2010 SCEC REPORT

SCEC COORDINATION WITH EARTHQUAKE ENGINEERING RESEARCH AND PRACTICE

PRINCIPAL INVESTIGATOR: Dr Paul Somerville, URS Group, Inc.

INTRODUCTION

The development of new knowledge about earthquakes and their effects is an important role of SCEC, but not its only role. Because earthquakes have major impacts on society, SCEC must also transfer knowledge about earthquakes and their effects for use in earthquake risk mitigation. This includes the transfer of knowledge to organizations involved in earthquake engineering research and practice. In the following, I describe the activities that I undertook in 2010.

1. Coordination of Ongoing SCEC Projects

I coordinated SCEC activities that involve interaction of SCEC scientists with earthquake engineers involved in advanced research and practice. These include SCEC projects that were funded in 2010, and other interactions with earthquake engineers that developed during the course of the year. Examples of the products of these reports are given in the Appendix.

2. SCEC Broadband Strong Motion Simulation Platform

I participated in weekly conference calls on the ongoing development and testing of the SCEC Broadband Strong Motion Simulation Platform, hosted by Phil Maechling. The objective of these calls was to identify and resolve discrepancies in the implementation of three code bases – SDSU/ETH; UCSB; and URS – on the Platform. This was done through comparing simulated time histories and goodness of fit results from the simulation validation exercises involving three earthquakes: Landers, Loma Prieta, and Northridge.

3. Technical Activity Group (TAG) focused on Ground Motion Simulation Validation (GMSV)

SCEC has established a Technical Activity Group (TAG) focused on Ground Motion Simulation Validation (GMSV) in order to develop and implement testing/rating methodologies via collaboration between ground motion modelers and engineering users. I helped Nicholas Luco to organize a planning workshop whose main purpose was to enumerate and prioritize work that should be conducted within the GSMV TAG. The issues that were discussed include:

Selection of Engineering Applications
Selection of Validation Methodologies
Selection of Ground Motion Simulations/Models to Validate
Archiving/Distribution of GM Simulations
Implementation of Validation Methodologies
TAG Organization/Approach

4. ATC-82: Selecting, Generating, and Scaling Earthquake Ground Motions for Performing Response-History Analysis

I am participating in ATC-82, whose objective is to provide guidance for selecting, generating, and scaling earthquake ground motions for performing response-history analysis of low- and medium-rise buildings, such that ground motion uncertainties do not necessarily dominate the accuracy of the results. Both code-based design and seismic performance assessment are addressed. The project also identifies areas of research that are needed to further improve practice.

5. GEM: Contributions to the Development of Open Risk Software

The GEM (Global Earthquake Model) project is developing a global model for the estimation of earthquake hazard and risk. As a member of the GEM1 Model Advisory Group, I participated in peer review of GEM1 final products that was held in Pavia on April 26-29, 2010. I also participated in an Outreach Meeting held in Washington DC in June 3-4, 2010.

6. Improved Ground Motion Models

The recently released NGA ground motion models represent a significant improvement over the previous generation of models, but there are still important ground motion effects that are not explicitly included in these models, or that are included in approximate ways. These include including the effects of rupture velocity, rise time, and sedimentary basins. I fostered research into ways in which the application of the NGA models in the Southern California region can be enhanced by incorporating region specific information about earthquake source and wave propagation effects.

7. Improved Ground Motion Parameters

The correlation between building damage and simple ground motion parameters such as peak acceleration, peak velocity and response spectral acceleration is quite low, causing large uncertainty in the prediction of building damage. Reduction in this uncertainty through the development of improved ground measures and parameters is an important focus of research at the interface between earthquake science and earthquake engineering. I fostered the collaborative development of improved ground motion measures and parameters by the SCEC and earthquake engineering research communities.

8. Fostering Growth in Participation in SCEC by Engineers

I have actively fostered the participation of highly capable young engineers in SCEC. These participants include prominent young engineers such as Jack Baker of Stanford University, Keith Porter of the University of Colorado, and Christine Goulet of PEER. At the 2007 Annual Meeting, it was agreed that we establish a goal of this group about 5% of the SCEC Community. I have continued to identify additional candidates through my participation in meetings with the earthquake engineering research community described below.

9. Participation in Meetings with Engineering Research and Practice Organizations

I participated in meetings with engineering organizations that are involved in research and practice. My participation in these meetings provides a vehicle for communication of SCEC research results and products to these engineering organizations, and informs me of new developments in earthquake engineering research and practice, providing a basis for the planning of future collaborative projects between SCEC and these organizations.

10. Participation in SCEC Meetings

I participated in all of the SCEC meetings that are relevant to the Implementation Interface. These meetings include the Planning Committee Meeting, The Leadership Meeting, the Annual Meeting, and workshops in fields that are closely related to Seismic Hazard and Risk Analysis.

APPENDIX. SCEC 2010 SHRA ACCOMPLISHMENTS

This appendix highlights the results of five projects that made significant contributions to seismic hazard and seismic risk analysis.

Non-Linear Structural Simulations using SCEC Simulated Ground Motions

Although substantial progress has been made in physics-based ground motion simulations in the recent years, the engineering community is still reluctant to use simulated time series for design. One of the reasons for this is a lack of understanding of how simulated ground motions compare to recorded ground motions, especially when it comes to their impact on structural response. There are on-going efforts at validation and verification of simulated ground motions, but these tend to be focused on record properties or on the response of single-degree-of-freedom systems. Goulet, Haselton and Bayless (2011) used a different approach by comparing the nonlinear structural response of buildings subjected to recorded and simulated ground motions, given that both sets had similar response spectral shapes.

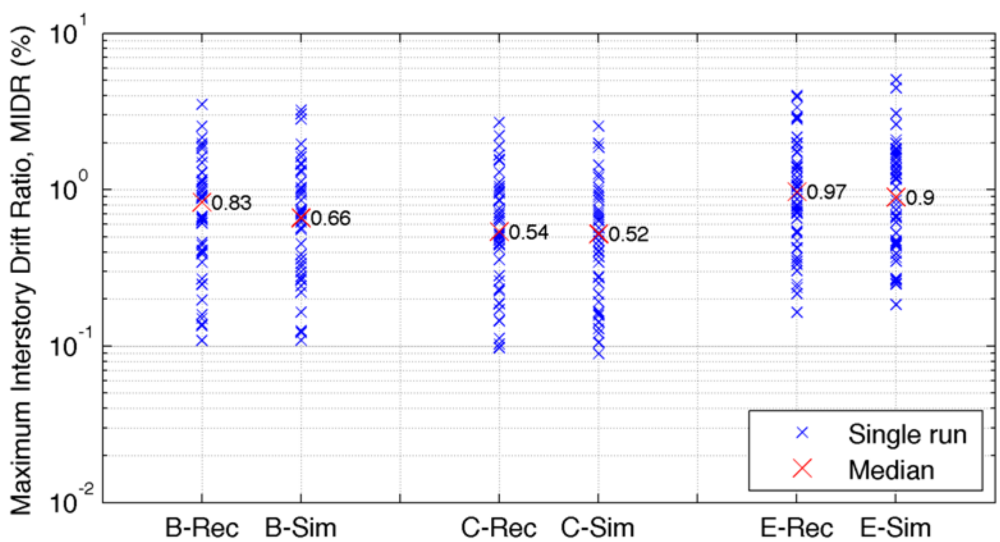

Figure 1. Summary of structural simulation results for buildings B (12 stories), C (20 stories) and E (4 stories) and for both the recorded (Rec) and simulated (Sim) acceleration time series.

The responses of buildings to recorded motions were already been processed in a project recently completed by the PIs. The recorded set is representative of a magnitude 7 earthquake, rupturing within 20 km from a site in a shallow crustal tectonic environment such as California. The SCEC simulated records were selected for the same type of event and distance with spectral shapes that were consistent with the recorded set. Structural simulations were then performed for three computer-modeled concrete structures, and the response results from both sets of time series were compared. Figure 1 shows a summary of the maximum inter-story drift ratio (MIDR) results obtained from the structural simulations. The vertical data stripes correspond to the MIDR results for all three buildings, for both the recorded and simulated time series. For each stripe, the maximum and minimum values were removed. For all three buildings, the ranges of MIDR values are similar, but the overall distribution of values for the recorded and simulated sets tend to differ for a given building. This leads to a large difference in the median MIDR estimate for building B, but to no statistical difference for building C. The preliminary conclusion based on the two datasets used is that the simulated ground motions led to structural response that were consistent with those derived from recorded motions.

Validation of End-to-End Simulation of Building Response using Ground Motion Simulations

This study had the objective of validating the use of simulated ground motions by integrating physics-based ground motion simulation and performance-based damage estimates and examining, probabilistically, building response due to both simulated and recorded ground motions. The research involved the comparison of building response to two earthquake scenarios: the 7.8Mw Los Angeles region ShakeOut scenario developed by Graves et al. (2008), a repeat of the 1906 San Francisco earthquake generated by Aagaard et al. (2009), and the Puente Hills scenario developed by Graves et al. (2006).

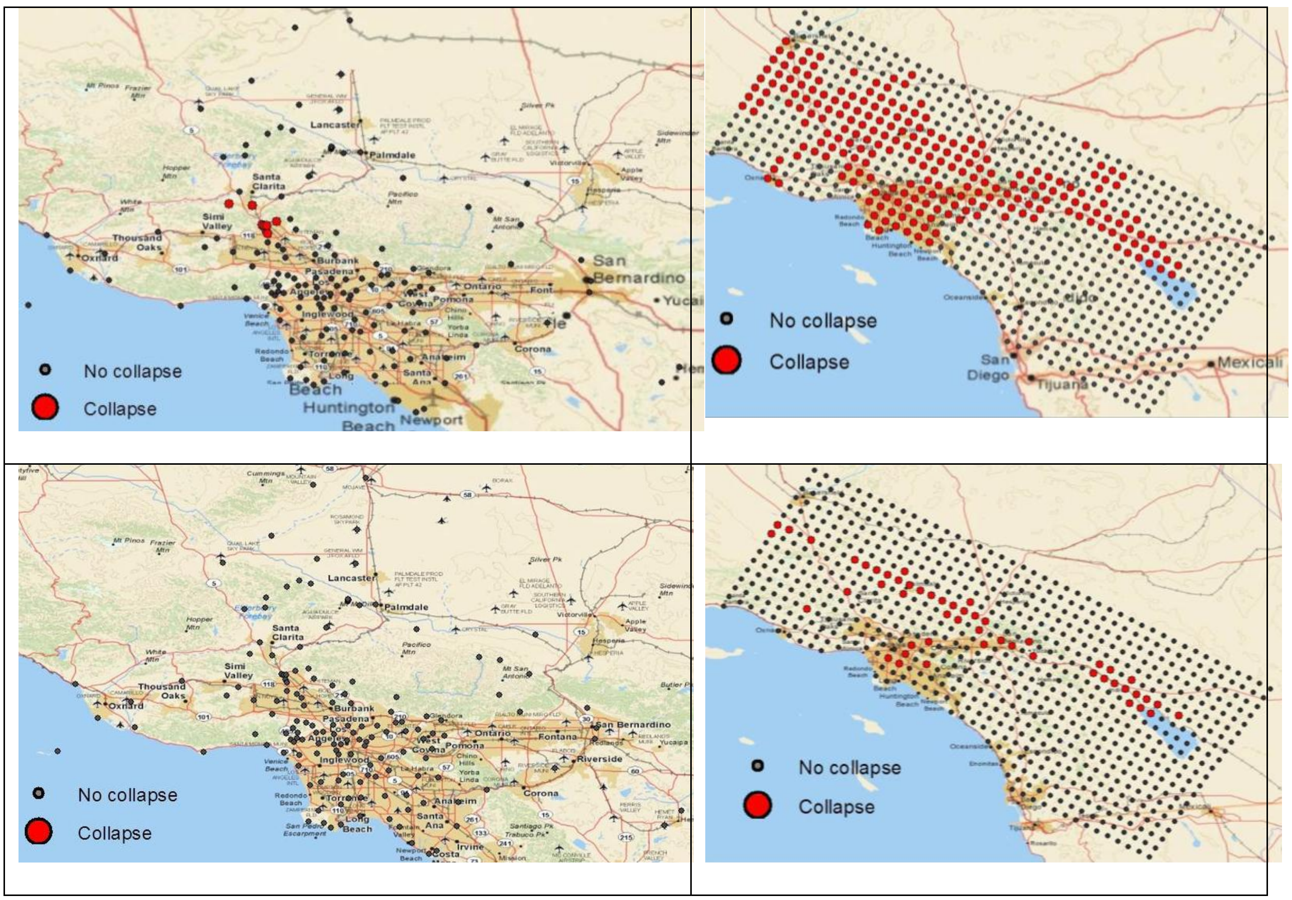

Figure 2. Collapse results of older (top) and modern (bottom) 8-story RC frame for (left) Northridge earthquake recorded ground motions and (right) ShakeOut scenario simulated ground motions. Source: Liel and Rowe (2010).

This analysis considered 735 evenly spaced sites for the hypothetical ShakeOut scenario earthquake and 157 sites where the Northridge earthquake was recorded. As a preliminary check on the simulation results, geographic trends of areas high collapse risk for both the Northridge and ShakeOut earthquakes were identified as those sites where building simulation models collapsed, as shown in Figure 2. These figures reveal that, for both the Northridge earthquake and the simulated LA ShakeOut scenario, the older RC frame building is more likely to collapse than the modern building. This study predicts 12 collapses for the older RC frames during the Northridge earthquake (concentrated in the region shown on the map) and no collapses for the modern building subjected to the same ground motions. For the ShakeOut scenario, the study predicts 231 failures for the older RC frame and only 51 for the modern building. This difference between older and modern buildings is expected, due to the stricter building codes governing the seismic detailing of RC structures after 1970, and is consistent with observed results during the Northridge earthquake, during which very few modern RC buildings collapsed.

Loss Estimates for Kinematic and Dynamic ShakeOut Earthquake Scenarios

The goal of this project was to compare HAZUS®-estimated economic loss and population impacts for six San Andreas Fault (SAF) scenarios. Long period ground motions for the SAF ruptures were simulated using dynamic rupture propagation. Five realizations of the “ShakeOut” scenario with dynamic rupture propagation were analyzed. The synthetic ground motions provided for the loss estimation within HAZUS® were 0-10Hz broadband synthetics generated by combining long-period (0-1Hz) finite-difference synthetics with high-frequency scattering operators.

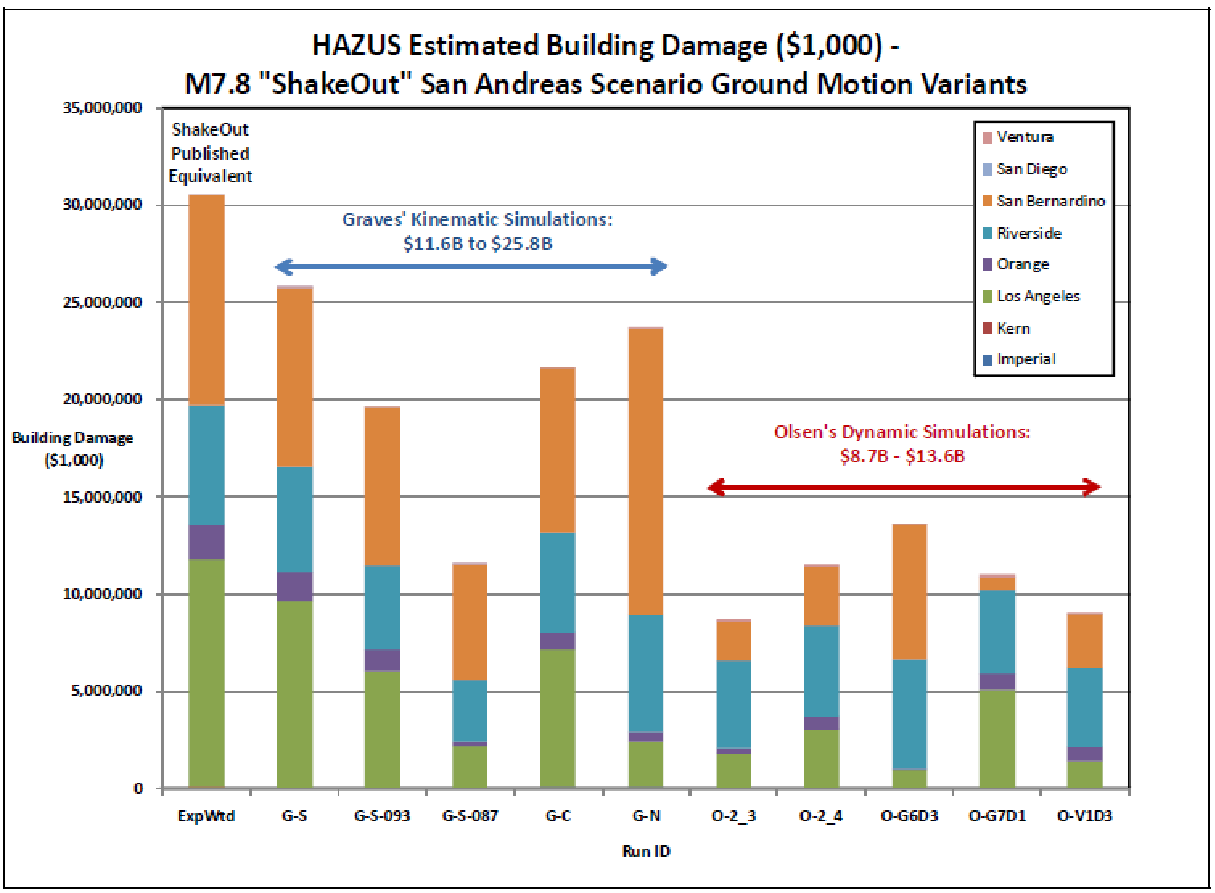

Figure 3. HAZUS® Estimates of Building Damage for the ShakeOut Ground Motion Scenarios. Source: Seligson and Olsen (2010).

Each M7.8 scenario variant was a 300-km S-N rupture on the southernmost San Andreas Fault, with dynamic source descriptions; the variants are designated as 2_3, 2_4, G6D3, G7D1 and V1D3. HAZUS® analyses were conducted for each of these five scenario variants, for comparison with the kinematic results. All “ShakeOut” HAZUS® analyses were conducted with enhanced inventory data. Database enhancements included improvements to the underlying building inventory data as well as to information utilized by HAZUS® on construction patterns throughout the eight county study area. As shown in Figure 3, the kinematic simulations produce larger loss estimates than do the dynamic simulations.

A Nonlinear Site Response Computer Application for the SCEC Broadband Ground Motion Simulation Platform

This project involved the implementation of a nonlinear site response computer application in the SCEC Braodband Ground Motion Simulation Platform. The site response model was developed for nonlinear site response analyses based on a viscoelastic formulation for frequency-independent Q and a hysteretic model. The model can simulate close to frequency-independent viscous damping in the strain range below the linear threshold, and match the nonlinear dynamic soil properties of soils (G/Gmax and damping) in the intermediate to high strain range ($>10^{-3}$). The model was implemented into the 1D site response computational tool “Site1D” of the SCEC Broadband Ground Motion Simulation Platform.

Figure 4 shows the deviation of linear elastic prediction from site-specific nonlinear predictions as a function of (PGAROCK, FI) for three sites in the LA Basin: a stiff (Class C), a medium stiff (Class D) and a soft (Class E) site. As can be seen, the trend is the same for all three sites. Large PGAROCK and FI close to unity imply that empirical amplification factors do not adequately describe the site response, and that site-specific analyses should be employed.

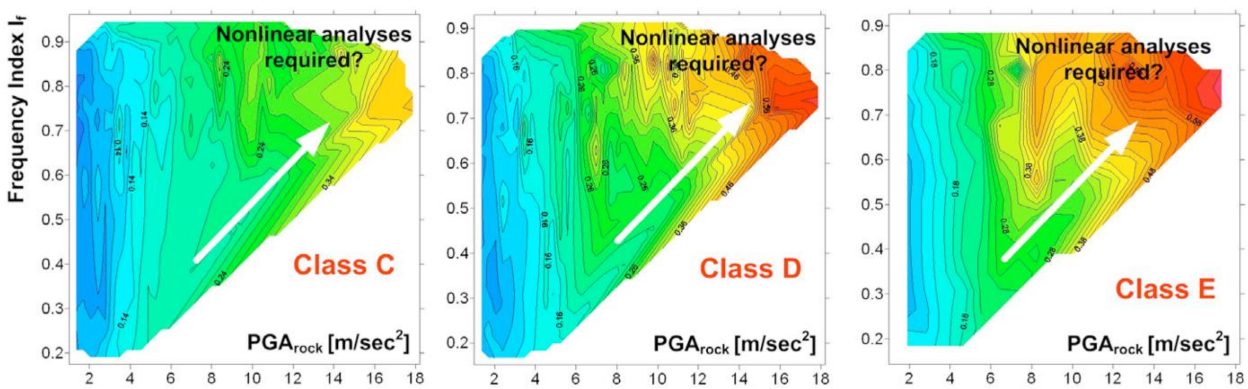

Figure 4. (PGA, FI) criteria implementation at three sites (Class C, D and E) in the Los Angeles basin for a series of broadband ground motion synthetics. The contour plots indicate the deviation of linear elastic predictions from nonlinear site-specific response predictions. Source: Assimaki (2010).

Implementation of a generalized conditional intensity measure (GCIM) approach in OpenSHA

The fundamental basis of the GCIM approach is that for a given earthquake scenario (Rup) the joint distribution of a vector of intensity measures (i.e. IM|Rup) has a multivariate lognormal distribution [1]. Characterisation of IM|Rup, therefore requires the marginal distributions, IMi|Rup and correlations between IMi and IMj for which several prediction equations already exist. The total probability theorem can then be used to construct the conditional distribution of any intensity measure given the occurrence of a specific value of another intensity measure. Figure 5 illustrates the conditional spectral acceleration and Arias Intensity distributions given Sa(1.0) with an annual exceedance probability of 1/475. This project involved the implementation of this generalized conditional intensity measure (GCIM) approach in OpenSHA.

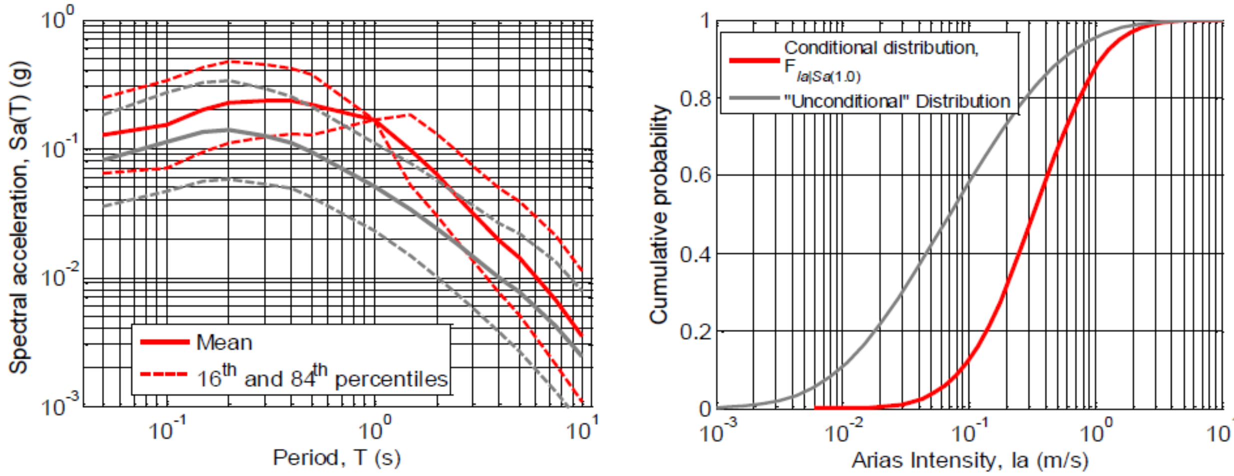

Figure 5: Example conditional distributions for a site in Christchurch, New Zealand. Source: Bradley (2010).

References

Assimaki, D. (2010). A Nonlinear Site Response Computer Application for the SCEC Broadband Ground Motion Simulation Platform. Report to SCEC.

Bradley, B. (2010). Implementation of a generalized conditional intensity measure (GCIM) approach in OpenSHA. Report to SCEC.

Goulet,C., K. Haselton and J.Bayless (2011). Non-linear structural simulations using SCEC simulated ground motions – one-to-one comparisons. Report to SCEC.

Liel, A.B. and K.L. Rowe (2010). Integration of Physics-Based Ground Motion Simulation and Performance-Based Building Damage Estimates for Improved Assessment of Seismic Risk. Report to SCEC.

Seligson, H. and K.B. Olsen (2010). HAZUS® Loss Estimates for Six Large San Andreas Fault Earthquake Scenarios, including the Mw8.0 "Wall to Wall." Report to SCEC.