SAND2022-16145C

Analysis of Ground Shock Reflections Through Explosions at Various Heights of Burst

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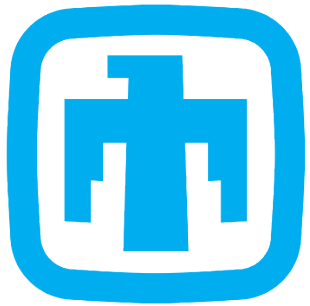

Sandia National Laboratories

Presented at APS-DFD 2022

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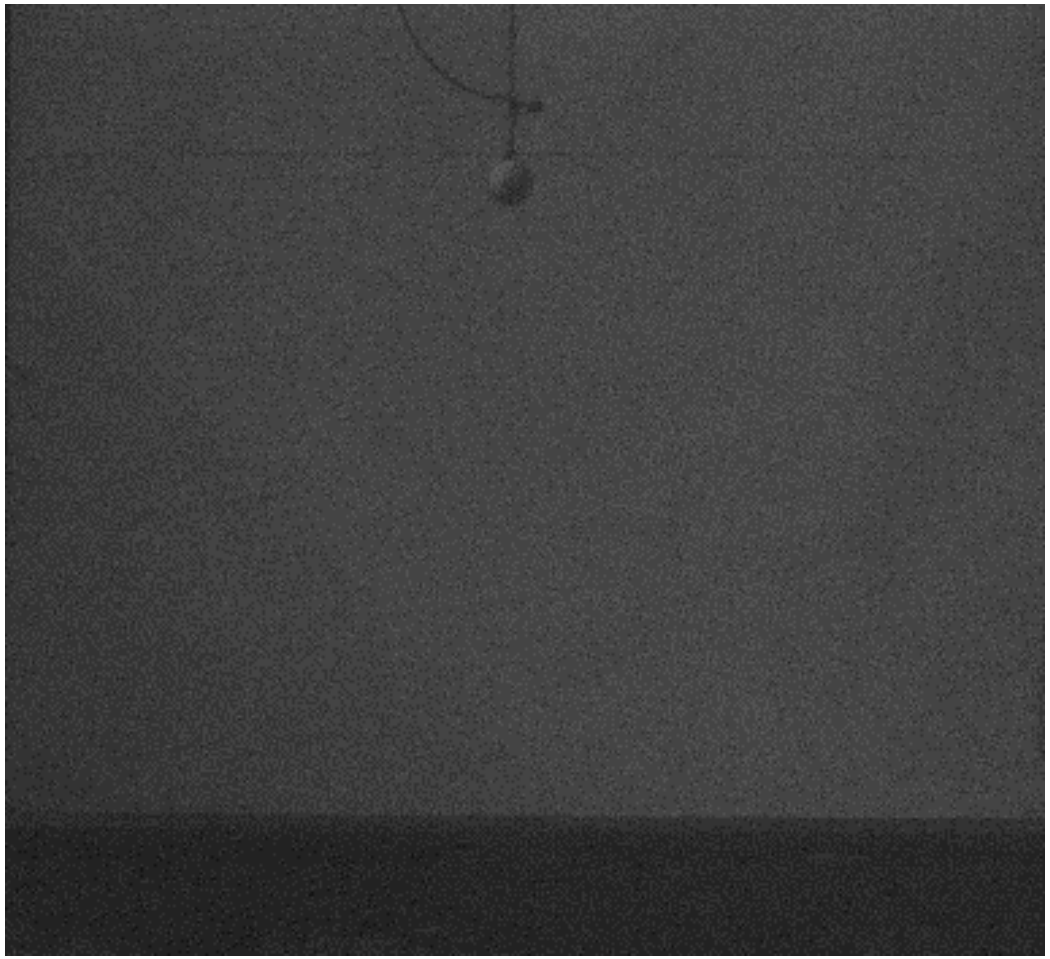
Explosions that occur above a ground plane will experience a re-shock process as the blast wave reflects from the ground

- The reflected shock passes through the expanding explosive fireball
- This causes the fireball to be reheated, accelerated upward, and increases mixing with the environment
- The reflected shock wave also accelerates as it passes through the hot product gas fireball

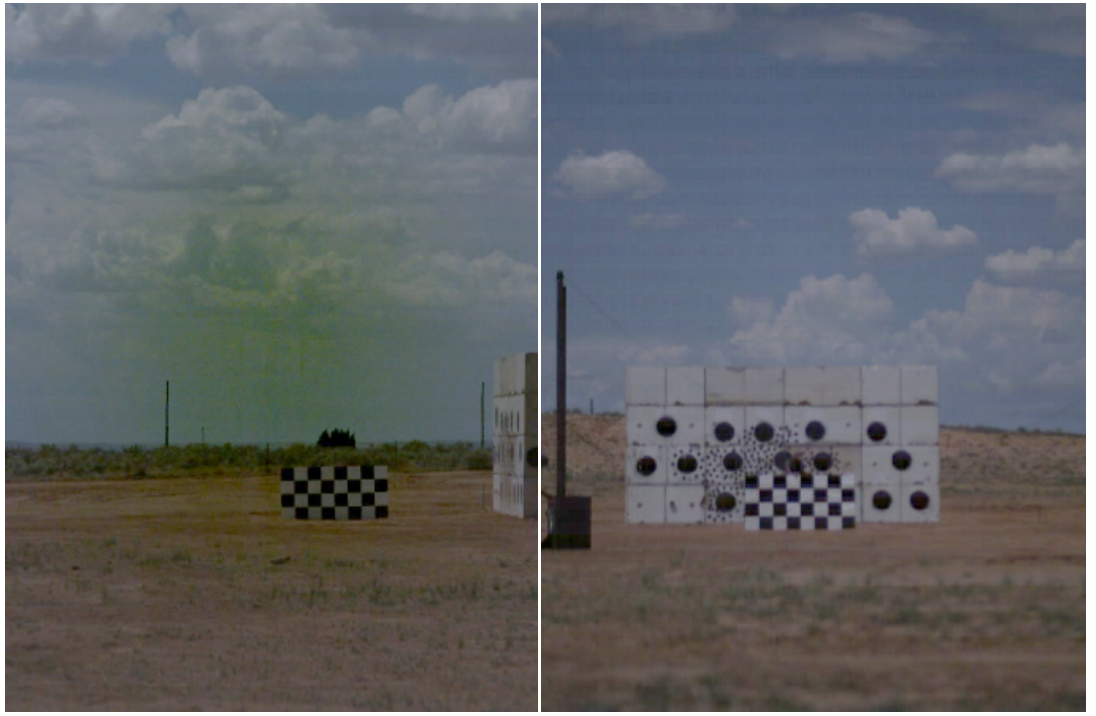
The goals here are to quantify aspects of the reshock process

- Measure the reflected shock wave arrival time at the fireball
- Measure the transit time for the shock wave to exit the fireball
- Characterize the shape of the shock wave as it passes through the fireball
- Explore the light intensity variations of the fireball due to re-shock



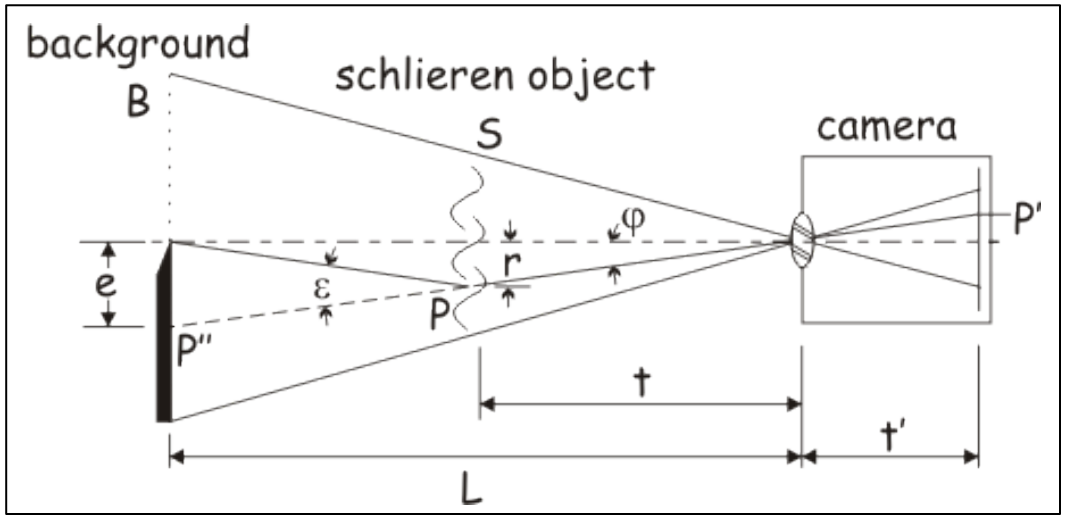
Experiments were performed at Sandia National Laboratories in Albuquerque, New Mexico

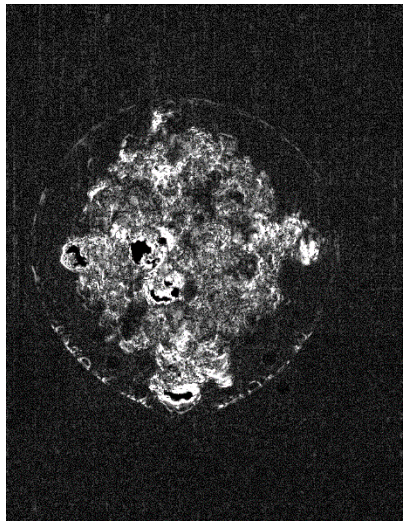
- Spherical charges of explosive material
- Heights of burst varied from 1.8 to 4.3 meters
- Imaging conducted using high speed cameras
  - Between 32000 and 37500 frames per second
  - Image resolution is 896 x 672
- Reflecting surfaces included the ground and a wall built to act as a ground plane



Background Oriented Schlieren (BOS) was used to visualize the shock wave propagation in the high-speed images

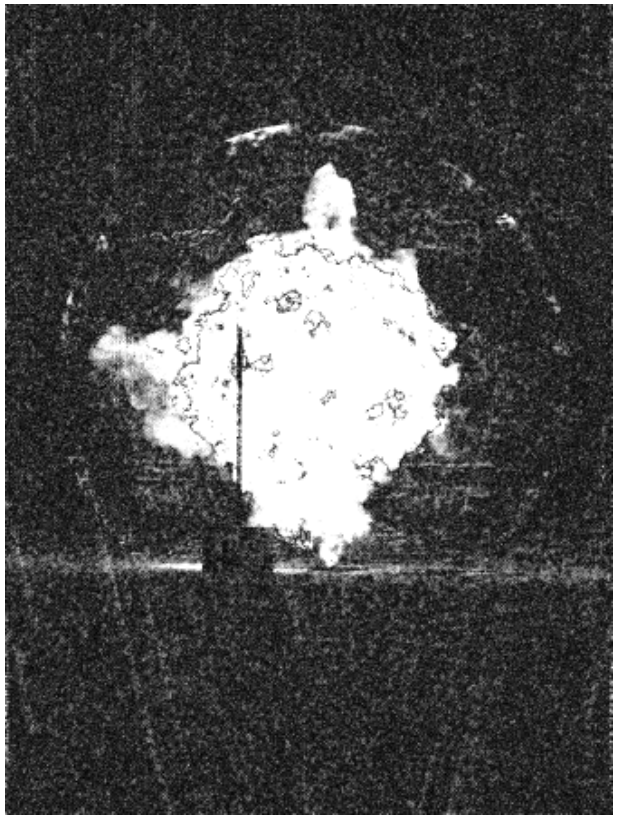
- Refractive imaging technique that highlights the distortion of a distant background
- Technique is useful for large scale tests
- Images the distortion of light around light-dark boundaries
- Visualization and quantification of shock wave propagation from explosions





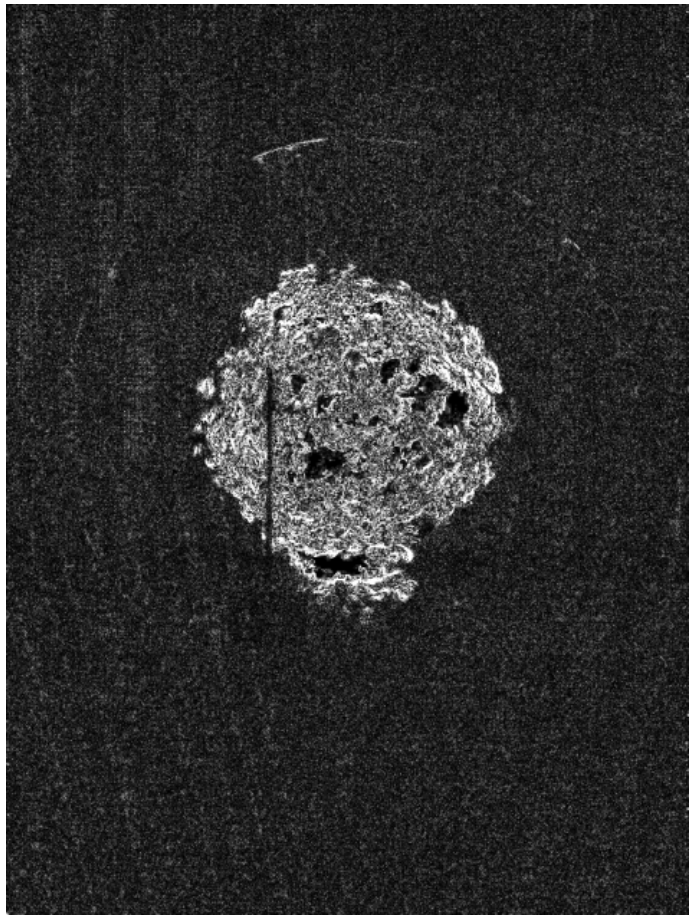
An image subtraction routine was used to highlight optical distortions captured in the high-speed video frames

- Subtract a ‘flow on’ image from a ‘flow off’ image
- Identifies areas of intensity change between the images



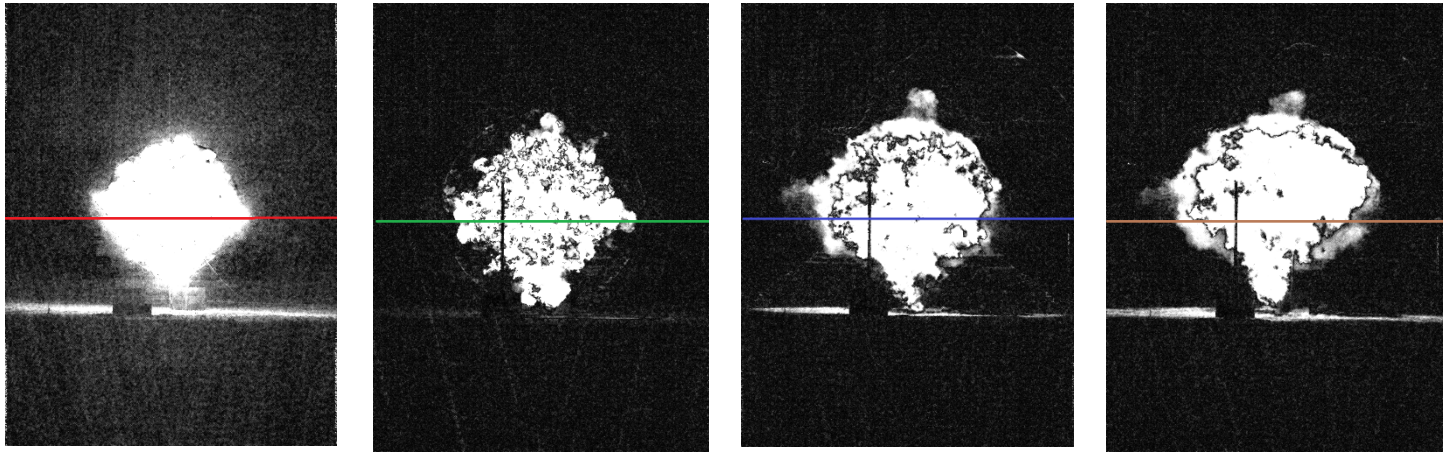
Sequential Image Processing subtracts sequential images of the high-speed video record to produce a difference image

- The ‘flow off’ image is one frame before the ‘flow on’ image

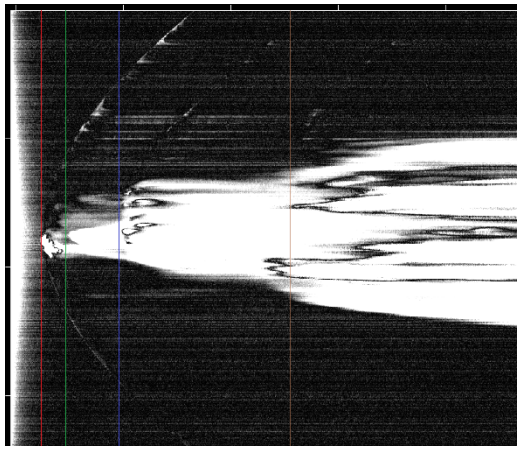


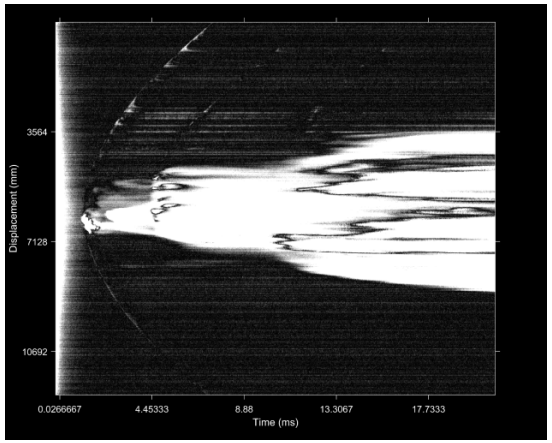
Digital streak images are created to visualize the shock and fireball position versus time

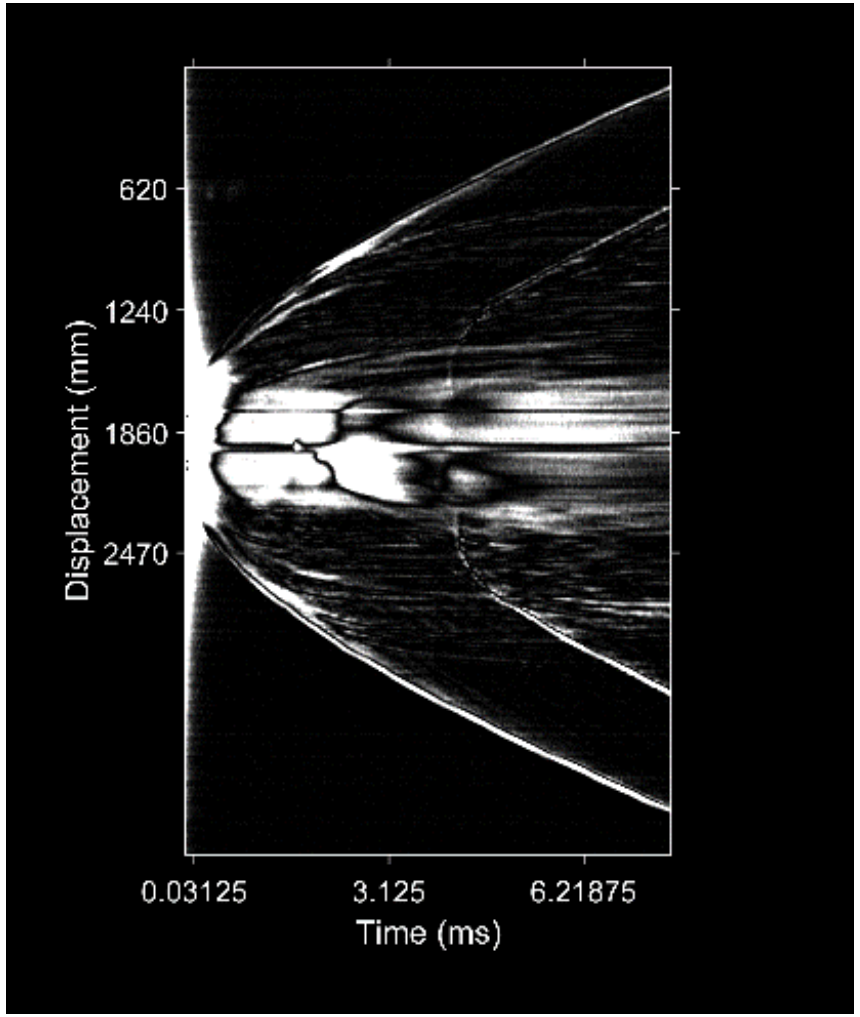
- One row of pixels from each frame in a series of processed images



- Creates a position vs time plot

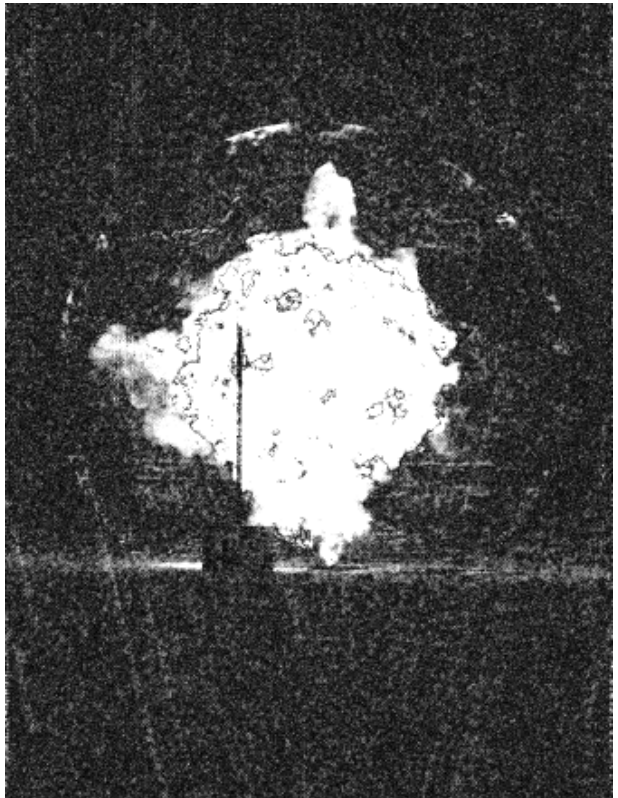






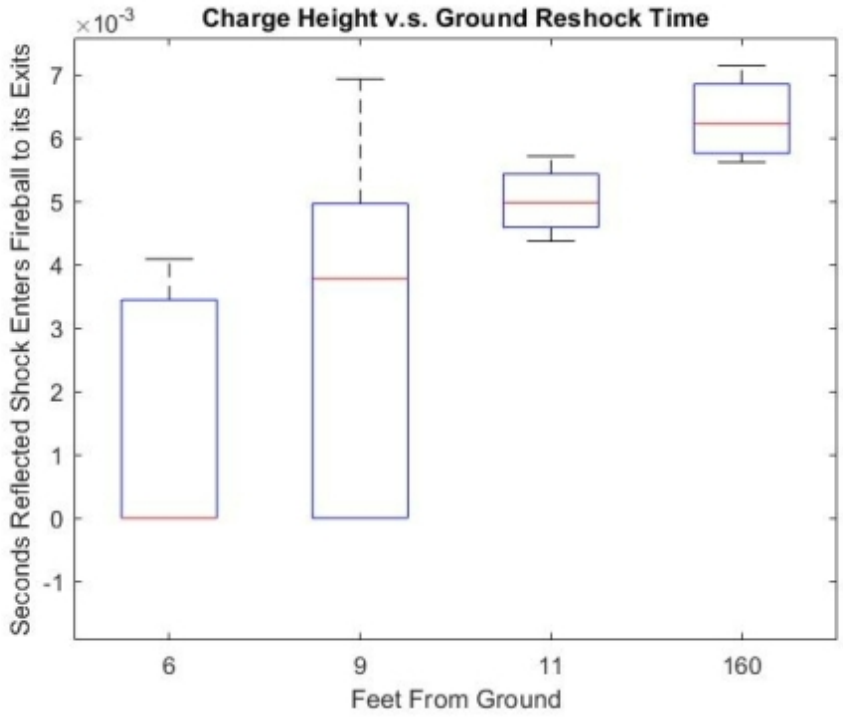
The BOS images are trying to focus on both the shockwave propagation and fireball evolution

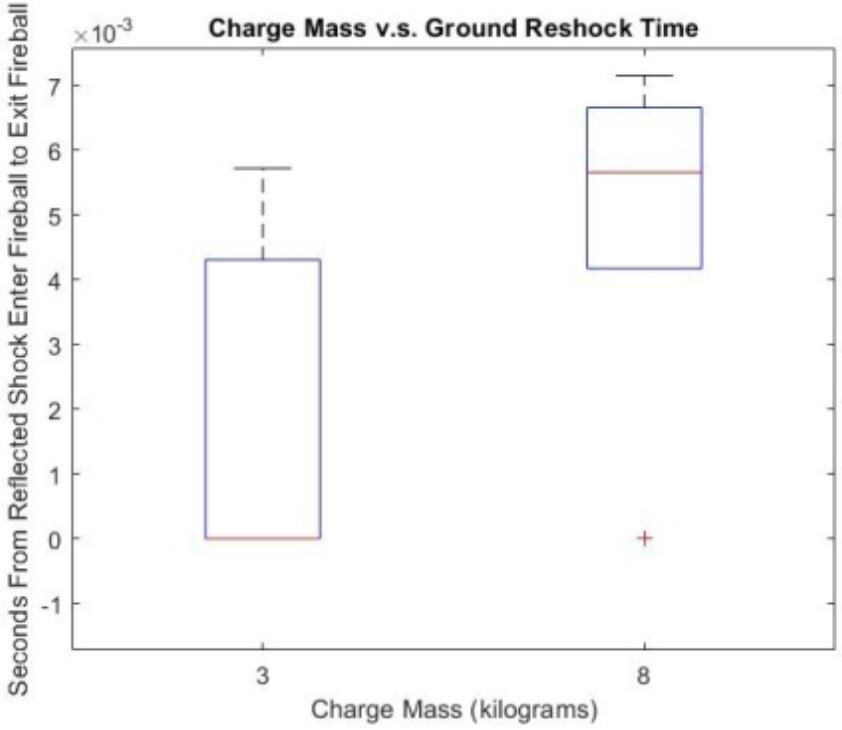
- The raw high-speed images are dark to ensure the fireball is not over-ranged during the recording of the event
- The cameras are too dark in some instances to allow good BOS data extraction
- Much of the background is also pure sky with no pattern, preventing BOS imaging



The height of the charge affects its transit time through the fireball

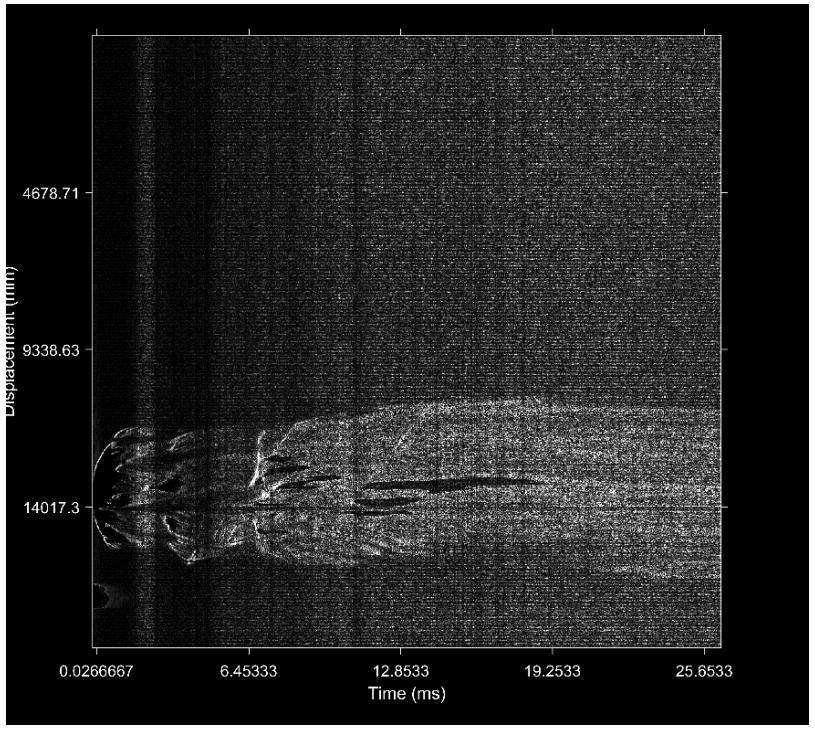
- Greater distances between the charge and the ground decrease the velocity of the shockwave as it propagates
- Charges with a higher mass spend more time in the fireball

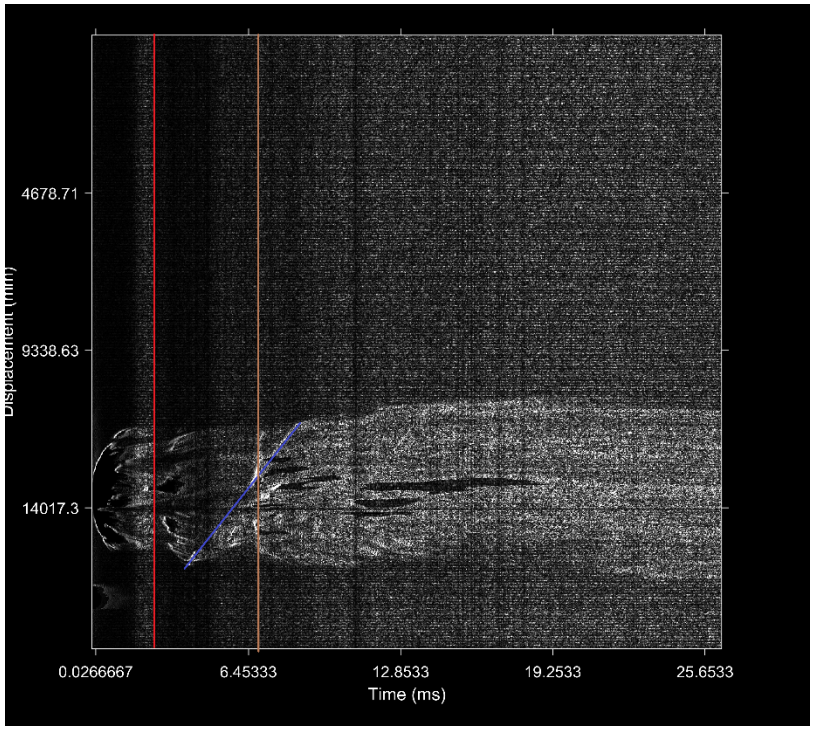




Streak images track shockwave propagation and allow correlation to changes in light intensity

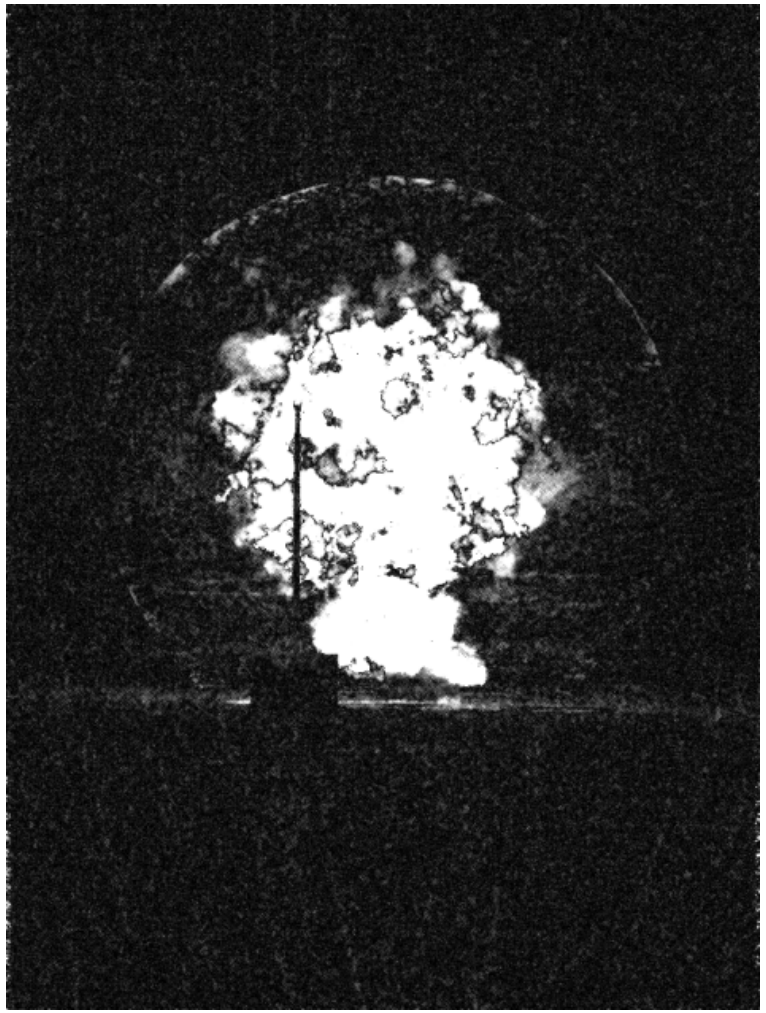
- Vertical and horizontal streaks display different qualities of the explosive
- The change in light intensity can be seen as the shockwave reaches the front of the fireball in the first camera angle





This process yields quantitative data

- BOS and image processing allow better visualization of shock waves
- The mass of the charge also affects the re-shock time. The shock from charges with a higher mass spend more time in the fireball
- The light intensity of the fireball varied as it interacted with the re-shock
- More information will be obtained as the rest of the data from these tests are processed



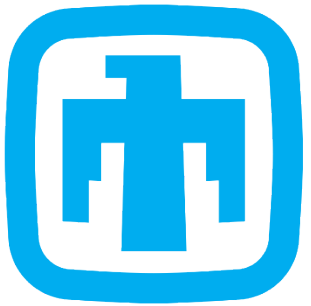
Future work will explore scaling of the data

- Initial trends show re-shock effects vary with height of burst and explosive mass
  - Apply traditional scaling relationships to shock propagation distance
  - Develop scaling for fireball expansion
- Explore light intensity variation in more detail

Acknowledgement

- This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

- Funding for this work at New Mexico Tech was provided by Sandia National Laboratories PO 2347214



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Thank you

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