disciplinary activities relevant to the SCEC science plan, and they will make recommendations to the SCEC Planning Committee regarding the support of disciplinary infrastructure. High-priority disciplinary objectives include the following tasks:

1. Seismology

Data Gathering: Maintain and improve the ability of SCEC scientists to collect seismograms to further the goals of SCEC. Efforts may include: 1) Maintaining and adding to the network of borehole seismometers in order to improve resolution of earthquake source physics and the influence of the near-surface on ground motions, and 2) maintaining and upgrading a pool of portable instruments in support of targeted deployments or aftershock response.

Other activities might include seed money for design of future experiments such as dense array measurements of basin structure and large earthquake properties, OBS deployments, and deep basement borehole studies. Workshops to explore SCEC's interface with EarthScope are encouraged.

Data Products: Improve the ability of users to retrieve seismograms and other seismic data and enhance the usefulness of data products, such as catalogs of earthquake parameters, arrival time and polarity information, and signal-to-noise measures. An important SCEC resource is the Southern California Earthquake Data Center (SCEDC), which continues to be an integral part of the Center. The continued operation of the SCEDC is essential to deciphering Southern California seismicity and fault structure.

Enhancements to the SCEDC are encouraged that will extend its capabilities beyond routine network operations and waveform archiving, and assist researchers in using more of the data. Desirable improvements include support hardware and software enhancements, better integration with data centers in other regions, and expansion of catalogs, including the offshore region. Specific goals include: 1) developing the ability to preview seismograms and construct record sections before downloading, 2) implementing software that permits accessing both northern and southern California data with a single data request, 3) improving feedback mechanisms for users to report problems and assist in network quality control, 4) incorporating additional catalogues of locations and moment tensors as they become available, and 5) keeping the database up to date with current data.

2. Tectonic Geodesy

Data gathering: Provide support to assist in the operation of, and data distribution from, the Southern California Integrated GPS Network (SCIGN); support to be provided in response to a single proposal (addressing all aspects of SCIGN), prepared by the SCIGN Executive Committee and approved by the SCIGN Coordinating Board.
Provide support to assist in the operation of, and data distribution from, the WInSAR Archive.

Support the collection of geodetic data (other than continuous GPS) that will improve knowledge of crustal motion in areas of special interest; the proposal should explain how this improvement is likely to occur. Examples of such areas are the San Gabriel Mountains, the Ventura and Los Angeles Basins, northern Baja California, the Garlock fault, and the eastern California Shear Zone north of the Landers/Hector-Mine area. Provide support to assist in the collection of other data relevant to time-varying deformation. Support acquisition and distribution of high-resolution topographic data in areas where it will be useful to other SCEC activities.

Data products: Prepare and release Version 4.0 of the Crustal Motion Map, which should incorporate additional GPS data and other data (possibly along a larger portion of the transform boundary) and provide estimates of vertical motions, along with better descriptions of the postseismic and coseismic motions from previous earthquakes. Support small-scale projects which use InSAR data, combined with other measurements, to improve our knowledge of tectonic deformation (which may include delineating areas of nontectonic motion). Investigate the usefulness of combining GPS data with data from inertial seismometers for improving measurements of ground motion.

3. Earthquake Geology

Data gathering: Plan, coordinate, and provide infrastructure for onshore and offshore geologic fieldwork, including chronologic support and shared equipment; formulate field tests of paleoseismic methodology; collect new information on fault slip rates, including rates over 10^4-10^6 year timescales to compare to short term and GPS rates, paleoseismic chronologies that span multiple recurrence cycles, slip in past earthquakes, and other geologic measurements of active tectonics; develop, build and contribute new and existing data sets to the Fault Information System (FIS), including probability density functions of earthquake event ages; complete initial population of the vertical motion database and incorporate as a layer into the FIS; assess models used to segment fault zones and the role of structural features that limit fault rupture. Foster subsurface analysis of fault systems, including blind thrusts and the role of off-fault deformation; begin incorporation of horizon structure maps, including well-dated Quaternary stratigraphy and magnetic reversal stratigraphy, all in a geo-referenced format, for incorporation into the FIS; develop techniques to test and validate kinematic and structural models of fold and fault growth.

Develop methodology to test and improve resolution of event chronologies, including methods for resolving event correlations; develop statistical tests for models of earthquake recurrence, clustering and other behavior based on geologic data; compile existing information and conduct detailed studies of fault zone materials and structures in and adjacent to active and exhumed faults in order to understand deformation processes and conditions, and their implications for the nucleation and propagation of earthquake ruptures.

Organize workshops and other activities to develop proposals for alternative major sources of external funding of collection of earthquake geology data.

Data products: Integrate field and laboratory efforts to date geologic samples and events, including standardized procedures for field documentation, sample treatment, dating methodologies, and data archiving and distribution (FAD); produce long-term rupture histories for selected fault systems in Southern California, with specific interest in the Los Angeles, Mojave, and southern San Andreas systems; construct a community vertical motions map (10^5 yr timescale).

4. Fault and Rock Mechanics

Data gathering: Areas of FARM research include fault modeling, laboratory studies, and field studies of exhumed faults. While all areas of FARM research in support of the interdisciplinary working groups will be considered, greatest emphasis will be given to research that can increase our understanding of fault behavior during dynamic earthquake slip and thereby provide useful input for models of dynamic rupture propagation. In particular, emphasis will be given to: 1) pilot studies to determine the feasibility of using a variety of new experimental techniques to measure sliding resistance at seismic slip rates, with the aim of ascertaining whether these techniques, or perhaps a new facility using these or other techniques, might allow the collection of these important data, 2) exploring the capabilities of a variety of existing and analytical techniques, and laboratories, to detect and characterize small amounts of rheologically important materials on slip surfaces in experimental and natural fault zones, and 3) modeling activities to predict fault behavior during dynamic slip with extreme weakening. Also of importance, but of lower priority, is to conduct coordinated field, laboratory and theoretical studies to determine the time evolution of physical parameters during the inter-seismic period that might control the onset and characteristics of earthquake faulting. Such parameters might include those controlling fault/fluid interactions and frictional properties.

Data products: Assess information and products from rock-mechanics experiments and fieldwork that will be most useful in SCEC studies of earthquake source physics and fault-system dynamics; begin to outline an IT framework for an open database of experimental, model, and field results.

Workshops fostering collaborative interactions for research on fault and earthquake processes are encouraged.

B. Interdisciplinary Focus Areas

Interdisciplinary research will be organized into five science focus areas**: 1) structural representation, 2) fault systems, 3) earthquake source physics, 4) ground motion, and 5) seismic hazard analysis.** In addition, interdisciplinary research in risk assessment and mitigation will be the subject for collaborative activities between SCEC scientists and partners from other communities – earthquake engineering, risk analysis, and emergency management. This partnership will be managed through: **6) an implementation interface**, designed to foster two-way communication and knowledge transfer between the different communities. SCEC will also sponsor a partnership in**: 7) information technology**, with the goal of developing an advanced IT infrastructure for system-level earthquake science in Southern California. High-priority objectives are listed for each of the five interdisciplinary focus areas below. Collaboration within and across focus areas is strongly encouraged.

1. Structural Representation

- ***Community velocity model (CVM):*** Refine and test the CVM by improving the definition of model objects (e.g., incorporating fault representations from the Community Fault Model), evaluating the model with data (e.g., waveforms, gravity), and comparing the model to alternative structural representations. Add attenuation to the model. Quantify the uncertainties in the model. Provide interfaces with focus and disciplinary groups to permit ready use of the model. Develop specifications for new velocity model schemes that will facilitate alternative parameterizations.

- ***Community fault model (CFM):*** Improve and evaluate the CFM, placing emphasis on: a) defining the geometry of major faults that are incompletely, or inaccurately represented in the current model; b) producing and evaluating alternative fault representations, and c) delivering the model and database to users.

- ***Unified structural representation (USR):*** Develop specifications for a unified, object-oriented representation of active faults and 3D earth structure for use in fault-system analysis, earthquake source physics, and ground-motion prediction. Refine the Community Block Model (CBM). Begin integration of CVM, CBM, and CFM into the USR.

2. Fault Systems

- ***Fault-system behavior:*** Investigate the system-level architecture and behavior of fault networks to better understand the cooperative interactions that take place over a wide range of scales, assessing the ways in which the system-level behavior of faults controls seismic activity and regional deformation; produce fault-slip and surface-strain maps from the CMM; compare short-term geodetic rates with long-term geologic rates and explain the differences; quantify the space-time behavior of the Southern California fault system, both on-shore and off-shore, using tectonic geomorphology, paleoseismology, historical records of seismicity, and instrumental catalogs; foster collaborations to obtain outside funding to investigate paleoseismic earthquake history to illuminate disagreements between geodetic and geologic inferences of fault slip rates and discriminate among competing stress evolution and seismicity simulation models; determine how geologic deformation is partitioned between slip on faults and distributed off-fault deformation and how geodetic strain is partitioned between long-term and short-term elastic strain and on-fault slip or permanent distributed strain.

- ***Deformation models:*** Develop, validate, and facilitate use of modular 3D quasi-static codes for simulating crustal motions utilizing realistic, highly resolved geometries (e.g., USR fault geometry and elastic structure) and rheological properties (e.g., Burgers body viscoelasticity, rate-state friction, poroelasticity, damage rheology); develop representations of fault system behavior on scales smaller than can be resolved on computationally feasible meshes; develop a closed volume representation of southern California (Community Block Model—CBM) that unifies the geometric representations of CFM and the CVM and that serves as a basis for efficient meshing and remeshing of models; assess mechanical compatibility of CFM and how slip is transferred between recognized fault segments, beginning with simple geometries and moving to the actual geometry; evaluate mesh generation strategies and generate realistic finite element meshes of Southern California consistent with CFM and CVM/USR structure; develop models of time-dependent stress transfer and deformation of Southern California over multiple earthquake cycles addressing geologic slip rates, geodetic motions (including CMM 4.0), and earthquake histories; use these models to infer fault slip, 3D rheologic structure, and fault interactions through the transfer of stresses; test model predictions of stress evolution by comparisons with observations of state of stress, high-resolution earthquake location and mechanism studies, and constraints from earthquake source physics models; develop tectonic models that explain the rates of fault slip inferred for the southern California fault system; develop systems which can be used to estimate earthquake parameters to rapidly provide information, such as expected postseismic deformation, useful in planning post-earthquake geodetic deployments.

- ***Seismicity evolution models:*** Develop, validate, and facilitate use of codes for ensemble models simulating earthquake catalogs using CFM fault structure, USR and CBM, as well as stochastic representations of faults not included in CFM; incorporate constraints (including data assimilation) from geologic slip rates, geodetic data, realistic boundary conditions, and fault rupture parameterizations, including rate-state friction and normal stress variations; assess the processes that control the space-time-magnitude distribution of regional seismicity; quantify sources of complexity, including geometrical structure, stress transfer, fault zone heterogeneity, and slip dynamics; assess the utility of these models in forecasting Southern California earthquakes as part of the RELM effort; search for statistically significant signals in the space-time-magnitude distribution of seismicity and understand their physical origin.
- ***Quantify the temporal evolution of fault zone properties on postseismic, interseismic, and pre-rupture time scales to better understand stress transfer and to constrain conditions at the onset of failure (with Earthquake Source Physics):*** Develop numerical models of the interseismic period and couple them to quasi-static full-cycle fault models to better constrain stress transfer and conditions and processes at the start of dynamic rupture. Include forcing by realistic coseismic displacements and dynamic stresses.

3. Earthquake Source Physics

- ***Numerical simulations of the earthquake source****:*Conduct numerical simulations of dynamic rupture nucleation, propagation, and termination that include known or realistic complexity in fault geometry, material properties, and stress state, with an emphasis on models that can test constitutive relations. Compare results with source and fault zone observations. Use this information to test hypotheses or develop new testable hypotheses about earthquake source physics. Explore what aspects of the source generate high-frequency waves. Use numerical simulations results to guide the use of fault segmentation in seismic hazards analysis (*joint with SHA Focus Group*). Participate in the code validation exercises for 3D spontaneous rupture simulations (Pathway 3 of the SCEC ITR) by performing benchmark tests and comparing results with the rest of the Pathway 3 community. Bridge the interface between Earthquake Source Physics and Fault Systems by conducting multi-earthquake-cycle physics-based dynamic simulations (*joint with Fault Systems Focus Group*).

- ***Reference earthquakes:*** Establish a reference southern California earthquake, such as Landers, for which geodetic, geologic, and seismological data (and metadata) as well as models derived from them, are gathered in a common database in order to facilitate comparison of different models and analysis of multiple datasets. The reference earthquake database will be used for testing/validation of earthquake physics concepts and modeling techniques and as a template for additional reference earthquakes.

- ***In-situ studies of fault-zones (exhumed faults and cores from depth):*** Examine and document features of fault zones in Southern California, including the San Andreas fault system, that reveal the mechanical, chemical, thermal, and kinematic processes that occur during dynamic rupture. Include measurements and inferences of on-fault and near-fault stress, slip-zone thickness, fine-scale fault-zone geometry, adjacent damage, and fluid content at seismogenic depths. *(Joint with Geology Disciplinary Group).*

- ***Earthquake scaling:*** Determine to what extent earthquake behavior depends on earthquake size. Determine if there are breaks in scaling behavior of quantities, such as stress drop or radiated seismic energy. If so, determine how they can constrain models of the earthquake source.

- ***Laboratory studies of the earthquake source:*** Explore lab experiments on faults in rock or analog materials, to determine shear resistance at high slip speeds (on the order of 1 m/s) and stress conditions at seismogenic depths (or appropriately scaled conditions for analog materials). Measure hydrologic properties of likely fault zone materials at high rates of deformation and fluid flow. Conduct theoretical studies of expected behavior for possible high-speed weakening mechanisms. Determine how changes in normal stress might affect shear resistance during dynamic rupture. Compare results with source observations. Use this information to test proposed constitutive relations or develop new testable constitutive relations. (*Joint with FARM).*

- ***Earthquake interaction as an approach to explain earthquake physics:*** Use observations of earthquake triggering or suppression to test models of earthquake interaction and constrain the physics of earthquake rupture nucleation, propagation, and arrest.

4. Ground Motions

- ***Deterministic wavefield modeling:*** Analyze the computed ground motion from the scenario earthquakes* for deterministic and stochastic effects. Determine how the complexity in the ground motion can be related to the complexity in the source. Determine where geometrical and geological structures manifest their presence in the ground motion. Compare wavefields for moderate-sized events (M 3.5 to 5.0 earthquakes) with synthetics using both the CVM and the Harvard model. Determine at what frequencies such events can be successfully modeled deterministically with particular attention to the SCEC borehole data when possible. Develop and quantify a goodness-of-fit criterion for time series. Use ground motion from scenario earthquakes to quantify differences in ground motion.

- ***CVM improvement:*** Use data from well-recorded earthquakes to assess, as a function of frequency, wavefield simulations based on the CVM. Improve the S-wave velocity structure in the CVM and the Harvard model. Develop models for seismic attenuation (1/Q) based on data recorded by CISN and borehole instruments in Southern California. Attenuation models are to complement the SCEC CVM and be used in comparisons between data and synthetics for well-recorded earthquakes. Develop methods for incorporating nonlinear site response for large amplitude ground motion events in Southern California. Ideas that improve our understanding of linear site response should make a significant improvement over the SCEC Phase 3 work or lead to a new understanding of how site response varies spatially. Develop methods for improving the accuracy and frequency range of deterministic 3D wavefield modeling, including the assimilation of seismographic data into the CVM. Compare 3D results with those from other structural representations including 1D and 2D representations that will allow propagation of higher frequencies.

- ***Stochastic wavefield models:*** *This is a high-priority research item in 2004*. Develop stochastic models of high-frequency ground motion that can be combined with models of low-frequency ground motion from scenario earthquakes* to predict strong ground motion. Validate models by comparisons and testing with observed data. Validate hybrid models—models that combine deterministic low-frequency with stochastic high-frequency ground motion—by comparing different metrics of the radiation versus data. For example, metrics that might be useful can be found in *Geotechnical Earthquake Engineering*, Chapter 3, Section 3, by Steven L. Kramer. Estimate the range of different ground motion parameters that might be expected from simulated broadband scenario earthquakes. Produce broadband ground motions for earthquake scenarios* simulated in 2003. Develop methods that assess broadband ground motion that include nonlinear site response.

*A description of scenario earthquakes will be posted on the SCEC website; data from the scenario earthquakes will be available to SCEC researchers.

5. Seismic Hazard Analysis

- ***OpenSHA*:** Contribute to the developing Community Modeling Environment for Seismic Hazard Analysis (known as OpenSHA; www.OpenSHA.org). This is an open-source, object oriented, and web-enabled framework that will allow various, arbitrarily complex (e.g., physics based) earthquake-rupture forecasts, ground-motion models, and engineering response measures to plug in for SHA. Part of this effort is to use information technology to enable the various models and databases they depend upon to be geographically distributed and run-time accessible. Contributions may include: 1) implementing any of the various components (in Java or other language), 2) testing any of the various components/applications, and 3) extending the existing framework to enable other capabilities, such as vector-valued hazard analysis, to interface with existing risk/loss estimation tools, or to web-enable the testing of the various RELM forecast models.

- ***Regional Earthquake Likelihood Models (RELM):*** Via the RELM working group, develop various, viable earthquake-forecast models for southern California (the more physics-based approaches should be developed in coordination with the Fault Systems focus group). Continue the development of shared data resources needed by the RELM working group, especially in terms of making them on-line and machine readable. These should be coordinated with other focus/disciplinary groups as appropriate (e.g., the needed quantification of alternative, internally-consistent fault-system representations should be coordinated with the CFM effort). Establish quantitative tests of the various forecast models using observed seismicity, precarious-rock constraints, historically observed intensity levels, or other viable approaches.

- ***Improved Intensity-Measure Relationships:*** Work with the Ground Motion focus group and/or the Implementation Interface to develop improved models for predicting intensity measures (empirical attenuation relationships, theoretical models, or hybrid approaches). Proposals to implement new types of Intensity Measures (new functionals of ground motion, or vectors of functionals) that predict engineering damage measures better than traditional peak acceleration or spectral response are encouraged.

- ***Contribute to SCEC's System-Level Earthquake Rupture Forecast Model:*** Although several of the RELM models are appropriately exploring the use of different types of information separately (e.g., a model based only on geology or only on geodesy), there is the need for a system-level model that attempts to reach consilience among all significant processes and constraints. Such a model is currently under development (see http://www.RELM.org/models/scec_erf). The structure of this model is necessarily object oriented, enabling different groups to develop the different modular components separately, as well as enabling alternative components (e.g., with more or less physics) to be swapped in or added later. Proposals will be considered for participation in the following tasks: 1) quantify alternative, viable CFMs for at least the greater LA region; 2) quantify slip rates for the CFM(s) using geology and/or other constraints; 3) quantify the stress-loading rates for faults in the CFM(s) using virtual dislocation, deep slip, community block, finite element, or other types of models; 4) develop fault-rupture models for faults in southern California (e.g., based on a synoptic view of paleoseismic data; with or without fault segmentation); 5) help constrain fault-to-fault rupture probabilities using dynamic-rupture modeling (or by compiling previous results thereof) 6) develop stress-change-dependent probability models; 7) develop stress-change monitors or calculators that provide the average stress change on an arbitrary surface caused by an arbitrary rupture (e.g., using Coulomb or viscoelastic models, or by inversion of observed seismicity using rate and state), 8) develop methods of adding foreshock/aftershock statistics to the model.

C. <u>Special Projects</u>

The following are SCEC special projects with which proposals in above categories can be identified.

1. SCIGN (www.scign.org)

Southern California now benefits from a state-of-the-art geodetic array for monitoring earthquake-related crustal deformation, and we encourage use of these data in support of the SCEC science goals and mission. The Southern California Integrated GPS Network (SCIGN), an array of 250 continuously operating GPS stations and one long-baseline laser strainmeter, tracks regional strain changes with unprecedented precision. Scientists of organizations participating in SCEC designed and manage SCIGN; SCEC also played a vital coordinating role in making SCIGN possible. The array is now operational and is already providing horizontal station velocities good to within 1 mm/yr for most stations. This new network provides data with which to improve seismic hazard assessments, through the innovation of new methods as part of the SCEC seismic hazard analysis efforts. SCIGN will also enable us to quickly measure the larger displacements that occur during and immediately after earthquakes, and it is important that these static deformation data are integrated with other intensity measures for use by emergency responders and the engineering community, through SCEC's Implementation Interface efforts. SCEC encourages proposals that make innovative use of the openly available data from this unique array to further any of the short or long-term scientific goals of SCEC, and in any of the interface areas that will potentially foster greater use of SCIGN data throughout an even wider range of applications.

2. Continental Borderland (www.scec.org/borderland)

SCEC recognizes the importance of the offshore Southern California Continental Borderland in terms of understanding the tectonic evolution, active fault systems, and seismic hazard of Southern California. SCEC encourages projects that focus on the offshore region's: 1) plate-boundary tectonics, including the currently active Pacific-North American plate motions, and its lithospheric seismic and geologic structure; 2) fault systems, including the distribution and subsurface geometry of active faults, the Quaternary rates of fault slip, and the interactions between intersecting fault systems in three dimensions with time (for example, resolving how high-angle and low-angle faults interact to accommodate long-term oblique finite strain); and 3) offshore earthquakes, including their parameters and the hazard potential of offshore geologic structures in general.

To address these issues, new methods, new datasets, and in some cases new technology may need to be developed and/or acquired. For example, detailed mapping of the active offshore faults will require complete coverage of the Borderland with high-resolution multibeam bathymetry or other high-resolution seafloor imaging systems. Development of high-resolution techniques for conducting paleoseismology in a submarine environment will require innovative multidisciplinary techniques for imaging, sampling, and dating. Long-term monitoring of earthquake activity and geodetic strain in the Borderland will require the establishment of seafloor observatories. Such efforts may be best developed in collaboration with other disciplines (climate, oceanography, marine habitat studies, etc.), programs (EarthScope) and agencies (NOAA, NSF, ONR, etc.). SCEC wishes to encourage and endorse cooperative and collaborative projects that promote these objectives.

3. Information Technology (www.scec.org/cme)

SCEC needs to implement the tools of information technology (IT) to carry out its research agenda. A major collaboration involving SCEC scientists and IT researchers was recently funded by the NSF Information Technology Research Program to develop an advanced information infrastructure for earthquake science in Southern California (the SCEC Community Modeling Environment). The Center encourages participation by SCEC scientists in its IT activities, either directly or as part of ongoing research projects. These include: 1) defining the data structures needed to exchange information and computational results in SCEC research, including implementing these data structures via XML schema for selected computational pathways in seismic hazard analysis and ground-motion simulation; 2) developing, verifying, benchmarking, documenting, and maintaining SCEC community models; 3) developing tools for visualizing earthquake information that improve the community's capabilities in research and education; and 4) organizing collections for, and contributing IT capabilities to, the *Electronic Encyclopedia of Earthquakes* (E^3).

VIII. SCEC COMMUNICATION, EDUCATION, AND OUTREACH PLAN

SCEC is a community of over 500 scientists, students, and staff from 44 institutions across the United States, in partnership with more than 50 other science, engineering, education, and government organizations worldwide. To facilitate applications of the knowledge and scientific products developed by this community, SCEC maintains a *Communication, Education, and Outreach* (CEO) program with four long-term goals:

- Coordinate productive interactions among a diverse community of SCEC scientists and with partners in science, engineering, risk management, government, business, and education.
- Increase earthquake knowledge and science literacy at all educational levels, including students and the general public.
- Improve earthquake hazard and risk assessments
- Promote earthquake preparedness, mitigation, and planning for response and recovery.

Short-term objectives are outlined below. Many of these objectives are opportunities for members of the SCEC community to become involved in CEO activities. These objectives set the programmatic milestones for the Center's internal assessments, guide the development of research results needed for effective education and outreach, and identify priorities for information technology and other resources.

Management Objectives

M1. Develop CEO five-year strategic plan
M2. Establish additional collaborations with partner organizations and pursue funding opportunities
M3. Represent the SCEC Community in partner organizations, science, engineering and education conferences, etc.

CEO Focus Area Objectives

SCEC Community Development and Resources ***(activities and resources for SCEC scientists and students)***

SC1 Increase diversity of SCEC leadership, scientists, and students
SC2 Facilitate communication within the SCEC Community
SC3 Increase utilization of products from individual research projects

Education ***(programs and resources for students, educators, and learners of all ages)***

E1 Develop innovative earth-science education resources
E2 Interest, involve and retain students in earthquake science
E3 Offer effective professional development for K-12 educators

Public Outreach ***(activities and products for media reporters and writers, civic groups and the general public)***

P1 Provide useful general earthquake information
P2 Develop information for the Spanish-speaking community
P3 Facilitate effective media relations
P4 Promote SCEC activities

Implementation Interface ***(activities with engineers and other scientists, practicing professionals, risk managers, and government officials.***

I1 Engage in collaborations with earthquake engineering researchers and practitioners

I2 Develop useful products and activities for practicing professionals

I3 Support improved hazard and risk assessment by local government and industry

I4 Promote effective mitigation techniques and seismic policies

A. Potential CEO-Supported Projects for 2004

Projects listed below are new opportunities for involvement within the CEO program. To support as many of these activities as possible, budgets for proposed projects should be on the order of $5,000 to $10,000. Therefore proposals that include additional sources of support (cost-sharing, funding from other organizations, etc.) are recommended. Those interested in submitting a CEO proposal should first contact Mark Benthien, director for CEO, at 213-740-0323 or benthien@usc.edu.

Application and implementation of SCEC research is especially important during the next year, as SCEC coordinates plans for activities related to the ten-year anniversary of the Northridge earthquake (January 17, 2004). Products and activities, developed around a consistent theme, will be promoted throughout 2004 at earthquake-related annual conferences, seminars, and workshops. A public awareness campaign at multiple levels will include earthquake education, mitigation advocacy, and involvement of policy makers. These activities will be opportunities for communicating outcomes of projects within all SCEC focus groups, disciplinary committees, special projects, and CEO focus areas.

1. Education Focus Area

College Course Development. CEO seeks proposals to participate in the development of resources for undergraduate general-education earthquake courses. Materials will include online PowerPoint files for lectures, portable demonstrations, and interactive online exercises for use in the classroom for by students at home. The online materials will be freely available to instructors at any school. The project may eventually lead to the development of a consensus-based course that could allow interaction between students and faculty at separate institutions.

SCEC Student Network. This network will involve students at SCEC institutions (and elsewhere) in SCEC activities (research, seminars, workshops, annual meeting), provide educational and career resources, and encourage continuation to graduate school. The network will eventually be expanded to include high schools students through mentoring by SCEC undergraduate and graduate students. CEO seeks proposals for creation of this network, including developing a database of potential student members, establishing communication tools (e-mail lists, web pages, etc.), and coordinating participation in SCEC activities.

Education Products and Activities Assessment Planning. In order to understand and improve the effectiveness of SCEC's educational activities, CEO is developing a formal evaluation plan. Partners experienced in evaluation of education products and activities are invited to help CEO staff in this process. This first phase will be to develop evaluation methodologies for SCEC's activities, based on decisions of what should be evaluated and why the evaluation is needed. Proposals that combine education assessment and public outreach assessment planning will be considered.

2. Public Outreach Focus Area

Spanish-Language Products and Activities Development. To be responsible to a large portion of the southern California population, CEO plans to develop products and activities in Spanish. These will include the update of "*Roots*" (see above) as well as portions of the SCEC web pages, fact sheets, media interactions, etc. Proposals are requested for participation in this effort; contact Mark Benthien to discuss details.

Public Outreach Assessment Planning. In order to understand and improve the effectiveness of SCEC's public outreach activities, CEO is developing a formal evaluation plan. Partners experienced in evaluation of public outreach products and activities are invited to help CEO staff in this process. This first phase will be to develop evaluation methodologies for SCEC's activities, based on decisions of what should be evaluated and why the evaluation is needed. Proposals that combine education assessment and public outreach assessment planning will be considered.

3. Implementation Interface Focus Area

a. General

Implementation Interface Management. CEO provides coordination for developing research partnerships between SCEC scientists and partners that are involved in earthquake engineering or other earthquake-related technical disciplines. Proposals are requested from investigators with multi-disciplinary expertise for management of this coordination.

Southern California HAZUS User Group. CEO is coordinating the development and activities of the Southern California HAZUS Users Group (SoCalHUG) with the Federal Emergency Management Agency (FEMA) and the California Office of Emergency Services (OES). HAZUS is FEMA's earthquake loss estimation software program. SCEC is also encouraging the improvement of USGS ShakeMap (to include scenarios based on SCEC Research) for use in HAZUS scenarios. Proposals are requested for assistance with coordinating user group activities, such as: coordinating meetings, trainings, and presentations; working with local governments getting started with HAZUS; and working with the HAZUS Resource Committee to develop a system for sharing building inventory, demographic, and geological data.

Implementation assessment. In order to understand and improve the effectiveness of SCEC's implementation interface activities, CEO is developing a formal evaluation plan. Partners experienced in evaluation of technical products and activities are invited to help CEO staff in this process. This first phase will be to develop evaluation methodologies for SCEC's activities, based on decisions of what should be evaluated and why the evaluation is needed.

b. Implementation Interface Research Projects

The purpose of the Implementation Interface is to implement knowledge about earthquake hazards developed by SCEC into practice. Essential to this objective is fostering collaboration between SCEC scientists and partners that are involved in research or practice in earthquake engineering, or other earthquake-related technical disciplines. Individual SCEC investigators or groups of SCEC investigators are encouraged to identify collaborative projects with individuals or groups of investigators from other organizations. SCEC investigators should request funding within SCEC Focus Groups, and describe how the project will relate to projects with partners, such as those listed in the tables below. Engineers and other potential partners should seek funding from their own organizations. As a guide to this process, Tables 1 and 2 list

current ongoing projects and potential future project topics that could involve collaboration between SCEC and earthquake engineering organizations.

As a guide to this process, Table 1 lists potential future project topics that could involve collaboration between SCEC and earthquake engineering organizations. Table 1 also identifies potential co-sponsors of collaborative implementation-oriented work. The identification of these potential collaborative projects and potential co-sponsors does not imply a commitment on the part of these organizations to co-fund projects. These organizations have their own internal processes for reviewing and approving projects, whose schedules are not necessarily synchronous with the SCEC schedule. Accordingly, Table 1 should be viewed as a preliminary identification of potential mutual interests that could be pursued with additional discussion, and does not preclude other ideas for collaboration with these or other earthquake-related research organizations.

Table 1. Potential Research Partnership Projects

THEME	PROJECT	POTENTIAL PARTNERS
Ground Motion Time Histories	Provide spatial wave-field and distributed input ground motions for bridges	PEER
	Provide ground motion time histories for use in earthquake engineering testing facilities and simulation software	NEES
	Validation of simulated ground motions for performance assessment of buildings and bridges, including site effects	PEER
Information Technology	Exchange information on information technologies	NEES
	Simulation and visualization of earthquake hazards, ground motions, geotechnical/structural response and damage	PEER
Ground Motion Response	Improved regional site response factors from detailed surface geology and from geotechnical borehole data bases (follow through on SCEC Phase III)	CGS, PEER-Lifelines
	Seismic velocity profiles from micro-tremor arrays for deep Vs profiles to complement SASW testing	PEER-Lifelines
	Mapping of basin edge effects using geological data consistent with engineering model from the "Basins" project (see Table 1)	CGS, PEER-Lifelines
Relationship Between Ground Motion Characteristics and Building Response	Identify damaging characteristics of ground motions, and mapping of associated hazard intensity measures	PEER
	How ground motions enter low-rise buildings	PEER
Societal Implications of Earthquake Hazard	Risk and implications of earthquake hazards on distributed lifeline systems and regional economies	PEER, PEER-Lifelines

Ground Motion Prediction Model	Next Generation Attenuation Ground Motion Model	PEER-Lifelines
Loss Estimation	Loss estimation methodology for evaluating societal impacts of SCEC products such as alternative RELM fault models or alternative ground motion models	