Southern California Earthquake Center

SCEC5 Annual Report (Year 2)

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Southern California Earthquake Center: Research Program in Earthquake System Science, 2017-2022

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Director's Summary

John E. Vidale, *SCEC Director*

The Southern California Earthquake Center (SCEC) is one of the world's largest geoscience collaborations, involving over 1000 scientists at more than 70 universities and research organizations in the study of earthquakes and their hazards, using Southern California as its main natural laboratory. The SCEC community advances earthquake system science by gathering information from seismic and geodetic sensors, geologic field observations, and laboratory experiments; synthesizing knowledge of earthquake phenomena through system-level, physics-based modeling; and communicating understanding of seismic hazards to reduce earthquake risk and promote community resilience.

This report outlines SCEC accomplishments for the period from November 15, 2017 - November 15, 2018, the second year of SCEC5.

The strategic framework for the SCEC5 Science Plan (see Section 1) was cast in the form of five basic questions of earthquake science: (1) How are faults loaded on different temporal and spatial scales? (2) What is the role of off-fault inelastic deformation on strain accumulation, dynamic rupture, and radiated seismic energy? (3) How do the evolving structure, composition and physical properties of fault zones and surrounding rock affect shear resistance to seismic and aseismic slip? (4) How do strong ground motions depend on the complexities and nonlinearities of dynamic earth-quake systems? (5) In what ways can system-specific studies enhance the general understanding of earthquake predictability?

These priorities are investigated through four themes:

Modeling the fault system: We seek to know more about the geometry of the San Andreas system as a complex network of faults, how stresses acting within this network drive the deformation that leads to fault rupture, and how this system evolves on time scales ranging from milliseconds to millions of years.

Understanding earthquake processes: Many important achievements in understanding fault-system stresses, fault ruptures, and seismic waves have been based on the elastic approximation, but new problems motivate us to move beyond elasticity in the investigation of earthquake processes.

Characterizing seismic hazards: We seek to characterize seismic hazards across a wide spectrum of anticipation and response times, with emphasis on the proper assessment of model uncertainties and the use of physics-based methods to lower those uncertainties.

Reducing seismic risk: Through partnerships coordinated by SCEC's Earthquake Engineering Implementation Interface, we will conduct research useful in motivating societal actions to reduce earthquake risk.

Highlights of those accomplishments, elaborated in Sections 2-5 of this report, include:

- Several studies find that while stress state in southern California appears to be relatively homogeneous or smoothly varying over large wavelengths (100 km), strong heterogeneity may occur at shorter spatial scales near faults.
- We finished development of the web-based data access tool for MCER ground motions and released it in May 2018. The MCER response spectra cover greater Los Angeles, providing a resource for cities and counties in the region.
- A particularly successful UseIT summer session for 24 undergraduate students, which formed teams to evaluate San Andreas fault system earthquake scenarios that were both dire and frequent, examined with supercomputer-generated million-year catalogs and some machine learning tools.
- Completion of a CyberShake hazard run for Northern California, in collaboration with the USGS and other partners. This largest CyberShake simulation to data, 200 by 400 km area, which includes 40,000+

earthquakes and 800 assessed sites, provides a first physics-based earthquake hazard estimation for an area with 15-20% of the earthquake risk in the United States.

- Advances on a suite of machine learning and advanced algorithm problems are revolutionizing the ways seismic data can be interrogated. Automatic and accurate phase picking and highly effective detections of seismic events deeply buried in noise have already led to dramatically enhanced seismicity catalogs for southern California and improved understanding of a range of seismicity patterns, especially for induced seismicity.

- Enactment of a SCEC Code of Conduct to preserve a safe and diverse working environment.

- The Advisory Council reports that SCEC continues to operate at a high level, and highlights another successful SCEC annual meeting (featuring new lightning talks) and a great year for SCEC with a smooth and positve transition in leadership.

This report period coincides with the first full year of John Vidale as SCEC Director and the last year of John McRaney as the Associate Director for Administration. Other notable transitions, along with rest of the SCEC leadership and management structure, community demographics, and international collaborations, are enumerated in Section 2. SCEC continues to examine leadership and mangement models to optimize the performance of the center, as we gear up for the SCEC6 proposal.

Section 6 describes the Year 2 budget and funding for the Center, and planned request for the next year.

Salient planned new activities for 2019, which are explained in detail in Sections 7 and 8, include:

- Gain understanding of the Cajon Pass earthquake gate. More specifically, collect and synthesize earthquake recurrence, slip-rate, interseismic deformation and fault geometry information.

- Major activities for SCEC's CEO program in 2019 include: establishing a *Knowledge Implementation Working Group* to identify research needs and potential collaborations with practicing engineers, government officials, and other decision makers; overhauling the ShakeOut website and expanding international participation; releasing the *Quake Heroes* film through a series of special screenings; distributing *Quake Heroes* toolkits (with lesson plans) to high schools; and further developing the *Transitions Program* through expanded partnerships with mentors and SCEC institutions.

- Initiation of a collaboration with NASA, striving to eventually be similar to our partnerships with the USGS and PGE. The modest first year, assuming the proposal to NSPIRES is successful, will provide $120,000 to fund a half dozen or so projects in the realm of geodesy and satellite data, which will also have direct support given from NASA.

1. Introduction

The Southern California Earthquake Center (SCEC) was founded as a Science & Technology Center on February 1, 1991, with joint funding by the National Science Foundation (NSF) and the U. S. Geological Survey (USGS). Since 2002, SCEC has been sustained as a stand-alone center under cooperative agreements with both agencies in three consecutive, five-year phases (SCEC2 through SCEC4). This project is an extension of those agreements for the fourth 5-year period from 1 Feb 2017 to 31 Jan 2022 (SCEC5 USGS) and 1 May 2017 to 30 Apr 2022 (SCEC5 NSF). SCEC coordinates fundamental research on earthquake processes using Southern California as its main natural laboratory. Currently, over 1000 earthquake professionals are participating in SCEC projects. This research program is investigator-driven and supports core research and education in seismology, tectonic geodesy, earthquake geology, and computational science. The SCEC community advances earthquake system science by gathering information from seismic and geodetic sensors, geologic field observations, and laboratory experiments; synthesizing knowledge of earthquake phenomena through system-level, physics-based modeling; and communicating understanding of seismic hazards to reduce earthquake risk and promote community resilience.

SCEC5 Research Vision

Earthquakes are emergent phenomena of active fault systems, confoundingly simple in their gross statistical features but amazingly complex as individual events. SCEC's long-range science vision is to develop dynamical models of earthquake processes that are comprehensive, integrative, verified, predictive, and validated against observations. The science goal of the SCEC5 core program is to *provide new concepts that can improve the predictability of the earthquake system models, new data for testing the models, and a better understanding of model uncertainties*.

The validation of model-based predictions against data is a key SCEC activity, because empirical testing is the most powerful guide for assessing model uncertainties and moving models towards better representations of reality. SCEC validation efforts tightly couple basic earthquake research to the practical needs of probabilistic seismic hazard analysis, operational earthquake forecasting, earthquake early warning, and rapid earthquake response. Moreover, the risk-reduction problem—which requires actions motivated by useful information—strongly couples SCEC science to earthquake engineering. SCEC collaborations with engineering organizations are directed towards end-to-end, physics-based modeling capabilities that span system processes from "ruptures-to-rafters."

SCEC connects to the social sciences through its mission to convey authoritative information to stakeholders in ways that result in lowered risk and enhanced resilience. SCEC's vision is to engage end users and the public at large in ongoing, community-centric conversations about how to manage particular risks by taking specific actions. The SCEC Communication, Education, and Outreach (CEO) program seeks to promote this dialog on many levels, through many different channels, and inform the conversations with authoritative earthquake information. Towards this goal, the SCEC5 CEO program will continue to build networks of organizational partners that can act in concert to prepare millions of people of all ages and socioeconomic levels for inevitable earthquake disasters.

Intellectual Merit of SCEC5 Research

Southern California is SCEC's principal natural laboratory for the study of earthquake physics and geology. Earthquake processes in this tectonically diverse stretch of the Pacific-North America plate boundary are closely monitored by instrumental systems of increasing density and resolution. Recent research has posed crucial questions about the current earthquake hazard of the San Andreas fault system. In particular, the observed open intervals (times since the last large ruptures) on major faults are skewed to higher values than expected from the latest Uniform California Earthquake Rupture Forecast (UCERF3). Random chance or subtle data or model bias are potential explanations, but another hypothesis of basic-research interest is the synchronization of fault ruptures into "seismic super-cycles" modulated by the largest ruptures. Understanding the earthquake behavior of the San Andreas system is a fundamental problem for SCEC5 that has considerable practical implications.

The SCEC5 Science Plan was developed by the SCEC Planning Committee and Board of Directors with extensive input from issue-oriented "tiger teams" and the community at large. The strategic framework for the SCEC5 Science Plan was cast in the form of five basic questions of earthquake science: (1) How are faults loaded on different temporal and spatial scales? (2) What is the role of off-fault inelastic deformation on strain accumulation, dynamic

rupture, and radiated seismic energy? (3) How do the evolving structure, composition and physical properties of fault zones and surrounding rock affect shear resistance to seismic and aseismic slip? (4) How do strong ground motions depend on the complexities and nonlinearities of dynamic earth-quake systems? (5) In what ways can system-specific studies enhance the general understanding of earthquake predictability? These questions cover the key issues driving earthquake research in California, and they provide a basis for gauging the intellectual merit of SCEC5 research activities.

Science Plan

Research priorities were developed to address these five basic questions. Tied to the priorities are fourteen science topics distributed across four main thematic areas.

Modeling the fault system: We seek to know more about the geometry of the San Andreas system as a complex network of faults, how stresses acting within this network drive the deformation that leads to fault rupture, and how this system evolves on time scales ranging from milliseconds to millions of years.

- **Stress and Deformation Over Time.** We will build alternative models of the stress state and its evolution during seismic cycles, compare the models with observations, and assess their epistemic uncertainties, particularly in the representation of fault-system rheology and tectonic forcing.
- **Special Fault Study Areas.** Focus on Earthquake Gates. Earthquake gates are regions of fault complexity conjectured to inhibit propagating ruptures, owing to dynamic conditions set up by proximal fault geometry, distributed deformation, and earthquake history. We will test the hypothesis that earthquake gates control the probability of large, multi-segment and multi-fault ruptures.
- **Community Models.** We will enhance the accessibility of the SCEC Community Models, including the model uncertainties. Community thermal and rheological models will be developed.
- **Data Intensive Computing.** We will develop methods for signal detection and identification that scale efficiently with data size, which we will apply to key problems of Earth structure and nanoseismic activity.

Understanding earthquake processes: Many important achievements in understanding fault-system stresses, fault ruptures, and seismic waves have been based on the elastic approximation, but new problems motivate us to move beyond elasticity in the investigation of earthquake processes.

- **Beyond Elasticity.** We will test hypotheses about inelastic fault-system behavior against geologic, geodetic, and seismic data, refine them through dynamic modeling across a wide range of spatio-temporal scales, and assess their implications for seismic hazard analysis.
- **Modeling Earthquake Source Processes.** We will combine co-seismic dynamic rupture models with inter-seismic earthquake simulators to achieve a multi-cycle simulation capability that can account for slip history, inertial effects, fault-zone complexity, realistic fault geometry, and realistic loading.
- **Ground Motion Simulation.** We will validate ground-motion simulations, improve their accuracy by incorporating nonlinear rock and soil response, and integrate dynamic rupture models with wave-scattering and attenuation models. We seek simulation capabilities that span the main engineering band, 0.1-10 Hz.
- **Induced Seismicity.** We will develop detection methods for low magnitude earthquakes, participate in the building of hydrological models for special study sites, and develop and test mechanistic and empirical models of anthropogenic earthquakes within Southern California.

Characterizing seismic hazards: We seek to characterize seismic hazards across a wide spectrum of anticipation and response times, with emphasis on the proper assessment of model uncertainties and the use of physics-based methods to lower those uncertainties.

- **Probabilistic Seismic Hazard Analysis.** We will attempt to reduce the uncertainty in PSHA through physics-based earthquake rupture forecasts and ground-motion models. A special focus will be on reducing the epistemic uncertainty in shaking intensities due to 3D along-path structure.
- **Operational Earthquake Forecasting.** We will conduct fundamental research on earthquake predictability, develop physics-based forecasting models in the new Collaboratory for Interseismic Simulation and Modeling, and coordinate the Working Group on California Earthquake Probabilities.
- **Earthquake Early Warning.** We will develop methods to infer rupture parameters from time-limited data, ground-motion predictions that account for directivity, basin, and other 3D effects, and better long-term and short-term earthquake rupture forecasts for conditioning of early-warning algorithms.
- **Post-Earthquake Rapid Response.** We will improve the rapid scientific response to strong earthquakes in Southern California through the development of new methods for mobilizing and coordinating the core geoscience disciplines in the gathering and preservation of perishable earthquake data.

Reducing seismic risk: Through partnerships coordinated by SCEC's Earthquake Engineering Implementation Interface, we will conduct research useful in motivating societal actions to reduce earthquake risk. Two topics investigated by these engineering partnerships will be:

- **Risk to Distributed Infrastructure.** We will work with engineers and stakeholders to apply measures of distributed infrastructure impacts in assessing correlated damage from physics-based ground-motion simulations. An initial project will develop earthquake scenarios for the Los Angeles water supply.
- **Velocity and Rheology of Basin Sediments.** In collaboration with geotechnical engineers, we will advance the understanding of site effects and soil-structure interactions by incorporating nonlinear rheological models of near-surface rock and soil layers into full-physics earthquake simulations.

Communication, Education and Outreach Plan

The SCEC CEO program manages and expands a suite of successful activities within four CEO focus areas. *Knowledge Implementation* connects SCEC scientists and research results with practicing engineers, government officials, business risk managers, and other professionals in order to improve application of earthquake science. The *Public Education and Preparedness* focus area educates people of all ages about earthquakes, tsunamis, and other hazards, and motivate them to become prepared. The *K-14 Earthquake Education Initiative* improves earth science education in multiple learning environments, overall science literacy, and earthquake safety in schools and museums. The *Experiential Learning and Career Advancement* (ELCA) program provides research opportunities, networking, and other resources to encourage students and sustain careers in STEM fields. Four long-term intended outcomes of the CEO program are: improved application of earthquake science in policy and practice; reduced loss of life, property, and recovery time; increased science literacy; and increased diversity, retention, and career success in the scientific workforce. SCEC's vigorous promotion of workforce diversity is now being augmented by its Transitions Program (within ELCA) that provides students and early-career scientists with resources and mentoring at major steps in their careers.

Broader Impacts of Proposed Research

California comprises about two-thirds of the nation's long-term earthquake risk, and Southern California about 40% of this total. SCEC5 will translate basic research into practical products that will inform efforts to reduce risk and build resilience in California and elsewhere. The Center works with the USGS and California agencies to improve the two basic elements of seismic hazard analysis, earthquake rupture forecasting and ground-motion modeling. It will equip long-term seismic hazard analysis and short-term earthquake forecasting with physics-enabled, system-specific models that can provide authoritative information about the time dependence of seismic hazards to help communities prepare for potentially destructive earthquakes. This research will also lead to improvements in earthquake early warning as well as the delivery of post-event information about strong ground motions and secondary hazards, such as landsliding, liquefaction, and tsunamis.

Los Angeles Mayor Garcetti's plan to strengthen buildings, fortify the water system, and enhance reliable telecommunications has demonstrated how the quantitative characterization of seismic hazards can provide the scientific basis for strong civic actions to mitigate risk and improve resilience. SCEC5 will support the chain of scientific inference that proceeds from hazard characterization to loss estimation and eventually to implementation of effective mitigation options with well-defined costs and benefits.

SCEC, through its CEO program, continues to manage the statewide Earthquake Country Alliance, which now comprises more than 400 associates partner organizations and sponsors a yearly preparedness campaign—the Great California ShakeOut—that has involved millions of California citizens. SCEC coordinates ShakeOut activities in all U.S. states and territories and internationally into Canada, Japan, New Zealand, and a growing number of other countries.

SCEC is a center-without-walls that has developed the virtual organization needed to coordinate and sustain interdisciplinary, multi-institutional earthquake system science. The SCEC5 working groups, workshops, field activities, intern programs, and annual meeting fosters deep collaborations and strong interpersonal networks among earthquake scientists, earthquake engineers, and other professionals. SCEC5 will promote intellectual exchange and amplify the support for students and early-career scientists, giving them the organizational resources and experience to become the field's future leaders

2. Organization and Management

SCEC has developed an effective management structure for coordinating earthquake research and education activities. The Center's ability to facilitate collaborative, investigator-driven research has been repeatedly proven in its diverse accomplishments. Participation in SCEC is rising despite flat funding and its national and international partnerships are flourishing. In its annual reports, the SCEC External Advisory Council has repeatedly documented the enthusiasm among SCEC participants and endorsed their high levels of satisfaction with the Center's leadership and management.

Core and Participating Institutions

SCEC continues as an institution-based center, governed by a Board of Directors, who represent its members. The Center currently involves more than 1000 scientists and other experts in active SCEC projects, making it one of the largest formal collaborations in geoscience. It continues to operate as an open consortium, available to all qualified individuals and institutions seeking to collaborate on earthquake science in Southern California, and its membership continues to evolve. The institutional membership currently stands at 76, comprising 18 core institutions and 58 participating institutions (not limited to universities, nor to U.S. organizations). The three USGS offices in Menlo Park, Pasadena, and Golden and the California Geological Survey are core institutions. Fourteen foreign institutions are currently recognized as partners with SCEC through a set of international cooperative agreements.

Board of Directors

Each core institution has appointed one member to the SCEC Board of Directors, which is chaired by the Center Director. The Board is the primary decision-making body of SCEC; it meets three times per year (typically in February, June, and September) to approve the Annual Collaboration Plan and budget and deal with major business items. The SCEC board comprises 17 voting members. The USGS members serve in non-voting liaison capacity. Kate Scharer from the Pasadena office of the USGS joined the Board this year, replacing Rob Graves. *Ex officio* members include the Co-Director; the PC Vice-Chair; the Executive Science Director for Special Projects; and the Associate Directors for CEO, IT, Science Operations, and Administration. The Board is empowered to elect two nominees from the participating institutions to serve two-year terms as At-Large Members. Rachel Abercrombie (Boston University) and Rowena Lohman (Cornell University) joined the Board this year, representing the participating institutions as At-Large Members of the Board.

Director Transition

The SCEC Director acts as Principal Investigator (PI) on most proposals submitted by the Center, retaining final authority to make and implement decisions on Center programs, budgets, and financial obligations. The Director

oversees all Center activities and is the Center's official liaison to the rest of the world, and specifically, to the funding agencies. The Director chairs the SCEC Board of Directors, and may appoint committees as needed to carry out Center business.

John Vidale, who signed up in April 2017, started at USC in August 2017, took over as SCEC Director in September 2017. Tom Jordan, the SCEC5 proposal PI, had been the Center Director since 2002, and remains at USC and deeply engaged, but will be out of town on sabbatical this next year.

Executive Committee

The changes in the SCEC leadership structure and formation of an Executive Committee of the Center (ExCom), as written in the modified SCEC By-Laws, were intended to redistribute some of the Director's responsibilities and workload. The ExCom handles daily decision-making responsibilities for the Center. It currently comprises of the Center Director (John Vidale), the Co-Director (Greg Beroza), the Board Vice-Chair (John Shaw), the PC Vice-Chair (Judi Chester), the Executive Director for Special Projects (Christine Goulet), the Associate Directors for CEO (Mark Benthien), Information Technology (Philip Maechling), Administration (John McRaney), and Science Operations (Tran Huynh).

The Board Chair and Vice-Chair coordinate program activities with the SCEC Board of Directors. The Co-Director and Executive Science Director for Special Projects (ED-SP) may serve as the Principal Investigator of SCEC special projects. The PC Chair serves as a liaison to SCEC science partners, chairs of the annual meeting, and oversees the annual science planning process. The PC Vice-Chair and the ED-SP provide added science leadership when formulating and implementing the annual science program. The ED-SP manages the science activities of applied science projects and coordinated these activities with the PC and Associate Directors for IT and Science Operations. The Associate Director for Science Operations manages all operational and financial aspects of the science planning process. The Associate Director for CEO is responsible for Center communication, education, and outreach activities. The Associate Director for Administration manages the Center budget as approved the Board and liaises with the funding agencies.

John McRaney (the AD for Administration) will retire early in 2019, and new hiring will precede the retirement to assure continuity and maintain operational capacity of the SCEC headquarters.

Science Planning Committee

The Science Planning Committee (PC) is responsible for formulating the Center's science plan, conducting proposal reviews, and recommending projects to the Board for SCEC support. The chair of the PC is the SCEC Co-Director, Greg Beroza of Stanford, and its Vice-Chair is Judi Chester of Texas A&M. The PC comprises the leaders of the SCEC science working groups—disciplinary committees, focus groups, and special project groups—who, together with the working group co-leaders, guide SCEC's research program. Its members play key roles in implementing the SCEC science plan.

SCEC5 science planning organization chart, consisting of Disciplinary Committees (green boxes), Interdisciplinary Focus Groups (yellow boxes), and Technical Activity Groups (ellipses) coordinated by Working Group leaders in Special Projects, San Andreas Fault System, SCEC Community Models, and the Earthquake Engineering Implementation Interface.

Science Working Groups

The SCEC organization comprises a number of disciplinary committees, focus groups, special project teams, and technical activity groups (TAGs). These working groups have been our engines of success, and many of the discussions at this meeting will feed into their plans.

The Center supports disciplinary science through standing **disciplinary committees** in Seismology, Tectonic Geodesy, Earthquake Geology, and Computational Science. These groups are responsible for disciplinary activities relevant to the SCEC Science Plan, and they make recommendations to the Planning Committee from the perspective of disciplinary research and infrastructure. The leaders of the disciplinary committees are Seismology: Yehuda Ben-Zion and Jamie Steidl; Tectonic Geodesy: Gareth Funning and Manoochehr Shirzaei (who replaced Dave Sandwell); Earthquake Geology: Mike Oskin and Whitney Behr; Computational Science: Eric Dunham and Ricardo Taborda.

SCEC coordinates earthquake system science through **interdisciplinary focus groups**. The leadership are Fault Rupture and Mechanics (FARM): Nadia Lapusta and Nick Beeler; Earthquake Forecasting and Predictability (EFP): Max Werner and Ned Field; Stress and Deformation Over Time (SDOT): Kaj Johnson and Bridget Smith-Konter; Earthquake Engineering Implementation Interface (EEII): Jack Baker and Jon Stewart; Ground Motions (GM): Domniki Asimaki, Annemarie Baltay-Sundstrom; San Andreas Fault Sytem (SAFS): Ramon Arrowsmith (who replaced Kate Scharer) and Michele Cooke; SCEC Community Models (CXM): Liz Hearn and Scott Marshall.

SCEC **special projects** are research partnerships in targeted earthquake research that heavily leverage the core program. Synergy between the special projects and the core program is ensured by a central SCEC policy, instituted by the Board of Directors in 2005: the science objectives of all SCEC special projects must be aligned with those of the SCEC core program and explicitly included as objectives in the SCEC Annual Science Plan. Current SCEC special projects include UCERF, CSEP, SEISM2, CISM, MSW, and CCSP. Special Projects are currently funded by NSF, USGS, the California Earthquake Authority, the W. M. Keck Foundation, and Pacific Gas & Electric Company. The ED-SP (Christine Goulet) manages the science activities of special projects in coordination with the Associate Director for IT (Phil Maechling), who oversees the SCEC's CME, a high-performance collaboratory for large-scale earthquake simulations. The CME infrastructure and software developers currently support five major SCEC computational platforms: High-F, CyberShake, Broadband, F3DT, and UCVM. The importance and scale of effort involved with CSEP, CXM, and data management led us to request additional funding for software developers focused on these activities in the SCEC5 proposal.

SCEC researchers are encouraged to self-organize into **technical activity groups** (TAGs) to develop and test critical methodologies for solving specific problems. TAGs have formed to verify the complex computer calculations needed for wave propagation and dynamic rupture problems, to assess the accuracy and resolving power of source inversions, and to develop geodetic transient detectors and earthquake simulators. TAGs share a modus operandi: the posing of well-defined "standard problems", solution of these problems by different researchers using alternative algorithms or codes, a common cyberspace for comparing solutions, and meetings to discuss discrepancies and potential improvements. TAGs are initiated through successful proposals submitted through the science collaboration process. TAG proposals typically involve a workshop and include a research coordination plan that sets a timetable for successful completion of TAG activities no later than the end of SCEC5.

Science Planning Process

The annual budget cycle begins with a SCEC Leadership Meeting in early June, when the Board, Planning Committee, Executive Committee of the Center, and agency representatives discuss SCEC research priorities. Based on these discussions, the PC drafts an annual SCEC Science Plan (www.scec.org/scienceplan), which is presented to the SCEC community at the Annual Meeting in early September. The PC uses the feedback received at the meeting to finalize the Annual Science Plan, and a project solicitation released in October. SCEC participants submit proposals in response to this solicitation in November. All proposals are independently reviewed by the Director, the Co-Director, Vice-Chair of the PC, and the leaders of at least three relevant science working groups. Reviews are assigned to avoid conflicts of interest.

The PC meets in January to review all proposals and construct an Annual Collaboration Plan. The plan's objective is a coherent science program, consistent with SCEC's basic mission, institutional composition, and budget that achieves the Center's short-term objectives and long-term goals, as expressed in the Annual Science Plan. The PC Chair submits the recommended Annual Collaboration Plan to the Board of Directors for approval. The annual budget

approved by the Board and the Center Director is submitted to the sponsoring agencies for final approval and funding. Upon approval by the agencies, notifications are sent out to the investigators.

To construct the annual SCEC Collaboration Plan, proposals submitted in response to the annual solicitation are evaluated based on: (a) scientific merit of the proposed research; (b) competence, diversity, career level, and performance of the investigators; (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 principal investigator and institution to the SCEC mission; (f) value of the proposed research relative to its cost; and (g) the need to achieve a balanced budget while maintaining a reasonable level of scientific continuity given funding limitations. With respect to criterion (b), improving the diversity of the SCEC community and supporting early-career scientists is a major goal of the Center. It is important to note that a proposal that receives a low rating or no funding does not necessarily imply it is scientifically inferior. Rather, these proposals may be downgraded because they may not meet other criteria noted above.

SCEC maintains close alignment with the USGS Earthquake Hazards Program during the science planning process through three mechanisms: (1) reporting and accountability required by USGS funding of SCEC, (2) liaison memberships on the Board of Directors by the three USGS offices now enrolled as SCEC core institutions, and (3) a Joint SCEC/USGS Planning Committee (JPC). The JPC augments the SCEC Planning Committee with a group of program leaders designated by the USGS who participate in the construction of the Annual Collaboration Plan. If requested, the PC chair will continue to sit on the Southern California Proposal Review Panel for the USGS External Research Program.

Communication, Education and Outreach

The Associate Director for CEO (Mark Benthien) manages SCEC's Communication, Education, and Outreach program, with activities focused on four areas: Knowledge Implementation, Public Education and Preparedness, K-14 Earthquake Education, and Experiential Learning and Career Advancement. The Earthquake Engineering Implementation Interface, led by Jack Baker (Stanford) and Jon Stewart (UCLA), provides the organizational structure for connecting SCEC scientists and research results with practicing engineers, government officials, business risk managers, and other professionals in order to improve application of earthquake science. Through coordination with the Earthquake Country Alliance (ECA) and other outreach partners, SCEC educates people of all ages about earthquakes, tsunamis, and other hazards, and motivate them to become prepared. SCEC's education programs are managed by Gabriela Noriega of USC through the Office of Experiential Learning and Career Advancement.

The **CEO Planning Committee**, comprises members representing the four CEO focus areas. They are chartered to provide guidance and support for the portfolio of SCEC/CEO activities and partnerships, review reports and evaluations, and identify synergies with other parts of SCEC and external organizations. The CEO-PC includes CEO partners and SCEC Community stakeholders, with some members drawn from the AC, Board, and Science Planning Committee. The Chair of the CEO-PC is Tim Sellnow (U. Central Florida), who is also on the AC. Sellnow represents the Public Education and Preparedness CEO focus area along with Kate Long (formerly CalOES, now with the Dr. Lucy Jones Center). Danielle Sumy (IRIS) represents the K-14 Earthquake Education Initiative. Sally McGill (CSU San Bernardino) represents the Experiential Learning and Career Advancement focus area. Tim Dawson (California Geological Survey) and Ricardo Taborda (Universidad EAFIT, Colombia) represents the Knowledge Implementation focus area. Dawson and Taborda are also the representatives of the SCEC Board and PC, respectively, on the CEO-PC.

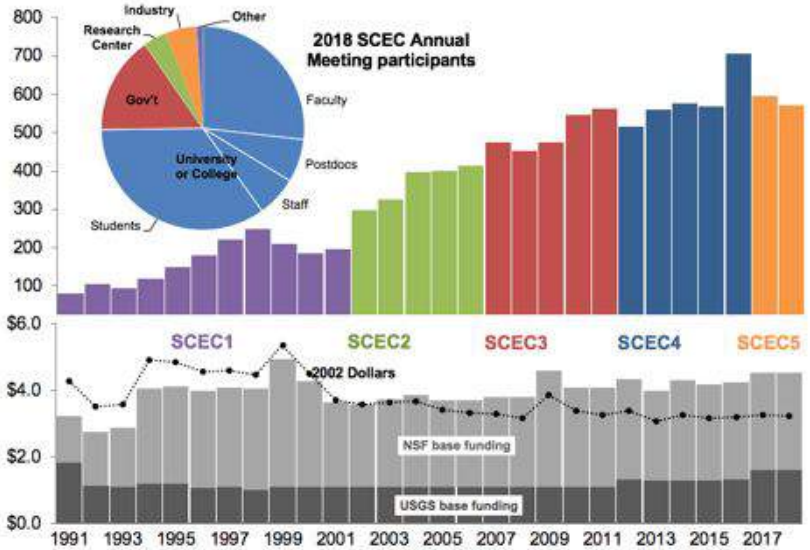
External Advisory Council

The external Advisory Council (AC) serves as an experienced advisory body to the Center, charged with developing an overview of SCEC operations, identifying strengths, opportunities, and vulnerabilities, and advising the Director, the Executive Committee, and the Board. Since the inception of SCEC in 1991, the AC has provided perspective to maintain the vitality of the SCEC and help its leadership chart new directions. The Center provides its sponsoring agencies and participants, with a complete copy of the yearly AC report.

The AC was reconstituted as part of the SCEC5 transition in 2017. Meghan Miller, the president of UNAVCO, is the current AC Chair. The new AC members are Ellen Rathje (University of Texas, Austin), Louise Kellogg (UC Davis). Continuing members are Warner Marzocchi (INGV, Rome), Rick Aster (Colorado State U), Susan Beck (U Arizona), Yann Klinger (IPGP/Paris), Tom O'Rourke (Cornell), Susan Owen (JPL), Heidi Tremayne (EERI), and Tim Sellnow (U. Central Florida). Rotating off the AC this past year are Donna Eberhart-Phillips (UC Davis) and Roger Bilham (U. Colorado).

SCEC Participants and Demographics

SCEC is a large consortium of institutions with a national, and increasingly worldwide, distribution that coordinates earthquake science within Southern California and with research elsewhere. The SCEC community now comprises one of the largest formal research collaborations in geoscience. Among the most useful measures of SCEC size are the number of people on the Center's email list (2,478 as of November 2018) and the registrants at the SCEC Annual Meeting (571 in 2018). Annual Meeting registrations for SCEC's entire history and other demographic information are shown in below.



Upper bar chart shows registrants at SCEC Annual Meetings 1991-2018. Pie chart shows the demographic profile for 2018 pre-registrants (571 total). The lower bar chart is the history of SCEC base funding in as-spent millions of dollars; the connected dots are the base-funding totals in 2002 dollars.

SCEC is an open community of trust that nurtures early-career scientists and shares information and ideas about earthquake system science. The Center's working groups, workshops, field activities, and annual meeting enable scientists to collaborate over sustained periods, building strong interpersonal networks that promote intellectual exchange and mutual support. In particular, SCEC encourages colleagues with creative physics-based ideas about earthquakes to formulate them as hypotheses that can be tested collectively. An advantage is that researchers with new hypotheses are quickly brought together with others who have observational insights, modeling skills, and knowledge of statistical testing methods. Participation in SCEC is open, and the participants are constantly changing.

The SCEC leadership is committed to the growth of a diverse scientific community and actively pursues this goal by (1) encouraging core institutions to consider diversity in their appointments of Board members and electing the Board's members-at-large; (2) making diversity a major criterion in appointments to the Planning Committee, a crucible for developing leadership because it has significant responsibilities in managing SCEC activities; (3) including diversity as a criterion used to evaluate proposals and construct the Annual Collaboration Plan; and (4) promoting diversity among our students and early-career scientists through recruitment for the SCEC internship and diversity programs.

Recognizing that diversity is a long-term issue requiring continuing assessments and constant attention, SCEC continues to track the demographics in order understand the composition and evolution of the SCEC community. For example, people who participate in the SCEC Annual Meeting and/or Annual Collaboration Plan must register in the SCEC Community Information System, which includes providing demographic information. The table below shows a snapshot of the diversity of the SCEC Community as a whole. The SCEC community generally follows historical trends in the geosciences, with much greater diversity among students than senior faculty. Participation of underrepresented minorities is very low, again reflecting the Earth Sciences at large.

We recognize that the current situation is not unique to SCEC and reflects historical trends in the geoscience and physical science communities. We believe SCEC can be most effective in changing these trends by promoting diversity among its students and early-career scientists; i.e., by focusing on the “pipeline problem”. The SCEC internship programs have been an effective mechanism for this purpose and we will redouble our efforts to encourage a diverse population of students to pursue careers in earthquake science through the launch of the Transitions Program in 2017. This program will provide junior members of the SCEC community with resources and mentoring across key career transitions, directing efforts to encourage and sustain careers in the geosciences and other STEM fields.

Center database of SCEC participants in 2018

	Race						Ethnicity		
	Native	Asian	Black	Pacific	White	NA	Latino	Not	NA
Faculty (Tenure-Track)	0	22	1	0	134	59	12	146	58
Faculty (Non-Tenure-Track)	0	2	0	0	6	3	0	7	4
Research Faculty (Tenure-Track)	0	2	0	0	6	8	0	6	10
Research Faculty (Non-Tenure-Track)	0	8	0	0	18	6	2	23	7
Postdoctoral Scholar or Fellow	0	17	1	0	35	28	0	42	39
Teacher (K-12)	0	0	0	0	0	1	0	0	1
Student (Graduate)	0	48	4	0	84	64	15	119	66
Student (Undergraduate)	1	6	1	1	19	28	14	18	24
Student (High School)	0	0	0	0	0	0	0	0	0
Staff (Management and Administration)	0	2	0	0	18	3	1	18	4
Staff Scientist (Doctoral Level)	0	18	1	0	61	25	3	75	27
Staff (Research)	0	8	1	0	17	12	0	19	19
Staff (Comm, Outreach, Public Relations)	0	0	1	0	5	3	2	6	1
Technician	0	0	0	0	2	0	0	2	0
Professional Engineer (Civil and Environ)	0	1	0	0	4	2	0	3	4
Professional Engineer (Other)	0	0	0	0	2	2	0	2	2
Professional Geologist	0	0	0	0	18	11	3	14	12
Consultant (Engineering)	0	1	0	0	2	4	0	4	3
Consultant (Information Technology)	0	2	0	0	1	3	0	3	3
Consultant (Other)	0	0	0	0	2	2	0	1	3
Building Official	0	0	0	0	0	0	0	0	0
Emergency Manager	0	0	0	0	3	2	1	1	3
Self-Employed	0	0	0	0	0	1	0	0	1
Unemployed	0	0	0	0	0	0	0	0	0
Retired	0	0	0	0	4	0	0	4	0
Other	0	0	0	0	4	10	1	3	10
Unspecified	0	5	0	0	19	55	2	18	59

	Gender			Citizenship		
	Male	Female	NA	US	Other	NA
Faculty (Tenure-Track)	148	44	24	133	57	26
Faculty (Non-Tenure-Track)	7	4	0	5	5	1
Research Faculty (Tenure-Track)	11	3	2	7	7	2
Research Faculty (Non-Tenure-Track)	21	8	3	17	11	4
Postdoctoral Scholar or Fellow	54	18	9	24	45	12
Teacher (K-12)	0	1	0	1	0	0

Student (Graduate)	104	76	20	100	94	6
Student (Undergraduate)	24	17	15	35	11	10
Student (High School)	0	0	0	0	0	0
Staff (Management and Administration)	14	9	0	21	2	0
Staff Scientist (Doctoral Level)	75	20	10	69	24	12
Staff (Research)	23	10	5	20	12	6
Staff (Comm, Outreach, Public Relations)	3	6	0	9	0	0
Technician	1	1	0	2	0	0
Professional Engineer (Civil and Environ)	4	1	2	5	0	2
Professional Engineer (Other)	2	2	0	3	1	0
Professional Geologist	22	6	1	26	2	1
Consultant (Engineering)	5	2	0	3	4	0
Consultant (Information Technology)	4	1	1	3	3	0
Consultant (Other)	2	2	0	3	1	0
Building Official	0	0	0	0	0	0
Emergency Manager	3	1	1	4	1	0
Self-Employed	1	0	0	0	1	0
Unemployed	0	0	0	0	0	0
Retired	4	0	0	3	1	0
Other	5	3	6	5	4	5
Unspecified	25	9	45	16	53	10

Activities Code of Conduct

SCEC takes pride in fostering a diverse and inclusive community of collaborators. In the Spring of 2017, in response to inquiries from the SCEC community, the Director and Board approved the formation of an ad-hoc committee charged with (1) publishing a statement of SCEC's commitment to providing a safe, productive, and welcoming environment for all participants, (2) formulating a system for reporting conduct-related complaints, and (3) recommending response plans to the SCEC Leadership for such complaints. The resulting SCEC Activities Code of Conduct, approved by the Board of Directors in June 2018, was incorporated into the registration process for the 2018 SCEC Annual Meeting. A post-meeting survey of participants indicated that the community response to the Code was overwhelmingly positive. Invitations to the smaller meetings and workshops SCEC hosts will include the following statement: "By accepting an invitation to participate in a SCEC-supported event, by email or online registration, participants agree to abide by the SCEC Activities Code of Conduct." The text of the Code, which draws heavily on similar policies found online, is available at https://www.scec.org/meetings/code-of-conduct. In November 2018, NSF published new requirements that all conference proposals must include such conduct guidelines. The SCEC Conduct Committee's final task will be to confirm that the Code and SCEC's response plan incorporate the new resources available from NSF's Office of Diversity and Inclusion website.

International Collaborations

- **SCEC Advisory Council.** We have two international members, Yann Klinger of Institute for Physics of the Globe in Paris and Warner Marzocchi of INGV in Rome.
- **CEO Planning Committee.** Ricardo Taborda, formerly of Memphis, but now at the Universidad EAFIT in Medellin, Colombia is a member.
- **CEO/ShakeOut.** SCEC collaborates with more than 60 countries on ShakeOut activities, including partnerships with Afghanistan, Canada, Colombia, Greece, Iran, Mexico, New Zealand, India, Japan, Italy, Afghanistan, Pakistan, CNMI, and the Philippines on holding ShakeOut drills. SCEC hosts the websites for all ShakeOut drills worldwide. In 2018, there were > 62 million participants worldwide, with >20 million participating in the U.S. See www.ShakeOut.org.
- **ERI/Tokyo and DPRI/Kyoto.** SCEC has long term MOU's with the Earthquake Research Institute in Tokyo and the Disaster Prevention Research Institute in Kyoto. Christine Goulet, SCEC Executive Science Director for Special Projects visited ERI in October 2018. She made presentations on 1) Active Tectonic Region Ground Motion Models related to NGA-West, and 2) SCEC's Simulations Program and the OpenSource Broadband Platform (BBP). Hiroshi Tsuruoka of ERI/Tokyo participates in CSEP activities.
- **CSEP (Collaboratory for the Study of Earthquake Predictability).** SCEC founded CSEP in 2006. CSEP testing centers are now located at USC, ERI/Tokyo, GNS/New Zealand, ETH/Zurich, and CEA/China.
- **ACES (APEC Cooperative for Earthquake Simulation).** SCEC and JPL are the U.S. organizations participating in ACES. Information on ACES can be found http://www.quakes.uq.edu.au/ACES/. Tony Song of JPL is the U.S. delegate the ACES International Science Board and John McRaney of SCEC is the secretary general. Eiichi Fukuyama of the National Research Institute for Earth Science and Disaster Prevention (NIED) in Japan is the current Executive Director of ACES. The 2018 ACES workshop was held September 25-28, 2018 on Awaji Island near Osaka, Japan. Awaji Island was the epicenter of the 1995 Kobe Earthquake. SCEC scientists Jean-Paul Ampuero (Caltech and Universite Cote d'Azur, France) and Jean-Philippe Avouac were two of the keynote speakers. Other SCEC invited speakers were Sylvain Barbot (USC), Eric Dunham (Stanford), Kaj Johnson (Indiana), Lengsen Meng (UCLA), and Robert Viesca (Tufts).
- **Universidad EAFIT in Medellin, Colombia.** Ricardo Taborda is co-leader of the Computational Science group. Taborda and Doriam Restrepo are Co-PIs with Dominic Asimaki of Caltech on a SCEC funded project. Taborda also collaborates on a TAG group project with Asimaki.
- **Universite Paris-Est and University of British Columbia.** Luis Bonilla of Paris-Est and Mahdi Taiebat of UBC collaborate on a SCEC-funded project with Pedro Arduino of the University of Washington.
- **Nanyang Technological University.** Aron Meltzner of NTU in Singapore is a Co-PI on a SCEC-funded project on faulting in the Brawley Seismic Zone with Kyriakopoulos and Oglesby of UCR and Rockwell of SDSU.
- **ETH Zurich/Switzerland.** Whitney Behr of ETH is co-leader of the Earthquake Geology group. Stefan Wiemar participates in the SCEC/CSEP projects. Luis Dalguer participates in the rupture validation project.
- **KAUST/Saudi Arabia.** Martin Mai participates in the Source Inversion Validation TAG.
- **IGNS/New Zealand.** David Rhoades and Matt Gerstenberger of the Institute for Geological and Nuclear Sciences of New Zealand are involved in the CSEP program. Charles Williams, Caroline Holden, and Susan Ellis participate in the ground motion modeling program.
- **University of Otago/New Zealand.** Mark Stirling of Otago participates in the ground motion modeling program.

- **Canterbury University/New Zealand.** Brendon Bradley of QuakeCore participates in the SCEC ground motion simulation program.
- **GFZ Potsdam/Germany.** Danijel Schorlemmer participates in the CSEP special project. Olaf Zielke participates in the simulators project.
- **University of Bristol/UK.** Max Werner is the co-leader of the Earthquake Forecasting and Prediction Interdisciplinary Focus Group of the SCEC PC. Max also participates in CSEP activities.
- **University of Naples/Italy.** Iunio Iervolino participates in the Ground Motion Simulation Validation TAG under support from the European REAKT Project.
- **CICESE/Mexico.** Alejandro Gonzalez-Ortega and Jose Gonzalez-Garcia are collaborating with David Sandwell on a SCEC-funded project where data from Baja California included in the SCEC CGM.
  International HPC Summer School, Ostrava, Czech Republic, July 2018. SCEC Software Engineer Scott Callaghan served as an instructor at this workshop on High Performance Computing.
- **Banff International Induced Seismicity Workshop, October 2018, Banff, Canada.** The theme of the workshop was bridging and integrating knowledge across sectors, and across different induced seismicity settings and types. SCEC participants included Yehuda Ben-Zion, Ilia Zaliapin, Zachary Ross, David Shelly, Bill Ellsworth, Gail Atkinson, and Norm Abrahamson.
- **KAUST Workshop on Advancing Seismic Hazard Assessment, KAUST Saudi Arabia, November 2018.** Thomas Jordan, Kevin Milner, and Mark Stirling gave presentations on SCEC seismic hazard research at this meeting. Martin Mai of SCEC was the host.
- **IUGG 32nd Conference on Mathematical Geophysics, Nizhny Novgorod, Russia, June 2018.** SCEC scientists participating in this conference included Co-Director Greg Beroza, Yehuda Ben-Zion, Andrea Donnellan, and Ilya Zaliapin.
- **UJNR Panel on Earthquake Research, Kumamoto, Japan, October 2018.** SCEC has been an active participant in this biennial meeting, having hosted the first meeting in 1994. The meeting promotes advanced research toward a more fundamental understanding of the earthquake process and hazard estimation. SCEC coordinates the participation of U.S. academic scientists in the meeting with NSF supplemental support focused on early career scientists. SCEC scientists participating in the 2018 meeting included Director John Vidale, Co-Director Greg Beroza, and Heidi Houston. Early career scientists participating in the meeting included Julian Lozos and Eileen Evans of Cal State-Northridge, Jayne Bormann of Cal State-Long Beach, Ting Lin of Texas Tech, Nori Nakata of Oklahoma, and William Frank of USC.
- **Korea Institute of Geoscience and Mineral Resources (Daejeon, South Korea and Seoul National University (Seoul, South Korea).** Co-Director Greg Beroza of Stanford gave presentations on SCEC research in ambient field seismology and Mining Seismic Wavefields in March 2018.
- **Conference on Neural Information Processing Systems.** Co-Director Greg Beroza gave a presentation on “Machine Learning for Geophysical and Geochemical Signals” at the annual meeting in Montreal, Canada in December 2018.
- **International Conference for the Decade Memory of the Wenchuan Earthquake, May 2018, Chengdu, China.** SCEC Director John Vidale gave a keynote talk on SCEC at this meeting. Bruce Shaw, Gareth Funning, Zhigang Peng, and John Rundle also made presentations at this meeting.
- **Broadband Seismology Workshop Honoring Donald Helmberger, Singapore.** SCEC Director John Vidale gave a talk at this workshop at NTU in August 2018 on SCEC broadband seismology.
- **SCEC Annual Meeting.** The SCEC annual meeting continues to attract international participants each year. There were participants in the 2017 annual meeting from Australia, China, Japan, India, Mexico, Canada, France, Switzerland, Germany, Russia, Italy, Taiwan, Turkey, and New Zealand.

- **International Participating Institutions.** ETH/Zurich, CICESE/Mexico, Western University/Canada, University of Bristol/UK, University of Canterbury/New Zealand, and Institute for Geological and Nuclear Sciences/New Zealand; and 4 institutions from Taiwan (Academia Sinica; National Central University; National Chung Cheng University; National Taiwan University) are participating institutions in SCEC.
- **China Earthquake Administration/Beijing.** Then Director Thomas Jordan signed an MOU to work for closer collaboration between the China Earthquake Administration and SCEC in the future. The first workshop, International Conference for the Decade Memory of the Wenchuan Earthquake, resulting from this MOU was held in May 2018. See above for report on that workshop.
- **International Travel by PI and SCEC Scientists.** The PI and other SCEC scientists participated in many international meetings and workshops during the report year.

3. Research Accomplishments

Gregory C. Beroza, *SCEC Science Planning Committee Chair*
Judith S. Chester, *SCEC Science Planning Committee Vice-Chair*

Introduction

The SCEC5 Science Plan comprises 14 topical elements, organized into four themes (see Introduction, Science Plan). Research priorities within each topical element are guided by a progressive set of science milestones, used by SCEC and its sponsoring agencies as indicators of research progress along conceptual pathways. The milestones are more explicit in the early years than the out-years of SCEC5 owing to the evolving and unpredictable nature of basic research. This section summarizes the science accomplishments under each topical element.

Theme A: Modeling the Fault System

1. Stress and Deformation Over Time

We are making progress developing models of the stress state and its evolution during seismic cycles, comparing those models with observations, and assessing their uncertainties, particularly in the representation of fault-system rheology and tectonic forcing. The construction of the Community Thermal Model and the Community Rheology Model builds on this effort (see "Community Models" section below).

An important contribution to deformation over time is characterizing the non-secular, transient deformation associated with the earthquake cycle (milestone 1c). Devries and Meade have made an important contribution to computing efficiently the transient deformation due to viscoelastic flow in the mantle. They trained neural networks to approximate the solutions of the viscoelastic mantle response to fault slip with accurate approximations of the predicted motions (mean absolute errors were ~2x10^{-6} mm) for a range of input parameters with a computational run time reduction of 500x.

We continue to develop and populate the Community Stress Model with constraints from borehole stress measurements (milestone 1d). Persaud and colleagues have compiled industry borehole breakout data to constrain the direction of maximum horizontal compressive stress (SH) at Long Beach and Inglewood at depths less than 2 km. They find an unexpectedly heterogeneous stress state with significant variations in SH (45-90 degrees) over spatial scales less than 1 km. Abolfathian and Ben-Zion have conducted stress inversions using dense focal mechanism data sets

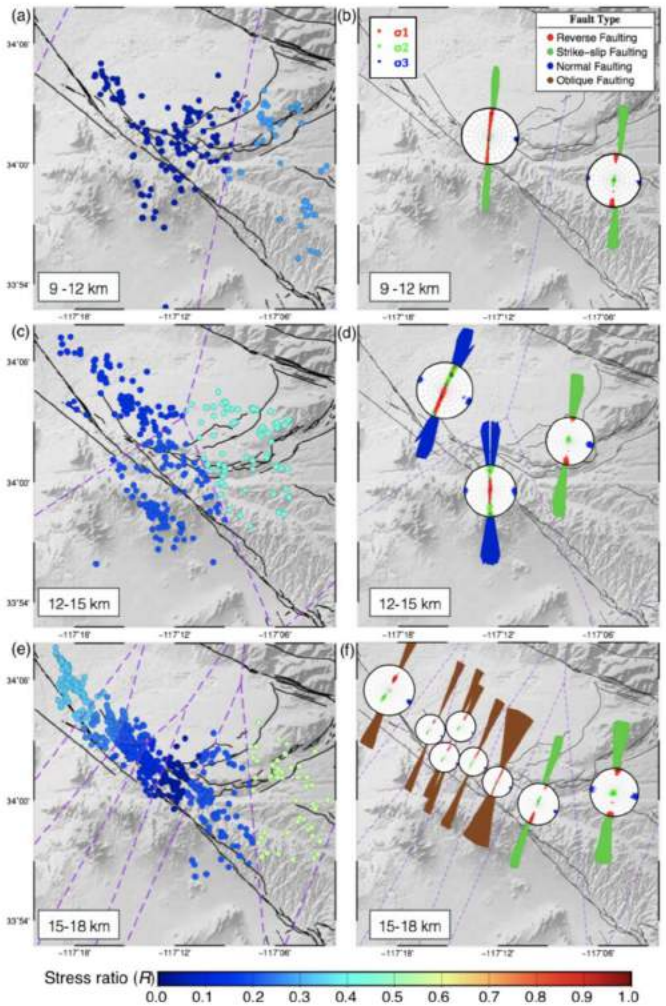


Figure 1. Variations in SH max directions, faulting types, and stress ratio R with depth in the Crafton Hills region of the San Jacinto fault zone near Riverside. From Abolfathian et al. (2018).

in the Crafton Hills region of the San Jacinto fault zone near Riverside (Figure 1). They too find remarkable variation in stress with depth, over small intervals (a few km), and short spatial scales (5-10 km). These studies highlight an important observation that while stress state in southern California appears to be relatively homogeneous or smoothly varying over large wavelengths (100 km), strong heterogeneity may occur also at shorter spatial scales near faults. Characterizing and understanding both the cause and the effect of this heterogeneity is an unanticipated direction for the CSM effort.

Cooke and Beyer contributed to efforts to map the partitioning between seismic and aseismic deformation along major faults using geodetic and seismic data along the San Jacinto fault and San Bernardino Basin (milestone 1f). They find that focal mechanisms show enigmatic normal slip below 7.5 km that would not be expected during interseismic loading of the San Bernardino basin; however, they show with mechanical models that off-fault normal slip distributed through the crust is consistent with interseismic fault creep on the San Andreas and San Jacinto Faults below 10 km depth. This suggests that the local, off-fault stress state may not necessarily reflect the far-field loading on faults.

Smith-Konter and colleagues made important contributions to ongoing efforts to develop physics-based fault system models that capture possible variations in elastic material properties (milestone 1h). They compared the computed moment accumulation rate on faults in California using both homogeneous and heterogeneous elastic models and found systematic biases in the homogeneous calculations (Figure 2). In the southern portion of the fault system (near the Salton Trough), there is a significantly lower seismic moment accumulation rate with heterogeneous models. In contrast, along the Mojave segment of the SAFS, heterogeneous models imply systematically higher moment accumulation rate on the fault.

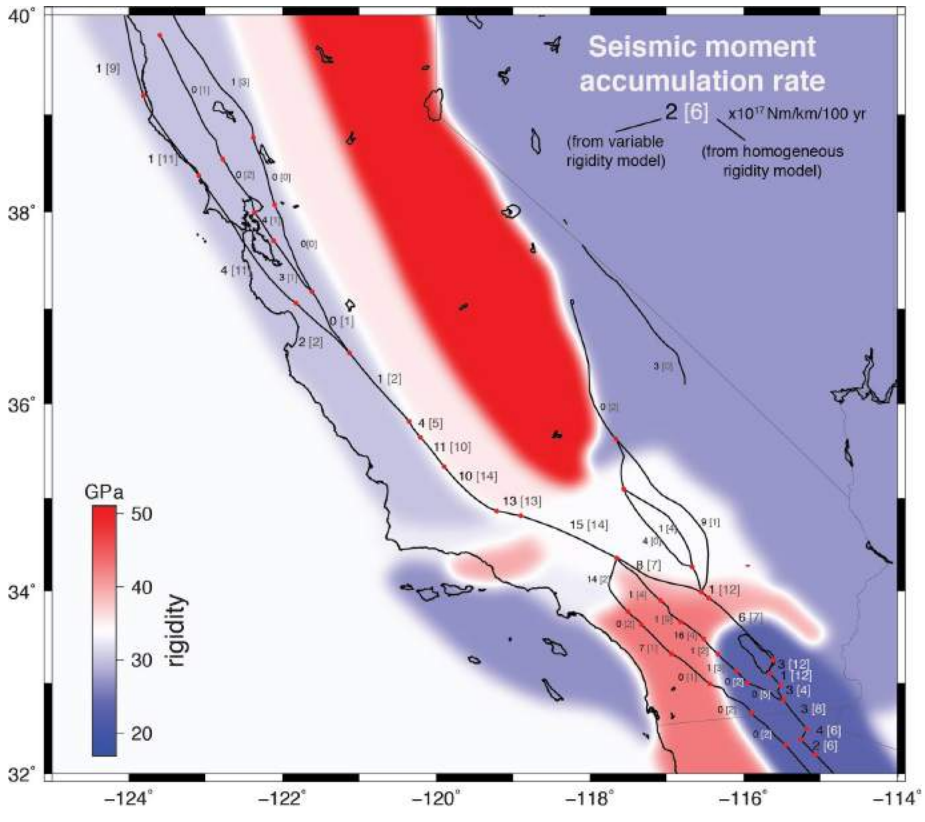


Figure 2. Crustal rigidity and computed seismic moment accumulation rates from both the homogeneous (bracketed value on the right) and variable crustal rigidity (value on the left) models of the SAFS. The background map indicates the prescribed crustal rigidity variations.

Milestone		Y1	Y2	Y3	Y4	Y5
a	Compare GPS-based stressing rates with focal mechanism-based stressing rates.		x	x	x	
b	Collect and analyze campaign GPS data in areas of sparse GPS coverage and poor InSAR correlation.	x	x	x		
c	Assess level and impact of non-secular deformation in SCEC region from the combined CGM inputs				x	
d	Populate the CSM below the upper crust with depth-dependent modeled stresses. Release updated versions of the CSM based on additional borehole constraints and geodynamic modeling.		x	x		

e	Update high-precision earthquake catalogs, including detection of small events, improved locations, and focal mechanisms, to help inform the CSM.	x	x	x	x	x
f	Map the partitioning between seismic and aseismic components of deformation along the major faults using geodetic and seismic data.		x	x	x	
g	Refine the geologic slip rates on faults in Southern California, including offshore faults, and optimally combine the geologic data with geodetic measurements to constrain fault-based deformation models, accounting for observational and modeling uncertainties.				x	
h	Develop physics-based fault system models that capture possible variations in elastic material properties, and permanent/inelastic deformation processes in the crust.			x	x	x

2. Special Fault Study Areas – Focus on Earthquake Gates

Earthquake Gate Areas (EGAs) are regions of fault complexity that may control the propagation of large earthquakes. The Cajon Pass EGA was established in year 1 of the SCEC collaboration, so this was the first year of proposal solicitation for it, and several projects are now underway. Work proposed for the Cajon pass addresses each of milestones 2d, 2e, 2f and 2h. The Cajon Pass EGA held a one-day field trip and ½ day workshop before the 2018 SCEC annual meeting (milestones 2b and 2c). These activities represent the very initial stages of research in the region and a focus has been to highlight knowledge gaps to investigate within the next few years (milestone 2c). The SCEC Planning Committee decided not to designate a second earthquake gate area but encourages investigators to submit proposals related to conditional termination of rupture, which was the motivating scientific question for the EGA initiative, outside of Cajon Pass through the 2019 SCEC science planning process.

Several recently published papers (Barrett et al., 2018; Rockwell, et al., 2018) have refined the slip history of the San Andreas Fault system (milestones 2g and 2h). On-going analysis by Arrowsmith, Alana Williams, Grant-Ludwig, and Akciz of paleoseismic events along the Cholame segment shows correlation of five slip events with previously documented events on the SAF (milestone 2h). Guns, Bennett and Blisniuk are collecting data to investigate geologic and geodetic evidence for activity along the Blue Cut fault (milestone 2h). In studies of the Agua Blanca fault, Behr, Rockwell, Fletcher, Owen and Gold found that the paleoseismic, slip-per-event and slip rate measurements over the past ~1.6-1.4 kyr are mutually consistent and suggest that, whether or not displacement is regular or variable, the Agua Blanca fault is likely near the middle of an earthquake cycle and thus is unlikely to produce a strong earthquake in the immediate future (milestone 2h, Figure 3).

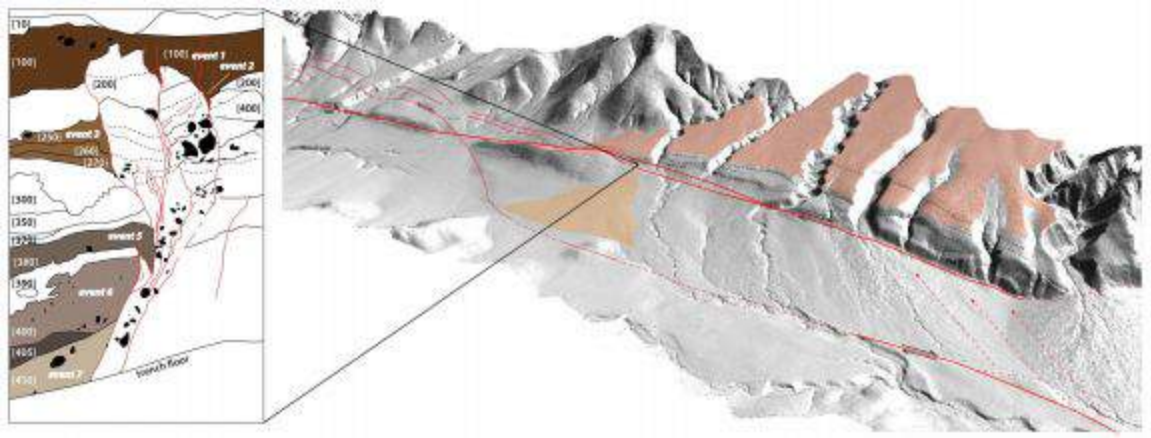


Figure 3. Valle Agua Blanca Lidar Perspective Map.

Preliminary mapping of sediment provenance and landform dating by Blisniuk, Fosdick and Moon (and students Waco and Emmons) show evidence of recent slip along the Mission Creek fault in a region previously interpreted as inactive (milestone 2h). The paleoseismic event database is currently under development by Biasi and Rockwell (milestone 2g).

Milestone		Y1	Y2	Y3	Y4	Y5
a	Hold incubator workshop to develop a research strategy and candidate locations or topics for the Earthquake Gates initiative.	x				
b	Decide on at least one target for the Earthquake Gates initiative and hold an inaugural workshop.		x			
c	Hold joint workshop on multi-disciplinary research on Earthquake Gates focus area(s). Assess scope of Earthquake Gates projects, solicit work as needed.		x	x		
d	Collect and synthesize earthquake recurrence, slip-rate, interseismic deformation and fault geometry information within Earthquake Gate Area(s).	x	x	x	x	
e	Develop multi-cycle rupture and deformation models within the Earthquake Gate focus area(s).	x	x	x	x	
f	Calibrate the model results from the Earthquake Gate area(s) with geologic and geophysical data from within the EGA(s). Incorporate understanding developed under this initiative to improve earthquake rupture forecasts.			x	x	x
g	Develop a paleoseismic event database that includes event ages and quality ranking not limited to Earthquake Gate Area(s).	x	x	x	x	
h	Determine how model-based hypotheses about fault interactions through zones of complexity can be tested by observations of accumulated slip and paleoseismic chronologies.			x	x	x

3. Community Models

We have created a portal website (www.scec.org/research/cxm) to facilitate access to individual community model products, together with a template for standardization of individual CXM websites (milestone 3c). The Community Fault Model (CFM) website is the first to be updated making use of the new template (milestone 3i), and work on updating and linking the Community Stress Model (CSM) website is underway. We will add new borehole stress constraints (milestone 3aa) and modeled stresses to the CSM once the new website is live. We have also linked the Unified Community Velocity Model (UCVM), a collection of software tools and application programming interfaces designed for standardized access to the multiple seismic velocity models used in SCEC research, to the portal website. A paper describing the UCVM software framework was published in September 2017. During 2018 we incorporated new seismic velocity models representing central and northern California into the UCVM, bringing SCEC closer to completing a state-wide seismic velocity model (milestone 3m). Detailed seismic velocity models of the Central Valley and the Santa Maria Basin, based on extensive new well log datasets, are embedded in the new central California velocity model, CS173-H (milestone 3k). In year 2, a workshop was held focused on CVM issues and jump-starting a technical activity group (TAG) to drive CVM development within SCEC and with our partners. The workshop gathered scientists with expertise in (1) body-wave, surface wave, and full waveform tomography, (2) model validation, (3) seismic and other data sources, (4) 3D model integration and representation, and (5) high-performance computing to identify and prioritize research tasks in support of existing and future CVMs (www.scec.org/proposal/report/18118). The group has planned activities aimed at identifying and developing appropriate methods for advancing CVMs as well as their verification, testing and validation (working towards milestones 3k, 3l, 3m and 3q). These CVM TAG efforts (workshop and proposals submitted to SCEC) are supported by a combination of SCEC core-science and PG&E funds. Several of the participants of this CVM TAG are also involved in developing updated CVMs for Northern California within the USGS. Both groups (USGS and SCEC) share the same interest in using several different techniques to develop, verify and validate models. This is a prime example of SCEC leveraging other sources of funding and coordinating projects to improve science and its products.

A Community Rheology Model (CRM) workshop held in September 2017 (milestone 3a) resulted in a prioritized list of research tasks to move the CRM toward a draft product by 2019 (www.scec.org/proposal/report/17206). During the remainder of 2018, progress continued on defining and reviewing the geologic framework (milestone 3n), as well as

flow laws for rocks and shear zones (milestone 3o). This included a second CRM workshop, held at the 2018 SCEC Annual Meeting, that focused on exploring observations and models bearing on the existence (or not) of narrow ductile shear zones and distributed ductile deformation in southern California's lower crust and upper mantle lithosphere (milestone 3a and 3n). SCEC-supported passive seismic imaging of the central Mojave region will address key problems in understanding tectonic layering and underplating in this region that may affect strain accumulation within the Eastern California Shear Zone. A preliminary Community Thermal Model (milestone 3e) is complete and under refinement in preparation for distribution.

Following a September, 2017 workshop, the CFM group released CFM 5.2, which includes geometrical refinements based on the latest earthquake catalogs and surface trace maps; a new metadata spreadsheet featuring fault hierarchies and other supporting information; regular-gridded representations of the CFM 5.2 fault surfaces; and linkages of CFM faults to UCERF3 slip rates (milestones 3i and 3j). We developed a website featuring downloadable versions of recent CFM's in a consistent format (milestone 3i) and linked it to the CXM web portal page. 2018 saw a torrent of activity in the Community Geodetic Model (CGM) group and significant progress toward its SCEC5 milestones. A workshop was held March, 2018, in addition to several virtual meetings for GPS and InSAR specialists. One focus of the workshop (Figure 4) was comparing 3D cGPS time series for southern California by six individual research groups and addressing how to combine them with campaign GPS data into a comprehensive consensus GPS velocity field (milestones 3t and 3r). Another was comparing interferograms and LOS time series for a test problem, to understand and reconcile differences in results from different processing methods and identify best practices (milestone 3u). Strategies for combining GPS and InSAR datasets, and for delivering consensus InSAR LOS datasets to SCEC, were also addressed in both the workshop and associated virtual meetings (milestones 3u and 3v).

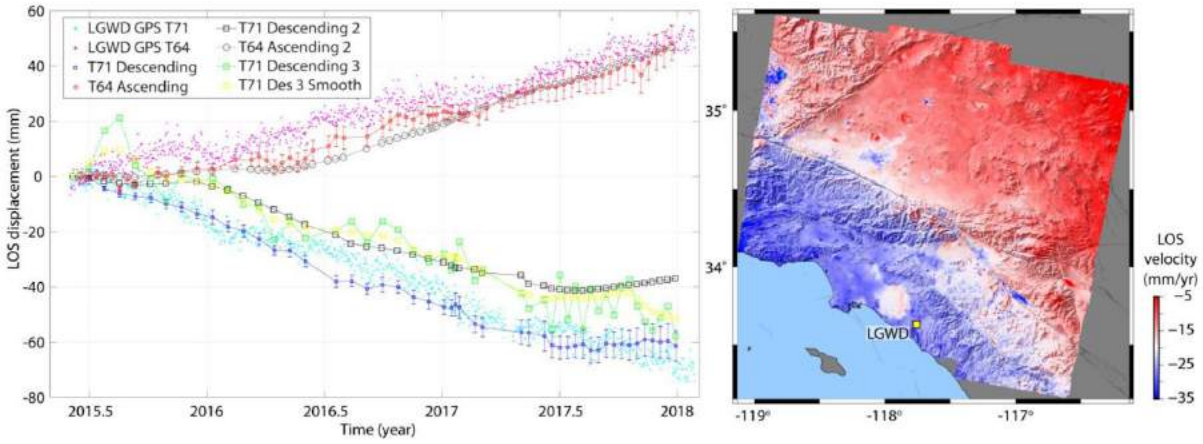


Figure 4. Left – Comparison of GPS daily solutions provided by UNAVCO for station LGWD and InSAR time series derived using different software for location of LGWD. Cyan and magenta dots are GPS daily solutions projected to satellite LOS. Blue and red curves represent descending and ascending solutions (Xu, 2017) using GMTSAR. Black and grey curves show the descending and ascending solutions by Zhen Liu using ISCE and framework developed by H. Fattahi. Green and yellow curves show descending solutions (Neely et al., 2017) using GMTSAR, with different degrees of smoothing applied. All curves are referenced to zero initial displacement. Right – LOS velocity map from descending track T71 with constraints from GPS ITRF08 velocity field (Xu, 2017). Location of GPS station LGWD marked by yellow square. Figure courtesy of Xiaohua Xu.

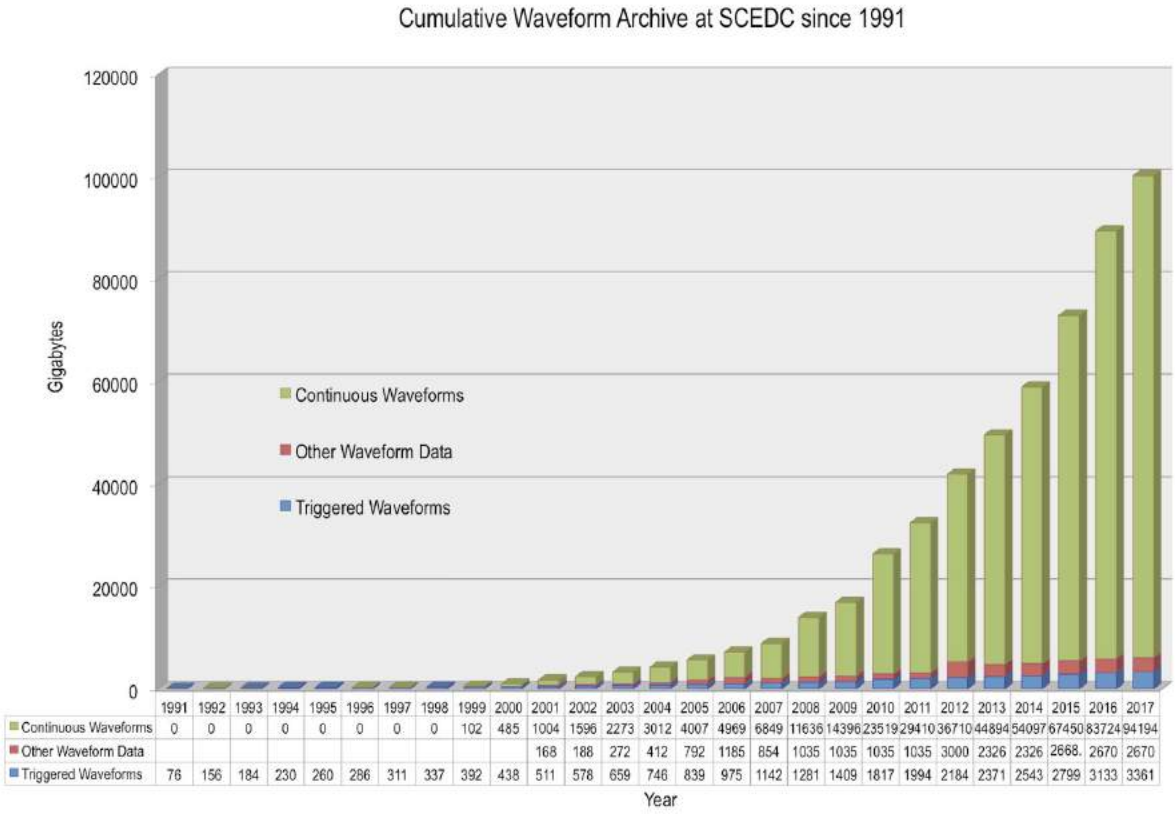
Milestone		Y1	Y2	Y3	Y4	Y5
a	Convene a workshop focused on guiding community model development towards self-consistent and well-integrated community models.		x			
b	Organize TAGs for community models, as appropriate, including a TAG to develop a geologic framework for the Community Rheology Model (CRM).	x				

c	Develop a strategy for a unified approach to data integration, manipulation and querying of community models (CXMs), and identify common or sharable data structures between different CXMs.		x			
d	Develop standards to represent smaller scale features in the CXMs, such as stochastic variations in elastic properties, attenuation, stress, temperature, rheology, fluid transport properties, and fault orientation.				X	
e	Deliver a preliminary Community Thermal Model (CTM) that provides crustal temperatures throughout southern California based on 1D conductive heat flow and a simplified 3D distribution of thermal properties.	x				
f	Update the CTM from 1D to 3D so that it is consistent with CRM lithologies and field data. Improve surface heat flow maps. Search for additional heat flow and thermal property data in areas with poor coverage.		x	x		
g	Add a CTM branch that quantifies advective heat transport, and evaluate the need for anisotropic thermal properties. Provide error ranges for modeled temperatures and alternative models where there are significant disagreements.				x	x
h	Conduct peer review of the Community Fault Model (CFM) 5.1 through a virtual workshop; release a revised version with preferred fault representations.	x				
i	Implement a portable, user-friendly interface to access CFM model versions, components, and metadata, incorporating a new fault naming and number system compatible with the USGS Fault and Fold database.		x	x		
j	Refine CFM representations of the linkages among major fault systems.				x	x
k	Improve the resolution of the Community Velocity Models (CVM-S and CVM-H) in the shallow crust, by adopting products developed or results obtained through the research activities defined for D.14 (physics of the geotechnical layer) and validate against observations.			x		
l	Define and implement a protocol to introduce alternative representations into existing CVMs, leveraging the seismic studies of various geographic regions (e.g., San Jacinto, Salton Sea).			x		
m	Develop a statewide CVM, and validate against independent ambient seismic field measurements.				x	
n	Construct a provisional 3D geologic framework of southern California, as a first step towards developing a CRM. Convene a workshop on how to characterize the brittle, ductile, plastic, and viscoelastic rheologies of the southern California lithosphere, including shear zones.		x			
o	Implement mixing laws for polymineralic rocks of the CRM. Release CRM version 1.0 that includes 3D geologic framework and constitutive models consistent with the CTM.				x	
p	Unify representation of SCEC community models, including refined CFM and CVM structures and prototypes of the CTM and CRM, and enhance their interoperability. Release a CRM that incorporates the rheologies of shear zones.					x
q	Define and implement standards for the periodic evaluation (verification and validation) of different CXMs through direct (e.g., exploration or experimental) and indirect (modeling and simulation) methods, as applicable.	x	x	x		
r	Produce a consensus combined campaign/continuous GPS time series product.	x	x			
s	Develop grids of horizontal velocity and strain rate derived from consensus GPS time series. Upload to CGM v. 1.0 website.	x	x			
t	Develop consensus vertical time series from continuous GPS sites.		x	x		
u	Identify and develop best practices for producing and updating LOS time series from the new data streams provided by Sentinel-1A and 1B, and ALOS-2.		x	x		
v	Produce a consensus secular velocity InSAR product using the full archive of SAR data (ERS, Envisat, ALOS-1, Sentinel) for the SCEC region.	x	x	x	x	
w	Conduct peer review of initial CGM products through a virtual workshop.			x		

x	Develop methods for integrating full vector GPS time series with LOS InSAR time series from multiple platforms to construct 1 km spatial resolution grids of horizontal and vertical time series.				x	x
y	Populate the CSM below the upper crust with depth-dependent modeled stresses. Release updated versions of the CSM based on additional borehole constraints and geodynamic modeling.		x	x		
z	Populate CSM at all depths with stresses (amplitudes) from static deformation models that account for upper crustal rheology as well as ductile rheologies from the CRM			x	x	x
aa	Extend the Community Stress Model (CSM) to incorporate borehole stress data.		x	x		
bb	Deliver a deformation model based on the Community Geodetic Model (CGM) to the CSM.			x		

4. Data-Intensive Computing

Continuous seismic waveform data is accumulating rapidly at the Southern California Earthquake Data Center (SCEDC) and the volume is growing at an accelerating rate both due to the development of a denser seismic network for earthquake early warning, and due to the increasing trend for dense seismic deployments (Figure 5).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Continuous Waveforms	0	0	0	0	0	0	0	0	102	485	1004	1596	2273	3012	4007	4969	6849	11636	14396	23519	29410	36710	44894	54097	67450	83724	94194
Other Waveform Data											168	188	272	412	792	1185	854	1035	1035	1035	1035	3000	2326	2326	2668.	2670	2670
Triggered Waveforms	76	156	184	230	260	286	311	337	392	438	511	578	659	746	839	975	1142	1281	1409	1817	1994	2184	2371	2543	2799	3133	3361

Figure 5. Data volumes stored at the SCEDC for seismological research. Note the dramatic acceleration in continuous data holdings (green) over the past decade.

With these larger data sets comes a need for novel approaches that can extract as much useful information as possible from them. This need was one of the motivating factors for creating the Computational Science disciplinary focus group. We have developed methods for signal detection and identification that scale efficiently to very large data volumes, which we are applying to key problems in Earth structure and seismicity. The initial “Mining Seismic Wavefields” NSF geoinformatics grant and a follow-on bridge grant from NSF has allowed SCEC to sustain this work. Participants in this proposal, and others at SCEC, are aggressively adopting machine learning for a variety of

purposes that advance earthquake science, including supervised and semi-supervised machine learning for ground motion prediction (Figure 6). These efforts address milestones 6a-6d.

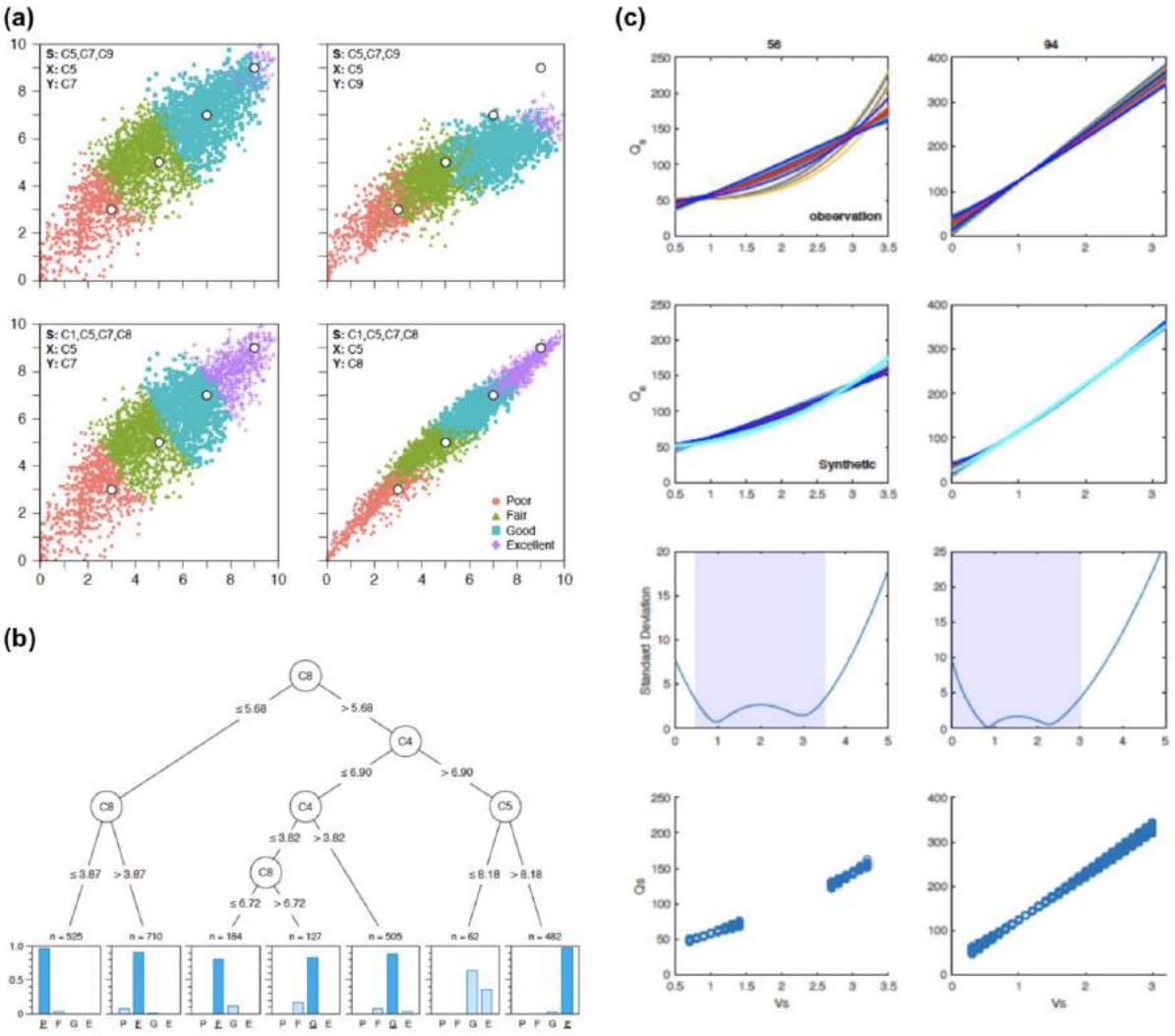


Figure 6. Clustering analysis carried out on a large dataset of results from a ground motion simulation validation process comparing the relationships that exist in a multidimensional space of goodness-of-fit metrics. (b) Topology of a decision tree reducing the validation of ground motion simulations to a comparison of only three goodness-of-fit metrics (C4, C5, C8) after having identified the thresholds needed to discretize the validation scores into for different categories (poor, fair, good, and excellent). (c) Optimization process to identify Qs-Vs relationships when comparing synthetic results from surrogate simulators with observations (from Khoshnevis, N. and Taborda, R., 2018).

Milestone		Y1	Y2	Y3	Y4	Y5
a	Develop a distribution pathway (e.g., via GitHub or CIG) for SCEC community software.	x				
b	Distribute efficient earthquake detection software for community use.		x	x	x	x
c	Develop computing tools to handle large datasets from geodesy, lidar and structure-from-motion, 3D tomography, ambient seismic field measurements, and other signal processing techniques used, for example, to search for tectonic tremor and repeating events.		x	x	x	x
d	Develop tools and algorithms for uncertainty quantification in large-scale inversion and forward-modeling studies, for managing I/O, data repositories, workflow, advanced seismic data format, visualization, and end-to-end approaches.		x	x	x	x

Theme B: Understanding Earthquake Processes

5. Beyond Elasticity

SCEC is engaged in multiple efforts to examine the interplay of fault roughness and plasticity from an observational point of view: as it may explain the apparent deficit of shallow slip in earthquakes, as it affects numerical models of rupture and ground motion, and as it affects long-term fault behavior. Among the ongoing work are sensitivity studies of differing forms of plastic response, and modeling advances where off-fault distributed deformation can be non-continuum (milestones 5d, and 5e). Off-fault plasticity was introduced into rate-and-state earthquake cycle simulations, and for certain parameter choices up to 10% of the tectonic displacement in the shallow crust was accommodated by distributed deformation extending a few hundred meters from the fault (Erickson et al., 2017, Figure 7). This addresses milestones 5d and 5f. Effort commenced to build a paleoseismic event database to characterize better natural earthquake recurrence behavior and potential system-wide super-cycles. This addresses several milestones: 2g, 5i, 9d, 9e, and 9g. Due to the interdisciplinary character of the SCEC collaboration, progress on some of the milestones listed under the "beyond elasticity" theme are reported in other sections of this document.

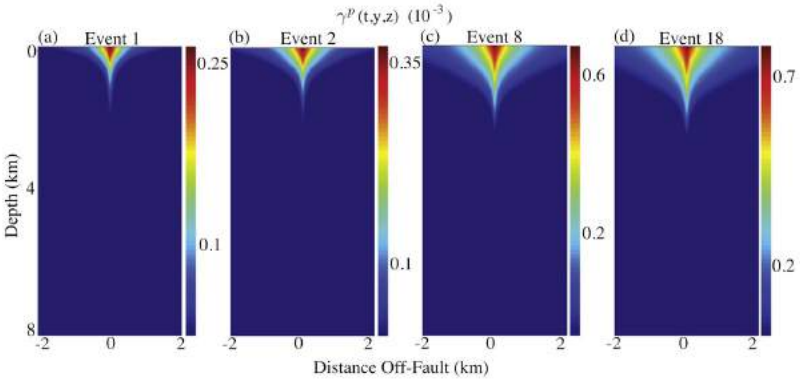


Figure 7. Panels show off-fault equivalent plastic strain after the first, second, eighth and eighteenth rupture events. For this choice of parameters the magnitude and off-fault extent of plastic strain increases at a decreasing rate with successive ruptures. After 18 events, it has begun to saturate near 2 km. (from Erickson et al., 2017).

Milestone		Y1	Y2	Y3	Y4	Y5
a	Hold an interdisciplinary workshop focused on the topic of Beyond Elasticity.	x				
b	Identify existing modeling capabilities for inelastic rheology, how these are compatible with each other, and establish a framework for verification as presently done for linear anelastic problems.	x	x			
c	Develop inelastic wave propagation codes that can be ported to HPC architectures.	x				
d	Develop strategies to quantify the contribution of inelastic off-fault deformation to geodetic estimates of strain accumulation.		x	x		
e	Apply inelastic crustal deformation models to estimate fault slip rates and assess results through comparison to geologic slip rates.				x	
f	Develop strategies to identify the potential of near-surface distributed deformation and its effect on ground motion prediction, with emphasis on forward wave propagation simulation, to develop multi-step strategies to account for inelastic behavior.		x	x	x	
g	Develop and quantify the uncertainty of prototype approaches to represent the effects of non-linearity that would allow the continued use of linear wave propagation as an effective approximation.		x	x	x	
h	Identify key material parameters that will be necessary to characterize inelastic behavior of geomaterials in the upper crust and near-surface deposits, and define strategies to add these data to community models (e.g., CVM, CRM) for use in forward and inverse modeling.		x	x	x	
i	Assess the evidence for earthquake supercycles in southern California, and identify future data needs.		x	x		
j	Constrain alternative forms of fault-zone and distributed inelasticity, as well as the factors that influence it, such as cohesion and pore fluid pressure.			x		

k	Quantify the differences between full 3D nonlinear and simpler approximations (developed under milestone 5h) and linear anelastic simulations; and their effects on ground motion prediction, intensity measures, and hazard estimation.			x	x	x

6. Modeling Earthquake Source Processes

Among the accomplishments for 2018 has been a first-of-its-kind experiment to image flash-heated contacts formed during sliding of rock surfaces at seismic slip rates in the laboratory (milestone 6d). Quantification of temperature distributions on sliding interfaces helps define stress heterogeneity and provides independent information to test flash-weakening constitutive relations used in modeling dynamic rupture. This has the potential to provide key insights into earthquake source processes, particularly when paired with recent developments in thermometry techniques to quantify localized heating within exhumed and drilled fault-zones. Uncovering the physics of the earthquake source and its evolution with time requires rigorous modeling of seismic and aseismic slip and their interaction (milestone 6f). We have made several advancements on that front. We have initiated an exercise of comparing simulations of Earthquake Sequences and Aseismic Slip (SEAS) among groups with different methodologies that will not only ensure that the problems are properly treated computationally, but also determine best practices in this challenging field, facilitating the associated scientific studies. Also on this topic, we have been developing increasingly realistic multi-cycle earthquake simulations that include coupled thermal-mechanical effects (milestone 6d), using the SEAS simulations to investigate the correspondence between on-fault and seismologically inferred properties of the earthquake sources (milestone 6e), and implementing a new source inversion validation plan that is initially focused on stress-drop validation. Several numerical studies have considered the factors that allow ruptures to propagate through geometric complexities (milestone 6c; Figure 8). Finally, Meng et al. (2018) developed a novel eGf deconvolution method that greatly increases the number of events that can be analyzed, and that improves the number of apparent duration measurements sufficiently to resolve forward and backward directivity effects in both the P and S-wave derived measurements (milestone 6e).

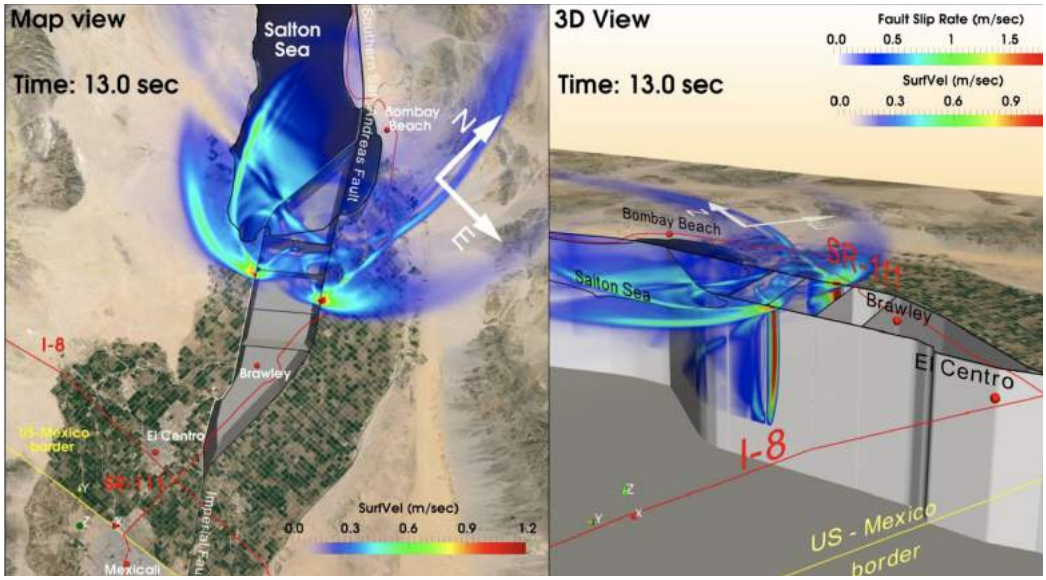


Figure 8. Dynamic rupture model of through-going rupture in the Brawley Seismic Zone (Kyriakopoulos, annual report). Nucleation location is on the SSAF (North to South propagation). Note rupture propagates through an area of fault complexity and where cross-faults intersect the main segments. Interstate 8 and SR-111 are marked with red lines. Yellow line shows US-Mexico border. Black line represents Salton Sea shoreline. The dynamic rupture code used for this simulation is FaultMod (Barall, 2009).

Milestone		Y1	Y2	Y3	Y4	Y5
a	Understand and quantify how different levels of complexity and variability in source models influence advances in other areas such as broadband and deterministic ground motion simulation.	x	x	x		
b	Understand how inelastic strain associated with fault roughness and discontinuities influences seismic radiation and scaling of earthquake source parameters, and quantify their effects on ground motion.		x	x	x	
c	Describe how fault complexity, fluid pressure and inelastic deformation interact to determine the probability of rupture propagation through structural complexities.			x		
d	Assess how shear resistance and energy dissipation depend on the maturity and hydrogeological state of the fault system, and how these are expressed geologically.				x	
e	Determine how earthquake source properties such as stress drop estimated from seismic observations based on simplified models correspond to properties of physically realistic sources.		x	x		
f	Study how seismic and aseismic deformation processes interact, and how that interaction affects long-term fault behavior, by exploring how slow slip and microseismicity redistributes stress for the following large events and how large events interact with deeper fault extensions.	x	x	x	x	x
g	Use numerical models to investigate which fault constitutive laws and parameter ranges are compatible with paleoseismic findings, including average recurrence, slip rate, coefficient of variation of earthquake recurrence, and the possibility of earthquake supercycles; determine whether such behavior can be compatible with the currently observed statistics of smaller-magnitude events.					x

7. Ground Motion Simulation

SCEC has built a broad range of ground motion simulation tools that include the effects of topography, fault roughness, and plasticity—both near that fault and remote from it; as well as improved velocity models, including refined shallow geotechnical layers and with stochastic representation (milestone 7b) of crustal properties (Shi and Asimaki, 2018). In 2018, we further improved the one-dimensional (1D) depth-dependent stochastic model for the shallow crust of the Los Angeles basin sediments, previously referred to as Geotechnical Layer (or GTL). We also performed preliminary tests to extend the model to 3D by coupling the depth-dependent statistical properties with stochastic representation of high resolution array inversions in Southern California; we plan to implement the 3D stochastic model in UCVM and validate shortly thereafter the formulation and correlation structure by comparison against strong ground motion records and scattering attenuation properties. The stochastic sediment model realization along a cross-section of the Los Angeles Basin is compared to the realization of the same cross section using GTL in Figure 9.

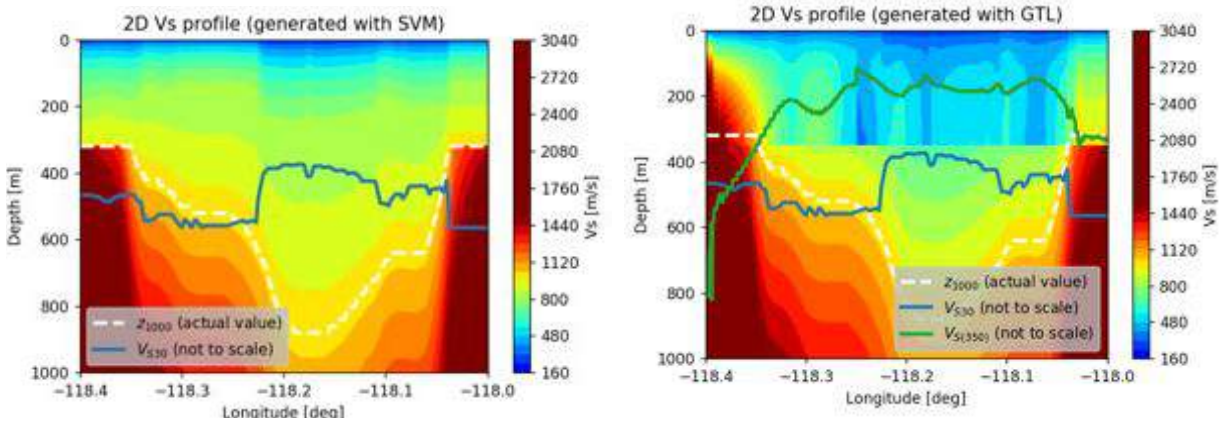


Figure 9. Example of 2D realization of the stochastic sediment model (left panel) relative to the previous GTL version (right panel).

We also developed improved imaging products to map the shallow crust using scattered waves or fiber optic cables spanning the highly populated urban centers of the Los Angeles basin (milestone 7d). We further expanded many of these modeling efforts into Central California with the benefit of additional support from PG&E. Examples include the imaging of the Diablo Canyon subsurface using dense arrays.

During Year 2, we continued the development and implementation of several inelastic realistic constitutive models to represent the inelastic behavior of rock and deposit materials (soils) in 3D deterministic and 2D broadband ground motion simulations (milestones 5h, 5k, 7e). These include an enhanced Drucker-Prager plasticity model that uses a multi-surface parallel-series type Iwan model; and a J2 bounding surface plasticity model with a vanishing elastic region, called multi-axial cyclic plasticity model for cyclic clay behavior. To coordinate research and dissemination of work on the velocity model and nonlinear laws governing the shallow crustal sediments, members of the SCEC community have formed a Technical Activity Group that will convene at the 2018 Annual Meeting.

On the broadband platform, we have extended modules to capture multi-segment kinematic ruptures (milestone 7a), inter-period correlations of ground motions (milestone 7j), and more realistic seismogram durations. We have also been developing two families of nonlinear Fourier-based amplification factors: one based on empirical Fourier amplitudes from the PEER NGA West2 database (Bayless et al., SCEC Annual Report 17148); and one based on simulated ground motions coupled to a rigorous nonlinear soil model developed during SCEC4. We expect both families to be tested, validated and implemented on the platform by Year 3 (milestone 7e).

With guidance of the Committee for the Utilization of Ground Motion Simulations (UGMS), we finished development the web-based data access tool for MCER ground motions and released it in May 2018 (milestone 7k). The MCER response spectra cover greater Los Angeles, providing a resource for cities and counties in the region. The UGMS also continued to validate CyberShake using data from the 1994 Northridge earthquake, and the committee examined differences between long-period response spectra from the UCERF2 model used in the CyberShake simulations and the UCERF3 model used by the USGS to develop the 2014 national MCER maps. UGMS chair, C.B. Crouse, gave a similar presentation at the COSMOS seminar on November, 2017 and at the 11th National Conference on Earthquake Engineering in Los Angeles in June, 2018. The UGMS group held their 2018 in-person meeting on November 7 to plan the activities for 2019, which include the expansion of the data access to for building retrofit criteria, the development of disaggregation tools and the selection of CyberShake time series for engineering analyses. Other validation exercises consist of the continuation of the Ground Motion Simulation Validation (GMSV) TAG for SCEC5 led by Rezaeian and Stewart (SCEC Annual Report 17185), and specific projects coordinated therein. The UGMS and GMSV groups are coordinating efforts on several tasks.

Milestone		**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
a	Incorporate and validate multi-segment rupture, non-linear amplification factors, and inter-period correlations in the Broadband Platform.	x	x			
b	Derive and implement stochastic models for the representation of the heterogeneous, anisotropic near-surface velocity structure for CVMs.	x	x	x		
c	Implement standardized approaches and develop software tools to analyze recorded data and synthetic seismograms, and facilitate streamlined verification and validation of broadband and deterministic simulations.	x	x			
d	Gather and develop novel data sets (e.g., small earthquakes, tremor/low-frequency earthquakes, ambient noise) and new instrumentation (e.g., cell-phone accelerometers, strainmeter data, dense arrays) to develop and validate ground motion predictions.	x	x	x		
e	Develop, validate and incorporate appropriate and realistic constitutive models to represent the inelastic behavior of rock and deposit materials (soils) in 3D deterministic and 2D broadband ground motion simulations.		x	x	x	x
f	Investigate ground motion intensity proxies to automate the selection of scenarios that will integrate nonlinear effects in Cybershake via forward nonlinear 3D simulations.			x	x	x
g	Quantify the relative roles of fault geometry, heterogeneous frictional resistance, wavefield scattering, intrinsic attenuation, and near-surface heterogeneities and nonlinearities in controlling ground motion and its variability.		x	x	x	

h	Quantify the relative importance of nonlinearities near the fault, along the path, and in near surface soft-material deposits, and their susceptibility to subsurface topography (i.e., 3D basin and site effects).			x	x	x
i	Develop and implement methods for computing, storing, and serving 3D Green's functions.				x	
j	Evaluate the spatio-temporal correlation of ground motions at regional scales from recordings and using CyberShake data. Compare and validate pertinent CyberShake results against empirical correlations.			x	x	x
k	Develop programs and activities to advance the use of 3D deterministic and broadband ground motion simulation products, and results in engineering design, seismic hazard assessment and mitigation.	x	x	x	x	x

8. Induced Seismicity

The USGS Earthquake Hazards Program has a well-developed program to investigate induced seismicity nationwide, and SCEC has been asked to coordinate activities in this area with the USGS program through FARM leader Nick Beeler. Relevant to this work is the development of methods for detecting small earthquakes under the Mining Seismic Wavefields NSF geoinformatics grant. We have used these methods to develop an understanding of the signature of non-earthquake sources, including planes and helicopters (Figure 10), and to detect induced earthquakes (milestone 8c).

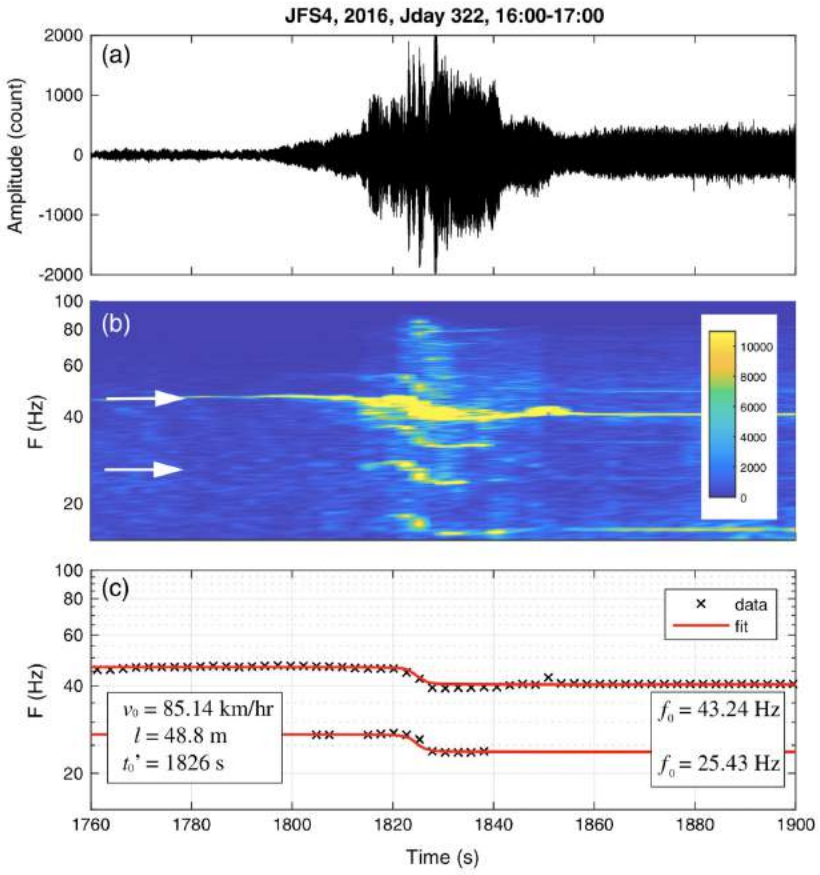


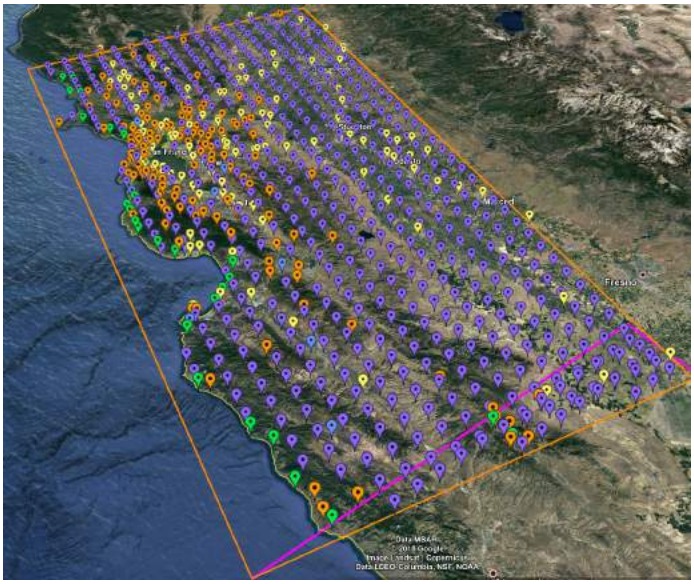
Figure 10. a) A raw vertical component waveform for a known helicopter event flying over seismic station JFS4. (b) Corresponding spectrogram with vertical axis in log scale. Arrows denote two strong overtones picked for analysis. (c) Time and frequency data (black crosses) for two overtones picked in the spectrogram in (b) and line fit to the data based on equation (1) (red curves). Inferred parameters for the helicopter are indicated in the box. (from Meng and Ben-Zion, 2018)

	Milestone	Y1	Y2	Y3	Y4	Y5
a	Assemble appropriate fluid flow data to assess the relationship to earthquakes.		x			
b	Determine the degree to which ground motion from induced seismicity is similar, or different, than that from natural tectonic seismicity.			x		
c	Develop and apply approaches for improved detection and improved characterization, e.g., microseismic detection using fingerprinting and matched-filter approaches to suspected induced seismicity in California.				x	

Theme C. Characterizing Seismic Hazards

9. Probabilistic Seismic Hazard Analysis

We are continuing to develop physics-based earthquake rupture forecasts and ground-motion models within the CyberShake PSHA framework (milestones 9f,9h). We simulated ground motions for ~40,000 ruptures of moment magnitude M ≥ 6 in California from the Uniform California Earthquake Rupture Forecast, UCERF2. The Southern California simulations generated ~440,000 pairs of horizontal component time series for 336 sites. This ensemble is large enough to sample aleatory variability of the rupture process, including hypocenter and slip variations. The latest computations study, initiated in early 2018, is focused on the Northern California region and involved a strong collaboration with USGS stakeholders (Figure 11). The velocity models used for the simulations included the USGS Bay Area model, and the two SCEC models developed through 3D tomography, CCA06 and CVM-4.26.



We are increasingly focused on fully characterizing faults, velocity models, and recurrence in order to first properly bound, and then reduce systematically, the epistemic uncertainty in shaking intensities for hazard maps. We continue to verify and validate CyberShake to higher frequencies - now up to 1 Hz - and expand the areal coverage; with the latest model, we are now covering most of California. As a proof of concept for evaluating long-term earthquake forecasts on faults, we evaluated the 1988 WGCEP rupture forecast (milestone 9a).

Figure 11. Map showing Study 18.8 sites (sites of interest=yellow, CISN stations=orange, missions=blue, 10 km grid=purple, 5 km grid=green). The Bay Area box is in orange and the Study 17.3 box is in magenta.

Milestone		Y1	Y2	Y3	Y4	Y5
a	Develop methods for evaluating forecasts of finite-size earthquake ruptures against observations. Identify and characterize suitable datasets for retrospective tests of finite-rupture forecasts.		x	x		
b	Identify pathways for using information from physics-based simulators in PSHA and OEF.		x			
c	Carry out targeted experiments to validate ground motion effects identified through simulations of wave propagation in the CVMs.	x	x	x	x	
d	Assess predictive capability of long-term earthquake rupture forecasts by combining patterns of earthquake occurrence and strain accumulation with neotectonic and paleoseismic observations of the last millennium.			x		
e	Place geologic bounds on the character and frequency of multi-segment and multi-fault ruptures of extreme magnitude.				x	
f	Develop a statewide Cybershake-based hazard model.					x
g	Develop earthquake cycle models consistent with paleoseismic chronologies (slip estimates and event dates) that investigate stress accumulation and stress drop sequences over multiple earthquake cycles. Test the hypothesis that seismic supercycles seen in earthquake simulators actually exist in nature and explore the implications for earthquake predictability.					x
h	In coordination with the USGS, communicate improvements in physics-based seismic hazard analysis to the earthquake engineers, emergency responders, and general public.	x	x	x	x	x

10. Operational Earthquake Forecasting

We held the third Workshop on Operational Earthquake Forecasting (OEF) in April, 2017, and published a full OEF model for California (UCERF3-ETAS). Potential early adopters attended this meeting and articulated and compiled potential use cases and their value. One goal of this meeting was to provide guidance to the USGS on what level of effort should be put into developing these capabilities (milestones 9b,9h,10a). The importance of accounting for faults in time-dependent hazard calculations is demonstrated in Figure 12.

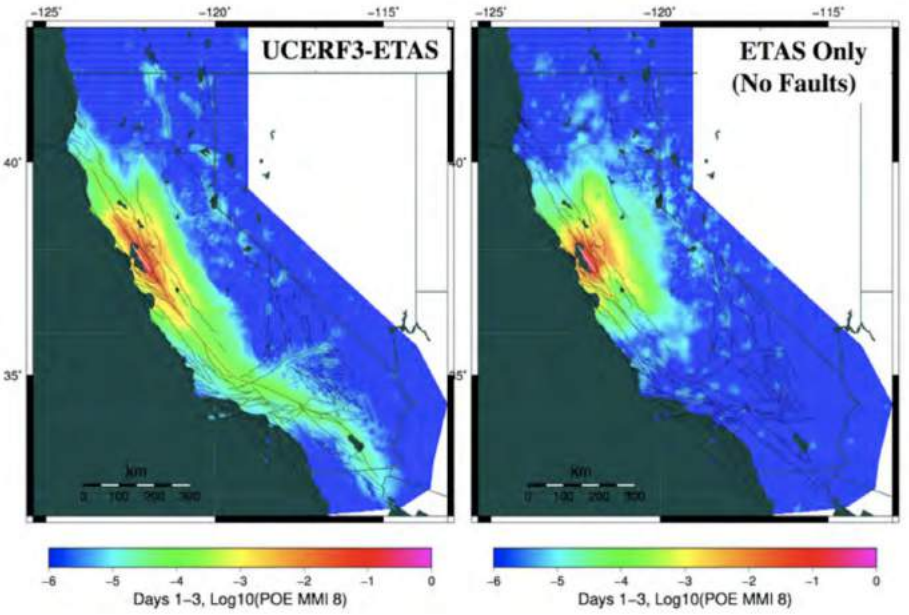


Figure 12. Average hazard maps following the M 7.1 Hayward Fault "Haywired" scenario earthquake, with panels on the left showing UCERF3-ETAS results and those on the right showing results for a pure (no faults) ETAS model. Maps show the probability of exceeding MMI 8 over the first 3 days, for which the influence of faults is profound (from Field and Jordan, SCEC Annual Report 17091).

We continue to make progress towards earthquake-simulator-based forecasting through the Collaboratory for Interseismic Simulation Modeling (CISM) project (milestone 9b).

The Collaboratory for the Study of Earthquake Predictability (CSEP) published a Focus Section in the Seismological Research Letters in July 2018, containing nine articles that present new CSEP evaluations of forecast models from around the globe, many relevant as OEF candidate models. We found that the Coulomb hypothesis, when described with appropriate uncertainty, could compete with (but not yet surpass) statistical ETAS clustering models during the 2010-12 Canterbury, New Zealand, earthquake sequence. Another, global, study found support for merging strain-rate data into smoothed seismicity models for improved forecasting skill.

Milestone		Y1	Y2	Y3	Y4	Y5
a	Develop methods for validating UCERF3-ETAS model forecasts utilizing CSEP or other tools.		x			
b	Formulate approaches for validating physics-based earthquake simulators against observations, and for using them to help constrain existing uncertainties in statistically based OEF models (e.g. UCERF3-ETAS).			x		
c	Assess the predictive power of the Coulomb stress hypothesis by testing physics-based clustering models against multiple earthquake sequences across various tectonic settings.				x	
d	Integrate ensemble modeling techniques within CSEP to enable ensemble forecasting.			x		
e	Assess the importance of visco-elastic post-seismic response for earthquake cycle models.				x	
f	Develop earthquake simulators that can resolve fault processes across the range of scales required to investigate stress-mediated fault interaction, including those caused by dynamic wave propagation or that combine coseismic dynamic rupture and multi-cycle				x	

	simulators; generate synthetic seismicity catalogs; and assess the viability of earthquake rupture forecasts.					
g	Develop approaches for incorporating real-time data products into OEF candidate models.				x	
h	Develop methods for prospectively testing UCERF3-ETAS.				x	
i	Extend CSEP capability to evaluate real-time OEF models.					x

11. Earthquake Early Warning

We set no milestones for this topical element, which the USGS is covering well under research programs outside of SCEC.

12. Post-Earthquake Rapid Response

We continue to improve the rapid scientific response capability for future earthquakes in Southern California through development of new methods and protocols for mobilizing and coordinating the core geoscience disciplines, and gathering and preservation of perishable earthquake data. In March of 2018, SCEC participated in a USGS-led exercise to improve coordination of public communication and event-response activities. A workshop will be held to continue these discussions and update the SCEC response plan and knowledge base of available resources for scientific response (milestones 12a,12c,12d,12e,12f).

During this project period, Shaw, Plesch, Hauksson, and Meier developed a new, statistically robust way to identify the fault (or sets of faults) in the Community Fault Model (CFM) that generated an earthquake using information typically provided soon after an event occurs. This effort is important to rapid response, and it bridges the information provided by increasingly sophisticated near real-time seismograph networks, and the capabilities they enable, with comprehensive 3D CFM's developed by SCEC (Figure 13)

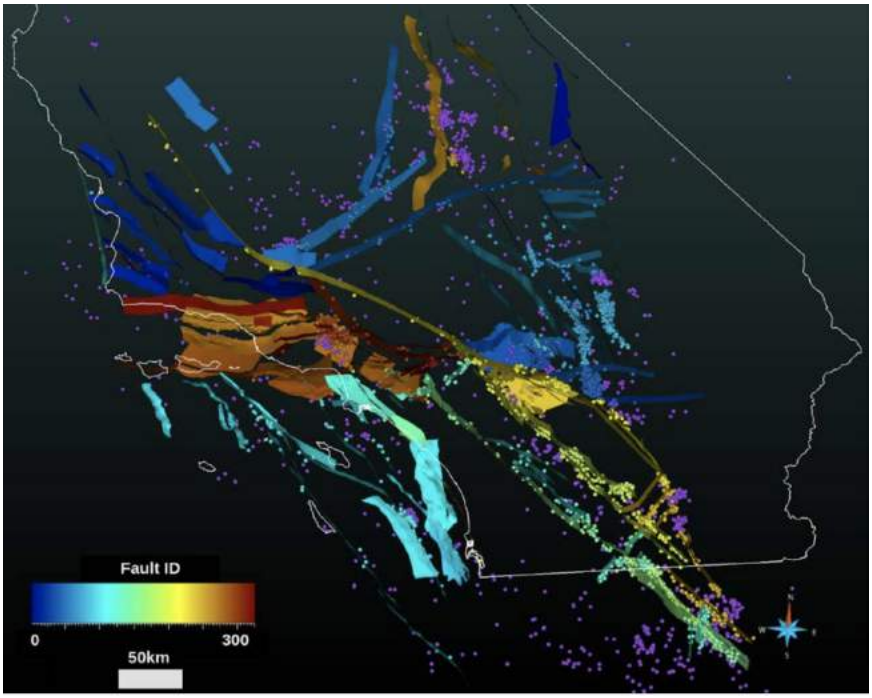


Figure 13. Catalog of M > 3 earthquakes, associated with CFM 5.1 faults. Colors for both earthquakes and faults represent a fault identification number. Thus, colors of events are shared with the fault that has the highest probability of association. Purple color for events indicates the lack of primary fault association.

Milestone		Y1	Y2	Y3	Y4	Y5
a	Hold an annual scientific earthquake response exercise.	x	x	x	x	x
b	Update earthquake response plans, including satellite communication and data exchange capabilities.	x				
c	Coordinate response plans annually with the USGS and the California Earthquake Clearinghouse.	x	x	x	x	x

d	Work with partners (e.g., IRIS, UNAVCO, USGS) to improve instrumental availability for rapid response.		x			
e	Identify and develop opportunities for linking high-resolution postseismic deformation to geological observations (UAVSAR, lidar, SfM).		x			
f	Improve post-event communication between SCEC and other agencies through sharing of information portals, datasets, etc.		x	x	x	x

Theme D. Reducing Seismic Risk

13. Risk to Distributed Infrastructure

The spatial correlation of strong ground motion is critical to quantifying the risk to spatially extensive infrastructure. Baker and Chen (SCEC Annual report 17058) have evaluated spatial correlation in ground motion residuals using CyberShake simulations (milestone 13c). The results show general agreement between the distance decay of correlations relative to empirical recordings. The simulations also show strong period dependence in correlations – perhaps stronger than empirical recordings indicate (Figure 14). It will be important to validate/calibrate this correlation structure of simulations against data. This need provides strong motivation for future dense array deployments.

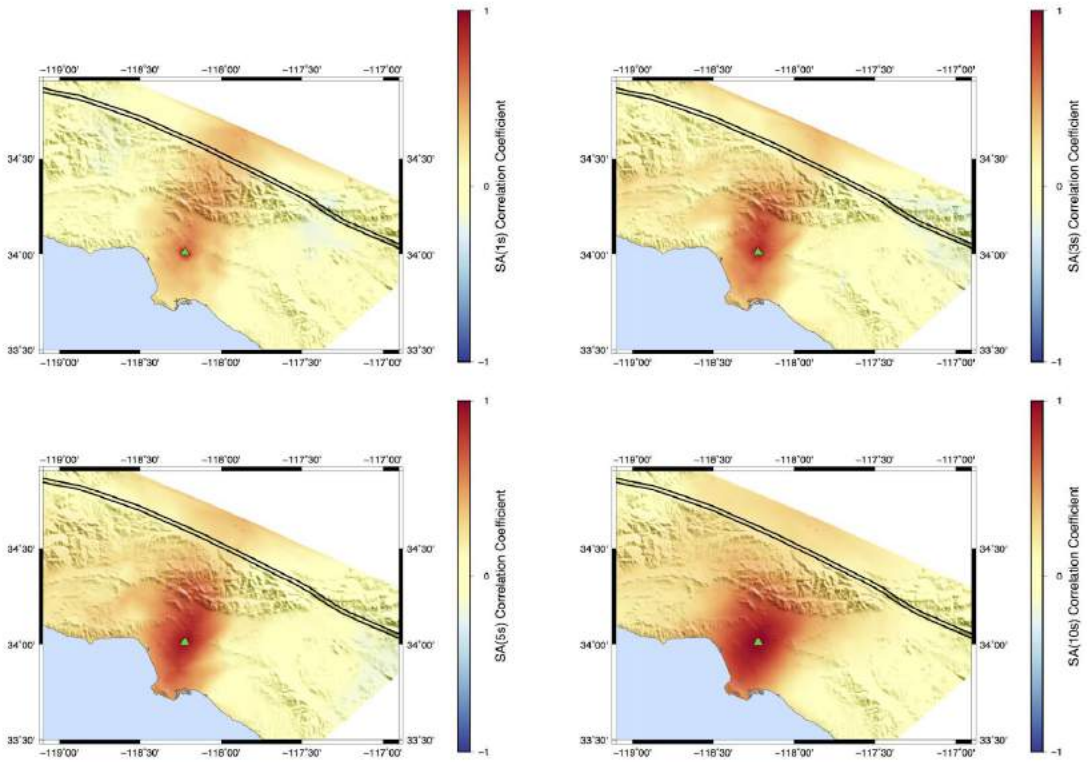


Figure 14. Correlation coefficients for spectral acceleration at T=1s, 3s, 5s, and 10s. A reference site is indicated by a triangle, and correlation coefficients between this site and all other sites in the region are indicated by colored shading.

Work is progressing rapidly on the dissemination of ground motion simulation data to engineers responsible for design and assessment of both individual buildings and distributed infrastructure. An engineering-centric tool for accessing CyberShake ground motion predictions in Los Angeles is now active. A recent special session on ground motion simulations at the 11th National Conference on Earthquake Engineering was attended by over 100 research and practicing engineers.

We are working with engineers and stakeholders to apply measures of distributed infrastructure impacts in assessing correlated damage from physics-based ground-motion simulations (milestones 13a,13b,13d). These provide ground motion predictions at densities that existing seismic data cannot. Due to the scale of effort required, we expect that research on this topic will likely be funded under Special Projects rather than the base funding from NSF and USGS. We submitted a proposal to NIST entitled “Development of Science-Based Tools and Framework for Seismic Resilience Assessment of Regional Lifeline Systems,” which included several of the California water agencies as partners. Unfortunately, despite very good reviews, this proposal was not funded, but we continue to engage public utilities, the California Department of Water Resources, and the City of Los Angeles on this topic to pursue funding opportunities and the broader impacts that would result from such pursuits.

Milestone		Y1	Y2	Y3	Y4	Y5
a	Identify engineering needs for integrated (multi-step or end-to-end) earthquake simulation. Convene an interdisciplinary workshop bringing together ground motion modelers and earthquake engineers to define a reduced number of scenarios and case-studies that can be used to concentrate subsequent research activities (e.g., LA water supply).	x	x			
b	Develop computational tools to facilitate integrated earthquake modeling and site-city interaction effects. These tools should allow multi-step or end-to-end simulation and analysis of ground motion and infrastructure (buildings or distributed systems such as buried pipelines) response.		x	x	x	
c	Investigate the implications of ground motion simulations (including amplitude and spatial variability) by integrating observed and simulated ground motions with engineering-based building and distributed infrastructure systems response models. Validate the results by comparison to observed response of instrumented building and distributed infrastructure systems.			x	x	x
d	Develop methods for estimating fault displacements, including distributed deformation and large-scale tilts, for the evaluation of risk to large distributed infrastructures.		x	x	x	
e	Assess the performance of distributed infrastructure systems using simulated ground motions. Evaluate the potential impact of basin effects, rupture directivity, spatial distribution of ground motion, or other phenomena on risk to infrastructure systems.				x	x

14. Velocity and Rheology of Basin Sediments

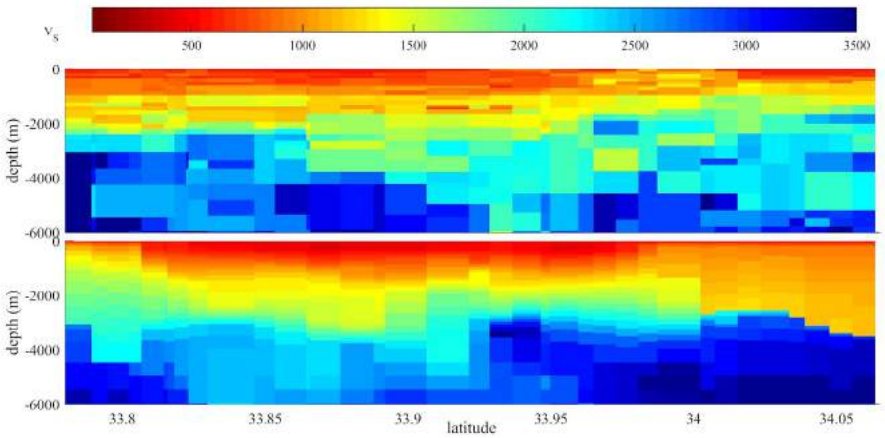


Figure 15. Top shows results of joint inversion for S-wave velocity across the LA Basin using fundamental mode Love wave and fundamental and first-higher mode Rayleigh wave dispersion, together with HVSR measurements of the ambient field along the LASSIE line. Lower panel shows SCEC CVM-H. (from Spica et al., 2018).

In this effort, which focuses on what is sometimes called the geotechnical layer, we are drawing from the extensive geotechnical engineering literature to advance the implementation of site effects by incorporating nonlinear rheological models of near-surface rock and soil layers into full-physics earthquake simulations. A Workshop on Nonlinear Shallow Crust Effects was held September, 2017. Progress towards milestones 14b, 14d, and 14e, are reported under the closely related topical element of ground motion prediction in section 7. A longer-term goal of effort in this area is to develop accurate, efficient methods to characterize nonlinear effects to implement in SCEC simulation platforms (Broadband, CyberShake, High-F). Several groups developed improved techniques to image the Los Angeles and other basins in southern

California. SCEC research also analyzed differences between classical site amplification effects in basins associated with vertically-incident body waves from those generated by surface waves. We continue to use ambient-seismic-field measurements to constrain shallow basin structure. The efforts are important for reducing epistemic uncertainties in ground motion prediction. In the current year we have begun to use the HVSR method to characterize basin structure along the LASSIE profile (Figure 15). This helps to address milestone 14c.

Milestone		Y1	Y2	Y3	Y4	Y5
a	Create a Sediment Velocity and Rheology Model (SVRM) TAG to foster collaborations between geotechnical engineers and ground motion modelers to advance modeling and simulation of the physics and effects of the geotechnical layer on ground motion prediction.	x				
b	Develop and validate 3D constitutive models to capture nonlinear phenomena such as near-surface plasticity, permanent ground deformation and earthquake triggered ground failure, for implementation into physics-based simulations.	x	x	x		
c	Develop new velocity parameterizations of the near-surface sediments, based on available site characterization data from past invasive and non-invasive methods, and constrained by the deeper CVM basement structure, and implement these in CVM applications (i.e., UCVM) to facilitate their evaluation through validation exercises.	x	x			
d	Use borehole measurements, near-surface material stiffness proxies (e.g., Vs30, topography), and empirical correlations to estimate input parameters necessary for nonlinear ground motion modeling in both physics-based simulations and empirical models .		x			
e	Develop empirical correlations between measured near-surface sediment properties and the rheology model parameters of these sediments, also drawing information from the velocity and rheology CXMs, to facilitate incorporation of nonlinear response and effects of permanent ground deformation.into regional-scale ground motion simulations.		x	x	x	
f	Populate the CRM with rheology models (velocity, anelastic attenuation, nonlinear properties) of the rock and soil layers of the crust to capture nonlinear phenomena such as off-fault plasticity, permanent ground deformation and earthquake triggered ground failure phenomena in physics-based simulation.			x		
g	Quantify epistemic uncertainties of the velocity variability and nonlinear constitutive laws and parameters derived and implemented for the response of the soft sediments.		x	x	x	x

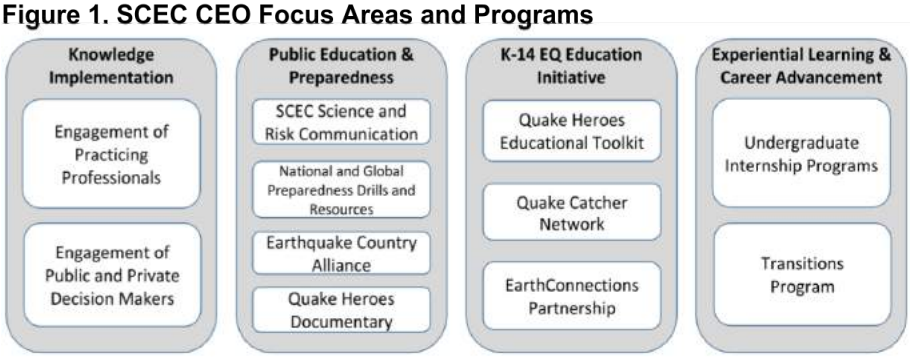
4. Communication, Education, and Outreach Accomplishments

Mark Benthien, *SCEC Associate Director for CEO*

Evaluation Overview

SCEC's Communication, Education, and Outreach (CEO) program spans a suite of programs within four CEO focus areas (Figure 1). A five-year plan for evaluating these programs and focus areas is being implemented, with further input from the CEO Planning Committee, SCEC's Advisory Council, and our funding agencies. A key advisor is Dr. Michele Wood (CSU Fullerton), an experienced program evaluator who reviewed the CEO program [Wood, 2015] and suggested many of the evaluation strategies which are now being implemented.

Figure 1. SCEC CEO Focus Areas and Programs



The SCEC5 CEO evaluation structure is tied closely to a comprehensive logic model (shown in the SCEC5 CEO Evaluation Framework) that organizes CEO activities for the accomplishment of:

- annual short-term outcomes (for each program)
- multi-year mid-term outcomes for each focus area (within SCEC5), and
- broad long-term outcomes, each spanning multiple focus areas, that we intend to demonstrate progress towards during SCEC5.

Subsets of the logic model for each focus area are included below. The model also provides the basis for identifying appropriate measures for assessing progress towards achieving these outcomes. These measures include CEO metrics (select program outputs that most inform program management and that can be assessed within limited program resources) and CEO milestones (major program accomplishments and steps towards assessing and reporting progress towards mid-term focus area outcomes). Overall SCEC5 evaluation milestones are listed in Table 1, and show the five-year plan for assessing and reporting the impacts of the SCEC CEO program.

Table 1. SCEC5 CEO Evaluation Milestones		Y1	Y2	Y3	Y4	Y5
a	Finalize logic model, program metrics, focus area outcomes, and anticipated milestones	X	X			
b	Publish evaluation framework and engage more researchers in publishing results based on analysis of CEO datasets		X	X	X	
c	Coordinate publication (by CEO staff and by other researchers) of initial results of major projects along with a mid-term report about SCEC5 CEO			X	X	
d	Prepare data and reports and identify funding for a major external evaluation (in anticipation of the "SCEC6" proposal)			X	X	
e	Publish additional results of major projects and prepare final report				X	X

Of these milestones, the first (a) has been completed. The evaluation framework will be submitted for publication (b) in Y3, and expanded engagement of researchers who analyze CEO datasets will continue (this already happens with ShakeOut data). A mid-term report (milestone c) will be drafted in Y3 as a lead-up to external evaluation(s) prior to the completion of the SCEC6 proposal (this may be a single comprehensive evaluation or a set of evaluations for each focus area, as each area has very distinct disciplinary aspects).

For each focus area below, programs are assessed in terms of program outputs (metrics) and short-term program outcomes (ST1, ST2, etc.). Then the progress towards achieving milestones and (eventually) mid-term outcomes for the focus area as a whole are presented.

Knowledge Implementation (KI)

Knowledge Implementation spans two programs: *Engagement of Practicing Professionals* and *Engagement with Public and Private Decision Makers.* Table 2 shows the KI section of the CEO Logic Model, showing metrics and annually assessed short-term (ST) outcomes for each program (described below), leading to mid-term (MT) outcomes for the overall KI focus area that will indicate progress towards long-term (LT) outcomes. Milestones for the KI focus area are also discussed below. For a thorough description of this focus area and its programs, see section 8, 2019 CEO Plan.

Table 2. Knowledge Implementation Focus Area Outcomes

Programs	Program Outputs (Metrics)	Short-Term Program Outcomes	Mid-Term Focus Area Outcomes	Long-Term CEO Outcomes
Engagement of Practicing Professionals	# Activities coordinated # Participants in activities # Resources created & distributed # Citations of SCEC research/ resources	• Increased knowledge and use of SCEC science among technical audiences	• Documented examples of increased life safety and resilience (policies enacted, improved buildings or infrastructure, etc.) • Expanded partnerships, additional activities/ resources, and "next level" policies/plans	• Improved application of earthquake science in policy and practice • Reduced loss of life, property, and recovery time
Engagement with Public and Private Decision Makers	# Activities coordinated # Participants in activities # Resources created & distributed # Policies/changes enacted	• Awareness increased (EQ issues in general, and of SCEC science) • Legislation or other actions (i.e., cities and organizations develop/ revise resilience plans)		

KI-1: Engagement of Practicing Professionals

Tracking the activities of this program is just getting started in Year 2 with the completion of the SCEC Logic Model and selection of metrics based on key program outputs, as shown in Table 3. The activity coordinated in Y2 is the 11NCEE conference Ground Motions workshop and the MCE_R tool is the initial resource listed. Determining how to track citations of SCEC research or resources is a next step.

Table 3. KI-1 Metrics	Y1	Y2
Activities coordinated	n/a	1
Participants in activities	n/a	80
Resources created/distributed	n/a	1
Citations of SCEC research/resources	n/a	n/a

KI-1, ST1: Increased knowledge and use of SCEC science among technical audiences

In June, 2018, SCEC and EERI co-organized the *11th National Conference on Earthquake Engineering* in Los Angeles, which was a significant opportunity to achieve this outcome. As the co-program chair, SCEC's Executive Science Director for Special Projects Christine Goulet developed the conference technical program entitled "Integrating Earthquake Science, Engineering, and Policy" with the goal of increasing visibility of SCEC research products for earthquake engineering researchers and practitioners. This included a pre-conference *Ground Motion Simulations and Engineering Applications Workshop* with 80 attendees (primarily structural and geotechnical engineers) featuring presentations by SCEC scientists about seismic hazard products, including the new MCE tool (https://data2.scec.org/ugms-mcerGM-tool_v18.4/) developed by the SCEC Committee for the Utilization of Ground Motion Simulations. SCEC CEO's Mark Benthien and Jason Ballmann supported publicity for the conference, which resulted in articles highlighting SCEC research and products, including in the New York Times. Ballmann also led a pre-conference workshop on Media Interview and Press Conference Techniques, and Gabriela Noriega coordinated a visit by SCEC's undergraduate interns to observe the Undergraduate Seismic Design Competition.

KI-2: Engagement with Public and Private Decision Makers

Metrics for this program are shown in Table 4. The activity coordinated in Y2 is the USC Alumni event described below. No new resources for this audience were created in 2018. We will develop a plan for tracking citations or use of SCEC research or resources among this audience in 2019.

Table 4. KI-2 Metrics	Y1	Y2
Activities coordinated	n/a	1
Participants in activities	n/a	80
Resources created/distributed	n/a	0
Citations/use of SCEC research/resources	n/a	n/a

KI-2, ST1: Awareness increased (Earthquake issues in general, and of SCEC science)

SCEC CEO's Sharon Sandow de Groot coordinated with USC's Price School of Public Policy, USC Dornsife College Alumni Relations, and the Real Estate Affinity Network through Alumni Affinity Programs to present a special event, "Evaluating Risk and Building Resilience: Preparing LA for the Big One," on September 26 at the Intercontinental Hotel in Los Angeles. More than 80 local government, business leaders, developers, and real estate professionals attended. The evening featured a keynote address from SCEC Director John Vidale about SCEC science as well as a panel discussion about the vulnerability of Los Angeles (focusing on high rise buildings as well as overall infrastructure). The panel was moderated by Ryan Arba of the California Governor's Office of Emergency Services. The panel featured Christine Goulet from SCEC, Mark Humphreys from Watt Investment Companies, and Marissa Aho, the Chief Resilience Officer of the City of Los Angeles, and explored the implications of the vulnerability of Los Angeles on policy makers, real estate developers, and the community at large.

KI-2, ST2: Legislation or other actions (i.e., cities and organizations develop/ revise resilience plans)

Marissa Aho (City of LA) spoke at the 2018 SCEC Annual Meeting in the Wednesday morning session highlighting the 10th Anniversary of the ShakeOut Scenario and drills. She commented on how the ShakeOut Scenario inspired the *Resilience By Design* project led by Dr. Lucy Jones which resulted in new retrofitting ordinances for "Tuck Under Parking" apartment buildings and Non-Ductile Concrete Buildings. SCEC CEO will be working with Dr. Jones to help promote the adoption of similar ordinances in other cities; our new *Quake Heroes* film highlights the dangers of Tuck Under Parking buildings and also shows how to retrofit them, so this will be a tool for encouraging such ordinances and gaining public acceptance.

KI Focus Area Year 2 Milestones and Assessment

SCEC5 CEO focus area milestones for Knowledge Implementation, listed in Table 5, represent major activity goals and evaluation priorities for each year.

Table 5. KI Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	SCEC KI Working Group established to identify needed products/activities		X	X		
b	Products and activities delivered, with clear value for risk reduction			X	X	X
Evaluation Milestones						
c	Develop protocols for assessing mid-term KI outcomes		X			
d	Assess KI mid-term outcomes			X	X	X
e	Document results from KI assessment, with progress towards long-term outcomes				X	X
f	Future KI activities and outcomes established					X

A key Y2 CEO milestone remains to form a *SCEC KI Working Group* (a) of SCEC scientists, practicing engineers, government resilience leaders, and others to identify needed resources and potential activities in line with these outcomes; initial meetings of a core group will be held in January 2019. This group will also develop protocols (c) for how to document specific examples of improved resiliency as a result of SCEC research and activities. This focus area has incredible promise in SCEC5 as the results of many years of software development and applied research

become available as products to be delivered. See Section 8 for 2019 plans which will include initial assessments of KI mid-term outcomes as shown in Table 5.

Public Education and Preparedness (PEP)

The Public Education and Preparedness Focus Area spans four programs as shown in Table 6, the PEP section of the CEO Logic Model. Metrics and annual short-term (ST) outcomes for each program are listed (with results described below), leading to mid-term (MT) outcomes for the overall PEP focus area that will indicate progress towards long-term (LT) outcomes. Milestones for the PEP focus area are also discussed below. For a thorough description of this focus area and its programs, see Section 8, 2019 CEO Plan.

Table 6. Public Education and Preparedness Focus Area Outcomes

Programs	Program Outputs (Metrics)	Short-Term Program Outcomes	Mid-Term Focus Area Outcomes	Long-Term CEO Outcomes
National and Global Preparedness Drills/ Resources	# Visitors to websites # Participants (California, National, Global) # Resources distributed # Media citations about ShakeOut # Social Media followers	• Increased knowledge of EQ hazard/risk/safety • Increased participation in safety drills • Global adoption of consensus messaging • Sharing of best practices	• Expanded drill participation, school safety, and community resilience worldwide • Improved household, school, workplace and community planning, preparedness, and mitigation in California • Increased knowledge/visibility of SCEC as credible and trusted partner/resource (among public, decisionmakers, partners, reporters, etc.) • Increased knowledge of earthquake science (general concepts, local hazards/risk, etc.)	• Reduced loss of life, property, and recovery time • Increased science literacy
Earthquake Country Alliance	# Visitors to websites # ECA members & leaders # Participants in ECA events & meetings # Resources distributed # Social Media followers	• Increased coordination with key stakeholders • Increased use of ECA messaging and resources • Increased knowledge of EQ hazard/risk/safety • Sharing of best practices		
SCEC Science and Risk Communication	# Visits to SCEC.org # Participants in media trainings # SCEC-related media citations # Social Media followers	• Increased awareness of SCEC and EQ science • Improved SCEC Community media skills • SCEC known as valued media resource		
Quake Heroes Documentary	# Screenings and # of Attendees # Actions taken (CERT sign-ups, supplies purchased, etc.) # Visitors to website # Stories shared	• Increased knowledge of EQ hazard/risk/safety • Increased participation in CERT • Increased household/ community preparedness		

PEP-1: National and Global Preparedness Drills and Resources

The activities coordinated by the PEP-1 program have greatly exceeded expectations in terms of adoption worldwide and continued interest in improved resources, new levels of participation, and new partnerships. Metrics shown in Table 7 combine statistics for both ShakeOut and TsunamiZone websites, registrations, and resources. Improved ways of tracking distribution of resources are being developed as we know the number is far higher than currently listed (website downloads only).

Table 7. PEP-1 Metrics	Y1	Y2
Visitors to websites	489,729	482,561
Participants (CA, National, Global)	10.5M; 20M; 58M	10.4M; 21M; 62.7M
Resources distributed	28,197	60,158
Media citations about ShakeOut	1,580	3,880
Social media followers	~23,000	28,710

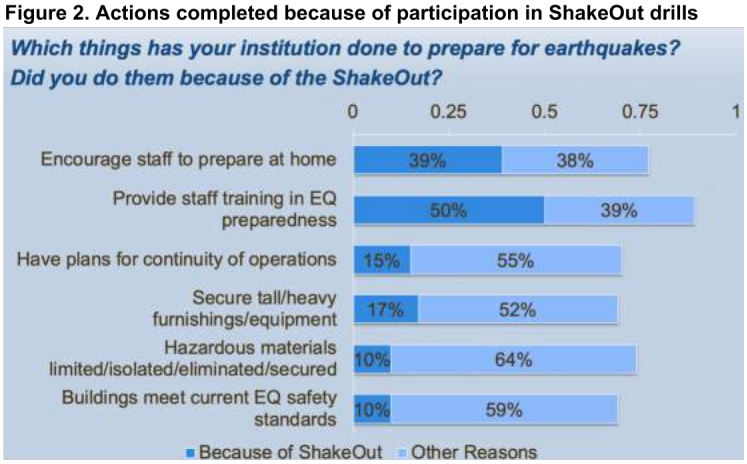
PEP-1, ST1: Increased knowledge of earthquake hazard/risk/safety

The various communications channels developed for recruiting ShakeOut participants and providing them information needed to conduct their drills have from the beginning been used to also communicate knowledge about earthquake hazard and risk (the Shakeout Scenario). These channels include ShakeOut Update emails, customized for each region, which regularly include overviews of earthquake science, resources for mitigating earthquake damage (such as the California Earthquake Authority's Brace and Bolt program), and resources for learning about recent earthquakes. As the ShakeAlert system expands its implementation, these channels will be employed to help educate people about earthquake science basics needed to understand the value (and the limitations) of earthquake early warning. As with the original scenario for Southern California, the new HayWired scenario for a M7.0 earthquake on the Hayward fault provides new information to form the basis of ShakeOut drills in the Bay Area.

SCEC is working to increase knowledge about earthquakes at all levels. In 2018 SCEC expanded its growing partnership with the local *Hero in You Foundation* non-profit to create earthquake science and preparedness "Rocket Rules" materials for grades K-3 (RocketRules.org). The "2018 Great ShakeOut Rocket Rules Challenge" (ShakeOut.org/rocketrules) was organized in which all Los Angeles Unified School District second grade classrooms can complete simple safety lessons and film a dance that demonstrates earthquake safety. Three winning schools were chosen from the submitted entries, with every participating classroom, school and student receiving educational and safety resources. A statewide program for afterschool programs was also created (ShakeOut.org/shakemob).

We also continue to assess how ShakeOut participation, and the information we provide to participants, is increasing overall preparedness and planning. Results from annual surveys (Figure 2) show and that organizations attribute ShakeOut participation to their completing a range of preparedness and mitigation activities.

Figure 2. Actions completed because of participation in ShakeOut drills



PEP-1, ST2: Increased participation in safety drills

ShakeOut participation in the U.S. reached a new record in 2018 with nearly 21 million people involved. SCEC CEO (Mark Benthien, Jason Ballmann, and student workers) supported recruitment efforts by local, state, regional, and international partners with emails and phone calls to participants, made possible by a new online "Coordinator Portal" system created in 2018. While K-12 and college students and staff comprise the largest number of participants, businesses, nonprofits, government agencies, neighborhoods groups, and individuals.

In 2018, SCEC also revised ShakeOut healthcare materials to show how ShakeOut can count towards new training requirements of all healthcare facilities nationwide, implemented in 2017 by the Centers for Medicare and Medicaid Services. SCEC partnered with with Connect Consulting Services to present a webinar on September 19 about how ShakeOut participation can meet these new requirements, with more than 450 attendees. This webinar and the materials are available at ShakeOut.org/healthcare. Because of these efforts, the number of ShakeOut participants in the healthcare sector nationwide have increased from 353,277 in 2016 to 526,573 in 2018. The number of locations participating grew from 1,689 to 4,547.

As a result of its leadership of ShakeOut, SCEC now also receives NOAA funding provided through the California Office of Emergency Services to create and manage TsunamiZone.org. This international site adapts the ShakeOut registration system to assess participation in Tsunami activities, whether as part of their ShakeOut activities or during local tsunami preparedness weeks or months. Participation in 2018 exceeded 570,000 people, primarily in California (181,305) and more than 40 countries in the Caribbean and surrounding areas that participated in the "Caribe Wave"

regional exercise (388,338). SCEC's Jason Ballmann has become a leader within the National Tsunami Hazard Mapping Program community, and redeveloped tsunami educational graphics (TsunamiZone.org/graphics) that are now being used worldwide.

PEP-1, ST3: Global adoption of consensus messaging

SCEC coordinates ShakeOut regions across the U.S. but also around the world (62+ million people participated in 2018), across 27 Official ShakeOut Regions and independently in more than 70 countries. SCEC CEO's webmaster John Marquis and a team of undergraduate students created and maintain websites for all these regions (except Japan). This provides a global platform for consensus however we have not been effectively tracking how our messaging is being adopted. The prime example of our impact is how our "Drop, Cover, and Hold On" graphics, and their corresponding messaging resources (EarthquakeCountry.org/step5), along with our tsunami safety graphics (TsunamiZone.org/graphics) are routinely being incorporated into local, state, national, and even international materials and messaging efforts. The value of consensus messaging is that we are able to amplify the global collective impact of all of our outreach efforts, especially since search results may show materials from other countries; if each country had different protective-action recommendations this might leave people confused and have them disregard the information. ShakeOut's growing visibility was also seen on social media with #ShakeOut trending in more than 76 cities worldwide in 2018.

PEP-1, ST4: Sharing of best practices (national/international)

ShakeOut and TsunamiZone continue to be best practices that are being adopted worldwide. While many regions are coordinating directly with us (Canada, New Zealand, Japan), others are implementing very similar structures for promoting and assessing participation in their drills. In 2018 New Zealand switched from participation every three years to holding its national ShakeOut annually (like all other regions) based on our experience that this maintains momentum and is easier to manage than effectively re-starting every 3rd year. Even areas with which we haven't developed official ties yet are using the name "ShakeOut" (a city in the Philippines) as a generic term for an earthquake drill. Interest from school officials in China is rapidly expanding (a group from Sichuan province observed ShakeOut activities in Los Angeles in October, 2018, and a ShakeOut discussion with another Chinese delegation was held in San Francisco in December). We plan to develop new structures within the ShakeOut website for international partnerships, with countries or regions being able to complete a form about their drills, how they count participants, the resources they use, and other elements that will then be posted for others to learn and adapt.

PEP-2: Earthquake Country Alliance

The Earthquake Country Alliance, created and led by SCEC's Mark Benthien, marks its 15th Anniversary in 2018, and is stronger than ever. Coordinating Committee structures for ECA SoCal and ECA Bay Area have provided more opportunity for local leaders to be involved in this success, increasing membership and participation in events. In 2018, ECA's website (EarthquakeCountry.org) was updated with responsive design aspects for better use via smartphones, and a new online-membership system will feature new membership levels and features that will greatly increase and improve ECA participation. As with ShakeOut, we are developing better ways of tracking all ECA activities (Table 8), including distribution of resources online, via shipping of materials, and at in-person events. We are also looking at how to increase engagement via social media, finding the balance between ShakeOut and ECA accounts (facebook.com/earthquakecountryalliance and twitter.com/eca) by distinguishing what information is distributed.

Table 8. PEP-2 Metrics	Y1	Y2
Visitors to websites	150,585	239,780
ECA members & leaders	~500; ~40	~600; ~50
Participants in ECA events & meetings	~500	1000+
Resources distributed	50,000+	200,000+
Social Media followers	4,500	4,764

PEP-2, ST1: Increased coordination with key stakeholders

The SCEC-managed Earthquake Country Alliance (ECA) is a statewide public-private-grassroots organization with regional alliances, sector- based committees, and outreach bureaus. SCEC manages annual budgets for each regional alliance, coordinates 6-8 local workshops each year, manages more than 40 conference call meetings

annually across all ECA committees and groups, creates messaging documents and graphics with input from these groups, distributes ECA materials, and maintains ECA's websites (including Terremotos.org in Spanish).

SCEC's Gabriela Noriega is the staff liaison for ECA SoCal, and SCEC's Sharon Sandow de Groot is the liaison for ECA Bay Area and the Redwood Coast Tsunami Workgroup. Each region has a coordinating committee of regional partners with specific roles, including three co-chairs for each region that serve on the statewide steering committee. In 2018 ECA SoCal and Bay Area each organized 3 regional workshops, held in various locations throughout the region in order to build local participation. Each was attended by 40-70 local partners, with topics including new ECA resources, opportunities to participate, local mitigation efforts, science updates, ShakeOut recruitment strategies, and announcements for the annual availability of 8-10 "mini awards" (purchases of resources worth up to $500) that support member efforts to improve preparedness and resilience. Each year these workshops become increasingly popular with ECA members encouraging colleagues and others to attend.

Recognition is great way to engage key stakeholders; thus on November 1 ECA SoCal commemorated the 10th Anniversary of ShakeOut, at the new Los Angeles County Fire Museum in Bellflower. This morning breakfast event had more than 50 attendees, and included a variety of displays and presentations highlighting how the ShakeOut scenario has led to many upgrades to utility systems and new retrofitting ordinances, as well as how the ShakeOut drill has improved planning and preparedness. A new ShakeOut awards program was launched at this event, which inducted original ShakeOut leaders from 2008 into a new "ShakeOut Hall of Fame" and recognized the efforts of several individuals and partner organizations.

SCEC's Sandow de Groot took over coordination of ECA sector-based committees in 2017 and is increasing participation, frequency of meetings, and development of products. These committees develop resources and organize activities for many audiences. Committee membership includes leaders from each sector, primarily within California however because the committees develop resources promoted via ShakeOut across the country (and beyond), some participants are from other regions. Sectors served include Businesses, the Public Sector, Non-Profits & Faith-Based Organizations, Healthcare, K-12 Schools, and Higher Education. A new multi-cultural committee will focus on ECA's outreach to the many language/cultural communities of California.

The newest organizational structure of the ECA are its three outreach bureaus, which coordinate campaign outreach and implement best practices with many partners. The Participation Bureau (led by Jason Ballmann) is building a network of County-level Coordinators who conduct direct outreach to their constituents to maintain and build ShakeOut and Tsunami Preparedness Week participation. The Media Bureau (also led by Ballmann) oversees ECA's media coordination via monthly or weekly meetings with representatives of the regional alliances, partnering organizations, and local/state/federal agencies. The Events Bureau (led by Mark Benthien) coordinates requests for ECA representatives at events organized by community groups, businesses, and other organizations. A new speaker/event request form was created in 2018 at EarthquakeCountry.org/events.

PEP-2, ST2: Increased use of ECA messaging and resources

We anticipate steady growth of ECA's regional alliances and sector-based committees in 2019 through the development of new web-based tools allowing the committees to curate their own set of resources on the ECA website. For example, ECA's Seniors and People with Disabilities committee has developed a variety of resources available at EarthquakeCountry.org/disability, and other committees will now have similar listings to showcase materials and activities. The committee also coordinated the filming of a ShakeOut Earthquake Safety Video Series segment on how people with disabilities can protect themselves during earthquakes, which was featured along with other materials at the annual Abilities Expo events in Los Angeles and the Bay Area where ECA has an information booth and leads 2-3 workshops a day for attendees (several thousand people attend each event). ECA's Business committee developed a video showcasing how to organize ShakeOut activities in the workplace.

As SCEC's coordination of earthquake science and safety information expands nationally and globally via ShakeOut communication channels, we are incorporating all ECA resources. Some states originally wanted to only promote their local materials, but most have come to see the value of consensus messaging along with the quality of ECA materials as a better alternative. Many states and regions have now adapted ECA's Seven Steps to Earthquake

Safety (EarthquakeCountry.org/sevensteps) as an organizational structure for their messaging, and FEMA is now incorporating the structure into an new version of their *Homeowner's Guide to Earthquake Safety.* To better assess this outcome going forward, we will begin to track how other organizations are using ECA materials in 2019.

PEP-2, ST3: Increased knowledge of earthquake hazard/risk/safety

Because primary support for ECA activities is provide by the California Office of Emergency Services via FEMA NEHRP support to the state, much of ECA's messaging has centered on mitigation and safety. ShakeOut surveys (see above) show increases in awareness of earthquake safety messaging, and we are encouraging state agencies to repeat a major 2018 assessment of household preparedness to see the results of our efforts. In addition, our resources such as *Putting Down Roots in Earthquake Country*, the ECA website, and ECA social media channels provide basic earthquake science overviews and feature earthquake hazard information and resources. Many ECA regional workshops have speakers who talk about local earthquake hazards and risk (such as a presentation by Dave Schwartz (USGS) at the August 15 workshop in Dublin, CA).

As in 2008 with the USGS-led ShakeOut Scenario, ECA Bay Area has also been active in the rollout of the USGS' HayWired Scenario. ECA leaders participate in the HayWired Coalition, which is now coordinated via biweekly calls led by SCEC's Mark Benthien. The initial release of the scenario (a final volume is still being reviewed) was held on April 18, 2018 with a press conference at Berkeley Stadium and in Central Park in Hayward. Benthien is also organizing HayWired messaging products; a messaging workshop held on August 30, 2018 at ABAG/MTC in San Francisco prioritized messaging topics for key audiences.

Each region also coordinated a Primary Media Event on ShakeOut day in 2018, with an earthquake simulator and displays for news media beginning at 4 a.m. at a Shakeout drill location. These events were at Los Angeles City Hall (which featured a test of the building's new ShakeAlert system) and at Berkeley's Civic Center Plaza. Both events had significant media coverage and local participation. SCEC Director John Vidale spoke at the Los Angeles event press conference, and SCEC Co-Director Greg Beroza participated in early-morning interviews at the Berkeley event.

Another example of how ECA works to increase knowledge happens each summer when ECA's Redwood Coast Tsunami Work Group hosts an "Earthquake and Tsunami Room" educational center at county fairs (which SCEC's Jason Ballmann helped staff in 2018). This room is filled with posters, displays, and hands-on demonstrations, staffed by local partners and attended by several thousand people during the fairs.

PEP-2, ST4: Sharing of best practices (local/statewide)

The ECA structures described above help coordinate communication of hazard and risk information, development and distribution of ECA resources, and implementation of ECA activities throughout the state. ECA also serves a role of sharing best practices it and other organizations develop for how to engage local residents, communities, and organizations in earthquake and tsunami drills; for how to promote mitigation and resilience; and for how to create local alliances (as we are now doing in the Central Coast). Sharing of best practices also happens within ECA, as the leaders of each region participate in quarterly *ECA Steering Committee* calls to learn what each region is doing, and bimonthly calls are held with leaders of ECA sector-based committees.

ECA also works with other organizations to bring its messaging and practices to new audiences. On May 16, ECA Bay Area partnered with the Neighborhood Empowerment Network to host the "2018 Bay Area Regional Community Resilience Summit" at City Hall in San Francisco. More than 150 community leaders from around the Bay Area attended the summit, which addressed the importance of applying a community-centered planning approach for creating culturally competent disaster resilience strategies that emphasize equity and ensure the health and well-being of all residents. The summit began with the "Run Your Resilientville" tabletop exercise which challenges participants to build teams at the community level to meet the care and shelter needs of residents. This was followed by an overview of the Haywired Initiative (Dale Cox, USGS); a briefing on the Empowered Communities Program ; a keynote address on *The Essential Role of Social Cohesion in Creating Resilient Communities*; a panel on *Advancing Equity in Our Pursuit of Resilience*; and a presentation on the work of the ECA.

The Summit also announced the planned expansion of the Neighborhood Empowerment Networks' *Neighborfest* project, which organizes more than 40 neighborhood block parties throughout San Francisco each summer and Fall featuring tabletop discussions on local vulnerabilities and resources, vendors and community groups, fun activities, and food. ECA is working with NEN and Ready America on a plan to expand the Neighborfest concept throughout the Bay Area (and eventually statewide). A "Neighborfest Plus" event was held on Sunday, September 15, 2018 in the Fruitvale community of Oakland, which will engage this historically challenged area in resilience conversations and feature the "Quake Cottage" earthquake simulator. More than 150 preparedness kits were distributed.

PEP-3: SCEC Science and Risk Communication

This program has grown rapidly in SCEC5 with several new structures and partnerships now in place to improve SCEC's capacity for media relations and risk communication. Table 9 shows relevant metrics; all are annual totals except the number of social media followers which is cumulative. We continue to improve our capacity for tracking such metrics, via subscriptions to media tracking and website analytic tools.

Table 9. PEP-3 Metrics	Y1	Y2
Visitors to scec.org	112,021	121,147
Participants in media trainings	30	40
SCEC-related media citations	n/a	358
Social Media followers	9,000	14,664

PEP-3, ST1: Increased awareness of SCEC and earthquake science

SCEC's Communications Manager Jason Ballmann disseminates SCEC research findings and information about the SCEC Community, as well as SCEC-managed preparedness activities and resources, via distribution of press releases, management of interviews and media events, developing articles for the SCEC website, oversight of SCEC's social media presence (Twitter.com/scec, Facebook.com/scec, Youtube/com/scecmovies, and Instagram.com/SCECinsta). Examples of news articles in 2018 include:

New York Times - *A Seismic Change in Predicting How Earthquakes Will Shake Tall Buildings*
Mashable - *We still don't know how to predict major earthquakes, and it's possible we never will*
Vice - *Here's What Will Happen After a Huge Earthquake Inevitably Hits California*
LA Times - *Dramatic photos show earthquake shaking cliffs at Santa Cruz Island*
Long Beach Post - *Second Annual Tsunami Preparedness Walk and Resource Fair*

PEP-3, ST2: Improved SCEC Community media skills

SCEC partners with several organizations (IRIS, UNAVCO, CalOES, CAPIO, etc.) to offer programs that train (1) the media on how to report earthquake science and (2) the SCEC community on how to communicate diverse and highly technical research to the public and media. For the latter, communications workshops for 30-40 participants are held at each SCEC Annual meeting, and a similar workshop was held at the 11NCEE (see KI-1 above) in July, 2018. These trainings continue to receive positive reviews from workshop participants; many have stated that they feel more empowered and in control of their interview experiences on from all technical perspectives (general messaging, word choice, tone, physical appearance and expressions, story development) and also state they better understand how they can help the media.

PEP-3, ST3: SCEC known as valued media resource

SCEC's positioning in Southern California makes it a go-to resource following significant earthquakes; we gained more than 2,000 followers on Twitter and many mentions across media for our timely tweeting of helpful, critical information during the magnitude 4.4 La Verne earthquake on August 28, 2018. This type of engagement has been carefully developed with strategies and resources in place for SCEC to leverage these teachable moments and are leading to increased traditional news media requests. For several years SCEC has been coordinating messaging for larger earthquakes (globally) with partners at IRIS (Wendy Bohon) and UNAVCO (Beth Bartel) under the umbrella of the GeoHazards Messaging Collaboratory (GMC), a multi-organization messaging group led by Jason Ballmann, which now also includes representatives of USGS (Lisa Wald) and NOAA (Cindi Preller). The GMC continues to provide a well-honed internal communications group that serves to fact-check and prioritize what resources to share

and how in times of crisis. In times of peace, the GMC operates to train scientists and the media on how to work together as well as educate the public on GeoHazards. Examples include coordination after the M7.0 Anchorage earthquake on November 30 and creation of new earthquake graphics for social media.

PEP-4: Quake Heroes Documentary

This will be one of SCEC's most easily measurable activities, and potentially very impactful. Surveys completed by more than 650 people over the past year (Table 10) were overwhelmingly positive and provided very useful suggestions and corrections, most which have been incorporated into the final product. With the film's completion in January 2019, the requests for Quake Heroes Special Events are likely to greatly expand which will have many evaluation components, especially in terms of actions taken as a result of viewing the film (such as registering for CERT or buying emergency supplies, both will be available at partner booths when the film ends). A website is being finalized, which will allow people to share their own stories from the Northridge earthquake as well as other disasters, and the actions they are now motivated to take because of seeing the film. See the 2019 CEO Plan for how the film will be distributed, including the high school toolkit with lesson plans that have been developed to accompany the film (see next section). Evaluation of short-term outcomes will be presented in the 2019 Annual Report.

Table 10. PEP-4 Metrics	Y1	Y2
# Screenings and # of Attendees	1; 50	4; 650
Actions taken (CERT registrations, etc.)	0	n/a
Visitors to website	n/a	n/a
Stories shared	n/a	n/a

PEP Focus Area Year 2 Milestones and Assessment

SCEC5 CEO focus area milestones for Public Education and Preparedness, listed in Table 11, represent major activity goals and evaluation priorities for each year.

Table 11. PEP Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	Coordinate 10th Anniversary ShakeOut with major events and participation increases in California, including HayWired scenario integration and EEW roll out.(west coast)		X			
b	US ShakeOut websites combined in a simpler, unified and modern web framework		X			
c	ECA establishes statewide neighborhood-level earthquake resilience program			X	X	
d	Products and activities delivered, short-term outcomes achieved		X	X	X	X
Evaluation Milestones						
e	Develop protocols for assessing mid-term PEP outcomes		X			
f	Assess PEP mid-term outcomes			X	X	X
g	Document results from PEP area assessment, with progress towards long-term outcomes				X	X
h	Future PEP activities and outcomes established					X

Progress towards Y2 milestones of the PEP focus area have been complicated by external factors. ECA SoCal coordinated a 10th Anniversary ShakeOut event on November 1 including the launch of new awards (a), however the USGS HayWired scenario was only partly released in 2018 with the final (most societally-relevant) volume now planned for release in 2019 such that ShakeOut integration will then be possible. This is likewise for the incorporation of EEW messaging within ShakeOut, as messaging and educational products remain in development. We have begun planning for the update of US ShakeOut websites (b) into a more unified site and have begun interviewing potential developers. Many new products and activities were delivered in Y2 (d), and we have been implementing new protocols and structures for assessing mid-term PEP outcomes (e), including a revamped (and simplified) survey for all ShakeOut participants; new tracking software for news media, social media, and website visits; and plans for assessing actions taken by attendees of *Quake Heroes* events. Talks and posters about ShakeOut data analysis were presented at several conferences in 2017 and 2018, and papers are now being written for publication.

K-14 Earthquake Education Initiative (K14)

This Focus Area spans three programs as shown in Table 12, the K14 section of the CEO Logic Model. Metrics and annual short-term (ST) outcomes for each program are listed (with results described below), leading to mid-term (MT)

outcomes for the overall K14 focus area that will indicate progress towards long-term (LT) outcomes. Milestones for the K14 focus area are also discussed below. For a thorough description of this focus area and its programs, see section 8, 2019 CEO Plan.

Table 12. K-14 Education Initiative Focus Area Outcomes

Programs	Program Outputs (Metrics)	Short-Term Program Outcomes	Mid-Term Focus Area Outcomes	Long-Term CEO Outcomes
Quake Heroes Educational Toolkit	# Toolkits distributed # Teen CERT clubs established # Actions by students to improve home/school safety # Stories shared by students	• Increased awareness of geoscience and engineering degrees/careers • Increased knowledge of EQ hazard/risk/safety • Increased participation in Teen CERT	• Increased knowledge of key earthquake science concepts and engineering among participants • Participants improve preparedness in their school/household/ community • Participants pursue geoscience or STEM majors at higher rates • Improved retention of geoscience majors, including women and underrepresented minorities	• Increased science literacy • Increased diversity, retention, and career success in the scientific workforce.
Quake Catcher Network	# Active QCN stations # School/museum participants # Event recordings # Uses of curricula	• Increased knowledge/use of seismic concepts and data in classrooms/ museums		
EarthCon-nections Partnership (INCLUDES, etc.)	# Schools involved (HS, 2yr, 4yr) # Educators involved # Students involved and # Underrepresented # Participants in activities # New geology majors (2yr/4yr)	• Increased knowledge of EQ hazard/risk/ safety • Increased awareness of geoscience and engineering degrees/careers • Increase family/community support for students interested in geoscience careers		

K14-1: Quake Heroes Educational Toolkit

As descripted in PEP-4, the *Quake Heroes* film is nearly complete. Likewise, the accompanying high school toolkits with lesson plans and instructor guides are also being completed. Thus the activities for which metrics will be assessed in Table 13 have not yet begun. The first set of toolkits will be distributed in 2019 in Los Angeles Unified School District High Schools, with the support of a grant from State Farm.

Table 13. K14-1 Metrics	Y1	Y2
Toolkits distributed	n/a	n/a
Teen CERT clubs established	n/a	n/a
Actions by students to improve home/school safety	n/a	n/a
Stories shared by students	n/a	n/a

We are very hopeful that the toolkit is popular among schools and inspires more youth to become trained, prepared their families, and lead their communities. See the 2019 CEO Plan for our distribution plans. Outcomes will be assessed via surveys of both teachers and students who view the film and complete the lessons included in the toolkit; results will be summarized in the 2019 annual report.

K14-2: Quake Catcher Network (QCN)

QCN has a long history with bold ambitions in early years as a citizen-science data-gathering tool for researchers, for which many people worldwide voluntarily hosted a small seismometer attached to their desktop computer. The original developers moved on from Stanford and in 2015 the QCN servers were moved to Caltech, and eventually to SCEC at USC in partnership with IRIS and the USGS ShakeAlert Project science education initiative. During this time the project began to focus on school and free-choice learning (FCL) institution installations of QCN sensors, for use as educational resources and for introducing earthquake early warning concepts (P and S waves, intensity versus magnitude, etc.).

Table 14. K14-2 Metrics	Y1	Y2
Active QCN stations	n/a	TBD
School/Museum participants	~100	~130
Event recordings	n/a	TBD
Uses of curricula	n/a	TBD

With the advent of smartphone (Berkeley's MyShake App) and other alternatives (OSOP's Raspberry Shake) for citizen science, QCN partners have decided to focus primarily on formal and FCL educational institutions as QCN's primary audience. Language on the QCN website (QuakeCatcher.net) inviting anyone to host a QCN site is being changed to reflect this focus, and will redirect interested people to other initiatives

Over the past year, an upgrade of the hardware, data archiving software, and other programming that enable QCN's data collection has been underway by a contractor paid jointly by SCEC and IRIS. The effort has been challenging due to hardware and networking issues, but is nearly complete. Next, the consultant will improve the user interface and other aspects that will improve our tracking of metrics listed in Table 14.

K14-2, ST1: Increased knowledge/use of seismic concepts and data in classrooms/FCL institutions

As we focus QCN efforts on institutions in educational settings, additional curricular resources are being developed for analyzing data recorded by sensors in schools and FCL institutions (and from others in the network), in order to achieve this short-term outcome. This includes new online tools for visualizing and interpreting QCN data, which will also be a key component of the USGS' ShakeAlert Project science education initiative. In addition, a joint "tectonic" partnership of two QCN "Hubs" that share a plate boundary, though are far apart (Alaska and the Coachella Valley in California) is now established. QCN sensors were installed in Anchorage Unified School District schools, led by Dr. Jennifer Witter. ASD IT specialists will manage QCN infrastructure, and Tracy Castoe from Central Middle School of Science will infuse the program with technology education. New QCN stations have also been brought to Kodiak High School and the National Wildlife Refuge Kodiak Visitor Center, completing the ASD Hub. These activities are an integral part of the EarthScope ANGLE program. The 35-station Coachella QCN hub is led by Michaeleen Gallagher at Sunnylands Center and Gardens in Rancho MIrage. Both hubs will share data and practices as a way to understand more about the earthquakes each region faces. This partnership may also become a model for similar school/museum hubs in other regions.

K14-3: EarthConnections

Y2 was the final year of this pilot activity for the San Bernardino, CA region supported through the NSF INCLUDES program. A field research activity was held with 10 student participants (including several new geology majors). Several educators and partners were involved in planning additional activities. See Table 15 for Y2 metrics. Under a proposal submitted to the GEOPATHS solicitation in November, 2018, this regional activity would expand with more participating schools (high schools, community colleges, and UC Riverside), further connection with SCEC's internship programs and other initiatives, and funding for SCEC staff to support activities. Visit https://serc.carleton.edu/earthconnections/regional_alliances/sanbernardino.html to learn more about the San Bernardino Alliance activities.

Table 15. K14-3 Metrics	Y1	Y2
Schools involved (HS, 2yr, 4yr)	3	5
Educators involved	24	28
Students involved	31	10
Underrepresented students	20+	7
Participants in activities	~75	~35
New geology majors	3	6

K14-3, ST1: Increased knowledge of earthquake hazard/risk/safety

The San Bernardino Alliance worked to improve and connect introductory geoscience teaching at high schools, community colleges, and universities and to strengthen ties between the schools and local geoscience professional societies within Inland Southern California, focusing primarily on the local societal issue of earthquake hazards. Activities in Y1 included an educator workshop, a field trip with high school and community college students, and the introduction of a college-level geology course at a local high school. Participants in these activities remained engaged in Y2. A field research activity at a fault trench provided new experiences for 10 students. Two other activities were worked on, but both had issues; a plan for improving earthquake hazard and risk information provided by San Bernardino County Office of Emergency Management staff along with their mobile "Seismic Simulator" was delayed

because of turn over of county staff, and a GIS lesson plan for high school could not move forward due to issues with ESRI licenses. Both of these activities may be developed if our GEOPATHS proposal to NSF is funded.

K14-3, ST2: Increased awareness of geoscience and engineering degrees/careers

The San Bernardino Alliance has worked to accomplish this outcome by improving collaborations between 4YR, 2YR and high school institutions, as well as with SCEC and professional geologist organizations such as the Inland Empire chapter of the Association for Environmental and Engineering Geology and the Inland Geological Society. The purpose is to connect students to their peers and to mentors at institutions that represent the next step on their educational pathway, as well as to expose them to careers in geology and to geoscience issues that impact the local community. For example, participants in a field trip learned from a professional geologist and a graduate student about graduate school and careers in the geosciences. Moving forward joint activities for students in the geology clubs at local high schools, community colleges and universities may be coordinated with representatives who are professional geologists so that students at earlier stages of the geoscience pathway will have opportunities to meet and interact with students and faculty who are from institutions that represent later stages in the pathway as well as with geologists who are engaged in various careers.

K14-3, ST3: Increase family/community support for students interested in geoscience careers

The San Bernardino Alliance remains embedded in the local community via the participation of high school and college students from the region, who bring with them the experiences of their families and communities. Student participants have surveyed their family and friends to discover the geoscience issues that are considered of highest importance within local communities. A “community night” at CSU San Bernardino was initially planned, but has not yet happened, where participating students and educators can showcase their activities, highlight local earthquake hazards (including a small hike to the San Andreas fault), and build understanding of career opportunities via a round table of professional geologists and engineers. While the service learning project in collaboration with the San Bernardino County Office of Emergency Services did not take off, one CSUSB student did receive service learning credit by leading geoscience outreach activities for K-12 students.

K14 Focus Area Year 2 Milestones and Assessment

SCEC5 CEO focus area milestones for the K-14 Education Initiative, listed in Table 16, represent major activity goals and evaluation priorities for each year.

Table 16. K14 Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	Initial Distribution of Quake Heroes Toolkits		X			
b	Completion of upgrade of QCN Server and expanded installations		X	X		
c	Renewal of EarthConnections project (or related funding); expansion within SoCal			X		
d	Products and activities delivered, short-term outcomes achieved		X	X	X	X
Evaluation Milestones						
e	Develop protocols for assessing mid-term K-14 outcomes		X			
f	Assess K-14 mid-term outcomes			X	X	X
g	Document results from K-14 assessment, with progress towards long-term outcomes				X	X
h	Future K-14 activities and outcomes established					X

Progress towards Y2 milestones of the K-14 focus area has been challenging, though steady: the distribution of *Quake Heroes* toolkits (a) will begin in late January with the completion of the film; the upgrade of the QCN server is nearly complete and sensors were installed in Anchorage (b); a proposal to the NSF GEOPATHS solicitation submitted in November will support the continuation and expansion of the EarthConnections project if funded (c); in Y3 these and other products/activities will be linked together to better achieve both short-term (d) and mid-term outcomes. Each of the three programs will have ongoing evaluation protocols (e) including surveys of teachers and students, classroom observations, and longitudinal tracking of student participants. If the GEOPATHS proposal is not funded, the proposed activities may be pursued at a smaller scale until another source can be secured (perhaps through another INCLUDES proposal for just our alliance).

Experiential Learning and Career Advancement (ELCA)

SCEC/CEO's manager of ELCA, Gabriela Noriega, coordinates two programs: undergraduate internship programs and the Transition Program launched in SCEC5 which offers resources and mentoring for students and early career scientists at key transitions (into graduate school, into industry, etc.). The ELCA portion of the SCEC5 CEO Logic Model is shown in Table 17. Metrics and annual short-term (ST) outcomes for each program are listed (with results described below), leading to mid-term (MT) outcomes for ELCA that will indicate progress towards long-term (LT) outcomes. Overall milestones for ELCA are also discussed below. For a thorough description of ELCA and its programs, see Section 8, 2019 CEO Plan.

Table 17. Experiential Learning and Career Advancement Logic Model

Programs	Program Outputs (Metrics)	Short-Term Program Outcomes	Mid-Term Focus Area Outcomes	Long-Term CEO Outcomes
Undergraduate Internship Programs	# Applicants # Undergraduate Interns (UseIT; SURE) # Female Interns # Underrep. minority interns # Mentors	• Increased knowledge of EQ & computer science • Increased interest in pursuing geoscience or other STEM graduate degrees and careers • Development of software applications for the SCEC Community and others	• Increased retention of women and underrepresented minorities (and others) in geoscience education and careers • Continued development of pathways to increase participation • Long-term SCEC participation among participants • Improved software applications for SCEC Community	• Increased diversity, retention, and career success in the scientific workforce • Improved application of earthquake science in policy and practice
Transitions Program	# Students supported (funding, application assistance, etc.) # Institutions involved # Networking events # Participants in events	• Improved relationships with partner institutions to increase recruitment and resource capacities • Improved support for SCEC students across transitions (undergrad->grad, grad->career) • Increased readiness for career advancement at all points of career		

ELCA-1 Undergraduate Internship Programs

Table 18. ELCA-1 Metrics	Y1	Y2
Applicants	251	160
Undergraduate interns (UseIT; SURE)	22; n/a	24; 5
Female interns	12; n/a	10; 3
Underrepresented minority interns	11; n/a	10; 1
Mentors	8; n/a	9; 5

UseIT is an ongoing success and many new structures are being developed under the leadership of Dr. Noriega, who has also reorganized how SURE is managed (due to the delayed funding of SCEC5, the SURE program was not held in Y1). This allowed five SURE internships to be awarded in 2018, with students working with SCEC mentors from UC Riverside, UC Irvine, UC San Diego, and Occidental College (for project details, see https://www.scec.org/internships/sure/researchprojects/2018). Targeted recruitment efforts to increase diversity are now focused on partnerships with southern California community colleges, rather than broad national efforts that in the past have resulted in more, yet less qualified, applicants (this accounts for the reduction in applicants in Y2 shown in Table 18). For example, in 2018 Pasadena City College funded the participation of 6 of their students in UseIT, and likewise East Los Angeles College supported 2 of their students.

ELCA-1, ST1: Increased knowledge of earthquake & computer science

Both of SCEC's internship programs provide opportunities for students of diverse majors to work with earthquake scientists to improve understanding of earthquake hazards and risk. Evaluation of the 2018 programs is underway by an external evaluator and is due for completion by the end of December. By observing and participating in the daily activities of earth science research, interns reported having an increased knowledge, including about working in research and education. SCEC's computational science staff, several of whom are UseIT alumni, as well as other SCEC researchers actively participate in the UseIT program as mentors to the 4-5 teams that are formed each summer. In recent years, the computational aspects of UseIT have expanded from software development (of the SCEC-VDO visualization system) to the application of High-Performance Computing (via successful proposals for annual allocations of processing time on the Blue Waters supercomputer) and in 2018 the inclusion of a machine

learning component. These new aspects have proven to expand opportunities for graduate school for student participants, especially our community college students who otherwise would not have had such experience.

ELCA-1, ST2: Increased interest in pursuing geoscience or other STEM graduate degrees and careers

All interns complete extensive pre- and post-internship surveys, and are tracked longitudinally to see how participation increases the likelihood of SCEC interns attending graduate school and/or remaining in STEM fields. Past evaluations show that intern program alumni report that their internship, coupled with networking at the SCEC annual meeting, made lasting impacts on their course of study and career plans, often influencing them to pursue or continue to pursue earthquake science degrees and careers. In 2018, UseIT intern Jordan Cortez (University of North Texas, Geophysics Major) met UC Riverside Professor David Oglesby at the SCEC Annual Meeting, and is applying to pursue a PhD next year (before UseIT, Cortez was not considering graduate school!). Another UseiT intern, Shril Panchigar (Pasadena City College, Engineering/Technology major), who had never heard of HPC before, won a grant/award to participate in the HPC Conference (SC18) Experiences for Undergraduates Program in November, where he was offered an HPC related internship at Lawrence Livermore National Laboratory in summer 2019.

ELCA-1, ST3: Development of software applications for the SCEC Community and others

The 2018 UseIT Grand Challenge was to: 1) develop a computational system for probabilistic forecasting of earthquake sequences in Southern California; 2) apply the system to initial-event scenarios and compare the simulator-based probabilities against official data of large aftershocks from Uniform California Earthquake Rupture Forecast version 3 (UCERF3); and 3) illustrate the hazards and risks of multi-event scenarios that could threaten the Los Angeles area with sequence-specific maps of expected ground motions, economic losses, and human casualties. Each year the Grand Challenge seems impossible to interns at the beginning of the summer, however once again this year's cohort was very successful. In addition to developing computational capabilities for earthquake forecasting, new features were added to the continually improving SCEC-VDO (Virtual Display Of Objects) visualization software. School-year research support for 2018 interns from USC and other local schools is allowing continued development prior to the summer 2019 UseIt program. For a complete overview of the 2018 UseIT program, including overviews of each teams projects, see https://www.scec.org/internships/useit/challenges/2018.

ELCA-2 Transitions Program

This new program is a very important priority for SCEC. Activities are still being developed, along with how the metrics shown in Table 14 (and other aspects) will be assessed. In 2018 we supported airfare for a PhD. student to travel to the SCEC annual meeting so she could present her poster, and the two early career/networking breakfast events at the meeting had higher attendance.

Table 19. ELCA-2 Metrics	Y1	Y2
Students supported (funding, application assistance)	0	1
SCEC Institutions & Partner Organizations involved	1	4
Networking events	2	2
Participants in events	120	160

ELCA-2, ST1: Improved relationships with partner institutions to increase recruitment and resource capacities

In partnership with IRIS and UNAVCO, SCEC has been planning an AGU Seismology & Geodesy Sections joint Early Career/Student Networking Luncheon at the 2018 AGU Fall Meeting. The session will focus on discussing strategies to achieve work/life balance in STEM careers. To date, we have 15 confirmed mentors and have 85 registered participants, although we expect to reach max participation of 100. In 2019 such partnerships will be expanded to include individual SCEC institutions, such that opportunities that support women and underrepresented minority students can be leveraged via SCEC coordination, promotion, and possibly financial support. This is similar to our successful partnerships with community colleges in southern California who have sponsored students to participate in UseIT through separate grant funding.

ELCA-2, ST2: Improved support for SCEC students across transitions (undergrad->grad, grad->career)

Efforts to achieve this outcome are just beginning. In 2018 we supported airfare for a PhD. student to travel to the SCEC annual meeting so she could present her poster. In 2019 we plan to implement summer "bridge" support for 1-2 students (depending on available funding) so they can arrive to graduate school and begin research prior to the Fall semester. This will depend greatly on the development of our connections with SCEC institutions.

ELCA-2, ST3: Increased readiness for career advancement at all points of career

For the second year, ELCA hosted two breakfasts at the SCEC Annual Meeting to connect early career attendees with peers and mentors to share experiences and develop strategies for navigating the transition from undergraduate to graduate school and from graduate school to professional career (within and outside of academia). Attendees reported that the events were very beneficial, and sign-ups for both breakfasts in 2018 exceeded capacity very quickly. In addition to the breakfasts, new "Lightning" talks highlighting poster topics were added to this year's program and were considered an ELCA activity as their purpose was to provide new opportunities for students and early career scientists to increase visibility for their work. Surveys will be expanded in 2019 to assess how these activities (and others to be introduced) are increasing career readiness.

ELCA Focus Area Year 2 Milestones and Assessment

SCEC5 CEO focus area milestones for Experiential Learning and Career Advancement, listed in Table 20, represent major activity goals and evaluation priorities for each year.

Table 20. ECLA Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	Partnerships with new and existing institutions increase mentor, recruitment, and resource capacities.		X	X		
b	Longitudinal tracking processes show impact of ELCA programs		X	X	X	X
c	SCEC's learning and career pathways advance diversity in geoscience education and careers.		X	X	X	X
Evaluation Milestones						
d	Develop protocols for assessing mid-term ELCA outcomes		X			
e	Assess ELCA mid-term outcomes			X	X	X
f	Document results from ELCA assessment, with progress towards long-term outcomes				X	X
g	Future ELCA activities and outcomes established					X

Progress towards Y2 milestones has been steady; SCEC Annual Meeting activities have greatly expanded awareness of SCEC's new Transitions program leading to new partnerships (a) with SCEC institutions and others (IRIS, UNAVCO, etc.). We are updating our longitudinal tracking processes (b) that show impact of ELCA programs (including the transitions program). In 2018 we redesigned SURE and UseIT webpages, which included creating scec.org profiles for all previous UseIT and SCEC interns from both of the programs' inception. This will impact recruitment and will help with longitudinal tracking. In 2019 we will launch a new ELCA page that will highlight ELCA activities and the Transitions program. External evaluation is underway based on post-internship surveys for 2018 to assess how SCEC's learning and career pathways are advancing diversity in geoscience education and careers (c). Each of these evaluation structures are the protocols (d) for how we will assess mid-term ELCA outcomes. This is especially important for UseIT this year, as 2019 is the final year of our current REU award, and a new proposal will be submitted in the Fall.

5. Report of the Advisory Council

M. Meghan Miller, *SCEC Advisory Council Chair*

Summary Commendations and Observations

- Another great SCEC meeting (and we really liked the lightning talks)!
- And another great year for SCEC
- Smooth and positive transition in leadership
- Productive and informative meeting with federal stakeholders
- Commendable collaborative engagement across a broad community
- Early career inclusion strategies are strong
- We support continued transparency in the criteria and prioritization of SCEC Grants
- Planning committee does a good job of tailoring priorities as new things are learned
- Given evolving national funding landscapes, are there aspects of the SCEC vision or approach that should be refreshed? Specifically, we recommend a concerted strategy for providing input into NSF EAR's upcoming Decadal Survey process.

Comments on Specific Initiatives and Questions to the Advisory Council

- It was abundantly apparent at this meeting that connectivity between faults and fault segment assemblages, addressed by the Earthquake Gates initiative, is centrally important for improved understanding of the earthquake system and the behavior of earthquake rupture. When and how will this focus expand to include gates with different geometries or other conditions?

- Community models continue to be a highlight of the SCEC community's overall contributions. It is paramount to keep these models usable as baselines and, at the same time, to keep the process sufficiently dynamic so that alternative hypotheses and modeling concepts can be accommodated moving forward.

- SCEC's cyberinfrastructure projects have high visibility and have benefited from collaborations with computational scientists. The committee recommends an assessment of the role of cyberinfrastructure in SCEC's scientific landscape, to prioritize scope, partnerships, sustainability, and opportunities. What can SCEC uniquely contribute?

- The recent efforts to educate earthquake engineers on SCEC ground motion products is commended. Validation of ground motion simulations remains an important task that is critical to engineers/public agencies because these entities use the simulation results in realworld decision making. The committee recommends that these efforts continue to be emphasized, including the new efforts to characterize the geotechnical layer and to include the effects of nonlinearity.

- We encourage SCEC CEO to develop outreach activities in support of Earthquake Early Warning, with sponsorship from USGS or other partners.

- We encourage continued discussions with NASA to thoroughly explore and advance common NASA/SCEC interests. Some NASA projects could overlap with SCEC core funding and some may be better addressed through Special Projects.

Introduction

The SCEC Advisory Committee (AC) convened at the SCEC Annual meeting in Palm Springs from September 9 to 12, 2018, reviewing SCEC activities in order to offer advice to the SCEC leadership. The SCEC AC comprises the following members, most of whom were present at the meeting, except where noted:

M. Meghan Miller, Chair, UNAVCO
Rick Aster, Rapporteur, Colorado State U.
Susan Beck, U. Arizona
Louise Kellogg, U. California, Davis
Yann Klinger, IPGP/Paris
Warner Marzocchi, INGV, Rome (not present)
Tom O'Rourke, Cornell U. (not present)
Susan Owen, JPL
Ellen Rathje, U. Texas at Austin
Tim Sellnow, U. Central Florida
Heidi Tremayne, EERI (not present)

Overarching Existential Thought

SCEC has historically shown a sustained capacity to navigate a well-defined path for success. Given changing landscapes nationally and scientifically, are there any aspects of the vision or approach that should be refreshed? Are there new opportunities on the horizon that should be pursued? Are there things that SCEC is doing that should be rethought? What are the risks and opportunities provided by sticking to the historical path? Putting this another way: how does a mature organization like SCEC remain nimble? We recommend a concerted strategy for providing input into NSF EAR's upcoming Decadal Survey process. Having the Decadal Survey include recommendations for the science that SCEC addresses and the format/mechanism that SCEC operates under could prove critical to the future of SCEC.

Opportunities/Issues to Highlight in this Report

- PG&E reconnection
- FEMA, USGS EEW communications partnership invitations
- Continue to encourage NASA tie ins for projects that meet common NASA/SCEC goals
- Code of conduct

Response to "Current Issues for the Advisory Council Consideration"

The SCEC Leadership requested that we consider the numbered questions during the meeting:

1. Earthquake Gate(s) Area Initiative. The Earthquake Gates special focus addresses the general problem of understanding the likelihood that ruptures pass through geometric complexities. ***Is this effort on track and making progress?***

It remains clear (and abundantly so at this meeting) that general connectivity between faults and fault segment assemblages addressed in the EG initiative is indeed centrally important for improved understanding the earthquake system and the behavior of earthquake rupture. This year, SCEC hosted a very productive field trip and workshop that fostered in depth discussion about the Cajon Pass target among contributors. A strength of this initiative is that it brings people from many different communities to work together (e.g., modeling and data acquisition researchers).

Because of the multidisciplinary nature of the problem this is applauded, and a continued emphasis is strongly encouraged. However, while we agree that Cajon Pass is an excellent target for this effort, to ensure a larger engagement of the SCEC community, structures that are tectonically similar to Cajon Pass might be considered as well. This would complement the Cajon Pass gate studies to broaden the impact of the Earthquake Gate Area

Initiative and enable participation by additional scientists. An obvious question is how and when the initiative and lessons learned will be expanded to “gates” with different/more complex geometries and other conditions.

2. Community Models. The CXM effort has been catalyzed in SCEC5 with the formation of a dedicated group, and the hiring of a Community Models Manager. ***Is the development and evolution of community models proceeding as it should or should we make adjustments?***

Community models continue to be a highlight of the SCEC community’s overall contributions. The thermal model is at a relatively early stage, but is an especially critical complement as SCEC modeling and science increasingly explores the anelastic regime. It is paramount to keep these models both usable as baselines and to keep the process sufficiently dynamic so that alternative hypotheses and modeling concepts can be accommodated moving forward.

Given the Beyond Elasticity emphasis for SCEC5, it continues to be important to update the Community Velocity Model to better represent the “geotechnical” upper crust layer. New data and modeling will be critical for validation exercises in ground motion simulation, seismic hazard, and seismic risk research themes.

3. CyberShake Hazard Studies and Distributed Infrastructural Studies, PGE. We are pursuing a range of opportunities. However, in the long term, maintaining Special Project funding at the $3-5M per year level of recent years remains a challenging goal. Also, in the long term, perhaps this effort should be better supported by funding sources more motivated by improving hazard maps. We had ambitions for CyberShake to be deployed statewide by the end of SCEC4, which didn't happen, and it's not likely to happen in SCEC5, although there is current progress in the Bay Area. ***How do we obtain funding from those who most benefit from the improved hazard maps, i.e., the USGS, states, cities, utilities, and/or the construction industry?***

When approaching other funding agencies regarding special projects, in particular, the CyberShake and the underlying 3D seismological simulations, **it is important to emphasize the potential improvements provided by these hazard maps**. A key to these improvements is the improved characterization of ground shaking provided by 3D simulations as compared to the traditional approach using ground motion prediction equations (GMPEs).

Nonetheless, validation studies are required to improve the current 3D simulations and demonstrate that they can do a better job than GMPEs. A focus on validation efforts, including both improvement of the velocity model of the geotechnical layer and inclusion of the nonlinearity in these materials, could be compelling in cultivating these funding agencies. **Model validation is critical to agencies that use the results in realworld decision making.**

Jeff Bachhuber of PG&E indicated a desire to see other utilities involved in funding SCEC research and he offered to help SCEC approach these other entities.

4. DOE and NASA Sources of Funding. We can address DOE needs for hazard analysis while providing needed resources to maintain momentum in our CyberShake workflow development and implementation. Also, our community models and expert tectonic research teams, partnering with NASA to compile a more comprehensive SCEC/NASA California geodetic model and launch interpretative studies, can advance the frontier of basic science. ***How do we promote such collaborations without taking on unsustainable obligations and/or distracting SCEC from its core mission?***

We encourage continued discussions with NASA’s Earth Surface and Interior Focus Area Lead, Ben Phillips, to thoroughly explore and advance common NASA/SCEC interests, as there is significant overlap with the priorities of the Tectonic Geodesy group. We also encourage exploring NASA interest in advanced remote sensing beyond the CGM. Future collaborations could also explore the possibility of including NASA Applied Sciences in postearthquake response.

Some NASA projects could overlap with SCEC Core funding and some may be better addressed through Special Projects. It is important that SCEC leadership views the science outcomes of NASA (or DOE or other sponsors) as aligned with SCEC science goals.

We noted that DOE was not well represented at this meeting, and it was unclear whether this was a temporary anomaly. The committee recommends that DOE colleagues working in earthquake science be strongly incorporated in future meetings, both for scientific and potential future partnership.

5. NSF Cyberinfrastructure Funding. As SCEC evolves, the computational demands continue to increase in all of the research activities, extending beyond what were initially considered Special Projects. As Such, the CME plays a critical role in both the Core and Special Projects activities. SCEC has been successful in pursuing CyberInfrastructure initiatives in the past under the umbrella of Special Projects. However, most of the funding opportunities are focused on the development of new codes and software and tend to be of limited availability. One of the key challenges is on obtaining funding for CME development AND sustainability. Established software needs a financially supported partnership with Computer Scientists (such as the SDSC group) to continually adapt the codes to the ever evolving HPC architectures. Deviating from the co-development strategy that has been so successful for SCEC will seriously impede our ability to have access to HPC allocations, a process that is very competitive on its own. In addition to support for our partners, SCEC needs a new model to support software maintenance and data management to support Core activities. ***How might we work with our funding agencies to make this process work more smoothly?***

SCEC's cyberinfrastructure projects have high visibility and have benefited from collaborations with computational scientists at UCSD and elsewhere. Most SCEC cyberinfrastructure projects are special projects; some have become core activities as well. Sustaining this infrastructure and especially the software will be challenging. Special projects require a scientific champion; external funding sources for development of new software tends to be distinct from that to sustain and disseminate that software. Allocating resources from SCEC's core funding to cyberinfrastructure projects that began as special projects would be a significant decision and, due to flat funding, would result in reduced funding for other programs, likely an unpopular decision. Some SCEC projects require HPC resources and all require high quality scientific software developed by teams of domain scientists and computational scientists or software developers.

The committee recommends an assessment of SCEC's scientific priorities for cyberinfrastructure, together with an assessment of SCEC's needs, investments, and uses of cyberinfrastructure to establish priorities for sustainability of software and for cyberinfrastructure partnerships. The assessment should identify what SCEC can uniquely do in this area. Clarifying the priorities and current allocation of resources would ensure that the staffing balance aligns with the overarching scientific goals of SCEC. We also recommend that SCEC partner with organizations who are fostering software sustainability and best practices for developing, disseminating, and sustaining scientific software. We especially recommend that SCEC encourage all software projects to validate software and follow best practices developed by the software community.

6. Leadership Transition. The leadership transition from Tom Jordan to John Vidale is complete, although still maturing. ***Comments or suggestions about the transition are welcome.***

The committee commends the successful leadership transition and continued effectiveness of the SCEC staff throughout the year. The new leadership is clearly already engaged in coordinating a successor for the critical (AD for Administration) position opening up as a result John McRaney's retirement. As John Vidale continues to grow into his new role, continued development of both SCEC and personal connections with the broad range of stakeholders and sponsors will be essential to SCEC's success.

7. Augmentation of SCEC Tools, Goals, Infrastructure. Clearly, with an enthusiastic and active cohort of diverse experts, SCEC should keep an eye out for related new opportunities. Several possibilities often mentioned are

mounting science projects with new instrumentation such as dense nodal arrays, optical fiber sensors or LIDAR. An obvious goal is honing models of shallow structure, perhaps with the new dense sensor tools, in the ways that will improve CyberShake hazard maps and extend them to higher frequency or refine our understanding of fault systems. ***How do we take [these sorts of] special projects from the drawing board/discussion session to successful proposals?***

SCEC has a long history of special projects that support its mission and impact, and that emerge from discussion with potential sponsors or proposals. There is risk related to potential SCEC investment in infrastructure, as budget sustainability and avoiding redundancies are strong issues in the NSF landscape. Such infrastructure might compete with funding of direct community research projects. Two matters should be considered: (1) alignment of infrastructure investment with SCEC's mission and resources that can be accessed otherwise; and (2) sustainability planning for infrastructure. In general, infrastructure projects should be finite in length, and ramped down or decommissioned when funding ends. Is there a mechanism for someone with a new idea or suggested innovation to get it considered and possibly supported (perhaps on an experimental basis). Proposals are expected to be responsive to the RFP; is there a means to introduce new ideas in the RFPs or in the special projects?

8. Earthquake Early Warning (EEW) is now a strong focus of the USGS. ***Should SCEC step up EEW efforts, either in research or for outreach?***

SCEC should consider working closely with the USGS on communications and outreach, as the EEW is rolled out in California. This presents a high level opportunity to contribute SCEC-mediated preparedness and other messages in a high profile and multifaceted public engagement effort. Connections via EEW engagement may also assist in growing SCEC connections with additional potential partners (e.g., transportation, energy, water and other interests and stakeholders). Can SCEC-mediated earthquake scenario simulations be further utilized in the design of EEW scenarios and implementation strategies?

We encourage CEO to continue providing EEW education through existing channels. CEO could likely make a larger contribution to early warning if additional state and federal resources are secured.

9. Each year we take concrete steps to improve the **annual meeting**. Those steps have been successful, but we are always trying to improve. This year, for example, we are having lightning sessions. ***How do we further promote inclusivity and diversity?***

Once again, the annual meeting has clearly shown itself to be a hugely important forum for the earthquake science community, and a major contributor to cementing the common efforts and collaborative culture of SCEC. SCEC should continue to educate the public and early career participants in related fields with the goal of sustaining societal relevance, vibrancy, and openness at meetings, as well as community engagement. SCEC's recent track record is very good, giving us confidence that the meeting will stay in the forefront of the SCEC vision and action.

Inclusiveness is critically important to SCEC's future. Continuing to encourage robust interactions between modelers and empiricists is particularly powerful in this regard.

At the meeting, we were impressed by the evident continued connections between fundamental earthquake science with nonlinear fault and nearsurface processes with engineering, ground motion modeling, and other fundamental aspects of earthquake safety.

The lightning talks were a great new addition. We heard comments that there was little diversity in the first round of lightning tasks, however. We encourage the meeting planning committee to seek ways to encourage broader representation in the future, e.g., earlier announcement of the opportunity, perhaps requiring lightning talks for all students/postdocs, or incorporating an invited (in addition to volunteered) category can further improve the topic and representation balance of these talks.

Looking forward, the committee noted a priority for future Honors Banquets - we expect that SCEC will work to ensure an inclusive program with visible diversity on the stage and at the microphone that models diversity in its

multiple dimensions. As a leader among community-based Earth science organizations, and one that attracts diverse early career registrants, this highlight community and social event is critical to supporting the next generation of Earth scientists by tangibly modeling broad participation.

10. ***Does the AC recommend that any changes to the overall SCEC advisory structure?***

We recommend that the AC report to an executive session of the SCEC Board of Directors and Executive Committee. This will enable a discussion of the AC's findings and will complement the presentation in the plenary session.

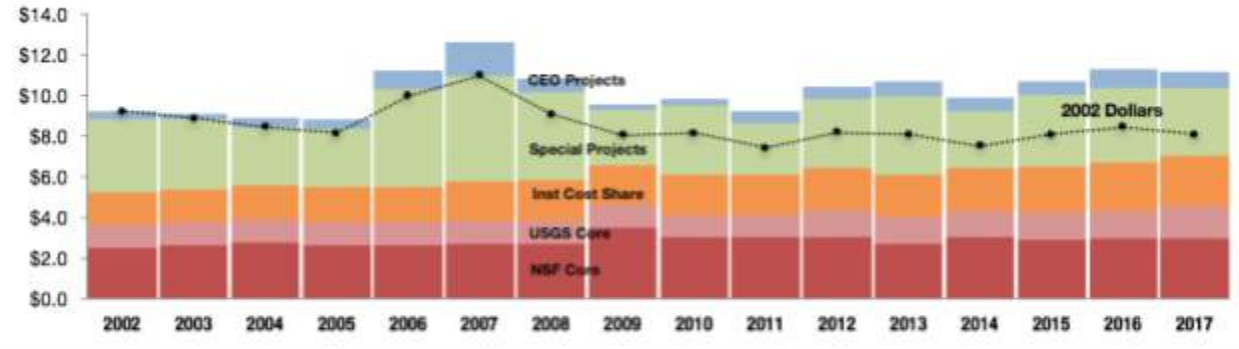
11. ***Is the composition of the AC appropriate to oversee the range if SCEC5 activities, or should people with specific expertise be added to the AC in future recruitments?***

The Advisory Council intends to consult via email on this topic and any other loose ends, in the weeks prior to the midyear meeting of the Leadership Council.

6. Budget and Project Funding

The Southern California Earthquake Center is funded by the NSF and USGS through cooperative agreements with the University of Southern California (USC). Additional funding for the annual SCEC research program may be provided by the Pacific Gas & Electric Company, the Keck Foundation, the California Earthquake Authority, geodesy royalty funds, and potentially other external sources. Funding to SCEC supports earthquake research in Southern California that engages an interdisciplinary community of over 1,000 active participants. The SCEC research program supports over 100 projects each year, including (a) smaller grants for individual scientists working in Center focus areas and collaborations, (b) larger grants for scientists and collaborative teams collecting new data on major Center projects or performing data integration and advanced modeling, and (c) workshops that bring all interested scientists together to focus on specific research initiatives. Funding from sources other than the NSF/USGS cooperative agreements target very specific parts of the overall SCEC research portfolio. For example, SCEC receives funding from PG&E for studies in rupture dynamics, development and maintenance of the broadband ground motion simulation platform, and ground motion prediction studies in central California.

The SCEC core program has been level-funded by NSF and USGS since 2002. About 69% of the NSF and USGS core funding is spent on science and infrastructure; other budget lines include management (11%), the education and outreach programs (12%), meetings (6%), and a Director's reserve fund (2%). Augmented USC support of the Center allows SCEC to maintain administrative costs at very low levels while increasing the professional staff at SCEC headquarters.



Total SCEC funding from 2002-2017, including base funding from NSF and USGS, core institution cost sharing, external funding sources for special projects and CEO projects. The connected dots are the totals in 2002 dollars.

In 2018, NSF cut base funding again by about $76K (from the $3,000,000 per year SCEC5 authorized level) to $2,923,365. The USGS fully funded SCEC at the authorized level of $1,602,965 in 2018. Building the 2018 SCEC budget was difficult due to staggered receipt of funding from all sources that contribute to the annual SCEC research program. The SCEC5 year 2 budget was not finalized until May 2018. For the 2018 funding cycle, SCEC received 152 proposals (by 188 distinct investigators) requesting a total of $4,895,422. The allocated funding for these 2018 science proposals is $3,010,800. Augmenting the base funding from NSF and USGS is an additional $586,263 from Pacific Gas & Electric Company, the Keck Foundation, geodesy royalties, and the 2017 Director's Reserve.

The annual SCEC Collaboration Plan is the suite of science projects selected for funding each year to meet the Center's research objectives. All SCEC research subawards are funded as subcontracts between USC and the entity to receive funding. Once the suite of projects are determined, each project must be allocated to a specific funding source. Different funding sources will have different legal flow-down provisions depending on the sponsor's requirements. When SCEC funding becomes available to investigators depends on (1) how soon SCEC/USC receives Center funding from the NSF and USGS and other external sources, and (2) how quickly contracts are negotiated between USC and institution to receive funding. Participant support (workshops, intern project supplement, and travel) award expenditures are managed through the master SCEC account at USC. For investigators at USC, the project expenses are also charged directly to the master SCEC account.

Current Funding (February 1, 2018 to January 31, 2019)

The table below shows the NSF and USGS base funding for SCEC5 Year 2 by budget category, compared to the original SCEC5 proposal request. In 2018, the USGS fully funded SCEC at the authorized level of $1,602,966 in Year 2. For the second year in a row, the NSF funding to SCEC was $2,923,365 (~$76K short of the $3,000,000 per year SCEC5 authorized level).

SCEC5 Base Funding by SCEC Activity (Year 2)

SCEC Activity	NSF	USGS	Combined
Science and IT Infrastructure	$1,566,991	$1,430,150	$2,997,141
Center Management	$258,600	$172,816	$431,416K
Communication, Education, and Outreach	$526,149	$0K	$526,149
Transitions Program	$74,425	$0K	$74,425
Undergraduate Intern Program (SURE)	$25,000	$0K	$25,000
Annual and Leadership Meetings	$371,250	$0K	$371,250
Director's Reserve	$100,950	$0K	$100,950
Total Request	**$2,923,2365**	**$1,602,966**	**$4,526,331**

Building the 2018 SCEC budget (and implementing the budget plans) was challenging. The fifth phase of the Southern California Earthquake Center (SCEC5) is funded under cooperative agreements NSF-EAR 1650087 and USGS G17AC00047. The cooperative agreement (CA) with the USGS is effective Feb 1, 2017 through Jan 31, 2022. Due to the new mandatory risk assessment required for federal awards over $10M, the CA with NSF was delayed and finally executed with effective dates of May 1, 2017 to Apr 30, 2022.

The research done by the community, and the progress reports submitted each year to SCEC, provide critical information for the Center's science and budget planning for following budget years. Therefore, all subawards are established with the same set of start/end dates and reporting requirements — irregardless of the funding source. Since 2002 (when SCEC graduated from an STC to a standalone center) the annual science planning process as described in Section 2 has been in place. The roster of participating investigators changes each year as new people and institutions join the SCEC research collaboration. The annual review of the SCEC program (and associated subawards) allows SCEC to drive and change the direction of research as needed to meet the Center's goals, milestones, and metrics. The fact that this is done on an annual basis, involving so many people and institutions, is a unique and necessary characteristic of SCEC and very different from how other research centers typically operate.

In October 2017, we requested that the NSF CA be amended to allow for Budget Years 2-5 to start February 1 and end January 31 the following year to allow annual dates to sync between the NSF CA and USGS CA. NSF approved this amendment request, which allowed executing Year 2 budget period to start February 1, 2018 and end January 31, 2019.

SCEC received full funding from the USGS on February 1, 2018, but the final funding level from NSF was not known until the end of April. Therefore, notification of SCEC subawards were delayed until mid-May 2018, after NSF funding was received and accounts established at USC.

Subcontracts from Year 1 were executed with a performance period from May 1, 2017 to April 30, 2018. However, Year 2 subawards were established with a performance period from February 1, 2018 to January 31, 2019. The different start/end dates between Year 1 to Year 2 SCEC subawards caused much confusion at investigator institutions that received funding from both years. This required much more communication between the SCEC administrative staff and the investigators, as well as their respective sponsored project offices, before Year 2 subcontracts could be established. For institutions that have multiple investigators who receive funding on different projects over different years, the "mixed options" of possible funding sources (and consequent flow-down rules) also causes added confusion that were addressed with lengthy communications between SCEC and the institutions before any agreements can be reached on new and/or amended subcontracts.

The staggered receipt of funding from all sources that contribute to the annual SCEC Collaboration Plan means that there is a very short “practical period” for executing on subcontracts and scheduling science workshops. The notifications of subaward are typically sent in the late spring or summer (after the first quarter of the performance period is over). This makes it virtually impossible for SCEC investigators to plan summer salary support and field studies for the current year. Science workshops have to be scheduled and planned for later the year also. Futhermore, investigators often face issues completing tasks by the project period end date (January 31 of the following year). At the of this report writing, the SCEC administration team is contacting all SCEC5 investigators for a status check on 2018 funded projects in order to determine if subcontracts should be amended to allow more time to complete 2018 SCEC-funded project tasks.

Despite the challenges of initiating SCEC5 and implementing the Year 1 and Year 2 budget plans, we can report that all 2018 (Budget Year 2) funds received from USGS and NSF have been obligated at this time. Subawards totaling $1,177,950 (USGS) and $1,455,549 (NSF) will have been executed by January 31, 2018.

Upcoming Year (February 1, 2019 to January 31, 2020)

As of December 2018, the USGS has indicated the SCEC5 Year 2 funding will be at the full requested amount of $1,622,311. NSF still does not have an agency budget, but SCEC has received guidance to assume level funding as in 2018 from NSF ($2,923,365). A combined Year 2 budget plan will be submitted to NSF and USGS for approval. In late 2018, SCEC received $110K from PG&E (derived from their 2018 end of year funds) to be directed towards workshops on fault displacement and fragile geologic structures and dynamic rupture validation efforts. However, we do not know the final funding for 2018 from PG&E and other external sources. SCEC has submitted a proposal to NASA, requesting $100K to fund SCEC-NASA collaborative projects. If recommended for funding, the $100K will support the non-NASA portion of the proposed project. NASA will fund its researchers internally for the remainder of the project award amount.

For the 2019 cycle, SCEC received 150 proposals requesting a total of $4,728,083 (from 191 distinct investigators). The plan is to establish Year 3 SCEC subawards with a start date of February 1, 2019 and and end date of January 31, 2018. If an investigator submits a successful proposal to SCEC the following year, his/her current subcontract is usually amended to add on the new year of funding, or transitioned to a new funding source through the establishment of a new subcontract to the investigators institution.

If final funding levels are known from the sponsoring agencies and increments that fund to the annual SCEC Collaboration Plan are received earlier in the Year 3 funding period, then some of the challenges faced in preivous years with implementing the budget plan could be mitigated.

7. 2019 Science Plan

The Southern California Earthquake Center (SCEC) was founded as a Science & Technology Center on February 1, 1991, with joint funding by the National Science Foundation (NSF) and the U. S. Geological Survey (USGS). Since 2002, SCEC has been sustained as a stand-alone center under cooperative agreements with both agencies in three consecutive, five-year phases (SCEC2–SCEC4). The Center was extended for another 5-year period, effective 1 February 2017 to 31 January 2022 (USGS SCEC5) and 1 May 2017 to 30 April 2022 (NSF SCEC5). SCEC coordinates fundamental research on earthquake processes using Southern California as its main natural laboratory. Currently, over 1000 earthquake professionals participate in SCEC projects. This research program is investigator-driven and supports core research and education in seismology, tectonic geodesy, earthquake geology, and computational science. The SCEC community advances earthquake system science by gathering information from seismic and geodetic sensors, geologic field observations, and laboratory experiments; synthesizing knowledge of earthquake phenomena through system-level, physics-based modeling; and communicating understanding of seismic hazards to reduce earthquake risk and promote community resilience.

The SCEC Science Plan solicits proposals from individuals and groups to participate in the SCEC research program on an annual basis. Typical grants awarded under the SCEC Science Plan fall 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, but rather to calibrate expectations for proposals submitted to SCEC. Field investigations outside southern California may be considered, provided the proposed research demonstrates direct relevance to SCEC5 goals that are not achievable within the southern California natural laboratory.

The 2019 Science Plan was announced to the SCEC community in October 2018 and posted on the SCEC website. The complete 2019 Science Plan can be downloaded at: https://files.scec.org/s3fs-public/SCEC2019RFP.pdf . In this report, we include only the “New This Year” section of the 2018 Science Plan. The science milestones for all years are included in the Research Accomplishments section of this report.

New This Year

The SCEC Science Plan (aka RFP) reflects the research priorities articulated in the SCEC5 proposal, and the project plan approved by the National Science Foundation and the U.S. Geological Survey. The SCEC Science Plan detailed in this document is provisional pending final SCEC5 Year 3 budget authorization. Substantial changes have been made to the RFP since last year, so we strongly encourage researchers to read carefully the RFP in its entirety.

- The time-period for SCEC-funded projects will have an effective February 1 start date and January 31 end date. Workshops funded in response to this Science Plan must be scheduled between February 1, 2019 and December 31, 2019.
- The Science Planning Committee (PC) was reconfigured for SCEC5. The current composition includes disciplinary committees (Seismology, Tectonic Geodesy, Earthquake Geology, and Computational Science), and interdisciplinary focus groups (FARM, SDOT, EFP, GM, SAFS, CXM and EEII), each with individual representation in the PC. The PC also includes two members representing the Special Projects.
- The Southern California Earthquake Center is committed to providing a safe, productive, and welcoming environment for all participants. We take pride in fostering a diverse and inclusive SCEC community, and therefore expect all participants to abide by the SCEC Activities Code of Conduct, as approved by the SCEC Board of Directors in June 2018.
- A new focus area, called “Earthquake Gates” was started in the first year of SCEC5. This initiative is designed to foster multidisciplinary studies of the factors that permit earthquakes to start or stop (as at a gate). To organize this initiative the SCEC community held an incubator workshop in March 2017 and solicited proposals to establish Earthquake Gate Areas. The Cajon Pass Region has been selected as the first and only Earthquake Gate of SCEC5. We do not plan to initialize any additional Earthquake Gate Areas in years 3-5 of SCEC5. Refer to section 5.5 SAFS for more information on the Earthquake Gates Initiative and the Cajon Pass Earthquake Gate Integrated Science Plan.

- This year, some geodesy, or other topical, proposals may be funded through partnerships with NASA scientists (including JPL). See details in Section 3.3.4: 2. Project plan.
- If identical or closely related work is also proposed to another institution (e.g., National Science Foundation), an explanation of the relationship of such work to the SCEC proposal should be provided.
- Investigators that anticipate extensive use of computational resources should consider consulting with the relevant SCEC Special Projects leadership to develop a strategy to acquire or support such resources.
- Investigators interested in undergraduate summer interns should include an "intern project" description in their proposal. The undergraduate intern will be recruited by the SCEC CEO Program staff. Selected intern projects will be awarded as supplemental funds on the proposal award. Funds used for summer stipends and travel support to the SCEC annual meeting for the selected undergraduate students will be managed at and dispersed from USC. The number of intern projects awarded each year will depend on available funding in the SCEC annual budget and the pool of interested applicants.
- The SCEC Transitions Program was launched for at the beginning of SCEC5. This program provides students and early-career scientists with resources and mentoring, particularly at major transitions in their educational and professional careers. In doing so, the Transitions Program aims to encourage and sustain careers in the geosciences and other STEM fields. The SCEC Transitions Program welcomes proposals that expand awareness of professional advancement opportunities and pathways, as well as improve competency in earthquake research tools and techniques of the junior members of the SCEC community.
- The geochronology infrastructure supports Accelerator Mass Spectrometer analysis of 14C, 10Be, 26Al, and 36Cl through collaboration with Lawrence Livermore National Laboratory and the University of California, Irvine (14C only). Luminescence dating (OSL, pIR-IRSL) will be supported through regular proposal budgets, through an arrangement with a luminescence laboratory (see Earthquake Geology section for suggestions).
- Funding for travel to participate in the SCEC Annual Meeting will be considered only in the context of a research proposal in response to the current Science Plan. International travel funding for a co-investigator to participate in the SCEC Annual Meeting will be considered, provided the proposal clearly states (a) how the investigators are critical to the project and (b) a plan for how the international participant's institution will cost-share the anticipated travel expenses.
- There is a renewed call to develop methodologies to validate ground motion simulations based on dynamic rupture simulations, for systematic assessment of aleatory variability and epistemic uncertainty in simulated ground motions, and for the development of methodologies to validate and calibrate estimates of permanent displacements.

8. 2019 Communication, Education, and Outreach Plan

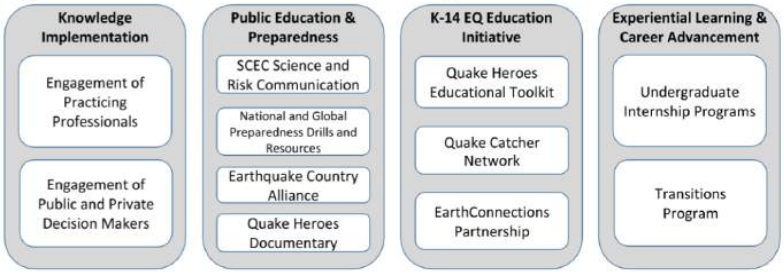
Mark Benthien, *SCEC Associate Director for CEO*

Overview

SCEC's Communication, Education, and Outreach (CEO) program addresses the final element of SCEC's mission: Communicate understanding to end-users and society at large as useful knowledge for reducing earthquake risk and improving community resilience. The theme of the CEO program in SCEC5 is ***Partner Globally, Prepare Locally***; preparing not only for local hazards, but also preparing students, engineers, government officials, the media and the public with enhanced science literacy to make informed decisions (split-second as well as long-term) to reduce their risk, and preparing the next generation of scientists via research opportunities and support through career transitions.

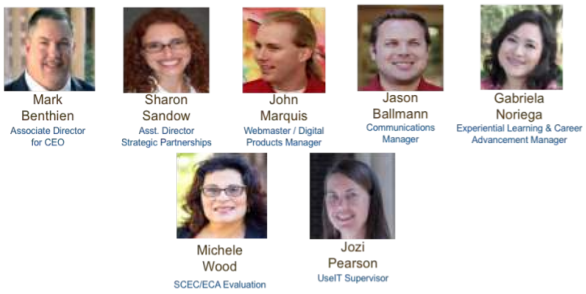
CEO is an evidence-based program built on education and social science research, organized within four CEO focus areas (Figure 1). ***Knowledge Implementation*** connects SCEC scientists and research with practicing engineers and other technical professionals, as well as with public and private decision makers. ***Public Education and Preparedness*** educates people of all ages about earthquakes, tsunamis, and other hazards, and motivates preparedness. ***K-14 Earthquake Education Initiative*** improves Earth science education and earthquake safety in schools and museums. ***Experiential Learning and Career Advancement*** organizes research and networking opportunities to sustain careers in STEM fields.

Figure 1. SCEC CEO Focus Areas and Programs



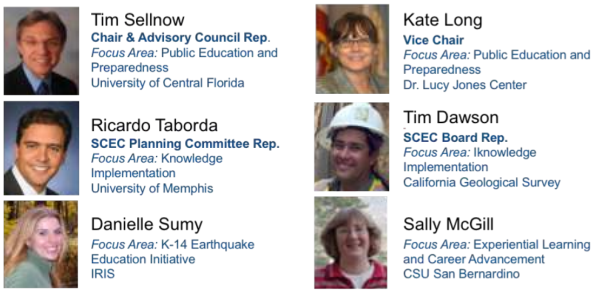
Associate Director for CEO Mark Benthien leads an accomplished team of staff and consultants (Figure 2), each managing portfolios that span the CEO focus areas. CEO staff are John Marquis (CEO web manager), Jason Ballmann (communications manager), Sharon Sandow de Groot (assistant director for strategic partnerships), and Dr. Gabriela Noriega (manager for Experiential Learning and Career Advancement). CEO consultants include Jozi Pearson (UseIT supervisor), and Dr. Michele Wood (CSU Fullerton) who supports evaluation activities. See Section 4 for an overview of the SCEC5 CEO evaluation plan including five-year evaluation milestones.

Figure 2. SCEC CEO Staff and Consultants



The CEO Planning Committee (CEO-PC, Figure 3) provides guidance and support for CEO activities and partnerships, review evaluation, and identifies synergies across SCEC and with external organizations. The Chair of the CEO-PC is Tim Sellnow (U. Central Florida), who is also on the AC. Sellnow represents the Public Education and Preparedness CEO focus area along with Kate Long (Dr. Lucy Jones Center). Danielle Sumy (IRIS) represents the K-14 Earthquake Education Initiative. Sally McGill (CSU San Bernardino) represents the Experiential Learning and Career Advancement focus area. Tim Dawson (California Geological Survey) and Ricardo Taborda (Universidad EAFIT, Colombia) represents the Knowledge Implementation focus area. Dawson and Taborda are also the representative of the SCEC Board and PC, respectively.

Figure 3. SCEC CEO Planning Committee



Knowledge Implementation (KI)

SCEC's Implementation Interface working group provides the organizational structure for connecting SCEC scientists and research results with research engineers and key partners (such as Pacific Gas & Electric) to improve application of earthquake science. The CEO Knowledge Implementation focus area extends these connections to practicing engineers, government officials, business risk managers, and other professionals. SCEC CEO has partnered for many years with local and state agencies who need earthquake information, organizes workshops and other trainings (including those provided by the Earthquake Country Alliance and GeoHazards Messaging Collaboratory), and held activities with the EERI Southern California Chapter and the Structural Engineers Association of Southern California.

A key aspect of this focus area is to expand these activities and increase the adoption of SCEC science and products in the development of improved building codes, updated insurance rates, and more realistic emergency management planning scenarios. Example products include the Maximum Considered Earthquake response spectra (MCE_R) data access tool released in 2018 by the SCEC Committee for Utilization of Ground Motion Simulations (or "UGMS Committee"), SCEC simulations (High-F, Broadband, CyberShake), UCERF (Uniform California Earthquake Rupture Forecast), and OEF (Operational Earthquake Forecasting).

Knowledge Implementation spans two programs: *Engagement of Practicing Professionals* and *Engagement with Public and Private Decision Makers*. See Section 4, Table 2 for the annual short-term outcomes for each program, which combine together to achieve mid-term outcomes for the KI focus area, which then in turn indicate progress towards CEO long-term outcomes.

KI-1: Engagement of Practicing Professionals

This program seeks to increase the knowledge and use of SCEC science among technical audiences that directly implement earthquake science and engineering research products. Examples include practicing structural and civil engineers, geotechnical consultants, building officials and others involved in designing structures to withstand levels of shaking determined from the USGS National Seismic Hazard Maps, or insurers who use the Uniform California Earthquake Rupture Forecast to set rates. The strategy is to encourage SCEC scientists to interact with these audiences through meetings and webinars of professional associations (SEAOSC, ATC, CGS, CALBO, ASCE, AEG, EERI, etc.) and to invite their participation in SCEC activities, including the Annual Meeting, technical workshops and outreach partnerships such as Earthquake Country Alliance regional alliances and statewide committees.

2019 KI-1 Plans:

- CEO will host monthly calls/meetings of the Knowledge Implementation Working Group, comprised of SCEC scientists and representatives of the audiences listed above, which will identify needed information and resources, opportunities for coordination, and how to document SCEC KI mid-term outcomes.
- We will also organize 3-5 presentations by SCEC Scientists at professional association meetings in both Southern California and the San Francisco Bay Area.
- As part of our long-standing leadership within the EERI Southern California chapter, we will jointly organize a workshop, field trip, or other engagement activity.

KI-2: Engagement with Public and Private Decision Makers

This KI program builds connections between SCEC and those who make decisions based on an increased awareness of earthquake hazards and risk, including elected officials, emergency managers, business leaders, building owners, financial institutions, and insurers. SCEC is increasing its involvement with professional associations and regional government groups such as the Building Owners and Managers Association (BOMA), Association of Contingency Planners (ACP), California Emergency Services Association (CESA), Southern California Association of Governments (SCAG), and Association of Bay Area Governments (ABAG). An example is the annual Structural Engineers Association of Southern California "Strengthening Our Cities" Summits, which SCEC and ECA have supported since 2011, that seeks to inform government officials and others of the latest approaches to managing earthquake risk. SCEC/ECA also helped create the FEMA QuakeSmart recognition program for businesses that demonstrate mitigation they have implemented; this program is now offered in many locations nationwide each year.

2019 KI-2 Plans:

- The Knowledge Implementation Working Group will also include representatives of these audiences, and likewise identify appropriate resources and ways to collaborate to achieve KI mit-term outcomes.
- We will organize 3-5 presentations by SCEC Scientists in both Southern California and the San Francisco Bay Area for business continuity associations, government agencies, or elected officials.
- Through SCEC's leadership of the HayWired Coalition in the Bay Area (which is working to encourage new policies based on the results of the HayWired Scenario), we are also involved in the "Outsmart Disaster" business resilience campaign that the California Seismic Safety Commission developed first in the Bay Area (based on the Scenario) and has now taken statewide. We will be promoting its resources and encouraging businesses to take the "Business Resilience Challenge."

KI Focus Area Year 3 Milestones and Assessment Plans

SCEC5 CEO focus area milestones for Knowledge Implementation, listed in Table 5, represent major activity goals and evaluation priorities for each year.

Table 1. KI Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	SCEC KI Working Group established to identify needed products/activities		X	X		
b	Products and activities delivered, with clear value for risk reduction			X	X	X
Evaluation Milestones						
c	Develop protocols for assessing mid-term KI outcomes		X			
d	Assess KI mid-term outcomes			X	X	X
e	Document results from KI assessment, with progress towards long-term outcomes				X	X
f	Future KI activities and outcomes established					X

The *SCEC KI Working Group* will meet throughout the year to identify needed resources and potential activities (a), several of which will be delivered in 2019 (b; see plans for each program above). The group will also develop protocols (c) for how to document specific examples of improved resiliency as a result of SCEC research and activities (d). We will also continue tracking of program outputs (metrics) as listed in Section 4, tables 3 and 4, and assessment of the short-term outcomes listed in Section 4, table 2.

Public Education and Preparedness (PEP)

The activities and products in this focus area are intended to educate people of all ages about earthquakes, tsunamis, and related hazards, and motivate them to improve resilience and personal preparedness. PEP spans four programs: *National and Global Preparedness Drills and Resources; Earthquake Country Alliance; SCEC Science and Risk Communication;* and *Quake Heroes Documentary.* See Section 4, Table 6 for the annual short-term outcomes for each program, which combine together to achieve mid-term outcomes for the PEP focus area, which then in turn indicate progress towards CEO long-term outcomes.

PEP-1: National and Global Preparedness Drills and Resources

SCEC worked with the USGS and Earthquake Country Alliance leaders to create the first multi-sector "Great ShakeOut" earthquake safety drill in 2008, which involved 5.4 million southern Californians. This one-time event now has expanded to 27 official ShakeOut regions across the U.S. and around the world. ShakeOut has become a global infrastructure for providing earthquake information to the public and involving them in community resiliency. New countries are being actively recruited to join the ShakeOut movement, which serves to coordinate earthquake messaging internationally. Participants receive monthly ShakeOut newsletters and more frequent

Figure 5. ShakeOut websites managed by SCEC

ShakeOut websites are now online in English, Spanish, French, Italian, and Japanese.

content via social media. Millions more learn about ShakeOut via broad news media coverage that encourages dialogue about earthquake preparedness. In the near future, ShakeOut will be utilized for educating West Coast residents about Earthquake Early Warning, with yearly tests to be held on ShakeOut day.

In Year 3 we will continue to implement the *Collective Impact Framework* for planning and assessing all aspects of the initiative. This is an approach which CEO has discovered as part of participation in the EarthConnections initiative (see K14-3 below). Collective Impact has five key elements:

1. Common Agenda for change including a shared understanding of the problem and a joint approach
2. Mutually Reinforcing Activities via a plan of action that outlines roles and leverages expertise
3. Common Progress Measures across all participants that ensure alignment and accountability.
4. Continuous Communication that builds trust, assures mutual objectives, and creates common motivation.
5. Backbone Organization(s) that coordinates participating organizations and agencies.

SCEC/CEO is the Backbone Organization of ShakeOut, and we are increasing the visibility of this role in SCEC5. Activities include: creating and distributing customized monthly update emails for all Shakeout regions; contacting organizations to renew participation each year; posting frequent social media messaging (ShakeOut.org/messaging), new drill guidance resources and educational content; training ShakeOut Regional Coordinators and developing tools for their use (such as the new ShakeOut Coordinators Portal which allows state or local coordinators to access their participant data in order to increase participation and improve networking); and coordinating Evaluation (via Michele Wood, CSU Fullerton). SCEC/CEO's Jason Ballmann oversees most of these efforts with web and database support from CEO webmaster John Marquis.

Figure 7. TsunamiZone.org website

As a result of its leadership of ShakeOut, SCEC now also receives NOAA funding provided through the California Office of Emergency Services to create and manage TsunamiZone.org (Figure 7). This international site adapts the ShakeOut registration system to assess participation in Tsunami activities, whether as part of their ShakeOut activities or during local tsunami preparedness weeks or months.

2019 PEP-1 Plans:

- A major activity of Y3 will be to implement a major update of all U.S. ShakeOut websites by combining most content into a national site and creating state/regional subpages, which will greatly improve the ability to make updates, provide better access via smartphones, and simplify overall management. Once the new website structure is complete for ShakeOut, the TsunamiZone site will also be updated.
- The *Collective Impact Framework* will be fully implemented in how we coordinate ShakeOut in California, how we support the efforts of other states and countries, and how they coordinate their own regions.
- All remaining ShakeOut regions will be given access to the Coordinators Portal and trained how to increase participation and gain awareness of participant activities. U.S. ShakeOut participation will exceed 22 million.
- International participation will grow with efforts underway in Asia (especially in China) and Latin America. Total global participation (including US) will exceed 65 million.
- With the completion of the HayWired Scenario, Bay Area ShakeOut messaging will encourage use of its results as inputs to drill planning and multi-organizational exercises.
- Messaging about Earthquake Early Warning (ShakeAlert) will be delivered via Shakeout channels.
- In 2019, Oregon, Washington, Alaska and Hawaii will expand their use of the TsunamiZone website. Total TsunamiZone participation will exceed 1 million for the first time.

PEP-2: Earthquake Country Alliance

In 2003, SCEC created the Earthquake Country Alliance (ECA) with partner organizations in southern California, and is now a statewide public-private-grassroots organization with regional alliances which organize local activities (Figure 8), sector-based committees which develop resources and programs for statewide audiences (and beyond), and outreach bureaus which manage recruitment for ShakeOut and Tsunami Week, provide speakers and booths for

events, and coordinate media relations. SCEC manages annual budgets for each regional alliance, coordinates 6-8 workshops each year, manages more than 40 conference call meetings annually across all ECA groups, creates messaging documents and graphics with input from these groups, distributes ECA materials, maintains ECA's EarthquakeCountry.org (English) and Terremotos.org (Spanish) websites, and manages ECA social media channels (facebook.com/earthquakecountryalliance and twitter.com/eca). Mark Benthien serves as ECA's Executive Director. Financial support for ECA is provided to SCEC by the California Governor's Office of Emergency Services (CalOES) and FEMA.

Figure 8. ECA Regional Alliances

Regional Alliances. ECA expanded statewide along with ShakeOut in 2009. In addition to a new Bay Area alliance, the Redwood Coast Tsunami Work Group (which was organized in the early 1990s) also joined the statewide effort. ECA Central Coast is now being established with local champions. Each Regional Alliance has three co-chairs, who collectively comprise the Steering Committee of ECA which meets quarterly. *ECA SoCal* is chaired by Connie Lackey (Providence Health) Heidi Rosofsky (Global Vision), Margaret Vinci (Caltech Earthquake Programs) and is supported by SCEC's Gabriela Noriega. The chairs lead a Coordinating Committee via bimonthly teleconferences with reports from committee members who manage regional workshops (3-4/year), membership, communications, events bureau activities, and other efforts. *ECA Bay Area* has been revitalized over the past two years with the support of SCEC's Sharon Sandow de Groot, working with a local Coordinating Committee chaired by Daniel Homsey (City of San Francisco Neighborhood Empowerment Network (NEN), Jennifer Lazo (City of Berkeley), and Bob Beecher (Cisco, San Jose). The group has the same structure as ECA SoCal and similar activities. The *Redwood Coast Tsunami Work Group* coordinates earthquake and tsunami resources and activities for the northernmost counties of California's coastline, including Tsunami Preparedness Week activities with "live-code" drills of tsunami warnings, "Earthquake and Tsunami Rooms" at county fairs each summer, and promotion of ShakeOut registration each October. SCEC worked with RCTWG leaders to update the tsunami safety imagery shown in FIgure 10, which is now used globally. RCTWG is represented on the statewide ECA steering committee by Kerry Sherin (Humboldt State University), Ryan Aylward (National Weather Service), and Charlie Helms (Crescent City Harbormaster).

Figure 10. Tsunami Safety Guidance

Sector-Based Committees. ECA's sector-based committees develop resources and organize activities for many audiences. SCEC's Sandow de Groot took over coordination of the committees in 2017 and is increasing participation, frequency of meetings, and development of products. Sectors served include Businesses, the Public Sector, Non-Profits & Faith-Based Organizations, Healthcare, K-12 Schools, and Higher Education. ECA's EPIcenter Network of Museums, Parks, and Libraries is being reorganized with the same structures of other sector-based committees, and a new multi-cultural committee will focus on ECA's outreach to the many language/cultural communities of California. Figure 11 shows a very popular product developed by the ECA Seniors and People With Disabilities Committee. Each committee has a new set of tasks to accomplish each year:

1. Engage leaders from within the sector
2. Hold bimonthly committee meetings (online)
3. Review and update existing ECA materials
4. Develop new sector-based materials
5. Represent ECA at a workshop or other event
6. Develop/host a webinar

Outreach Bureaus. The newest organizational structure of the ECA are its three bureaus, which coordinate campaign outreach in support of ECA's Regional Alliances and Committees. The *Participation Bureau* (led by SCEC/CEO's Jason Ballmann) is building a network of County Coordinators who conduct direct outreach to their constituents to maintain and build ShakeOut and Tsunami Preparedness Week participation. Each Coordinator has access to the ShakeOut Coordinator Portal for recruiting and registering participants and developing

multi-organization drills. In 2018 this structure was established in southern California by chairs Ken Kondo (Los Angeles County Emergency Management) and Jenny Novak (CalOES). Ballmann also oversees ECA's statewide media coordination, through monthly meetings/calls of the *Media Bureau* with representatives of the regional alliances, partnering organizations, and local/state/federal agencies. The group coordinates promotion of ShakeOut and Tsunami Preparedness Week, along with post-earthquake messaging, media trainings, etc. Finally, the ECA *Events Bureau* coordinates requests for ECA representatives at events organized by community groups, businesses, and other organizations. This includes speaking invitations as well as requests for information tables. A new request form has been created at EarthquakeCountry.org/events and a series of presentations are being developed for ECA speakers. SCEC/CEO's Benthien coordinates the Bureau with chairs Lance Webster and John Hammett.

Figure 11. Earthquake Safety Guidance

2019 PEP-2 Plans:

- Organize a statewide leadership retreat in Spring, 2019 with leaders from each regional alliance, sector-based committee, outreach bureau, and major partners (FEMA, CalOES, USGS, Seismic Safety Commission, EERI, SEAOC, and others). This retreat will identify long-term strategies, develop assessment structures, and review ECA resources and messaging.
- Survey ECA members for how they use ECA resources, the value of ECA workshops and other activities, and for examples of what they achieve in their communities and organizations.
- ECA Bay Area will further develop its partnership with the San Francisco Neighborhood Empowerment Networks' *Neighborfest* project to expand the concept throughout the Bay Area. Pilot activities planned for 2019 are being discussed with several cities.
- Continue efforts to establish a Central Coast Earthquake Alliance with at least 2 local activities in 2019.
- The ECA website (www.EarthquakeCountry.org) will launch new membership tools and abilities for each ECA alliance, committee, or bureau to post articles, links, and resources to the ECA website.
- ECA Committee membership will be expanded with new chairs for less active committees.
- The ECA Participation Bureau will expand its membership to include county representatives from the Bay Area and North Coast and coordinate all local recruitment for Tsunami Preparedness Week and ShakeOut.
- Messaging about Earthquake Early Warning (ShakeAlert) will be delivered via ECA channels and activities.
- These are in addition to the regular activities ECA and its groups coordinate each year.

PEP-3: SCEC Science and Risk Communication

This program led by Jason Ballmann focuses on communicating SCEC research findings as well as about the SCEC Community, as well as coordinating activities that improve risk communication both internally and externally of SCEC. This includes the distribution of press releases, management of interviews and media events, developing articles for the SCEC website, oversight of SCEC's social media presence (Twitter.com/scec, Facebook.com/scec, Youtube/com/scecmovies, and Instagram.com/SCECinsta, and coordination via all these aspects for post-event messaging and media requests. Each year SCEC partners with several organizations to offer programs that train (1) the media on how to report earthquake science and (2) the SCEC community on how to communicate diverse and highly technical research to the public and media. Ballmann leads the *GeoHazards Messaging Collaboratory (GMC)* with partners at IRIS (Wendy Bohon), UNAVCO (Beth Bartel), USGS (Lisa Wald) and NOAA (Cindi Preller) to present webinars for media and scientists, coordinate special outreach campaigns, and lead conference workshops, all focused on the value of messaging consistency and resource leveraging. Post-earthquake messaging coordination has been an active aspect of the GMC, allowing each organization to share or amplify key findings or messaging in order to reach more people with the information they need.

2019 PEP-3 Plans:

- SCEC's collaborative approach to post-earthquake messaging coordination and media skills training will be presented at several conferences in 2019.
- The popular communications training workshop will be offered again at the 2019 SCEC Annual Meeting.
- CEO will coordinate with SCEC leadership to identify key research results to highlight in the press, especially at the SCEC Annual Meeting.
- The successful efforts to increase SCEC's social media following with each "teachable moment" (earthquake) will continue.

PEP-4: Quake Heroes Documentary

Quake Heroes, a 52-minute documentary based on interviews of people who experienced the Northridge earthquake, has been in development by SCEC and Blue Tavern Productions (established by Mark Romano, a former SCEC intern), and is about to be completed after a year of feedback screenings. The film portrays stories of people who took action to help their neighbors, along with a description of the science of the earthquake by SCEC and USGS scientists, and several others. Recent interview footage is shown with archival news footage, as well as live-action reenactments filmed with actors. The *Seven Steps to Earthquake Safety* are featured with the goal of prompting viewers to take action. Primary funding was provided by FEMA; sponsors include Simpson Strong Tie, State Farm, the Structural Engineers Assoc. of So. California (SEAOSC), and the Hero in You Foundation.

Figure 13. A scene from *Quake Heroes*

The film will be made available in 2019 via a variety of settings and approaches. *Quake Heroes Special Events* will be organized (many have already been requested) to screen the film and then have a Seven Steps to Earthquake Safety event where attendees can buy furniture straps, disaster supplies, learn about earthquake insurance, register for CERT and other trainings, and much more. The *Quake Heroes* website will let viewers (and anyone) share their own earthquake stories, expanding on the personal stories showcased in the film. It is also hoped that the film will be of interest to cable television or streaming services. A classroom toolkit is described in the next section.

2019 PEP-3 Plans:

- Release the completed film as part of the 25th Anniversary of the Northridge earthquake.
- Create and continue expansion of the *Quake Heroes* website.
- Hold initial *Special Events* and develop their long-term business plan (these will be great opportunities for partnership and sponsorship with many organizations).
- Submit the film for screening at film festivals and for documentary award competitions.
- All events will have surveys and track actions taken (purchases of supplies, registrations for trainings, etc.)

PEP Focus Area Year 3 Activities and Milestones

SCEC5 CEO focus area milestones for Public Education and Preparedness, listed in Table 11, represent major activity goals and evaluation priorities for each year.

Table 11. PEP Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	Coordinate 10th Anniversary ShakeOut with major events and participation increases in California, including HayWired scenario integration and EEW roll out.(west coast)		X			
b	US ShakeOut websites combined in a simpler, unified and modern web framework		X			
c	ECA establishes statewide neighborhood-level earthquake resilience program			X	X	
d	Products and activities delivered, short-term outcomes achieved		X	X	X	X
Evaluation Milestones						
e	Develop protocols for assessing mid-term PEP outcomes		X			
f	Assess PEP mid-term outcomes			X	X	X
g	Document results from PEP area assessment, with progress towards long-term outcomes				X	X
h	Future PEP activities and outcomes established					X

As stated in Section 4, progress towards Y2 milestones of the PEP focus area have been complicated by external factors. ECA SoCal coordinated a 10th Anniversary ShakeOut event on November 1 including the launch of new awards (a), however the USGS HayWired scenario was only partly released in 2018 with the final (most societally-relevant) volume now planned for release in 2019 such that ShakeOut integration will then be possible. This is likewise for the incorporation of EEW messaging within ShakeOut, as messaging and educational products remain in development. In 2019 we will complete the update of US ShakeOut websites (b) into a more unified site and have begun interviewing potential developers. The *Neighborfest* program will be expanded in the Bay Area in 2019 (c). Existing PEP products and activities will be joined by major new resources such as the *Quake Heroes* film and new materials developed by ECA committees. New protocols and structures (e) will be implemented for assessing mid-term PEP outcomes (e), including a revamped (and simplified) survey for all ShakeOut participants and (for Fall 2019) a more detailed questionnaire for assessing participation of more statistically-representative sample of the many types of organizations involved; new tracking software for news media, social media, and website visits; and plans for assessing actions taken by attendees of *Quake Heroes* events. We will also continue tracking of program outputs (metrics) as listed in Section 4, tables 7-10, and assessment of the short-term outcomes listed in Section 4, table 6.

K-14 Earthquake Education Initiative (K14)

This CEO focus area aims to improve earth science education in multiple learning environments, overall science literacy, and earthquake safety in schools and museums via three programs: *Quake Heroes Educational Toolkit; Quake Catcher Network; and EarthConnections*. See Section 4, Table 12 for the annual short-term outcomes for each program, which combine together to achieve mid-term outcomes for the K14 focus area, which then in turn indicate progress towards CEO long-term outcomes.

In addition to these primary programs, SCEC also supports earth science education (primarily focused on earthquake topics) by participating with CGS and USGS at a joint booth at the California Science Teachers Association (CSTA) annual conference and occasionally at the National Science Teachers Association annual conference. Earthquake science resources such as SCEC's very popular Plate Tectonics Puzzle Map are distributed, SCEC internship programs and other opportunities are shared, and and all attendees are encouraged to participate in Great ShakeOut Earthquake Drills.

K14-1: Quake Heroes Educational Toolkit

This program is a counterpart of PEP-4, *Quake Heroes Documentary.* The film has been designed to deliver basic earthquake science and engineering concepts, in addition to raising awareness of what can happen in a major earthquake (which relatively few Americans have experienced, especially those that were born since the mid 1990s). To improve the ability for *Quake Heroes* to be shown in high-school classes, a toolkit has been developed that features several simple earthquake science and engineering lessons and activities that correlate with each act of the film (allowing the film to be shown over several days, with a lesson delivered each day). The toolkit will also include household preparedness guidance, and encourage schools to organize a Teen CERT (Community Emergency Response Teams) club at their school. State Farm has provided sponsorship support of this program for bringing the toolkits to Los Angeles Unified School District high schools, which will be among the first to receive the toolkits. We hope to expand such sponsorships to deliver more free kits to schools, however they also will be available for sale.

Figure 14. Quake Heroes Toolkit Cover

2019 K14-1 Plans:

- Distribute the initial Toolkits to LAUSD high schools and assess outcomes
- Develop a national toolkit for distribution for the Utah ShakeOut in April and all other states in October.

- Expand the collection of materials available through the toolkit at *Quake Heroes* website.

K14-2: Quake Catcher Network (QCN)

SCEC, IRIS, and the USGS ShakeAlert Project science education initiative have built on QCN's citizen science concept by installing the network's low cost seismometers in over 200 educational institutions across 7 US States including those currently served by ShakeAlert (Washington, California and Oregon). This includes more than 100 schools in each West Coast state and Alaska, all being served by newly upgraded QCN servers located at USC. The goal has been to establish several K-14 and free-choice learning (FCL) institutions (e.g. museums, park visitor centers, etc.) sensor stations around a local hub as a means to build long-term educational partnerships as part of ShakeOut and by enriching educational experiences in formal and FCL environments. Sensors have also been installed in 14 schools and FCL institutions in the Central U.S. (in partnership with the Central U.S. Earthquake Consortium), and in several Coachella Valley school districts (along the San Andreas fault). As described in the 2018 CEO Accomplishments section, the Coachella Valley "hub" is now part of a "tectonic" partnership with schools in Anchorage (with recent expansion to Kodiak and the Kenai Peninsula) where QCN sensors were also installed, in partnership with EarthScope's Alaska Native Geoscience Learning Experience (ANGLE) program.

While QCN has a long history as a citizen-science data-gathering tool for researchers, with the advent of smartphone (Berkeley's MyShake App) and other alternatives (OSOP's Raspberry Shake) for citizen science, QCN partners have decided to focus primarily on formal and FCL institutions as QCN's primary audience. Language on the QCN website (QuakeCatcher.net) inviting anyone to host a QCN site is being changed to reflect this focus, and will redirect interested people to other initiatives. QCN will be focused as a real-time, hands-on, and accessible educational tool for explaining place-based earthquake science in the classrooms and other learning venues. QCN sensor data shows the Earth's movement in three dimensions which helps students visualize and understand that when earthquakes occur, the energy is experienced in the form of waves. Educators can use QCN Live (software that allows learners to see outputs in all three axes when the sensor is manipulated and the real-time QCN database to create lesson plans centered around earthquakes, plate tectonics, and technology.

2019 K14-2 Plans (in collaboration with IRIS and USGS):

- Continue improvement of QCN server configuration and software, user management, data access, and visualization tools as part of major software update begun in 2018.
- Continue revising the QCN website to better serve educational purposes, including interpretive resources for instructors and learners in schools, museums, and other FCL institutions. .
- Work with other initiatives (MyShake, Raspberry Shake, Caltech's Community Seismic Network, etc.) to develop opportunities for jointly reaching common goals.
- Identify assessment tools (website use, surveys, etc.) for tracking K14-2 metrics and short-term outcomes.
- Begin development of proposal for continued support to government or private sources.

K14-3: EarthConnections

For many years, SCEC worked with Professor Sally McGill (CSU San Bernardino) in support of summer GPS data collection by teachers and students in the "Inland Empire" region of Southern California, as part of the NASA-funded *InSight Vital Signs of the Planet (VSP) Professional Development Program.* VSP involved more than 30 teachers and students in real-world research along with lesson plan development and presentation of posters at the SCEC Annual Meeting. This partnership led to SCEC and Prof. McGill partnering together as one of 3 regional alliances of *EarthConnections*, an NSF INCLUDES 2-year project to increase diversity in the geosciences led by InTeGrate and involving AGU, UNAVCO and IRIS. Since 2017 SCEC's participation has been managed by Gabriela Noriega. The program develops pathways for high school, community college, and university students to explore career opportunities, including geology club joint activities, field trips, and meetings with geotechnical professionals and research scientists. Learn more at https://serc.carleton.edu/earthconnections/regional_alliances/sanbernardino.html.

Because the national INCLUDES proposal for continuing EarthConnections was not successful, SCEC collaborated on a proposal to the NSF GEOPATHS solicitation with CSU San Bernardino and UC Riverside (and additional

community college and high school partners) for an expanded program that will now include a summer fieldwork component along with career development opportunities, with connections with SCEC's Experiential Learning and Career Advancement programs. If this proposal is not successful, the connections among the local partners are likely to continue and perhaps a new proposal to INCLUDES or GEOPATHS in 2019 will be submitted.

2019 K14-3 Plans:

- Much depends on the status of our GEOPATHS proposal; if not successful we may still coordinate in some way, to be determined
- Develop opportunities for high school students to be exposed to earthquake research and geoscience career pathways
- Connect with other SCEC institutions to discuss similar networks in other parts of Southern California.

K14 Focus Area Year 3 Activities and Milestones

SCEC5 CEO focus area milestones for the K-14 Education Initiative, listed in Table 16, represent major activity goals and evaluation priorities for each year.

Table 16. K14 Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	Initial Distribution of Quake Heroes Toolkits		X			
b	Completion of upgrade of QCN Server and expanded installations		X	X		
c	Renewal of EarthConnections project (or related funding); expansion within SoCal			X		
d	Products and activities delivered, short-term outcomes achieved		X	X	X	X
Evaluation Milestones						
e	Develop protocols for assessing mid-term K-14 outcomes		X			
f	Assess K-14 mid-term outcomes			X	X	X
g	Document results from K-14 assessment, with progress towards long-term outcomes				X	X
h	Future K-14 activities and outcomes established					X

In 2019 the rollout of the *Quake Heroes* Toolkit will be in full swing (a), the updates for QCN software tools will be complete and additional educational installations will continue (b), and we are hopeful that a successful GEOPATHS proposal will allow the continued development of our *EarthConnections* Alliance activities (c). In Y3 these and other products/activities will be linked together to better achieve both short-term (d). A Y3 milestone will be to assess progress towards K-14 mid-term outcomes (f). We will also continue tracking of program outputs (metrics) as listed in Section 4, tables 13-15, and assessment of the short-term outcomes listed in Section 4, table 12.

Experiential Learning and Career Advancement (ELCA)

This focus area works to increase diversity, retention, and career success in the scientific workforce and improve the application of earthquake science in policy and practice. SCEC/CEO's manager of ELCA, Gabriela Noriega, coordinates two programs: *Undergraduate Internship Programs* and the *Transitions Program* launched in SCEC5. See Section 4, Table 17 for the annual short-term outcomes for each program, which combine together to achieve mid-term outcomes for the ELCA focus area, which then in turn indicate progress towards CEO long-term outcomes.

Figure 16. 2018 UseIT Interns

ELCA-1 Undergraduate Internship Programs

The SCEC Experiential Learning and Career Advancement (ELCA) program enhances the competency and diversity of the STEM workforce by engaging students in research experiences at each stage of their academic careers and by providing leadership opportunities to students and early career scientists that engage them in the SCEC Community. ELCA manages two undergraduate

internship programs that involve over 30 students each summer. Since 2002, over 1600 eligible applications have been submitted to the SCEC internship programs (at scec.org/internships).

The flagship *Undergraduate Studies in Earthquake Information Technology (UseIT)* program brings together students from across the country to an NSF Research Experience for Undergraduates Site at USC. The eight-week program develops programming skills while teaching the critical importance of collaboration for successful learning, scientific research and product development. Since 2002, 261 students have participated from more than 40 colleges and universities, including 24 interns in 2018 (Figure 16). The program is managed by Dr. Noriega with full-time in-lab supervisor Jozi Pearson and the support of intern program alumni. Many of SCEC's computational science staff as well as other SCEC researchers actively participate in the program as mentors. UseIT interns tackle a scientific "Grand Challenge" each year that involves developing software and resources for use by earthquake scientists or outreach professionals.

SCEC's *Summer Undergraduate Research Experience (SURE)* program places undergraduate students with SCEC scientists around the country to conduct primary research. More than 270 interns have participated since 1994, with research projects spanning earthquake science, engineering, and education. In advance of the 2018 intern application process, a few changes were made to the funding and selection process to address complications of the SCEC funding cycle. SURE internships now are awarded outside of SCEC's funding cycle, with intern support fully paid by SCEC and not dependent on whether SCEC scientists' proposals were successfully funded. This previously delayed timing of notifications meant many qualified students had already accepted another internship by the time SCEC offers arrived. The SCEC5 base budget enables 3-4 students to participate in the SURE program each year.

2019 ELCA-1 Plans:

- Submission of a proposal to the NSF Research Experience for Undergraduates (REU) program to continue UseIT for another three years. An external evaluator is already involved in reviewing 2018 (and prior) activities, which will provide useful feedback for preparing the proposal
- Increase recruitment activities among local minority-serving institutions, including community colleges.
- Expand graduate school preparation support and exposure to career pathways, for interns in both programs.

ELCA-2 Transitions Program

Figure 17. Transitions Breakfast

SCEC launched the *Transitions Program* in 2017 to provide junior members of the SCEC community with resources and mentoring across key career transitions (into graduate school, into industry, etc.), directing efforts to encourage and sustain careers in the geosciences and other STEM fields. At the 2017 SCEC Annual Meeting, ELCA hosted two breakfasts to connect early career attendees with peers and mentors to share experiences and develop strategies for navigating the transition from undergraduate to graduate school and from graduate school to professional career (within and outside of academia), and these breakfasts even more popular at the 2018 SCEC Annual Meeting. In partnership with IRIS and UNAVCO, SCEC coordinated a similar activity as an AGU Seismology & Geodesy Sections joint Early Career/Student Networking Luncheon at the 2018 AGU Fall Meeting. In 2019 such partnerships will be expanded to include joint activities with individual SCEC institutions.

2019 ELCA-2 Plans:

- *Mentor development:* Focus on increasing mentor capacity by providing mentor development activities and training. Activities include mentor and mentee workshops and webinars. The topics will focus on mentoring in STEM and in particular geosciences with an emphasis in diversity and inclusivity. A Transitions Program Planning Group may involve mentors who participated in the SCEC Annual Meeting breakfasts.
- *Career development:* Focus on early career and networking. Activities include Transitions Breakfast and Early Career workshops (i.e. AGU), as well as webinars (such as "HPC careers in earthquake science")

- *Scholarship & Research:* Focus on supporting students' research, travel, and graduate school efforts. Via an application process (twice a year?) students can apply for funds to travel to present their research, GRE fees and training, and research stipends. We have also discussed summer "bridge" support for 1-2 students (depending on available funding) so they can arrive to graduate school and begin research early.
- *Assessment:* Surveys will be expanded in 2019 to assess how these activities (and others to be introduced) are increasing career readiness.
- *Website:* In 2019 we will launch a new ELCA page that will highlight the Transitions program.

ELCA Focus Area Year 3 Activities and Milestones

SCEC5 CEO focus area milestones for Experiential Learning and Career Advancement, listed in Table 20, represent major activity goals and evaluation priorities for each year.

Table 20. ECLA Milestones		Y1	Y2	Y3	Y4	Y5
Activity Milestones						
a	Partnerships with new and existing institutions increase mentor, recruitment, and resource capacities.		X	X		
b	Longitudinal tracking processes show impact of ELCA programs		X	X	X	X
c	SCEC's learning and career pathways advance diversity in geoscience education and careers.		X	X	X	X
Evaluation Milestones						
d	Develop protocols for assessing mid-term ELCA outcomes		X			
e	Assess ELCA mid-term outcomes			X	X	X
f	Document results from ELCA assessment, with progress towards long-term outcomes				X	X
g	Future ELCA activities and outcomes established					X

In 2019 partnerships with SCEC institutions and other partners (a) will increase our capacities to achieve ELCA objectives Our longitudinal tracking processes (b) will show impact of ELCA programs (including the transitions program). External evaluation is underway based on post-internship surveys for 2018 to assess how SCEC's learning and career pathways are advancing diversity in geoscience education and careers (c). Each of these evaluation structures are the protocols (d) for how we will assess mid-term ELCA outcomes (e). This is especially important for UseIT this year, as 2019 is the final year of our current REU award, and a new proposal will be submitted in the Fall. We will also continue tracking of program outputs (metrics) as listed in Section 4, tables 18 and 19, and assessment of the short-term outcomes listed in Section 4, table 17.

SCEC Publications

This section lists the publications recorded as submitted and/or published in the SCEC community database (www.scec.org/publications) between November 15, 2017 to November 15, 2018. Each publication is preceded by its SCEC publication number.

Journal Articles (130 total)

6238 Onderdonk, N. W., McGill, S. F., & Rockwell, T. K. (2018). A 3700 year paleoseismic record from the northern San Jacinto fault and implications for joint rupture of the San Jacinto and San Andreas faults.. Geosphere,.

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7287 Shi, J., & Asimaki, D. (2018). A Generic Velocity Profile for Basin Sediments in California Conditioned on VS30. Seismological Research Letters, 89(4), 1397-1409.

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8102 Gheibi, A., & Hedayat, A. (2018, 06). The Relation between Static Young's Modulus and Dynamic Bulk Modulus of Granular Materials and the Role of Stress History. Oral Presentation at 5th Geotechnical and Earthquake Engineering and Soil Dynamics Conference.

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8123 Legg, M. R., Sorlien, C. C., Nicholson, C., Kamerling, M. J., & Kuhn, G. G. (2018, 06). Potential for large complex multi-fault earthquakes offshore southern California. Poster Presentation at 11th National Conference on Earthquake Engineering.

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8152 Petal, M. A. (2018, 07). Causes of deaths and injuries in the 2015 Gorkha (Nepal) earthquake . Poster Presentation at 2018 SCEC Annual Meeting.

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8245 Carlson, G., Shirzaei, M., Ojha, C., & Werth, S. (2018, 08). Seasonal and long-term crustal stress modulation due to aquifer compaction and groundwater unloading during the 2007-2010 drought in California. Poster Presentation at 2018 SCEC Annual Meeting.

8246 Heimisson, E. R., Dunham, E. M., & Almquist, M. (2018, 08). Nucleation and propagation of slow slip pulses on rate-strengthening faults. Poster Presentation at 2018 SCEC Annual Meeting.

8247 Trotter, A., Mei, R., Given, P. R., Polcino, C., Carrillo, E., Wolz, J., Verna, R., Pearson, J. K., Noriega, G. R., & Jordan, T. H. (2018, 08). Visualization of Hazards Associated with Simulated Earthquakes in Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8248 Cortez, J., Beas, G., Wang, S., Tong, C., Rossouw, S. D., & Ascencio, K. (2018, 08). Predictive Skill: Using the Bayesian Inference to Study RSQSim and UCERF3. Poster Presentation at 2018 SCEC Annual Meeting.

8249 Ho, B. T., Weerasooriya, S. R., Narvaez-Colon, A. G., Streitenberger, T., Zhu, D., Jones, T. L., Addo, B., Yu, J., Milner, K. R., Noriega, G. R., Pearson, J. K., & Jordan, T. H. (2018, 08). The Development of 3-D Software to Assist the Visualization of Large and Concurrent Earthquake Data. Poster Presentation at 2018 SCEC Annual Meeting.

8250 Kababjyan, V., Panchigar, S. P., Lopez, A. G., Mizutani, T., Guerra, A. A., Callaghan, S., Gilchrist, J. J., Pearson, J. K., Noriega, G. R., & Jordan, T. H. (2018, 08). Simulating Millions of Years of Earthquakes in California using HPC. Poster Presentation at 2018 SCEC Annual Meeting.

8251 DeVries, P., Thompson, T. B., Wattenberg, M., Viegas, F., & Meade, B. J. (2018, 08). Deep learning for aftershock location patterns and the earthquake cycle. Oral Presentation at 2018 SCEC Annual Meeting.

8254 Reed, M. P., Burgette, R. J., Scharer, K. M., Lifton, N., & McPhillips, D. (2018, 08). Geomorphic and structural mapping in pursuit of a slip rate for the Santa Susana Fault, Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8265 De Pascale, G. P., Froude, M., Penna, I., Hermanns, R., Moncada, D., Sepulveda, S., Persico, M., Petley, D., Vargas, G., Murphy, W., & Pairoa, S. (2018, 08). Preliminary geologic slip rates along Andes fastest slipping crustal fault, the Liquiñe-Ofqui Fault Zone (LOFZ), Patagonia, Chile . Poster Presentation at 2018 SCEC Annual Meeting.
8277 Hua, W., Ke, N., & DAI, Y. (2018, 08). Comprehensive Study on Reservoir-induced Seismicity in the Xiaowan Reservoir, Yunnan Province, China. Poster Presentation at 2018 SCEC Annual Meeting.
8279 Aso, M., Aso, N., & Ide, S. (2018, 08). Focal mechanisms and seismicity of LFEs on Parkfield. Poster Presentation at 2018 SCEC Annual Meeting.
8284 Denolle, M. A., & Danré, P. J. (2018, 08). Earthquake behaviors in Source Time functions: energetic onset of earthquakes and biases from over-simplifying the source pulse. Poster Presentation at 2018 SCEC Annual Meeting.
8286 Langenheim, V. E., & Matti, J. C. (2018, 08). Gravity and aeromagnetic maps of the San Gorgonio Pass region, California: Potential insights from potential-field data on fault and basin geometry in a restraining bend. Poster Presentation at 2018 SCEC Annual Meeting.
8287 Ross, Z. E., Hauksson, E., Trugman, D. T., & Shearer, P. M. (2018, 08). Detecting millions of earthquakes in southern California with template matching. Oral Presentation at 2018 SCEC Annual Meeting.
8289 Hollis, D. D., & Clayton, R. W. (2018, 08). A Proposal for an Industry-Scale Seismic Survey in the Los Angeles Basin. Poster Presentation at 2018 SCEC Annual Meeting.
8291 McGregor, I., & Onderdonk, N. W. (2018, 08). Late Quaternary Deformation in the Inverted Santa Maria Basin, CA: Documenting and Quantifying Active Folding from Syn-Tectonic Deposits. Poster Presentation at 2018 SCEC Annual Meeting.
8292 Wang, N., Takedatsu, R., Olsen, K. B., & Day, S. M. (2018, 08). Implementing Inter-Frequency Correlations into the SDSU Broadband Ground Motion Method. Poster Presentation at 2018 SCEC Annual Meeting.
8295 Aslam, K., & Daub, E. G. (2018, 08). Modeling damage evolution in the near-fault region as a result of rupture on complex fault . Poster Presentation at 2018 SCEC Annual Meeting.
8296 Danré, P. J., Yin, J., Lipovsky, B. P., & Denolle, M. A. (2018, 08). Earthquake sub-event scaling: new perspective for rupture determinism. Poster Presentation at 2018 SCEC Annual Meeting.
8304 Renou, J., & Vallée, M. (2018, 08). Fast moment acceleration in the development phase of an earthquake derived from a large catalog of Source Time Functions. Poster Presentation at 2018 SCEC Annual Meeting.
8305 Meng, G., Su, X., Hong, S., Zhou, X., Dong, Y., & Li, C. (2018, 08). Pre-seismic and co-seismic deformation of the 2017 Mw 6.5 Jiuzhaigou, eastern Tibet earthquake constrained by GPS and InSAR data. Poster Presentation at 2018 SCEC Annual Meeting.
8308 Lambert, V. R., Perry, S. M., & Lapusta, N. (2018, 08). Earthquake Sequences in Rate-and-State Fault Models with Thermal Pressurization. Poster Presentation at 2018 SCEC Annual Meeting.
8309 White, M. C., Ben-Zion, Y., & Vernon, F. L. (2018, 08). Detailed seismic catalog for the San Jacinto fault zone region (2008-2016) from automated processing of raw waveform data. Poster Presentation at 2018 SCEC Annual Meeting.
8310 Juarez, A., & Jordan, T. H. (2018, 08). Optimization of Data Functionals for Full-3D Tomography. Poster Presentation at 2018 SCEC Annual Meeting.
8311 Larochelle, S., Lapusta, N., Ampuero, J., & Cappa, F. (2018, 08). Numerical Modeling of a Fluid-Induced Aseismic-Seismic Slip Sequence on a Rate-and-State Fault. Poster Presentation at 2018 SCEC Annual Meeting.
8312 Chartier, T., Scotti, O., & Lyon-Caen, H. (2018, 08). Constraining epistemic uncertainties on hazard models in the Marmara region using SHERIFS (Seismic Hazard and Earthquake Rates in Fault Systems). Poster Presentation at 2018 SCEC Annual Meeting.
8313 Blanton, C. M., Rockwell, T. K., Gontz, A., & Kelly, J. (2018, 08). Analysis of Offset Stream Channels – Deconstructing Creep and Coseismic Slip Components Using Very High Resolution SfM Imagery, Southern San Andreas Fault, Coachella Valley, California . Poster Presentation at 2018 SCEC Annual Meeting.
8314 Rollins, C., & Avouac, J. (2018, 08). A long-term-average estimate of earthquake likelihoods and the largest earthquake in central Los Angeles. Poster Presentation at 2018 SCEC Annual Meeting.

8318 Thatcher, W. R., & Chapman, D. S. (2018, 08). Heat Flow Data and Seismic Imaging Reveal Both Transient and Steady-State Thermo-Mechanical Processes at Work Beneath Southern California. Oral Presentation at 2018 SCEC Annual Meeting.

8320 Yong, A., McPhillips, D., Herrick, J., & Dozal, J. (2018, 08). An Updated Compilation of VS30 in the United States. Poster Presentation at 2018 SCEC Annual Meeting.

8321 Douilly, R., Oglesby, D. D., Cooke, M. L., & Beyer, J. L. (2018, 08). Effects of Fault Geometry and Pre-Stress Loading for Scenarios of Earthquakes on the Eastern San Gorgonio Pass Region in CA using Dynamic Rupture Simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8322 Harris, R. A. (2018, 08). Moving Earthquake Science Forward - Earthquake Simulation Codes and the SCEC-USGS Dynamic Rupture Group. Oral Presentation at 2018 SCEC Annual Meeting.

8323 Shelly, D. R., & Hardebeck, J. L. (2018, 08). Illuminating faulting complexity of the 2017 Yellowstone (Maple Creek) earthquake swarm. Poster Presentation at 2018 SCEC Annual Meeting.

8324 Qiu, H., Ben-Zion, Y., & Lin, F. (2018, 08). Eikonal Tomography of the Southern California Plate Boundary Region□. Poster Presentation at 2018 SCEC Annual Meeting.

8325 Jiang, J., & Erickson, B. A. (2018, 08). Advancing Simulations of Sequences of Earthquakes and Aseismic Slip [SEAS]. Oral Presentation at 2018 SCEC Annual Meeting.

8327 Xie, J., Zimmaro, P., Li, X., & Wen, Z. (2018, 08). Effect of source rupture directivity on the ground shaking from strike-slip earthquakes and its implication for directivity models. Poster Presentation at 2018 SCEC Annual Meeting.

8330 Klotsko, S. A., Maloney, J. M., & Watt, J. (2018, 08). Shallow fault mapping in the Sacramento-San Joaquin Delta. Poster Presentation at 2018 SCEC Annual Meeting.

8331 Halkia, G., & Grant Ludwig, L. (2018, 08). Communicating Seismological Uncertainty to the Public: A Case Study in Oklahoma. Poster Presentation at 2018 SCEC Annual Meeting.

8332 Khoshmanesh, M., Weston, J. M., Shirzaei, M., & Uchida, N. (2018, 08). Periodic Slow Slip Events and Their Interactions with Megathrust Earthquakes on Northeast Japan Subduction Zone. Poster Presentation at 2018 SCEC Annual Meeting.

8333 Clayton, R. W., Denolle, M. A., Olsen, K. B., Persaud, P., & Polet, J. (2018, 08). Basin Amplification Seismic INvestigation: tracking the propagation of waves from the San Andreas Fault to Los Angeles. Poster Presentation at 2018 SCEC Annual Meeting.

8336 Klinger, Y., Okubo, K., Vallage, A., Champenois, J., Delorme, A., Rougier, E., Lei, Z., Knight, E., Munjiza, A., Satriano, C., Baize, S., Langridge, R. M., & Bhat, H. S. (2018, 08). Earthquake damage patterns resolve complex rupture processes. The 2016 M7.8 Kaikoura earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8339 McPhillips, D., & Scharer, K. M. (2018, 08). Quantifying uncertainty in cumulative surface slip along the Cucamonga Fault, a crustal thrust fault in southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8342 Moschetti, M. P., Hartzell, S., & Herrmann, R. B. (2018, 08). Rupture Model of the 2016 M5.8 Pawnee Induced Earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8344 Pritchard, E. H., Persaud, P., & Stock, J. M. (2018, 08). New Constraints on Stress Heterogeneity along High Risk Fault Systems in the Santa Barbara Channel, California from Borehole Breakouts. Poster Presentation at 2018 SCEC Annual Meeting.

8345 Allison, K. L., & Dunham, E. M. (2018, 08). Shear heating and the brittle-ductile transition: thermomechanical earthquake cycle simulations on continental strike-slip faults. Poster Presentation at 2018 SCEC Annual Meeting.

8346 Stirling, M. W. (2018, 08). Strong ground motions simulations for Dunedin city, New Zealand: First steps using the SCEC Broadband Simulation Platform. Poster Presentation at 2018 SCEC Annual Meeting.

8348 Hughes, A., Rood, D. H., Whittaker, A., Bell, R., Rockwell, T. K., Levy, Y., Wilcken, K., Corbett, L., Bierman, P., DeVecchio, D. E., Marshall, S. T., Gurrola, L. D., & Nicholson, C. (2018, 08). Geomorphic evidence for the geometry and slip rate of the Southern San Cayetano fault: Implications for hazard assessment and fault interaction in complex tectonic environments. Poster Presentation at 2018 SCEC Annual Meeting.

8359 Withers, K. B., Moschetti, M. P., & Duru, K. (2018, 08). Broadband Ground Motion and Variability from 3D Dynamic Rupture Simulations along the Wasatch Fault, Utah, incorporating both Stochastic Fault Roughness and Deterministic Long-wavelength Geometry. Poster Presentation at 2018 SCEC Annual Meeting.

8361 Hardebeck, J. L., Llenos, A. L., Michael, A. J., Page, M. T., & van der Elst, N. J. (2018, 08). Updated California Aftershock Parameters. Poster Presentation at 2018 SCEC Annual Meeting.

8362 Bayless, J. R., & Abrahamson, N. A. (2018, 08). Implementing Inter-Period Correlations into SCEC BBP Simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8365 Shearer, P. M., Abercrombie, R. E., Trugman, D. T., & Wang, W. (2018, 08). Testing and Reconciling EGF Methods for Estimating Corner Frequency and Stress Drop from P-wave Spectra. Poster Presentation at 2018 SCEC Annual Meeting.

8366 Bray, J. (2018, 08). Assessing Surface Fault Rupture Deformation. Oral Presentation at 2018 SCEC Annual Meeting.

8370 Kiuchi, R., Mooney, W. D., & Zahran, H. M. (2018, 08). Probabilistic Seismic Hazard Analysis for Harrat Madinah, Saudi Arabia Using Regional Ground Motion Prediction Equations. Poster Presentation at 2018 SCEC Annual Meeting.

8374 Persaud, P., Liu, G., & Clayton, R. W. (2018, 08). Urban Nodal Array Maps Structure of the Northern Los Angeles Basins with Teleseismic Receiver Functions. Poster Presentation at 2018 SCEC Annual Meeting.

8376 Fattaruso, L. A. (2018, 08). Lab Talk with Laura: STEM research meets comedy on the radio. Poster Presentation at 2018 SCEC Annual Meeting.

8379 Ben-Zion, Y., & Zaliapin, I. (2018, 08). Spatial variations of rock damage production by earthquakes in southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8382 Hatem, A. E., Dolan, J. F., Langridge, R. M., Zinke, R. W., Van Dissen, R. J., McGuire, C. P., & Rhodes, E. J. (2018, 08). Paleoearthquake record of the Conway segment of the Hope fault: Implications for patterns of earthquake occurrence in northern South Island and southern North Island, New Zealand. Poster Presentation at 2018 SCEC Annual Meeting.

8383 Wang, W., & Shearer, P. M. (2018, 08). Comparison of Brune-type Stress Drops Estimated from Direct P, S, and Coda Waves. Poster Presentation at 2018 SCEC Annual Meeting.

8384 Wang, K., Ellsworth, W. L., Beroza, G. C., Williams, G., Zhang, M., Schroeder, D., & Rubinstein, J. L. (2018, 08). Earthquake catalog reconstruction from analog seismograms: Application to the Rangely Experiment microfilms. Poster Presentation at 2018 SCEC Annual Meeting.

8385 Gage, N. S., Wald, D. J., & Marano, K. D. (2018, 08). Aftershock Matters. Poster Presentation at 2018 SCEC Annual Meeting.

8386 Ahdi, S. K., Sadiq, S., Ilhan, O., Bozorgnia, Y., Hashash, Y., Kwak, D., Park, D., Yong, A., & Stewart, J. P. (2018, 08). A Proposed Seismic Velocity Profile Database Model. Poster Presentation at 2018 SCEC Annual Meeting.

8390 Ogata, Y., Katsura, K., Tsuruoka, H., & Hirata, N. (2018, 08). 3D models of seismicity beneath the Greater Tokyo Area. Poster Presentation at 2018 SCEC Annual Meeting.

8393 Wang, K., & Bürgmann, R. (2018, 08). Probing fault frictional properties during afterslip up- and down-dip of the 2017 Mw 7.3 Iran-Iraq earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8394 Qin, L., Johnson, C. W., Vernon, F. L., & Ben-Zion, Y. (2018, 08). Multi-scale study of ground motion coherence in Piñon Flats Observatory. Poster Presentation at 2018 SCEC Annual Meeting.

8399 Muir, J. B., & Tsai, V. C. (2018, 08). Geometric and Level Set Tomography for Interface Detection in the Near Surface. Poster Presentation at 2018 SCEC Annual Meeting.

8402 Song, Y., Lambert, V. R., & Lapusta, N. (2018, 08). Investigation of Adaptive Time-Stepping Algorithms for Simulating Sequences of Earthquakes and Aseismic Slip (SEAS). Poster Presentation at 2018 SCEC Annual Meeting.

8404 Meltzner, A. J. (2018, 08). Coral microatolls as a tool for subduction zone paleoseismology: Identifying rare events along the Sunda megathrust and the Manila trench. Poster Presentation at 2018 SCEC Annual Meeting.

8405 Rhoades, D. A., & Christophersen, A. (2018, 08). Improved medium-term earthquake forecasting: Compensating for incomplete contributions of precursory earthquakes. Poster Presentation at 2018 SCEC Annual Meeting.

8409 Matsubara, M., & Yano, T. E. (2018, 08). Crustal seismogenic layer at active faults inferred by background seismicity and temperature data in Japan. Poster Presentation at 2018 SCEC Annual Meeting.

8410 Karlsson, K. W., Rockwell, T. K., Fletcher, J. M., Gontz, A. M., Figueiredo, P. M., & Owen, L. A. (2018, 08). Paleoseismology and Neotectonics of the Southern Sierra El Mayor, Baja California, Mexico. Poster Presentation at 2018 SCEC Annual Meeting.

8411 Don, J., Plesch, A., Newman, M. M., & Shaw, J. H. (2018, 08). Characterizing the 3D geometry of the Ventura-Pitas Point fault system and its implications for earthquake hazards in southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8412 Li, Y., & Bürgmann, R. (2018, 08). Present day interseismic slip rates of the Xianshuihe Fault observed by InSAR. Poster Presentation at 2018 SCEC Annual Meeting.

8415 Zinke, R., Hollingsworth, J., Dolan, J. F., & Van Dissen, R. J. (2018, 08). 3D surface deformation in the 2016 MW 7.8 Kaikōura, New Zealand earthquake from optical image correlation: Implications for strain localization and tectonic evolution of the Pacific-Australian plate boundary. Poster Presentation at 2018 SCEC Annual Meeting.

8416 Goebel, T. H., Rosson, Z., Brodsky, E. E., & Walter, J. I. (2018, 08). Rapid induced seismicity mitigation and its impact on aftershock productivity in Oklahoma. Poster Presentation at 2018 SCEC Annual Meeting.

8417 Yin, J., & Denolle, M. A. (2018, 08). Relating teleseismic backprojection images to earthquake kinematics. Poster Presentation at 2018 SCEC Annual Meeting.

8419 Lohman, R. B., Jordan, T., & Jiang, J. (2018, 08). Soil moisture effects on InSAR time series in arid regions. Poster Presentation at 2018 SCEC Annual Meeting.

8425 Wooddell, K. E., Al Atik, L., & Abrahamson, N. A. (2018, 08). GMPE specific average velocity profiles for developing spatially-varying path coefficients. Poster Presentation at 2018 SCEC Annual Meeting.

8427 Smith, I. (2018, 08). Tectonic and geometric constraints for the Wind Canyon fault block on the western Garlock fault: an apatite fission track analysis. Poster Presentation at 2018 SCEC Annual Meeting.

8429 Ault, A. K., Jensen, J. L., & McDermott, R. G. (2018, 08). Nanoscale evidence for transient rheology during an earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8431 Castillo, B. A., McGill, S. F., Scharer, K. M., Yule, D., McPhillips, D., McNeil, J. C., & Pace, A. (2018, 08). Preliminary ages of prehistoric earthquakes on the Banning Strand of the San Andreas Fault, near North Palm Springs, California. Poster Presentation at 2018 SCEC Annual Meeting.

8432 Peña, K., McGill, S. F., Rhodes, E. J., Dolan, J. F., Zinke, R., Hatem, A. E., & Brown, N. D. (2018, 08). Paleoseismology of the central Garlock Fault in Searles Valley, California.. Poster Presentation at 2018 SCEC Annual Meeting.

8436 Peshette, P. L., Lozos, J. C., Yule, D., & Evans, E. L. (2018, 08). Dynamic rupture modeling to investigate the role of fault geometry in jumping rupture between parallel-trace thrust faults. Poster Presentation at 2018 SCEC Annual Meeting.

8440 Roh, B., Heaton, T. H., & Ross, Z. E. (2018, 08). Envelope-Based Early Warning Algorithm Using Nested Grid Search. Poster Presentation at 2018 SCEC Annual Meeting.

8443 Johnson, C. W., Meng, H., Vernon, F. L., Nakata, N., & Ben-Zion, Y. (2018, 08). Characteristics of ground motion generated by interaction of wind gusts with trees, structures and other obstacles above the surface. Poster Presentation at 2018 SCEC Annual Meeting.

8445 Retailleau, L., & Beroza, G. C. (2018, 08). Towards Structural Imaging Using Scattering Artifacts Detected in Ambient Field Correlations. Poster Presentation at 2018 SCEC Annual Meeting.

8446 Silva, F., Maechling, P. J., Goulet, C. A., & Vidale, J. E. (2018, 08). The SCEC Broadband Platform: Open-Source Software for Strong Ground Motion Simulation and Validation. Poster Presentation at 2018 SCEC Annual Meeting.

8447 Burgette, R. J., Scharer, K. M., Lifton, N., Hanson, A., McPhillips, D., & Rittenour, T. M. (2018, 08). Quaternary Slip History of the Central Sierra Madre Fault, Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8449 Teng, G., & Baker, J. W. (2018, 08). Evaluation of CyberShake ground motions for engineering practice. Poster Presentation at 2018 SCEC Annual Meeting.

8450 Chen, Y., & Baker, J. W. (2018, 08). Spatial correlations in CyberShake physics-based ground motion simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8452 Dascher-Cousineau, K., Brodsky, E. E., & Lay, T. (2018, 08). Why do strike-slip earthquakes produce fewer aftershocks?. Poster Presentation at 2018 SCEC Annual Meeting.

8457 Ward, L., Smith-Konter, B. R., Xu, X., & Sandwell, D. (2018, 08). Strain rate dependence on crustal rheology for the Cajon Pass, California. Poster Presentation at 2018 SCEC Annual Meeting.

8458 Ulloa, S., & Lozos, J. C. (2018, 08). Surface Displacement and Ground Motion from Dynamic Rupture Models of Thrust Faults with Variable Dip Angles and Burial Depths. Poster Presentation at 2018 SCEC Annual Meeting.

8462 Shen, Z., & Lapusta, N. (2018, 08). Modeling low-frequency earthquakes on a rate-and-state fault. Poster Presentation at 2018 SCEC Annual Meeting.

8463 YAO, W., Liu, J., Oskin, M. E., Prush, V. B., Wang, W., & LI, Z. (2018, 08). Re-evaluation of the late-Pleistocene slip rate of the Haiyuan fault near Songshan, Gansu province, China. Poster Presentation at 2018 SCEC Annual Meeting.

8466 Wang, W., Zhang, X., Liang, M., & Zhang, J. (2018, 08). Post-seismic deformation mechanism of the Mw 9.0 Tohoku-Oki earthquake detected by GPS and GRACE observations. Poster Presentation at 2018 SCEC Annual Meeting.

8467 Gontz, A. M., Blanton, C. M., Rockwell, T. K., & Kelly, J. T. (2018, 08). Looking Ahead by Looking Down – Potential Applications of Very High Resolution Drone-Based Imagery for Tectonic Geomorphology. Poster Presentation at 2018 SCEC Annual Meeting.

8469 Meng, H., McGuire, J. J., & Ben-Zion, Y. (2018, 08). Towards Quasi-Automated Estimates of Source Properties of Small to Moderate Southern California Earthquakes with Second Seismic Moments . Poster Presentation at 2018 SCEC Annual Meeting.

8473 Lai, V., Zhan, Z., Graves, R. W., & Helmberger, D. V. (2018, 08). Long Shaking Durations within the Los Angeles Basin from Shallow Earthquakes. Poster Presentation at 2018 SCEC Annual Meeting.

8476 Hori, T., Ichimura, T., Fujita, K., Yamaguchi, T., Iinuma, T., & Agata, R. (2018, 08). Development of monitoring and forecasting methods for crustal activity utilizing large-scale high-fidelity finite element simulations with 3D heterogeneous medium. Poster Presentation at 2018 SCEC Annual Meeting.

8477 Zeng, Y., & Petersen, M. D. (2018, 08). Uncertainties in Probabilistic Seismic Hazard Analysis for a Poisson Earthquake Occurrence Model. Poster Presentation at 2018 SCEC Annual Meeting.

8478 van Dinther, Y., Dal Zilio, L., D'Aquisto, M., Herrendörfer, R., & Gerya, T. (2018, 08). On the Role of Temperature and Rheology in Seismicity in Convergent Margins. Oral Presentation at 2018 SCEC Annual Meeting.

8479 van Dinther, Y., Künsch, H., & Fichtner, A. (2018, 08). Sequential Data Assimilation for Seismicity: Probabilistic Estimation and Forecasting of Fault Stresses. Poster Presentation at 2018 SCEC Annual Meeting.

8482 Caklais, A. H., Rood, D. H., Stirling, M. W., Madugo, C. M., Abrahamson, N. A., Wilcken, K., Gonzalez, T., Kottke, A. R., & Whittaker, A. C. (2018, 08). Earthquake hazard assessment evaluated by fragile geologic features in coastal Central California. Poster Presentation at 2018 SCEC Annual Meeting.

8483 Taira, T., & Rodgers, A. J. (2018, 08). Evaluating and Improving Ground Motion Predictions for Scenario Earthquakes in The San Francisco East Bay by Integrating Earthquake Ground-Motion Simulations and Noise-Derived Empirical Green's Functions . Poster Presentation at 2018 SCEC Annual Meeting.

8486 Wade, A. (2018, 08). Geologic and Structural Characterization of The Rock Volume Imaged by the Dense Nodal Seismic Array Along the San Jacinto Fault at Sage Brush Flat, Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8488 Singleton, D. M., Rockwell, T. K., & Maloney, J. M. (2018, 08). Sequence of cascading earthquakes on the Newport-Inglewood-Rose Canyon Fault zone from paleoseismic observations. Poster Presentation at 2018 SCEC Annual Meeting.

8489 Coffey, G. L. (2018, 08). In search of earthquakes, a biomarker thermal maturity investigation into the seismic potential of the central San Andreas Fault . Poster Presentation at 2018 SCEC Annual Meeting.

8490 Guns, K. A., Bennett, R. A., Blisniuk, K. D., & McGill, S. F. (2018, 08). Investigating strain transfer along faults in Joshua Tree National Park, CA, with possible implications for along strike variations in southern San Andreas Fault slip rate. Poster Presentation at 2018 SCEC Annual Meeting.

8491 Tal, Y., Rubino, V., Lapusta, N., & Rosakis, A. J. (2018, 08). Evolution of frictional shear resistance in response to rapid variations of normal stress. Poster Presentation at 2018 SCEC Annual Meeting.

8492 Yu, E., Acharya, P., Bhaskaran, A., Chen, S., Andrews, J. R., Thomas, V., Hauksson, E., & Clayton, R. W. (2018, 08). Cloud Computing and Big Data – Using the Southern California Earthquake Data Center (SCEDC) and the Southern California Seismic Network (SCSN) Products and Services for Earthquake Research. Poster Presentation at 2018 SCEC Annual Meeting.

8494 Kain, J. O., Persaud, P., & Pritchard, E. H. (2018, 08). Borehole Breakout Determined Stress Regime in the Southern Los Angeles Basin, California. Poster Presentation at 2018 SCEC Annual Meeting.

8497 Levy, Y., Rockwell, T. K., Shaw, J. H., Plesch, A., Driscoll, N. W., & Parea, H. (2018, 08). Structural Architecture of the Western Transverse Ranges and Potential for Large Earthquakes - New Results of Trishear Forward Models . Poster Presentation at 2018 SCEC Annual Meeting.

8499 Kim, Y., Lim, H., Deng, K., Ree, J., & Song, T. (2018, 08). 2017 Mw 5.4 Pohang earthquake, South Korea and poroelastic stress change associated with fluid injection. Poster Presentation at 2018 SCEC Annual Meeting.

8500 Montesi, L. G., & Leete, W. (2018, 08). RHEOL_GUI: A Matlab-based graphical user interface for the interactive investigation of strength profiles. Poster Presentation at 2018 SCEC Annual Meeting.

8503 Evans, E. L., & Minson, S. E. (2018, 08). Optimal GNSS observations in Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8505 Abolfathian, N., Johnson, C. W., & Ben-Zion, Y. (2018, 08). Numerical simulations of stress variations with depth in a model for the San Jacinto fault zone. Poster Presentation at 2018 SCEC Annual Meeting.

8508 Nicholson, C., Plesch, A., Shaw, J. H., & Marshall, S. T. (2018, 08). Enhancements, Updates, and Improved Access to the Community Fault Model. Poster Presentation at 2018 SCEC Annual Meeting.

8509 Swiatlowski, J. L., & Funning, G. J. (2018, 08). Monitoring Fault Creep on the Hayward Fault using Structure from Motion. Poster Presentation at 2018 SCEC Annual Meeting.

8511 Zhai, G., & Shirzaei, M. (2018, 08). Induced Earthquake Forecasting in Oklahoma Using Models of Fluid Diffusion and Earthquake Nucleation. Poster Presentation at 2018 SCEC Annual Meeting.

8516 Xie, Y., & Meng, L. (2018, 08). Compressional branching during the 2012 Mw 8.6 Off-Sumatra Earthquake: Implications from Earthquake Cycle Simulations . Poster Presentation at 2018 SCEC Annual Meeting.

8518 Burgi, P., & Lohman, R. B. (2018, 08). Quantifying the bias introduced by vegetation in InSAR studies of ground deformation and surface processes. Poster Presentation at 2018 SCEC Annual Meeting.

8520 Yu, C., Hauksson, E., Zhan, Z., Cochran, E. S., & Helmberger, D. V. (2018, 08). Absolute and relative focal depth determination of moderate-sized earthquakes: An example from the 2010 El Mayor-Cucapah earthquake sequence. Poster Presentation at 2018 SCEC Annual Meeting.

8521 Ma, S., & Nie, S. (2018, 08). Inelastic Wedge Failure and Along-Strike Variations of Tsunami Generation in the Shallow Subduction Zone. Poster Presentation at 2018 SCEC Annual Meeting.

8523 Wu, B., Li, B., Oglesby, D. D., & Ghosh, A. (2018, 08). Using Kinematic models to Evaluate the Back Projection Results. Poster Presentation at 2018 SCEC Annual Meeting.

8529 Shadoan, T., Carpenter, B. M., Reches, Z., Chen, X., & Zu, S. (2018, 08). Seismic Radiation During Slip Along a Bimaterial Fault: An Experimental Investigation. Poster Presentation at 2018 SCEC Annual Meeting.

8530 Wang, Y., Oskin, M. E., & Li, Y. (2018, 08). Deducing Crustal-scale Reverse-Fault Slip Distribution from Folded River Terraces, Qilian Shan, China. Poster Presentation at 2018 SCEC Annual Meeting.

8533 Calzolari, G. V., Ault, A. K., & Hirth, G. (2018, 08). Preliminary data on detecting asperity flash heating on hematite faults with laboratory experiments and hematite (U-Th)/He thermochronometry. Poster Presentation at 2018 SCEC Annual Meeting.

8534 Wooten, M. R., Castillo Castellanos, J. A., & Clayton, R. W. (2018, 08). Modeling Crust of Columbia River Basalts Using Ambient Noise Recordings. Poster Presentation at 2018 SCEC Annual Meeting.

8536 Bradley, B. A., Tarbali, K., Lee, R. L., Huang, J., Lagrava, D., Polak, V., Motha, J., & Bae, S. (2018, 08). Cybershake NZ v18.6: New Zealand simulation-based probabilistic seismic hazard analysis. Poster Presentation at 2018 SCEC Annual Meeting.

8540 Ingram, J., Burgette, R. J., & Hampton, B. A. (2018, 08). Quaternary slip history of the Santa Susana fault, western Transverse Ranges: Insights from U-Pb detrital zircon geochronology. Poster Presentation at 2018 SCEC Annual Meeting.

8541 Hu, Z., Roten, D., Olsen, K. B., & Day, S. M. (2018, 08). Kinematic Source Models for Earthquake Simulations with Fault-zone Plasticity. Poster Presentation at 2018 SCEC Annual Meeting.

8542 Haddon, E. K., Miller, D. M., Langenheim, V. E., Liu, T., Wan, E., & Walkup, L. C. (2018, 08). Distributed fault slip in the Eastern California shear zone: adding a piece to the puzzle. Poster Presentation at 2018 SCEC Annual Meeting.

8543 Williams, E. F., Zhan, Z., Karrenbach, M., Cole, S., & LaFlame, L. (2018, 08). Dense mapping of shallow velocity structure in the Raymond Basin using the Pasadena Distributed Acoustic Sensing Array. Poster Presentation at 2018 SCEC Annual Meeting.

8546 Abrahams, L. S., Allison, K. L., & Dunham, E. M. (2018, 08). Rupture Dynamics at the Interface Between a Thin Compliant Layer and Stiffer Underlying Half-Space. Poster Presentation at 2018 SCEC Annual Meeting.

8547 Share, P., Guo, H., Thurber, C. H., Zhang, H., & Ben-Zion, Y. (2018, 08). Seismic imaging of the Southern California plate boundary around the South-Central Transverse Ranges using double-difference tomography and fault zone head waves. Poster Presentation at 2018 SCEC Annual Meeting.

8548 Sager, K., Boehm, C., Ermert, L., Krischer, L., & Fichtner, A. (2018, 08). Full waveform ambient noise inversion. Poster Presentation at 2018 SCEC Annual Meeting.

8549 Zhu, W., Allison, K. L., & Dunham, E. M. (2018, 08). Coupled interactions of fluid-pressure and earthquake cycles: Numerical simulations of fault-valve behaviour. Poster Presentation at 2018 SCEC Annual Meeting.

8551 Evans, J. P., Reimann, R., Studnicky, C., & Bradbury, K. K. (2018, 08). The composition and structure of shallow portions of the San Andreas and San Gabriel Faults. Poster Presentation at 2018 SCEC Annual Meeting.

8552 Thomson, E. M., Bradley, B. A., & Lee, R. L. (2018, 08). The New Zealand Velocity Model (NZVM) Version 2.0 and ground motion simulations of Hope Fault earthquakes. Poster Presentation at 2018 SCEC Annual Meeting.

8554 Aagaard, B. T. (2018, 08). Earth Science Research Needs for Improving Earthquake Scenarios. Oral Presentation at 2018 SCEC Annual Meeting.

8555 Milliner, C. W., & Donnellan, A. (2018, 08). High Resolution Geodetic Measurements of Co-seismic Fault-zone Deformation for Probabilistic Fault Displacement Hazard Assesment and Confidence Intervals on Geologic Slip Rates. Poster Presentation at 2018 SCEC Annual Meeting.

8560 Tullis, T. E. (2018, 08). Progress Report 2 on Addition of a High-Speed Drive to High-Pressure, Rotary-Shear Apparatus. Poster Presentation at 2018 SCEC Annual Meeting.

8562 Lynch, D. K., Deane, T., Zamora, C., Francuch, D. G., Bailey, J. S., Allen, C. W., Rogers, J. D., & Gouger, C. (2018, 08). A Moving Mud Pot Threatening Railroad Tracks and a Highway, Imperial County, California. Poster Presentation at 2018 SCEC Annual Meeting.

8563 Kanaya, T., & Hirth, G. (2018, 08). Mechanics of Fault-Tip Deformation in Brittle and Ductile Faults: Laboratory Test of Off-Fault Yield Models & Fracture Energy Budget. Poster Presentation at 2018 SCEC Annual Meeting.

8564 Marshall, S. T., Madden, E. H., Dorsett, J. H., & Cooke, M. L. (2018, 08). Fault linkage through the Imperial Valley, California is required to match current slip rate estimates. Poster Presentation at 2018 SCEC Annual Meeting.

8565 Gualandi, A., & Liu, Z. (2018, 08). Afterslip and Viscoelastic Processes and Their Relation with Seismic Activity: An Example from the Study of the Mw 7.2 El Mayor-Cucapah Earthquake (Mexico). Poster Presentation at 2018 SCEC Annual Meeting.

8566 Spica, Z., Perton, M., Clayton, R. W., & Beroza, G. C. (2018, 08). Assessing the Deep Geometry of the Los Angeles Basin Using Full H/V Spectral Ratio and Multimode Surface Waves . Poster Presentation at 2018 SCEC Annual Meeting.

8568 Jiang, J., & Fialko, Y. (2018, 08). Probing mechanisms of unsteady shallow creep on major crustal faults. Poster Presentation at 2018 SCEC Annual Meeting.

8569 Dougherty, S. L., Cochran, E. S., Harrington, R. M., & Ross, Z. E. (2018, 08). Tracking thousands of microearthquakes for a month in northern Oklahoma: What a large-N array can reveal about induced seismicity. Poster Presentation at 2018 SCEC Annual Meeting.

8570 Wang, J., & Tanimoto, T. (2018, 08). Mapping Near-Surface Rigidity Structure using Co-located Pressure and Seismic Sensors from the EarthScope Transportable Array. Poster Presentation at 2018 SCEC Annual Meeting.

8571 Maneerat, P. (2018, 08). Active Tectonics across the Indo-Burma Range. Poster Presentation at 2018 SCEC Annual Meeting.

8574 Idini, B., & Ampuero, J. (2018, 08). Persistent effects of low-velocity fault zones on earthquake rupture after multiple earthquake cycles. Poster Presentation at 2018 SCEC Annual Meeting.

8575 Ajala, R., Persaud, P., Stock, J. M., Fuis, G. S., Hole, J. A., Goldman, M. R., & Scheirer, D. S. (2018, 08). 3-D upper crustal velocity structure of the Coachella Valley, Southern California: results from the salton seismic imaging project. Poster Presentation at 2018 SCEC Annual Meeting.

8576 Song, S., Yun, K., & Kwak, S. (2018, 08). Investigating the Ground Motion Characteristics of the 2016 Mw 5.5 Gyeongju, South Korea, Earthquake Using the SCEC Broadband Platform. Poster Presentation at 2018 SCEC Annual Meeting.

8578 Yang, Z., Yehya, A., & Rice, J. R. (2018, 08). Effect of fault architecture and permeability evolution on response to fluid injection. Poster Presentation at 2018 SCEC Annual Meeting.

8579 Wang, Y., Day, S. M., & Shearer, P. M. (2018, 08). A Physical Interpretation for Anomalous Source Spectra with a Deficit at Intermediate Frequencies. Poster Presentation at 2018 SCEC Annual Meeting.

8582 Maechling, P. J., Bielak, J., Callaghan, S., Cui, Y., Field, E. H., Goulet, C. A., Graves, R. W., Jordan, T. H., Milner, K. R., Olsen, K. B., Roten, D., Savran, W. H., Silva, F., Su, M., Taborda, R., & Vidale, J. E. (2018, 08). The SCEC Software Ecosystem for Earthquake System Science Research. Poster Presentation at 2018 SCEC Annual Meeting.

8586 Nie, S., & Ma, S. (2018, 08). Testing the Amplitude of Ambient-field Green's Function by Simulated Scattered Waves in a 3D Sedimentary Basin . Poster Presentation at 2018 SCEC Annual Meeting.

8587 Grenier, M., & Fialko, Y. (2018, 08). Using a dense GPS array as a strain meter on the Anza section of the San Jacinto fault . Poster Presentation at 2018 SCEC Annual Meeting.

8588 Meng, L., Zhou, T., Yuqing, X., & Han, J. (2018, 08). Tsunami Source Inversions Using Adjoint-state Methods. Poster Presentation at 2018 SCEC Annual Meeting.

8591 Walls, C., Mann, D., Turner, R. C., Lawrence, S., Austin, K., Mattioli, G. S., Dittman, T., & Feaux, K. (2018, 08). The Network of the Americas (NOTA) GNSS Network in California - Providing Reliable Data Streams for Early Warning Applications. Poster Presentation at 2018 SCEC Annual Meeting.

8593 Bao, H., & Meng, L. (2018, 08). Mitigating Spatial Bias of Back-projections with the Slowness Enhanced Back Projection. Poster Presentation at 2018 SCEC Annual Meeting.

8594 Wu, Y. (2018, 08). Pre-seismic and Co-seismic Deformations in the Seismogenic zone of the Lushan MS7.0 earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8597 Tymofyeyeva, E., Fialko, Y., Jiang, J., Bilham, R., Sandwell, D. T., Rockwell, T. K., Blanton, C. M., & Gontz, A. M. (2018, 08). Geodetic and geologic observations of creep on the Southern San Andreas Fault triggered by the 2017 Chiapas (Mexico) earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8601 Biasi, G. P., & Scharer, K. M. (2018, 08). The Current Unlikely Earthquake Hiatus at California's Transform Boundary Paleoseismic Sites. Poster Presentation at 2018 SCEC Annual Meeting.

8605 Schulte-Pelkum, V., Ross, Z. E., Mueller, K. J., & Ben-Zion, Y. (2018, 08). Dipping fault structures near the brittle-ductile transition and deep foliation fabric in southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8606 Li, B., & Ghosh, A. (2018, 08). Delayed Triggering of small Local Earthquakes near the San Jacinto Fault after the 2014 Mw 7.2 Papanoa Earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8609 Williams, A. M., Arrowsmith, R., Rockwell, T. K., Akciz, S. O., & Grant Ludwig, L. (2018, 08). Refining the earthquake chronology of the last millennium along the Cholame segment of the San Andreas fault. Poster Presentation at 2018 SCEC Annual Meeting.

8610 Lee, R. L., Bradley, B. A., & Bellagamba, X. (2018, 08). Toward Hybrid Broadband Ground Motion Simulation Validation for Mw>3.5 New Zealand Earthquakes. Poster Presentation at 2018 SCEC Annual Meeting.

8612 Meng, X., Goulet, C. A., Milner, K. R., & Callaghan, S. (2018, 08). Preliminary Results on Fully Nonergodic Ground Motion Models in Central California Using NGA-West2 and SCEC CyberShake Datasets. Poster Presentation at 2018 SCEC Annual Meeting.

8617 Burkhard, L., Smith-Konter, B. R., Ward, L., Scharer, K. M., & Sandwell, D. T. (2018, 08). Earthquake cycle stress accumulation disparities of the Cajon Pass region. Poster Presentation at 2018 SCEC Annual Meeting.

8618 Tang, C., Hsu, Y., Barbot, S. D., Moore, J., & Chang, W. (2018, 08). Lower-crustal rheology and thermal gradient in the Taiwan orogenic belt illuminated by the 1999 Chi-Chi earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8620 Hok, S., Sassi, R., & Klinger, Y. (2018, 08). Investigating and validating surface rupture characteristics with rupture dynamics on faults with shallow complexities. Poster Presentation at 2018 SCEC Annual Meeting.

8622 Hashima, A., Sato, H., Ishiyama, T., Freed, A., & Becker, T. W. (2018, 08). Stress accumulation rate on source faults around the junction of Ryukyu and Southwest Japan arcs using finite element model. Poster Presentation at 2018 SCEC Annual Meeting.

8624 Bormann, J. M., Kent, G. M., & Driscoll, N. W. (2018, 08). Rupture scenarios for the San Diego Trough and San Pedro Basin fault systems, offshore Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8627 Viesca, R. C., & Dublanchet, P. (2018, 08). The slow slip of viscous faults. Poster Presentation at 2018 SCEC Annual Meeting.

8629 Gabriel, A., Wollherr, S., Ulrich, T., Madden, E. H., Duru, K., & Li, D. (2018, 08). Unraveling earthquake dynamics through large-scale multi-physics simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8630 Kuehn, N. M., Abrahamson, N. A., & Walling, M. (2018, 08). Probabilistic Seismic Hazard Analysis in California Using Non-Ergodic Ground-Motion Prediction Equations. Poster Presentation at 2018 SCEC Annual Meeting.

8631 Asimaki, D., & Shi, J. (2018, 08). Nonlinear Fourier-based Amplification Factors for the SCEC Broadband Platform. Poster Presentation at 2018 SCEC Annual Meeting.

8632 Santullo, L. M., Elbanna, A. E., & Hajarolasvadi, S. (2018, 08). Nonlinear Modeling of High-Rise Buildings Subject to Long-Period Ground Motion. Poster Presentation at 2018 SCEC Annual Meeting.

8633 Chu, S., Beroza, G. C., & Ellsworth, W. L. (2018, 08). Source parameter variability of intraslab earthquakes as determined from the empirical Green's function method. Poster Presentation at 2018 SCEC Annual Meeting.

8637 Magnani, M. (2018, 08). Can we hide an active fault within a geodetic network? Yes, we can.. Poster Presentation at 2018 SCEC Annual Meeting.

8639 Fischer, T., & Hainzl, S. (2018, 08). Effective stress drop and aseismic deformation. Poster Presentation at 2018 SCEC Annual Meeting.

8640 Patyniak, M., Landgraf, A., Arrowsmith, R., Dzhumabaeva , A., Williams, A. M., Abdrakhmatov , K., & Strecker, M. (2018, 08). The Hidden Past of the Alai Valley: Understanding the Seismic History and Behavior of the Central Pamir Frontal Thrust System through Paleoseismology.. Poster Presentation at 2018 SCEC Annual Meeting.

8642 Nakata, N. (2018, 08). Characterization of high-wavenumber subsurface random heterogeneity using a very dense array at Diablo Canyon, California. Poster Presentation at 2018 SCEC Annual Meeting.

8643 Chen, J., Luo, M., Qin, J., Yin, J., Owen, L. A., Wang, H., Yang, H., Liu, J., & Zhang, B. (2018, 08). Seismic and aseismic fault slip revealed by luminescence bleaching depth profiles of the bedrock normal fault scarp. Poster Presentation at 2018 SCEC Annual Meeting.

8644 DuRoss, C. B., Gold, R. D., Briggs, R. W., & Bennett, S. E. (2018, 08). Using relative structural complexity of fault segment barriers to model prehistoric earthquake rupture histories. Poster Presentation at 2018 SCEC Annual Meeting.

8645 Vierra, E. J., Flynn, B. A., Bermudez, M. S., Webb, H. N., Girty, G. H., & Rockwell, T. K. (2018, 08). Assessing off-fault damage during development of a dismembered flower structure. Poster Presentation at 2018 SCEC Annual Meeting.

8651 Luginbuhl, M., Rundle, J. B., & Turcotte, D. L. (2018, 08). Nowcasting Induced Seismicity at the Groningen gas field in the Netherlands . Poster Presentation at 2018 SCEC Annual Meeting.

8653 Wu, Q., & Chen, X. (2018, 08). Characteristics of earthquake source complexity in the San Jacinto Fault Zone. Poster Presentation at 2018 SCEC Annual Meeting.

8655 Crempien, J. G., & Archuleta, R. J. (2018, 08). Kinematic rupture simulations of earthquakes on multi-segment faults . Poster Presentation at 2018 SCEC Annual Meeting.

8656 Wesnousky, S. G., & Biasi, G. P. (2018, 08). How Much Farther? Estimating Rupture Length Probabilities After a Rupture Has Started. Poster Presentation at 2018 SCEC Annual Meeting.

8657 Boyd, D., & Bormann, J. M. (2018, 08). Towards characterizing the geometry and potential fault system connectivity at the southern termination of the Palos Verdes fault, offshore southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8659 Kluesner, J. W., Brothers, D. S., Wright, A., & Johnson, S. (2018, 08). 3D insights into active deformation, stratigraphic architecture, and submarine slope failure in the Santa Barbara Channel, southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8660 Graves, R. W. (2018, 08). Sampling Parametric Rupture Variability using Broadband Ground Motion Simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8661 Kendrick, K. J., & Fumal, T. E. (2018, 08). Paleoseismology of the northern San Jacinto fault, San Bernardino County. Poster Presentation at 2018 SCEC Annual Meeting.

8664 Chen, K., Smith, J., Avouac, J., Liu, Z., & Y. Tony, S. (2018, 08). Magma movement from Nāpau down to Leilani Triggered the 4th May 2018 Mw 7.0 Hawaii earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8667 Ma, X., & Elbanna, A. E. (2018, 08). Modeling Dynamic Ruptures with High Resolution Fault Zone Physics. Poster Presentation at 2018 SCEC Annual Meeting.

8669 Allevato, A., Clayton, R. W., & Weeraratne, D. S. (2018, 08). New techniques in point cloud analysis of high-density seismic array data to determine three dimensional fault and crustal structures in the Long Beach Basin. Poster Presentation at 2018 SCEC Annual Meeting.

8671 Page, M. T., & van der Elst, N. J. (2018, 08). Faulty Intuition about b-values and Aftershock Productivity within a Fault Network. Poster Presentation at 2018 SCEC Annual Meeting.

8673 Thomann, C., Jänecke, S. U., Markowski, D., Evans, J. P., & Quinn, R. (2018, 08). Unraveling a tectonic knot: structural domains, voluminous fault zones, creep, and dispersed strain between the San Andreas Fault and Brawley Seismic Zone. Poster Presentation at 2018 SCEC Annual Meeting.

8674 Fialko, Y., & Tymofyeyeva, E. (2018, 08). Measurements of 3-component, time-dependent deformation using Sentinel-1 SAR interferometry and continuous GPS data. Poster Presentation at 2018 SCEC Annual Meeting.

8675 van der Elst, N. J., Milner, K. R., Field, E. H., McBride, S. K., & Page, M. T. (2018, 08). New software for computing time dependent seismic hazard during aftershock sequences using the OpenSHA platform. Poster Presentation at 2018 SCEC Annual Meeting.

8676 Abdelmeguid, M., Ma, X., & Elbanna, A. E. (2018, 08). A novel hybrid numerical finite element-spectral boundary integral scheme for modeling earthquake cycles. Poster Presentation at 2018 SCEC Annual Meeting.

8679 Hao, J., Deng, W., & Ji, C. (2018, 08). The rupture process of 2018 Mw 7.0 Kalapana, Hawaii earthquake and relation with the 1975 event. Poster Presentation at 2018 SCEC Annual Meeting.

8682 Rattez, H., Stefanou, I., Sulem, J., Veveakis, M., & Poulet, T. (2018, 08). Multi-physical couplings and microstructure size effects on the localization of deformation in a fault core. Poster Presentation at 2018 SCEC Annual Meeting.

8683 Milner, K. R., Shaw, B. E., Jordan, T. H., Callaghan, S., & Goulet, C. A. (2018, 08). Fully physics-based PSHA: coupling RSQSim with deterministic ground motion simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8684 Helgans, E. C., Luttrell, K. M., & Smith-Konter, B. R. (2018, 08). Multicomponent Model of Crustal Stress at Cajon Pass with Implications for Stress Field Heterogeneity. Poster Presentation at 2018 SCEC Annual Meeting.

8686 Elbanna, A. E., Hajarolasvadi, S., Ma, X., Abdelmeguid, M., Kammer, D., Albertini, G., Haber, B., & Madhukar, A. (2018, 08). Modeling Earthquake Mechanics with High Resolution Fault Zone Physics: New Computational Tools for Addressing The Conundrum of Scales. Poster Presentation at 2018 SCEC Annual Meeting.

8688 Murray, K. D., & Lohman, R. B. (2018, 08). Recent spatiotemporal evolution of deformation in the Los Angeles Basin and southern Central Valley of California in the context of anthropogenic activity. Poster Presentation at 2018 SCEC Annual Meeting.

8689 Bachhuber, J. L., De Pascale, G. P., Rathje, E., Little, m., Almond, P., Ruegg, C., & Finnemore, M. (2018, 08). Contemporary and Paleoliquefaction Induced Lateral Spreading in Christchurch New Zealand. Poster Presentation at 2018 SCEC Annual Meeting.

8690 Vandevert, I., Anderson, A. K., Okamoto, T., & Tanimoto, T. (2018, 08). Enhancing 0.4-1.0 Hz seismic signals in Green's functions through judicious selection of time intervals. Poster Presentation at 2018 SCEC Annual Meeting.

8691 Dieterich, J. H. (2018, 08). Earthquake and fault system dynamics – Putting the pieces together. Oral Presentation at 2018 SCEC Annual Meeting.

8692 Maher, E. L., Smith, K. D., Hatch, R. L., Graham, K. M., Driscoll, N. W., & Conway, N. (2018, 08). Two Moho-Depth Earthquake Swarms along the Sierra Microplate Basin and Range Boundary Region. Poster Presentation at 2018 SCEC Annual Meeting.

8693 Shen, Z., & Zeng, Y. (2018, 08). Decadal variation of crustal deformation in California inferred from EDM and GPS and its implication to seismic hazard. Poster Presentation at 2018 SCEC Annual Meeting.

8694 O'Reilly, O., Breuer, A. N., Cui, Y., Goulet, C. A., & Olsen, K. B. (2018, 08). Towards topography in AWP-ODC. Poster Presentation at 2018 SCEC Annual Meeting.

8695 Jiang, X., & Meng, L. (2018, 08). Exploration of Prompt Elastogravity Signal for the 2004 M9.0 Sumatra and 2010 M8.8 Maule Earthquakes. Poster Presentation at 2018 SCEC Annual Meeting.

8696 Hearn, E. H., Oskin, M. E., Thatcher, W. R., Hirth, G., Behr, W. M., & Legg, M. R. (2018, 08). Progress toward a Community Rheology Model of Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8699 Becker, T. W., Schulte-Pelkum, V., Behr, W. M., Porritt, R., & Miller, M. S. (2018, 08). Orientation of faults, fault roots, rock fabric, stress, and deformation in Southern California: Geographical comparisons and field and numerical experiments. Poster Presentation at 2018 SCEC Annual Meeting.

8701 Lawson, M. J., Okubo, S. G., Schlom, T. M., Rhodes, E. J., Knott, J., & Yin, A. (2018, 08). Complex faulting structures in Eureka Valley, Death Valley National Park, CA. Poster Presentation at 2018 SCEC Annual Meeting.

8702 Young, E. K., Cowgill, E. S., & Scharer, K. M. (2018, 08). Holocene slip rates along the Mojave Section of the San Andreas fault. Poster Presentation at 2018 SCEC Annual Meeting.

8704 Scharer, K. M. (2018, 08). Paleoearthquakes within 100 km and 1000 years of modern Cajon Pass, California. Poster Presentation at 2018 SCEC Annual Meeting.

8705 Shakibay Senobari, N., Funning, G., Zimmerman, Z., Zhu, Y., & Keogh, E. (2018, 08). The Similarity Matrix Profile, an efficient method for detecting both low and high signal to noise ratio seismic events in very long time series. Poster Presentation at 2018 SCEC Annual Meeting.

8709 Yang, L., Beroza, G. C., & Zhao, L. (2018, 08). Detecting the Earth's Interior Structure Using Reverse-Time Migration Based on Wavefield Normalized Cross-Correlation Imaging Condition. Poster Presentation at 2018 SCEC Annual Meeting.

8711 Parker, J. W., Lyzenga, G. A., Donnellan, A., Glasscoe, M. T., Pierce, M. E., Wang, J., Barba, M., & Tiampo, K. F. (2018, 08). Salton Trough Deformation in GeoGateway Tools, UAVSAR and GeoFEST. Poster Presentation at 2018 SCEC Annual Meeting.

8713 Guo, H., Huang, H., Feng, T., & Meng, L. (2018, 08). Machine Learning in detecting Low-frequency Earthquakes in Shikoku, Japan. Poster Presentation at 2018 SCEC Annual Meeting.

8714 Fildes, R. A., Kellogg, L. H., Turcotte, D. L., & Rundle, J. B. (2018, 08). Statistics of seismicity associated with a sequence of explosive eruptions at Kilauea, Hawaii. Poster Presentation at 2018 SCEC Annual Meeting.

8715 Liu, D., Duan, B., & Luo, B. (2018, 08). A Dynamic Earthquake Simulator for Geometrically Complex Faults Governed by Rate- and State- Friction. Poster Presentation at 2018 SCEC Annual Meeting.

8717 Brodsky, E. E., & Goebel, T. H. (2018, 08). The spatial footprint of injection wells in a global compilation of induced earthquake sequences. Poster Presentation at 2018 SCEC Annual Meeting.

8718 Kozdon, J. E., & Erickson, B. A. (2018, 08). An Efficient Numerical Method for the Simulation of Earthquake Cycles in Complex Geometries. Poster Presentation at 2018 SCEC Annual Meeting.

8720 Hatch, R. L., Abercrombie, R. E., Ruhl, C. J., & Smith, K. D. (2018, 08). Characteristics of Three Small (Mw < 4.5) Urban Area Sequences in the Walker Lane: Earthquake Interaction, Fault Structure, and Source Properties. Poster Presentation at 2018 SCEC Annual Meeting.

8722 Weeraratne, D. S., Amodeo, K., Rathnayaka, S., Lennin, E., Gomez, C. D., & Kohler, M. D. (2018, 08). Shear wave velocity structure of a remnant slab beneath the western Transverse Ranges offshore southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8724 Burns, J. E., McGill, S. F., Rhodes, E. J., Dolan, J. F., & Brown, N. D. (2018, 08). Dating of Offset Geomorphic Features Along the Garlock Fault, Mojave Desert, California: Testing a Proposed Earthquake Supercycle Model. Poster Presentation at 2018 SCEC Annual Meeting.

8725 Plesch, A., Shaw, J. H., SCFM Working Group, & Nicholson, C. (2018, 08). SCFM 3.1: Updates, maps and modeling support. Poster Presentation at 2018 SCEC Annual Meeting.

8727 Liu, X., & Beroza, G. C. (2018, 08). Finite Frequency Sensitivity Kernel for the Correlation of Ambient Noise Correlations: Theory and Numerical Tests. Poster Presentation at 2018 SCEC Annual Meeting.

8730 Scott, C. P., Toke, N. A., Bunds, M., & Shirzaei, M. (2018, 08). Creep Along the Central San Andreas Fault Measured from Surface Cracks, 3D Topographic Differencing, and UAVSAR imagery. Poster Presentation at 2018 SCEC Annual Meeting.

8731 Roten, D., Olsen, K. B., Day, S. M., & Cui, Y. (2018, 08). Implementation of Iwan-type Plasticity Model in AWP-ODC. Poster Presentation at 2018 SCEC Annual Meeting.

8732 Conrad, J., Brothers, D. S., Walton, M. L., Sliter, R. W., & Dartnell, P. (2018, 08). Seafloor scarps, stepover geometry, and kinematics of the Newport-Inglewood fault zone offshore Oceanside, California. Poster Presentation at 2018 SCEC Annual Meeting.

8733 Kim, J., Bahadori, A., & Holt, W. E. (2018, 08). Monitoring Seasonally-Driven Stress Changes on Faults within the Plate Boundary Zone in California using cGPS Observations. Poster Presentation at 2018 SCEC Annual Meeting.

8734 Thio, H., & Bayless, J. R. (2018, 08). Sensitivities and Uncertainties in Probabilistic Fault Displacement Hazard Analysis in Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8735 Reitman, N., Mueller, K. J., Tucker, G. E., & Barnhart, K. R. (2018, 08). Are offset channels accurate representations of strike-slip fault displacement? Implications from landscape evolution modeling. Poster Presentation at 2018 SCEC Annual Meeting.

8736 Holt, W. E., Montesi, L. G., & Bahadori, A. (2018, 08). Lithosphere Viscosity Variations in Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8737 Kroll, K. A., Dieterich, J. H., Richards-Dinger, K. B., & Oglesby, D. D. (2018, 08). 3D Ruptures Simulations Across Stepping Faults; Comparing the Slip Weakening and Rate-State Friction. Poster Presentation at 2018 SCEC Annual Meeting.

8741 Feng, T., & Meng, L. (2018, 08). Combining back-projection and matched filter in detecting offshore seismicity: Application to NE Japan subduction zone. Poster Presentation at 2018 SCEC Annual Meeting.

8742 Legg, M. R., & Oskin, M. E. (2018, 08). Offshore Geology Framework for the Community Rheology Model. Poster Presentation at 2018 SCEC Annual Meeting.

8744 Faherty, D., Petrashek, S. R., Contreras, R., & Pulver, N. W. (2018, 08). Characterization of Faulting at the San Andreas Oasis in the Dos Palmas Preserve Using Ground-based Magnetics, VLF and DC Resistivity. Poster Presentation at 2018 SCEC Annual Meeting.

8746 Smith-Konter, B. R., Xu, X., Ward, L., Burkhard, L., & Sandwell, D. T. (2018, 08). InSAR/GPS time series deformation of the 2018 Kilauea event: Preparation for a large Southern California event. Poster Presentation at 2018 SCEC Annual Meeting.

8747 Bahadori, A., Holt, W. E., Kim, J., Rasbury, T., Shen, W., & Grossman, J. (2018, 08). The role of rheological evolution on active deformation of Southwestern North America within the Pacific-North America Plate Boundary Zone since the Oligocene. Poster Presentation at 2018 SCEC Annual Meeting.

8748 Jordan, T. H., & Juarez, A. (2018, 08). Stress-glut representation by orthogonal moment-tensor fields. Poster Presentation at 2018 SCEC Annual Meeting.

8749 Cattania, C., & Segall, P. (2018, 08). Crack models of repeating earthquakes predict observed moment-recurrence scaling. Poster Presentation at 2018 SCEC Annual Meeting.

8752 Callaghan, S., Maechling, P. J., Goulet, C. A., Milner, K. R., Su, M., Graves, R. W., Olsen, K. B., Aagaard, B. T., Wooddell, K. E., Kottke, A. R., Jordan, T. H., & Vidale, J. E. (2018, 08). A SCEC CyberShake Physics-Based Probabilistic Seismic Hazard Model for Northern California. Poster Presentation at 2018 SCEC Annual Meeting.

8753 Morelan, A. E., & Oskin, M. E. (2018, 08). Modal mineralogy of the continental crust and implications for fault-zone rheology: Data mining the Southern Sierra Nevada exhumed crustal section. Poster Presentation at 2018 SCEC Annual Meeting.

8754 Bianco, M. J., Olsen, K. B., Gerstoft, P., & Lin, F. (2018, 08). Machine learning-based surface wave tomography of Long Beach, CA, USA. Poster Presentation at 2018 SCEC Annual Meeting.

8755 Torres Andrade, E., Funning, G., & Swiatlowski, J. L. (2018, 08). Updating GPS site positions and velocities and improving GPS coverage in southern California for the Community Geodetic Model. Poster Presentation at 2018 SCEC Annual Meeting.

8756 Saunders, J. K., Martinez, F., Haase, J. S., & Soliman, M. (2018, 08). Simulated ground motions for induced seismicity at a 12-story structure in Oklahoma using the SCEC Broadband Platform. Poster Presentation at 2018 SCEC Annual Meeting.

8757 Badt, N. Z., Tullis, T. E., & Hirth, G. (2018, 08). Thermal pressurization evolution with total slip. Poster Presentation at 2018 SCEC Annual Meeting.

8758 Hatch, J. L., & Cooke, M. L. (2018, 08). Assessing kinematic compatibility of fault geometry and slip rates along the southern San Andreas fault system in the San Gorgonio Pass region. Poster Presentation at 2018 SCEC Annual Meeting.

8760 Breuer, A. N., Heinecke, A., & Cui, Y. (2018, 08). Fused Earthquake Simulations on Deep Learning Hardware. Poster Presentation at 2018 SCEC Annual Meeting.

8764 Fan, W., & McGuire, J. J. (2018, 08). Investigating microearthquake finite source attributes with IRIS Community Wavefield Demonstration Experiment in Oklahoma. Poster Presentation at 2018 SCEC Annual Meeting.

8765 Hauksson, E., Ross, Z. E., & Cochran, E. S. (2018, 08). Sudden Surges of Seismicity within Natural Slow Growing and Long Duration Seismicity Swarms near Cahuilla Valley in the Central Peninsular Ranges, Southern California. Poster Presentation at 2018 SCEC Annual Meeting.

8767 Figueiredo, P. M., Weldon, R. J., & Owen, L. A. (2018, 08). Revisiting the Cajon Pass Quaternary Terraces with Geochronology dating implications for the long term slip rates of the San Jacinto and San Andreas systems. Poster Presentation at 2018 SCEC Annual Meeting.

8768 Bryan, J. T., Breuer, A. N., & Cui, Y. (2018, 08). Towards Seismic Inverse Problems Using Deep Learning. Poster Presentation at 2018 SCEC Annual Meeting.

8773 Baden, C. W., & Hilley, G. E. (2018, 08). Contrasts in integrated crustal strength drive the asymmetric distribution of topography and deformation within restraining bends. Poster Presentation at 2018 SCEC Annual Meeting.

8774 Donnellan, A., Parker, J. W., Heflin, M. B., Rundle, J. B., Grant Ludwig, L., & Lyzenga, G. A. (2018, 08). Deformation in the Yuha Desert from the 2010 M7.2 El Mayor – Cucapah Earthquake . Poster Presentation at 2018 SCEC Annual Meeting.

8775 Pauk, E., Huynh, T. T., Milner, K. R., Callaghan, S., Gill, D., Goulet, C. A., & Crouse, C. (2018, 08). Developing Software to Support SCEC Research Collaborations and Data Dissemination: A Case Study of the Committee for the Utilization of Ground Motion Simulations (UGMS) Project. Poster Presentation at 2018 SCEC Annual Meeting.

8779 Inserra, N. J., & Akciz, S. O. (2018, 08). Late Holocene Rupture History of the South-Central San Andreas Fault at the Van Matre Ranch site, Carrizo Plain, California. Poster Presentation at 2018 SCEC Annual Meeting.

8780 Savage, H. M., Williams, R., & Rowe, C. D. (2018, 08). Gouge Development in the San Andreas Fault from Lake Elizabeth core samples. Poster Presentation at 2018 SCEC Annual Meeting.

8784 Oglesby, D. D., Kyriakopoulos, C., Rockwell, T. K., Meltzner, A. J., Barall, M., & Fletcher, J. (2018, 08). Dynamic rupture and cross-fault activation: the effect of high pre-stress contrast. Poster Presentation at 2018 SCEC Annual Meeting.

8785 Lozos, J. C. (2018, 08). The Effect of Along-Strike Variation in Dip on Rupture Propagation on Strike-Slip Faults. Poster Presentation at 2018 SCEC Annual Meeting.

8786 Prush, V. B., & Oskin, M. E. (2018, 08). Dear Prudence: how many surface clasts are required to yield an accurate exposure date?. Poster Presentation at 2018 SCEC Annual Meeting.

8787 Cui, Y., Breuer, A. N., Konwar, R., & Lenz, D. (2018, 08). Unified and Continuous Software Development for AWP-ODC-OS. Poster Presentation at 2018 SCEC Annual Meeting.

8788 Huang, H., & Meng, L. (2018, 08). Matched-filter Detection of Microseismicity Around the Eruption of the 2018 Kilauea Volcano, Hawaii. Poster Presentation at 2018 SCEC Annual Meeting.

8789 Seitz, G. G., & Schwartz, D. P. (2018, 08). When do San Andreas Fault ruptures diverge on to other faults?. Poster Presentation at 2018 SCEC Annual Meeting.

8791 Toke, N. A., Marchetti, D. W., Bailey, C. M., Biek, R., Phillips, J., Bartram, H., & Forster, C. (2018, 08). The Thousand Lake Fault: Earthquake Geology of a Long Recurrence Normal Fault at the Eastern Edge of the Basin and Range. Poster Presentation at 2018 SCEC Annual Meeting.

8792 Tyagi, A. D., Grenier, M., Kreuziger, R., Kays, J. S., & Polet, J. (2018, 08). Preliminary Site Response Results across the San Gabriel and San Bernardino Basins Utilizing the Ambient Noise Spectral Ratio Method. Poster Presentation at 2018 SCEC Annual Meeting.

8793 Walker, R. L., Samnejad, M., & Aminzadeh, F. (2018, 08). Understanding Injection-induced Seismicity Effects on Fault Damage Zones: Beyond Poroelastic Models. Poster Presentation at 2018 SCEC Annual Meeting.

8794 Chen, X., & Abercrombie, R. E. (2018, 08). Applying improved spectral analysis to an induced earthquake sequence in Oklahoma and implications on earthquake triggering. Poster Presentation at 2018 SCEC Annual Meeting.

8796 Bedford, J., & Faulkner, D. (2018, 08). The effect of grain size and gouge microstructure on fault slip behavior. Poster Presentation at 2018 SCEC Annual Meeting.

8798 Wollherr, S., Gabriel, A., & Mai, P. M. (2018, 08). Landers 1992 "reloaded": an integrative dynamic earthquake rupture model. Poster Presentation at 2018 SCEC Annual Meeting.

8803 Luttrell, K. M., & Hardebeck, J. L. (2018, 08). Estimates of Shallow Crustal Stress Heterogeneity Length Scale from Borehole Breakouts and Local Earthquake Focal Mechanism Inversions in the Los Angeles Basin. Poster Presentation at 2018 SCEC Annual Meeting.

8804 Avouac, J., Michel, S. G., & Gualandi, A. (2018, 08). Slow Slip Events: Earthquakes in Slow Motion. Poster Presentation at 2018 SCEC Annual Meeting.

8805 Savran, W. H., Maechling, P. J., Werner, M. J., Jordan, T. H., Schorlemmer, D., Rhoades, D. A., Marzocchi, W., Yu, J., & Vidale, J. E. (2018, 08). The Collaboratory for the Study of Earthquake Predictability version 2.0 (CSEP2.0): New Capabilities in Earthquake Forecasting and Testing . Poster Presentation at 2018 SCEC Annual Meeting.

8806 Mendoza, M. M., Li, B., Ghosh, A., Karplus, M. S., Nabelek, J., Sapkota, S. N., Adhikari, L. B., Klemperer, S. L., & Velasco, A. A. (2018, 08). Capturing Frictional Asperities along the Complex Structure of the Main Himalayan Thrust in Nepal after the 2015 Mw 7.8 Gorkha Earthquake. Poster Presentation at 2018 SCEC Annual Meeting.

8807 Allam, A. A., Sorscher, A., Armstrong, A., Richards, C., McKell, A., & Clairmont, S. (2018, 08). Precariously Balanced Rocks in northern Utah: are Wasatch Fault earthquakes worse than expected?. Poster Presentation at 2018 SCEC Annual Meeting.

8808 Okaya, D. A., Chiang, Y., Maechling, P. J., & Su, M. (2018, 08). California Transverse Mercator projection (CATM) for Building Gridded Seismic Velocity Volumes for Seismic Wave Propagation Simulations. Poster Presentation at 2018 SCEC Annual Meeting.

8809 Barth, N. C., Howarth, J., Richards-Dinger, K. B., Fitzsimons, S., & Biasi, G. P. (2018, 08). Forecasting earthquake behavior on the Alpine Fault, New Zealand. Poster Presentation at 2018 SCEC Annual Meeting.

8811 Fulton, P. M., Kuo, S., Kitajima, H., & Liu, X. (2018, 08). Does effective stress have reduced sensitivity to pore pressure at seismogenic depths?. Poster Presentation at 2018 SCEC Annual Meeting.

8814 Bhattacharya, P., & Viesca, R. C. (2018, 08). Fluid-induced aseismic slip can outpace pore-fluid migration – evidence from in situ data. Poster Presentation at 2018 SCEC Annual Meeting.

8815 Logsdon, R., Walker, R. L., & Gibbons, S. (2018, 08). Building Earthquake Early Warning Networks With Low Cost, Off-the-Shelf Components. Poster Presentation at 2018 SCEC Annual Meeting.

8817 Ford, H. A. (2018, 08). Preliminary evidence for localized lithospheric deformation in the western Basin and Range and Walker Lane from Ps receiver function analysis. Poster Presentation at 2018 SCEC Annual Meeting.

8820 Condon, S. J. (2018, 08). Revisiting historical earthquakes in our backyard: 1925 Santa Barbara and 1952 Kern County. Poster Presentation at 2018 SCEC Annual Meeting.

8822 Miranda, E., & Perez-Huerta, A. (2018, 08). Fluid-enhanced grain boundary sliding in pseudotachylyte survivor clasts: does creep cavitation lead to earthquake rupture?. Poster Presentation at 2018 SCEC Annual Meeting.

8825 Sutkowski, C. S., Prado, O., Hernandez, V., & Polet, J. (2018, 08). Preliminary Results of a Study to Identify Archaeological Artifacts from San Salvador in Colton, CA, Using Ground Penetrating Radar. Poster Presentation at 2018 SCEC Annual Meeting.

8829 Kyriakopoulos, C., & Oglesby, D. D. (2018, 08). Combining 3D printing and virtual reality goggles in outreach and communication events . Poster Presentation at 2018 SCEC Annual Meeting.

8830 Scott, T. R., Arrowsmith, R., Scott, C. P., & Lao Davila, D. (2018, 08). Detailed mapping of normal fault array geometry using dm-scale high resolution topographic imagery from the Volcanic Tablelands, Bishop, California. Poster Presentation at 2018 SCEC Annual Meeting.

8833 Mirkhanian, M. A., Grant Ludwig, L., Donnellan, A., Parker, J. W., & Granat, R. A. (2018, 08). Using GeoGateway Data to Explore Deformation in the Cajon Pass Region. Poster Presentation at 2018 SCEC Annual Meeting.

8834 Smith, D. E., Kohler, M. D., Andrews, J. R., Chung, A. I., Hartog, R., Henson, I., Given, D. D., & Guiwits, S. (2018, 08). ShakeAlert v. 2.0 Testing and Certification. Poster Presentation at 2018 SCEC Annual Meeting.

8837 Meier, M., Ross, Z. E., Ramachandran, A., Balakrishna, A., Kundzicz, P., Nair, S., Li, Z., Hauksson, E., & Heaton, T. H. (2018, 08). Reliable Real-Time Signal/Noise Discrimination with Deep and Shallow Machine Learning Classifiers. Poster Presentation at 2018 SCEC Annual Meeting.

8838 Esmaeilzadeh Seylabi, E., Restrepo, D., Asimaki, D., & Taborda, R. (2018, 08). Modeling shallow crustal nonlinearity in physics-based earthquake simulations: Beyond perfect plasticity. Poster Presentation at 2018 SCEC Annual Meeting.

8839 Shaw, B. E. (2018, 08). Earthquake Simulators are Ready for Prime Time. Oral Presentation at 2018 SCEC Annual Meeting.

8840 Faulkner, D., Rempe, M., Bedford, J., Sanchez-Roa, C., Boulton, C., & den Hartog, S. (2018, 08). On the possibility of earthquake rupture through clay-rich faults. Oral Presentation at 2018 SCEC Annual Meeting.

8841 Lapusta, N. (2018, 08). On the present and future of physics-based earthquake source modeling. Oral Presentation at 2018 SCEC Annual Meeting.

8843 Guerra, A. A., Ho, B. T., Kababjyan, V., Mei, R., Mizutani, T., Streitenberger, T., Weerasooriya, S., Wolz, J., Beas, G., Wang, S., Kashyap, A., & Gilchrist, J. J. (2018, 08). 2018 USEIT: Using Machine Learning to Forecast Earthquakes. Poster Presentation at 2018 SCEC Annual Meeting.

8848 Aho, M. (2018, 08). Where We Have Been, Where We Are Going… And How We Can Work Together. Oral Presentation at 2018 SCEC Annual Meeting.

8913 Sleep, N. H., & Nakata, N. (2018). Nonlinear Body Waves In The Shallow Subsurface, Implications Of Flow-law Rheologies. Oral Presentation at 11th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute.

Books, Book Chapters, or Other Non-periodical, One-Time Publications (3 total)

8082 Kagan, Y. Y. (2013). EARTHQUAKES: Models, Statistics, Testable Forecasts. Hoboken, USA: Wiley/AGU.

8135 Li, Y. (2016). Seismic wave propagation in anisotropic rocks with applications to defining fractures in earth crust. Rock anisotropy, fracture and earthquake assessment, (Chapter 1, pp. 11-141) Beijing and Boston, China and USA: China High Education Press with De Gruyter

8136 Li, Y. (2017). Fault-Zone Guided Wave, Ground Motion, Landslide and Earthquake Forecast (pp232). Beijing and Boston, China and USA: China High Education Press with De Gruyter.

Websites

https://data2.scec.org/ugms-mcerGM-tool_v18.4/	Data access website for site-specific, risk-targeted Maximum Considered Earthquake (MCER) response spectra for the Los Angeles region
https://www.scec.org/research/ugms	An updated project portal for the Utilization of Ground Motions Simulations (UGMS) project.
https://www.scec.org/research/cism	A new project portal for the SCEC Collaboratory for the Interseismic Simulation and Modeling (CISM) project
https://www.scec.org/research/cxm	A new project portal describing each of SCEC's community models
https://www.scec.org/research/cfm	An updated project portal for the SCEC Community Fault Model (CFM)
https://www.scec.org/internships/	An updated project portal for SCEC internships

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The Southern California Earthquake Center (SCEC) is an institutionally based organization that recognizes both **core institutions**, which make a major, sustained commitment to SCEC objectives, and a larger number of **participating institutions**, which are self-nominated through the involvement of individual scientists or groups in SCEC activities and confirmed by the Board of Directors. Membership continues to evolve because SCEC is an open consortium, available to any individual or institution seeking to collaborate on earthquake science in Southern California.

Core Institutions and Representatives

Core institutions are designated academic and government research organizations with major research programs in earthquake science. Each core is expected to contribute a significant level of effort (both in personnel and activities) to SCEC programs, including Communication, Education and Outreach Program. Core institutions are obligated to contribute a yearly minimum of $35K of institutional resources (spent in-house on SCEC activities) as matching funds to Center activities. Each core institution appoints an Institutional Director to the Board of Directors.

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SCEC membership is open to participating institutions upon application. Eligible institutions may include any organization (including profit, non-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 (through appropriate official) appoints a qualified Institutional Representative to facilitate communication with the Center. The interests of the participating institutions are represented on the Board of Directors by two Directors At-Large.

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