PERSONNEL JUSTIFICATION AND MANAGEMENT PLAN

PERSONNEL JUSTIFICATION

1 TEAM DESCRIPTION

Our project will be led by PI Yehuda Ben-Zion and co-PI's Kim Bak Olsen, Yifeng Cui, and Alice Gabriel. This is a highly experienced interdisciplinary team that includes geoscientists (Ben-Zion, Olsen, Gabriel) and a high-performance computing expert (Cui). This group will lead the activities of a larger collaboration that includes scientists, engineers, research staff, graduate students, and postdoctoral scholars from SCEC, SDSU, SDSC and other organizations. Our project PI and co-PIs are all currently in-place and are all actively engaged in computational research. Most of the group has worked together for over a decade in affiliation with the current Statewide California Earthquake Center (SCEC) (formerly the Southern California Earthquake Center). We expect the team to remain stable throughout the project, notwithstanding the graduation of existing students or the welcoming of new students into the project.

Principal Investigator: PI Ben-Zion is the Director of the Statewide California Earthquake Center, with headquarters located at the University of Southern California (USC) where he is also Professor of Earth Sciences. SCEC research activities are distributed nationally, and internationally, through collaborations with academic, governmental, and commercial organizations. As SCEC Center Director, Ben-Zion is responsible for the scientific direction, organization, and operations of the center. Ben-Zion's research interests include the physics of earthquake processes, seismic hazard analysis, earthquake forecasting, and machine learning. He has published extensively on the physics of earthquakes and faults using theoretical, computational and observational investigations, and he has mentored many students and postdoctoral scholars. These activities, organization of numerous meetings and workshops, provide him with broad perspectives on earthquake science, education and engagement.

Co-Principal Investigator: Co-PI Kim Bak Olsen is the Rollin & Caroline Eckis Chair in Seismology at San Diego State University (SDSU) in San Diego, CA. As the original author of AWP-ODC, he pioneered simulations of wave propagation in 3D models of crustal structure and is an expert in modeling strong ground motion and earthquake rupture propagation on HPC platforms. Olsen is a seismologist with expertise in numerical modeling of dynamic rupture and wave propagation computation, high performance computing, nonlinear soil modeling, and seismic hazard analysis. He has extensive experience in 3D numerical simulation including frequency-dependent anelastic attenuation, visco-plasticity, and scattering due to statistical distributions of small-scale heterogeneities and topography. Olsen and his team of postdocs and PhD students have been involved in SCEC's HPC efforts for 20+ years. He has published more than 100 papers in international peer-reviewed journals.

Co-Principal Investigator: Co-PI Yifeng Cui is the Director of the High Performance GeoComputing Laboratory at the San Diego Supercomputer Center (SDSC). He has been leading the development and porting efforts for several codes used by SCEC. His research spans the boundary of geophysical numerical modeling and high-performance computing (HPC), with an emphasis on extreme-scale and end-to-end simulation. He has collaborated extensively with SCEC in the development of high-performance parallel codes, which have enabled large-scale earthquake simulations across several generations of supercomputers. His research focuses on preparing research codes for exascale systems by implementing the necessary parallelism, concurrency, and locality on all levels of applications. He is actively involved in interdisciplinary collaborations at the intersection of AI and HPC, and the development of novel numerical methods and community models ecosystem, co-designing applications and hardware, cloud computing, and acceleration of deep learning on heterogeneous computing platforms.

Co-Principal Investigator: Co-PI Alice Gabriel is an Associate Professor at UCSD and a Guest Professor at LMU Munich. She is a theoretical seismologist specializing in earthquake physics using high-performance computing. Her group routinely utilizes the largest supercomputers worldwide to tackle one of the grand challenges of seismology: uncovering the physical mechanisms relevant to understanding earthquakes. At SCEC, she currently serves as Planning Committee Co-Chair & ExComm member. With her UCSD and Munich-based team, She co-authored more than 65 peer-reviewed papers, including in *Nature* and *Science,* and SC' Gordon Bell Prize finalist, Best Paper, Student Cluster Competition Mystery application and Reproducibility Challenge awarded papers. She is the recipient of multiple awards, including the 2020 PRACE Ada Lovelace Award for HPC, the 2020 SSA Charles F. Richter Early Career Award, and the 2023 AGU Macelwane Award and a Fellow of the American Geophysical Union.

Senior personnel and staff researchers:

Scott Callaghan is a computer scientist at SCEC with a strong experience in HPC, high throughput computing, scientific workflows, and seismic hazard analysis, and leads the development of the CyberShake platform.

Kyle Withers is a Research Geophysicist at the United States Geological Survey (USGS). He has been an active member and key collaborator in our group over the past several years. His research will investigate the effects of topography on earthquake wave propagation simulations.

Robert Graves is a Research Geophysicist at the United States Geological Survey (USGS) and he has been an active member and key collaborator in our group.

Bruce Shaw is a Research Geophysicist at the Lamont Institute. He performs multicycle earthquake rupture simulations using realistic California fault models.

Kevin Milner is a computer scientist at SCEC who obtained his Ph.D. in geoscience in 2020. He is a key researcher and developer for UCERF, CyberShake, OpenSHA, and RSQSim-related activities. He is also involved in the development and validation of new hazard products.

Philip Maechling is SCEC's Associate Director for Research Computing who manages the computational science group at SCEC. As the full-time staff manager of SCEC's research computing group, he contributes to the software development, allocation development and management, and large-scale computational research activities of the group.

Camilo Pinilla Ramos is a postdoctoral scholar at USC who is studying the impact of velocity models on seismic hazards in northern and southern California.

Fabio Silva is a computer scientist at SCEC with a strong experience in HPC, high throughput computing, scientific workflows, and seismic hazard analysis, and leads the development of the Broadband Platform.

Mei-Hui Su is a research programmer at SCEC with extensive experience in HPC, high throughput computing, scientific workflows, and seismic hazard analysis, and leads the development of the Unified Community Velocity Model (UCVM) software.

Karan Vahi is a Senior Computer Scientist in the Science Automation Technologies group at the USC Information Sciences Institute. He has been working in the field of scientific workflows since 2002, and has been closely involved in the development of the Pegasus Workflow Management System. He is

currently the architect/lead developer for Pegasus and in charge of the core development of Pegasus, and is instrumental in supporting the CyberShake platform workflows and capabilities.

Dave A. May is an Associate Professor at UCSD. He is a theoretical geophysicist who employs applied mathematics, computer science and high-performance computing to develop new computational models of Solid Earth processes. His research activities fall into one of five themes: (1) methodological development; (2) fast linear and non-linear solvers for partial differential equations; (3) efficient software implementations; (4) computational geophysics application studies employing methods and/or specialized software I have developed; (5) non-intrusive reduced-order models. May is a PETSc co-developer.

Postdocs
Te-Yang Yeh is a postdoc at SDSU, working with Kim Olsen on wave propagation and strong ground motion. He has valuable experience with the AWP-Iwan and AWP-topo codes, from applications including California dams and fault zone structures.

Thomas Ulrich and Claudia Abril are postdocs at LMU Munich, working with Alice Gabriel on SeisSol earthquake rupture and seismic wave propagation simulations with a focus on cutting-edge geophysics applications.

Graduate students: Ke Xu and Anupam Patel are PhD students in the Joint Doctoral Program between SDSU and UCSD, working on linear and nonlinear wave propagation problems, validation of velocity models, and simulating future damaging earthquake scenarios.

John Rekoske is a PhD student in Geophysics at UCSD working with Alice Gabriel and Dave May on ML reduced order models for earthquake early warning and seismic hazard assessment, as well as physics-based earthquake simulations and ground motion modeling. He holds a NSF GRFP scholarship.

David Schneller and Vikas Kurapati are PhD students in Scientific Computing at TU Munich. Their work focuses on HPC optimization and multi-physics earthquake simulations. They will collaborate on GPU optimization of SeisSol and on extension of model capabilities of SeisSol (advanced rheologies, dynamic rupture laws, boundary conditions, etc.) and respective workflows (efficient I/O, etc.)

The involvement of graduate students in our HPC projects is critical to the success of the program. It is also in line with SCEC's broader impact objective to continuously form a new technically sophisticated research community. Students tend to join the regular research meetings and while they begin as observers, they gradually get more involved in making presentations and engaging in discussions.

Broader collaboration: A wide range of stakeholders are involved in our SCEC research collaborations. Our broader collaborative projects include CyberShake, Dynamic Rupture, and Displacement teams (include over 30 people, listing representative participants): Yousef Bozorgnia (UCLA), Morgan Moschetti (USGS), Albert Kottke (PG&E), Norm Abrahamson (UCBerkeley/UCLA) and Michael Bader (TU Munich). Several tens of additional collaborators participate in regular meetings (weekly to monthly depending on the specific focused project) in which we discuss scientific plans and results.

MANAGEMENT PLAN

PI Yehuda Ben-Zion is responsible for the overall project management and will provide scientific leadership on the project. The PI will define project priorities in collaboration with the project co-PIs and will coordinate activities among the collaborating organizations to ensure the project meets its goals and objectives. Ben-Zion will be the point of contact between this project and the earthquake science research community and will ensure that the computational research goals on this project are well aligned with the

overall goals of the SCEC research community. He will have overall responsibility for the project, ensuring that the research activities support the scientific goals expressed in our allocation request. He will establish appropriate coordination and communications mechanisms within the project required to monitor, track, and achieve the project milestones and metrics. He will ensure project activities are monitored through weekly project conference calls that include progress reporting, scientific collaboration, technical coordination, and project planning discussions. Philip Maechling, who is a project senior personnel and USC SCEC staff member, will serve as the project allocation manager. He will respond in a timely manner to any requests from the INCITE program coordinators and will disseminate information received from INCITE management to the project participants. He will be responsible for adding and removing users from the allocation as needed and will be responsible for monitoring project computing and storage usage, to ensure any awarded computing time is distributed appropriately to subgroups within the project.

Scientific and technical responsibilities for co-PIs are organized around scientific objectives and computational codes. While there is significant overlap and interdependencies between our work areas, and researchers will contribute to any area that they can, our project is organized into three main development areas. We organize teams to work on research priorities in our three project objective areas which are: (1) region-specific earth structure models, (2) deterministic earthquake wave propagation, and (3) Physics-based Probabilistic Seismic Hazard Analysis (PSHA) CyberShake platform development and operations. Project group responsibilities will be organized around these three working groups. Team researchers working on Objective 1 (Earth Model development) related research includes Kim Olsen and Camilo Pinilla-Ramos. Team researchers working on Objective 2 (Wave propagation model development) related research includes Kim Olsen, Camilo Pinilla-Ramos, Alice Gabriel, Te-Yang Yeh, and Yifeng Cui. Team researchers working on Objective 3 (PSHA Integration) include Yehuda Ben-Zion, Scott Callaghan, Kim Olsen, Philip Maechling, and Camilo Pinilla-Ramos.