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Additional Calibration Data For Large Scale and Expanded Large Scale Gap Tests using a Photonic Doppler Velocimeter

ARL

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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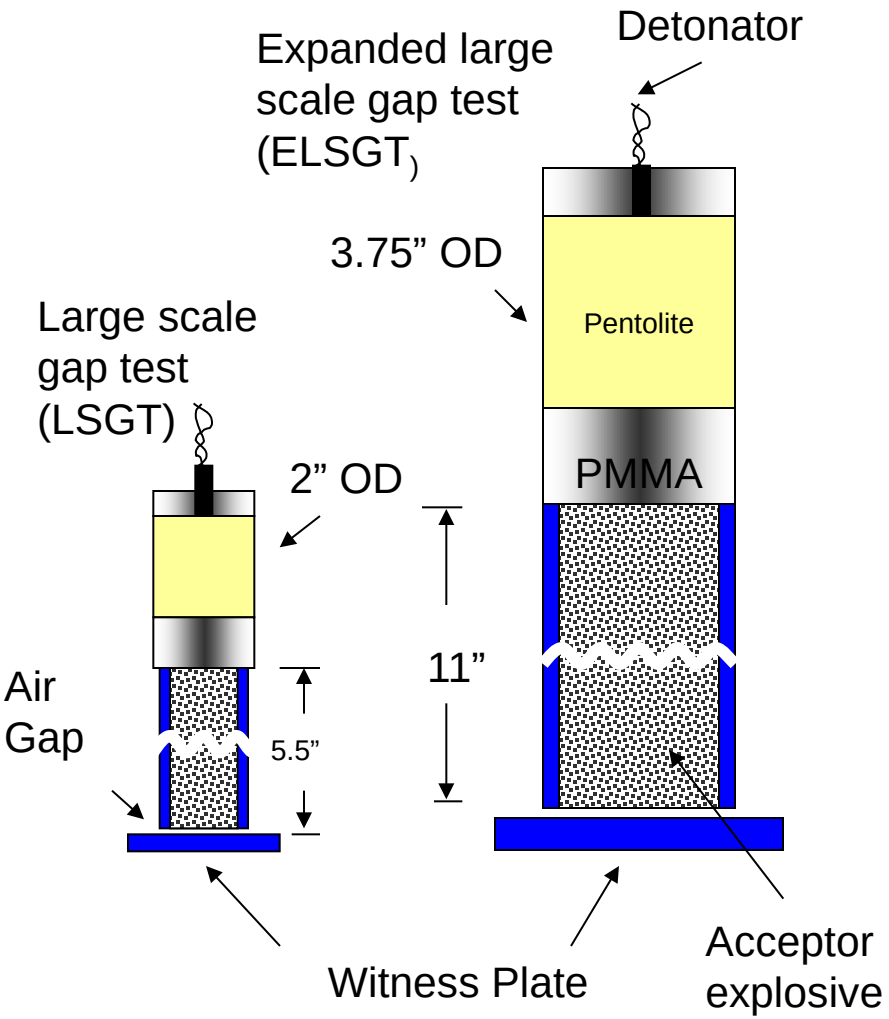
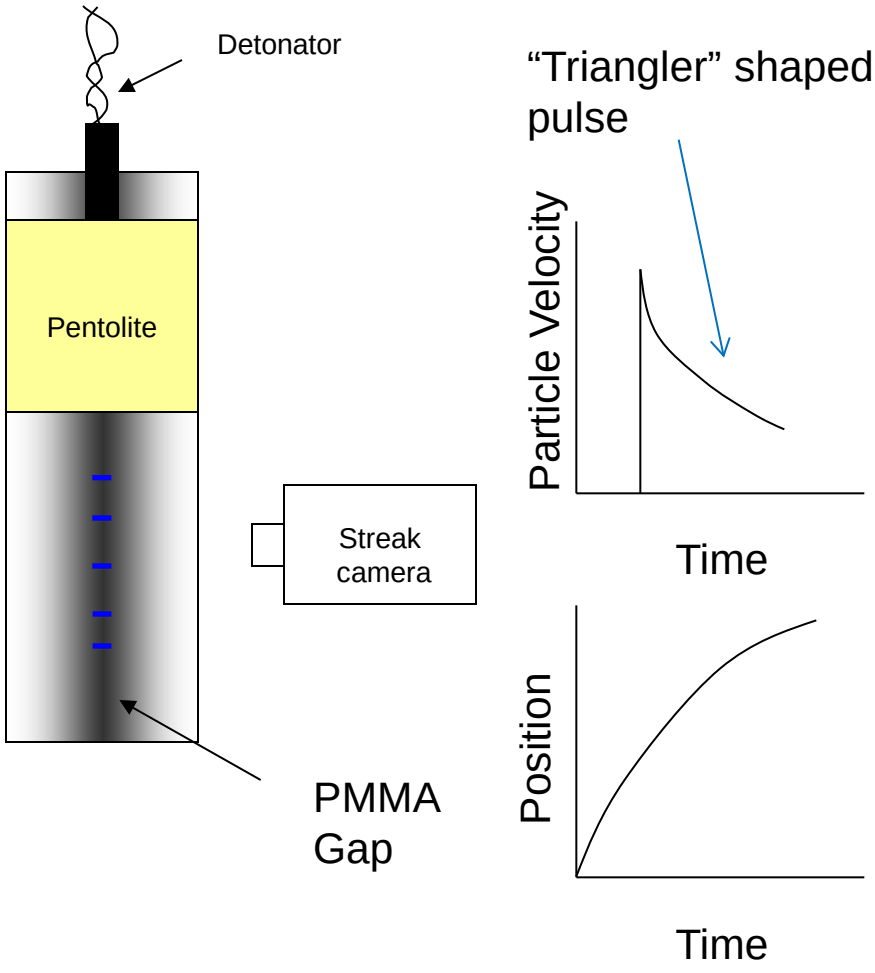
Background – Features of gap tests



- Commonly performed to rank the sensitivity of most DOD explosives
- When embedded gauge or “POP Plot” data not available, used to determine reactive-rate model parameters
- PMMA gap thickness adjusted until “GO-NO GO” point reached
  - Gap thickness recorded and converted by means of a calibration curve to peak PMMA pressure before it enters the gap
- “GO” ≡ clean hole in plate
- Pressure & Energy in gap will decrease due to:
  - axial attenuation at small gaps
  - axial and radial attenuation at large gaps

Background – Gap Testing



1. For LSGT, particle velocity measured by electromagnetic particle velocity gauges positioned at multiple locations along gap (Erkman et al. – 1973)
2. For ELSGT, position-time data obtained using a streak camera and data is numerically differentiated to obtain shock velocity-time data (Tasker and Baker - 1992)
3. For both methods, Rankine-Hugoniot jump conditions used to obtain pressure-distance curves with a two-region shock velocity- particle velocity relationship

For u = > 536 m/sec

$$U = 2.561 + 1.595\ u$$

For u < 536 m/sec

$$U = 2.7228 + 4.0667\,u - 10.9051u^2 + 10.6912\,u^3$$

Background

- Limitations of existing gap test calibration data
  - 2D strain condition and wave shape is “triangular” shaped
  - Existing calibrations only give peak pressure as function of gap length
    - Peak pressure is a poor metric of shock reactivity – a better metric is energy fluence

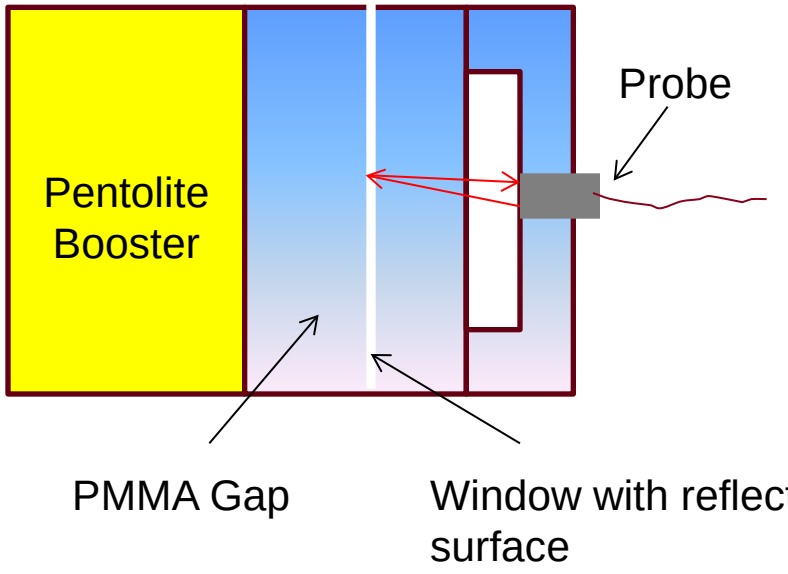
$$E = \int_{t_o}^{t_1} P \bullet u \, \partial t$$

    - A validation metric would be closeness of simulated and experimental u-t curves
  - Limited pressure or particle velocity time histories are available
    - No published profiles in Erkman et al; data for LSGT arrangement used in present gap tests
    - Limited PVDF [poly(vinylideine fluoride)] pressure gauge data for LSGT (results likely affected by 2D strain)
  - Calibrations of LSGT and ELSGT were done using different instrumentation

Objective and Approach

- **Objective**
  - Obtain *in situ* particle velocity histories for both the LSGT and ELSGT using a photonic Doppler velocimeter (PDV)
  - Compare our data with the previous calibrations
- **Approach**
  - Obtain particle velocity histories for the LSGT for gaps ½, 1, 1-½, and 2 inch thick
  - Obtain particle velocity histories for the ELSGT at scaled gap thickness (1.875 * LSGT gap thickness)

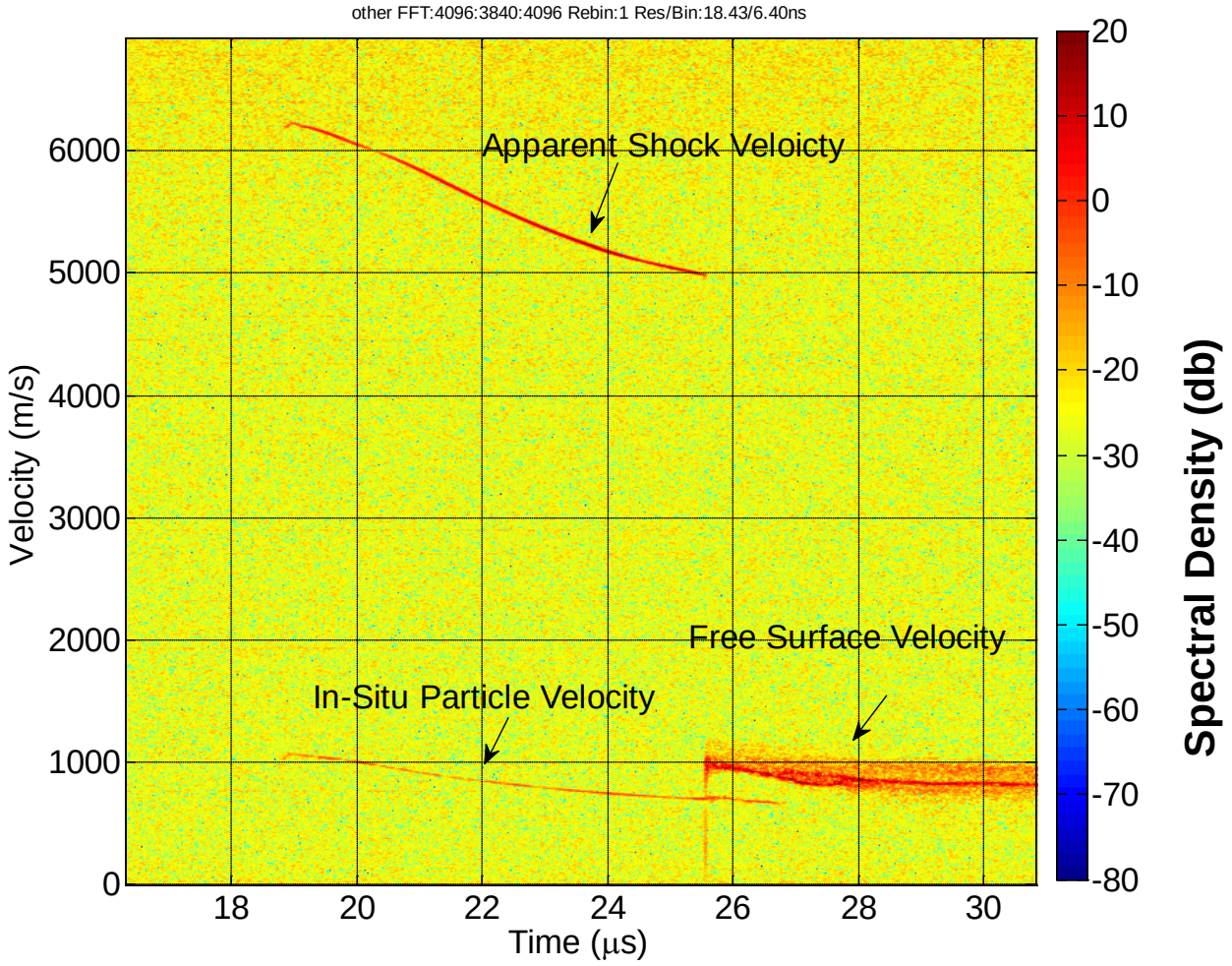
Test Setup



ARL PDV System

- 4 channel “conventional” PDV system made by Third Millennium Engineering of Plano, TX (0.5 W per channel max)
- Agilent 16 GHz oscilloscope
- Collimated probes Model # 1CL15A070LCD01 from AC Photonics
- Reflecting surface for most shots was “White Paint” - others used the dull side of aluminum “kitchen foil”
- No window correction for in-situ histories
- PMMA used in test was the same as that used in gap tests at ARL. (manufacturer unknown)

PDV has the ability to acquire much data from a single experiment

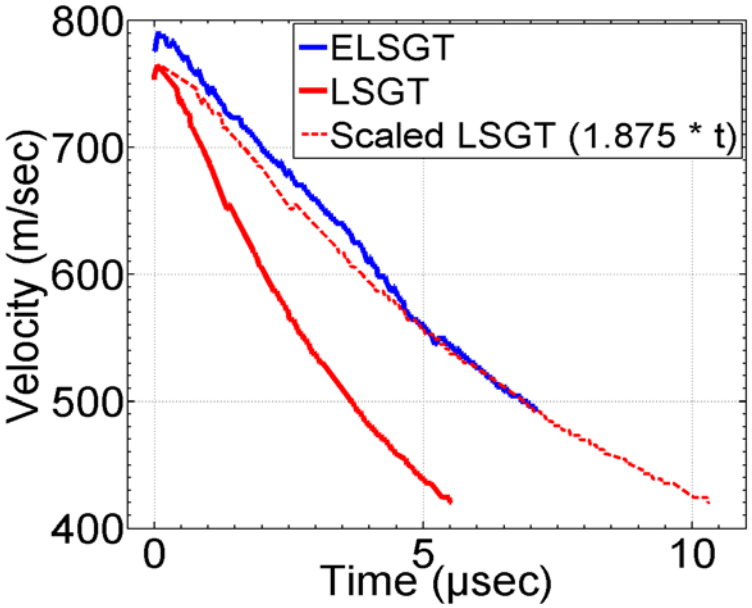


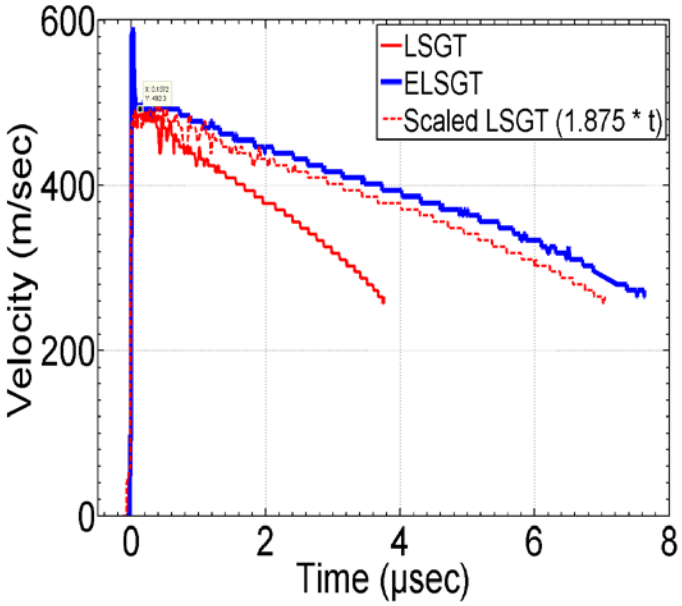
All three velocity histories will be useful to validate hydrocode simulations

Shock velocity records similar to those found by Mercier et al. (2011 APS) in heavy water

Did not always get all three records on every shot

Example of Particle Velocity Traces Obtained

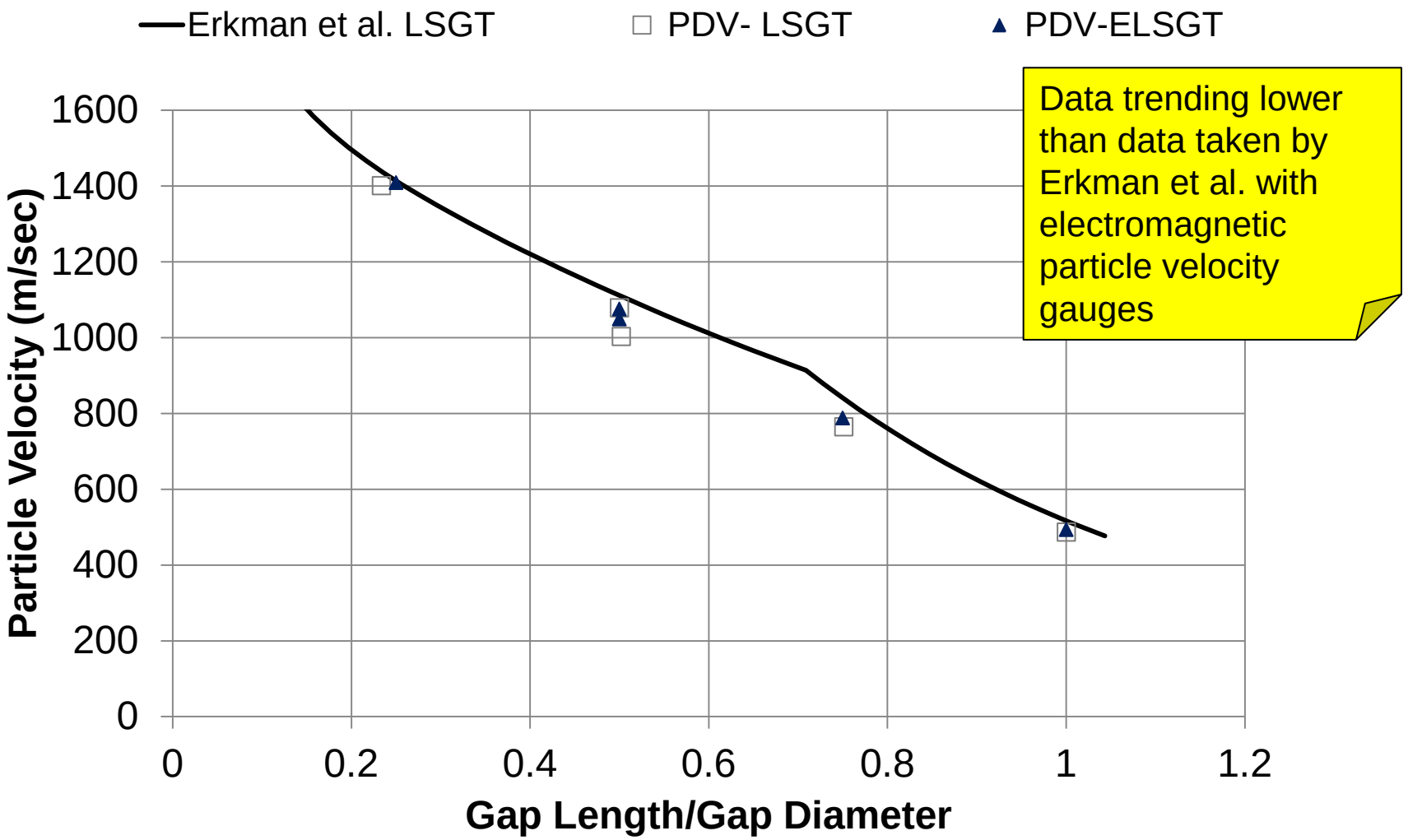




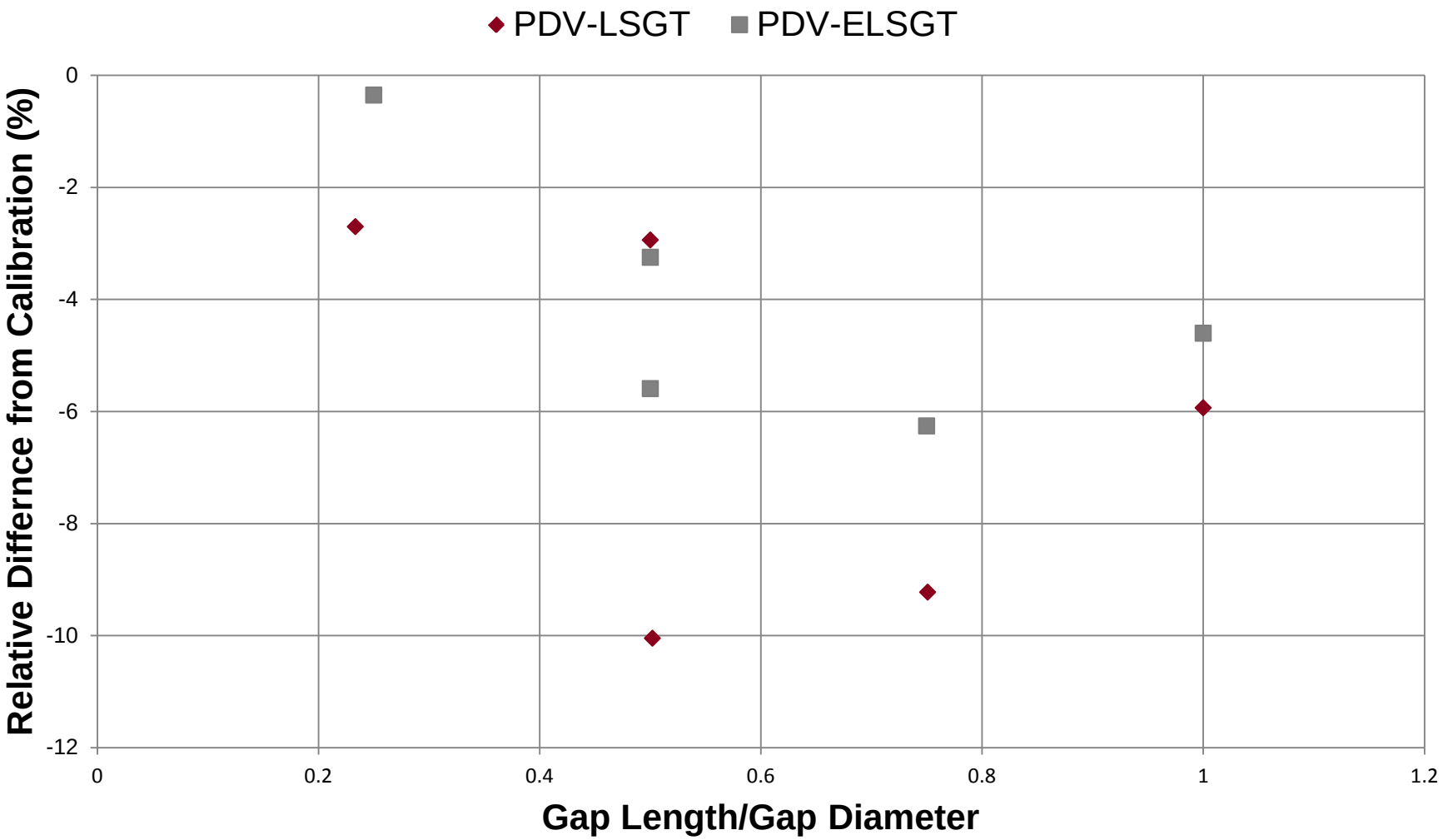
LSGT Gap 1.502”, 38.15 mm (150 cards)
ELSGT Gap 2.813”, 71.44 mm
Scale Factor 1.87

LSGT Gap 2.000”, 50.8 mm” (200 cards)
ELSGT Gap 1.875”, 95.25 mm
Scale Factor 1.88

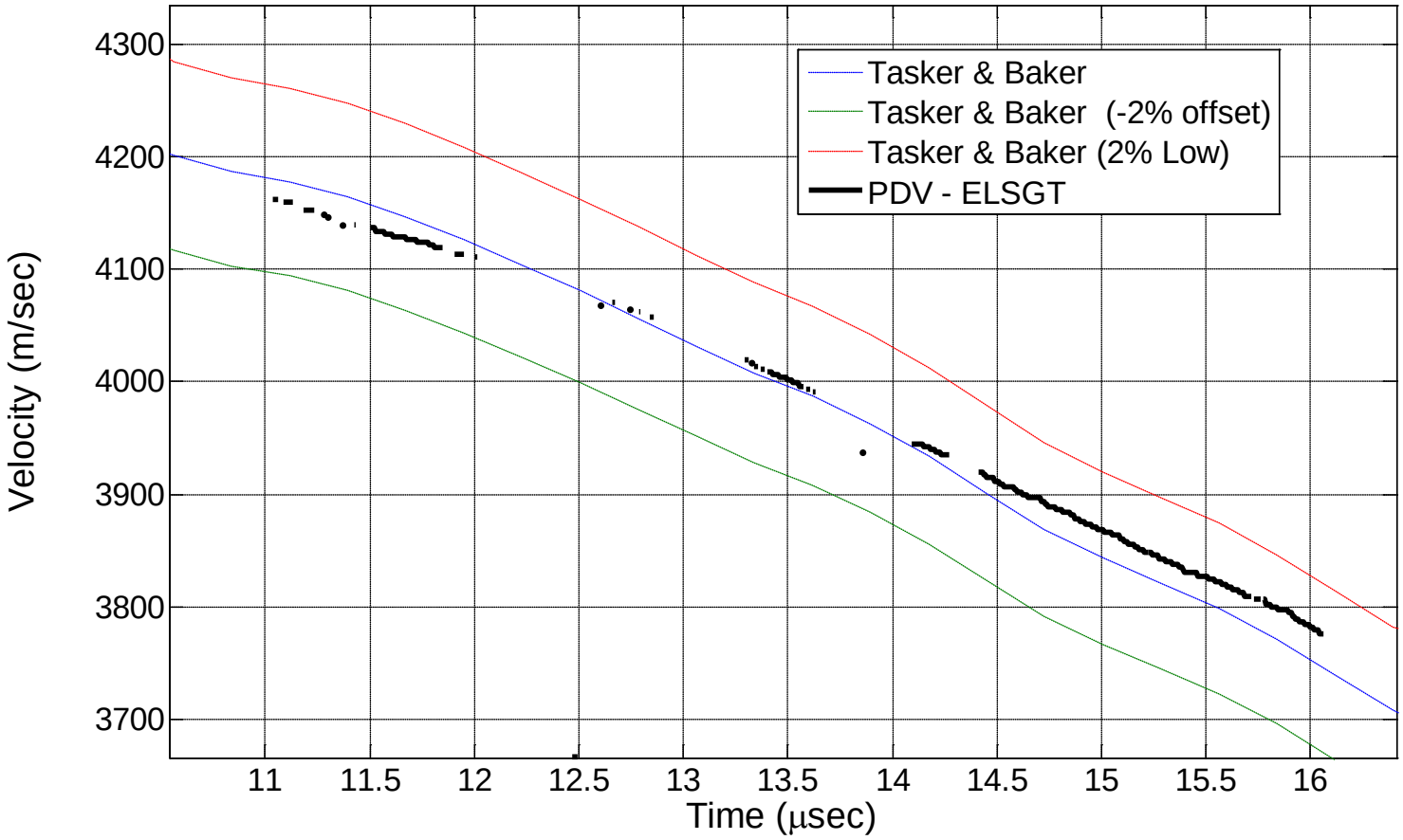
Peak Particle Velocities



Data shows velocities trending below Erkman et al. calibration

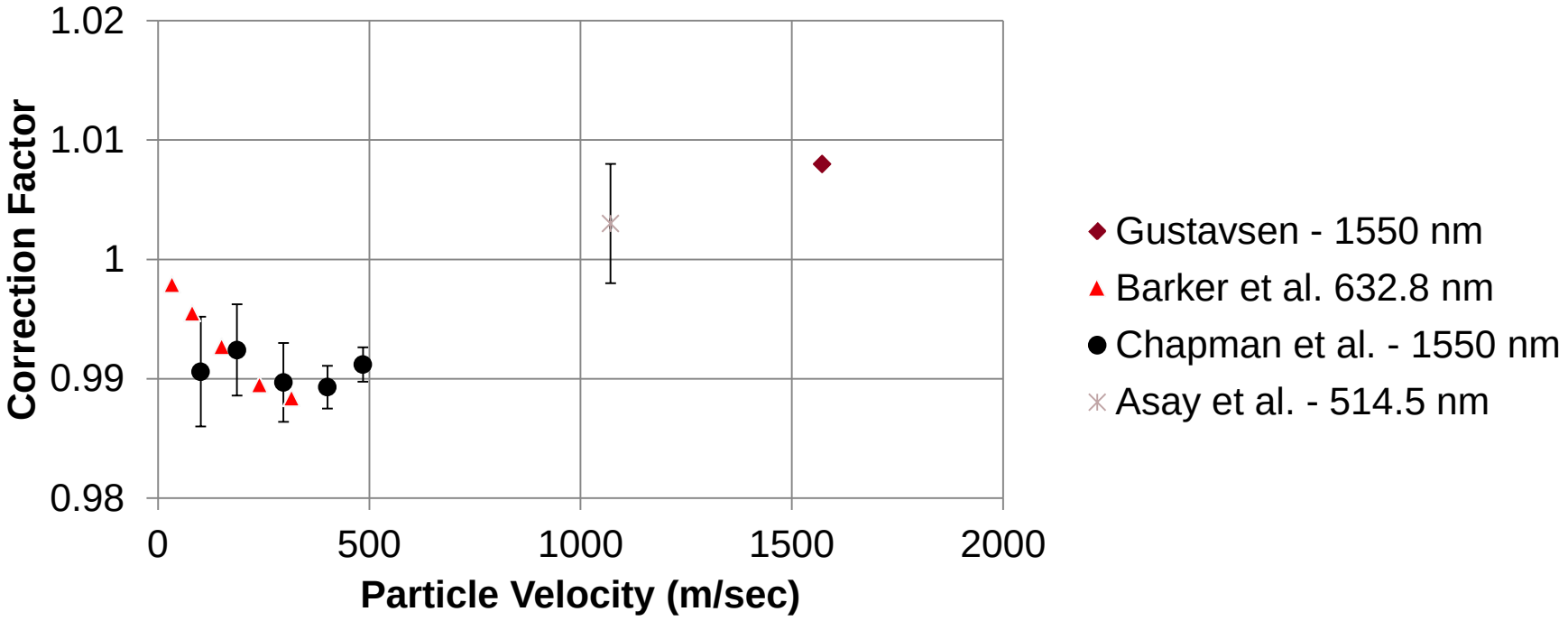


Shock velocity data in agreement with data of Tasker & Baker



Some Features of the PDV Experiments

- Limited data available on the window correction for PMMA for velocities used in this study

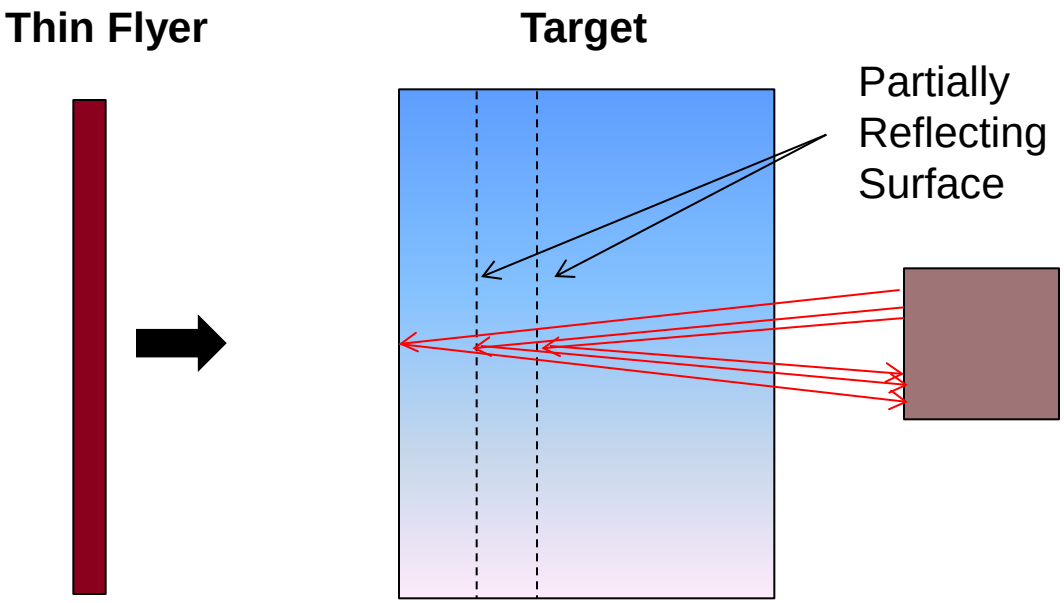


References – Gustavsen PDV Workshop, Barker, L. M., J. Appl. Phys., 41, 4208-4226 (1970), Chapman, D. J., D. E., Eakins, D. M. Williamson, W. Proud, AIP Conf. Proc. 1426, 442 (2012); Asay. J.R., and Hayes, D.B., J. Appl. Phys., 46, 4789 (1975).

Some Features of the PDV Experiments

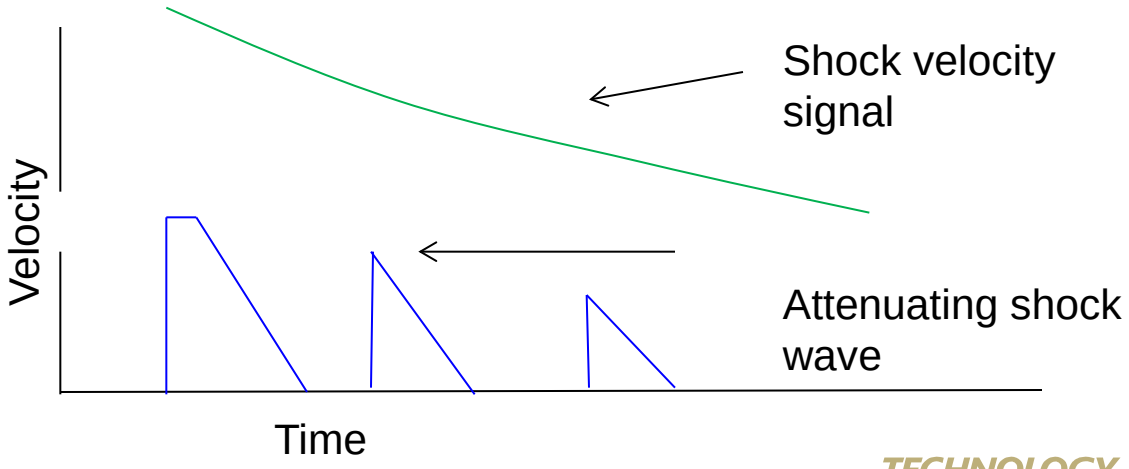
- Is ambient index of refraction (η) appropriate for converting apparent shock velocity to real shock velocity?
  - Some flyer plate experiments would be useful where shock velocity measured by PDV and another technique
- Some signals were weak - light losses are due to:
  - Reflection at PMMA free surface
  - Reflection off of interface due to the shock front
  - Attenuation of 1550 nm light in PMMA

Multiple Hugoniot Points from a Gun Experiment?



Similar to approach of Erkman et al.

U and peak u known for each interface so Hugoniot can be determined for three points



Suggested Future Work

- More replicate experiments and additional points at different gap thicknesses
- Obtain off-axis u-t histories
- Hydrocode simulations to determine how well simulations with existing material models can replicate *in situ*, free-surface and shock wave-time histories
- Determine accuracy
  - Perform an in-depth error analysis
  - Perform side-by-side experiments with a VISAR

Conclusion

- PDV provided three types of data (shock, free surface, and particle velocity histories) for both the ELSGT and LSGT
  - This data will assist in validation of hydrocode simulations of the ELSGT and LSGT

Acknowledgements

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  - Patrick Marine, Kevin McNesby
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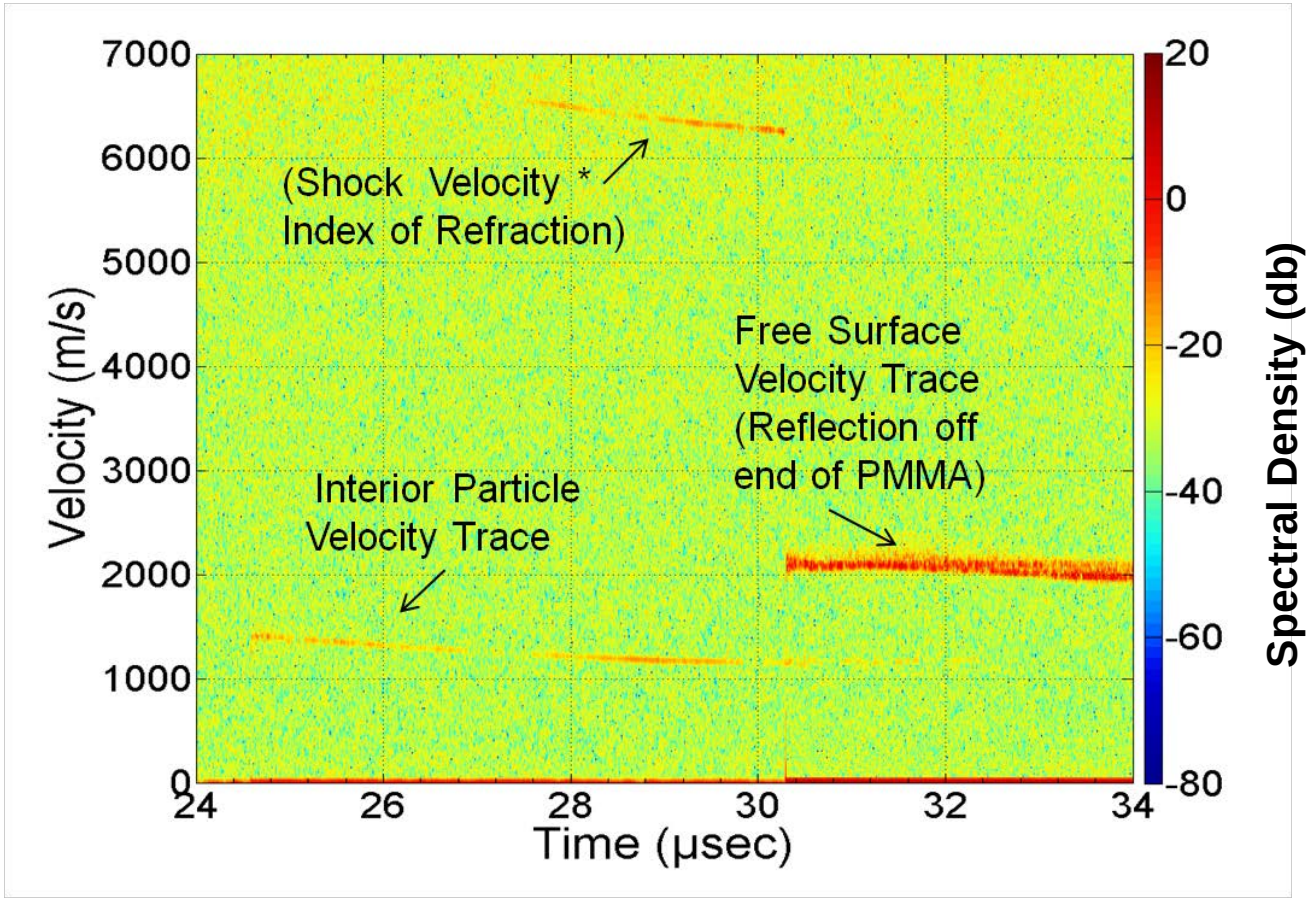
  - Sandia
    - Dan Dolan
  - NSWC IHD
    - Robert Hutcheson
  - Dynamic Sciences Incorporated
    - Vincent Boyle, Douglas Kooker
  - ARL
    - Matthew Biss

- Extra Slides

PDV has the ability to acquire much data from a single experiment



All three velocity histories will be useful to validate hydrocode simulations

In many cases the signals were weak