2008 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 freestanding center, funded by NSF/EAR and the U.S. Geological Survey. SCEC2 was funded for a five-year period, February 2002 to January 2007. SCEC was renewed for the period February 2007 through January 2012, referred to now as SCEC3. This document solicits proposals from individuals and groups to participate in the second year of the SCEC3 research program.

II. GUIDELINES FOR PROPOSAL SUBMISSION

A. **Due Date: Friday, November 2, 2007, 5:00 pm PST.** Late proposals will not be accepted. Note the different deadline for submitting annual progress reports below.

B. **Delivery Instructions.** Proposals must be submitted as PDF documents via the SCEC Proposal web site at http://www.scec.org/proposals. Submission procedures, including requirements for how to name your PDF files, will be found at this web site.

C. **Formatting Instructions.**

- ***Cover Page***: The cover page should be headed with the words "2008 SCEC Proposal" and include the project title, Principal Investigator(s), institutional affiliation, amount of request, and proposal categories (from types listed in Section IV). List in order of priority three science objectives (Section VII) that your proposal addresses, for example A3, A5 and A11. Indicate if the proposal should also be identified with one or more of the SCEC special projects (see Section VIII). 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, 2008.

- ***Technical Description***: Describe in up to **five pages (including figures)** the technical details of the project and how it relates to the short-term objectives outlined in the SCEC Science Objectives (Section VII). References are not included in the five-page limit.

- ***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.

- ***2007 Annual Report***: Scientists funded by SCEC in 2007 must submit a report of their progress **by 5 pm February 29, 2008**. 2008 proposals approved by the PC will not be funded until all progress reports are submitted. Reports should be up to five pages of text and figures. Reports should include bibliographic references to any SCEC publication during the past year (including papers submitted and in review), including their SCEC contribution number. Publications are assigned numbers when they are submitted to the SCEC publication database at http://www.scec.org/signin.

- ***Labeling the Submitted PDF Proposal***: PI's must follow the proposal naming convention. Investigators must label their proposals with their last name followed by 2008, e.g., Archuleta2008.pdf. If there is more than one proposal, then the file would be labeled as: Archuleta2008_1.pdf (for the 1st proposal) and Archuleta2008_2.pdf (for the 2nd proposal).

D. Principal Investigator Responsibilities. PI's 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, 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/signin. 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
- International Institutions (funding will mainly be for travel)

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. Budget Guidance. Typical SCEC grants funded under this Science Plan in the past have fallen in the range of $10,000 to $35,000. This is not intended to limit SCEC to a fixed award amount, nor to a specified number of awards, rather it is intended to calibrate expectations for proposals written by first-time SCEC investigators.

H. 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 data on earthquakes in Southern California and elsewhere
- Integrate information into a comprehensive, physics-based understanding of earthquake phenomena
- Communicate understanding to the world at large as useful knowledge for reducing earthquake risk

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 Appendix A.

B. Disciplinary Activities. The Center sustains disciplinary science through standing committees in *seismology, geodesy, and geology*. 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 VII.A.

C. Interdisciplinary Focus Areas. Interdisciplinary research is organized within five science focus areas: 1) Unified Structural Representation (URS), 2) Fault and Rupture Mechanics (FARM), 3) Crustal Deformation Modeling (CDM), 4) Lithospheric Architecture and Dynamics (LAD), 5) Earthquake Forecasting and Predictability (EFP), 6) Ground Motion Prediction (GMP) and 7) Seismic Hazard and Risk Analysis (SHRA). High-priority activities are listed for each of these interdisciplinary focus areas in Section VII.B.

D. Special Projects. SCEC supports eleven special projects that will advance designated research frontiers. Several of these initiatives encourage further development of an advanced IT infrastructure for system-level earthquake science in Southern California. High-priority initiatives are listed and described in Section VIII.

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; and 4) promote earthquake preparedness, mitigation, and planning for response and recovery. Opportunities for participating in the CEO program are described in Section IX. 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 VII, and may include a brief description (<200 words) as to how the proposed research and/or its results might be used in a special initiative (see Section VIII) or in an educational or outreach mode (see Section IX).

C. **Workshops**. SCEC participants who wish to host a workshop between February 2008 and February 2009 should submit a proposal for the workshop in response to this RFP. This includes workshops that might be organized around the SCEC annual meeting in September. Workshops in the following topics are particularly relevant:
   - Organizing collaborative research efforts for the five-year SCEC program (2007-2012). 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 IX. Investigators who are interested in participating in this program should contact Mark Benthien (213-740-0323; benthien@usc.edu) before submitting a proposal.

E. **SCEC/SURE Intern Project**. If your proposal includes undergraduate funding, please note this on the cover page. Each year SCEC coordinates the SCEC Summer Undergraduate Research Experience (SCEC/SURE) program to support one-on-one student research with a SCEC scientist. See http://www.scec.org/internships for more information. SCEC will be recruiting mentors in November, 2007, and will request descriptions of potential projects via email. In December, these descriptions will be published on the SCEC Internship web page to allow applicants to identify their preferred projects.

   Mentors will be required to provide at least $2500 of the $5000 intern stipend, and SCEC will pay the balance. Mentor contributions can come from any source, including SCEC-funded research projects. Therefore, interested SCEC scientists are encouraged to include at least $2500 for an undergraduate intern in their 2007 SCEC proposals, and then respond to the recruitment emails.

Questions about the SCEC/SURE Intern Project should be referred to Sue Perry, perry@gps.caltech.edu.

F. Workshop participation. Investigators who wish to only request funding to cover travel to the annual meeting can participate in a streamlined review process with an abbreviated proposal. Investigators who are already funded to study projects that would be of interest to the SCEC community, and investigators new to SCEC who would benefit from exposure to the annual meeting in order to fine-tune future proposals are encouraged to apply.

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).
  - 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 IX)
  - 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 and forwarded to the SCEC 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 the end of February, 2008.

VI. COORDINATION OF RESEARCH BETWEEN SCEC AND USGS-EHRP

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. Sue Hough, 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 governments, 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/research/topics.php

VII. SCEC3 SCIENCE PRIORITY OBJECTIVES

The research objectives outlined below are priorities for SCEC3. 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.

There are four major research areas with the headings **A, B, C** and **D** with subheadings given by numbers. The front page of the proposal should specifically identify subheadings that will be addressed by the proposed research.

A. Develop an extended earthquake rupture forecast to drive physics-based SHA

- A1. Define slip rates and earthquake history of southern San Andreas fault system for the last 2000 years
- A2. Investigate implications of geodetic/geologic rate discrepancies
- A3. Develop a system-level deformation and stress-evolution model

A4. Statistical analysis and mapping of seismicity and source parameters with an emphasis on their relation to known faults
A5. Develop a geodetic network processing system that will detect anomalous strain transients
A6. Test scientific prediction hypotheses against reference models to understand the physical basis of earthquake predictability
A7. Determine the origin, evolution and implications of on- and off-fault damage
A8. Test hypotheses for dynamic fault weakening
A9. Assess predictability of rupture extent and direction on major faults
A10. Develop statistical descriptions of heterogeneities (e.g., in stress, strain, geometry and material properties) in fault zones, and understand their origin and implications for seismic hazard by observing and modeling single earthquake ruptures and multiple earthquake cycles.
A11. Constrain absolute stress and understand the nature of interaction between the faulted upper crust, the ductile crust and mantle, and how geologic history helps to resolve the current physical properties of the system.

B. Predict broadband ground motions for a comprehensive set of large scenario earthquakes

B1. Develop kinematic rupture representations consistent with observations and realistic dynamic rupture models of earthquakes.
B2. Investigate bounds on the upper limit of ground motion
B3. Develop high-frequency simulation methods and investigate the upper frequency limit of deterministic ground motion predictions
B4. Validate earthquake simulations and verify simulation methodologies
B5. Improve our understanding of nonlinear effects and develop methodologies to include these effects in broadband ground motion simulations.
B6. Collaborate with earthquake engineers to develop rupture-to-rafters simulation capability for physics-based risk analysis

C. Improve and develop community products (data or descriptions) that can be used in system-level models for the forecasting of seismic hazard. Proposals for such activities should show how they would significantly contribute to one or more of the numbered goals in A or B.

D. Prepare post-earthquake response strategies

Some of the most important earthquake data are gathered during and immediately after a major earthquake. Exposures of fault rupture are erased quickly by human activity, aftershocks decay rapidly within days and weeks, and post-seismic slip decays exponentially. SCEC solicits proposals for a workshop to plan post-earthquake science response. The goals of the workshop would be to: 1) develop a post-earthquake science plan that would be a living document such as a wiki; 2) identify permanent SCEC and other science facilities that are needed to ensure success of the science plan; 3) identify other resources available in the community and innovative ways of using technology for coordination and rapid data processing that will allow for rapid determination of source parameters, maps, and other characteristics of the source and ground motion patterns.; 4) develop plans for use of Peta-scale computing resources in post-earthquake response for evaluation of crustal stress changes along faults as well as short term prediction of potentially damaging ground motion patterns along 'newly stressed' faults; and 5) develop mechanisms for regular updates of the SCEC post-earthquake response plan.

VII-A. DISCIPLINARY ACTIVITIES

The Center will sustain disciplinary science through standing committees in *seismology, geodesy, and geology*. 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

Objectives:
The objectives of the Seismology group are to support the SCEC mission to gather data on earthquakes in Southern California, and use the seismic networks as research tools to integrate the data into physics-based models that improve our understanding of earthquake phenomena. Proposals to enhance the seismic networks as research tools and foster innovations in network deployments, data collection, and data processing are encouraged, especially where they include collaboration with network operators in Southern California and provide community products that support one or more of the numbered goals in **A, B, C** or **D**.

Important SCEC resources are the Southern California Earthquake Data Center (SCEDC) whose continued operation is essential to deciphering Southern California earthquakes as well as crustal and fault structure, the network of SCEC funded borehole instruments to record high quality reference ground motions, and the pool of portable instruments that is operated in support of targeted deployments or aftershock response.

Research Strategies:
Examples of research strategies that support the objectives above include:

- Enhancement and continued operation of the SCEDC and other existing SCEC facilities. In particular, the near real-time availability of earthquake data from SCEDC and enhanced automated access are important for ongoing SCEC research activities. In support of tomographic, state of stress, earthquake predictability, and other seismicity studies, enhance the availability and usefulness of data products, such as waveforms, catalogs of earthquake parameters, arrival time and polarity information, and signal-to-noise measures as well as moment tensors and first motion mechanisms (A6, A7).

- Enhancements in the real-time processing of network data to improve the estimation of source parameters in relation to known and unknown faults (A3, A4, A10). Other activities could be testing of the performance of new early-warning algorithms, the determination of high precision real-time earthquake locations, or developing finite source algorithms for use in the real-time processing environment (D).
- Experiments that investigate the near-fault crustal properties as well as develop constraints on crustal structure and state of stress are also the goals of other SCEC groups (A7, A10, C). Develop innovative and practical strategies for densification of seismic instrumentation, including borehole instrumentation, along major fault zones in Southern California to measure fault zone properties and capture near-field motions for constraining kinematic and dynamic simulations of earthquakes (B1, B2, B3, B4, B5). Collaborations, for instance with the ANSS and NEES projects, that would augment existing and planned network stations with downhole and surface instrumentation to assess site response, nonlinear effects, and the ground coupling of built structures (B4, B6) are encouraged. Collaborations with EarthScope and other network operators to develop innovative new methods to search for unusual signals using combined seismic, GPS, and borehole strainmeter data (A5, A6) are also encouraged. Other possible strategies (often started with SCEC seed funds) include the design of future passive and active experiments such as dense array measurements of basin structure and large earthquake properties, OBS deployments, and deep basement borehole studies.

2. Tectonic Geodesy

Objective:
The broad objective of the geodesy group is to foster the availability of the variety of geodetic data collected in Southern California and the integrated use of these observations, in conjunction with other relevant data (e.g., seismic or geologic information), to address the spectrum of deformation processes affecting this region. Topics of interest include, but are not limited to, rapid earthquake response, transient deformation, anthropogenic or nontectonic effects, and the characterization and interpretation of strain accumulation and release, with one goal being the increased use of insights from geodesy in seismic hazard assessment. Proposed work may overlap with one or more focus areas, such as Crustal Deformation Modeling (CDM).

Research Strategies:
The following are research strategies aimed at meeting the broad objective:
- Develop reliable means for detecting transient deformation signals through the integrated use of GPS, strainmeter, and other data from Southern California. Use observations of transient deformation to investigate underlying processes and/or the seismic hazard implications (A5).
- Develop methods for combining data types (e.g., GPS, InSAR, strainmeter, and/or other data) that have differing spatial and temporal apertures, sampling frequencies, and sensitivities. Methods for assessing the utility of such combinations for the interpretation of tectonic or nontectonic signals are encouraged. (A1, A2, A3, A5, B1, D).
- Refine or extend estimates of interseismic crustal motion (A1, A2, A3, C). Possible areas of focus include:
    - Improvement of vertical velocity estimates through, for example, the combined use of multiple data types or improvements in data processing strategies.

    - Identification of possible trade-offs in regional slip rate models, quantitative comparison of such models, and/or development of new models.
    - Quantification of uncertainties (especially those relating to model uncertainty) in rate estimates.
    - Systematic assessment of existing geodetic observations throughout Southern California in order to identify locations for which further data collection is necessary to discriminate among regional deformation models, refine slip rate estimates, conduct future earthquake response and postseismic investigations, or for other applications related to SCEC goals.
- Increase the usability of high-rate GPS observations by developing community accessible tools for using these data. Such tools can address different goals including immediate response to major earthquakes (for which rapid availability of solutions is a priority) or detailed deformation analysis (for which the highest accuracy solutions are needed). Methods for assessing the required accuracy for specific problems of interest to SCEC are also encouraged (A5, D).

Studies should utilize data from the Plate Boundary Observatory wherever possible, and proposals for additional data collection should explicitly motivate how they complement existing coverage.

3. Earthquake Geology

Objectives:
The Geology Disciplinary Group supports hypothesis-driven research that uses the geologic record of the Southern California to address the over-arching SCEC goals of (A1-A7) physics-based probabilistic seismic hazard analysis and (B2-B5) ground motion prediction. The Committee also encourages data-gathering activities that will contribute demonstrably significant geologic information to (C) community data sets such as the Unified Structural Representation and Fault Activity Database. Collaborative proposals that cut across disciplinary boundaries are especially encouraged.

Research Strategies:
Examples of research strategies that support the objectives above include:

- Paleoseismic documentation of earthquake ages and displacement, including a coordinated effort to develop slip rates and earthquake history of southern San Andreas fault system for the last 2000 years (A1).
- Geologic and geomorphic investigations of fault slip rates at Quaternary time-scales and their relationship to fault-loading rates (A2, A3, A5).
- Development of methods to evaluate multi-site paleoseismic data sets and standardize error analysis.
- Characterization of fault-zone geology, material properties, and their relationship to earthquake rupture processes (A7).
- Quantitative analysis of the role of distributed deformation in accommodating block motions, dissipating elastic strain, and modifying volume-average rheology (A2, A3, A7).

- Development of constraints on the magnitude and recurrence of strong ground motions from geomorphic features and secondary ground failures (B2).

Geochronology Infrastructure:
The shared geochronology infrastructure supports C-14, optically stimulated luminescence (OSL), and cosmogenic dating for SCEC-sponsored research. The purpose of shared geochronology infrastructure is to allow flexibility in the number and type of dates applied to each SCEC-funded project as investigations proceed. Investigators requesting geochronology support must estimate the number and type of dates needed in their proposal. For C-14 specify if sample preparation will take place at a location other than the designated laboratory. For cosmogenic dating, investigators are required to arrange for sample preparation. These costs must be included in the proposal budget unless preparation has been pre-arranged with one of the laboratories listed. Investigators are strongly encouraged to contact the investigators at the collaborating laboratories prior to proposal submission. Currently, SCEC geochronology has established relationships with the following laboratories:

- C-14: University of California at Irvine (John Southon, jsouthon@uci.edu) and Lawrence Livermore National Laboratory (Tom Guilderson, tguilderson@llnl.gov).
- OSL: University of Cincinnati (Lewis Owen, lewis.owen@uc.edu) and Utah State University (Joel Pederson, bolo@cc.usu.edu).
- Cosmogenic: Lawrence Livermore National Laboratory (Bob Finkel, finkel@sirius.llnl.gov).

Investigators at collaborating laboratories are requested to submit a proposal that states the cost per sample analysis. These investigators are also encouraged to request for funds to support travel to the SCEC annual meeting. New proposals from laboratories not listed above will be considered, though preference will be given to strengthening existing collaborations.

Investigators may alternatively request support for geochronology outside of the infrastructure proposal for methods not listed here or if justified on a cost-basis. These outside requests must be included in the individual proposal budget. Please direct questions regarding geochronology infrastructure to the Geology Disciplinary Group leader, Mike Oskin (oskin@unc.edu).

VII-B. INTERDISCIPLINARY FOCUS AREAS

Interdisciplinary research will be organized into seven science focus areas: **1) Unified Structural Representation (USR), 2) Fault and Rupture Mechanics (FARM), 3) Crustal Deformation Modeling (CDM), 4) Lithospheric Architecture and Dynamics (LAD), 5) Earthquake Forecasting and Predictability (EFP), 6) Ground Motion Prediction (GMP) and 7) Seismic Hazard and Risk Analysis (SHRA).** High-priority objectives are listed below for each of the seven interdisciplinary focus areas below. Collaboration within and across focus areas is strongly encouraged.

1. Unified Structural Representation (USR)

The Structural Representation group develops unified, three-dimensional representations of active faults and earth structure (velocity, density, etc.) for use in fault-system analysis, ground motion prediction, and hazard assessment. This year's efforts will focus on making improvements to existing community models (CVM, CVM-H, CFM, CBM) and evaluating alternative structural representations. We will also support the use of these models in various aspects of earthquake science by other working groups in SCEC, as well as in post-earthquake response planning.

- ***Community Velocity Model (CVM & CVM-H):*** Improve the current SCEC CVM-H model, with emphasis on more accurate representations of Vp, Vs, density structure, basin shapes, and attenuation. Generate improved mantle Vp and Vs models, as well as more accurate descriptions of near-surface property structure that can be incorporated into a revised geotechnical layer. Make the model compatible with fault positions and displacements as represented in the CFM. Evaluate the existing models with data (e.g., waveforms, gravity) to distinguish alternative representations and quantify model uncertainties. Establish an evaluation procedure and benchmarks for testing how future improvements in the models impact ground motion studies. Special emphasis will be placed on developing and implementing 3D waveform tomographic methods for evaluating and improving the CVM's.

- ***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 alternative fault representations; and c) providing more detailed representations of fault terminations and linkages. Evaluate the CFM with data (e.g., seismicity, seismic reflection profiles, geodetic displacement fields) to distinguish alternative fault models. Integrate northern and Southern California models into a statewide fault framework, and update the CFM-R (rectilinear fault model) to reflect improvements in the CFM.

- ***Unified Structural Representation (USR):*** Develop better IT mechanisms for delivering the USR, particularly the CVM parameters and information about the model's structural components, to the user community for use in generating and/or parameterizing computational grids and meshes. Generate maps of geologic surfaces compatible with the CFM that may serve as strain markers in crustal deformation modeling and/or property boundaries in future iterations of the USR.

2. Fault and Rupture Mechanics (FARM)

The primary mission of the Fault and Rupture Mechanics focus group in SCEC3 is to develop physics-based models of the nucleation, propagation, and arrest of dynamic earthquake rupture. We specifically solicit proposals that address this mission through field, laboratory, and modeling efforts directed at characterizing and understanding the influence of material properties, geometric irregularities, and heterogeneities in stress and strain over multiple length and time scales (A7-A10, B1, B4), and that will contribute to our understanding of earthquakes in the Southern California fault system.

Proposed studies should aim to:

- Determine the properties of fault cores and damage zones and characterize their variability with depth and along strike, including descriptions of the width and particle composition of actively shearing zones, extent, origin and significance of on- and off-fault damage, and poromechanical behavior (A7-A11).
- Investigate the relative importance of different dynamic weakening and fault healing mechanisms, and the slip and/or time scales over which these mechanisms operate (A7-A10).
- Characterize the probability and possible signatures of preferred earthquake rupture direction (A7-A10, B1, B4).
- Determine the relative contribution of on- and off-fault damage to the total earthquake energy budget, and the absolute levels of local and average stress (A7-A10).
- Develop realistic descriptions of heterogeneity in fault geometry, properties, stresses, and strains, and tractable ways to incorporate heterogeneity in numerical models (A10-11, B1, B4).
- Understand the influence of small-scale processes on larger-scale fault dynamics (A7-11, B1, B4).
- Evaluate the relative importance of fault structure, material properties, and prior seismic and aseismic slip to earthquake dynamics, in particular, to rupture initiation, propagation, and arrest, and the resulting ground motions (A7-A10, B1).
- Better characterize earthquake rupture at the base of the seismogenic zone, and better develop constitutive descriptions of fault behavior at mid- and lower-crustal depths relevant to numerical modeling of fault loading, earthquake mechanisms and fault interactions over single and multiple earthquake cycles using the SCEC USR. Understand implications of slow events and non-volcanic tremors for constitutive properties of faults and overall seismic behavior (A3, A10, A11).

3. Crustal Deformation Modeling (CDM)

The CDM group focuses on deformation occurring within the earthquake cycle, at time scales linking dynamic rupture (minutes) to secular deformation (thousands of years). We are interested in proposals to (1) develop, or facilitate the development of, models of southern California fault systems based on the SCEC USR and (2) develop other models which contribute to the larger goal of understanding stress transfer and the evolving distribution of earthquake probabilities within active fault systems. Items (1) and (2) should contribute to our ultimate goal of developing physics-based seismic hazard assessments (SHA) for southern California faults. We also seek proposals to model postseismic deformation and communicate the results quickly enough to guide GPS site deployment for postseismic deformation monitoring. Collaborative research with other SCEC focus areas is encouraged, for example: a collaborative effort between geologists, deformation modelers, and geodesists, on development of multi-temporal fault slip rate and event slip catalogs and assessment of knowledge gaps..

- Develop kinematic or dynamic finite element models of the southern California crust, incorporating SCEC USR products (the CFM, CFM, and/or CBM) (C, A3, A11).
- Investigate how assumed rheologies for the upper crust, lower crust, and upper mantle affect modeled stress transfer among Southern California faults. Assess effects of aseismic fault creep (including transient slip events), inelastic upper crust, and poroelasticity on the seismic cycle and stress transfer (A7, A10, A11).
- Investigate how best to model and represent multi-scale fault complexity in the context of geological and geodetic constraints, and how to quantify model sensitivity to spatial heterogeneity of structure and material properties. Use inelastic upper crust rheologies (e.g., damage rheology) in models to represent accommodation of strain in areas where geologic structures are too small to be represented in a system-wide FE mesh. Use such models to help geologists discover what to look for, and where to look, to find evidence of how slip and deformation are distributed at fault intersections (A10, A11).
- Understand the statistical parameters of stress heterogeneity on faults and in the crust, and the extent to which such heterogeneity influences model results.
- Investigate connections between geodetic and geologic slip rates. Investigate factors that might make slip rates vary over different timescales. Collaborate with geologists to identify areas where slip rates over different time scales disagree, and identify targets for future studies where more information is needed (A1, A2).
- Develop methods to rapidly model postseismic deformation to predict time-dependent deformation as a guide for GPS site deployment, with an emphasis on precomputing and web-based platforms for data and model sharing (D).
- Develop comprehensive earthquake simulators to unify driving and initial-condition stresses and time-dependent stress interactions, with geologic, geodetic, and paleoseismic observations (A6).
- Evaluate sensitivity and use of deformation and triggering models in earthquake forecasting. For example, explore plausible range of seismic release scenarios consistent with deformation observations, or assess how different modeling approaches (or assumptions) affect estimates of hazard-forecast parameters (A6).

4. Lithospheric Architecture and Dynamics (LAD)

The lithospheric architecture and dynamics group (LAD) seeks proposals that will contribute to our understanding of the structure, geologic provenance and physical state of the major Southern California lithospheric units, and how these relate to absolute stress and its evolution (A3, A11). The principal objective of this group is to construct 3D geodynamic models that describe the vertical as well as horizontal tectonics into which the seismogenic crustal deformation model can be embedded. Of particular interest is how flow in the sub-seismogenic zone and the asthenosphere accommodates plate motion and loads faults. The geodynamic models would describe the evolution to the current physical state of the Southern California system. Physics models will be developed that use the paleo-history of the 3D geology to infer prior physical conditions, such as depths of Moho, the seismogenic layer, base of the lithosphere, topography and basin depths, rock type, temperature, water content, rheology and how these relate to mantle flow, velocity, anisotropy and density. The LAD work will interface with the geology group to incorporate fault slip, uplift and subsidence rates, with FARM on rheology and absolute and dynamic stress, with the USR and seismology groups on 3D structure and its provenance, and CDM on current stress and strain rates.

In this context, proposals are sought that contribute to our understanding of geologic inheritance as well as three-dimensional structure and physical properties of the lithosphere. Proposals should indicate how the work relates to stress evolution (A2, A3, A11) as well as the current geological structure (C). The ultimate goal is to obtain an absolute stress/rheology model (important to our understanding of how faults are loaded, the earthquake mechanism, fault friction, seismic efficiency, the heat flow paradox) and the expected evolution of stress and strain transients (A5).

5. Earthquake Forecasting and Predictability (EFP)

In general we seek proposals that will increase our understanding of how earthquakes might be forecast and whether or not earthquakes are predictable (A6). Proposals of any type that can assist in this goal will be considered, with the provision that they focus on seismicity and deformation data. We are especially interested in proposals that will utilize the new Collaboratory for the Study of Earthquake Predictability (CSEP). In order to increase the number of earthquakes in the data sets, and so decrease the time required to learn about predictability, proposals are welcome that deal with global data sets and/or include international collaborations.

For research strategies that plan to utilize CSEP, see the description of CSEP under Special Projects to learn of its capabilities. Successful investigators proposing to utilize CSEP would be funded via core SCEC funds to adapt their prediction methodologies to the CSEP framework, to transfer codes to the externally accessible CSEP computers, and to be sure they function there as intended (A6). Subsequently, the codes would be moved to the identical externally inaccessible CSEP computers by CSEP staff who will conduct tests against a variety of data as outlined in the CSEP description. In general, methodologies will be considered successful only if they do better than null hypotheses that include both time-independent and time-dependent probabilities. Proposals aimed toward developing useful measurement/testing methodology that could be incorporated in the CSEP evaluations are welcomed, including those that address how to deal with observational errors in data sets.

Proposals are also welcome that assist in attaining the goals of these two Special Projects: WGCEP (the Working Group on California Earthquake Probabilities) and SoSAFE (the Southern San Andreas Evaluation), especially if the proposals focus on understanding some physical basis for connections between earthquakes. Proposals to evaluate the significance of earthquake simulator results are encouraged. Investigation of what is an appropriate magnitude-area relationship, including the maximum depth of slip during large earthquakes, is encouraged. Studies of how to properly characterize the relationship between earthquake frequency and magnitude for use in testing prediction algorithms are also encouraged.

Proposals that can lead to understanding whether or not there exists a physical basis for earthquake predictability (A6) are welcome, even if they are not aimed toward, or are not ready for, tests in CSEP, or are not aimed toward assisting WGCEP or SoSAFE. For example, proposals could include ones that connect to objectives A1, A2, A3, A5, A9, A10 and A11, as well as ones focused on understanding patterns of seismicity in time and space, as long as they are aimed toward understanding the physical basis of some aspect of extended earthquake predictability (A6). Development of methods for testing prediction algorithms that are not yet in use by CSEP is encouraged.

Proposals for workshops are welcome. Specific workshops of interest include one on earthquake simulators and one on setting standards that could be used by CSEP for testing and evaluation, data, and products.

6. Ground Motion Prediction (GMP)

The primary goal of the Ground Motion Prediction focus group is to develop and implement physics-based simulation methodologies that can predict earthquake strong motion waveforms over the frequency range 0-10 Hz. At frequencies less than 1 Hz, the methodologies should deterministically predict the amplitude, phase and waveform of earthquake ground motions using fully three-dimensional representations of the ground structure, as well as dynamic or dynamically-compatible kinematic representations of fault rupture. At higher frequencies (1-10 Hz), the methodologies should predict the main character of the amplitude, phase and waveform of the motions using a combination of deterministic and stochastic representations of fault rupture and wave propagation.

Research topics within the Ground Motion Prediction program will include developing and/or refining physics-based simulation methodologies, with particular emphasis on high frequency (1-10 Hz) approaches (B3) and the incorporation of non-linear models of soil response (B2, B4, B5). Source characterization plays a vital role in ground motion prediction and research is needed to develop more realistic implementations of dynamic or dynamically-compatible kinematic representations of fault rupture that are used in the simulations (B1, B2). Verification (comparison against theoretical predictions) and validation (comparison against observations) of the simulation methodologies will continue to be an important component of this focus group with the goal being to develop robust and transparent simulation capabilities that incorporate consistent and accurate representations of the earthquake source and three-dimensional velocity structure (B4, C). It is expected that the products of the Ground Motion Prediction group will have direct application to seismic hazard analysis, both in terms of characterizing expected ground motion levels in future earthquakes, and in terms of directly interfacing with earthquake engineers in the analysis of built structures (B6). In addition, activities within the Ground Motion Prediction group will be closely tied to several special projects, with particular emphasis on addressing ground motion issues related to seismic hazard and risk. These special projects include the CEA Project, the Extreme Ground Motion Project, the NGA-H Project, the NSF Implementation Interface Project, and the Tall Buildings Initiative (see SHRA and Section VIII, below).

7. Seismic Hazard and Risk Analysis (SHRA)

The purpose of this activity is to apply SCEC knowledge to the development of useful and useable information and techniques related to earthquake hazard and risk in California. Such information and techniques may include improved representations of seismic hazards, in some cases in terms of new scalar or vector ground motion intensity measures; representations of seismic hazards using ground motion time histories that are also validated for risk analysis applications; rupture-to-rafters simulations that integrate the physics-based generation of ground motion, its propagation through the earth, and its interactions with the built environment; and improved site/facility-specific and portfolio/regional risk analysis (or loss estimation) techniques and tools. Projects that involve interactions between SCEC scientists and members of the community involved in earthquake engineering research and practice are especially encouraged. While supported from the same funds used for other SCEC activities, projects in this activity will often be linked to the Ground Motion Prediction and to special projects. These projects include the CEA Project, the Extreme Ground Motion Project, the NGA-H Project, the NSF LA Tall Buildings Project, and the Tall Buildings Initiative; these projects illustrate the kinds of work that are relevant to SHRA. In the following, the Special Projects are described and related to the various SCEC3 Priority Science Objectives.

The current California Earthquake Authority Project contains activities related to the development of a uniform earthquake forecast for the whole of California (A1, A2), the NGA-H Project discussed below (B1, B3, B4), and rupture-to-rafters simulations involving woodframe buildings (B6). Plans to continue this project in 2008 have not yet been developed.

The Extreme Ground Motion Project supports SCEC research on evaluation and validation of existing rupture dynamics models for ground motion simulation (B1); enhancement of rupture dynamics models to include more physics (B1); the use of these dynamic models, together with kinematic ground motion modeling, to simulate ground motions (B); and analyses of nonlinear wave propagation and site response (B5), for the purpose of understanding the generation of and potentially identifying bounds on extreme ground motions within the context of the Yucca Mountain Repository (B2). This project will continue in 2009 and beyond.

The planned NGA-H Project will involve the use of broadband strong motion simulation to generate ground motion time histories for use, in conjunction with recorded ground motions, in the development of ground motion attenuation relations for hard rock that are based on improved sampling of magnitude and distance and improved understanding of the relationship between earthquake source and strong ground motion characteristics (B1, B3, B4, B5). Of particular interest is that the NGA-E (empirical) relations are noticeably lower than earlier ground-motion attenuation relations. Are the current SCEC broad-band simulations consistent with the NGA-E findings? Broadband simulation methods are verified (by comparison of simple test case results with other methods) and validated (against recorded strong ground motions) before being used to generate broadband ground motions for use in model development. These simulation activities for verification, validation, and application are done on the SCEC Broadband Simulation Platform, which is currently under development.

The pending NSF LA Tall Buildings Project will involve enhancement of simulations of long period ground motions in the Los Angeles region that have been generated by TeraShake and CyberShake, using refinements in source characterization and seismic velocity models (B1, B4), and evaluation of the impacts of these ground motions on tall buildings (B6). It will also involve the development of methods for evaluating and characterizing the potential of faults to generate buried faulting as well as surface faulting earthquakes (A), and evaluating differences in seismic demands imposed by these two categories of earthquakes (B6).

The current Tall Buildings Initiative involves the simulation of ground motion time histories of large earthquakes in Los Angeles and San Francisco for use by practicing engineers in the design of tall buildings (B), and the development and application of procedures for selecting and scaling ground motion time histories for use in representing design ground motions (B6). As is the case in all of the Special Projects described above, validation of the earthquake simulations (B4) for use in seismic hazard and/or risk analysis is an important step that calls for collaboration between earthquake scientists and engineers.

Proposals for other innovative projects that would further implement SCEC information and techniques in seismic hazard and risk analysis, and ultimately loss mitigation, are encouraged.

VIII. SPECIAL PROJECTS AND INITIATIVES

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

1. Networks as Research Tools
2. Southern San Andreas Fault Evaluation (SoSAFE) project
3. Working Group on California Earthquake Probabilities (WGCEP)
4. Next Generation Attenuation (NGA) Project
5. End-to-End (“Rupture-to-Rafters”) Simulation
6. Collaboratory for the Study of Earthquake Predictability (CSEP)
7. National Partnerships through EarthScope
8. Extreme Ground Motions (EXGM)
9. Petascale Cyberfacility for Physics-Based Seismic Hazard Analysis (PetaSHA)
10. Advancement of Cyberinfrastructure Careers through Earthquake System Science (ACCESS)

1) Networks as Research Tools

SCEC encourages proposals that enhance the use of seismic and geodetic networks as research tools. The goal of such research is to promote innovations in network deployments and data integration that will provide new information on earthquake phenomena. Projects in this category are meant to be complementary to ANSS, IRIS, EarthScope, and UNAVCO. The Earthquake Early Warning Demonstration Project is an example of such an activity.

2) Southern San Andreas Fault Evaluation (SoSAFE)

The SCEC Southern San Andreas Fault Evaluation (SoSAFE) Project will continue to increase our knowledge of slip rates, paleo-event chronology, and slip distributions of past earthquakes, for the past two thousand years on the southern San Andreas fault system. From Parkfield to Bombay Beach, and including the San Jacinto fault, the objective is to obtain new data to clarify and refine relative hazard assessments for each potential source of a future 'Big One.' Most work to be funded is expected to involve paleoseismic and geological fault slip rate studies.

The second year of SoSAFE is expected to again be funded at $240K by USGS. Targeted research by each of several selected self-organized multi-investigator teams will be supported to rapidly advance SCEC research towards meeting objective A1. We encourage investigator teams to propose jointly in response to the RFP. Each team will address one significant portion of the fault system, and all teams will agree to collaboratively review one another's progress. We welcome requests for joint infrastructure resources, for example geochronology support. That is, an investigator may ask for dating support (e.g., to date 6 radiocarbon samples). Requests for dating shall be coordinated with Earthquake Geology.

Other SCEC objectives will also be advanced through the research funded by SoSAFE, such as A2, A10, and B1. For example, interaction between SoSAFE and the scenario rupture modeling activity will continue beyond the ShakeOut, as we discuss whether or not additional radiocarbon dating could be used to eliminate the scenario of a "wall-to-wall" rupture (from Parkfield to Bombay Beach). SoSAFE will also work to constrain scenario models by providing the best possible measurements of actual slip distributions from past earthquakes on these same fault segments as input, thereby enabling a more realistic level of scenario modeling. Use of novel methods for estimating slip rates from geodetic data would also potentially be supported within the upcoming year. Slip rate studies will continue to be encouraged, and for these it is understood that support may be awarded to study offset features that may be older than the 2000 yrs. stated in objective A1, perhaps as old as 60,000 yrs. in some cases. It is expected that much support will go towards improved dating (e.g., radiocarbon and OSL) of earthquakes within the past 2000 yrs., however, so that event correlations and coefficient of variation in recurrence intervals may be further refined.

We will also discuss common longer-term research interests and engage in facilitating future collaborations in the broader context of a decade-long series of interdisciplinary, integrated and complementary studies on the southern San Andreas fault system.

3) Working Group on California Earthquake Probabilities (WGCEP)

The ongoing WGCEP is developing a time-dependent, statewide earthquake-rupture forecast that uses "best available science". This model, called the Uniform California Earthquake Rupture Forecast (UCERF), will have the endorsement of SCEC, USGS, and CGS. The California Earthquake Authority, which holds about two-thirds of all homeowners earthquake insurance policies throughout the state, will use the model to set insurance rates. Development of this model is tightly coordinated with the USGS National Seismic Hazard Mapping Program. For example, the time-independent component of UCERF 2 was used in the 2007 USGS/CGS California hazard map. We are deploying the model in an adaptable, extensible framework where modifications can be made as warranted by scientific developments, the collection of new data, or following the occurrence of significant earthquakes (subject to the review process). Our implementation strategy is to add more advanced capabilities only after achieving more modest goals.

The following are examples of SCEC activities that could make direct contributions to WGCEP goals:

- Extend our UCERF, which gives the magnitude, average rake, and rupture surface of all possible earthquakes throughout the state, to include different viable slip time histories for each of these ruptures (A).
- Develop models that give fault-to-fault rupture probabilities as a function of fault separation, difference in strike, and styles of faulting (A9).
- Refine estimates of observed earthquake rates and their uncertainties, both statewide and as a function of space. This could include associating historic events with known faults (A4 and C).
- Further refinement of fault models including geometries, seismogenic depths, and aseismicity parameters (C).
- Development of deformation models that give improved slip- and stressing-rates on known faults, as well as off-fault deformation rates elsewhere (A3).
- Further constrain viable magnitude-area relationships, especially with respect to how they are being used in this project (A4).
- Develop moment-balanced rupture models that predict a long-term rate of earthquakes that is consistent with the historical record (e.g., no discrepancy near magnitude 6.5) (A6).
- Develop methodologies for computing time-dependent earthquake probabilities in our model. These methodologies could include approaches that invoke elastic-rebound-theory motivated renewal models, earthquake triggering effects that include aftershock statistics, or physics-based earthquake simulations (A6).
- Develop easily computable hazard or loss metrics that can be used to evaluate and perhaps trim logic-tree branch weights (B6, C).
- Develop a community-standard hazard-to-loss interface (i.e., that can be used by anyone from academics, government officials, and consulting companies) (B6, C).

Further suggestions and details can be found at http://www.WGCEP.org, or by speaking with the project leader (Ned Field: field@usgs.gov; (626) 583-7814).

4) Next Generation Attenuation Project (NGA)

The NGA Project is lead by PEER with the collaboration of SCEC and USGS to develop response spectral ground motion prediction models. The current focus is on shallow crustal earthquakes in tectonically active regions. The current phase (NGA-E) is nearing completion, and it is anticipated that the next phase (NGA-H) will begin in 2008. The NGA-H Project will involve the use of broadband strong motion simulation to generate ground motion time histories for use, in conjunction with recorded ground motions, in the development of ground motion attenuation relations for hard rock that are based on improved sampling of magnitude and distance, especially large magnitudes and close distances, and improved understanding of the relationship between earthquake source and strong ground motion characteristics. Broadband simulation methods are verified (by comparison of simple test case results with other methods) and validated (against recorded strong ground motions) before being used to generate broadband ground motions for use in model development. These simulation activities for verification, validation, and application are done on the SCEC Broadband Simulation Platform, which is currently under development. The main SCEC focus groups working on this project are Ground Motion Prediction; Seismic Hazard and Risk Analysis; and PetaSHA – Terashake and Cybershake.

5) End-to-End Simulation

The purpose of this project is to foster interaction between earthquake scientists and earthquake engineers through the collaborative modeling of the whole process involved in earthquake fault rupture, seismic wave propagation, site response, soil-structure interaction, and building response. Recent sponsors of this project have been NSF (tall buildings) and CEA (woodframe buildings), and new sponsors are being sought. The main SCEC discipline and focus groups working on this project are Geology, especially fault models; Unified Structural Representation; Faulting and the Mechanics of Earthquakes; Ground Motion Prediction; Seismic Hazard and Risk Analysis; and PetaSHA – Terashake and Cybershake.

6) Collaboratory for the Study of Earthquake Predictability (CSEP)

The goal of CSEP is to develop a virtual, distributed laboratory—a collaboratory—that can support a wide range of scientific prediction experiments in multiple regional or global natural laboratories. This earthquake system science approach seeks to provide answers to the questions: (1) How should scientific prediction experiments be conducted and evaluated? and (2) What is the intrinsic predictability of the earthquake rupture process? Contributions may include: (1) Establishing rigorous procedures in controlled environments (testing centers) for registering prediction procedures, which include the delivery and maintenance of versioned, documented code for making and evaluating predictions including intercomparisons to evaluate prediction skills; (2) Constructing community-endorsed standards for testing and evaluating probability-based and alarm-based predictions; (3) Developing hardware facilities and software support to allow individual researchers and groups to participate in prediction experiments; (4) Providing prediction experiments with access to data sets and monitoring products, authorized by the agencies that produce them, for use in calibrating and testing algorithms; and (5) Conducting workshops to facilitate international collaboratories. A major focus of CSEP is to develop international collaborations between the regional testing centers and to accommodate a wide-ranging set of prediction experiments involving geographically distributed fault systems in different tectonic environments.

7) National Partnerships through EarthScope

The NSF EarthScope project provides unique opportunities to learn about the structure and dynamics of North America. SCEC encourages proposals to the NSF EarthScope program that will address the goals of the SCEC Science Plan.

8) Extreme Ground Motion Project (ExGM)

Extreme ground motions are the very large amplitudes of earthquake ground motions that can arise at very low probabilities of exceedance, as was the case for the 1998 PSHA for Yucca Mountain. This project investigates the credibility of such ground motions through studies of physical limits to earthquake ground motions, unexceeded ground motions, and frequency of occurrence of very large ground motions or of earthquake source parameters (such as stress drop and faulting displacement) that cause them. Of particular interest to ExGM (and more generally to ground-motion prediction and SHRA) is why crustal earthquake stress drops are so sensibly constant and so much less than the frictional strength of rocks at mid-crustal depths.

This project is sponsored by DOE. The main SCEC discipline and focus groups that will work on this project are Geology – especially fault zone geology; Faulting and Mechanics of Earthquakes, Ground-Motion Prediction, and Seismic Hazard and Risk Analysis. This project is also discussed above within SHRA.

9) Petascale Cyberfacility for Physics-Based Seismic Hazard Analysis (PetaSHA)

SCEC's special project titled "A Petascale Cyberfacility for Physics-based Seismic Hazard Analysis" (PetaSHA) aims to develop and apply physics-based predictive models to improve the practice of seismic hazard analysis. This project will utilize numerical modeling techniques and high performance computing to implement a computation-based approach to SHA. Three scientific initiative areas have been identified for this project to help to guide the scientific research. The PetaSHA initiative areas are: (1) development of techniques to support higher frequencies waveform simulations including deterministic and stochastic approaches; (2) development of dynamic rupture simulations that include additional complexity including nonplanar faults, a variety of friction-based behaviors, and higher inner /outer scale ratios (e.g. (fault plane mesh dimension) / (simulation volume dimension)); and (3) physics-based probabilistic seismic hazard analysis including probabilistic seismic hazard curves using 3D waveform modeling. All of these modeling efforts must be accompanied by verification and validation efforts. Development of new techniques that support the verification and validation of SCEC PetaSHA modeling efforts are encouraged.

The SCEC PetaSHA modeling efforts address several of the SCEC3 objectives. Development of new verification and validation techniques (B4) are common to each of the PetaSHA initiative areas. Research activities related to the improved understanding and modeling of rupture complexity (A8, B1) support the PetaSHA initiatives. In addition, research into the upper frequency bounds on deterministic ground motion predictions (B2, B3) are SCEC3 science objectives that are important work areas in the PetaSHA Project.

10) Advancement of Cyberinfrastructure Careers through Earthquake System Science (ACCESS)

Project goal: Provide students with research experiences in earthquake system science to advance their careers and creative participation in cyberinfrastructure (CI) development.

Three programmatic elements:

- ACCESS-U: One-term undergraduate internships to support CI-related senior thesis research in the SCEC Collaboratory
- ACCESS-G: One-year graduate internships to support CI-related master thesis research in the SCEC Collaboratory
- ACCESS Forum: a new CEO working group to promote CI careers in earthquake system science

IX. SCEC COMMUNICATION, EDUCATION, AND OUTREACH

SCEC is a community of over 600 scientists, students, and staff from 56 institutions, in partnership with many other science, engineering, education, and government organizations worldwide. To facilitate applications of the knowledge and scientific products developed by this large 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, which are for the most part coordinated by CEO staff. To support the involvement of as many others as possible, budgets for proposed projects should be on the order of $2,000 to $7,000. Hence proposals that include additional sources of support (cost-sharing, funding from other organizations, etc.) are highly recommended. Smaller activities can be supported directly from the CEO budget and do not need a full proposal. Those interested in submitting a CEO proposal should first contact Mark Benthien, associate SCEC director for CEO, at 213-740-0323 or benthien@usc.edu.

CEO Focus Area Objectives

1. ***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

2. ***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

3. ***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

4. ***Knowledge transfer*** (activities to engage other scientists and engineers, practicing engineers and geotechnical professionals, risk managers, government officials, utilities, and other users of technical information.

   I1 Communicate SCEC results to the broader scientific community
   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

APPENDIX: SCEC3 LONG-TERM RESEARCH GOALS

This section outlines the SCEC science priorities for the five-year period from February 1, 2007, to January 31, 2012. 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/aboutscec/documents/).

Basic Research Problems

SCEC is, first and foremost, a basic research center. We therefore articulate our work plan in terms of four basic science problems: (1) earthquake source physics, (2) fault system dynamics, (3) earthquake forecasting and predictability, and (4) ground motion prediction. These topics organize the most pressing issues of basic research and, taken together, provide an effective structure for stating the SCEC3 goals and objectives. In each area, we outline the problem, the principle five-year goal, and some specific objectives. We then assess the research activities and the new capabilities needed to attain our objectives.

1. Earthquake Source Physics

Problem Statement. Earthquakes obey the laws of physics, but we don't yet know how. In particular, we understand only poorly the highly nonlinear physics of earthquake nucleation, propagation, and arrest, because we lack knowledge about how energy and matter interact in the extreme conditions of fault failure. A complete description would require the evolution of stress, displacement, and material properties throughout the failure process across all relevant scales, from microns and milliseconds to hundreds of kilometers and many years. A more focused aspect of this problem is the physical basis for connecting the behavior of large ruptures at spatial resolutions of hundreds of meters and fracture energies of megajoules per square meter with laboratory observations of friction at centimeter scales and fracture energies of kilo-joules per square meter. Two further aspects are the problem of stress heterogeneity—the factors that create and maintain it over many earthquake cycles—and the related problem of defining the concept of strength in the context of stress and rheological heterogeneity.

Goal and Objectives. The goal for SCEC3 will be to discover the physics of fault failure and dynamic rupture that will improve predictions of strong ground motions and the understanding of earthquake predictability. This goal is directly aligned with our mission to develop physics-based seismic hazard analysis. Specific objectives include:

(1) Conduct laboratory experiments on frictional resistance relevant to high-speed coseismic slip on geometrically complex faults, including the effects of fluids and changes in normal stress, and incorporate the data into theoretical formulations of fault-zone rheology.
(2) Develop a full 3D model of fault-zone structure that includes the depth dependence of shear localization and damage zones, hydrologic and poroelastic properties, and the geometric complexities at fault branches, step-overs, and other along-strike and down-dip variations.
(3) Combine the laboratory, field-based, and theoretical results into effective friction laws for the numerical simulation of earthquake rupture, test them against seismological data, and

extend the simulation methods to include fault complexities such as bends, step-overs, fault branches, and small-scale roughness.

(4) Develop statistical descriptions of stress and strength that account for slip heterogeneity during rupture, and investigate dynamic models that can maintain heterogeneity throughout many earthquake cycles.

2. Fault System Dynamics

Problem Statement. In principle, the Southern California fault system can be modeled as a dynamic system with a state vector S and an evolution law dS/dt = F(S). The state vector represents the stress, displacement, and rheology/property fields of the seismogenic layer as well as its boundary conditions. Its evolution equation describes the forward problem of fault dynamics. Many of the most difficult (and interesting) research issues concern two inference or inverse problems: (1) model building—from our knowledge of fault physics, what are the best representations of S and F?—and (2) data assimilation—how are the parameters of these representations constrained by the data D on the system's present state S0 as well as its history?

The SCEC approach is not to proceed by trying to write down general forms of S and its rate-of-change F. Rather, we use judicious approximations to separate the system evolution into a series of numerical simulations representing the interseismic, preseismic, coseismic, and postseismic behaviors. In particular, the natural time-scale separation between inertial and non-inertial dynamics usually allows us to decouple the long-term evolution of the state vector from its short-term, coseismic behavior. Therefore, in describing many interseismic and postseismic processes, we can treat the fault system quasi-statically, with discontinuous jumps in S at the times of earthquakes. On the other hand, the dynamics of earthquake rupture is clearly important to the basic physics of fault system evolution. In the modeling of stress heterogeneity, for example, the coupling of inertial and non-inertial dynamics must be addressed by integrating across this scale gap.

Goal and Objectives. The principal SCEC3 goal for fault system dynamics is to develop representations of the postseismic and interseismic evolution of stress, strain, and rheology that can predict fault system behaviors within the Southern California Natural Laboratory. The SCEC3 objectives are sixfold:

(1) Use the community modeling tools and components developed in SCEC2 to build a 3D dynamic model that is faithful to the existing data on the Southern California fault system, and test the model by collecting new data and by predicting its future behavior.
(2) Develop and apply models of coseismic fault slip and seismicity in fault systems to simulate the evolution of stress, deformation, fault slip, and earthquake interactions in Southern California.
(3) Gather and synthesize geologic data on the temporal and spatial character and evolution of the Southern California fault system in terms of both seismogenic fault structure and behavior at geologic time scales.

(4) Constrain the evolving architecture of the seismogenic zone and its boundary conditions by understanding the architecture and dynamics of the lithosphere involved in the plate boundary deformation.
(5) Broaden the understanding of fault systems in general by comparing SCEC results with integrative studies of other fault systems around the world.
(6) Apply the fault system models to the problems of earthquake forecasting and predictability.

3. Earthquake Forecasting and Predictability

Problem Statement. The problems considered by SCEC3 in this important area of research will primarily concern the physical basis for earthquake predictability. Forecasting earthquakes in the long term at low probability rates and densities—the most difficult scientific problem in seismic hazard analysis—is closely related to the more controversial problem of high-likelihood predictions on short (hours to weeks) and intermediate (months to years) time scales. Both require a probabilistic characterization in terms of space, time, and magnitude; both depend on the state of the fault system (conditional on its history) at the time of the forecast/prediction; and, to put them on a proper science footing, both need to be based in earthquake physics.

Goal and Objectives. The SCEC3 goal is to improve earthquake forecasts by understanding the physical basis for earthquake predictability. Specific objectives are to:

(1) Conduct paleoseismic research on the southern San Andreas and other major faults with emphasis on reconstructing the slip distributions of prehistoric earthquakes, and explore the implications of these data for behavior of the earthquake cycle and time-dependent earthquake forecasting.
(2) Investigate stress-mediated fault interactions and earthquake triggering and incorporate the findings into time-dependent forecasts for Southern California.
(3) Establish a controlled environment for the rigorous registration and evaluation of earthquake predictability experiments that includes intercomparisons to evaluate prediction skill.
(4) Conduct prediction experiments to gain a physical understanding of earthquake predictability on time scales relevant to seismic hazards.

4. Ground Motion Prediction

Problem Statement. Given the gross parameters of an earthquake source, such as its magnitude, location, mechanism, rupture direction, and finite extent along a fault, we seek to predict the ground motions at all regional sites and for all frequencies of interest. The use of 3D velocity models in low-frequency (< 0.5 Hz) ground motion prediction was pioneered in SCEC1 (§II.A), and this type of simulation, based on direct numerical solution of the wave equation, has been taken to new levels in SCEC2 (§II.B.6). The unsolved basic research problems fall into four classes: (a) the ground motion inverse problem at frequencies up to 1 Hz; (b) the stochastic extension of ground motion simulation to high frequencies (1-10 Hz); (c) simulation of ground motions using dynamically consistent sources; and (d) nonlinear wave effects, including nonlinear site response. In addition, there remain scientific and computational challenges in the practical prediction of ground motions near the source and within complex structures such as sedimentary basins, as well as in the characterization of the prediction uncertainties.

Goal and Objectives. The principal SCEC3 goal is to predict the ground motions using realistic earthquake simulations at frequencies up to 10 Hz for all sites in Southern California. The SCEC3 objectives are:

(1) Combine high-frequency stochastic methods and low-frequency deterministic methods with realistic rupture models to attain a broadband (0-10 Hz) simulation capability, and verify this capability by testing it against ground motions recorded at a variety of sites for a variety of earthquake types.
(2) Use observed ground motions to enhance the Unified Structural Representation (USR) by refining its 3D wavespeed structure and the parameters that account for the attenuation and scattering of broadband seismic energy.
(3) Apply the ground-motion simulations to improve SHA attenuation models, to create realistic scenarios for potentially damaging earthquakes in Southern California, and to explain the geologic indicators of maximum shaking intensity and orientation.
(4) Investigate the geotechnical aspects of how built structures respond to strong ground motions, including nonlinear coupling effects, and achieve an end-to-end simulation capability for seismic risk analysis.