# 2025 SCEC Report: SCEC Project 25259

## OneSciencePlace Cyberinfrastructure Developments in Support of SCEC Research

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| Funding | Organization Budget | Investigators | Funded |
|---|---|---|---|
| | University of California, San Diego | Alice-Agnes Gabriel, Amit Chourasia | $32,993 |
| | SCEC / University of Southern California | Philip J. Maechling (unfunded co-PI) | $0 |

**Category B:** Collaborative Research Project **Science Milestones:** C1,2,3-1, C1-2, C2-2, C3-1, D2-1, D3-1


**Abstract:** Quakeworx is an NSF-supported science gateway, led by SCEC researchers, that provides web-based access to advanced earthquake-research applications running on national high-performance computing (HPC) and cloud resources. This SCEC award supported targeted enhancements to the OneSciencePlace cyberinfrastructure underpinning Quakeworx, with the goal of integrating compute resources beyond the San Diego Supercomputer Center (SDSC) — specifically TACC Frontera, NCSA Delta, and IU JetStream2 — to support a broader range of SCEC science workflows including post-event UCERF3-ETAS forecasting, GPU-accelerated machine learning, and persistent cloud workspaces. Over the project period, the team built a staging gateway on OneSciencePlace with interactive (Jupyter, VNC) and batch app support, integrated single sign-on via Globus, deployed nine containerized SCEC science apps (Broadband Platform, HFQsim, Moose-FARMS, pyCSEP, QuakeNN, SeisSol, Tandem, UCERF3-ETAS, UCVM with CVM-H), and added job-provenance tracking together with an advanced UI builder for app creation. Community engagement included a January 2025 kick-off workshop training 65 selected participants from more than 150 applicants representing 16 countries, with subsequent open access reaching 1,300+ users, and a July 2025 Tandem Hackathon.

**Intellectual Merit:** This project advances open, reproducible, FAIR-aligned cyberinfrastructure for the SCEC community by extending the OneSciencePlace platform to support the heterogeneous compute needs of modern earthquake research, leadership-class CPU systems, large GPU systems, and cloud VMs. Containerized science apps with Tapis-based job submission, provenance tracking, and reduced-order modeling workflows lower the technical barrier to running complex simulations and enable rapid-response computing scenarios such as post-event UCERF3-ETAS forecasting and CyberShake-style physics-based hazard analysis. The Tandem and SeisSol app integrations give SCEC researchers a low-friction route from idealized benchmarks to data-constrained scenario simulations on national HPC.

**Broader Impacts:** Quakeworx makes advanced earthquake-simulation tools accessible to a broad community of researchers, students, and educators. The January 2025 kick-off workshop reached 65 hands-on participants from 16 countries selected from more than 150 applicants; training materials have since been accessed by over 1,300 users. The July 2025 Tandem Hackathon expanded the contributor base for the Tandem code through GPU-development tracks, benchmark contributions, and co-authorable publications. Quakeworx apps have been integrated into the Advanced Seismology course at UC San Diego, with new teaching materials co-developed for both undergraduate and graduate seismology curricula, and the team is planning use cases for secondary education through inquiry-based experiments on rupture directivity and shaking amplitudes. The cyberinfrastructure developed here also supports rapid-response forecasting workflows valuable to USGS and other operational seismic-hazard partners.

## Detailed Project Report

### 1. Project Context and Leadership Continuity

This award was initially led by Amit Chourasia (UCSD/SDSC), with Philip J. Maechling (SCEC/USC) as unfunded co-PI. Following Chourasia's transition out of SDSC during the project period, leadership of the SCEC reporting and remaining deliverables was assumed by Alice-Agnes Gabriel (UCSD/SIO), an active scientific collaborator on the broader Quakeworx project. The technical work described below was carried out by the SDSC engineering team in close collaboration with SCEC software staff (F. Silva, A. Bhatthal) and SCEC science-app PIs across UCSD, USC, UIUC, and UCLA.

## 2. Platform Infrastructure and Integration

A staging gateway for Quakeworx was built on the OneSciencePlace platform (Fig. 1). The system architecture is organized into four cooperating layers: (i) a virtual machine hosting the gateway frontend (Drupal/Apache/PHP/MariaDB behind a reverse proxy); (ii) a Tapis primary site running on AWS Kubernetes that provides authentication, file management, app definitions, and job lifecycle management; (iii) a set of integrated compute and data systems including SDSC Expanse, AWS, and additional national HPC and cloud resources; and (iv) a satellite proxy that bridges interactive access between the user's browser and running apps. Robust support has been added for both interactive (Jupyter, VNC) and batch apps, with job monitoring and user data management exposed through Tapis APIs. Single sign-on via Globus auth is in testing and will provide seamless access for users from academic and government institutions. The gateway is currently onboarding early users to finalize required capabilities ahead of the production launch.

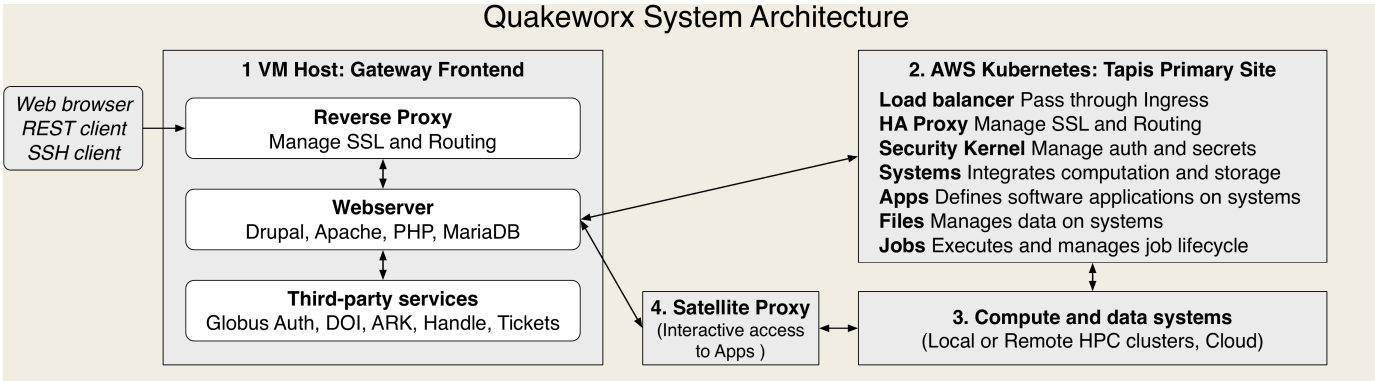


***Figure 1.*** *Quakeworx system architecture. Box 1: VM hosting the gateway frontend (Drupal/Apache, reverse proxy). Box 2: Tapis primary site on AWS Kubernetes managing auth, systems, apps, files, and jobs. Box 3: integrated compute and data systems (local and remote HPC clusters, cloud). Box 4: satellite proxy bridging interactive access to apps. Source: Chourasia et al., 2025 SCEC Annual Meeting Poster #304 (SCEC Contribution #14857).*

## 3. Curated Apps, Data, and Compute Resources

A curated registry of nine earthquake-modeling tools has been deployed and is available through the gateway (Fig. 2): Broadband Platform, HFQsim, Moose-FARMS, pyCSEP, QuakeNN, SeisSol, Tandem, UCERF3-ETAS, and UCVM with CVM-H, alongside general-purpose environments (Jupyter, Linux Desktop/Terminal, RStudio). Apps are containerized using Singularity/Docker, enabling reuse and reproducibility across heterogeneous compute backends. Initial reference problems and scenario datasets have been made available for download and execution with tracked provenance. Status tags (Stable, Beta, Dev) communicate readiness to end users. The gateway currently dispatches jobs to SDSC Expanse and AWS, with the Tapis abstraction layer designed to support the planned integrations with TACC Frontera (priority queue access for post-event UCERF3-ETAS), NCSA Delta (large GPU pool for ML-based apps), and IU JetStream2 (persistent cloud VMs).

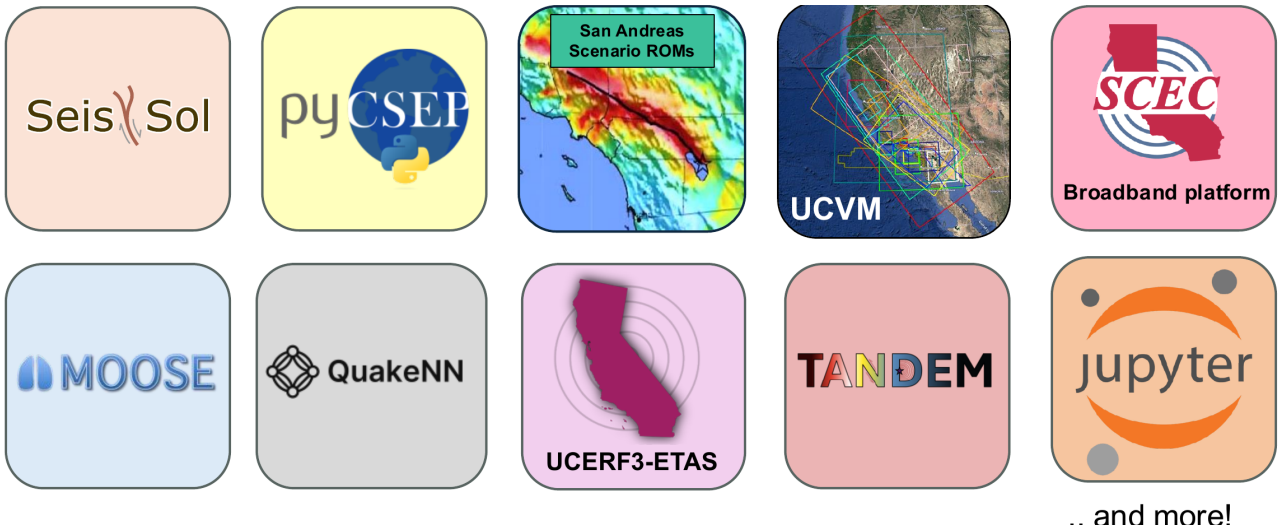


***Figure 2.*** *Selection of curated science apps deployed in Quakeworx, including SeisSol, pyCSEP, the San Andreas scenarios reduced-order modeling app, UCVM, the SCEC Broadband Platform, MOOSE-FARMS, QuakeNN, UCERF3-ETAS, Tandem, and Jupyter. Apps are containerized with Singularity/Docker and launchable in batch or interactive mode. Source: Rekoske et al., SSA 2026 talk.*

## 4. User Experience and Workflow Tools

Beyond app access, this project added an advanced UI builder for creating new apps and computational systems, capabilities for cloning prior jobs to support reproducibility, browsing of curated content, and job-provenance tracking with output previews. Each completed job carries metadata including remote job ID, creation and purge dates (consistent with cluster scratch-storage policies), and links to download or rerun outputs. These features substantially reduce the learning curve for non-expert users and support reproducible computational workflows.

## 5. Scientific Use Case: Reduced-Order Models for Physics-Based Ground Motion

To demonstrate the scientific value of the gateway, the team developed and deployed a Southern San Andreas earthquake-scenarios app based on reduced-order models (ROMs) of full SeisSol simulations (Rekoske et al., submitted; Rekoske et al., 2025 SCEC poster #236). For a single Southern San Andreas scenario, the full-order SeisSol simulation requires approximately 3,920 CPU-hours; the corresponding ROM evaluation runs in roughly 0.12 CPU-hours — a more than 30,000-fold speed-up at an approximation cost that remains acceptable for site-term and shaking-amplitude estimation (Fig. 3). The gateway-deployed app accepts user inputs (depth, strike, dip, rake) and returns ground-motion maps and time series, enabling rapid hypothesis testing of how rupture parameters affect shaking. This workflow is being extended toward a CyberShake-compatible physics-based hazard pipeline. Hobson, May, and Gabriel (2025 SCEC poster #163) further demonstrated the use of mesh morphing combined with ROMs to quantify the influence of fault geometry on dynamic rupture, a workflow that would be prohibitively expensive without the speed-up offered by reduced-order modeling on the gateway.

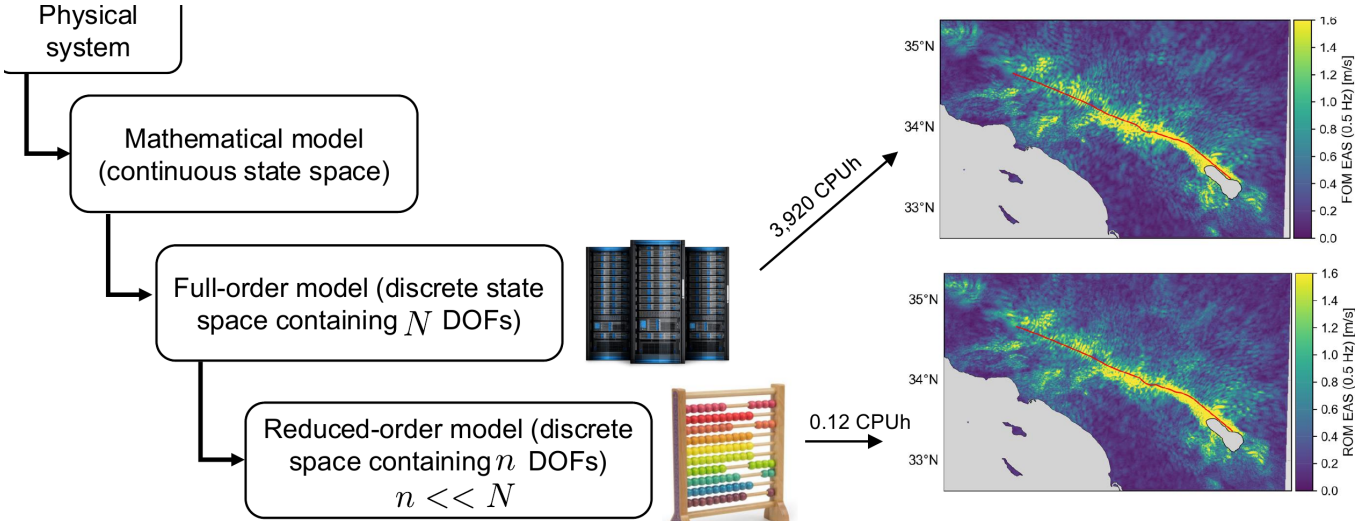


***Figure 3.*** *Reduced-order modeling workflow deployed in Quakeworx. A full-order SeisSol simulation of a Southern San Andreas scenario (~3,920 CPU-hours) is reduced to a ROM evaluable in ~0.12 CPU-hours, producing comparable peak-ground-motion structure (top vs. bottom map). Source: Rekoske et al., SSA 2026 talk; Rekoske et al., 2025 SCEC Annual Meeting Poster #236.*

## 6. Community Engagement and Education

The Quakeworx Kick-off Workshop (January 2025) selected 65 participants from more than 150 applicants representing 16 countries for hands-on training; subsequent open access to the training materials has reached over 1,300 users. The first Tandem Hackathon (July 2025) extended Tandem's capabilities through GPU-support development, benchmark contributions, and co-authorable publications, drawing participants from across the seismic-cycle modeling community. Quakeworx apps have been integrated into the Advanced Seismology course at UC San Diego, with new teaching materials co-developed for both undergraduate and graduate seismology curricula. The team has begun planning use cases for secondary education centered on inquiry-based experiments — e.g., how rupture direction affects shaking amplitudes, whether slow or fast ruptures produce stronger shaking, and along which axes shaking is generally strongest — leveraging the rapid ROM-based scenarios app described above.

## 7. Outputs and Next Steps

Across the broader Quakeworx project (with which this SCEC award is integrated), the team has published 14 peer-reviewed articles, presented 16 posters and oral presentations, and has 16 additional papers in press, preprint, or under review. Publications and presentations specifically acknowledging SCEC award 25259 are listed below. Next steps include the production launch of the gateway, expanded user-onboarding workshops and hackathons, completion of the planned integrations with TACC Frontera, NCSA Delta, and IU JetStream2, implementation of FAIR-aligned publishing options with persistent identifiers (DOIs via DataCite), and enabling user-contributed apps.

## Publications and Preprints Acknowledging this Award

1. Kurapati, V., Hillers, G., Krenz, L., Gabriel, A.-A., & Bader, M. (2026). Numerical wavefield simulations with instantaneous time mirror in a 3-D elastic medium. Geophysical Journal International, 245(1), ggag031.
2. Kurapati, V., Schneller, D., Seelinger, L., Niu, Z., Gabriel, A.-A., & Bader, M. (2026). Fused ensembles of dynamic-rupture earthquake simulations to accelerate Bayesian inference. International Journal on Geomathematics, 17, 8.
3. Biemiller, J., Gabriel, A.-A., Staisch, L. M., Ulrich, T., Dunham, A., Wirth, E. A., Watt, J. T., Lucas, M., & Ledeczi, A. (2025). Structural controls on splay fault rupture dynamics during Cascadia megathrust earthquakes. AGU Advances, 6, e2025AV001812.

4. Niu, Z., Gabriel, A.-A., & Ben-Zion, Y. (2025). Delayed dynamic triggering and enhanced high-frequency seismic radiation due to brittle rock damage in 3D multi-fault rupture simulations. Journal of Geophysical Research: Solid Earth, 130, e2025JB031632.
5. Rekoske, J. M., Callaghan, S., Milner, K., May, D. A., & Gabriel, A.-A. (submitted). CyberShake physics-based seismic hazard maps using reduced-order models: results from Southern San Andreas earthquake scenarios.
6. Wu, B., Oglesby, D. D., Kyriakopoulos, C., Tarnowski, J. M., & Gabriel, A.-A. (submitted). General solution scaling relations in linear elastic dynamic rupture models.
7. Ulrich, T., Magen, Y., & Gabriel, A.-A. (submitted). The complex rupture dynamics of an oceanic transform fault: supershear rupture and deep slip during the 2024 Mw 7.0 Cape Mendocino earthquake.

## SCEC Annual Meeting Presentations Acknowledging this Award

1. Chourasia, A., Youn, C., Silva, F., Oryan, B., Zhao, C., Yun, J., Tainpakdipat, N., Kutschera, F., Bhatthal, A., Serafini, F., Ronquillo, J., Winjum, B., Maechling, P. J., May, D. A., Elbanna, A. E., Gabriel, A.-A., & Ben-Zion, Y. (2025). The Quakeworx Science Gateway. Poster #304, 2025 SCEC Annual Meeting (SCEC Contribution #14857).
2. Gabriel, A.-A., Niu, Z., Kruse, M., Seelinger, L., Schliwa, N., Igel, H., & Ben-Zion, Y. (2025). Constraining on- and off-fault nonlinear dynamic rupture parameters via hierarchical Bayesian inversion of GNSS and satellite data for the 2019 Mw 7.1 Ridgecrest earthquake. Poster #165, 2025 SCEC Annual Meeting (SCEC Contribution #14774).
3. Hobson, G., May, D. A., & Gabriel, A.-A. (2025). Using mesh morphing and reduced-order modeling to quantify the influence of fault geometry on earthquake dynamic rupture. Poster #163, 2025 SCEC Annual Meeting (SCEC Contribution #14759).
4. Rekoske, J. M., Gabriel, A.-A., May, D. A., & Callaghan, S. (2025). Increasing the spatial resolution in physics-based site-term estimates: results from southern San Andreas ruptures. Poster #236, 2025 SCEC Annual Meeting (SCEC Contribution #14592).
5. Wong, J., Gabriel, A.-A., & Fan, W. (2025). Reconciling variability in finite-fault models through ensemble dynamic rupture simulations: the role of stress heterogeneity in the Tohoku-Oki earthquake. Poster #154, 2025 SCEC Annual Meeting (SCEC Contribution #14509).
6. Yun, J., Wong, J., Fialko, Y., Gabriel, A.-A., May, D. A., Wallace, L. M., & Williams, C. A. (2025). The 2016 Mw 7.8 Kaikōura, New Zealand, earthquake triggers slow-slip events and delays megathrust earthquakes in rate-and-state friction simulations of the Hikurangi subduction zone. Poster #152, 2025 SCEC Annual Meeting (SCEC Contribution #14499).