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YEARLY REPORT FOR THE PERIOD Jan–Dec 2021

IC Project: w20_earthquake

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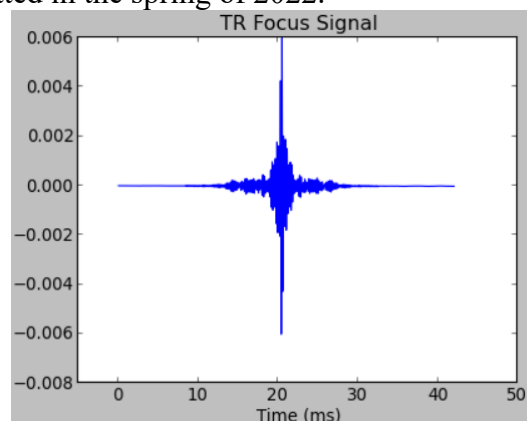
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Scientific and Programmatic Impact:

The simulations conducted under this IC project used an in-house code developed at Los Alamos National Laboratory called HOSS (Hybrid Optimization Software Suite) and its extended version called HOSS-FSIS (fluid-structure interaction solver). HOSS has been under development in LANL’s Geophysics Group since 2004 and was used to simulate the signal propagation in pieces of material with pre-existing defects and also to simulate the near source effects of above ground nuclear explosions. One of the key feature of HOSS is that it is superior to pure finite element method and discrete element method implementations because it allows for a natural transition from continuum to discontinuum when the material breaks or fractures.

Under this IC project in 2021, large-scale simulations were conducted using the computational tool HOSS to investigate scientific aspects of the time reversal (TR) process, see Figure 1. TR techniques have many applications, ranging from underwater acoustic communications between submarines, medical imaging, and the determination and characterization of microscopic defects in non-destructive evaluations. Immediate emphasis was placed on the identification of damage/defects in wellbores as part of carbon sequestration and capture projects. In particular, IC resources were used to study the viability of using numerical methods to explore time reversal acoustic techniques for mechanical components for near wellbore applications. As a result of the successful ‘proof of concept’ a journal article on time reversal simulations in a wellbore environment will be submitted in the spring of 2022.



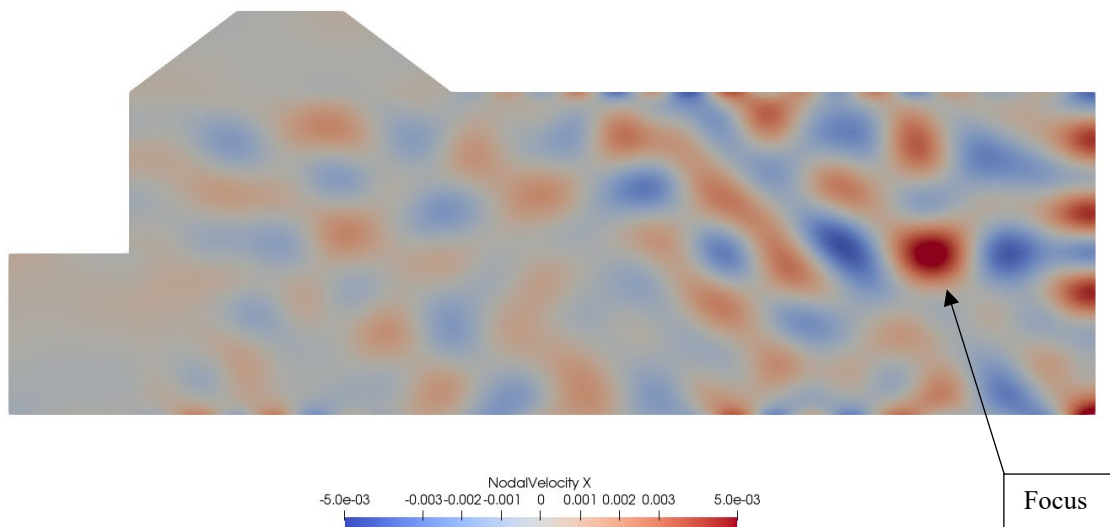


Figure 1. Top: Focused signal using a 6 kHz training signal, in an asymmetric 2D domain with multiple material blocks. Bottom: Visualization of the focused signal during the simulation.

Under this IC allocation the HOSS-FSIS was used to simulate a legacy nuclear tests in 3D. This allowed us to compare the numerical results against to actual data collected from the tests. In this work three different nuclear events were simulated: SEDAN, and SUGAR and UNCLE. SEDAN was as part of Operation Plowshare through LLNL, while and SUGAR and UNCLE were a part of operation Jangle through LANL and the DoD. This allows for comparison between numerical and observed criteria in an effort to firstly, confirm the accuracy of the HOSS code and secondly, to calibrate these models to the observed behavior conducted in the actual tests. These simulated tests include surface bursts and underground explosions at various yields to explore these explosions at different conditions. Additionally, tests that have not been physically conducted are simulated to estimate the effects and outputs of yields that have never been tested. Work has also been performed with high explosive (HE) tests to observe differences in HE and nuclear tests. The fluid-solid interaction is studied between the geomaterial being hit and the fluid from the explosive in these simulation. This work also aims to explore cratering and HOSS's capabilities in modeling the processes of crater formation.

The development of HOSS-FSIS was supported by the LDRD office and by the ASC program. The FSIS addresses transient pressure wave propagation in fluid, fluid viscosity, equation of state for the fluid, energy transport, momentum transport and interaction with the fracturing solid domains, which is done through a novel immersed boundary approach. The solver is based on the governing equations being resolved using different control volume schemes, with discretization errors of either third, second or first order. The solver is fully explicit and conditionally stable with a time step that is synchronized with the FDEM's time step. The FSIS was first developed in 2D and then extended to a 3D realm. The testing, verification, and validation followed the same path as the development stages.

Financial Impacts:

Present Sponsors: LDRD, NA-22

Future (potential) Sponsors: LDRD Office, Basic Energy Science Office, Office of Science, DTRA, DoD.

Summary of Computational Effort Accomplished:

We used ~1.57M CPU hrs for the testing, benchmarking, and application of the FSIS solver on Grizzly. The computational resources were mainly used to run different simulation scenarios for the programs being supported by this IC project.

Financial Impact by Fiscal Year. FY21: LDRD Project: \$200k. Special Project \$100k. Additionally, work conducted under this Institutional Computing allocation was aimed at program development; internal funding connected to this is projected to become available FY23.