Seismoacoustic Simulations & Predictions of the Source Physics Experiments SPE Phase III (RVDC): Impact on explosion monitoring & discrimination

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INTRODUCTION AND MAIN RESULTS

The Source Physics Experiments (SPE) are a series of chemical explosions at the Nevada National Security Site to gather observations, verify and validate physics-based numerical models, and understand shear waves generation to improve nuclear discrimination capabilities. Executed in 2011-2016, Phase I of SPE included 6 explosions in granite. Phase II included 4 explosions executed in 2018-2019 in dry alluvium. Phase III, will include 2 explosions in a dominant dolomite geology and co-located with a 1997 shallow earthquake. LLNL has developed a comprehensive numerical framework to simulate from source-to-receivers, the waves generated from the non-linear explosion source-region to linear-elastic seismoacoustic distances.

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Introduction

The Source Physics Experiments (SPE) are a series of controlled chemical explosions at the Nevada National Security Site to gather observations validate physics-based numerical models and understand the genesis of shear waves to improve nuclear discrimination and monitoring capabilities. SPE Phase III includes 2 planned chemical explosions in a dominant dolomite geology and co-located with a 1993 shallow earthquake. LLNL has developed a comprehensive numerical framework to simulate from source-to-receivers, the waves generated from the non-linear explosion source-region to linear-elastic seismoacoustic distances. We, summarize how modeling assisted with the testbed design of both projected chemical explosions.

Motivations

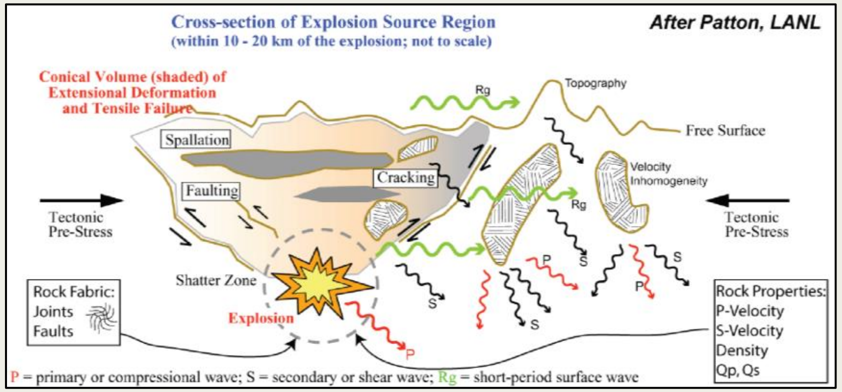
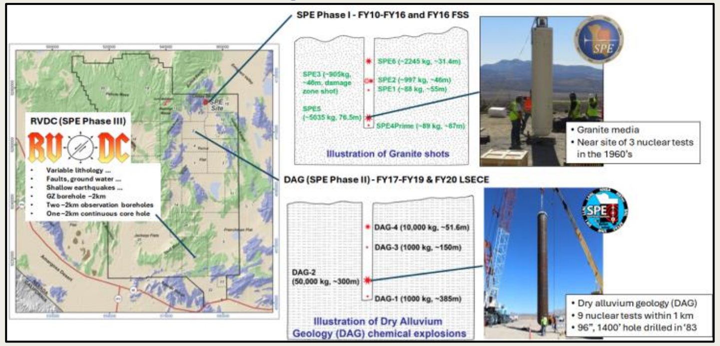


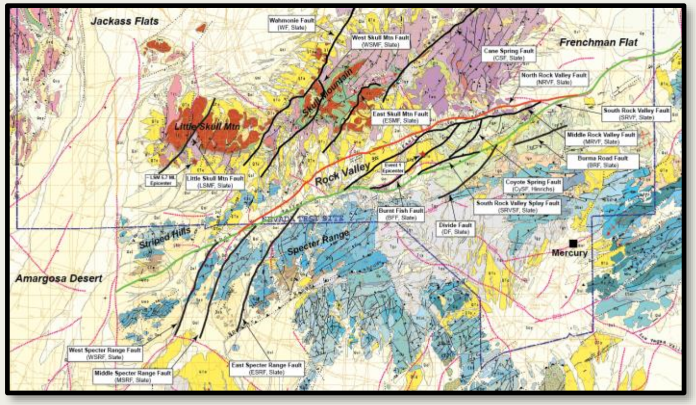
Illustration showing potential sources of S-waves originating from spherically symmetric explosive source. S-waves can either be generated because of scattering or non-linear processes in the source region.

The Source Physics Experiment SPE



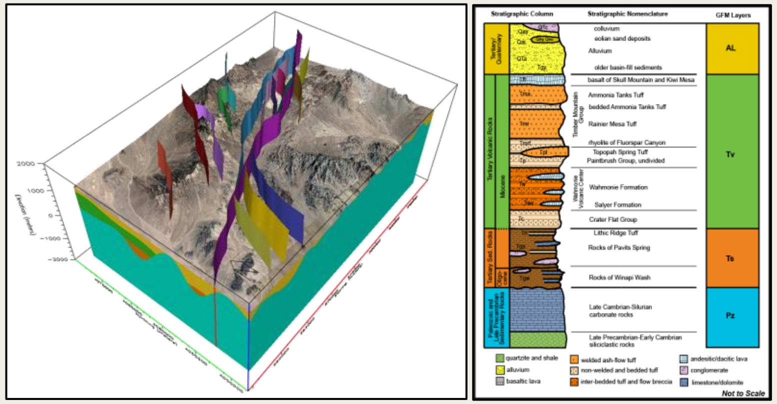
Size, depth, and geology for the SPE chemical explosions. Phase I consisted of 6 experiments in granite which is nearby past nuclear tests. Phase II is conducted in a weaker rock. dry alluvium. Phase III will include experiments close to a past earthquake for a direct comparison of the two sources.

Geology of SPE III – Rock Valley



Rock Valley fault zone (RVFZ) is an east-northeast-trending zone of mostly left-lateral strike-slip faulting in the southern portion of the NNSS. It is approximately 32 km long and 5 km wide.

The fault system is well exposed along the eastern upper portions of Rock Valley Wash & Hampel Wash.



Tertiary deposits form a northward-thickening wedge away from the Specter Range are observed. Four main lithologic packages in model area: 1) Alluvium, 2) Tertiary volcanic rocks, 3) Tertiary sedimentary rocks, & 4) Paleozoic and late Precambrian sedimentary rocks.

Photos of geological cores collected at Bourbon nuclear explosion site, Area 7 dolomite, used as surrogate material to Area 2

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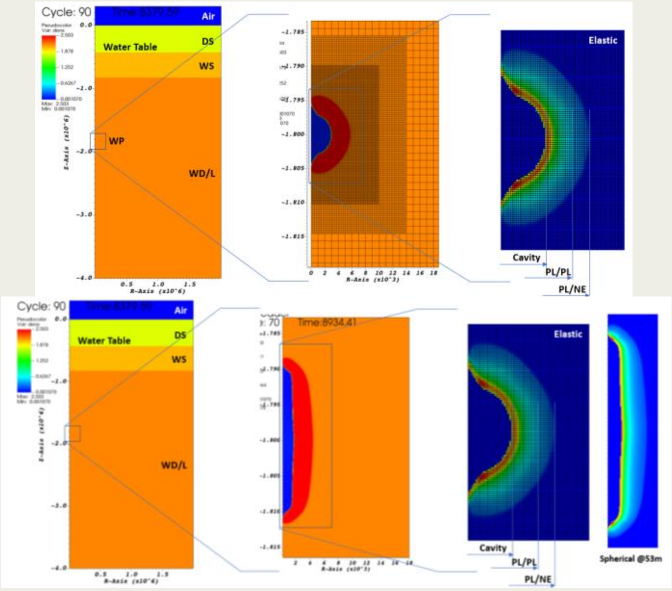
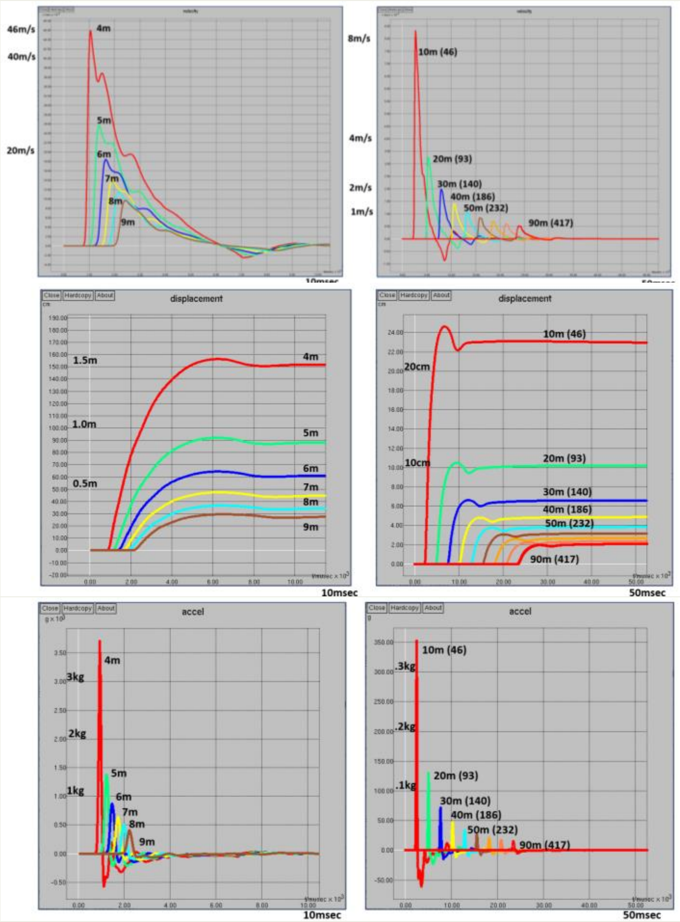
Simulations of 1- & 10-ton HE explosions

We have conducted non-linear hydrodynamic simulations to design the RVDC testbed. The testbed includes 1 Ground Zero (GZ) borehole, 2 observation boreholes (OBH) and 1 characterization corehole (CH), each is ~2km deep. The numerical simulations are conducted in 2D axisymmetric domain. We have conducted spherical and cylindrical shape charges to assess their differences in generating ground motions. Two chemical explosions are planned: one 1T at 2km depth, and one 10T at 1.8km depth.



Axisymmetric AMR hydrodynamic simulation. Top row shows a vertical cross-section of the geology, the working point location and a 'spherical source'. Bottom row shows the implementation of a cylindrical source.

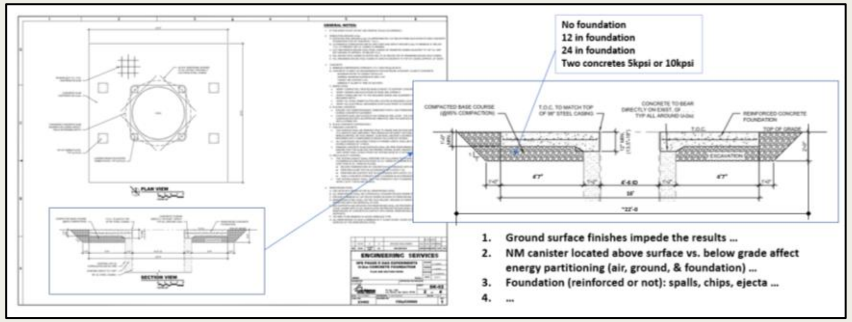
We have conducted several numerical simulations to predict ground motion at different ranges from the WP. The following figures show those predictions for Velocity, Displacement, and Acceleration, respectively.

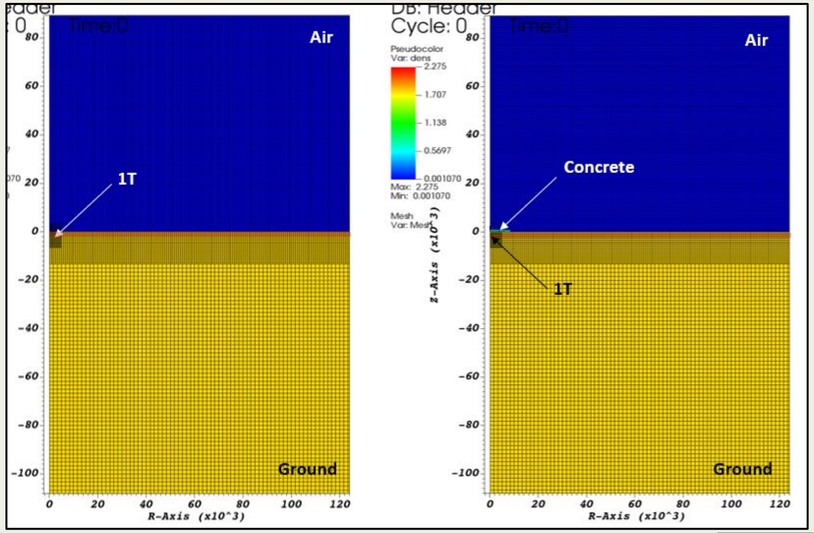


Each ground motion predictions are depicted on three different frames, for less than 10m, 10-100m, and greater than 100m range.

Integrated Surface Test (IST) simulations

One metric ton chemical explosion at the surface is planned as an Integrated Surface Test (IST). The effect of IST explosion depends on the emplacement environment. We assess the response of IST as function of the absence or presence of a concrete pad (slab) at SGZ.





Numerical simulation of 1T chemical explosion with & without a concrete slab (1' or 2' thick and 5kpsi or 10kpsi compressive strength).

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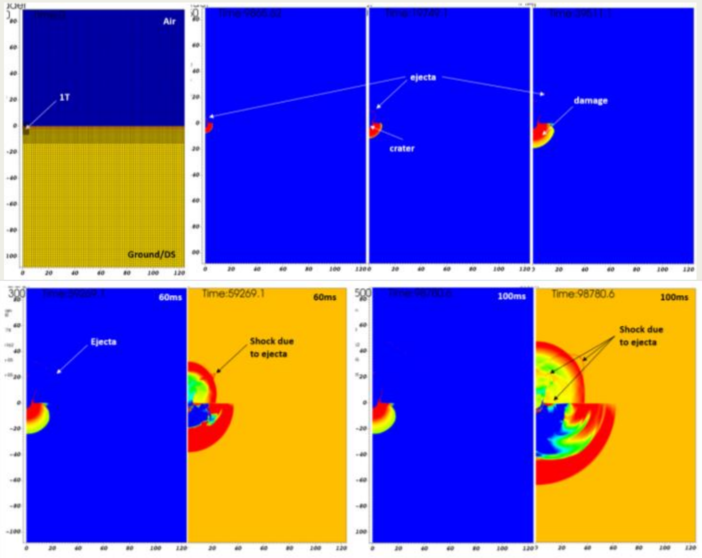
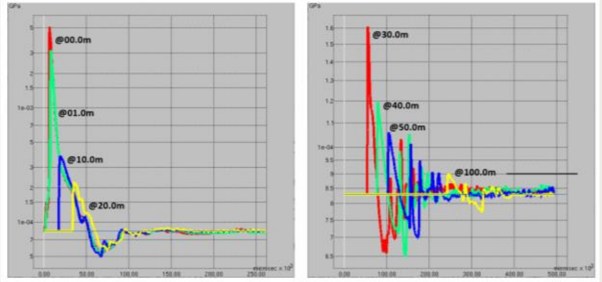
IST without concrete pad simulations

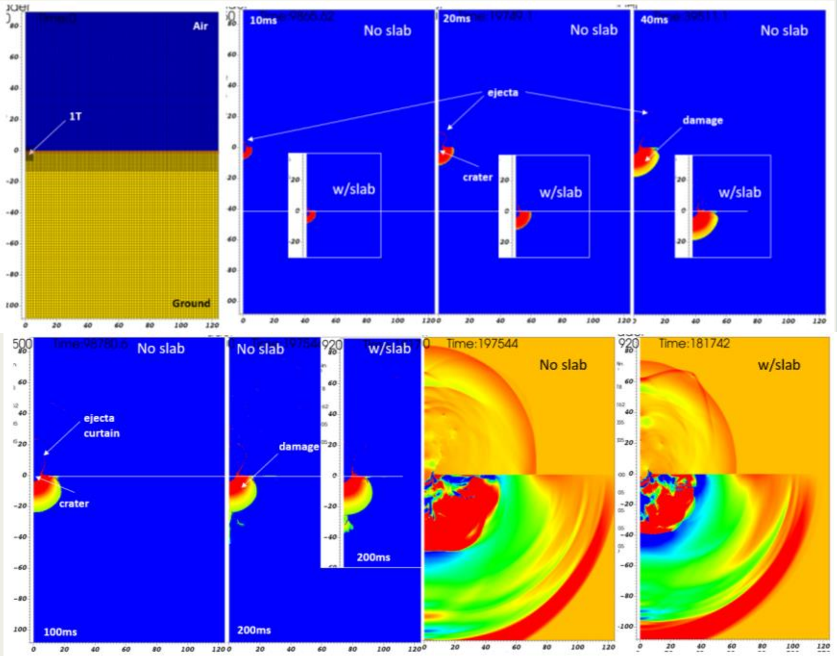
Numerical simulation of 1T chemical explosion without the presence of a concrete slab.

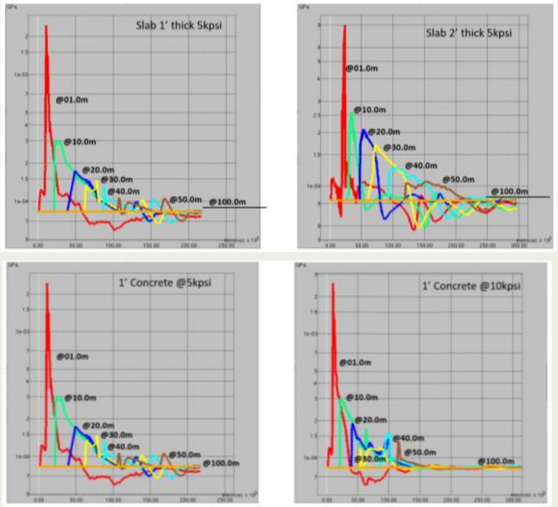




Three time-snapshots of the ejecta and damage zone are depicted. Two early time-snapshots shown the onset of the local shock wave due to ejecta. Each time-snapshot depicts damage/ejecta and pressure distribution above and below ground. Overpressure at different ranges from SGZ when no concrete slab is present

IST with concrete pad simulations





We highly recommend one-foot-thick concrete pad with a 10kpsi compressive strength or a two-feet –thick concrete pad with a compressive strength of 5kpsi.

Summary

- Numerical simulation of 1T chemical explosion with the presence of a concrete slab. Three time-snapshots of the ejecta and damage zone are depicted with inserts of no slab results
- Comparison of the curtain of ejecta of 1T chemical explosion without the presence of a concrete slab. Two time-snapshots of the ejecta and damage zone are depicted with insert of the resulting effects of the presence of the slab. Comparisons of pressure distributions shown the local shock waves created by the ejecta.
- Overpressure at different ranges from SGZ when a 1' (left) and 2'(right) thick concrete slab is present. The compressive strength of the concrete is 5kspi.
- Overpressure at different ranges from SGZ when a 1' thick concrete slab is present. The compressive strength of the concrete is 5kspi (left) or 10kspi (right).

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