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Impact of Burst Height on Fireball Expansion and Ground Shock Dynamics in C4 Explosions

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Expanding explosion gases create a complex 3D interface with strong surface instabilities

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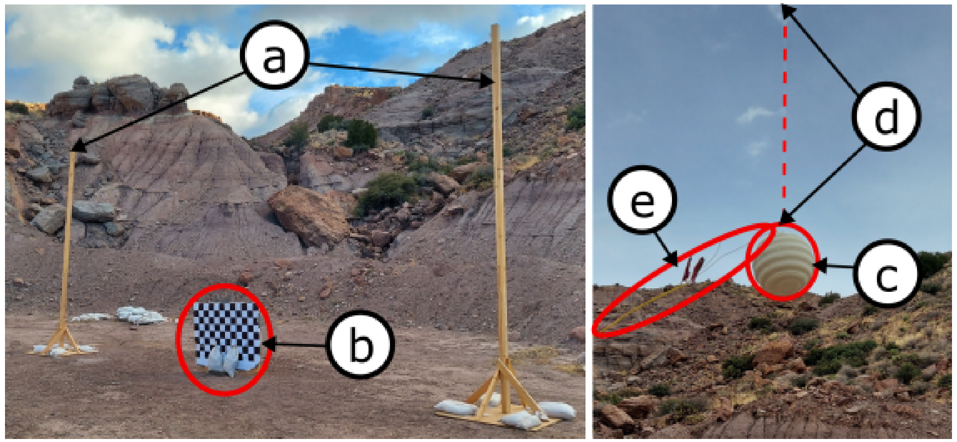
- Assessing the fireball's evolving surface requires robust, quantifiable metrics
- Focus on understanding interactions from initial shock emergence to reshock events
- The goal of this work is to characterize the expanding product gases as a function of time and height of burst

Fireball dynamics in free-air explosions provide foundational insights

- Previous experiments characterized the fireball surface in free-air explosions
- Documented time-dependent growth, interface evolution, and mixing zone properties
- This baseline enables the study of ground effects by comparing free-air results with near-ground fireball dynamics



Experimental setup for free-air explosion tests (Source: Peterson, 2023, Figure 2.16)

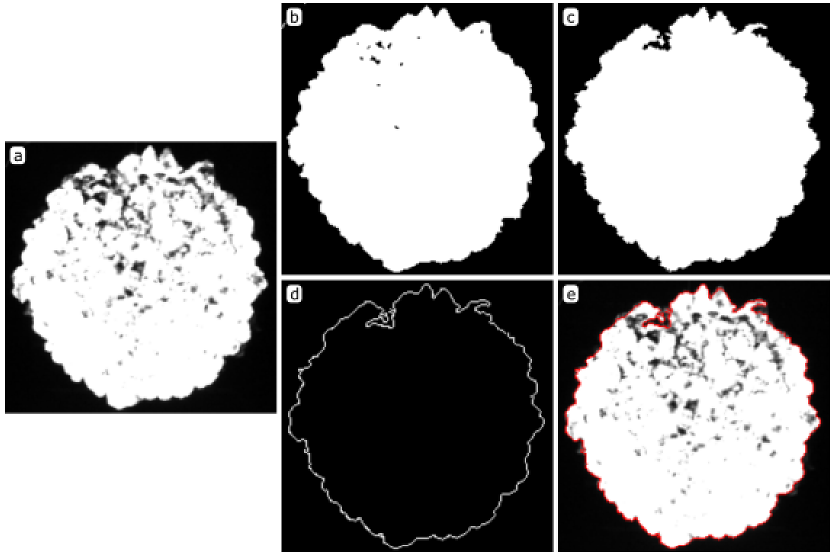
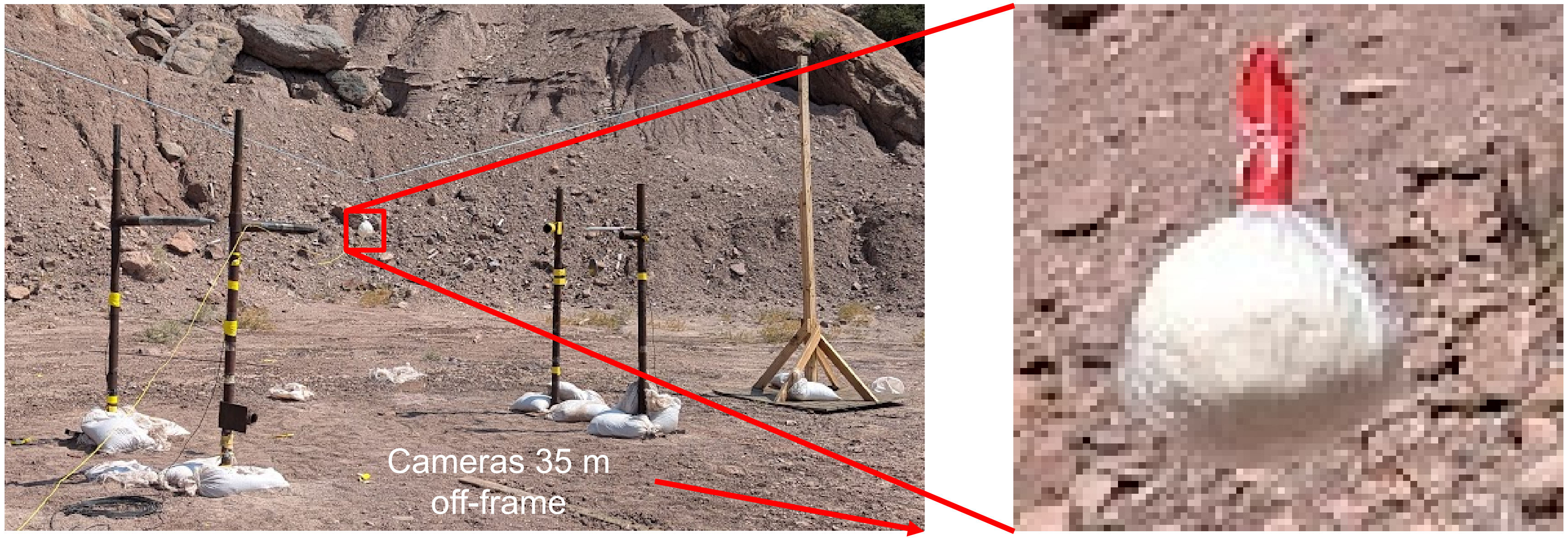
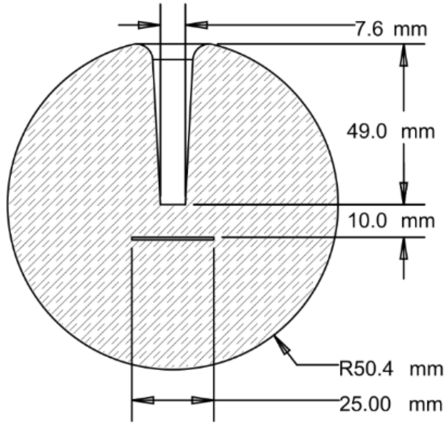


Image processing steps for fireball edge extraction (Source: Peterson, 2023, Figure 2.17)

Peterson. Christian. *Characterization of the Interface Between Detonation Product Gases and Ambient Air in an Explosion.* New Mexico Tech, 2023

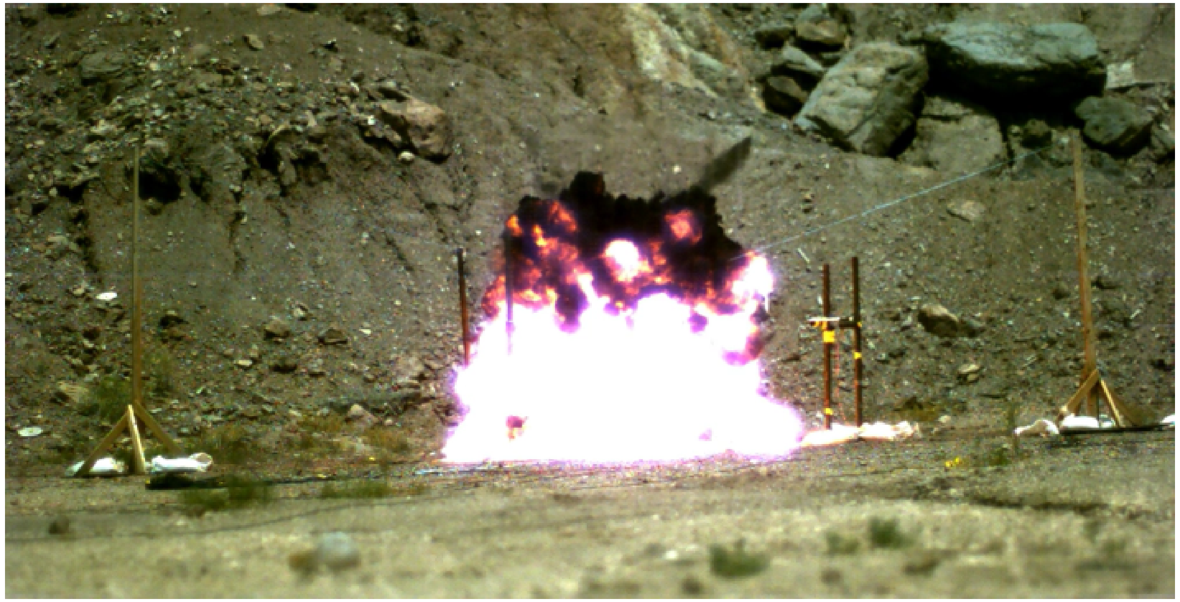
A test series was conducted here with molded spherical C4 charges to study the impact of height of burst on the evolution of the gas cloud





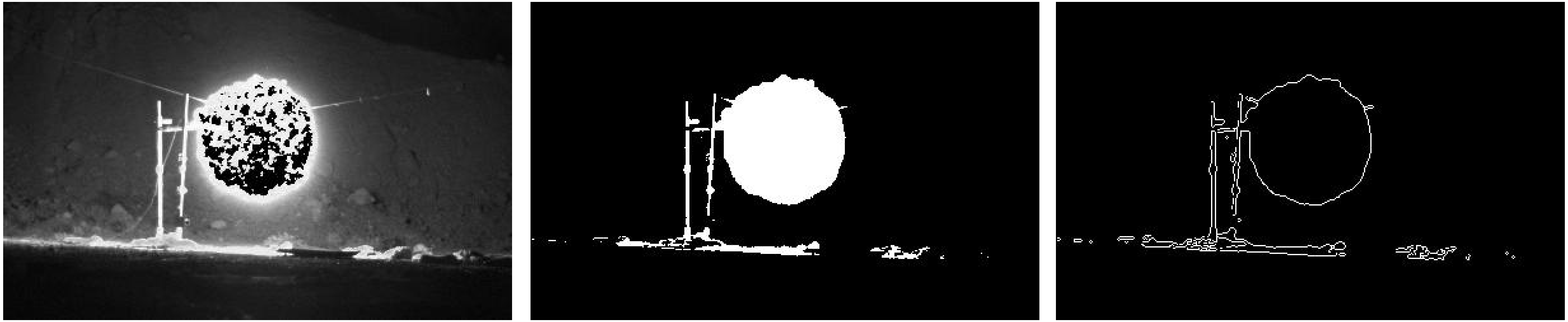
- Three cameras were used, each operating at a different frame rate: 200 kHz, 50 kHz, and 35 kHz
- Captured the evolution of the fireball’s surface, focusing on the moment just before the shock wave emergence and extending observations to include reshock phenomena

Reshock effects vary with burst height near the ground



- Higher burst heights result in a slower acceleration as the shock front passes through, causing a brief reshock event followed by turbulent mixing
- Lower burst heights lead to a faster, more intense upward and outward acceleration of the fireball

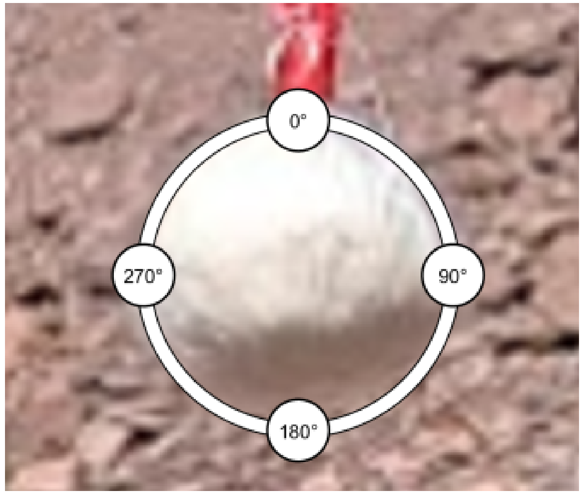
Image processing was used to isolate critical features in the explosive event imagery

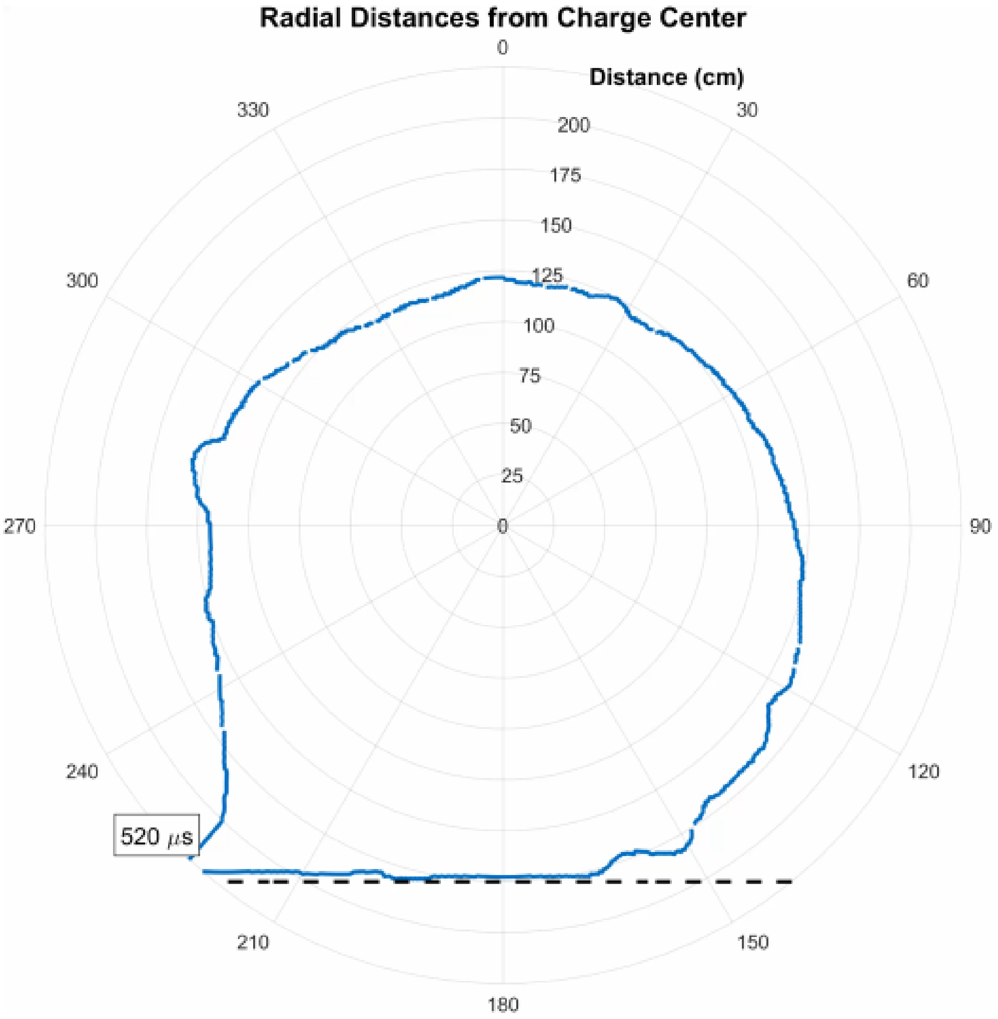


- **Background subtraction**: Highlights key features, including shock interactions
- **Edge detection (Canny method)**: Precisely identifies fireball and gas cloud contours
- **Morphological enhancements**: Cleans and extracts the fireball's projected boundary from complex visual data

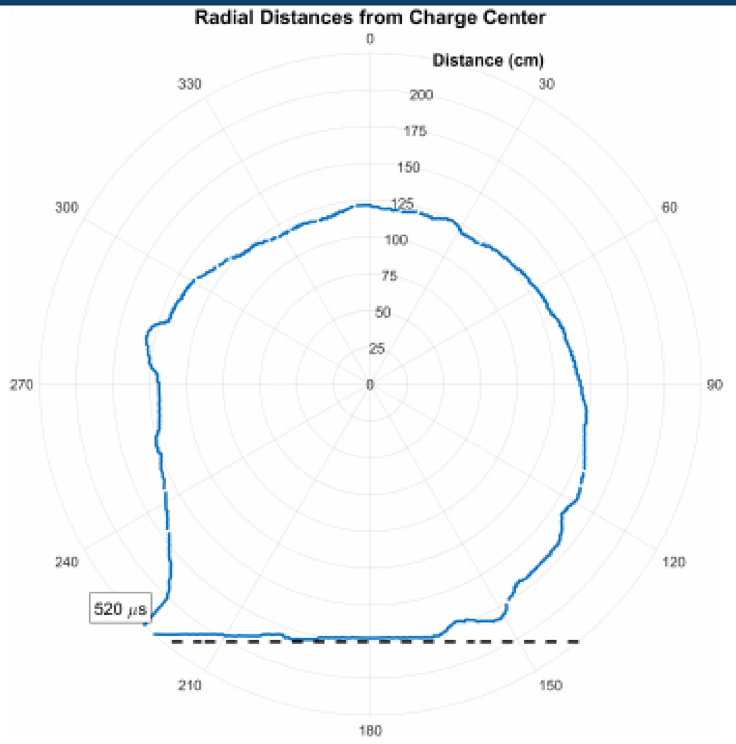
The fireball surface location is extracted as a function of time from each high-speed image

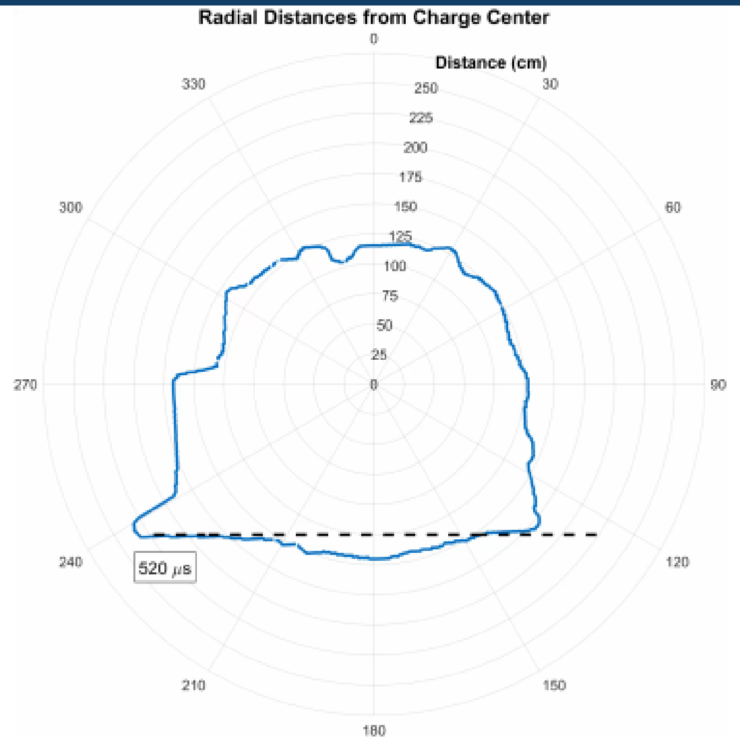
- Both Rayleigh-Taylor and Richtmyer-Meshkov effects influence initial expansion, with Richtmyer-Meshkov dominating during the reshock phase
- Time-resolved radius observations track growth stages and surface evolution over time





Examining reshock dynamics in the expanding fireball

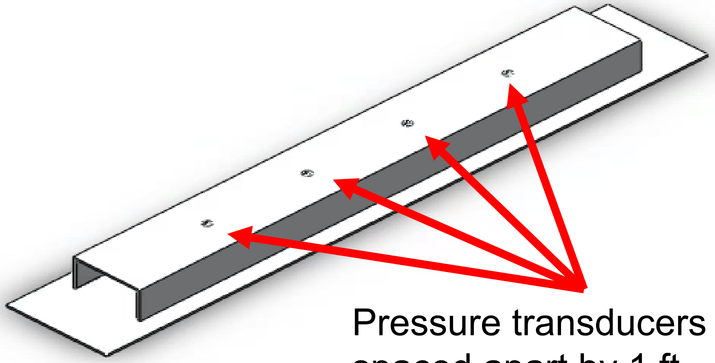




- Higher heights: weaker reshock and smoother surface evolution
- Lower heights: ground interactions amplify reshock, driving the transition from linear to nonlinear mixing

Surface-embedded pressure transducer setup for ground-level shock wave measurement

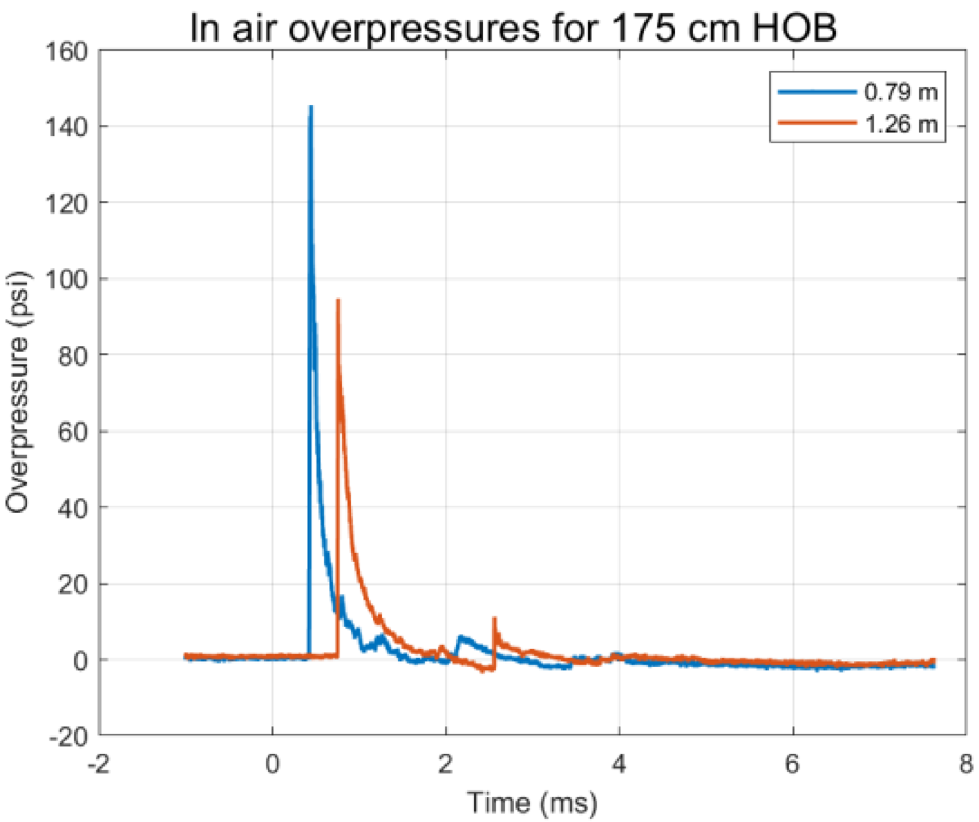
Free-air pressure transducers in line with the charge

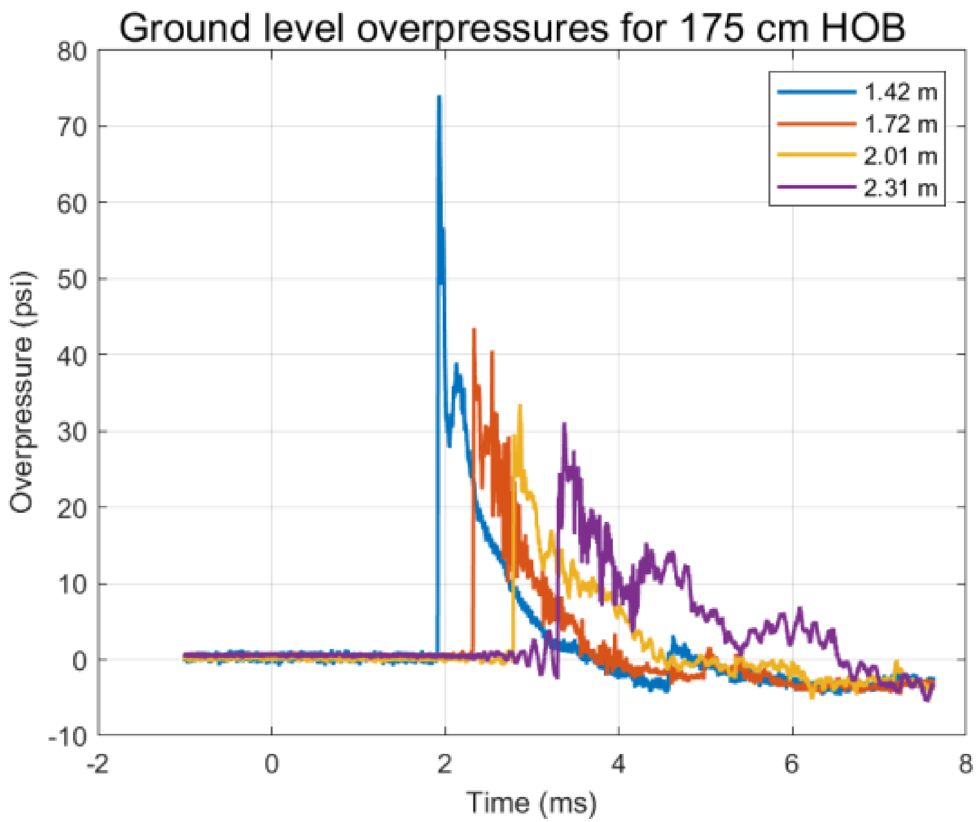


Pressure transducers spaced apart by 1 ft

- Pressure transducers embedded in a custom in-ground box recorded ground-level pressure
- Ground-level data helps to understand shock wave impact and pressure distribution across the surface

Charge-height aligned pressure measurement for shock wave propagation measurement

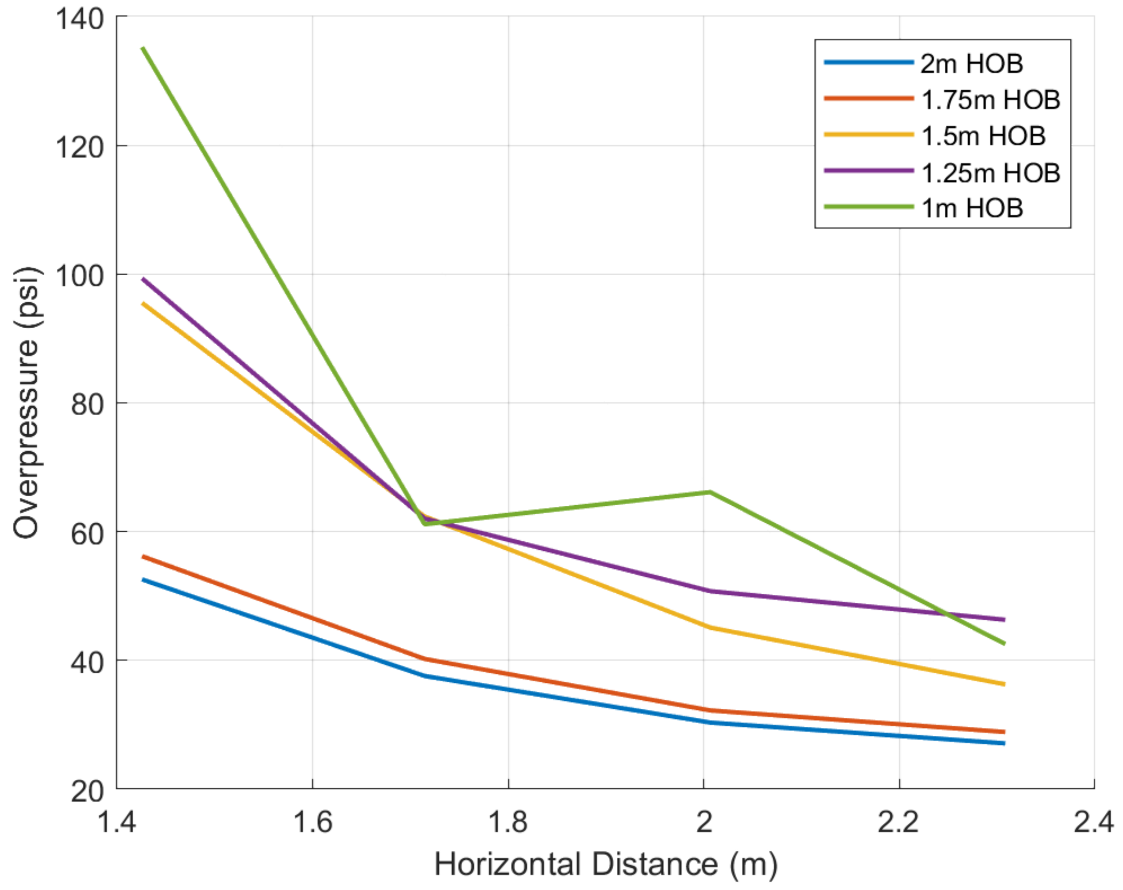




- Pressure transducers at the explosive charge height measured shock waves directly
- Comparing in-air and ground-level traces provided a way to determine where the reflected shock is in relation to the center of the charge once the fireball has engulfed the pressure transducers

Ground-level overpressure as a function of height of burst

- Data collected during experimentation shows the effect the fireball has on reflected shock pressure
- Large pressure differences between when the fireball is in contact with the ground and when it is only in air



Initial findings indicate an influence of burst height on fireball development and evolution, as well as ground shock intensity and distribution

- Burst height directly influences the symmetry and peak intensity of the fireball
- Ground shock characteristics, such as peak pressure and propagation speed, vary significantly with burst height

Questions

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