Experimental Characterization and Modeling of 5.56-mm Ammunition

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Motivation

- **Objective -** *develop state-of-the-art physics based interior ballistics (IB) predictive capability for small-caliber ammunition*

- **Leverage IB knowledge gained from large-caliber arena**
  - ARL-NGEN IB modeling capability in-hand (primer model not available)
  - Develop detailed primer (Primer No. 41) model to be coupled w/ NGEN code

- **Capability enables:**
  - Better understanding of current ammunition
  - Analysis of variations in performance
  - Optimization of components (primer, propellant, etc)
  - Comparison of alternative primers

PMMAS Funded Effort

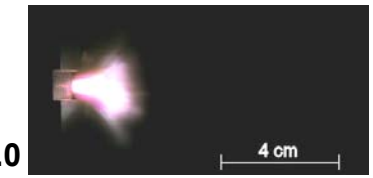
Status

- Initial phase of experimental primer and ignition system studies complete
- Initial results with ARL-NGEN code/gas only primer available
- Primer model developed and being validated
- Coupling new primer model with ARL-NGEN code in progress

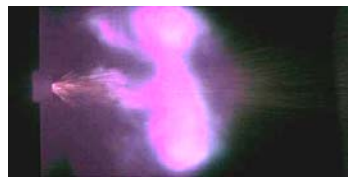
No. 41 Primer: Open-Air Studies

- **High speed digital video (38000+ fps)**
  - Particle size and velocity
  - Relative brisance

1st Light Time=0.0



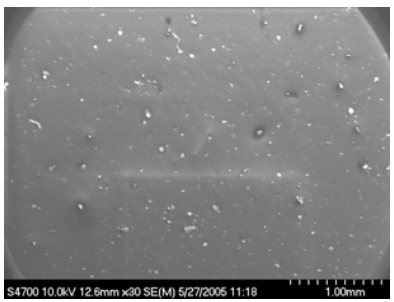
Time = 540 μs



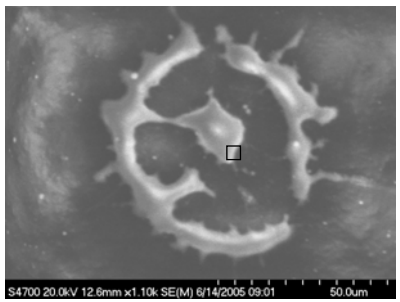
Time = 1080 μs

- **Witness plate studies**
  - Particle composition and size distribution

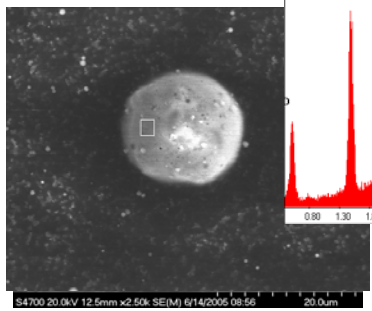
FE-SEM Images



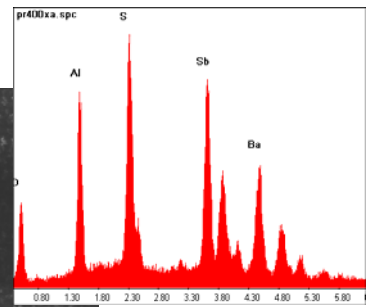
30X



1100X



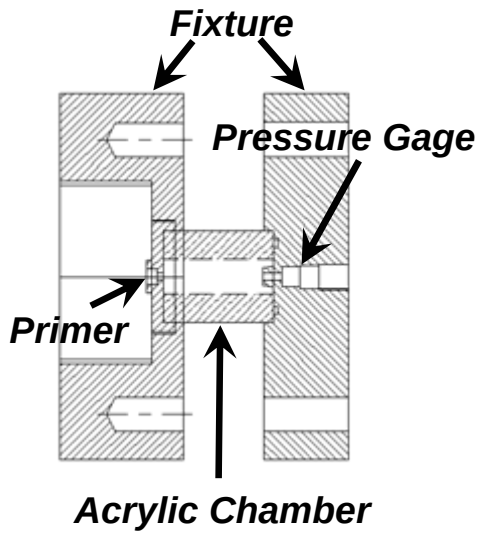
2500X

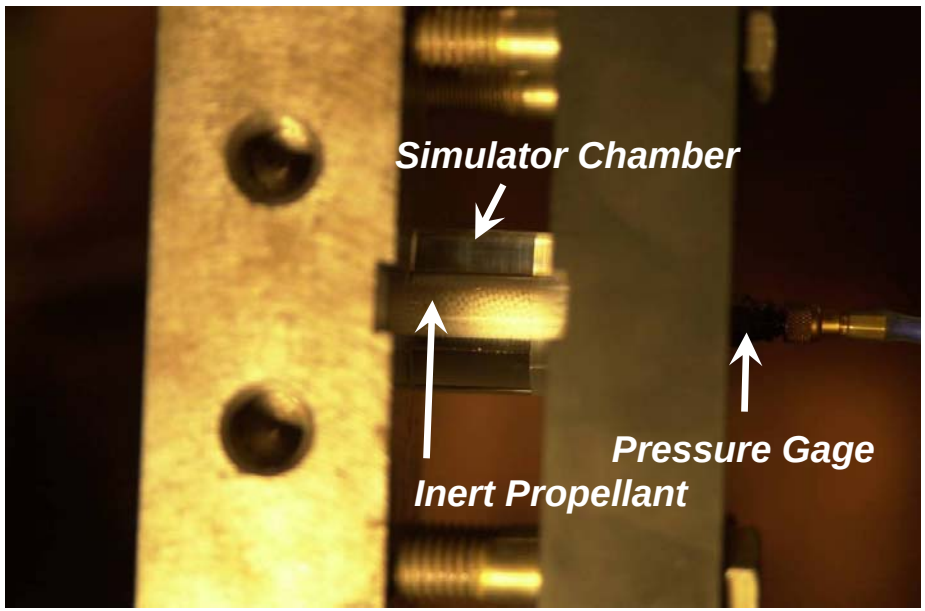


EDS Spectrum

5.56-mm Ballistic Simulator - setup

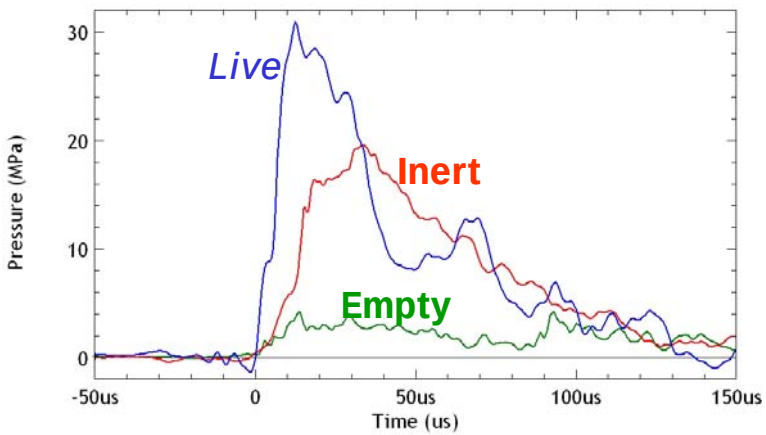
- Simulates 5.56-mm chamber volume and geometry
- Transparent chamber allows for visualization of primer output (flamespreading)
- Measure pressure-time response



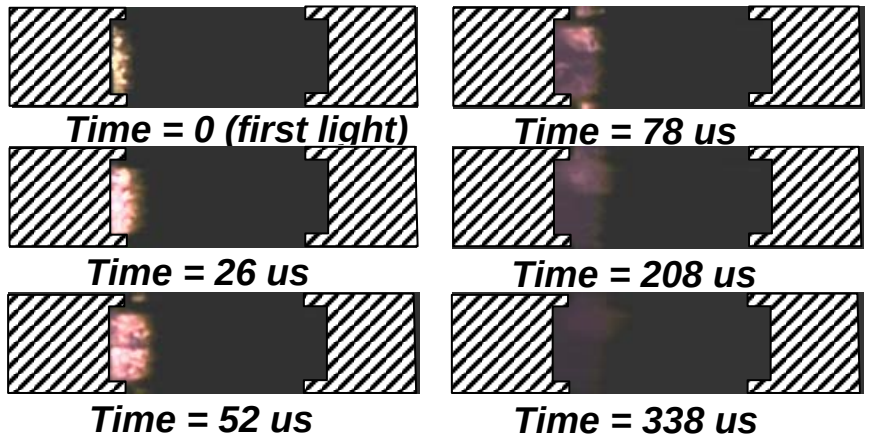


Typical Simulator Results

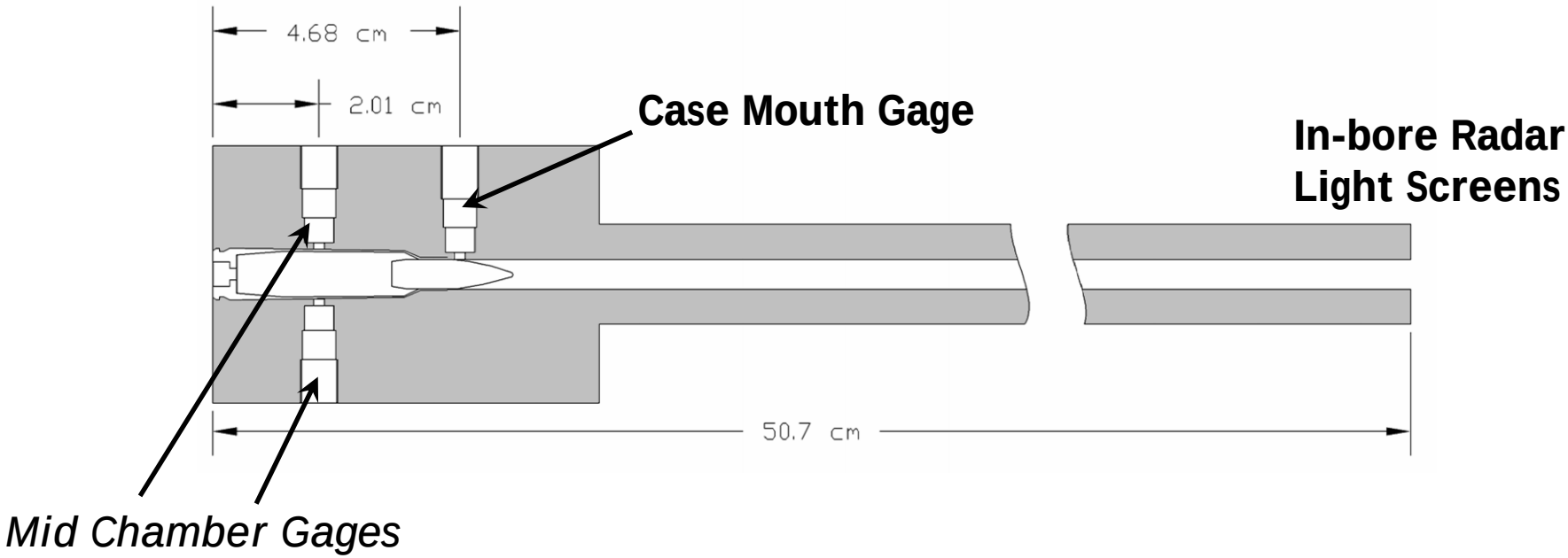
Typical Simulator Pressure-Time Curves



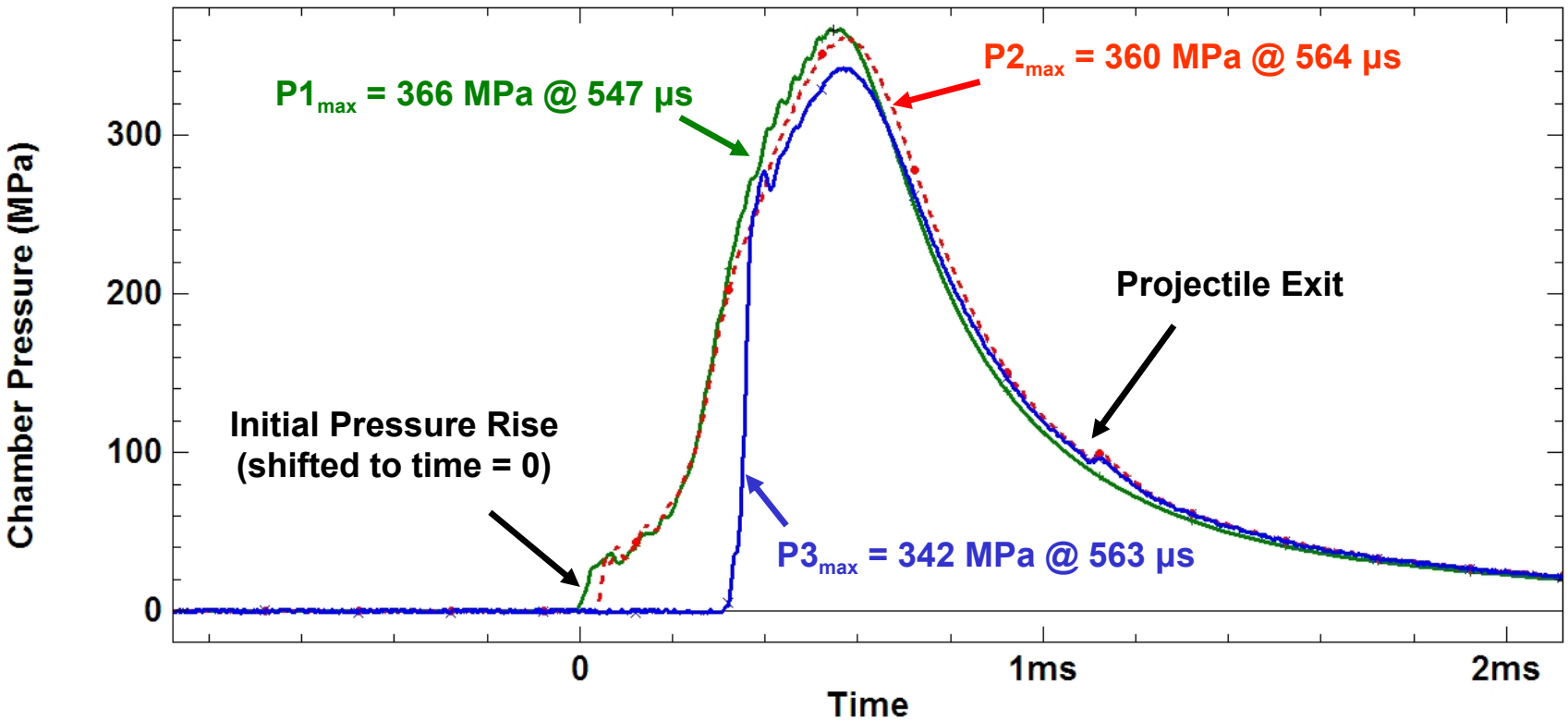
Typical Flamespreading for Live Propellant Simulator



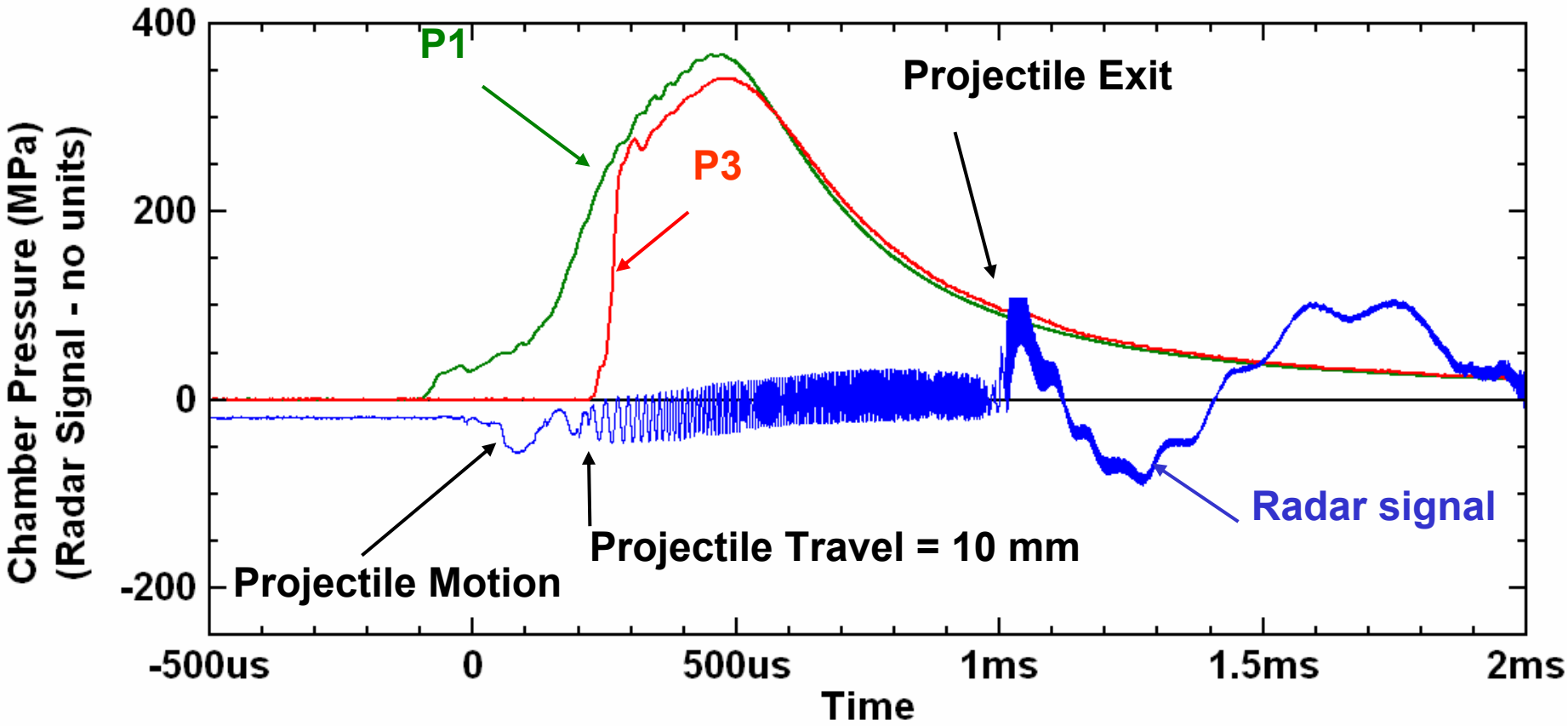
Gun Tests


4.68 cm
2.01 cm
Case Mouth Gage
In-bore Radar
Light Screens
50.7 cm
Mid Chamber Gages

Gun Pressure Data (Test 065)



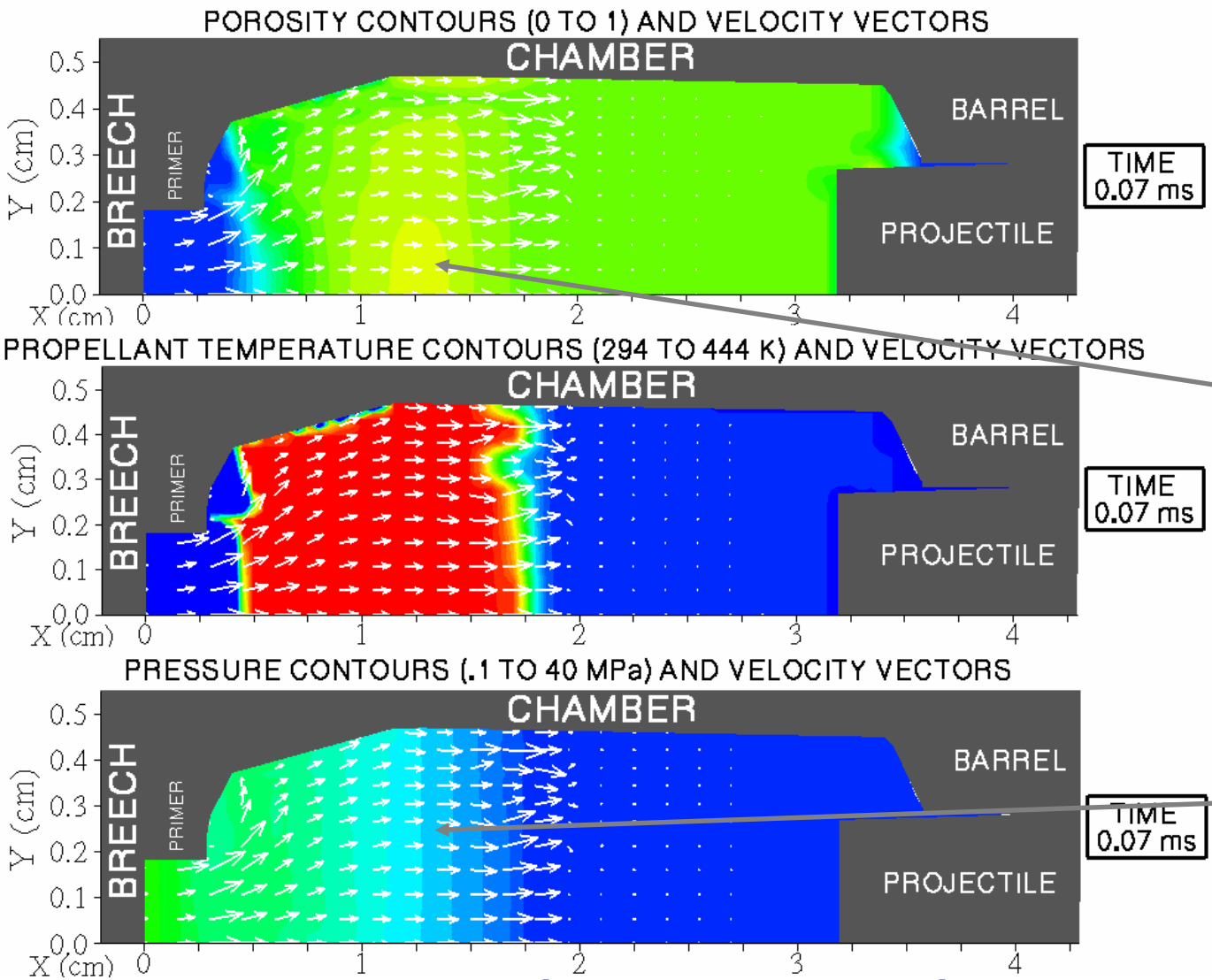
Pressure and Radar Data (Test 065)



Modeling motivation

- Experiments show that particles are released into the gun chamber by the igniter in a random manner. (Williams et al. 2005)
- IB models treat primers, flash tubes, and igniter tubes as look-up tables made up entirely of hot gases.
- Hot particles contribute to propellant ignition.
- With multidimensional, multiphase IB codes (NGEN) a two-phase stochastic primer model is an important step forward.

ARL-NGEN IB Code Simulation of Ignition and Flamespreading in 5.56 Ammunition



Primer: gas output only

These snapshots of the conditions within the ammunition case are at 0.07 ms from primer function (50% to cutoff).

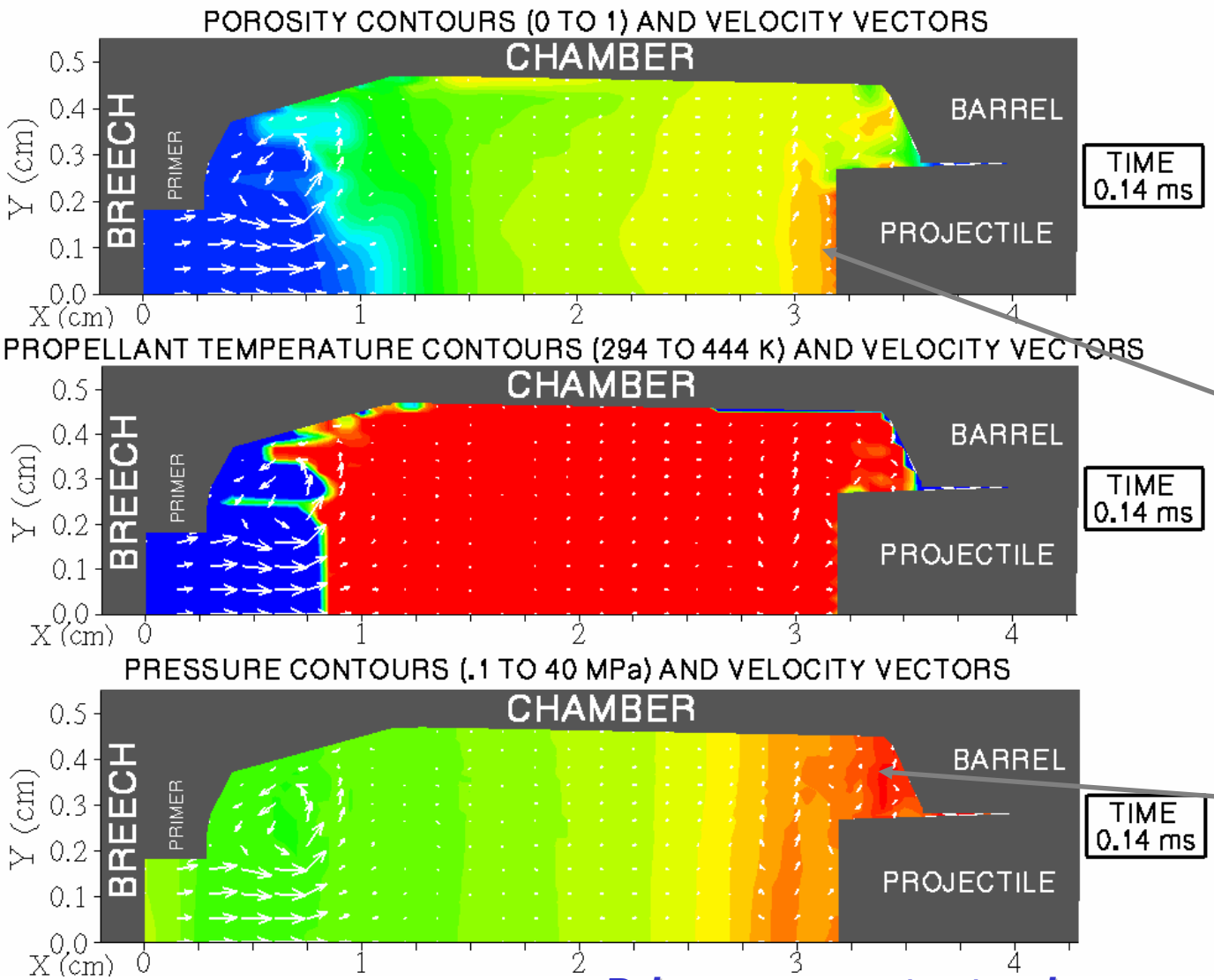
The map of porosity shows movement of propellant from primer face & some compaction of propellant in the case.

The map of propellant temperature shows ignited propellant (red color) and 50% bed flamespreading.

The map of gas pressure contours shows 2D gas flow near the primer and a nearly 1D pressure wave in the case.

Note: Each figure enlarged by 8x in the radial direction for clarity.

ARL-NGEN IB Code Simulation of Ignition and Flamespreading in 5.56 Ammunition



Primer: gas output only

These snapshots of the conditions within the ammunition case are at 0.14 ms from primer function (near cutoff).

The map of porosity shows movement of propellant from primer face and significant compaction of propellant against the projectile.

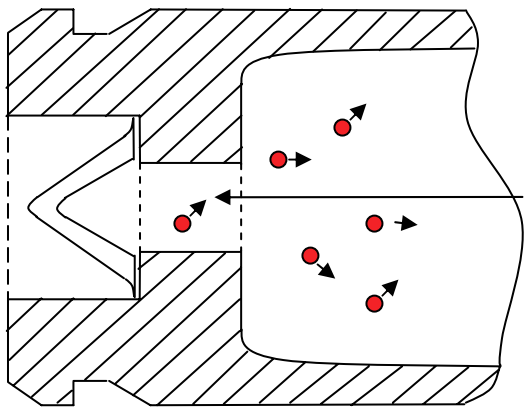
The map of propellant temperature shows ignited propellant (red color) and full bed flamespreading.

The map of gas pressure contours shows the occurence of negative ΔP.

Note: Each figure enlarged by 8x in the radial direction for clarity.

Primer Output and Modeling

- Particles are being transported (whipped around) in primer tube primarily by hot, turbulent gas flow.
- Desire to accurately model gas and particle generation at junction with chamber.
- Primer output is fed into NGEN which transports igniter particles into main gun charge for ignition modeling.



Hot gases and particles exit out of the primer hole

Summary

- Experimental characterization provides insight into current No. 41 primer performance in 5.56-mm ammunition
  - primer output
  - flamespreading
  - pressure-time-velocity history
  - propellant bed compaction
- State-of-the-art primer model incorporating gas and particle flow developed and poised for coupling with ARL-NGEN code
- Multi-phase primer model is utilizing some experimental results for validation
- ARL-NGEN code with gas only primer is consistent with experimental results