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Explosively Driven Flyer Plate Velocity Time Profiles Transformed to Internal Explosive Pressure

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PRESENTED BY

Marcus A. Chavez

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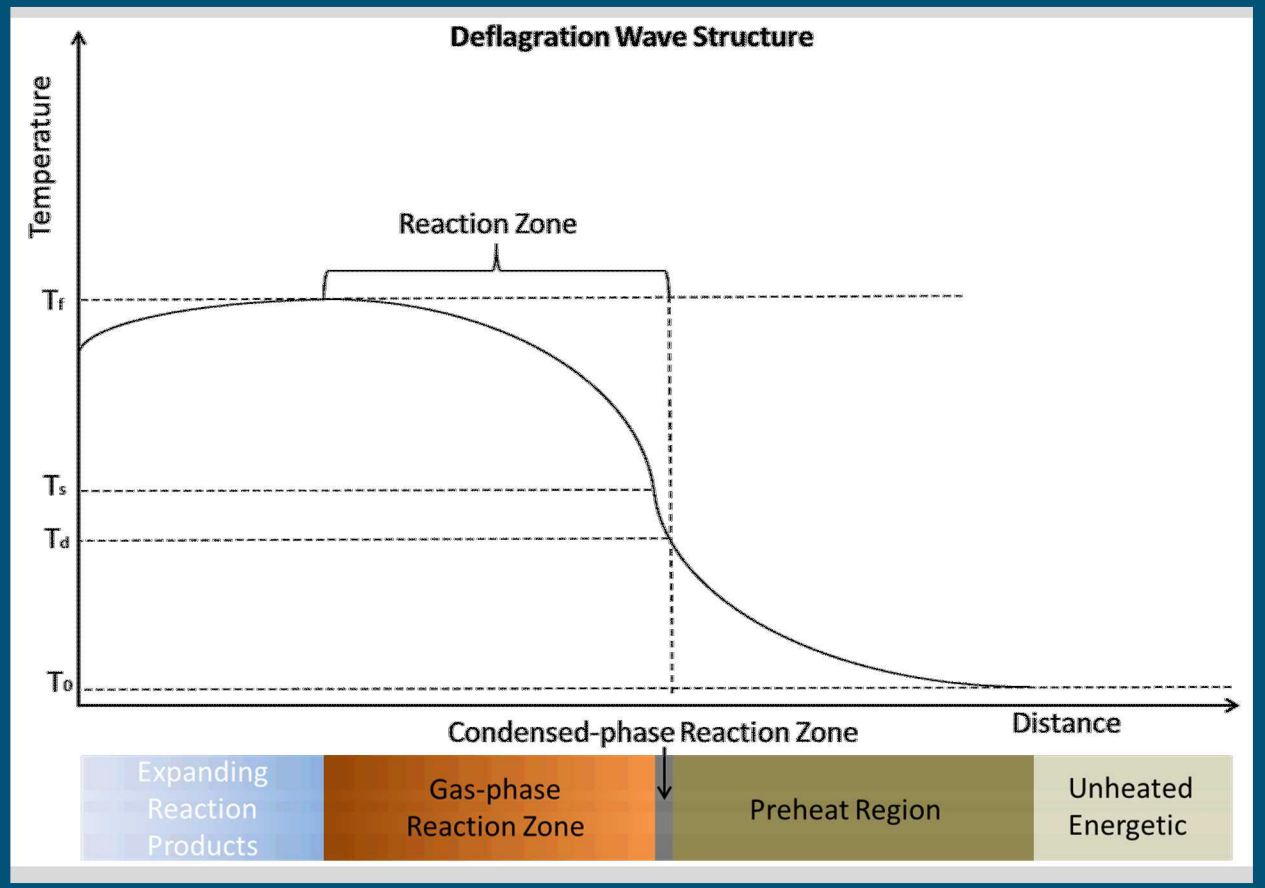
Outline

- Detonation Phenomena
- Detonation Diagnostics
- Light Initiated High Explosives
- Flyer Plate Experiments
- Technique for Velocity to Pressure
- Hydrocode Simulation Comparisons
- Sources of Error
- Independent Experimental Confirmation
- Conclusions

Detonation Phenomena

Deflagration



Refs: Kubota, N., *Propellants and Explosives*. Second Edition. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co KGaA, 2007, pgs 41-68.
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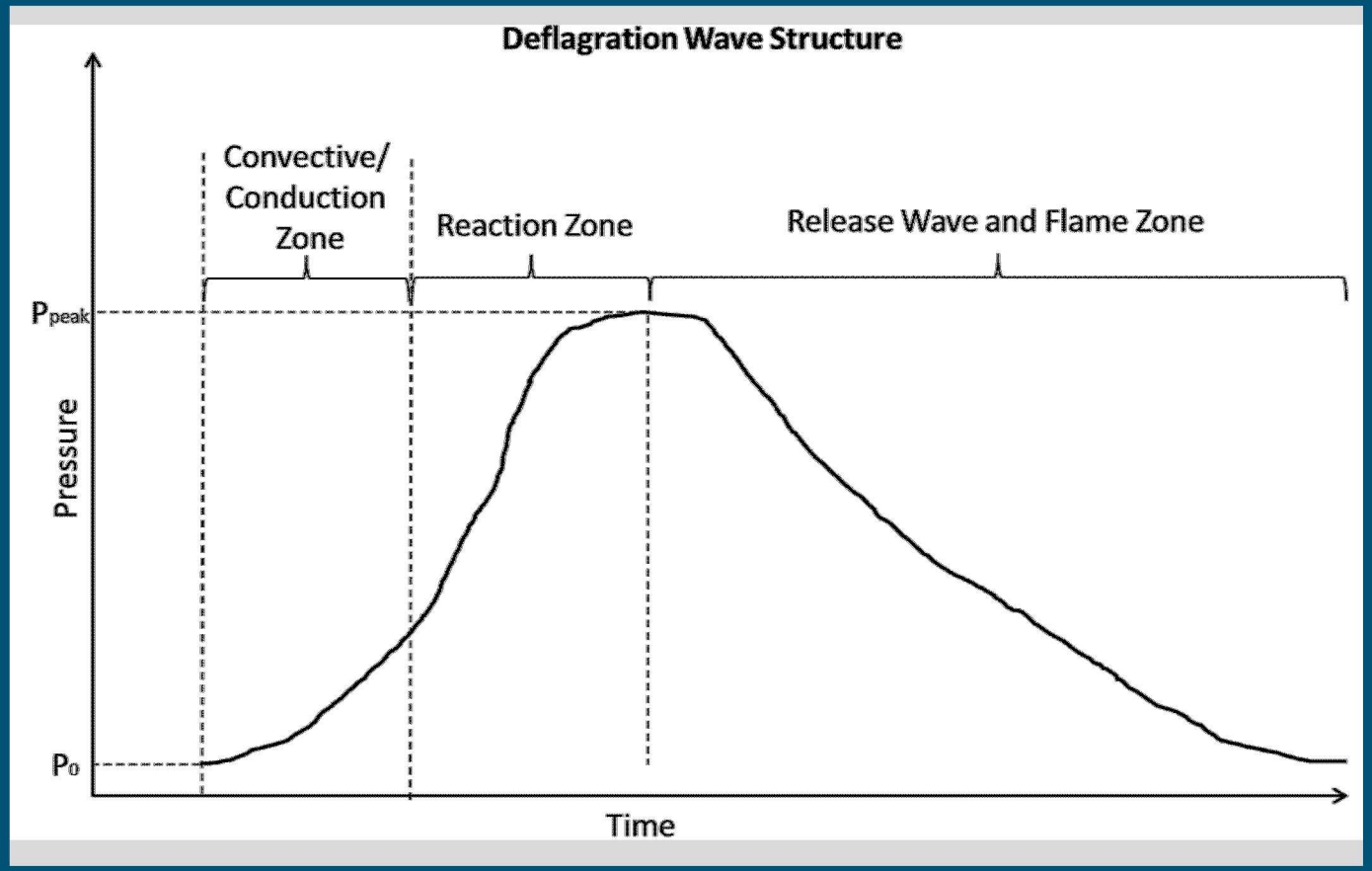
Detonation Phenomena



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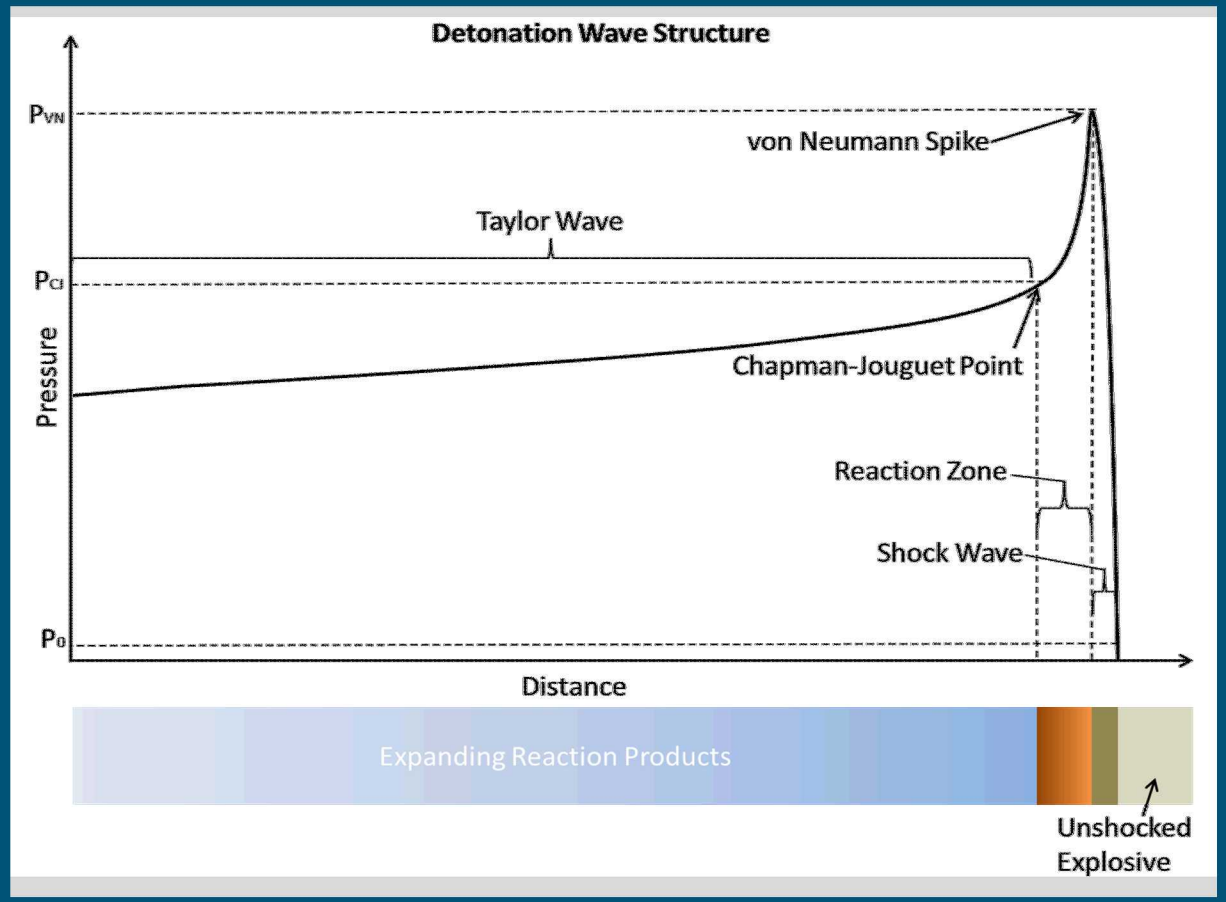
Detonation Phenomena

Zel'dovich-von Neumann-Döring (ZND) theory



Refs: F. Zhang (ed.), Shock Wave Science and Technology Reference Library, Vol. 6: Detonation Dynamics, DOI 10.1007/978-3-642-22967-1 2, 33 © Springer-Verlag Berlin Heidelberg 2012

Detonation Phenomena

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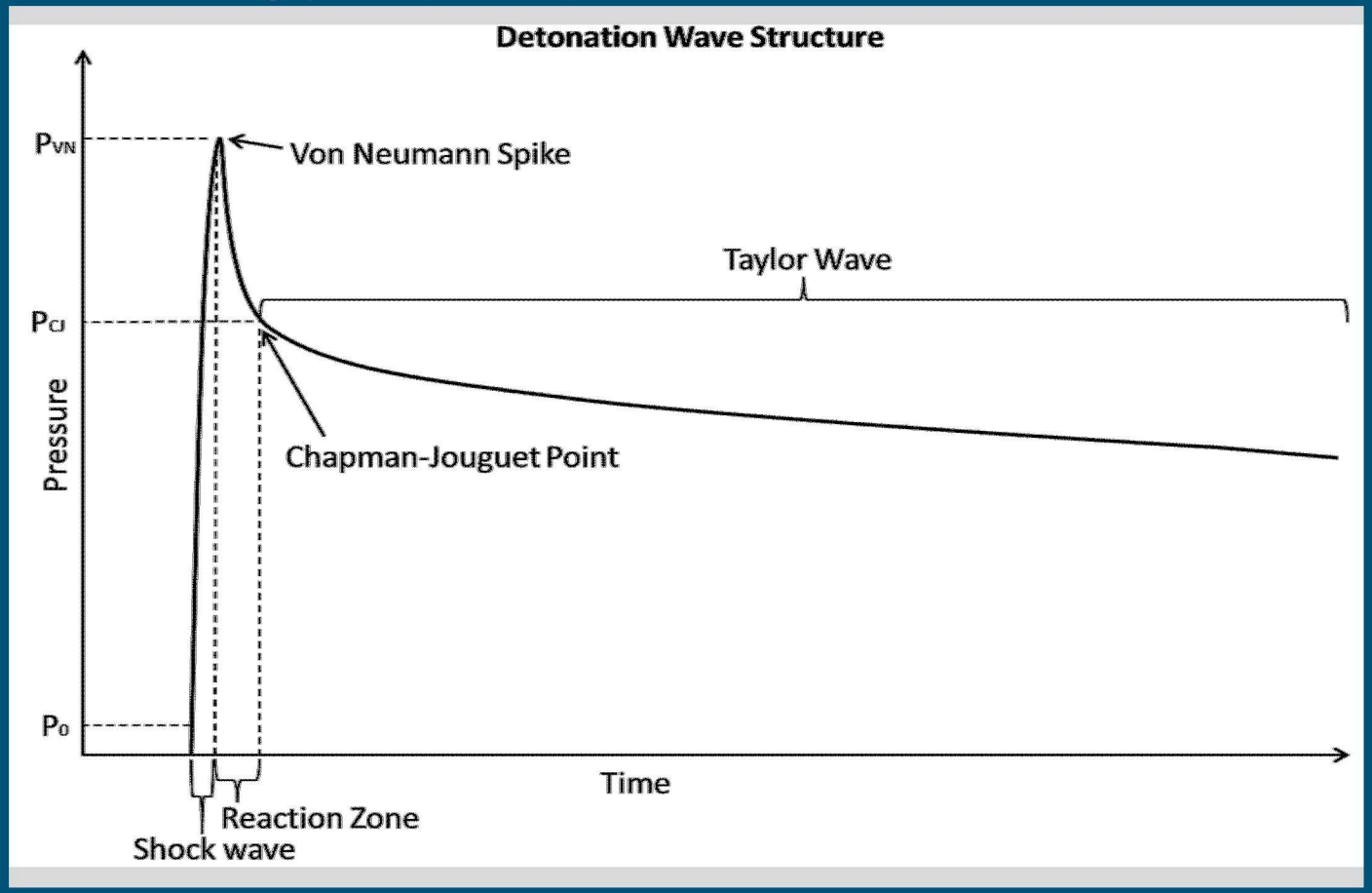

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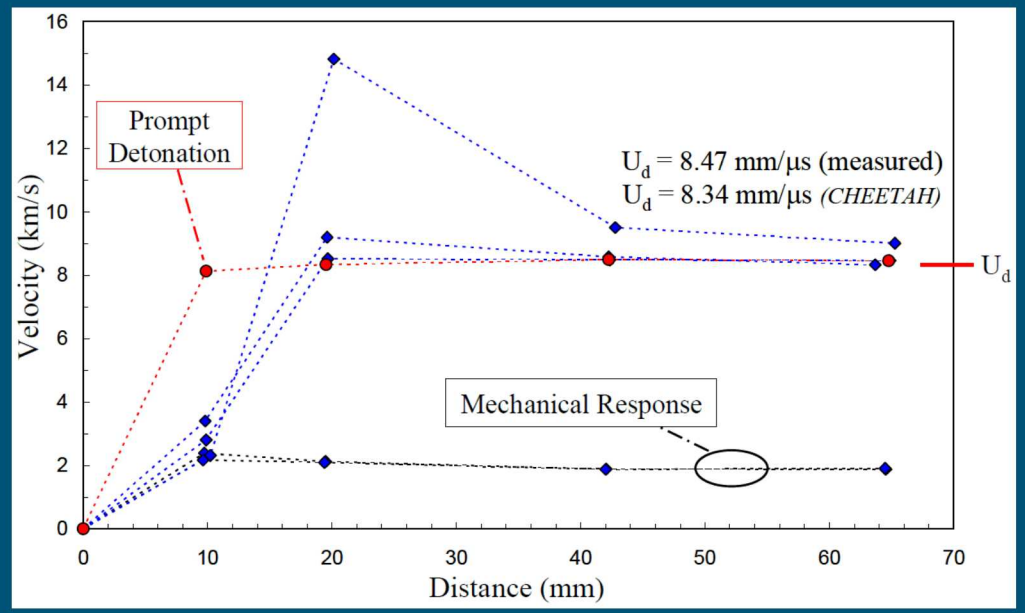
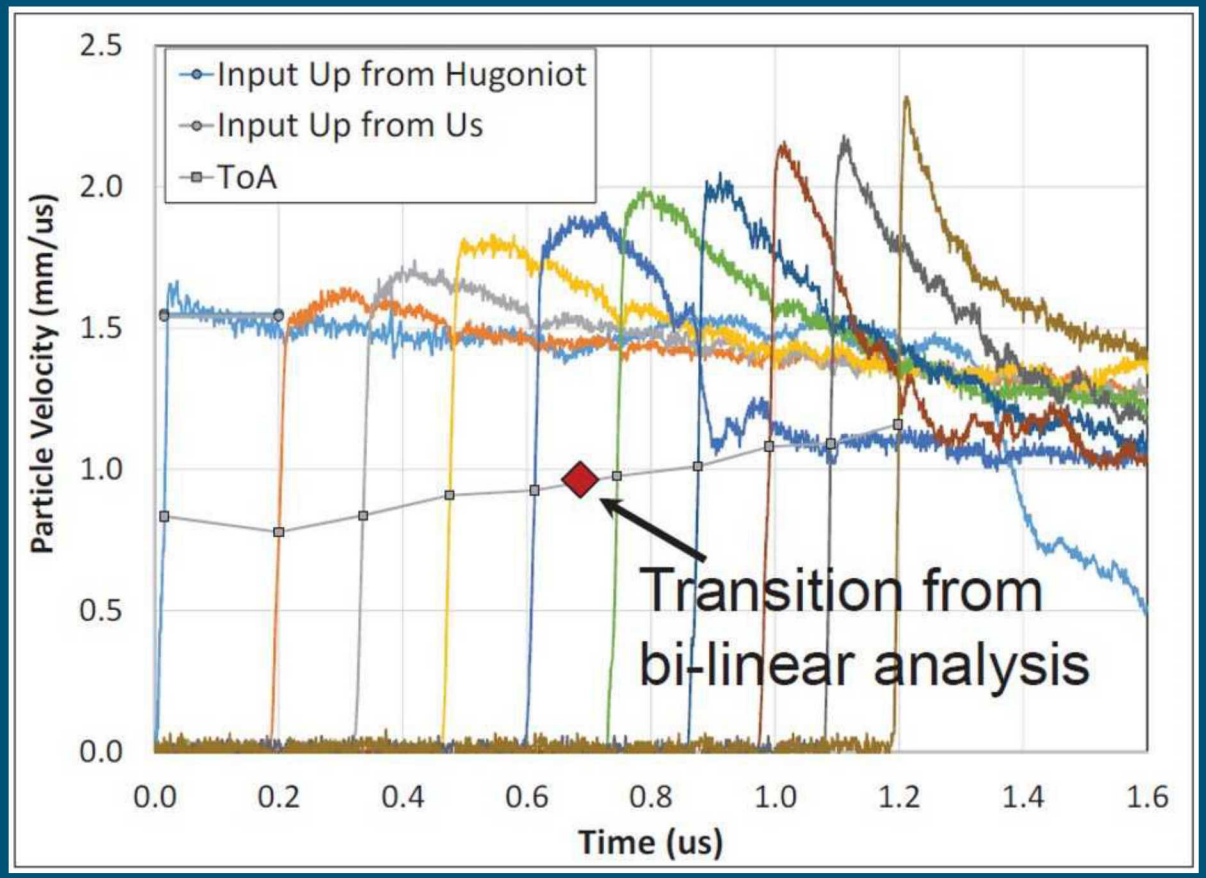
Detonation Phenomena

Transient Stages

- Deflagration-to-Detonation Transition (DDT)
- Shock-to-Detonation Transition (SDT)
- Over-driven or superdetonation
- Oscillatory detonation





Refs: Anderson, M. U., Todd, S. N., et al., *Non-shock Initiation Model for Explosive Families: Experimental Results*. Albuquerque, NM: Sandia National Laboratories, 2010. SAND2010-1394C.
Lee, R.J., Techniques for collection and analysis of pop-plot data for use in parameterization of reactive flow models. AIP Conference Proceedings 1979, 100026 (2018); https://doi.org/10.1063/1.5044898

Detonation Phenomena

Rational for using the terms, "Internal Explosive Pressure," and "Pressure Spike"

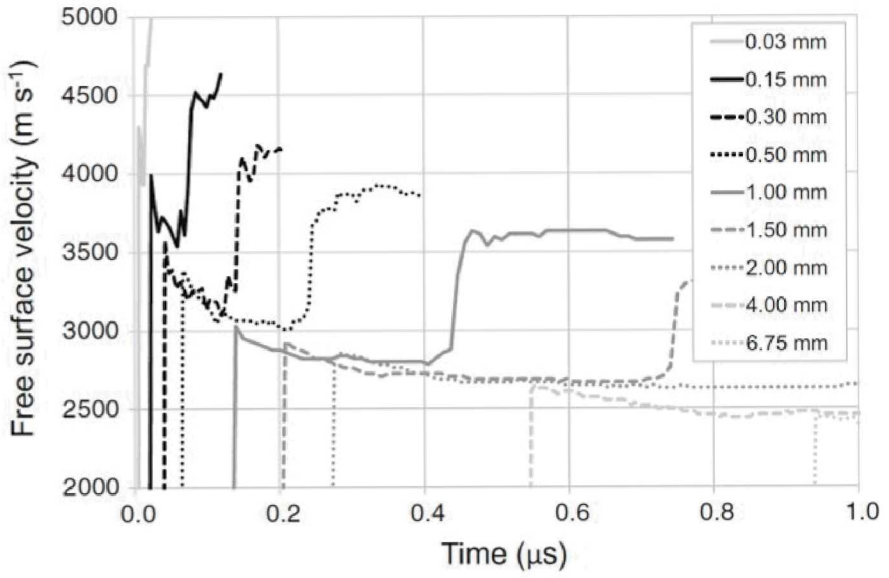


Fig. 4 Free-surface velocity profiles of aluminium flyers shifted in time by taking into consideration shock wave attenuation in aluminium. The latter records were shifted using shock wave velocities determined from the former records. The flyers thicker than 7 mm were omitted for clarity

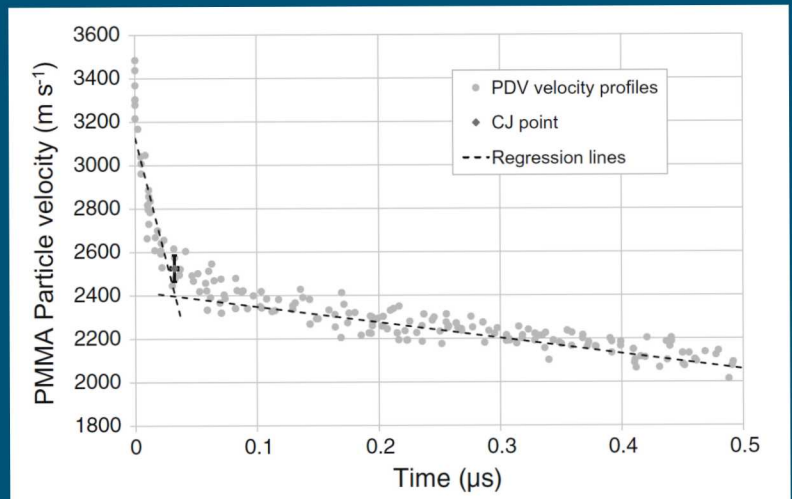
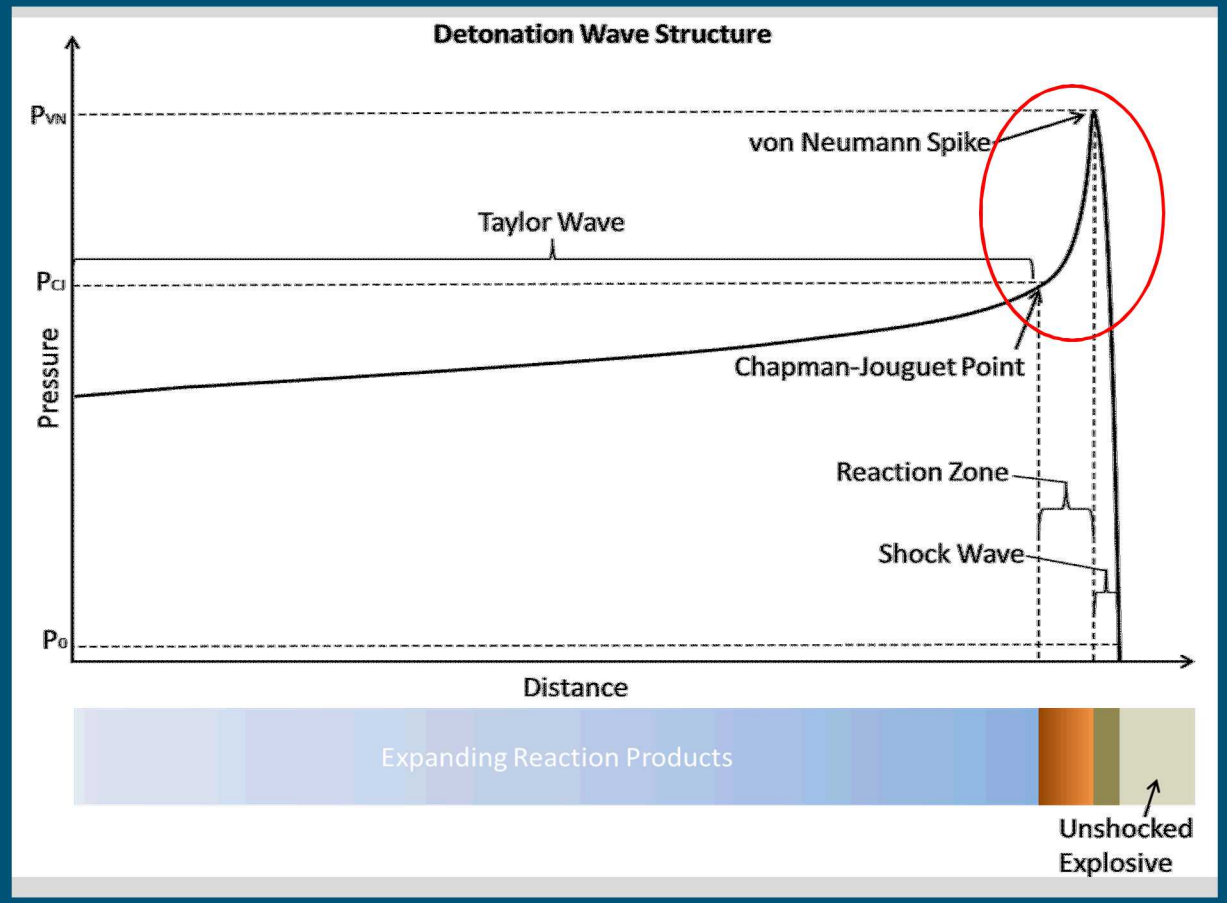


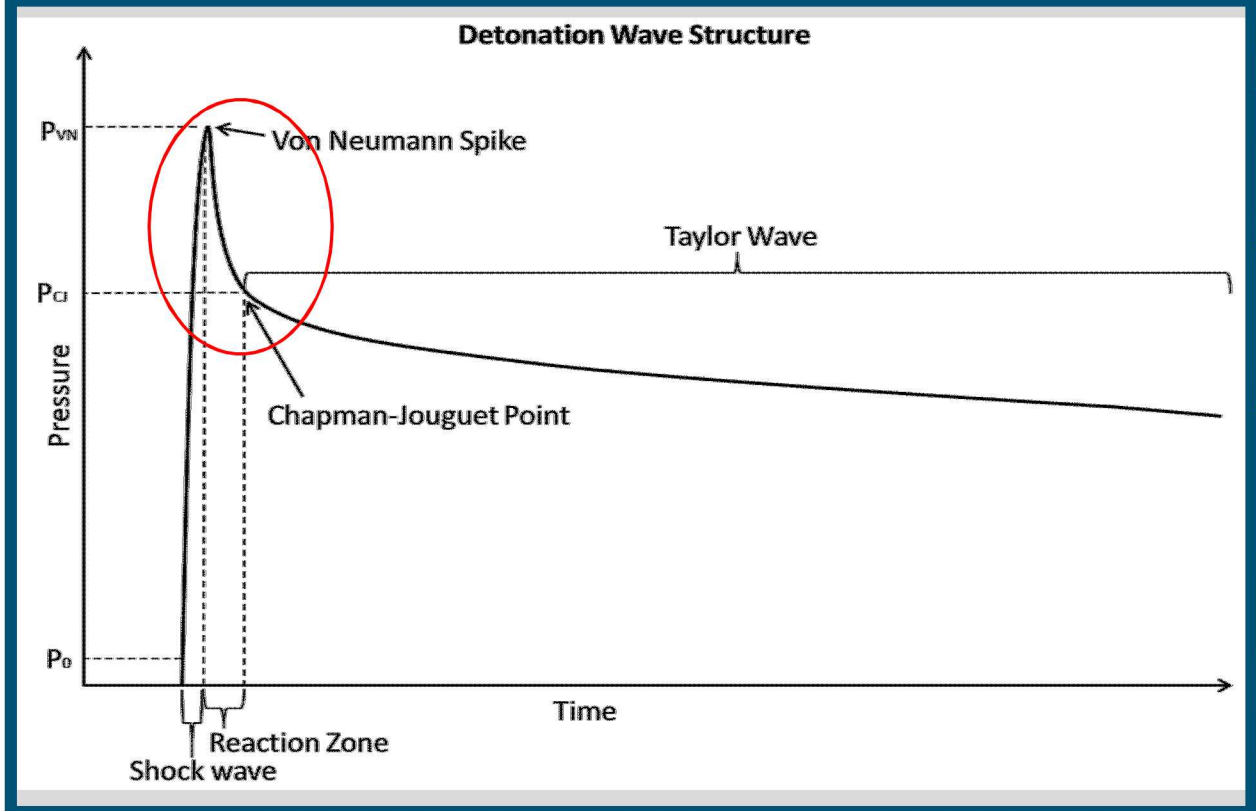
Fig. 6 Particle velocity profiles at the explosive/PMMA interface of eight identical charges. The linear regression lines corresponding to the VN spike and Taylor wave are shown for one of the profiles. The CJ point determined as the closest data point above the intersection of the two regression lines is shown. The median absolute deviations of time and particle velocity are indicated

Refs: J. Pachman, M. Künzel, O. Němec J. Majzlík, A comparison of methods for detonation pressure measurement, Shock Waves (2018) 28:217–225
https://doi.org/10.1007/s00193-017-0761-5

Detonation Phenomena

What do we actually measure for the peak pressure in explosives?





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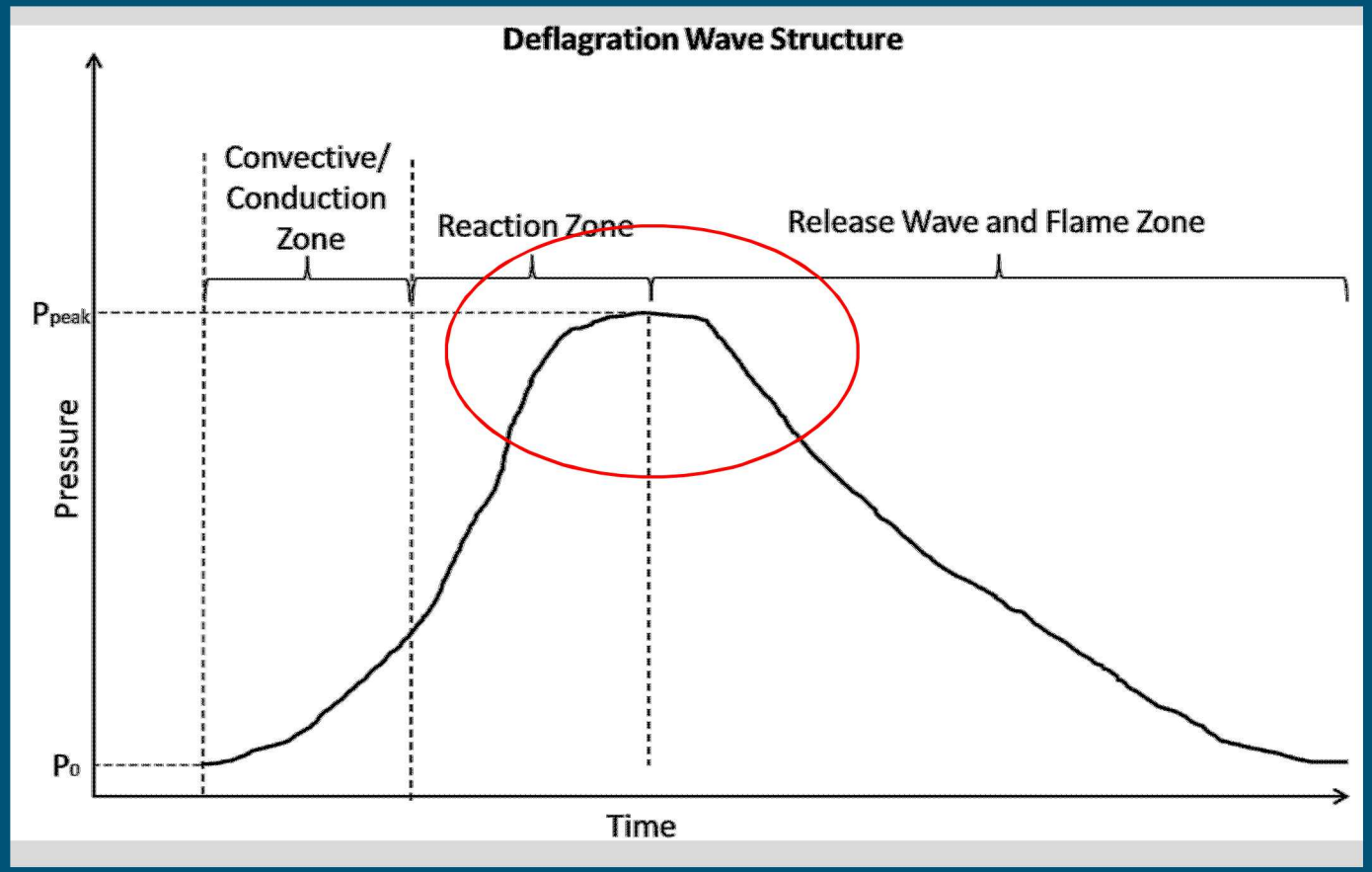

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Detonation Diagnostics

Laser Interferometry
- Photonic Doppler Velocimetry (PDV)
- Velocity Interferometer for Any Reflective Surface (VISAR)

Element-based Gauges
- Carbon Gauges
- Quartz
- PVDF
- PZT pins

Photometrics
- High-speed photography
- Streak cameras

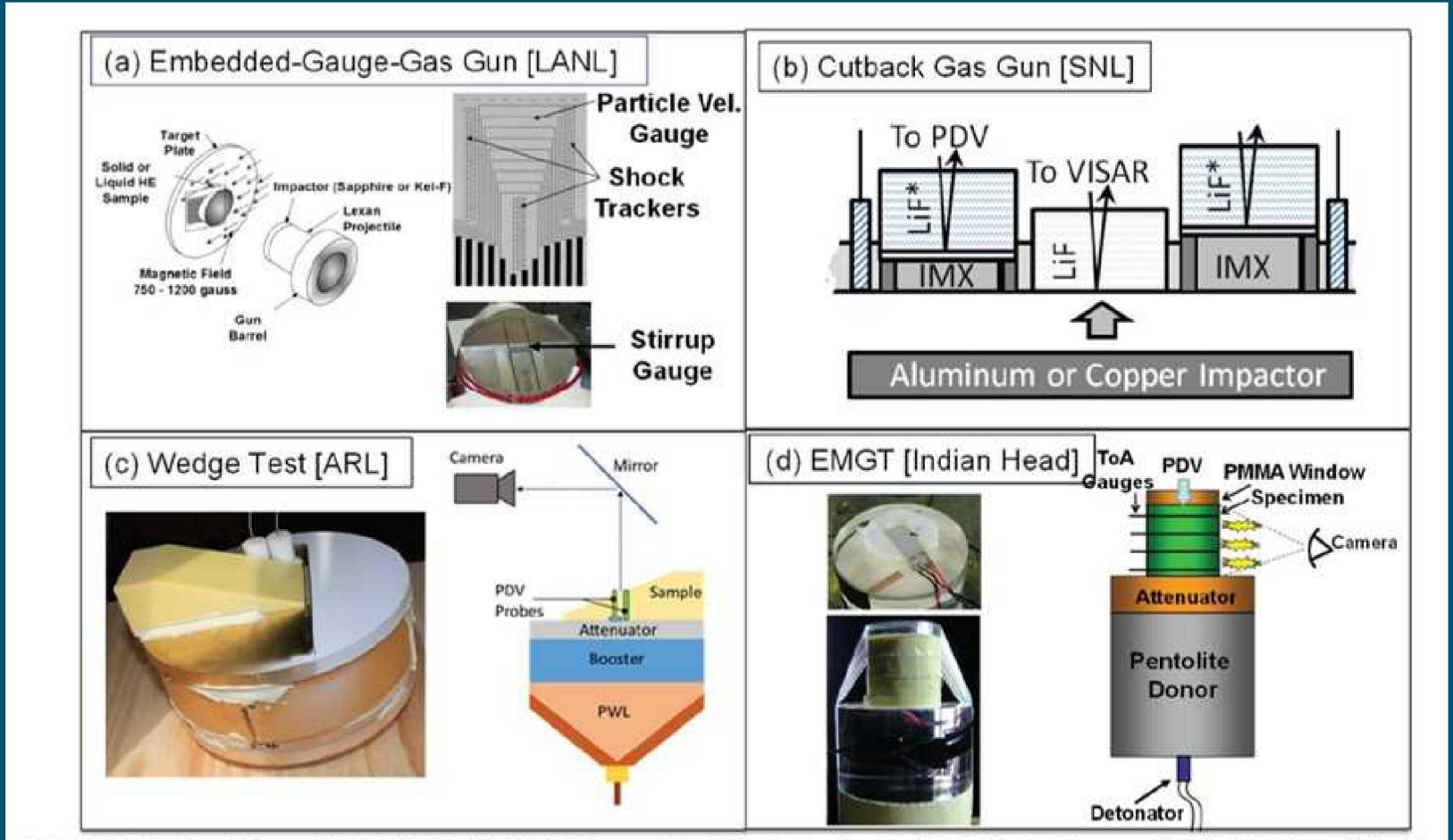


FIGURE 1. Four Tests: (a) LANL Embedded Gauge, (b) SNL Cutback, (c) ARL Wedge Test, and (d) NSWC IHEMGT

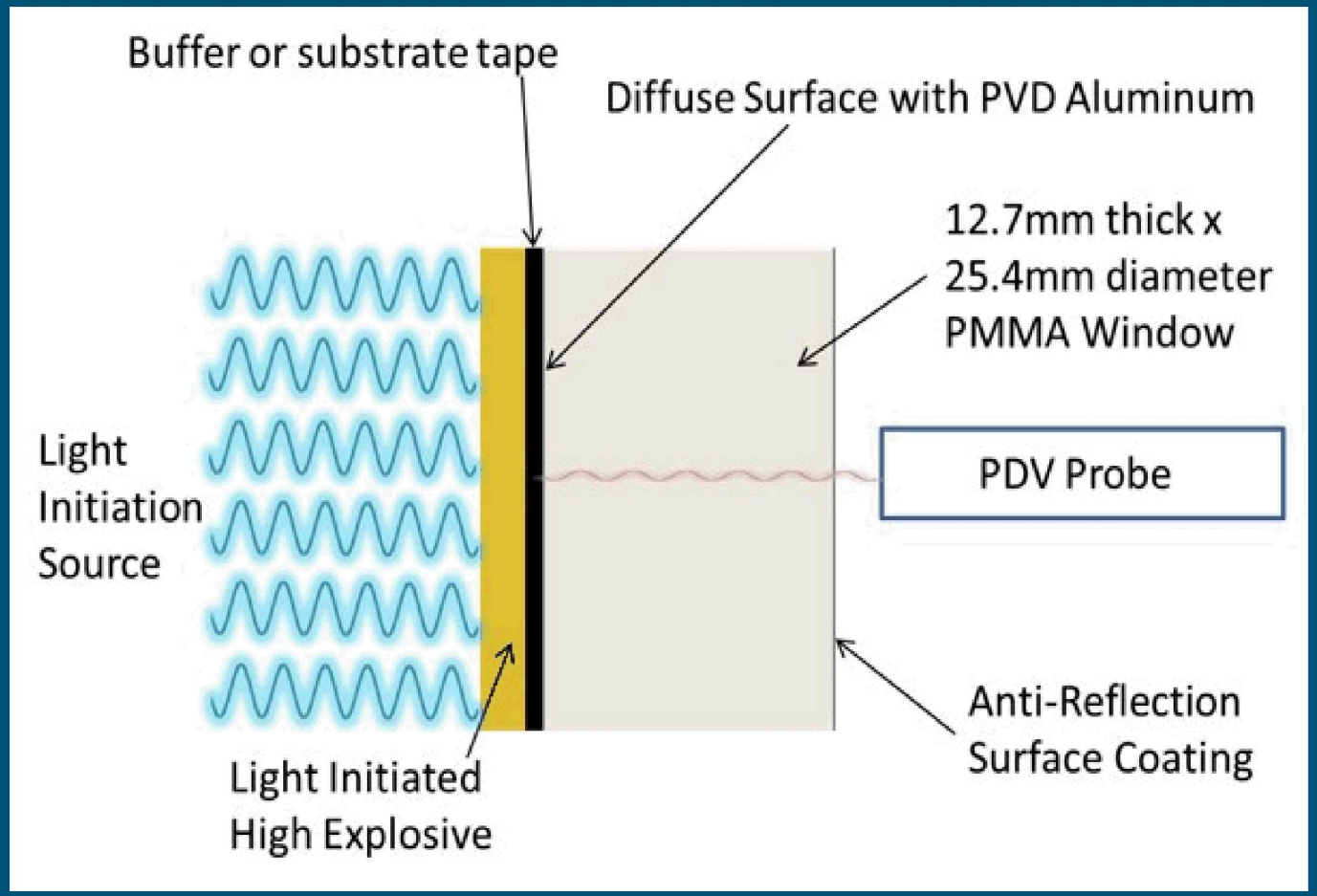
Ref: Lee, R.J., Techniques for collection and analysis of pop-plot data for use in parameterization of reactive flow models. AIP Conference Proceedings 1979, 100026 (2018); https://doi.org/10.1063/1.5044898

Detonation Diagnostics

Impedance Matching Window Technique

Laser Interferometry

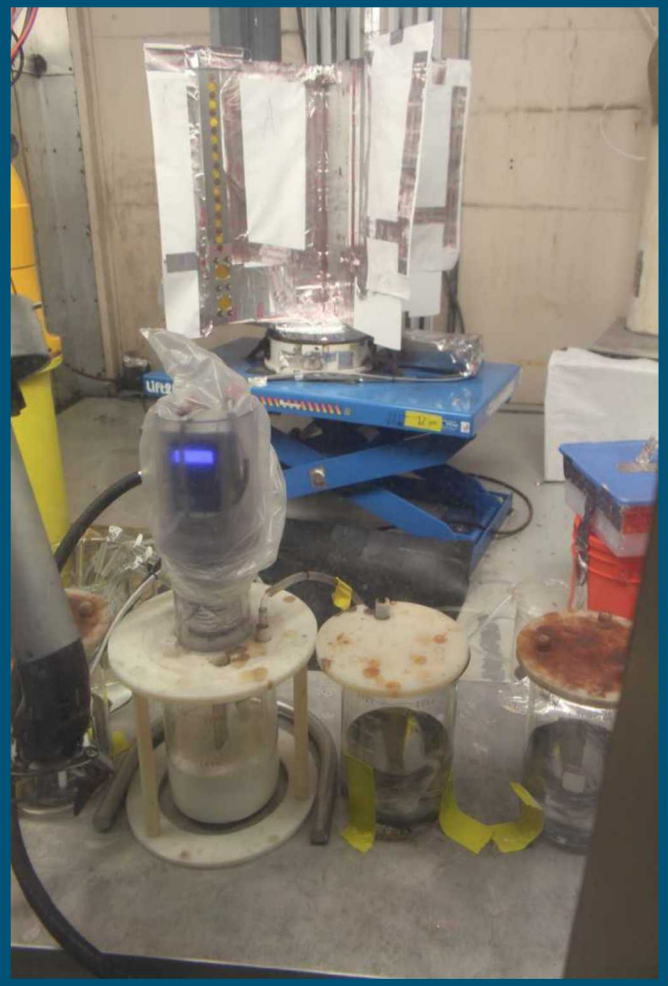
- Photonic Doppler Velocimetry (PDV)

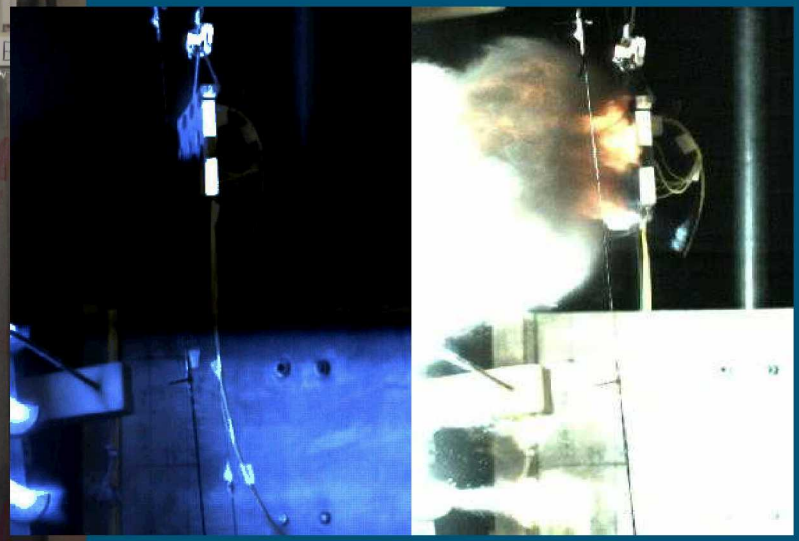


Light Initiated High Explosives

Silver acetylide-silver nitrate (SASN)

- $3AgNO_3(\text{in solution}) + C_2H_2(\text{gas}) \rightarrow Ag_2C_2 \cdot AgNO_3(\text{precipitate}) + 2HNO_3(\text{liquid})$

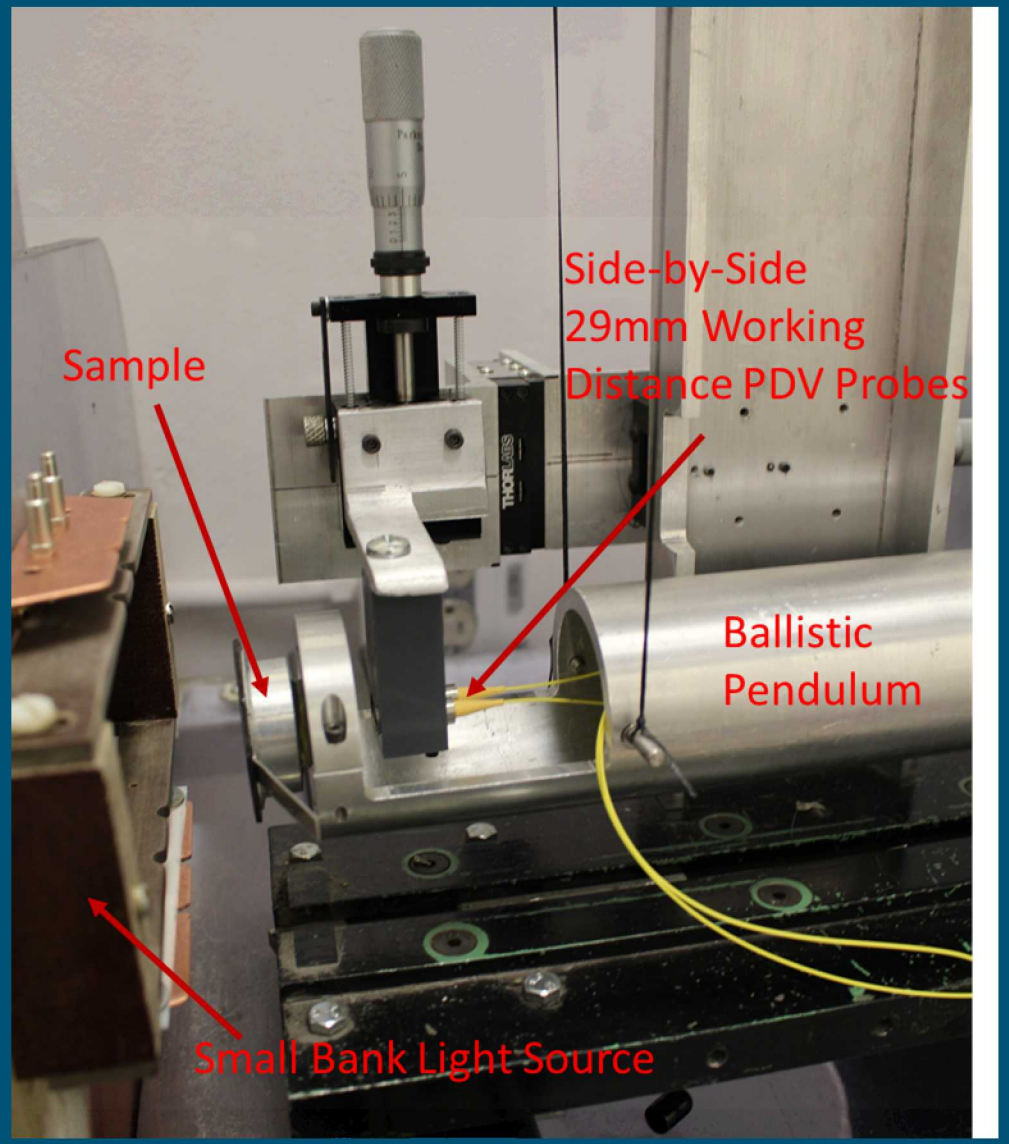




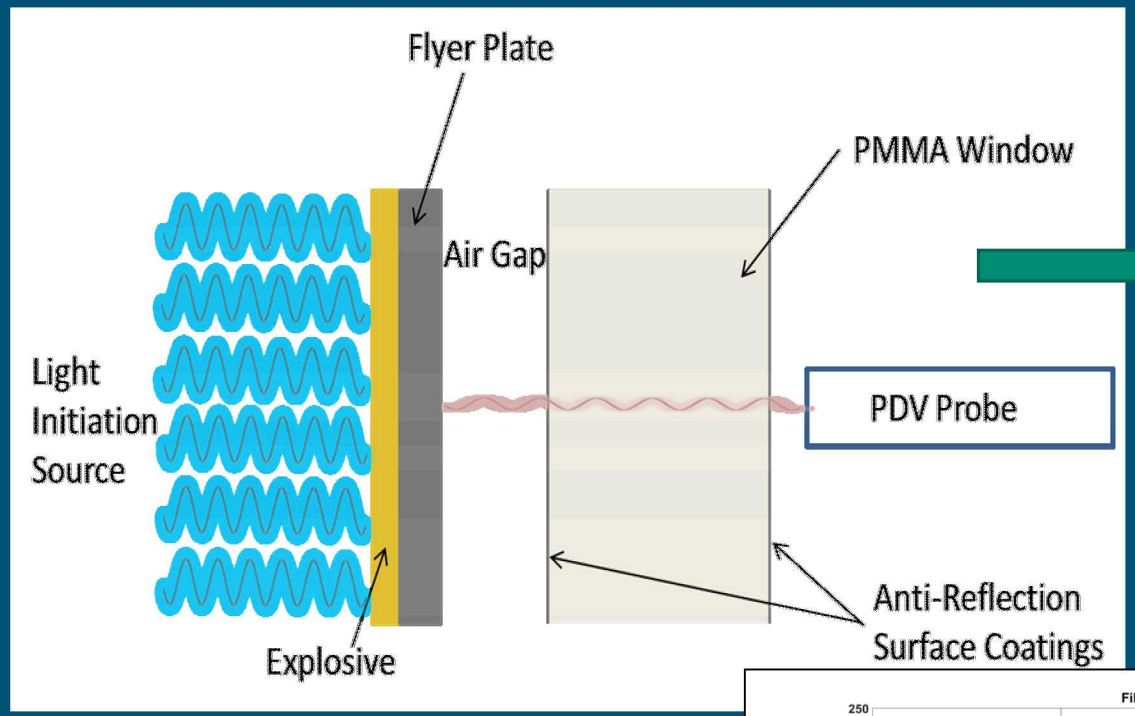
Flyer Plate Experiments

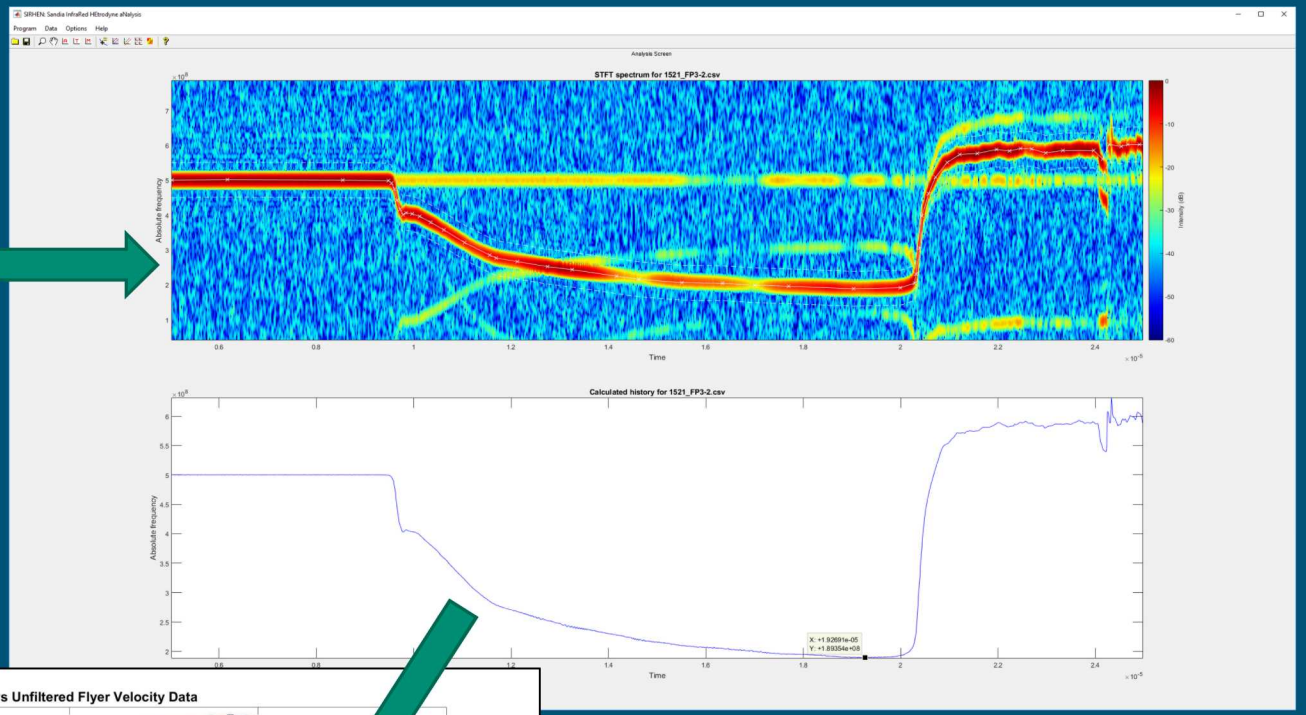
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Mini-flyer Steel Ring1		1
2	Mini-flyer 6mil Aluminum Disk	1in diameter 1100-O aluminum flye plate	1
3	Mini-flyer 1.8mil KaptonTapeFP	Bertech 1.8mil thick KPTLS-1 or KPTLS-2 Kapton Tape cut to size	1
4	1.75inSampleMagnet		1
5	1in PMMA Window		1
6	Interface Velocity Spacer		1
7	Magnetic Tape Ring2inDia		1

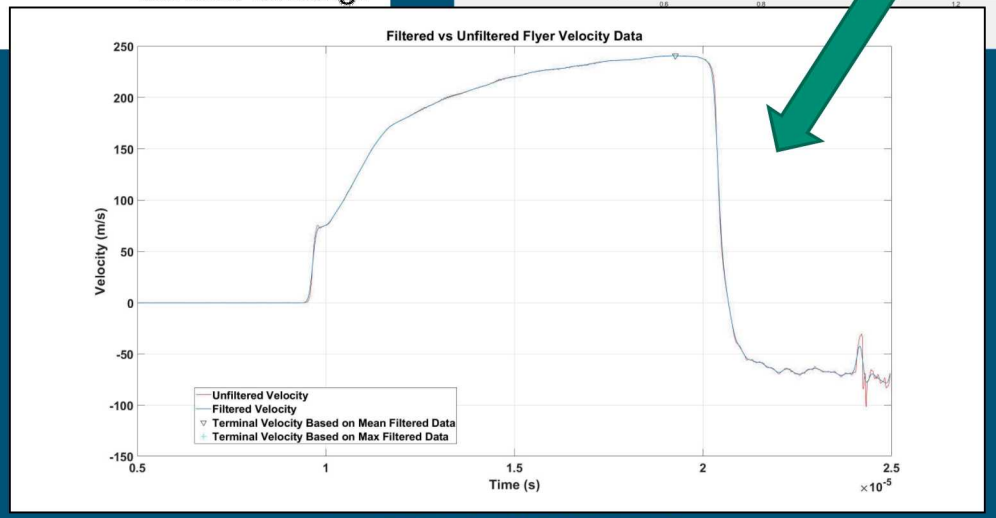
TITLE: Mini-flyer Interface Velocity Sample
SIZE B DWG. NO. 2019-1-17MACrev1 REV
SCALE: 1:1 WEIGHT: SHEET 1 OF 1



Flyer Plate Experiments

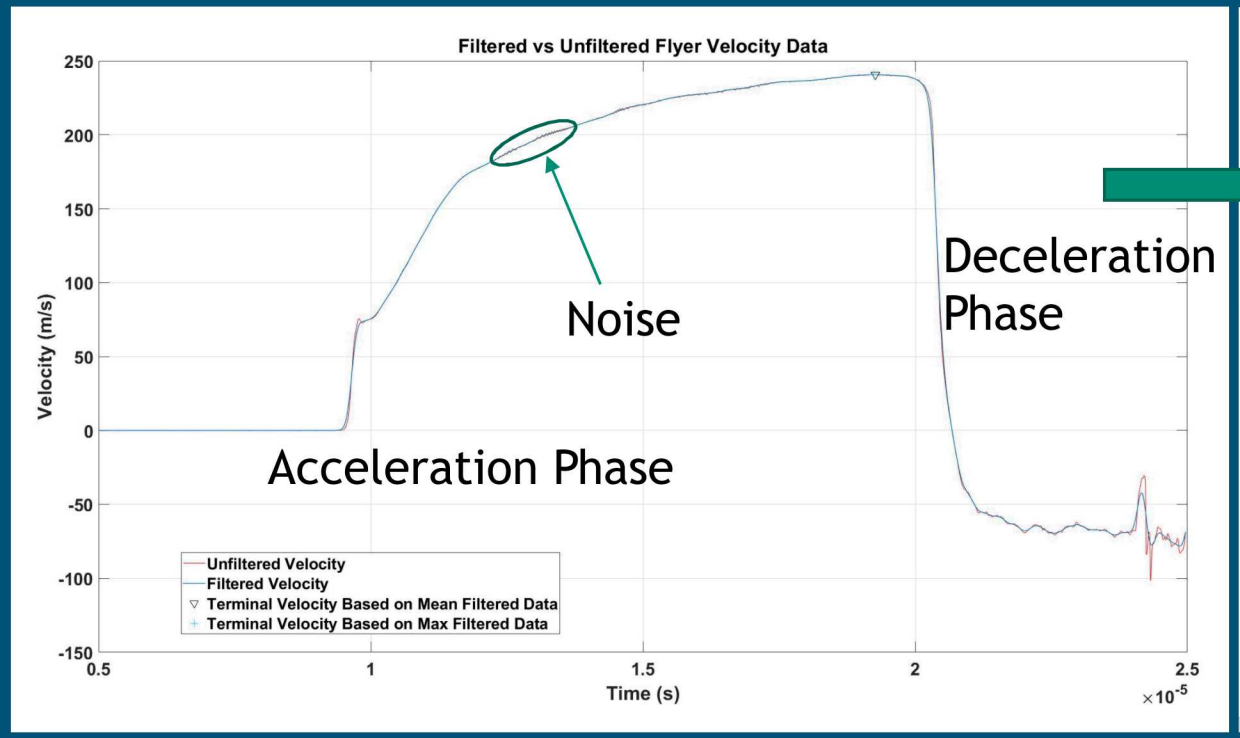


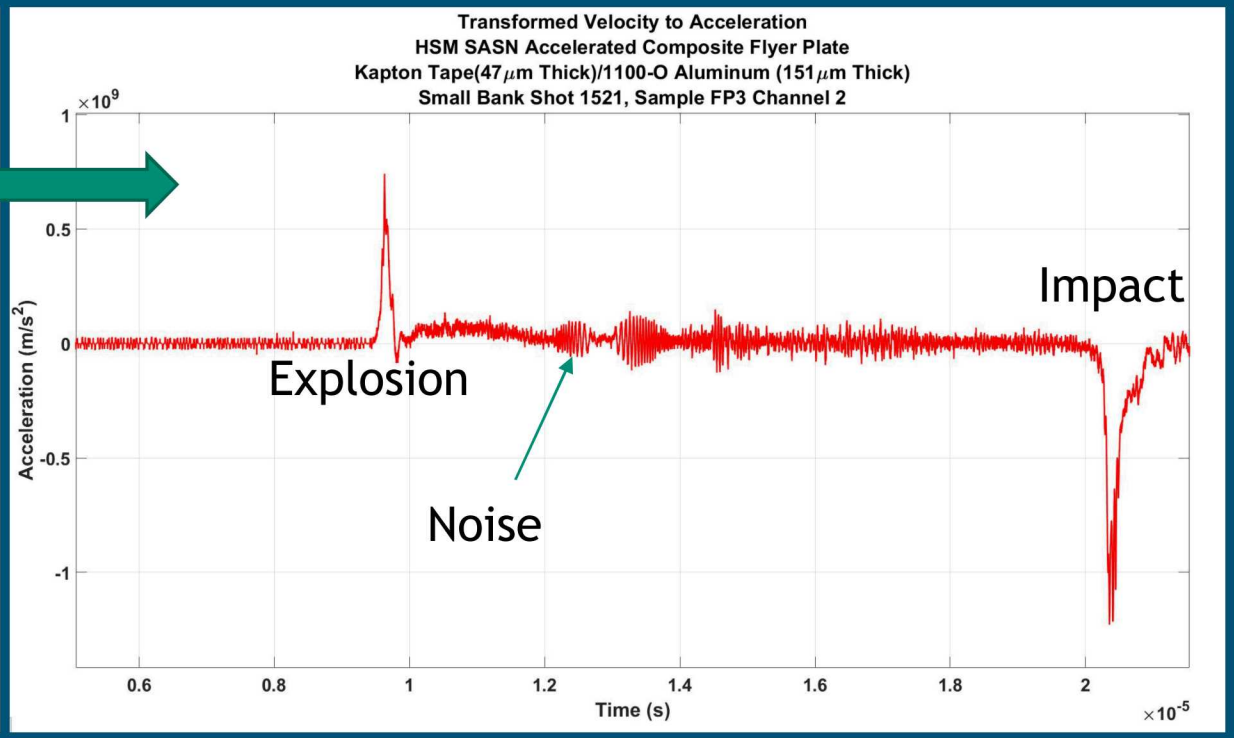




Technique for Velocity to Pressure

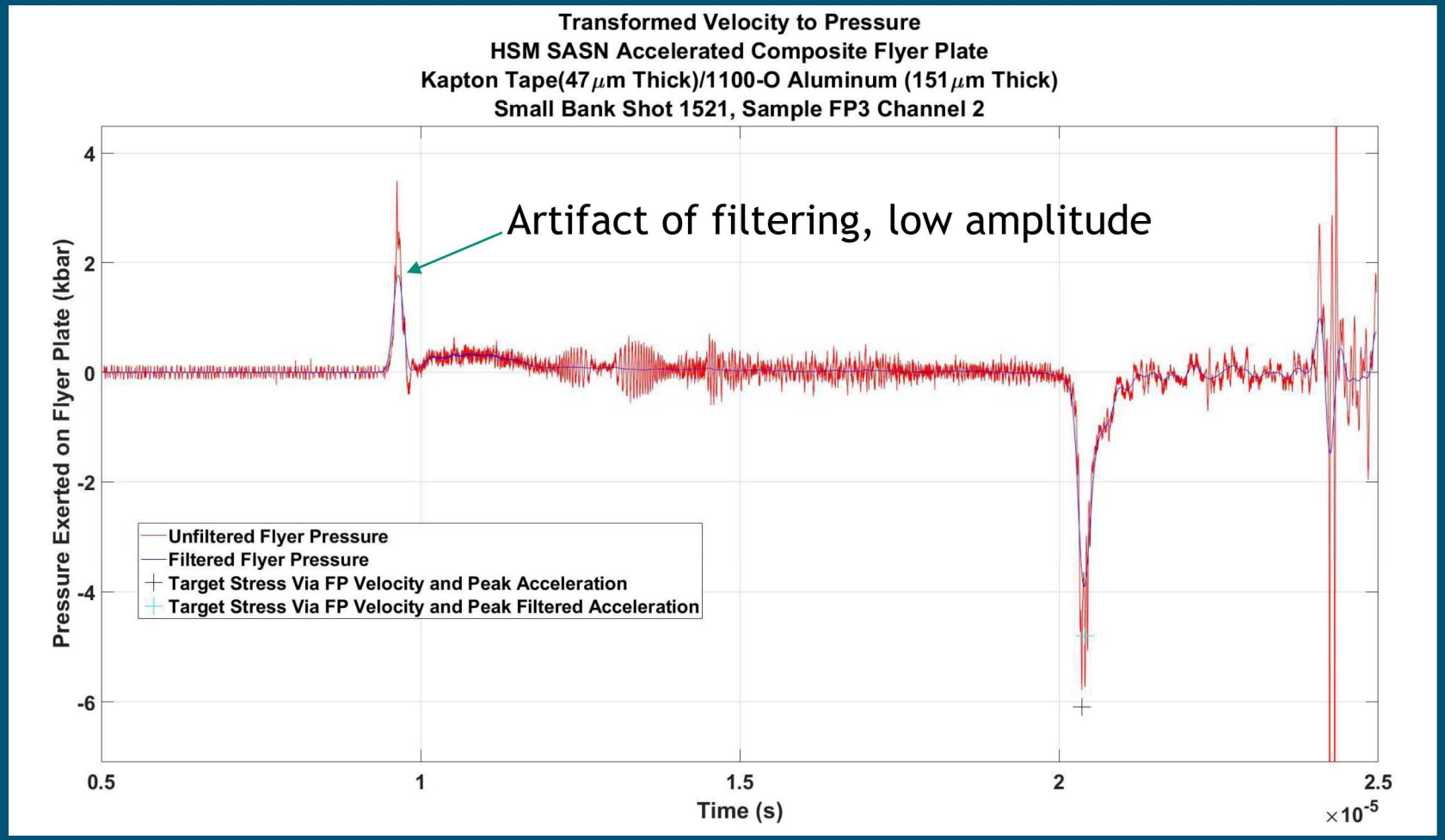
- Numerically differentiate velocity data
- Filtering can be used with caution and additional transformation steps





Technique for Velocity to Pressure

Multiply acceleration by the areal mass of the flyer plate



Technique for Velocity to Pressure

Apply P-u Hugoniot for explosive detonation products derived by Cooper

- Equate pressure in flyer plate to pressure in explosive products by iterating for P_{spike}

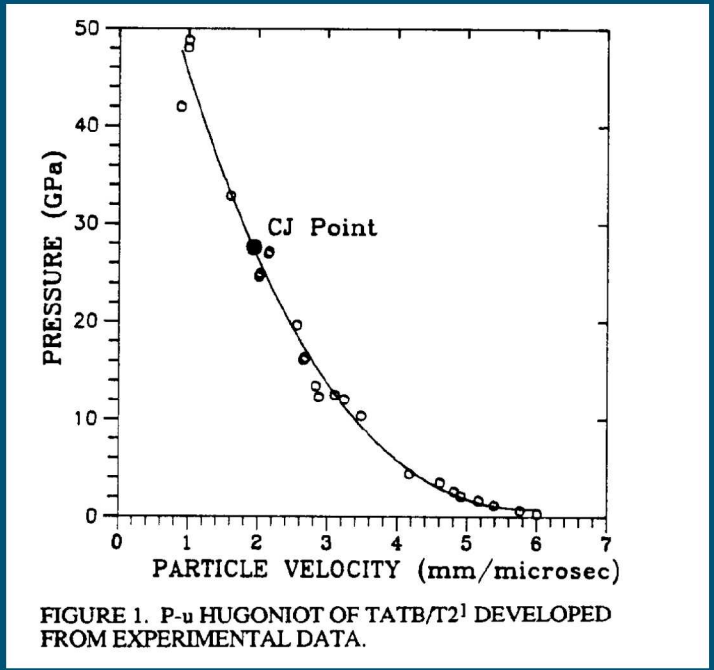
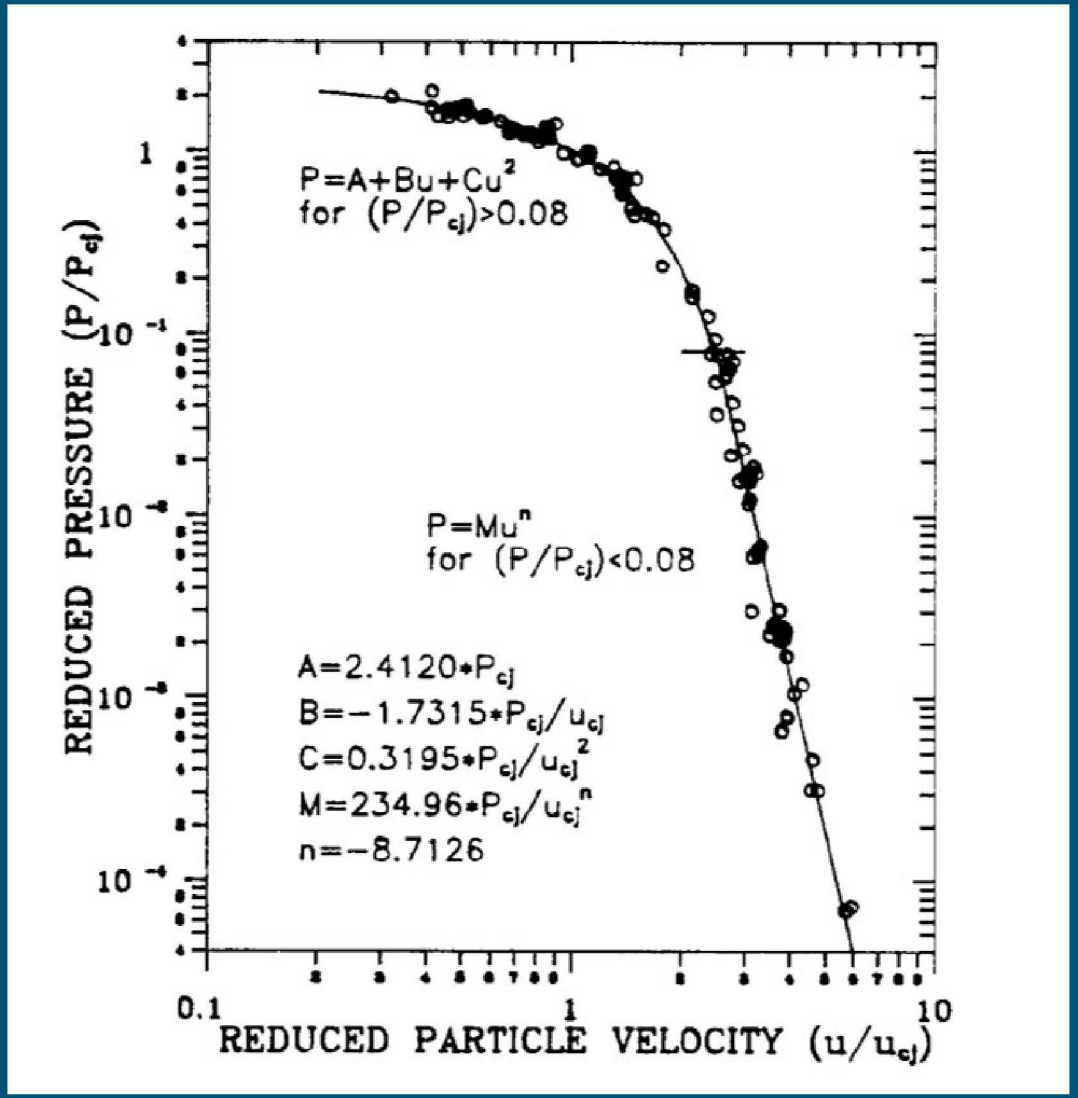


FIGURE 1. P-u HUGONIOT OF TATB/T2[1] DEVELOPED FROM EXPERIMENTAL DATA.



Ref: P. W. Cooper, Shock Behavior of Explosives about the CJ Point, Proceedings of the Ninth Symposium (International) on Detonation, Portland, Oregon, August 1989.

Technique for Velocity to Pressure

However, u_{spike} is needed:

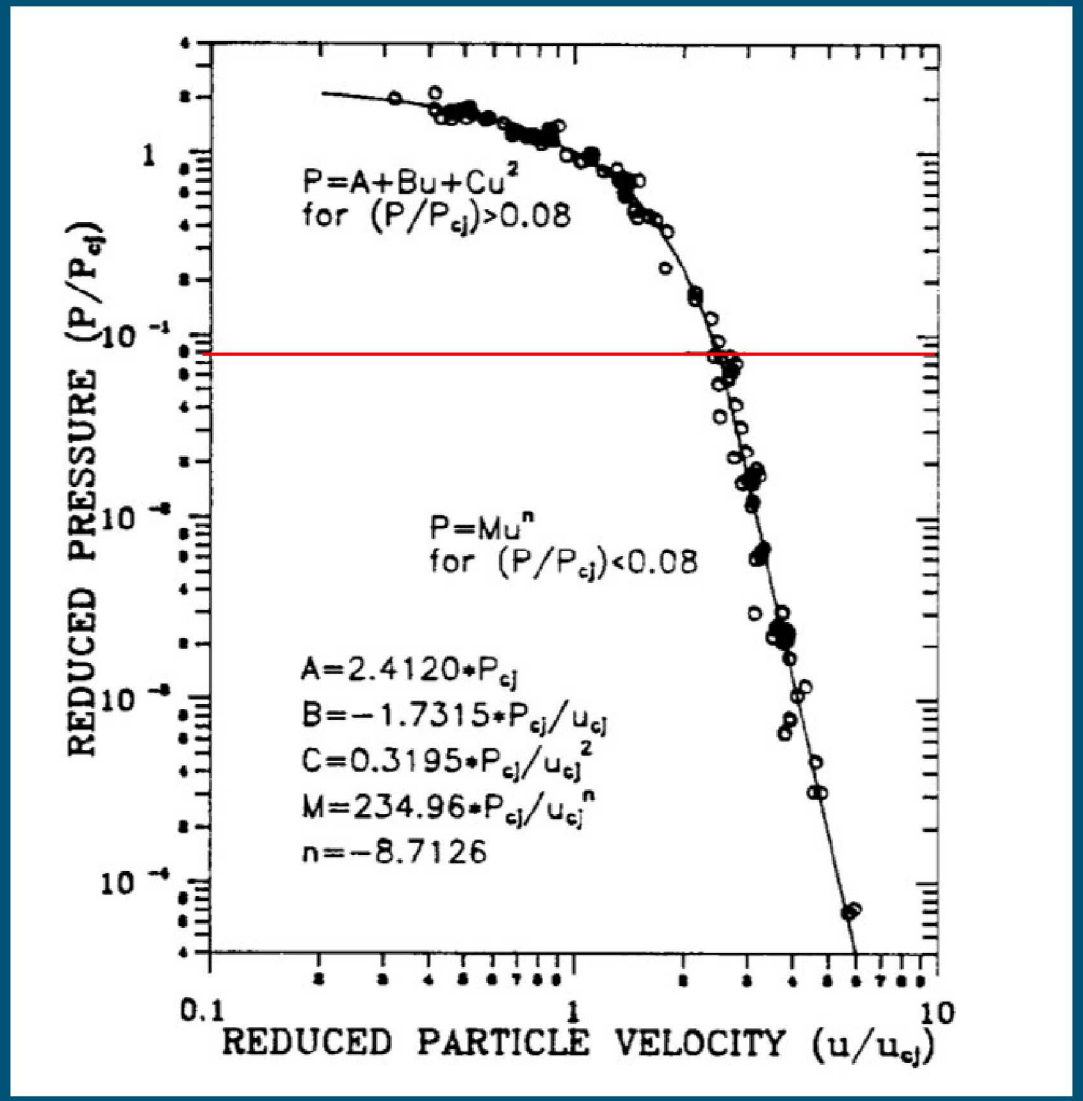
- Substitute u_{spike} by rearranging equation:

$$P_{spike} = \rho_0 u_{spike} D$$

D=explosive propagation rate

ρ_0=initial HE density

Once P_{spike} is found, normalize dataset and then multiply by P_{spike} to transform to internal explosive pressure as a function of time



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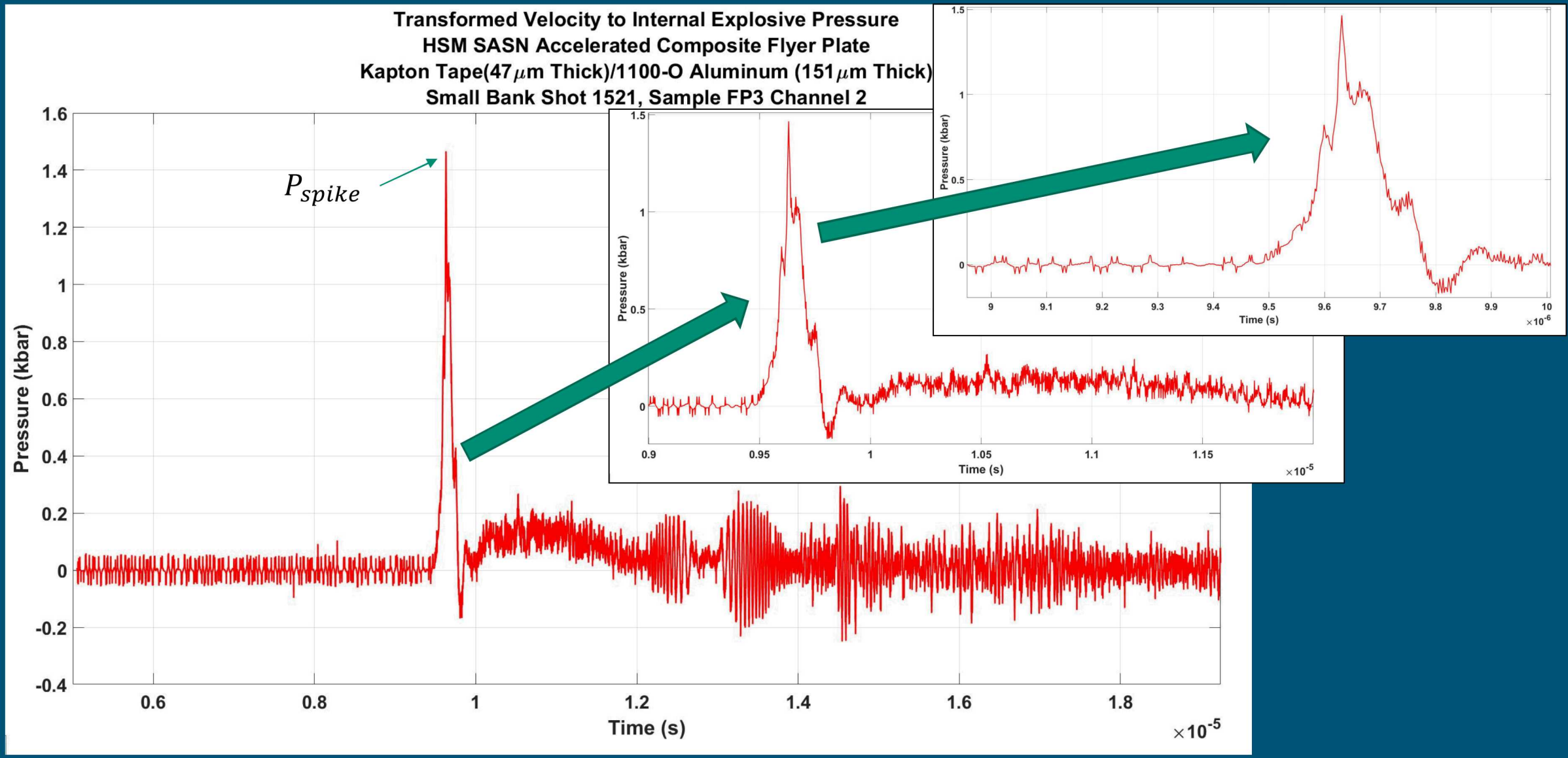
Technique for Velocity to Pressure

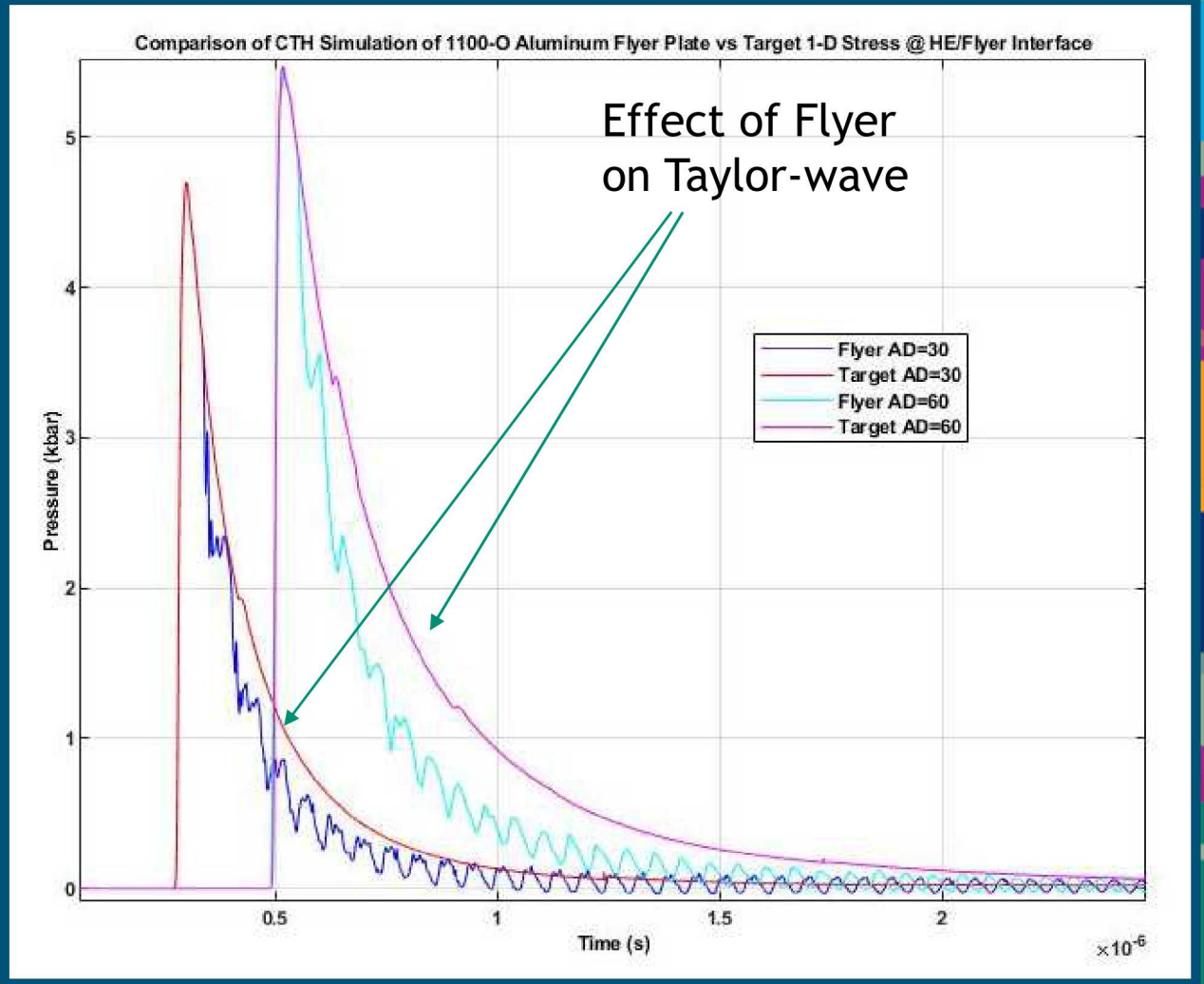


Hydrocode Simulation Comparisons

CTH Hydrocode

- Arbitrary, but relevant HE pressure pulse
- JWL with HE Burn function
- Case 1, HE propelling flyer plate (Aluminum and Kapton)
- Case 2, HE in contact with thicker target of same material
- Case 3, HE slab to acquire Pspike and D

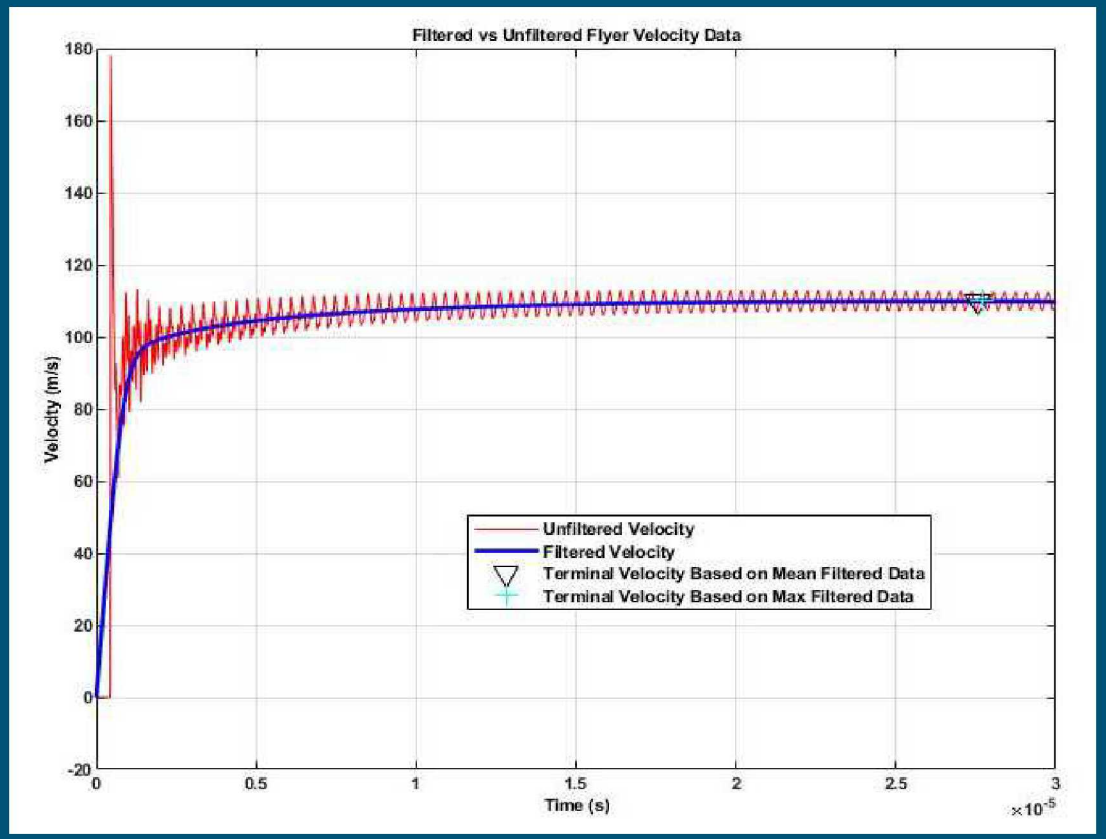
Measured pressure wave dependent on thickness of both flyer and explosive wave

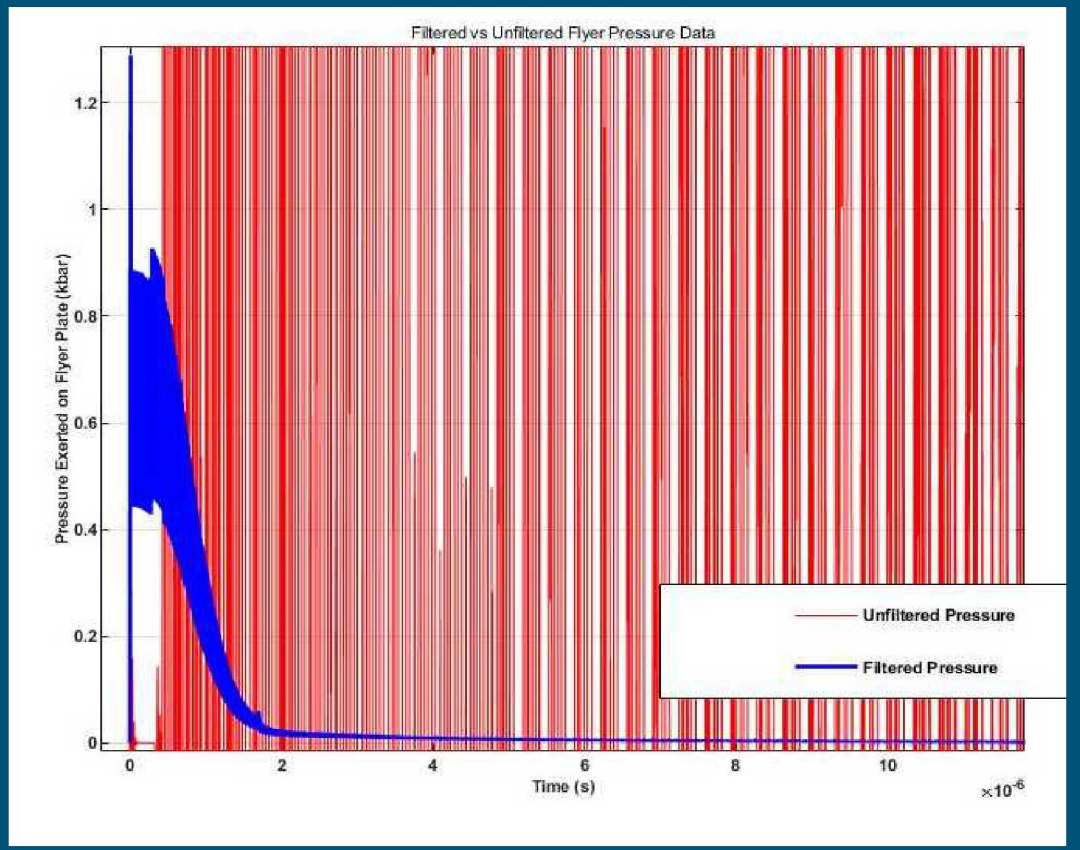


Hydrocode Simulation Comparisons

CTH Hydrocode

- Ran technique with FP velocity from simulation of 20mil thick Kapton flyer
- Not very useful results, too much noise, even with filtering

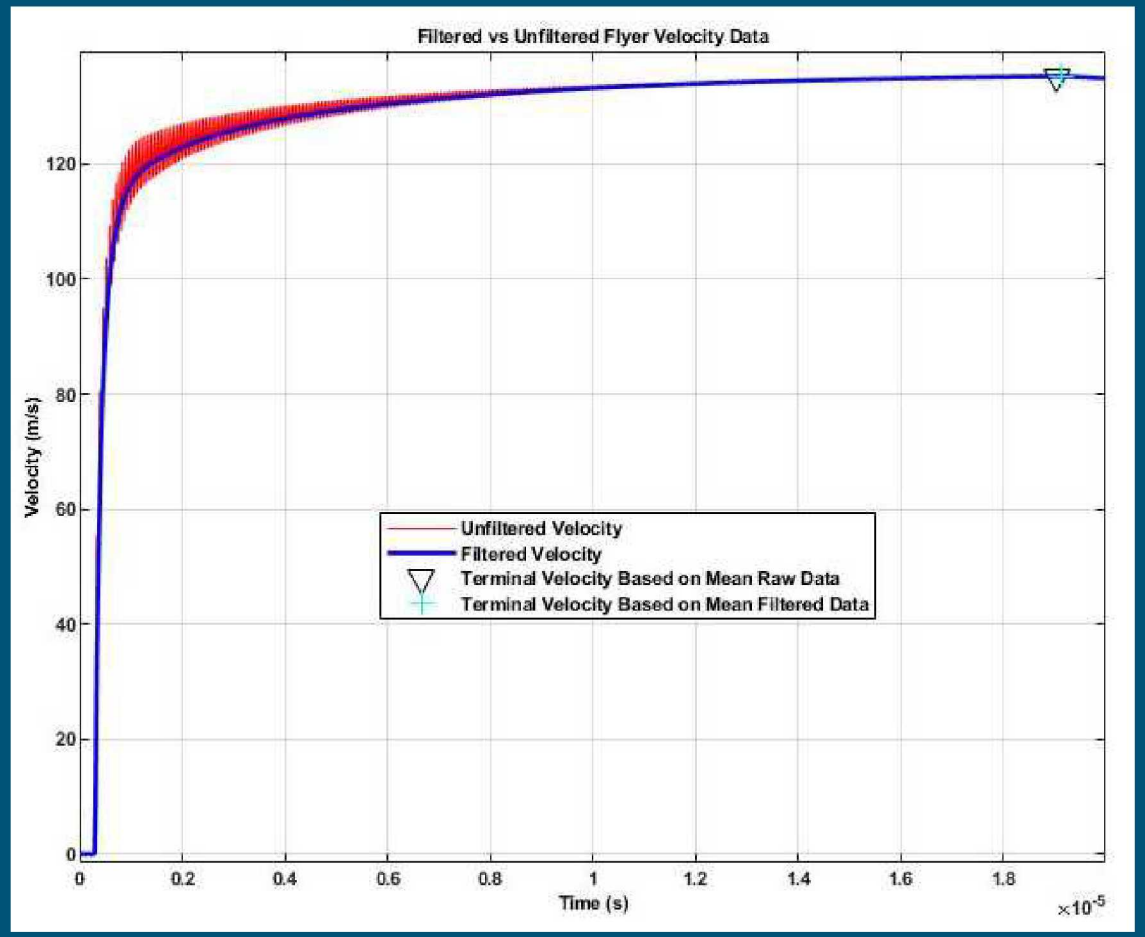


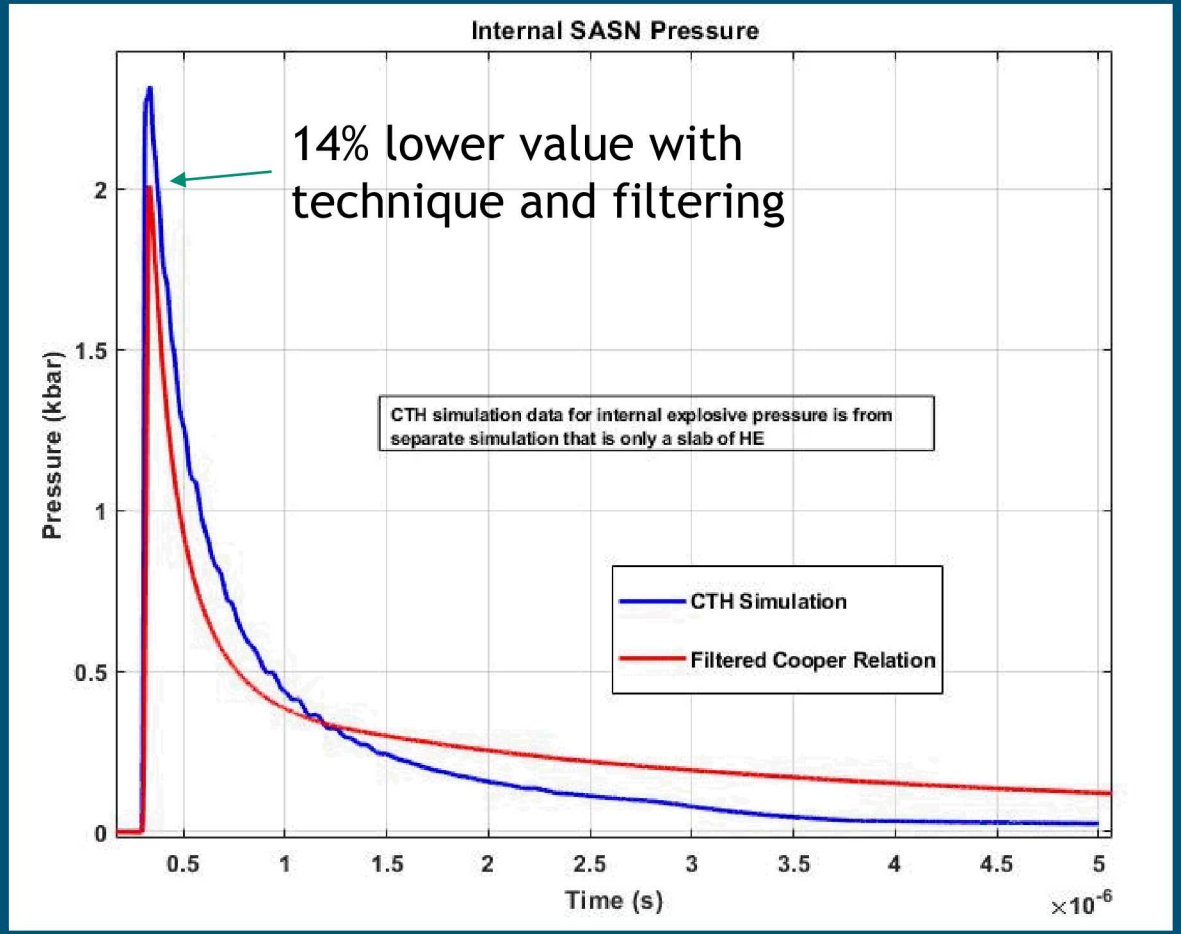


Hydrocode Simulation Comparisons

CTH Hydrocode

- Ran technique with FP velocity from simulation of 8mil thick aluminum flyer





Sources of Error

Differentiation is inherently noisy

Flyer ringing, especially for laminated flyer plates

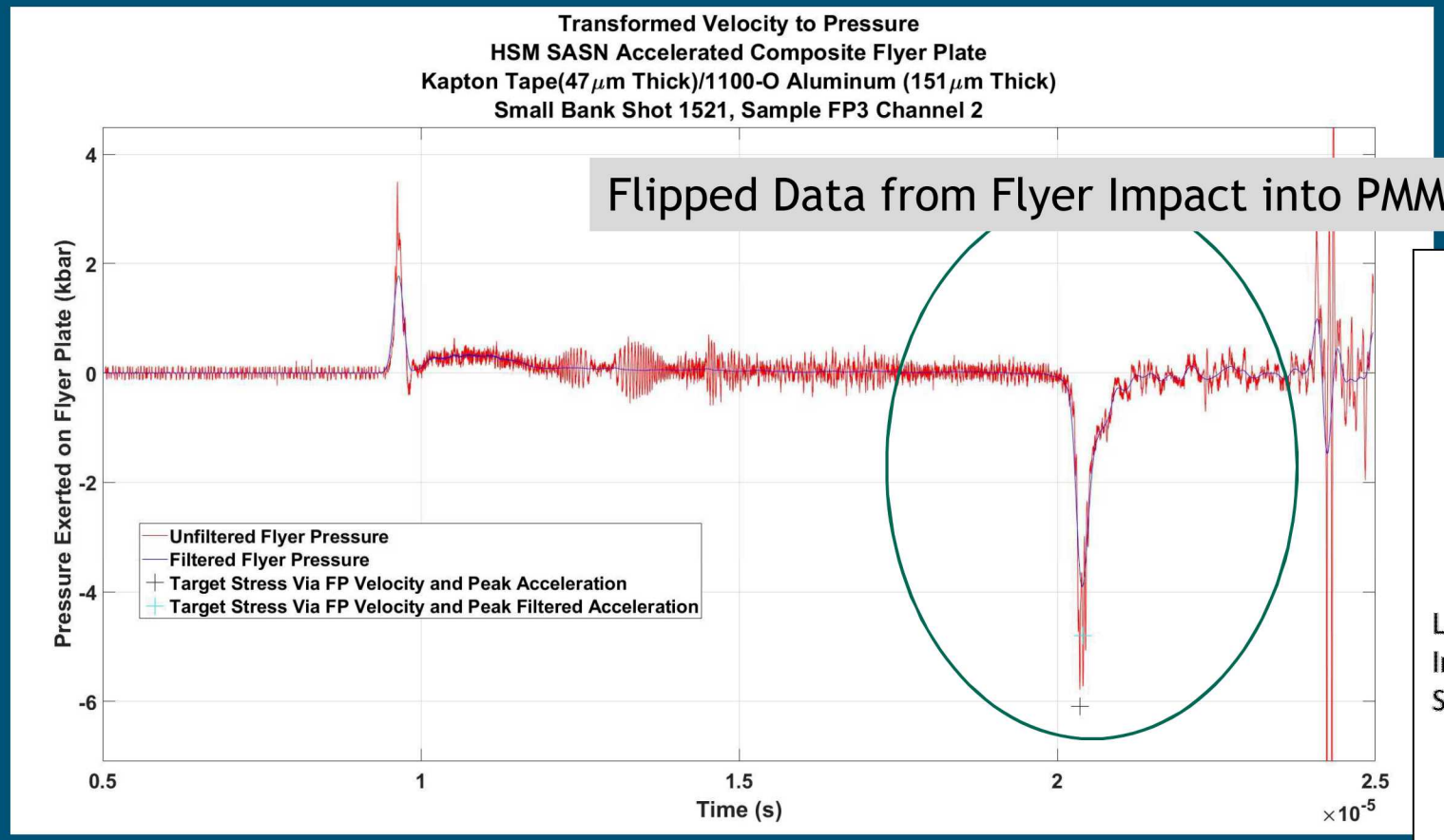
- Filtering helps, but can reduce amplitude as see in hydrocode modeling

Flyer thickness is assumed to be negligible

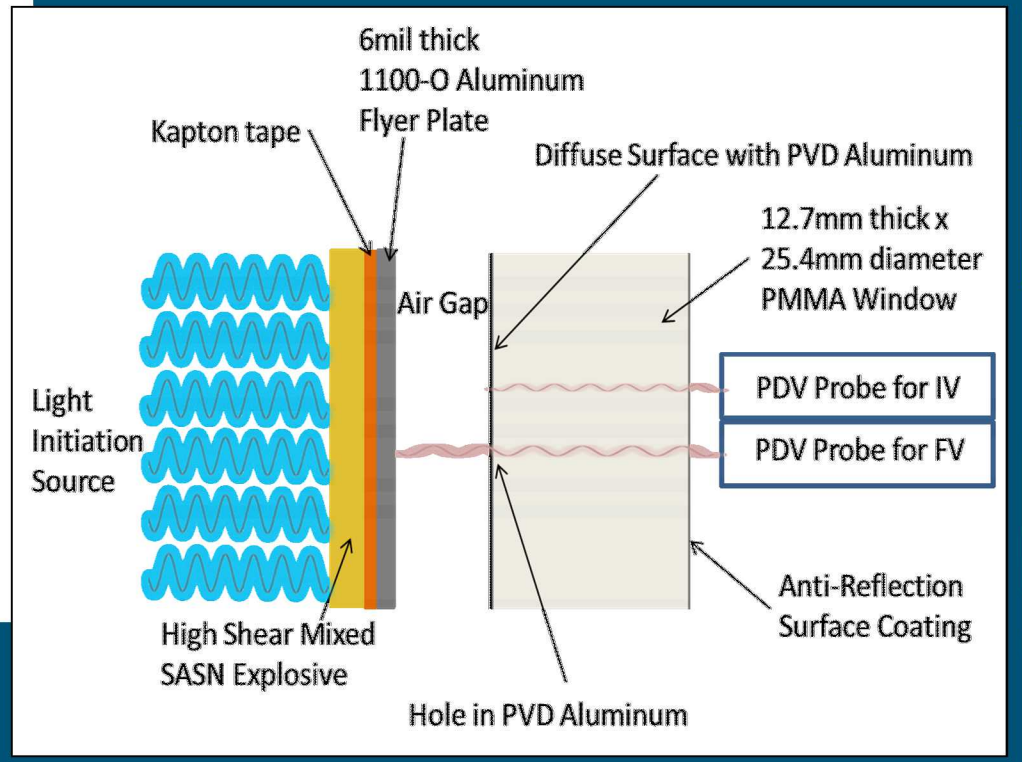
Non-planarity of wave-front

Experiment does not follow one-dimensional models, i.e. multi-faceted wave-front/wavelets

Independent Experimental Confirmation

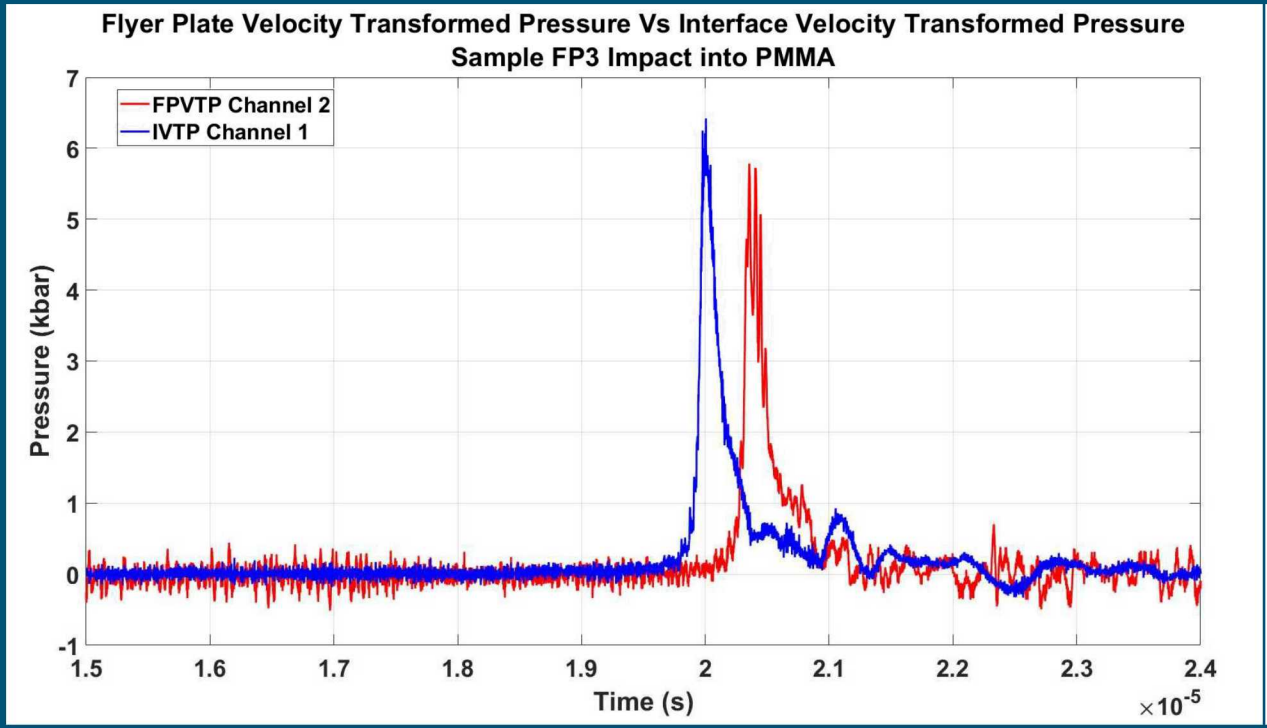


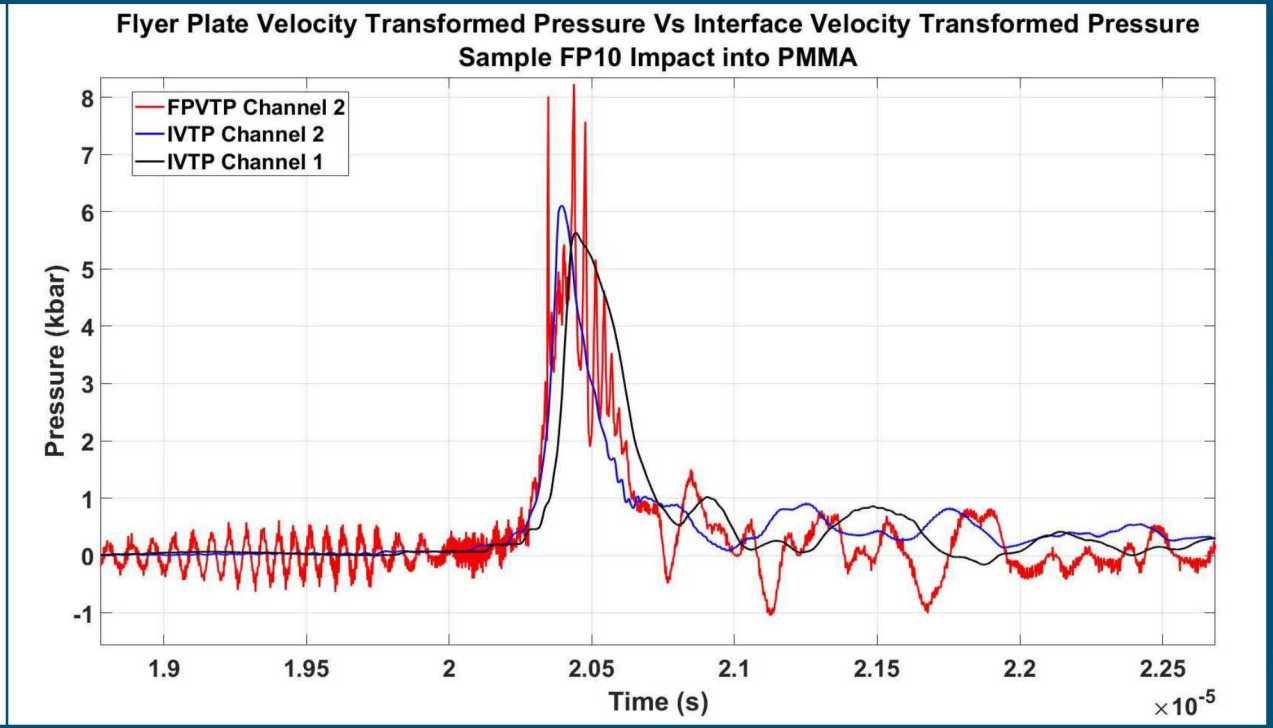
Flipped Data from Flyer Impact into PMMA Target



Independent Experimental Confirmation

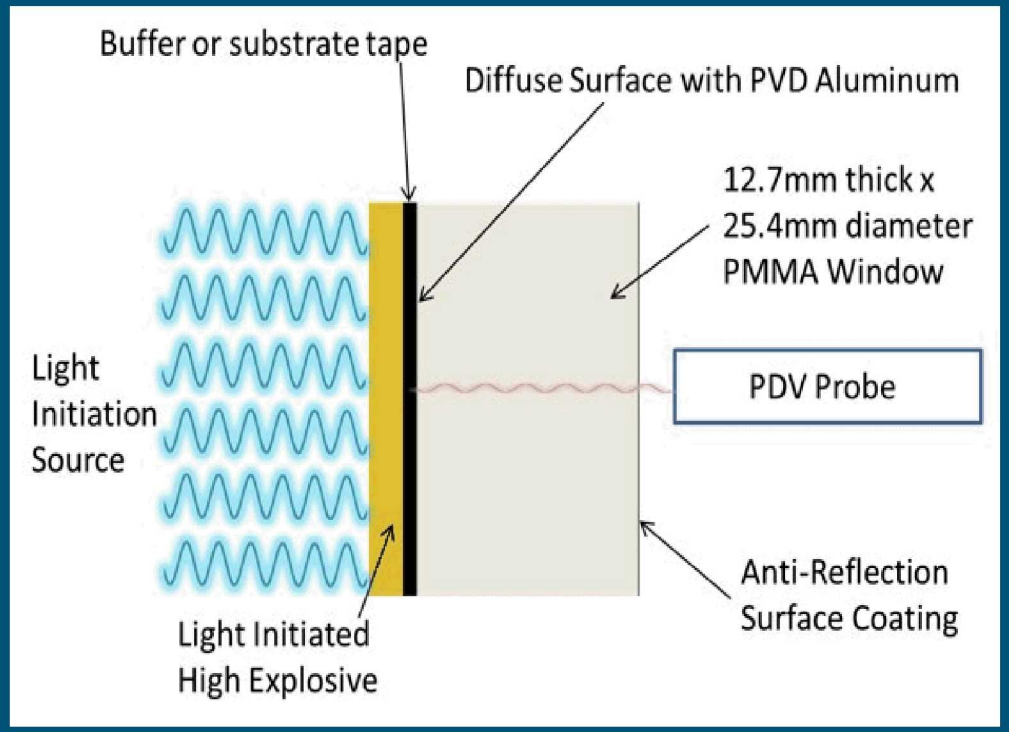
Flyer plate impact comparisons





Independent Experimental Confirmation

Impedance Window Matching Method



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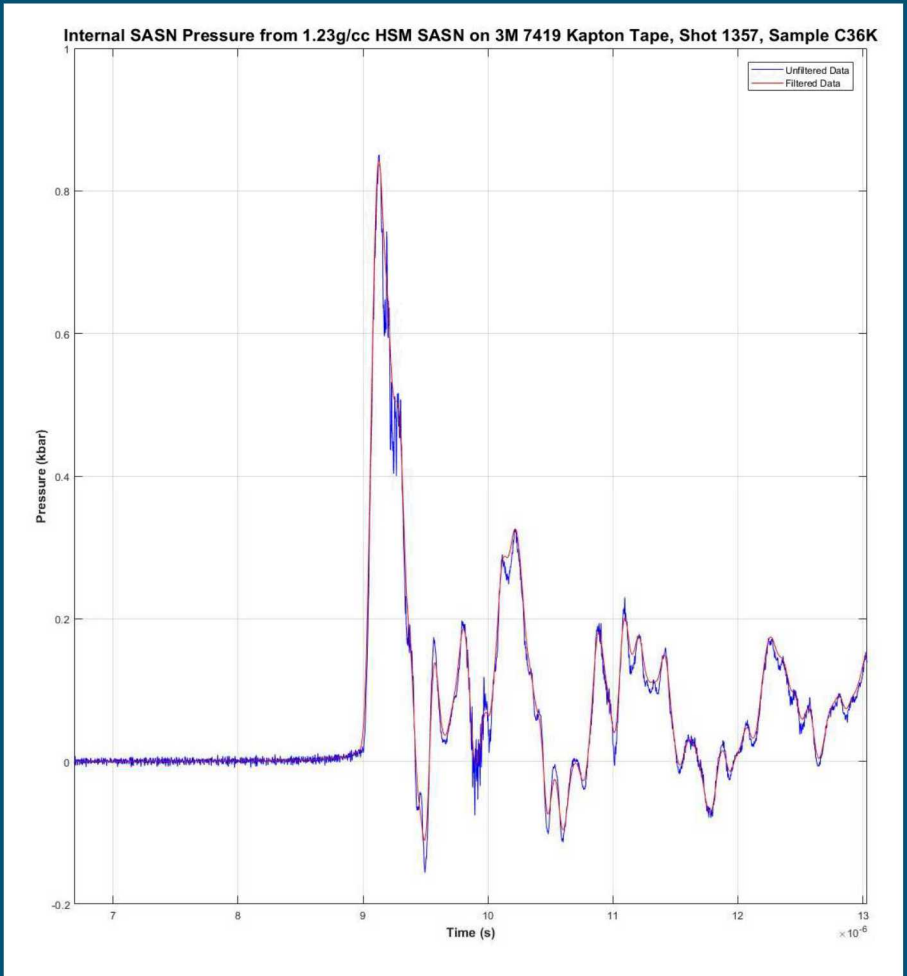

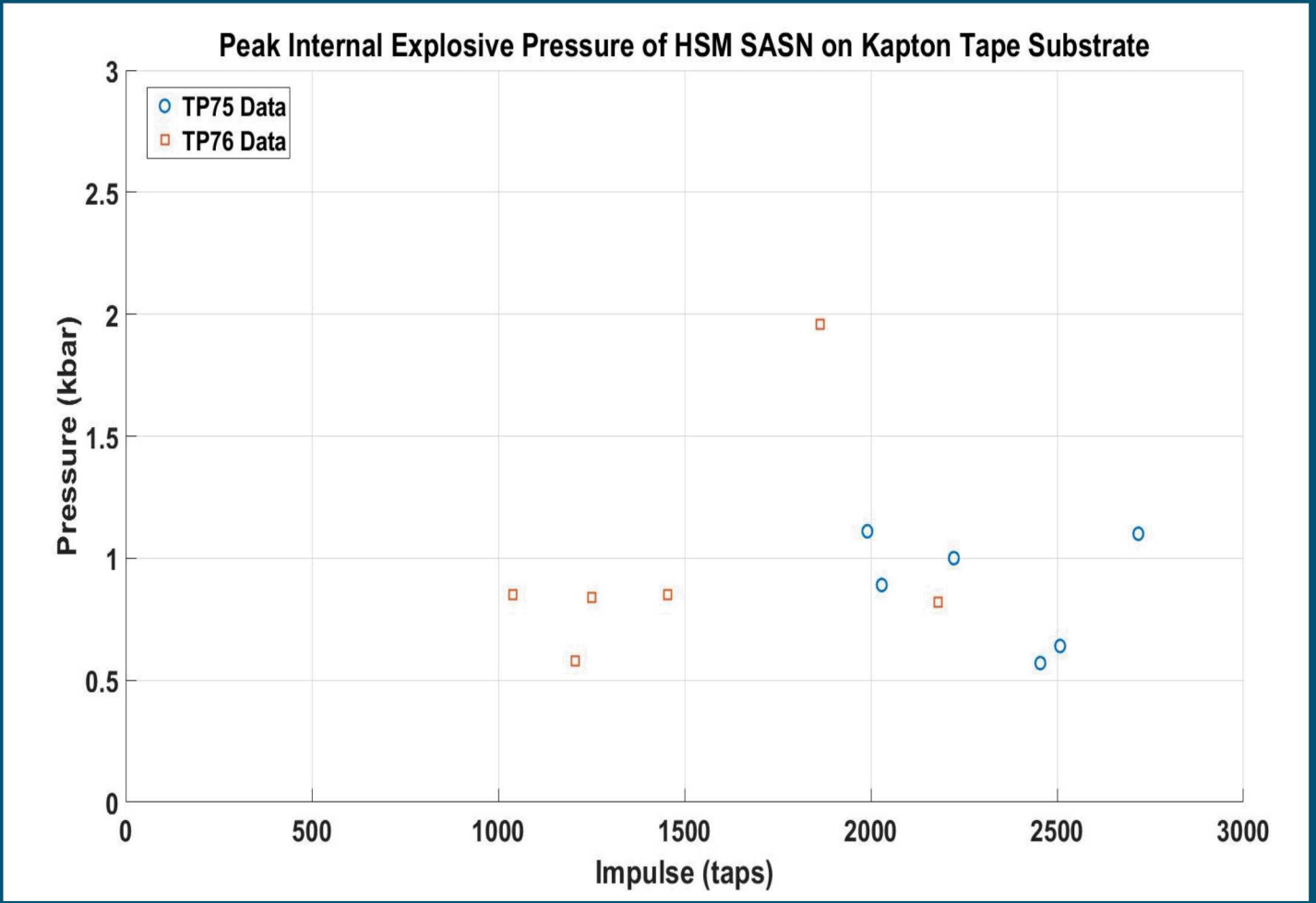

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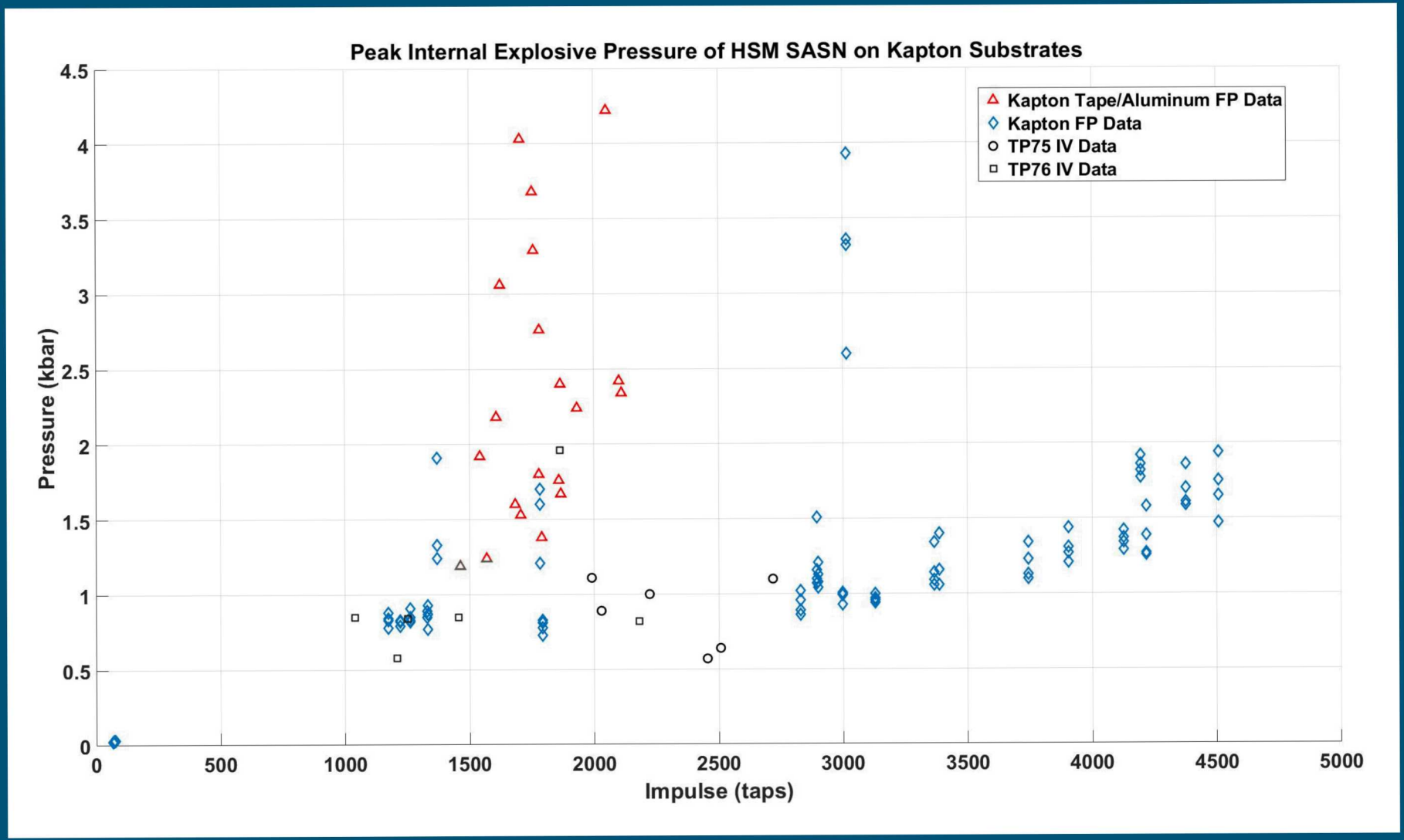

Conclusions

- Flyer plate experiments offer multitude of data mining opportunities
- Development of technique to derive internal explosive pressure
- Hydrocode analysis suggests Taylor wave will be cut short
  - Filtering is difficult to properly employ
  - Hydrocode suggests that technique may work for some combinations of HE/flyer materials
- Many sources of error to consider
- Experimental evidence suggests technique is valid for some cases and questionable for others