Final Project Summary— PEER Lifelines Program

Project Title—**ID Number**	*Validation of Basin Response Codes*—**1A01**		
Start/End Dates	9/1/99 – 9/30/00	Budget/ Funding Source	$100,000 / PG&E
Project Leader (boldface) and Other Team Members	**Henyey/Day (SCEC/SDSU)**		

1. Project goals and objectives

Numerical simulations of wave propagation can now be done in three dimensions for models with sufficient realism (e.g., three-dimensional geology, propagating sources, frequencies approaching 1 Hz) to be of engineering interest. However, before numerical simulations can be applied in the context of engineering studies or seismic hazard analysis, the numerical methods and the models associated with them must be thoroughly validated. Task 1A01 focused on validation of the underlying numerical methodologies and computer programs employed in numerical modeling of earthquake ground motion from propagating earthquakes in 3D earth models. The emphasis in 1A01 was on idealized sources in simple earth structures. Code verification was carried out through a systematic, coordinated program of test simulations.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

The project provided an essential foundation for simulation-based ground motion estimation in urban sedimentary basins.

3. Brief description of the accomplishments of the project

Tests verified the accuracy of basic equation solvers, source formulations and free surface boundary conditions, through comparisons with analytic solutions for uniform elastic halfspace problem. Further tests verified the accuracy and limitations of absorbing boundary conditions used to simulate radiation conditions at grid boundaries. Additional tests verified accuracy of material interface representation through comparisons with analytic solutions for layered a halfspace problem. Finally, test simulations were done to verify code accuracy for propagating earthquake sources. Test problems were documented and made available to any interested investigators.

4. Describe any instances where you are aware that your results have been used in industry

5. Methodology employed

Five different earthquake ground-motion simulation codes were tested. Of these, four are finite difference (FD), and one is finite element (FE). All of the FD codes use uniform, structured grids, with staggered locations of the velocity and stress components and fourth-order accurate spatial differencing of the elastodynamic equations. The codes were independently programmed. The main variations among them include: degree of computational parallelism, type of memory management (e.g., main-memory contained operation versus roll-in/roll-out from disk), free-surface boundary condition formulation, absorbing boundary formulation, material interface representation (e.g., type of averaging of material properties in vicinity of properties gradients or interface), and source formulation.

6. Other related work conducted within and/or outside PEER

The PI and several of the co-PIs conducted related SCEC research, including developmental work on the codes that were the subjects of this validation study.

7. Recommendations for the future work: what do you think should be done next?

(1) Testing of the methods for earth structure models with realistic levels of complexity, such as the SCEC Community Velocity Model, and for earthquake models with realistic levels of complexity, such as the published kinematic models of the 1994 Northridge, California, Earthquake. (2) Application of the methods to estimate basin amplification effects on seismic ground motion.

8. <u>Author(s), Title, and Date</u> for the final report for this project

Authors: S. M. Day, J. Bielak, D. Dreger, S. Larsen, R. Graves, A. Pitarka, and K. B. Olsen

Title: Tests of 3D Elastodynamic Codes

Date: September 10, 2001

9. Figures

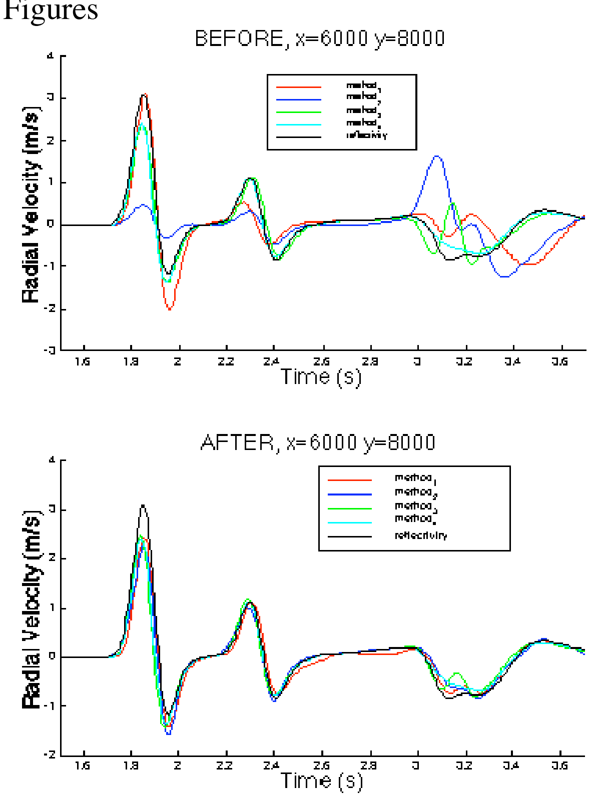

Figure 1. Comparison of results from 4 FD and FE wave propagation codes, at beginning (above) and end (below) of the validation study 1A01. Solutions are for uniform halfspace. Semi-analytic solution by integral tranform methods ("reflectivity") is also shown, for reference.

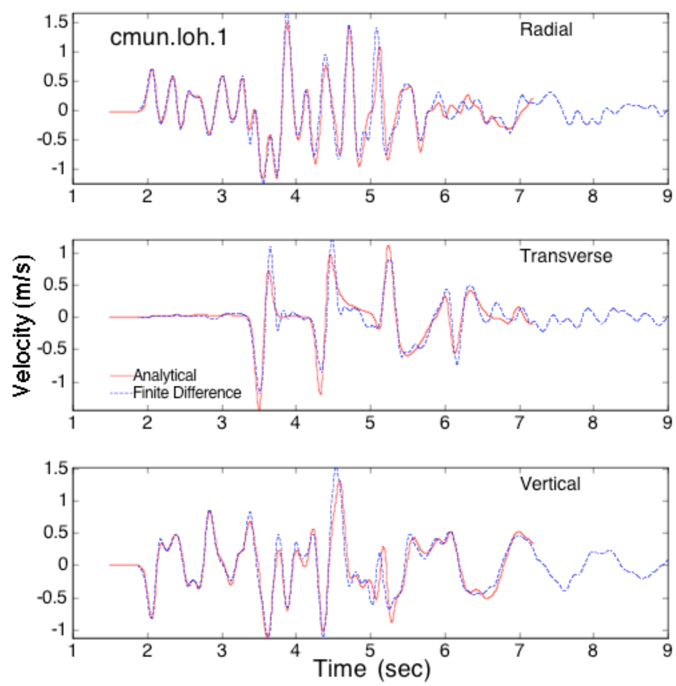

Figure 2. Comparison of FD and semi-analytic solutions for layer-over-halfspace test (point dislocation source), demonstrating accuracy of FD code.