THE SCEC SOFTWARE ECOSYSTEM FOR EARTHQUAKE SYSTEM SCIENCE RESEARCH

Philip J. Maechling
Southern California Earthquake Center

Jacobo Bielak, Scott Callaghan, Yifeng Cui, Edward Field, David Gill, Christine Goulet, R. Graves, Thomas H. Jordan, Kevin Milner, Kim Bak Olsen, Andreas Plesch, Ricardo Taborda, John Shaw, Fabio Silva and collaborators
SI2 received two awards through the NSF Program Software Infrastructure for Sustained Innovation (SI2)

Project Goals: Convert Research software into community software.

SI2-SSI: Community Software for Extreme-Scale Computing in Earthquake System Science (ACI-1450451)
PIs: Thomas H. Jordan, Yifeng Cui, Kim B. Olsen, Ricardo Taborda
Project Dates: 1 September 2015 through August 31, 2019

SI2-SSI: A Sustainable Community Software Framework for Petascale Earthquake Modeling (OCI-1148493)
PI: Thomas H. Jordan, Jacobo Bielak, Yifeng Cui, Kim B. Olsen
Project Start Date: 1 August 2012 through 31 July 2015
Software Environment for Integrated Seismic Modeling (SEISM)

**SSI**

- Physics-based PSHA
- 3D Wave Propagation
- 3D Velocity Models
- 1D Wave Propagation

**Scientific and Engineering Contributors**
- NSF and DOE HPC Resources
- Ground Motion Data Centers
- EarthCube

**Users**
- Public Risk Management
- NGA-E
- NEES
- SCEC
- Earthquake Engineers
- PEER
- Insurance
- Reinsurance
- SWUS
- FEMA HAZUS calculations
- EarthScope

**Public Preparedness Service Exercises**
- Arizona ShakeOut
- California DWR

**Horizontal Integration**

American Geophysical Union (AGU) Meeting - Dec 2018, Washington D.C.

(a)
SCEC CFM is a California statewide fault model with multiple alternative representations of many faults, used in UCERF3 development. Available at: https://www.scec.org/research/cfm
SCEC Community Velocity Model – Harvard (CVM-H)

Grid-based southern California velocity model with high resolution area in Los Angeles region constructed as part of a Unified Structural Representation (URS) for southern California that aims for consistency between CVM and CFM.

CVM-H Available From SCEC: https://scec.usc.edu/scecpedia/CVM-H
Fourth version of original SCEC 3D velocity model for southern California provides arbitrary precision and returns low Vs velocities in some southern California areas (Los Angeles and Salton Sea) using well log data.
Unified Community Velocity Model (UCVM) Software

SCEC’s UCVM framework is used to create input files for high-resolution, regional-scale, strong ground motion, earthquake simulations.

Multiple California Velocity Models can be queried through UCVM including CVM-S4, CVM-H, and the USGS Bay Area Model.

UCVM Available on Github: https://github.com/SCECcode/UCVM
OpenSHA Software

SCEC software developers have worked closely with USGS scientists and software developers to produce the OpenSHA seismic hazard platform since 2001.

OpenSHA is a Java-based computational platform that implements the Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3).

OpenSHA is used as a data source, and a data processing system for SCEC CyberShake platform.

OpenSHA software is being extended to include an implementation of an ETAS short-term earthquake forecast method.

OpenSHA Available at: https://www.opensha.org/
The SCEC Broadband Platform is a software system that can generate 0-100 Hz seismograms for historical and scenario earthquakes in California, Eastern North America, and Japan using several alternative computational methods.

BBP users may calculate broadband seismograms for both historical earthquakes (validation events including Northridge and Loma Prieta) and user-defined earthquakes.

<table>
<thead>
<tr>
<th>Rupture Generator</th>
<th>0 to 1Hz Deterministic Ground Motions</th>
<th>1 to 10Hz Stochastic Ground Motions</th>
<th>Common Ground-Motion Post-processing</th>
<th>Common Goodness of Fit Post-Processing</th>
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<td>GP</td>
<td>Gen_Slip</td>
<td>JB_Sim</td>
<td>HF_Sim</td>
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<td>SDSU</td>
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BBP Available on Github: https://github.com/SCECcode/BBP
Hercules Wave Propagation Software

(a) Goodness-of-fit scores map obtained for the 2008 Chino Hills earthquake in the frequency range 0–1 Hz using the velocity model CVM-S4, i.e. simulation S1. (b) Same as before, but corresponding to results obtained using the model CVM-S4.26.M01, i.e. simulation S2. (c) Difference between the previous two maps, where positive values indicate improvement in S2 with respect to S1. (d) Summary chart of the final average GOF scores obtained for 13 different earthquake simulations using two different California velocity models.

Available on Github: https://github.com/CMU-Quake/hercules
The Anelastic Wave Propagation software (awp-odc-os) simulates wave propagation in a 3D viscoelastic or elastic solid. Wave propagation uses a variant of the staggered grid finite difference scheme to approximately solve the 3D elastodynamic equations for velocity and stress. The GPU version offers the absorbing boundary conditions (ABC) of Cerjan for dealing with artificial wave reflection at external boundaries.

AWP-ODC-OS is implemented in C and CUDA. The Message Passing Interface supports parallel computation (MPI-2) and parallel I/O (MPI-IO).

Available on Github: https://github.com/HPGeoC/awp-odc-os
The CyberShake Physics-based Seismic Hazard system uses multiple codes in the ecosystem.

- Uses multiple SCEC CVMs
- Uses UCVM meshing software
- Uses OpenSHA software
- Uses a version of the Broadband Platform earthquake source generator software
- Uses AWP-ODC-OS GPU-based wave propagation software

This shows the great efficiency gained by Combining the capabilities of the codes in the Ecosystem.
SCEC Computational Research and Community Codes

- **SCEC Software Project Information:** https://www.scec.org/research/cme

- **SCEC Public Software Repositories:** https://github.com/SCECcode