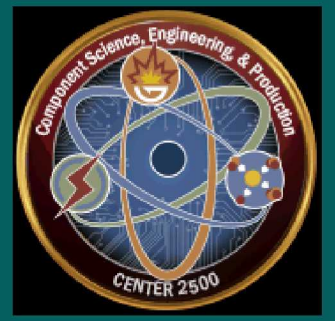
SAND2019-12720C

Gurney Analysis for High Shear Mixed Silver Acetylide-Silver Nitrate Explosive on Kapton Substrates



90th Shock & Vibration Exchange Symposium
November 3rd—7th 2019
Atlanta, GA

PRESENTED BY

Marcus A. Chavez

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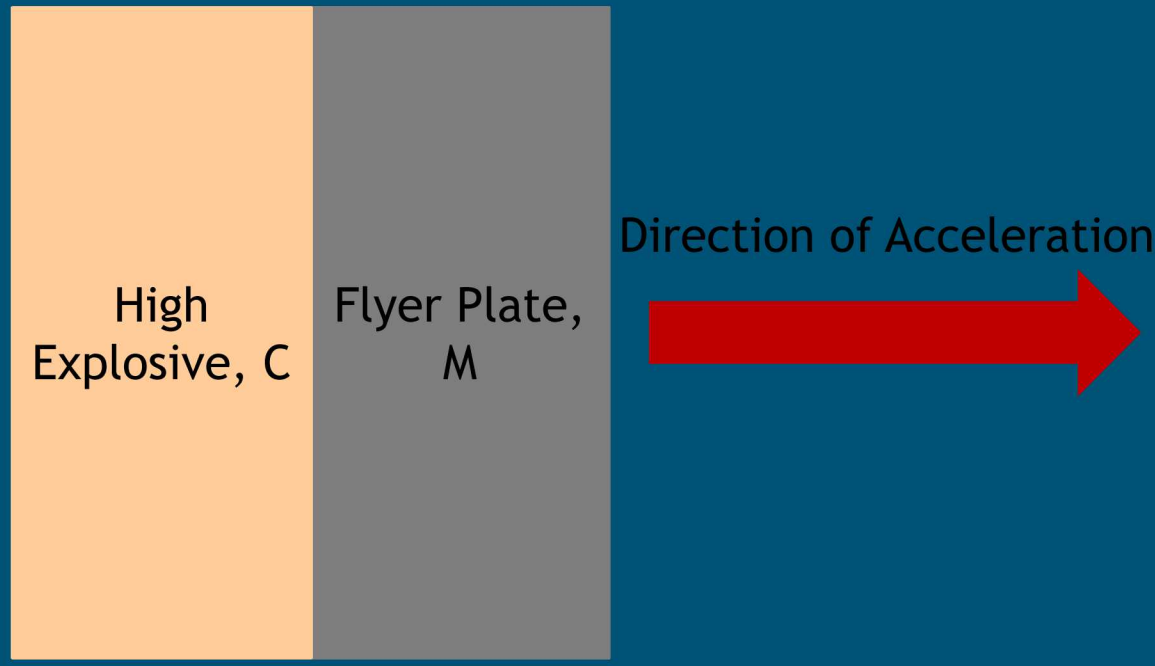
Outline

- General Gurney Analysis
- Light Initiated High Explosives
- Flyer Plate Experiments
- Process Variability
- Modified Processing Techniques
- Improved Flyer Plate Experiments
- Results
- Application of Gurney Analysis
- Summary

General Gurney Analysis

- Flyer plate to explosive mass ratio
  - C=HE mass
  - M=FP mass
- Open-face sandwich geometry

$$\frac{V}{\sqrt{2E}} = \left[\frac{\left(1+2\frac{M}{C}\right)^3+1}{6\left(1+\frac{M}{C}\right)}+\frac{M}{C}\right]^{-\frac{1}{2}}$$

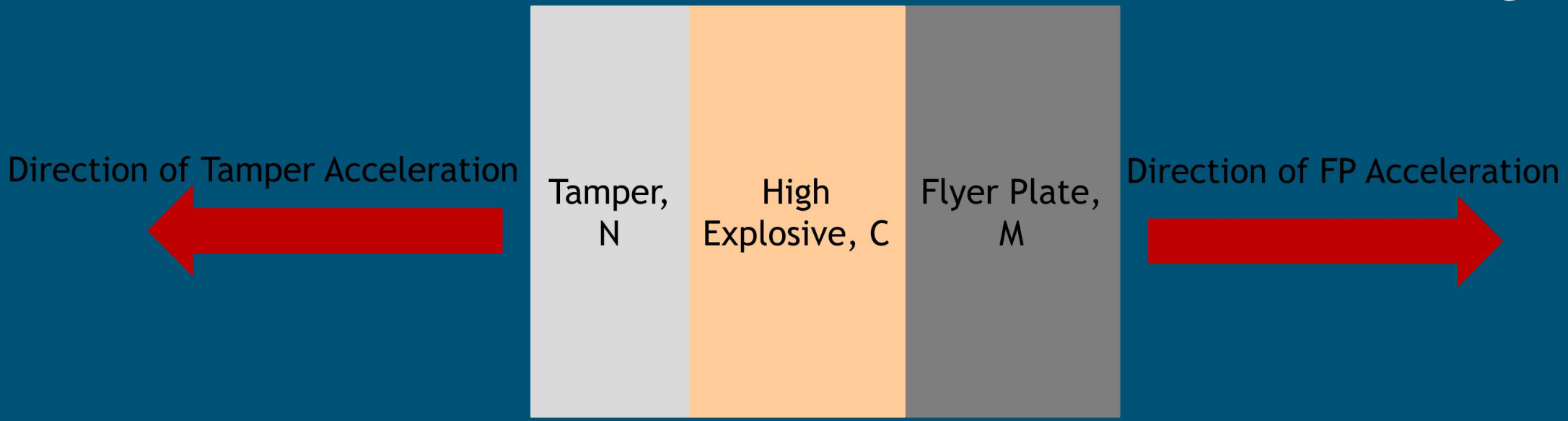


General Gurney Analysis

$$\frac{V}{\sqrt{2E}} = \left[\frac{1+A^3}{3(1+A)} + \frac{N}{C}A^2 + \frac{M}{C}\right]^{-\frac{1}{2}}$$

- Flyer plate explosive mass ratio
  - C=HE mass
  - M=FP mass
  - N=Tamper mass
- Asymmetric sandwich geometry

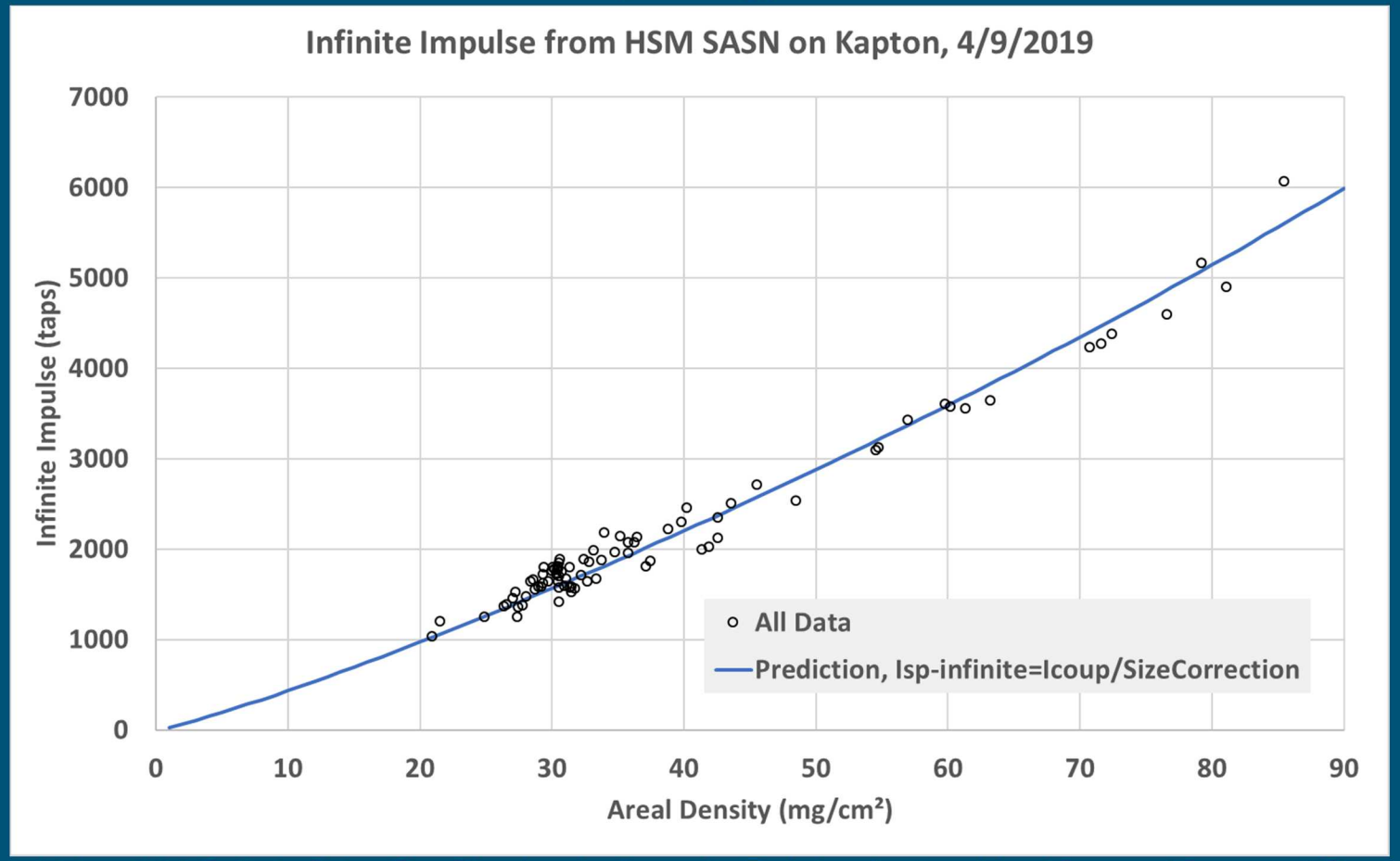
$$A = \frac{1+2\frac{M}{C}}{1+2\frac{N}{C}}$$



Ref: P. W. Cooper, Explosives Engineering, 2nd Edition, New York, Wily-VCH, 1996.

General Gurney Analysis

- Impulse can be used to determine the Gurney energy, $\sqrt{2E}$

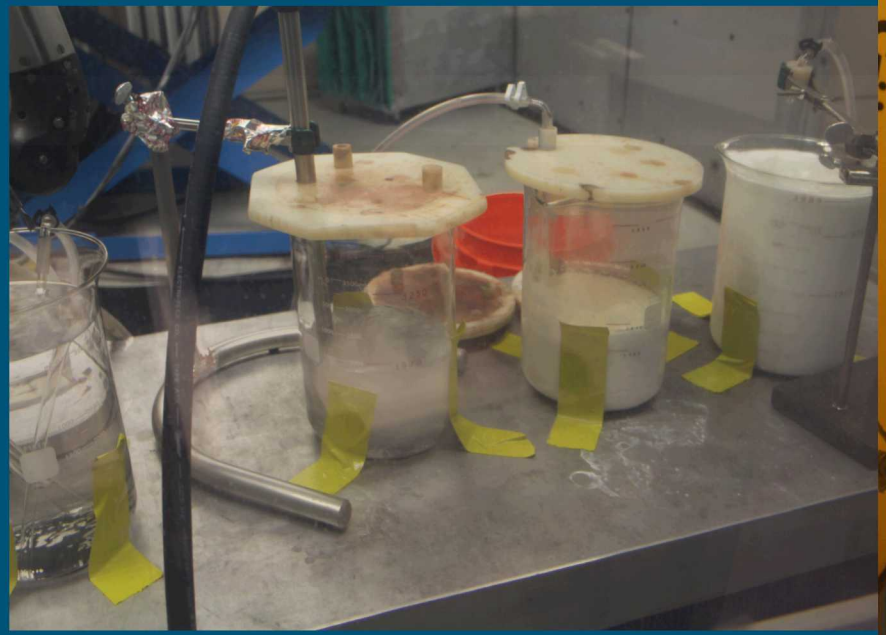


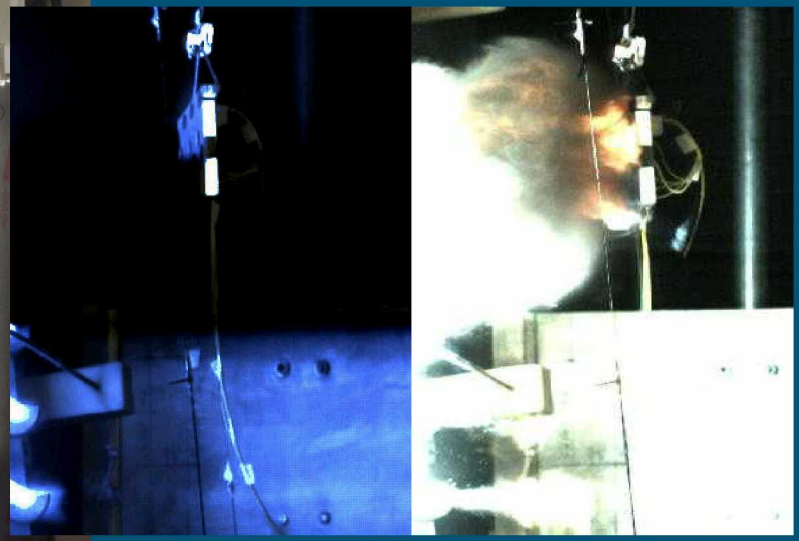
Ref: Rivera, W.G., *Light Initiated High Explosive Driven Flyer Plate Impulse Generation Technique for Material and Structural Response, A Dissertation*. Department of Materials and Metallurgical Engineering. Socorro, New Mexico : New Mexico Institute of Mining and Technology, Spring 2006.

Light Initiated High Explosives

Silver acetylide-silver nitrate (SASN)

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

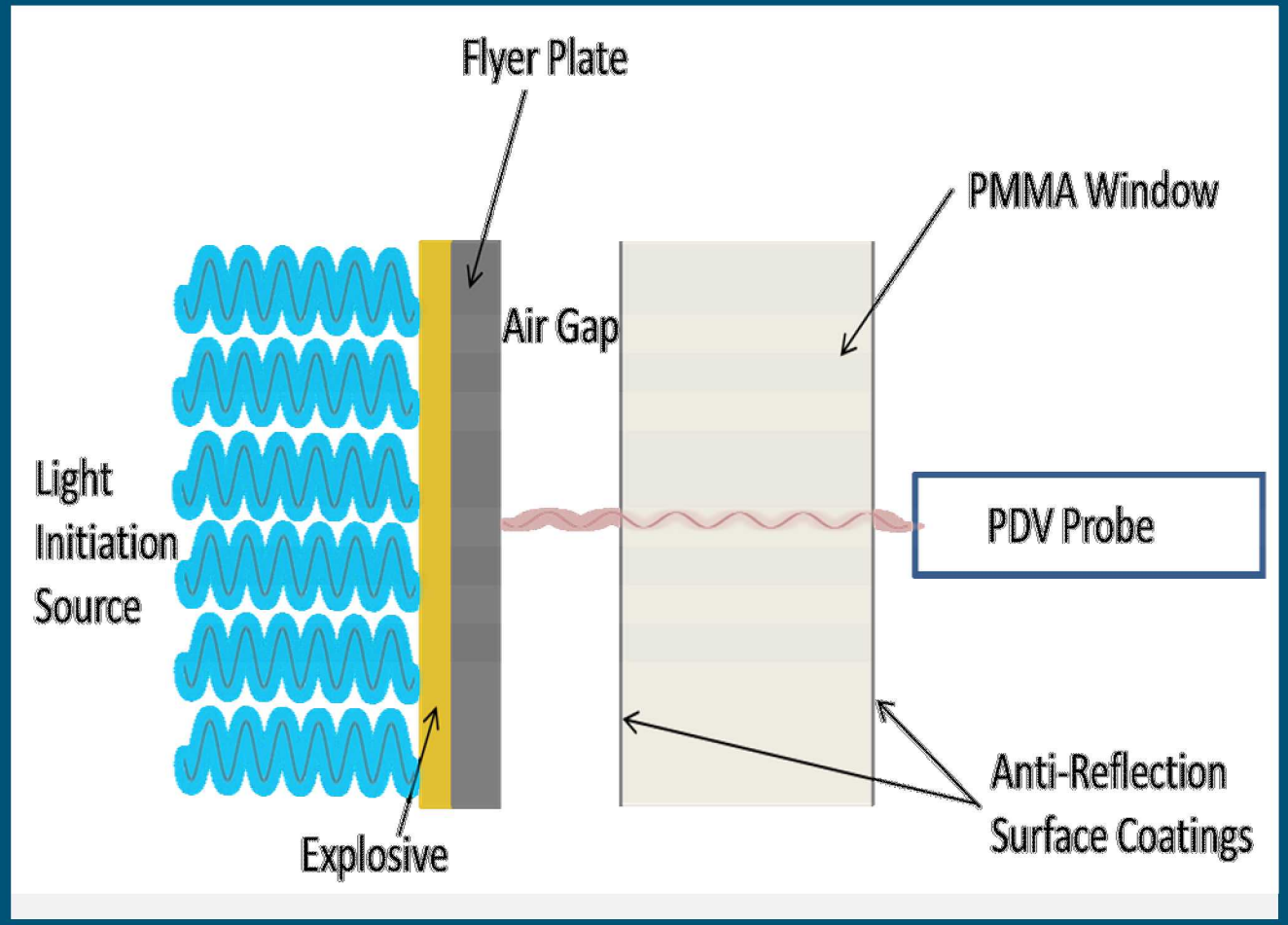




Flyer Plate Experiments

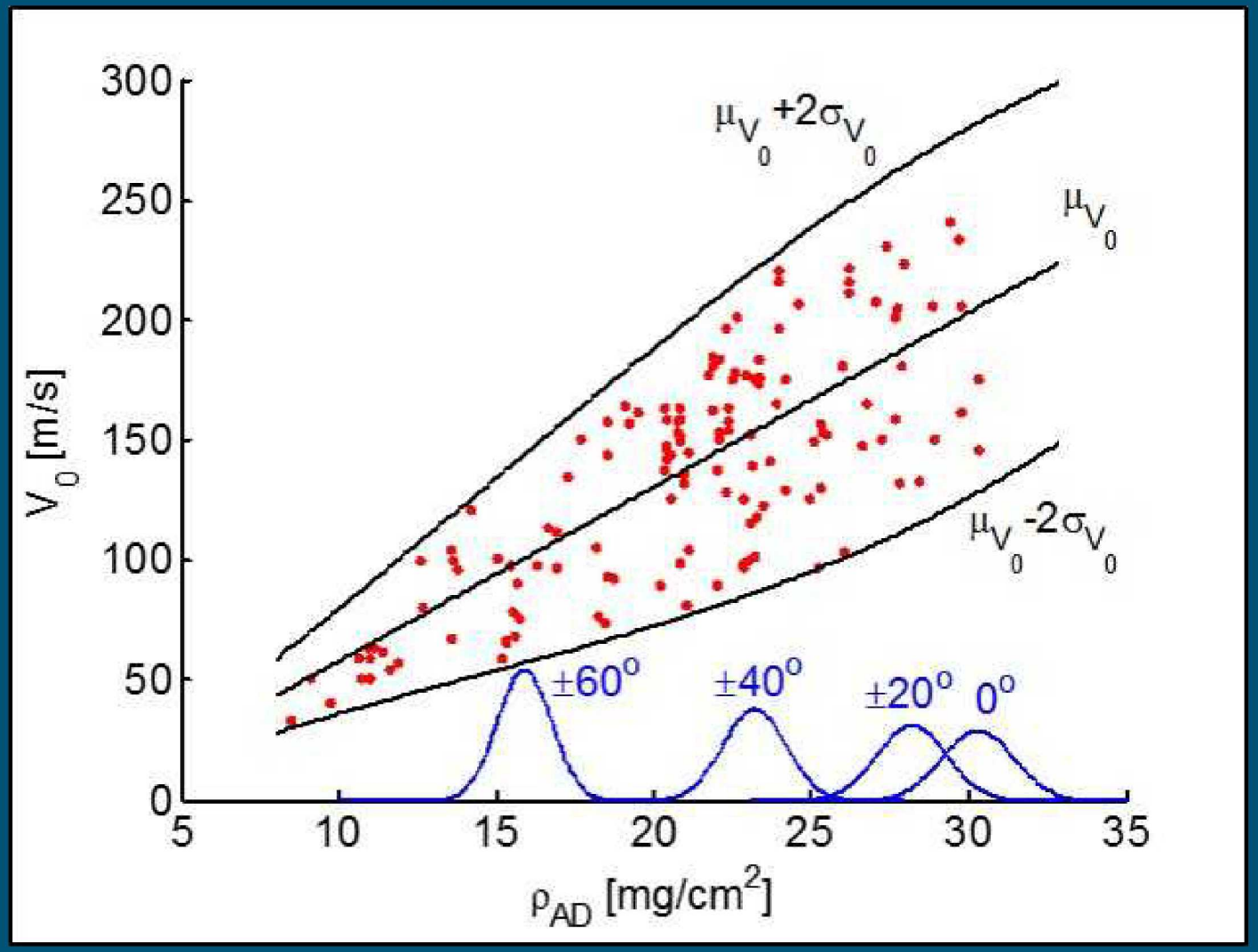
Experimental Set-up

Unmodified Explosive & Aluminum Substrate



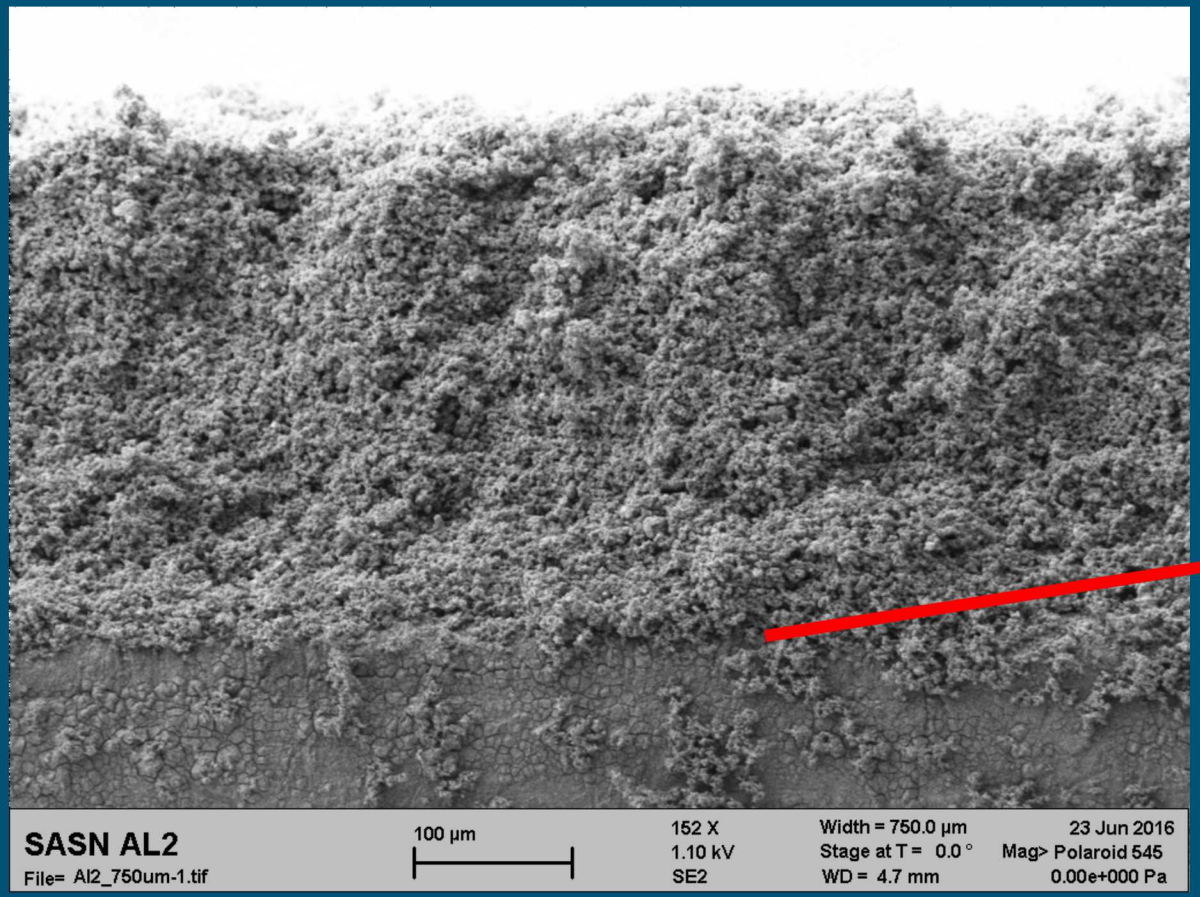
Process Variability

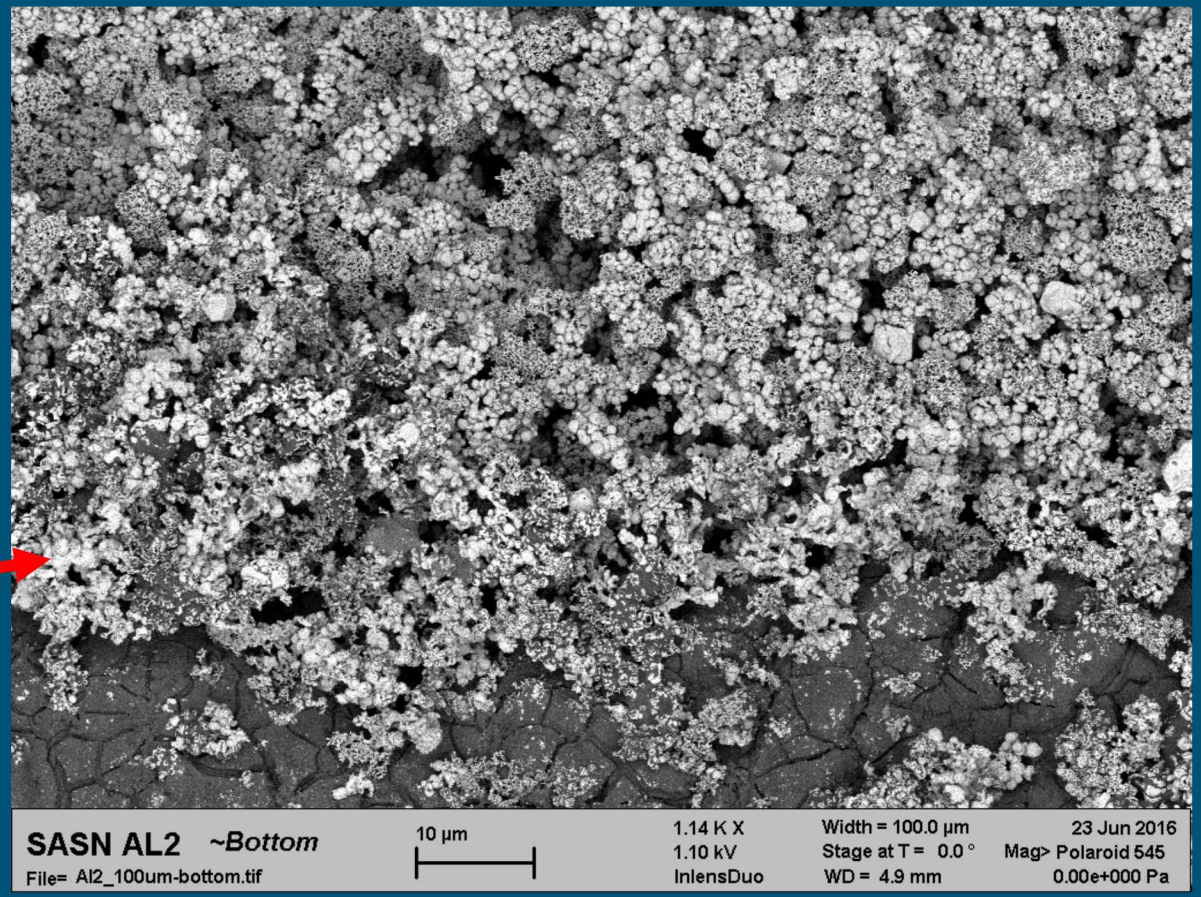
Unmodified Explosive & Aluminum Substrate



Process Variability

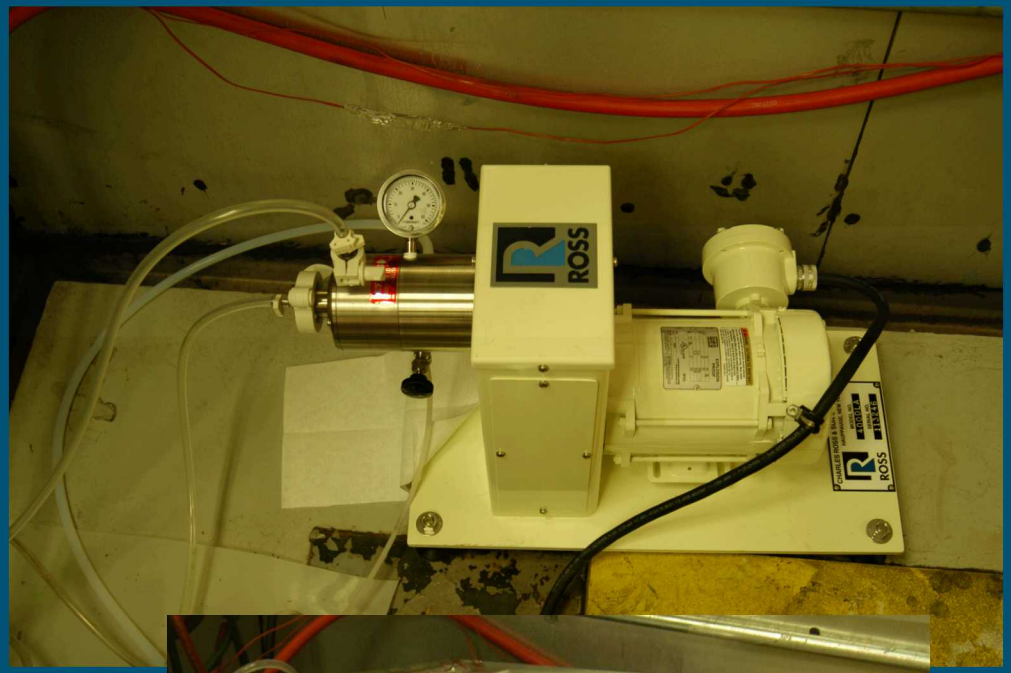
SASN is an explosive foam, ~90% air, when spray deposited by an air-driven system

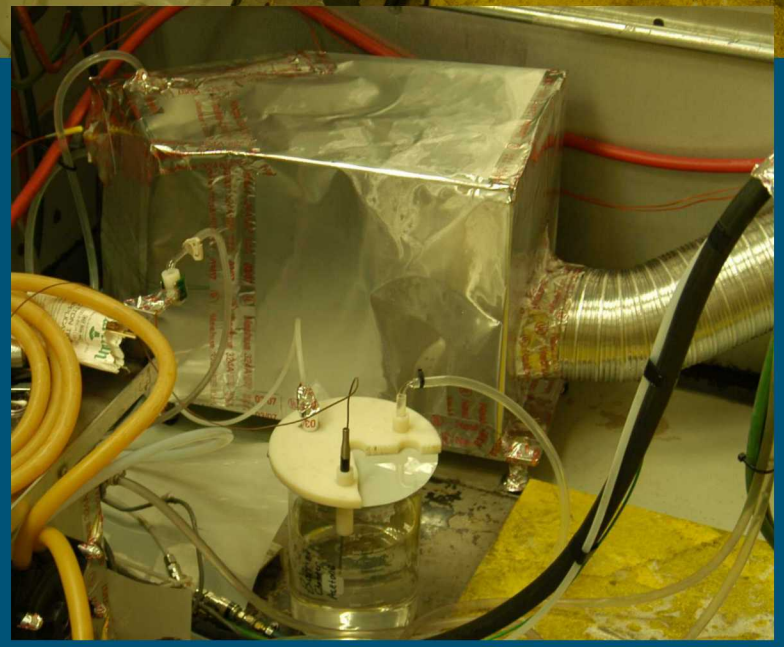




Modified Processing Techniques

High-shear mixing (HSM) equipment





Modified Processing Techniques

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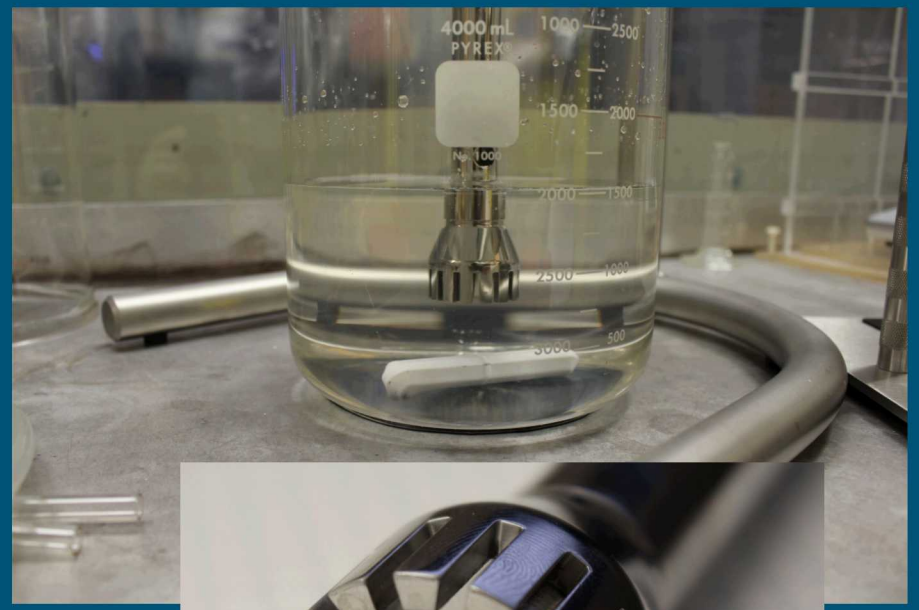


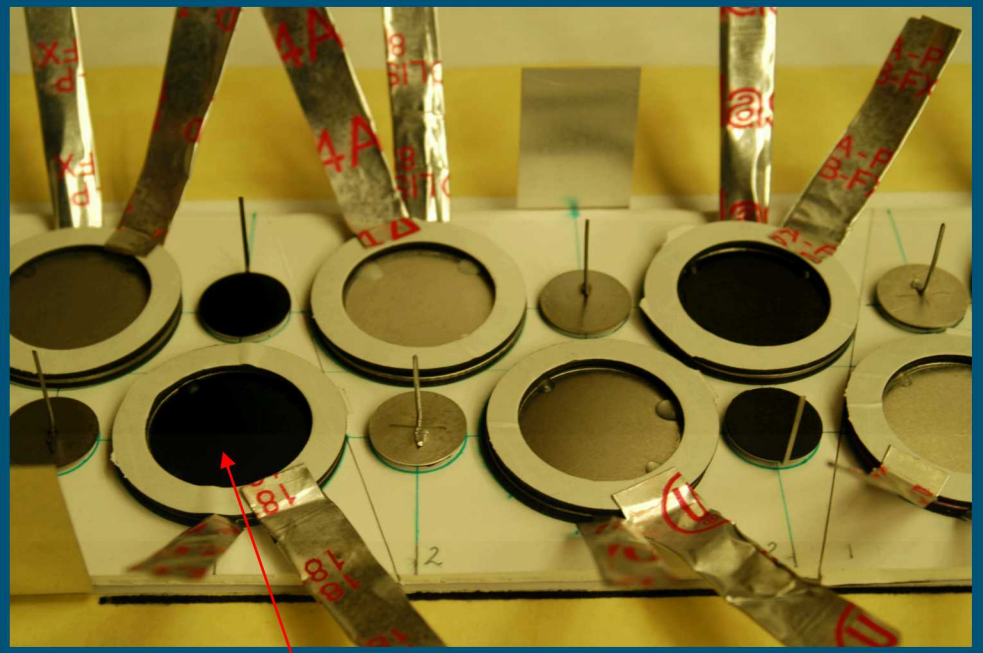
Modified Processing Techniques

Subsequent testing on 3 different substrate types:

1. Stainless steels (SS) (300 and 400 series)
2. Kapton (tapes and sheet)
3. 1100-O series aluminum for control dataset

Compare modified HE vs unmodified

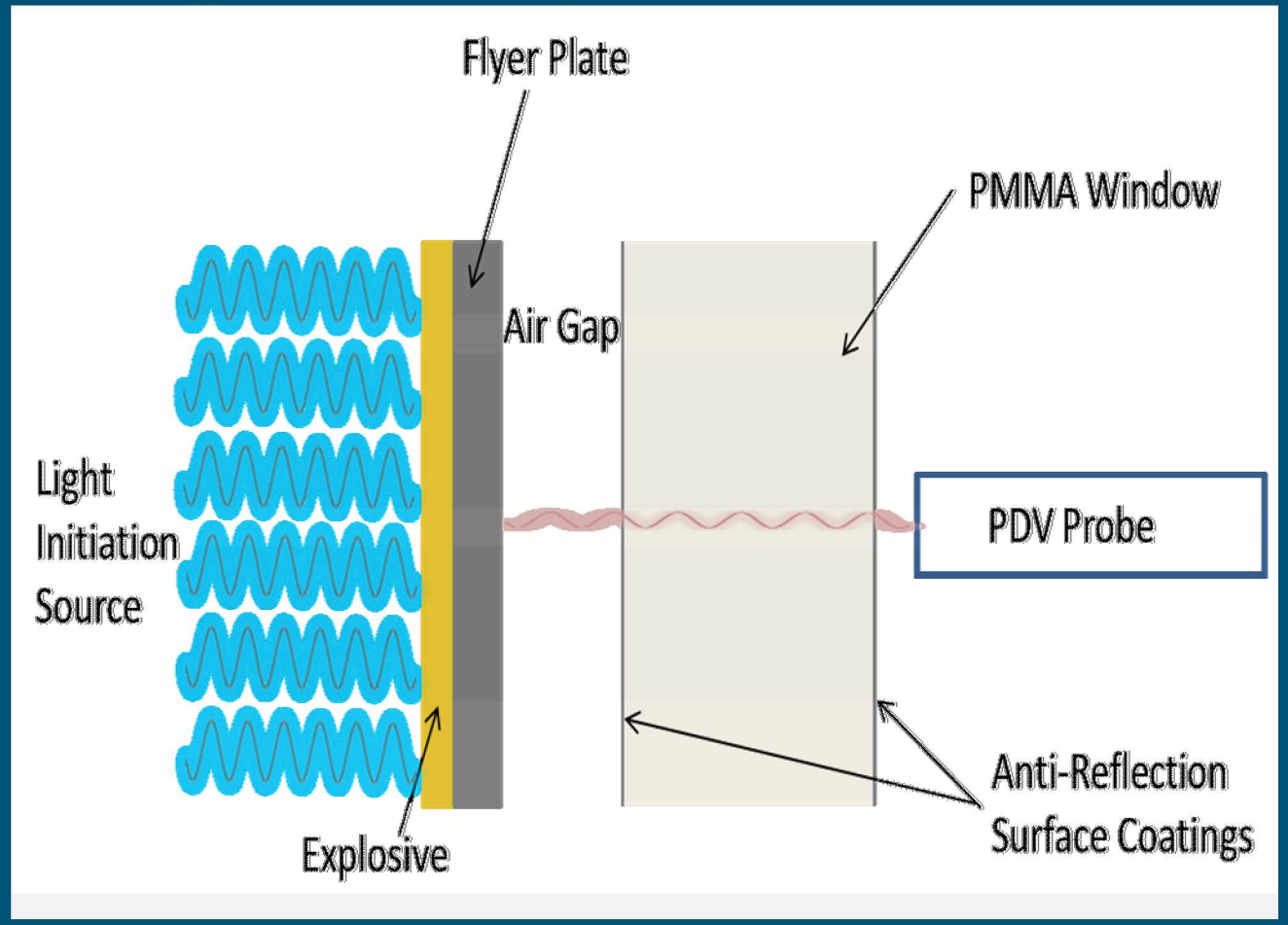
Kapton and SS thought to be chemically compatible



Improved Flyer Plate Experiments

Experimental Set-up

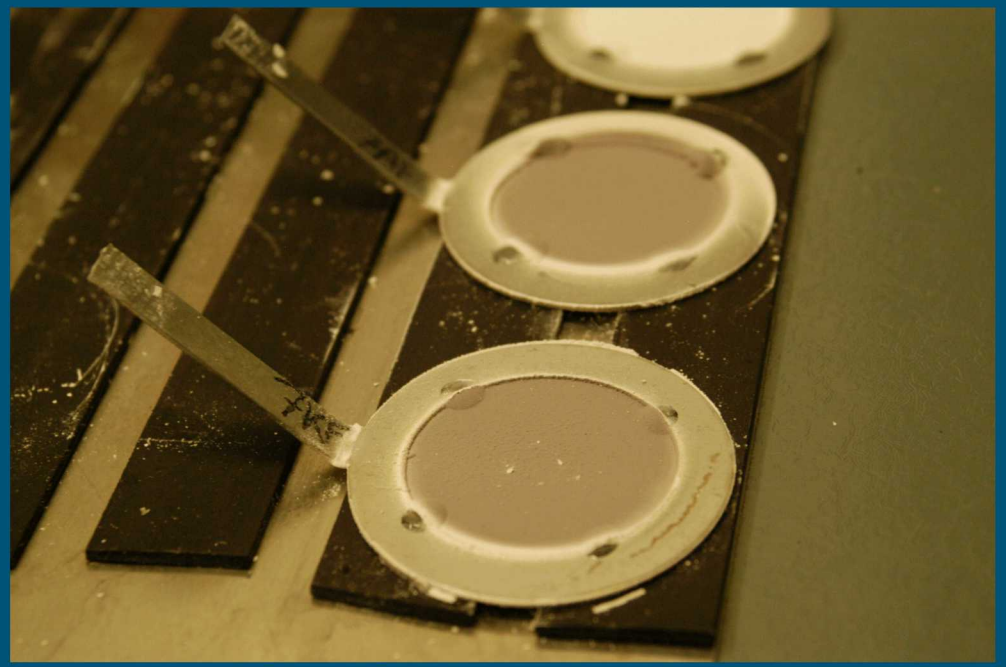
High Shear Mixed Explosive & Kapton Substrate

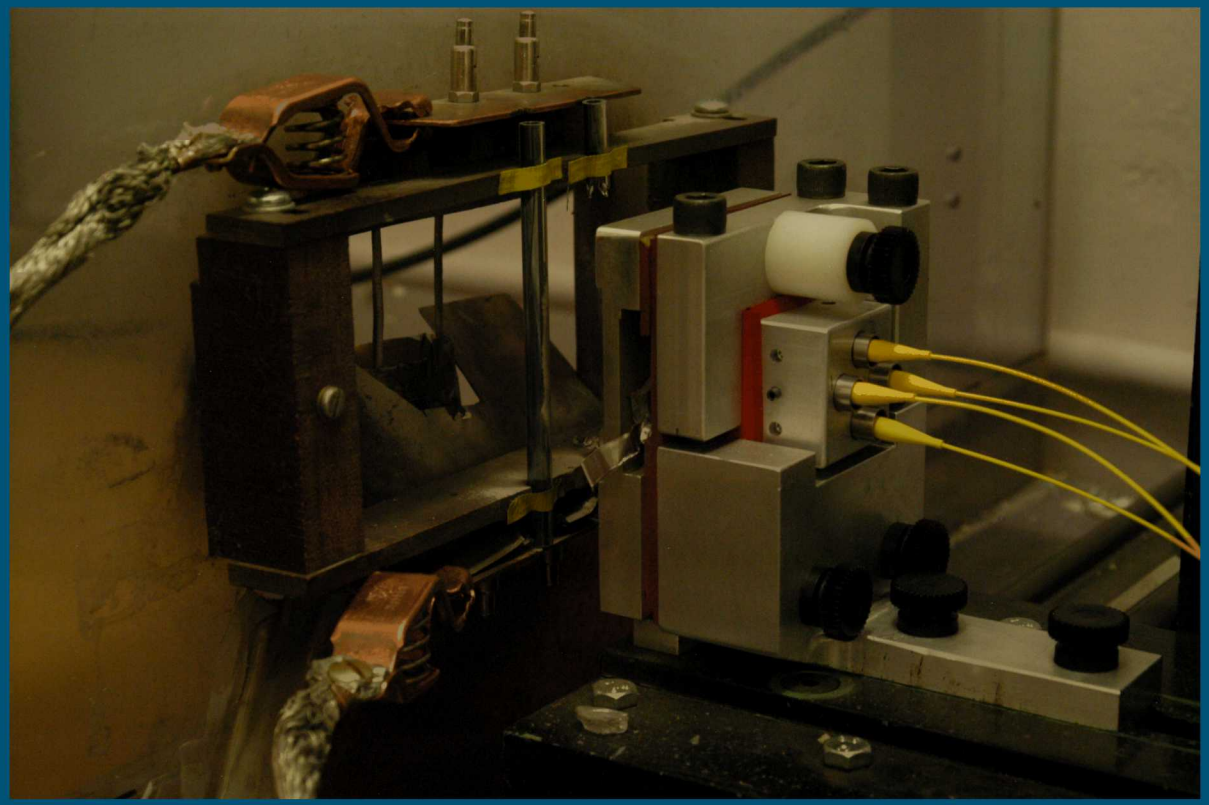


Improved Flyer Plate Experiments

Experimental Set-up

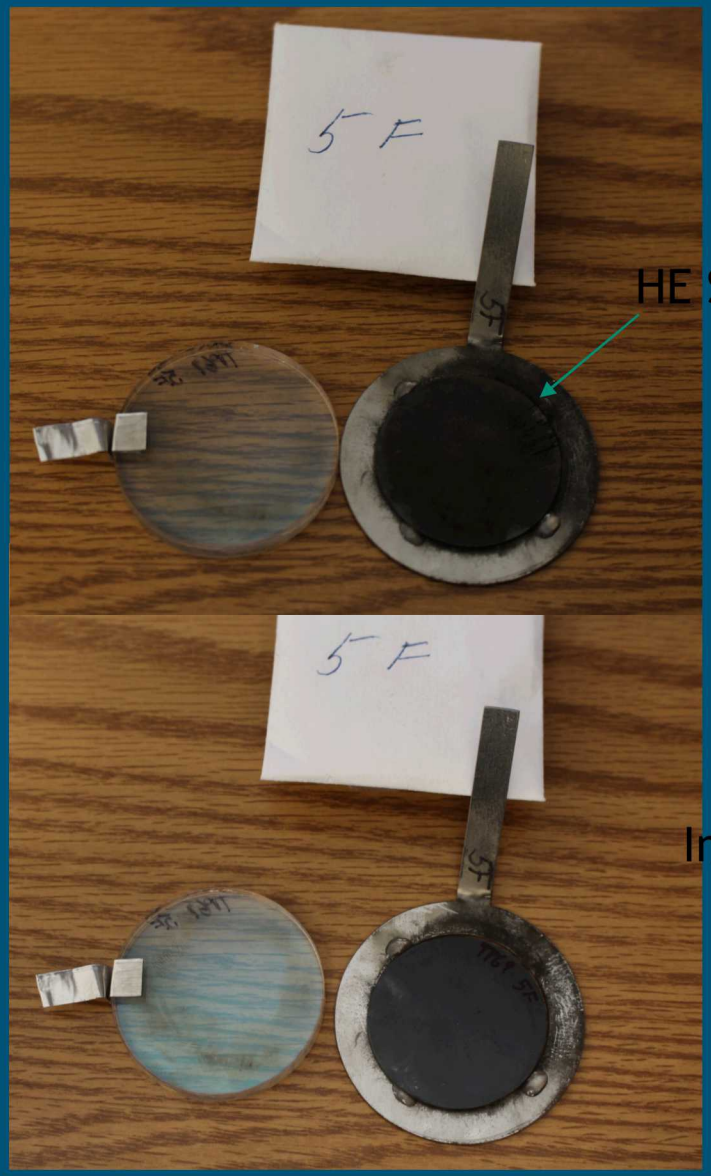
High Shear Mixed Explosive & Kapton Substrate



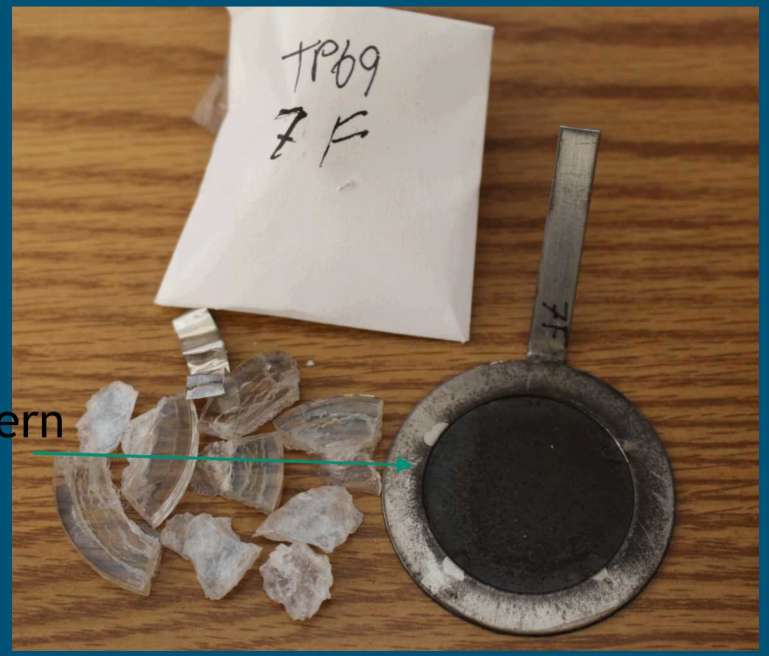


Improved Flyer Plate Experiments

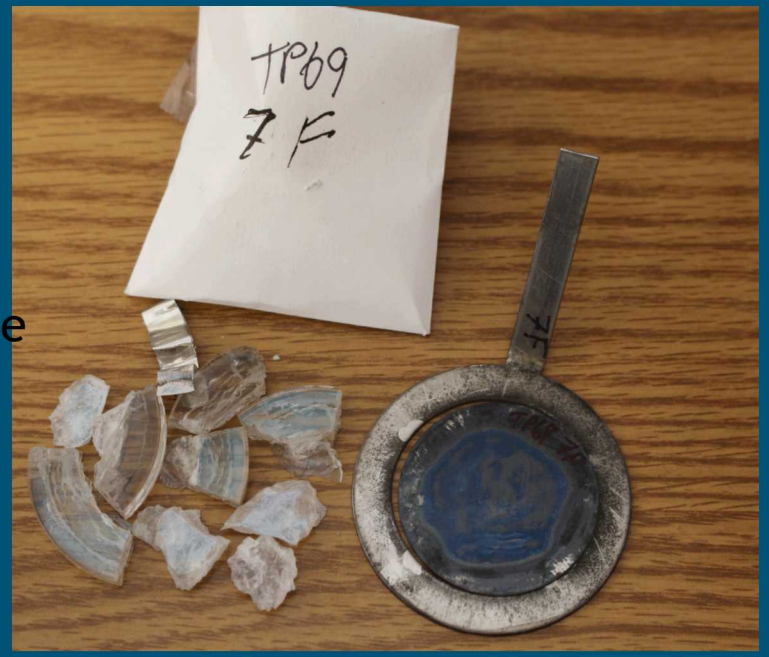
Post-shot



HE Soot Pattern



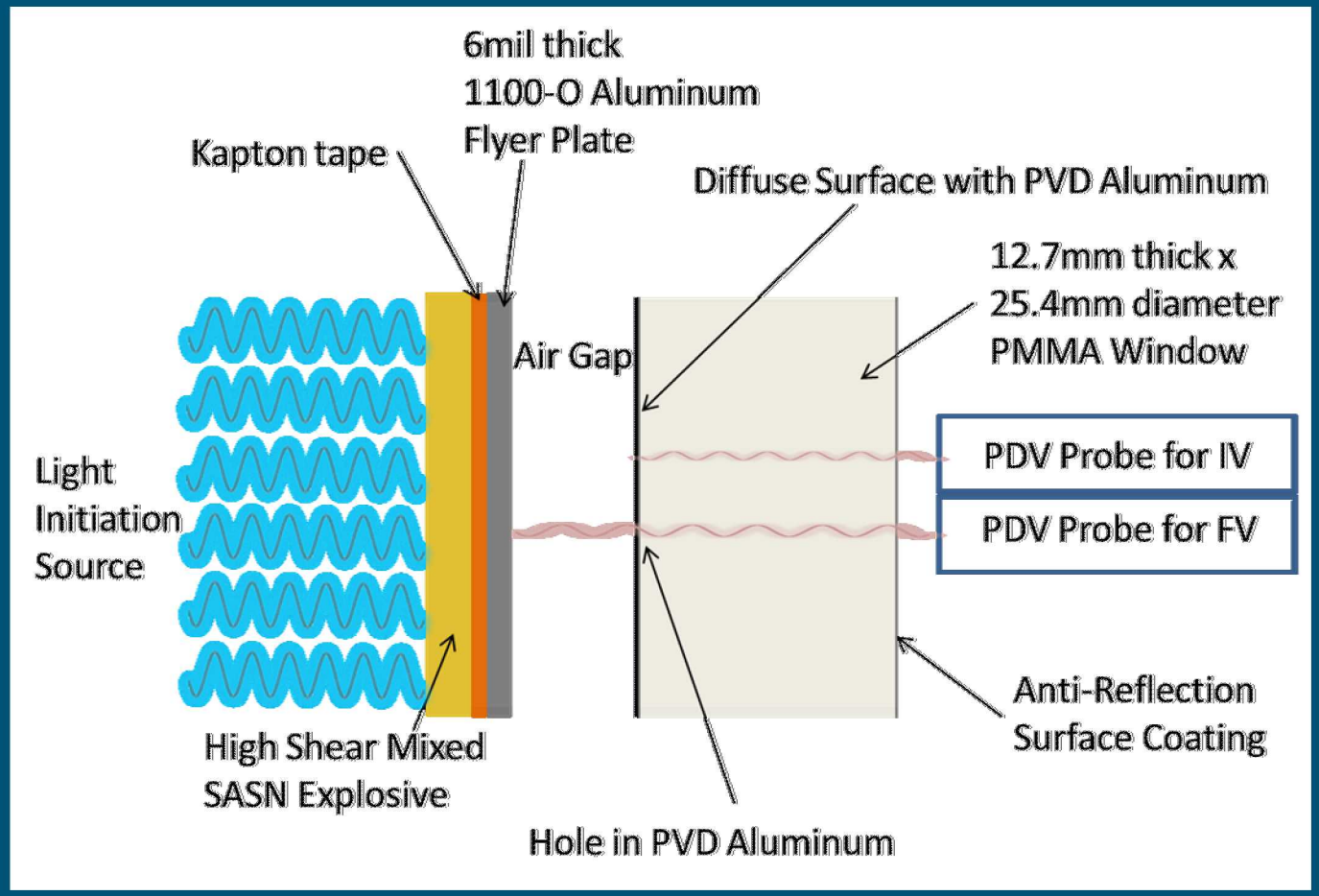
Impact Side



Improved Flyer Plate Experiments

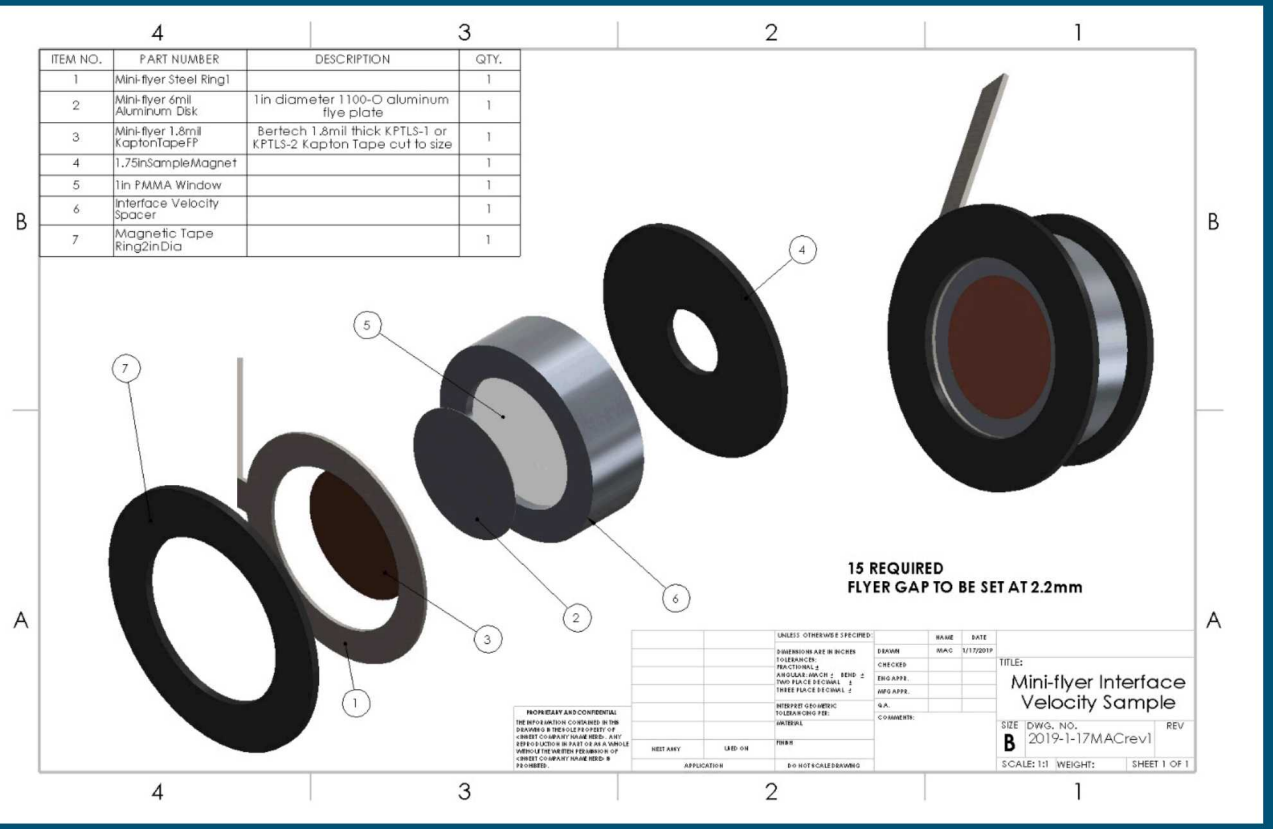
Experimental Set-up

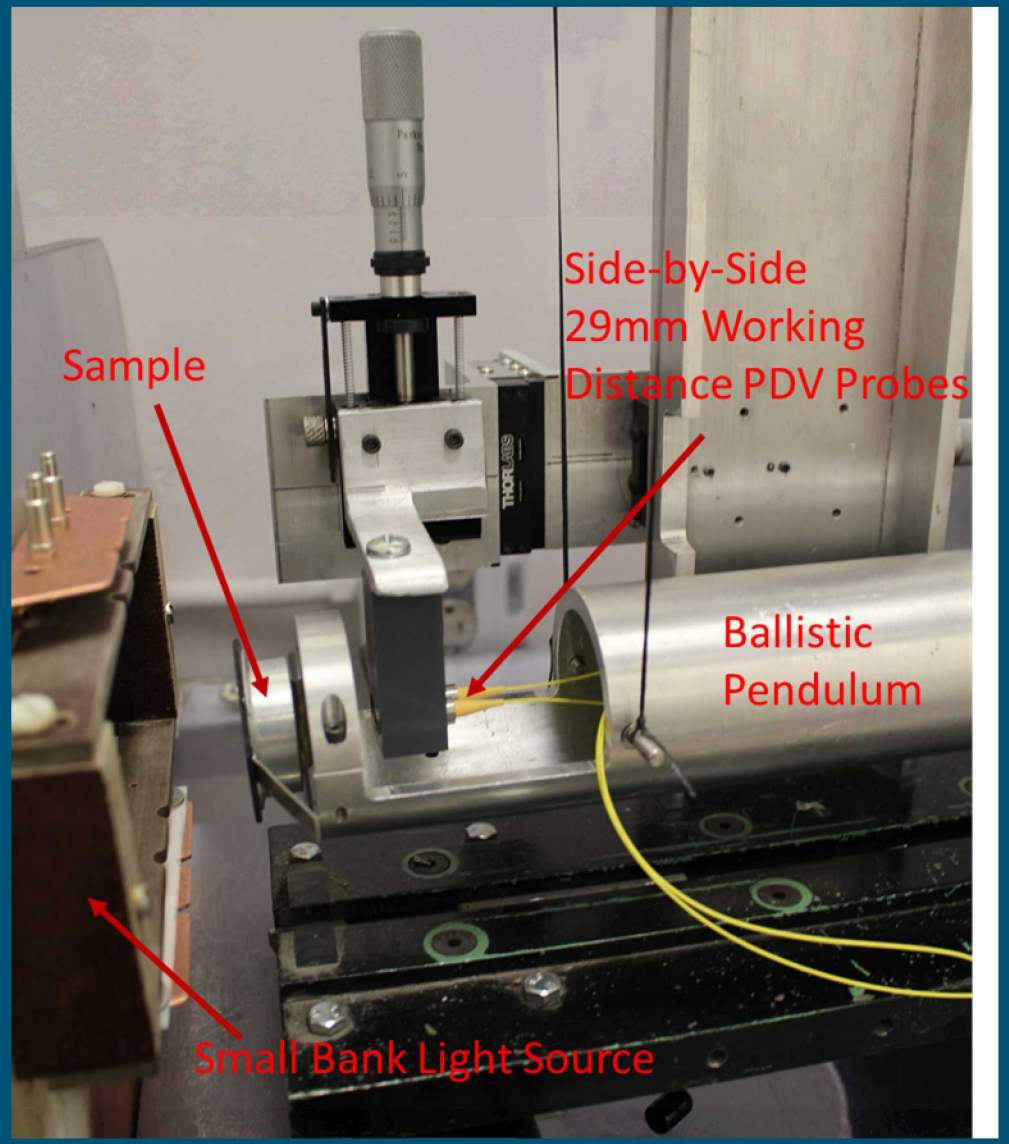
Modified Explosive & Composite Kapton/Aluminum Flyer Plate



Improved 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



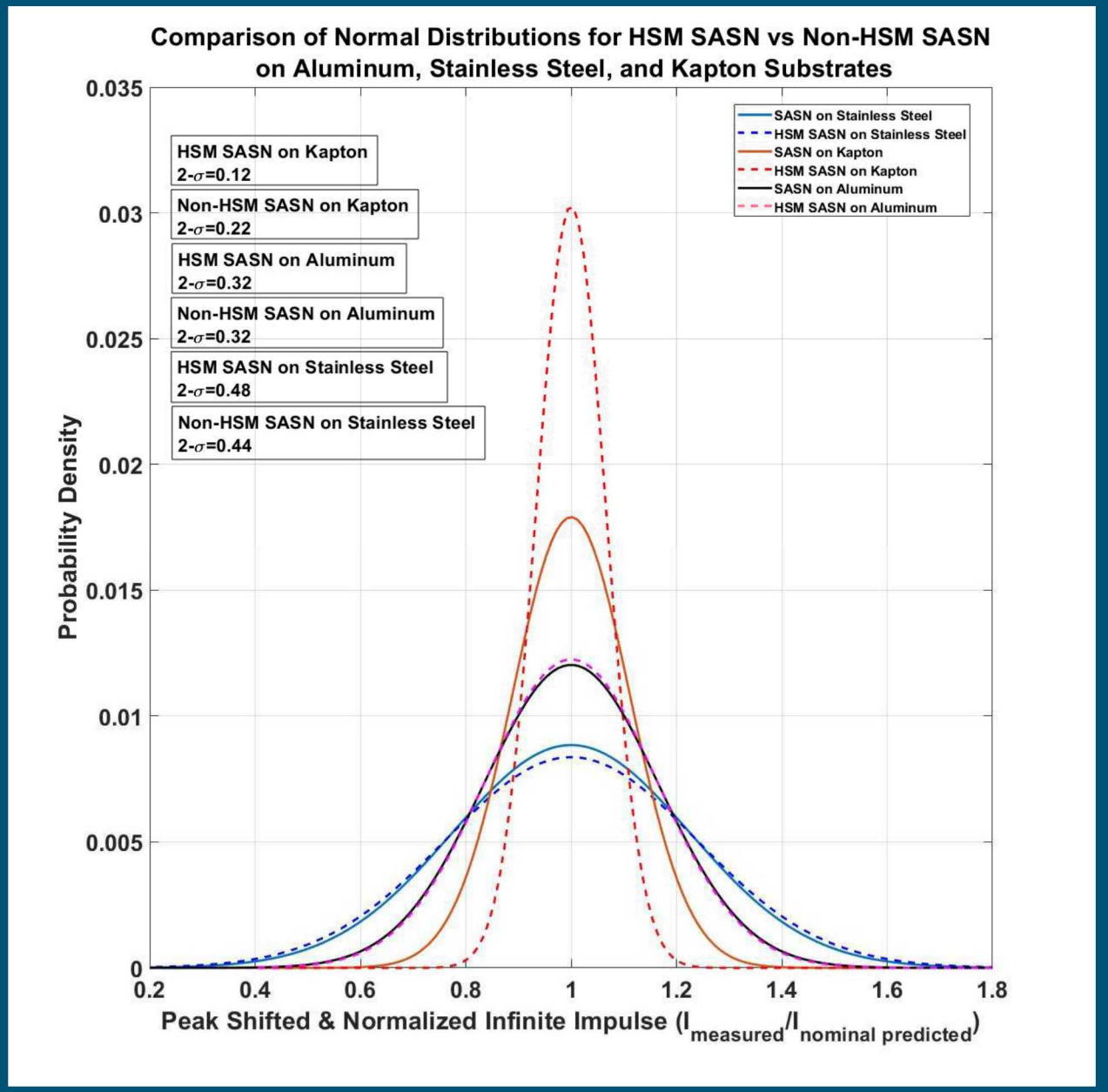


Improved Flyer Plate Experiments

Post-shot

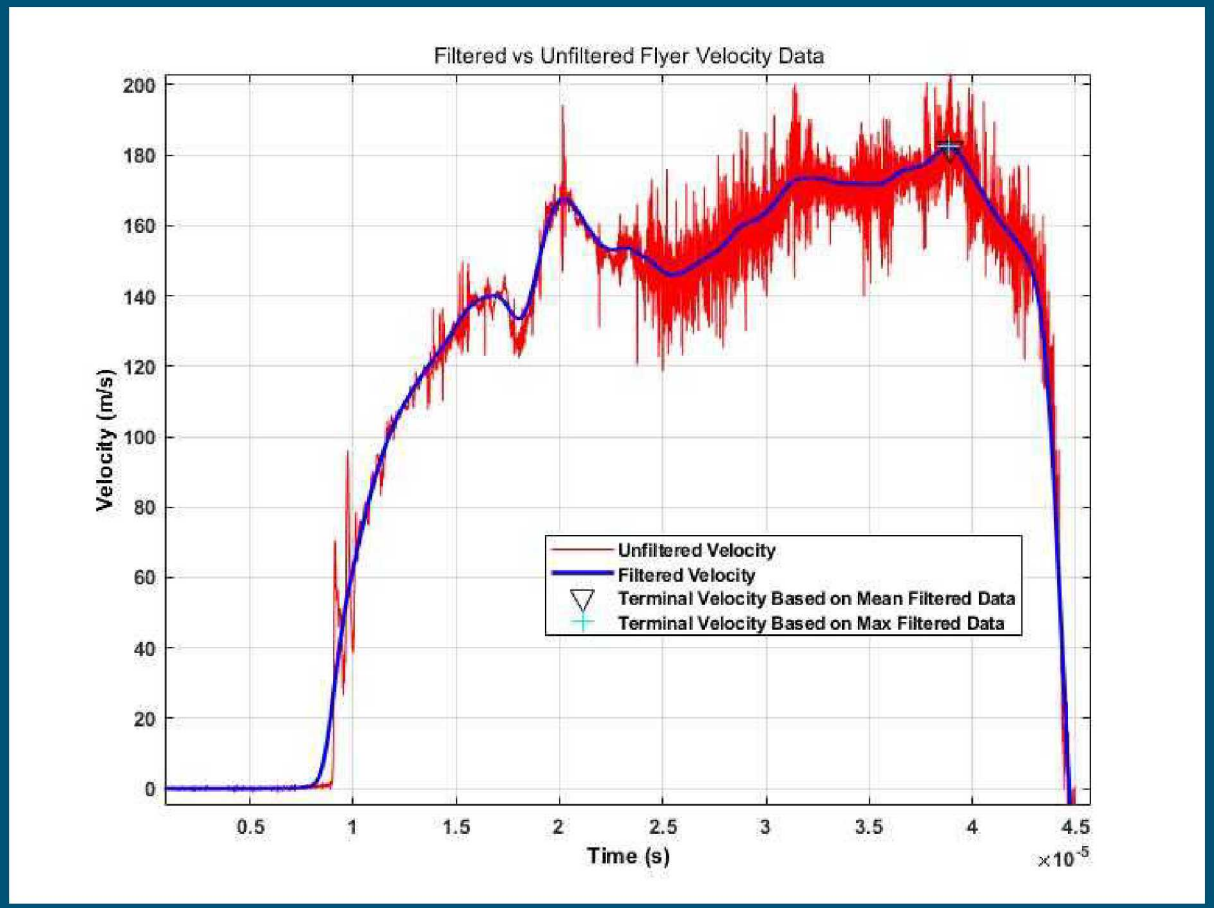
Results

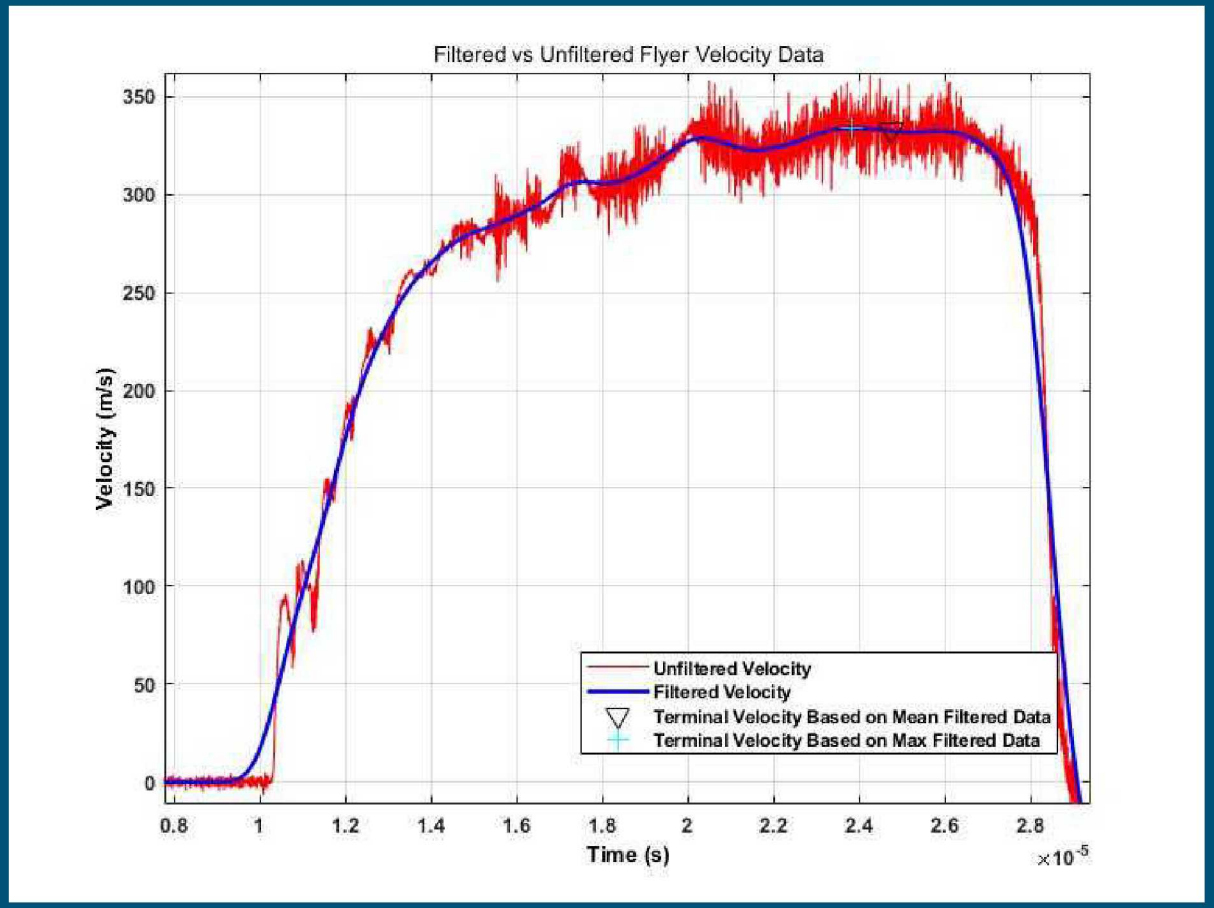
- Explosive density was nearly doubled
  - From 0.6-0.7g/cc to 1-1.2g/cc
- Impulse measurements indicated Kapton with HSM SASN performed best
- SS performed worst than control, not expected



Results

20 mil Kapton R sheet flyer plates





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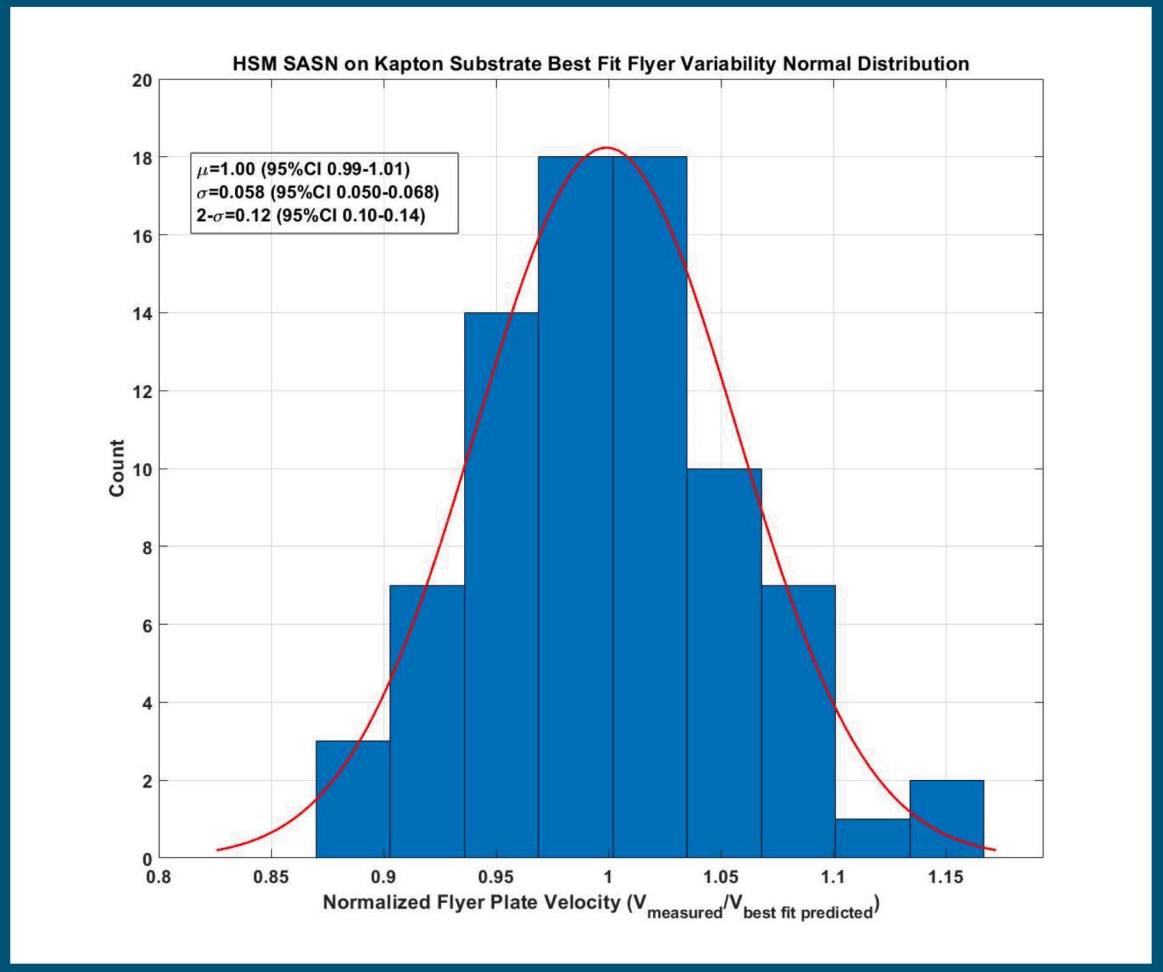
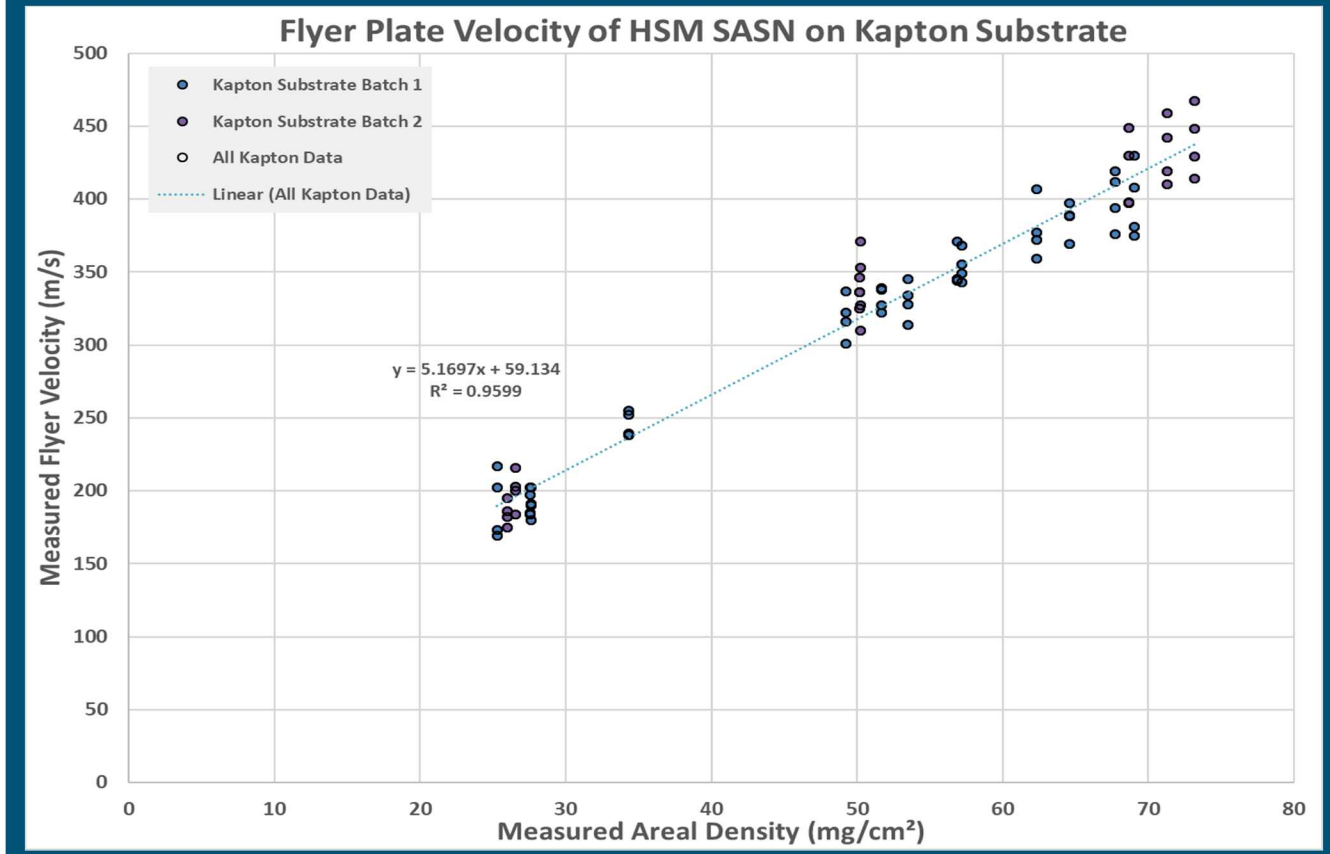
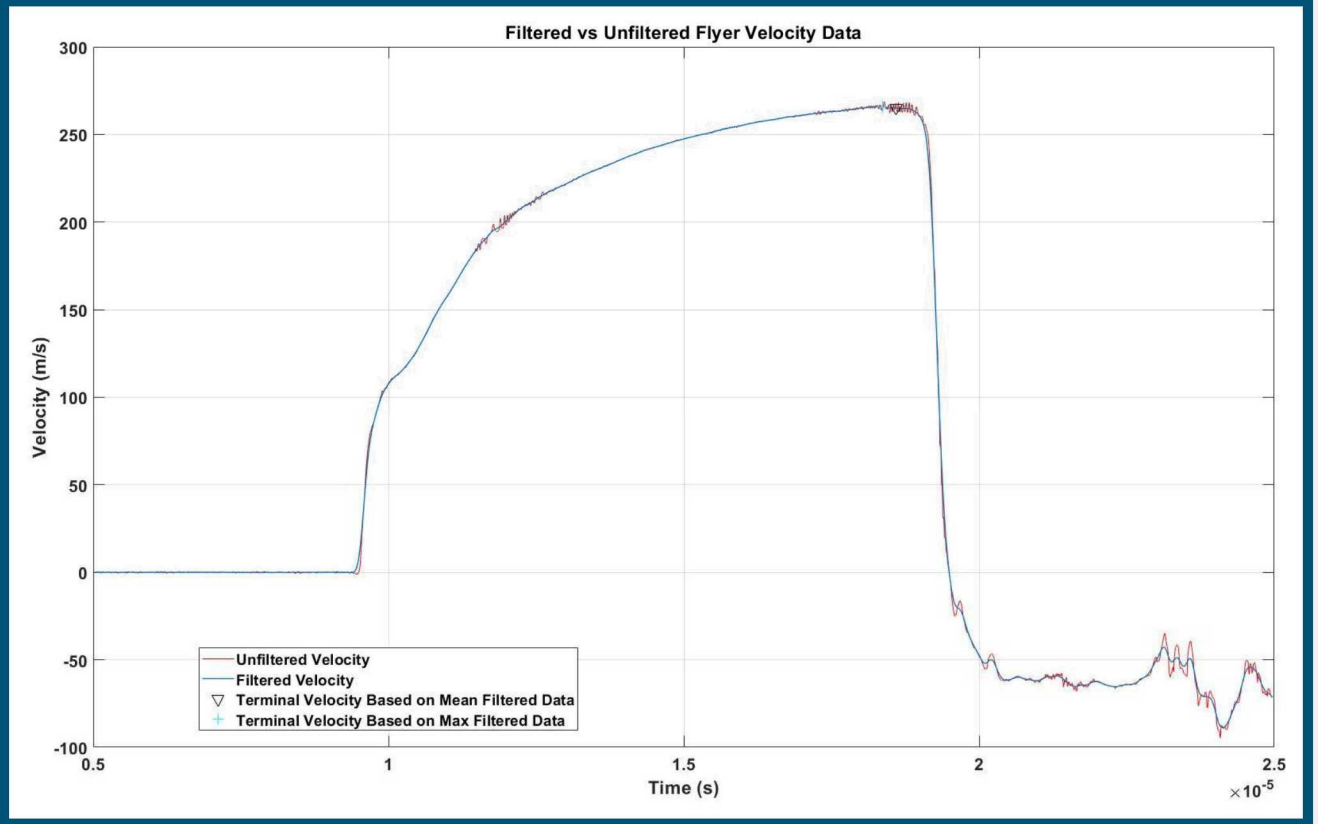
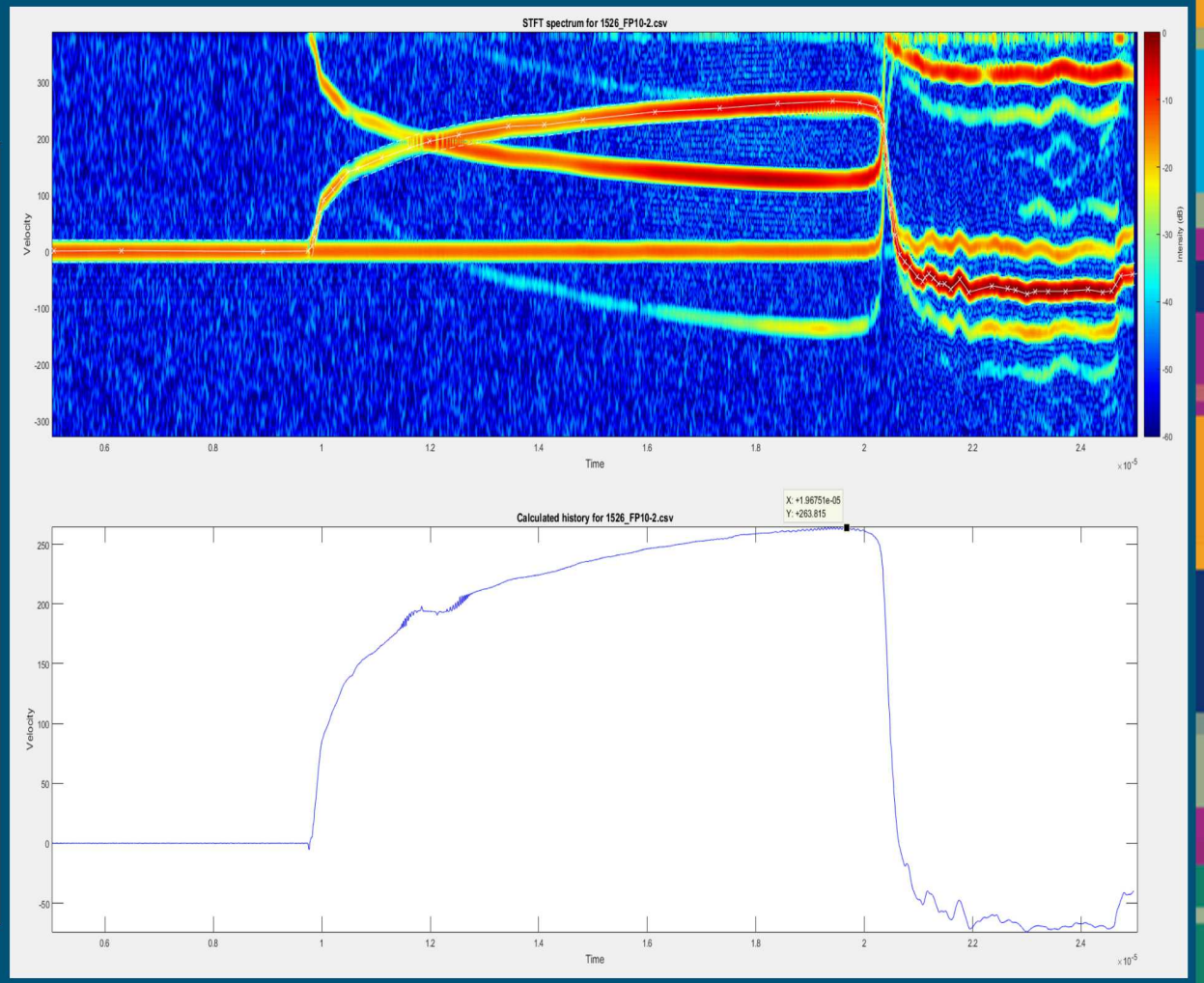




Results

Composite Flyer Plates

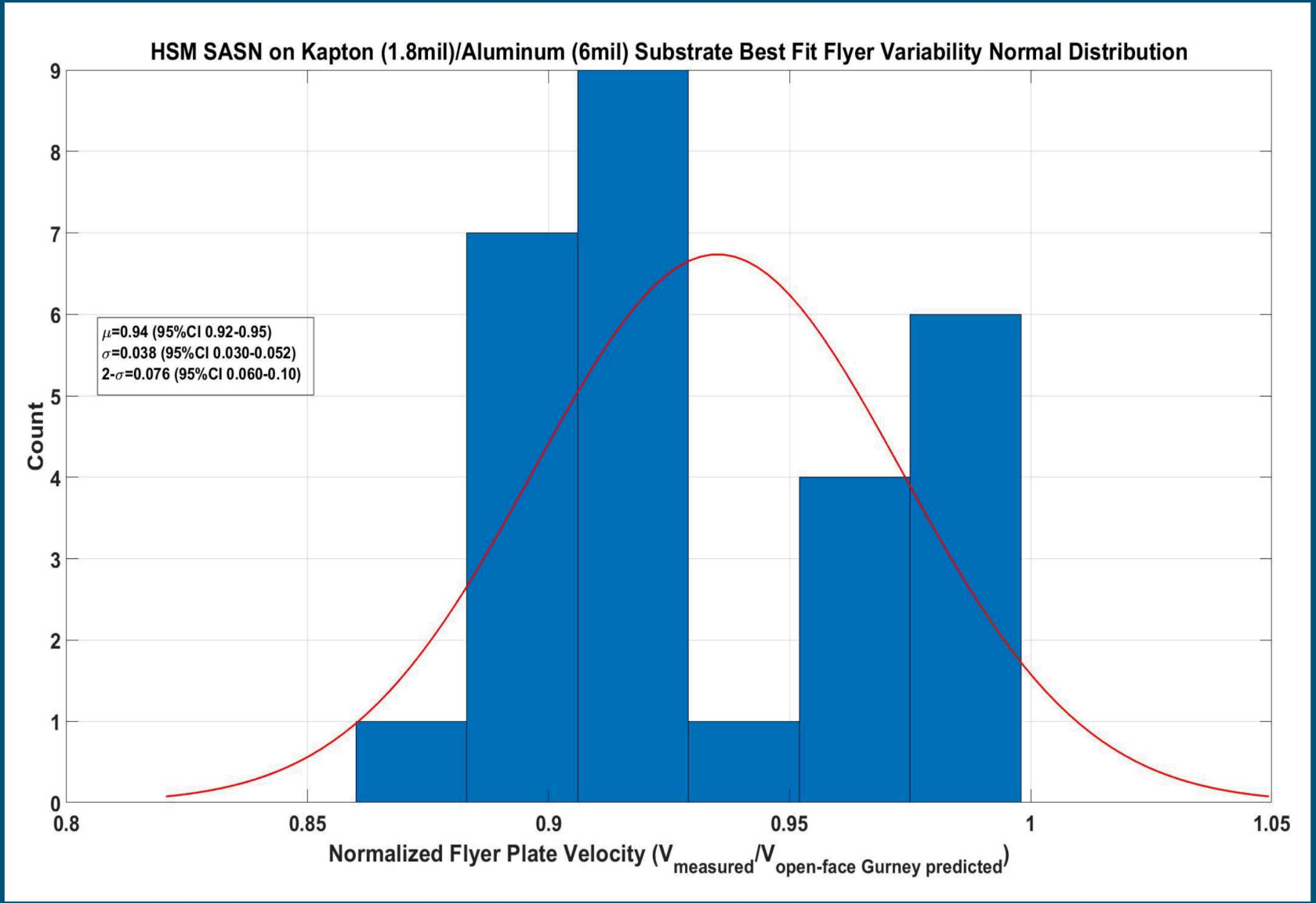




Results

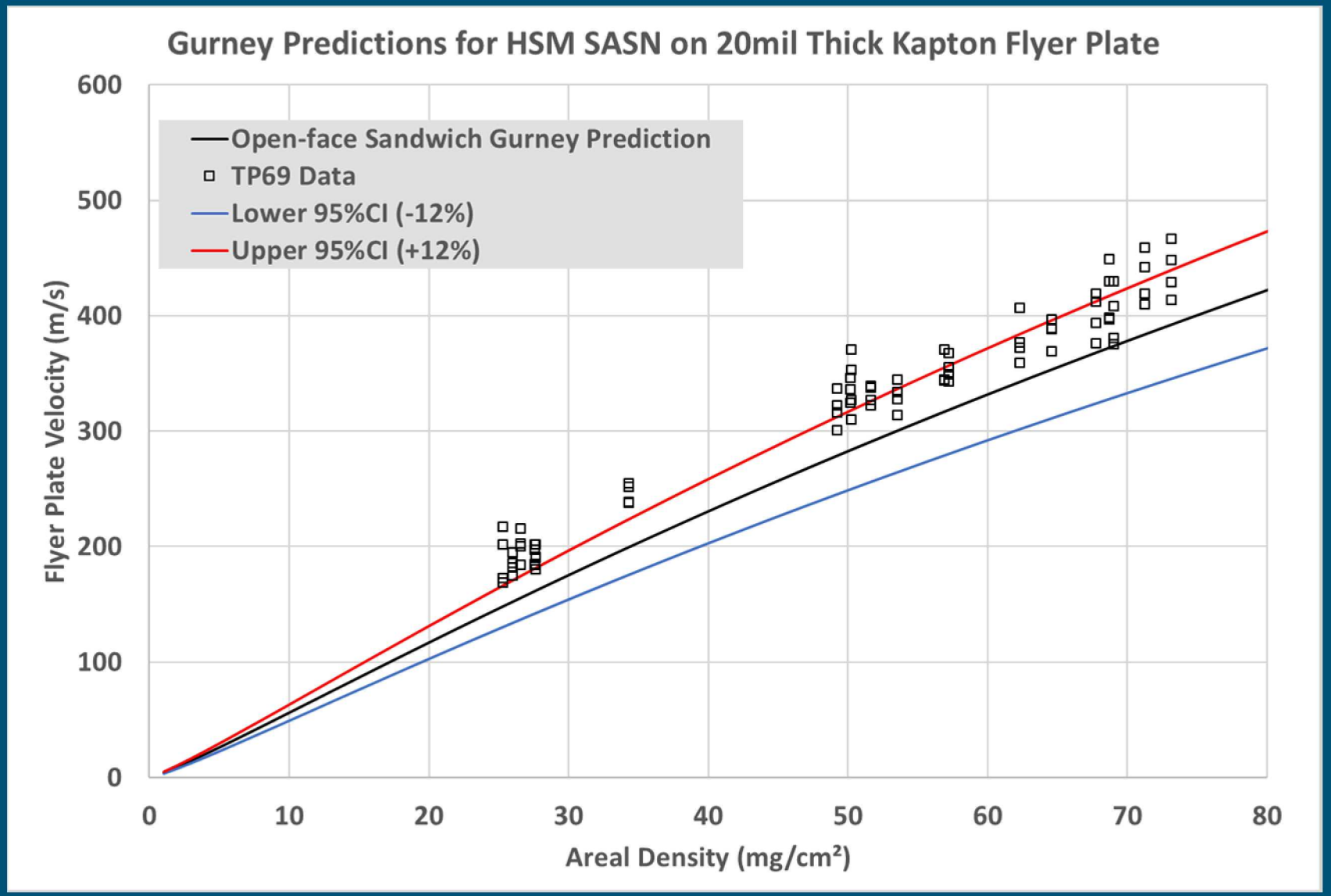
Composite Flyer Plates

- Bi-model distribution
  - More data required
- 2σ value is within expected ±12%



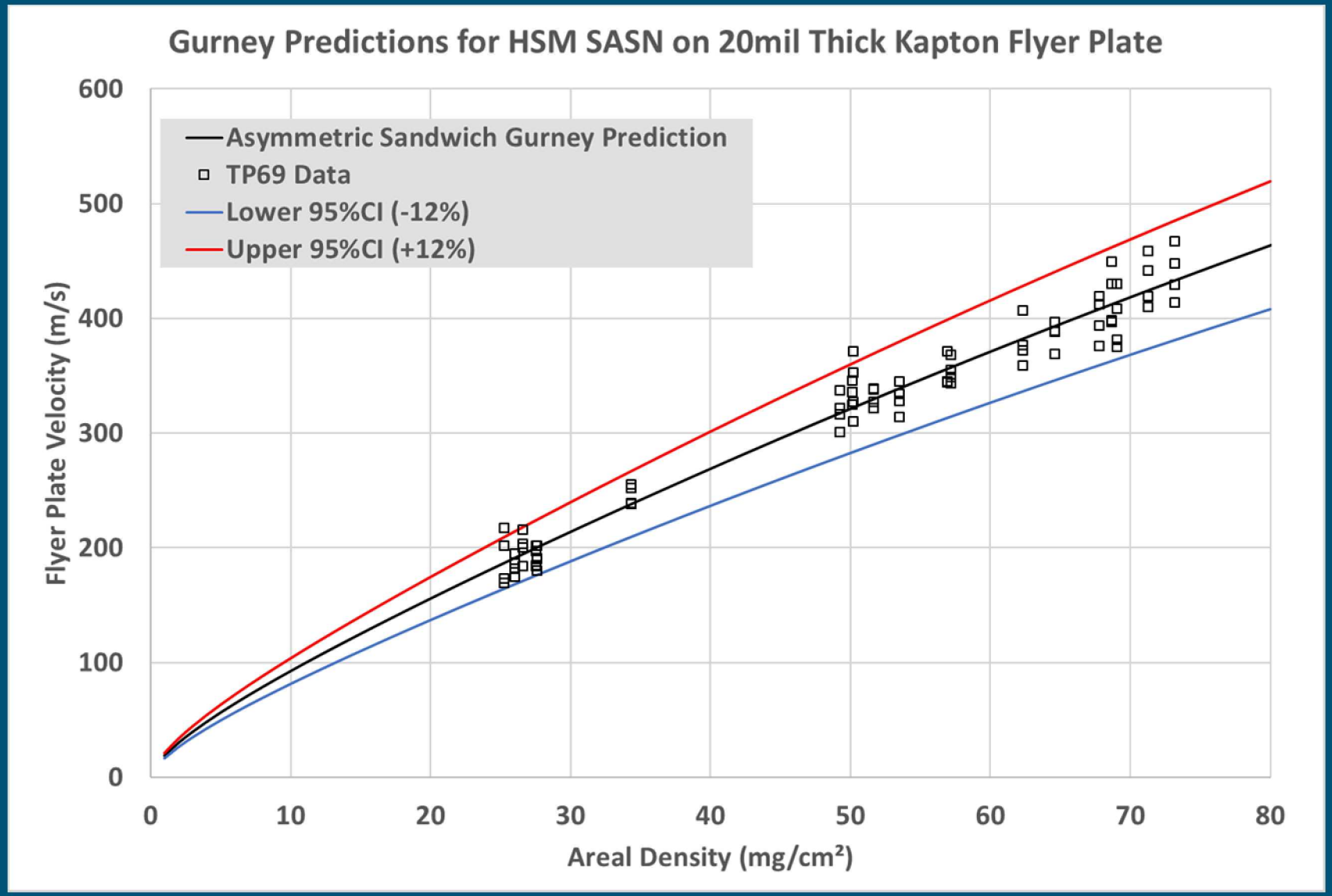
Application of Gurney Analysis

- Why does open-face Gurney prediction not work well?



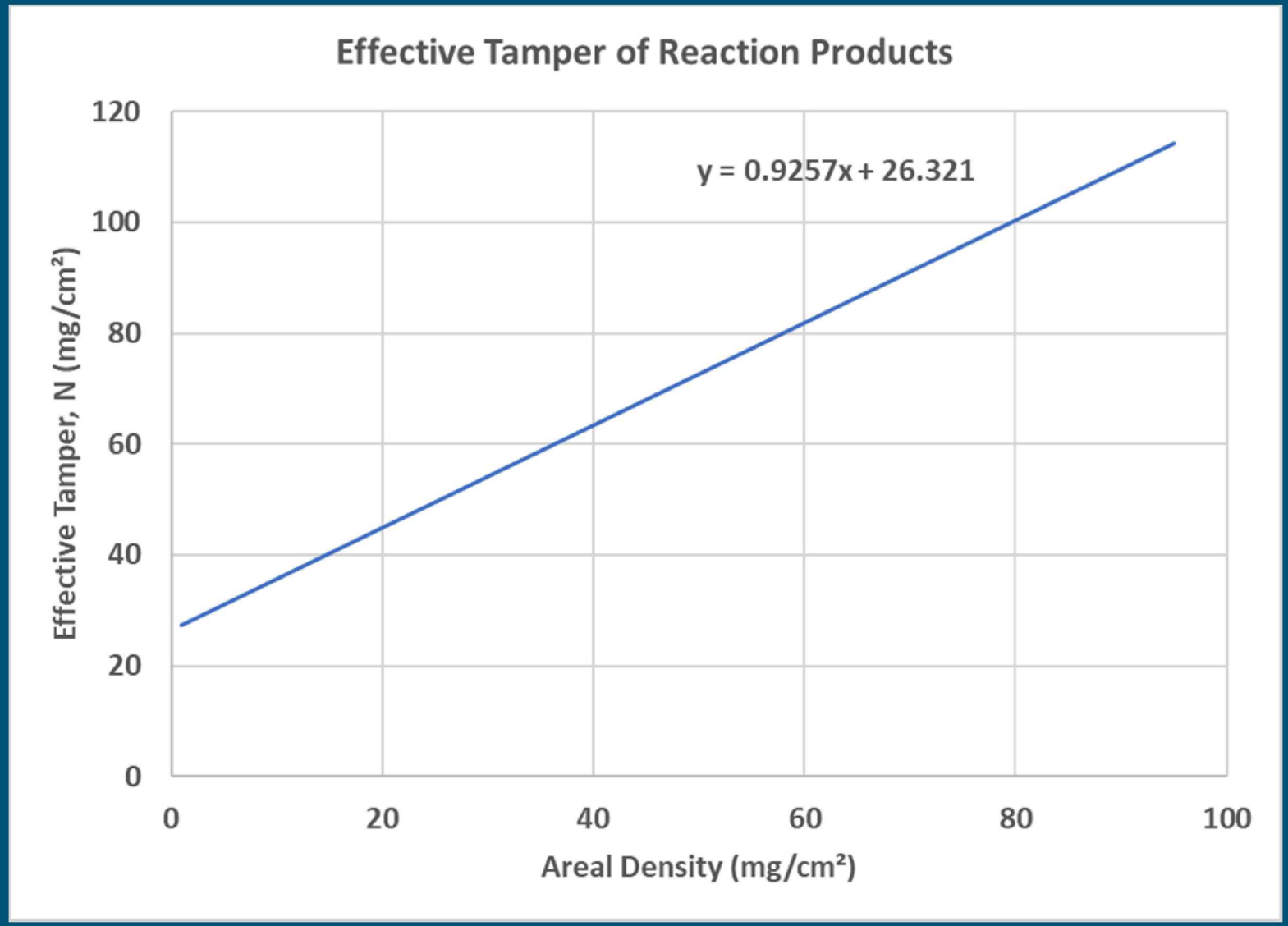
Application of Gurney Analysis

- Explosive pressure measurements suggested tamping effect present
- Solution iterated to find best fit for tamper mass



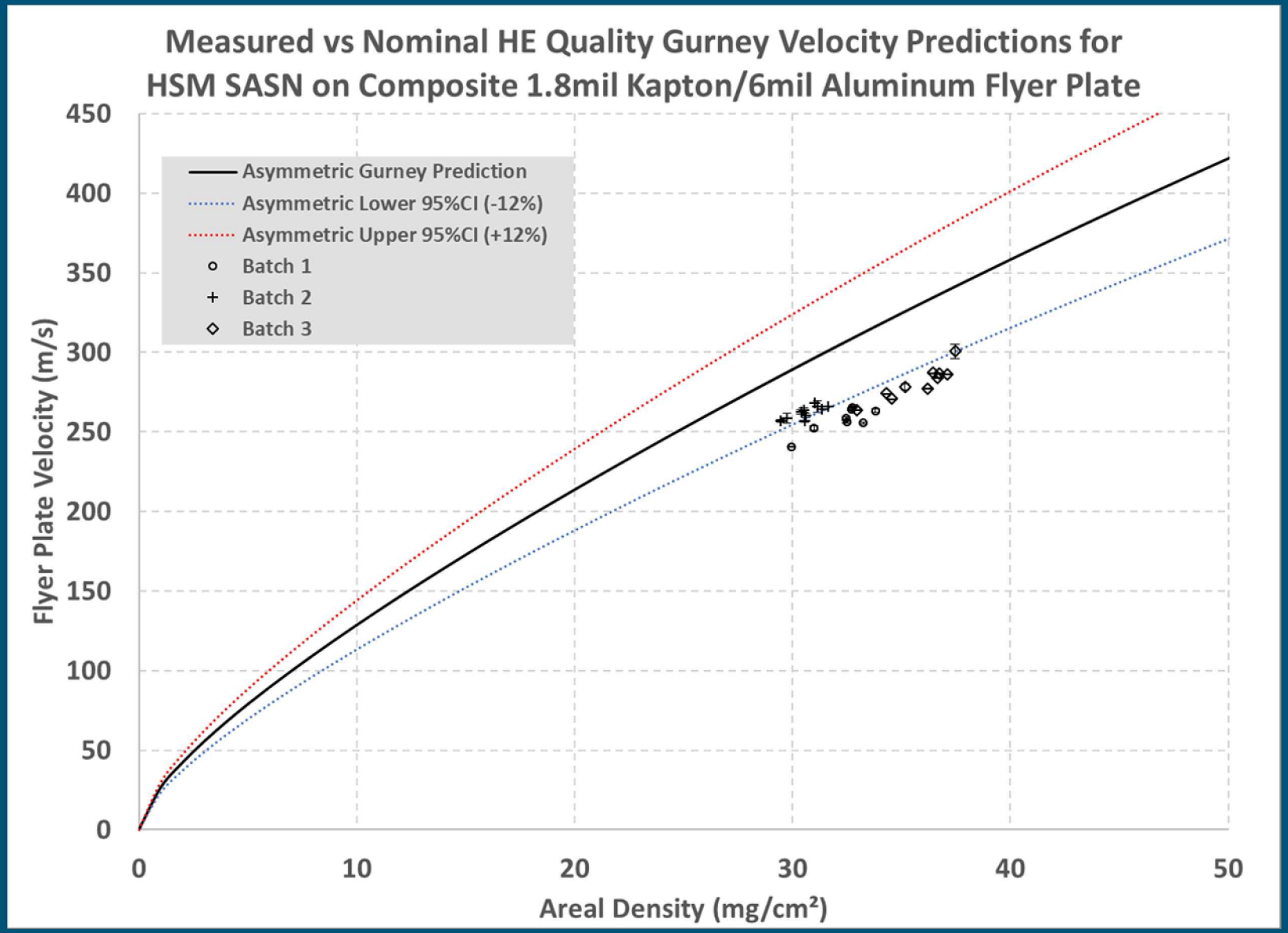
Application of Gurney Analysis

- Tamper mass found to be increasing
- Consistent with hypothesis that explosion products from deflagration were impeding higher velocity gas products



Application of Gurney Analysis

- Predicted tamper mass from previous dataset on 20mil thick Kapton R flyers
- No HE quality correction



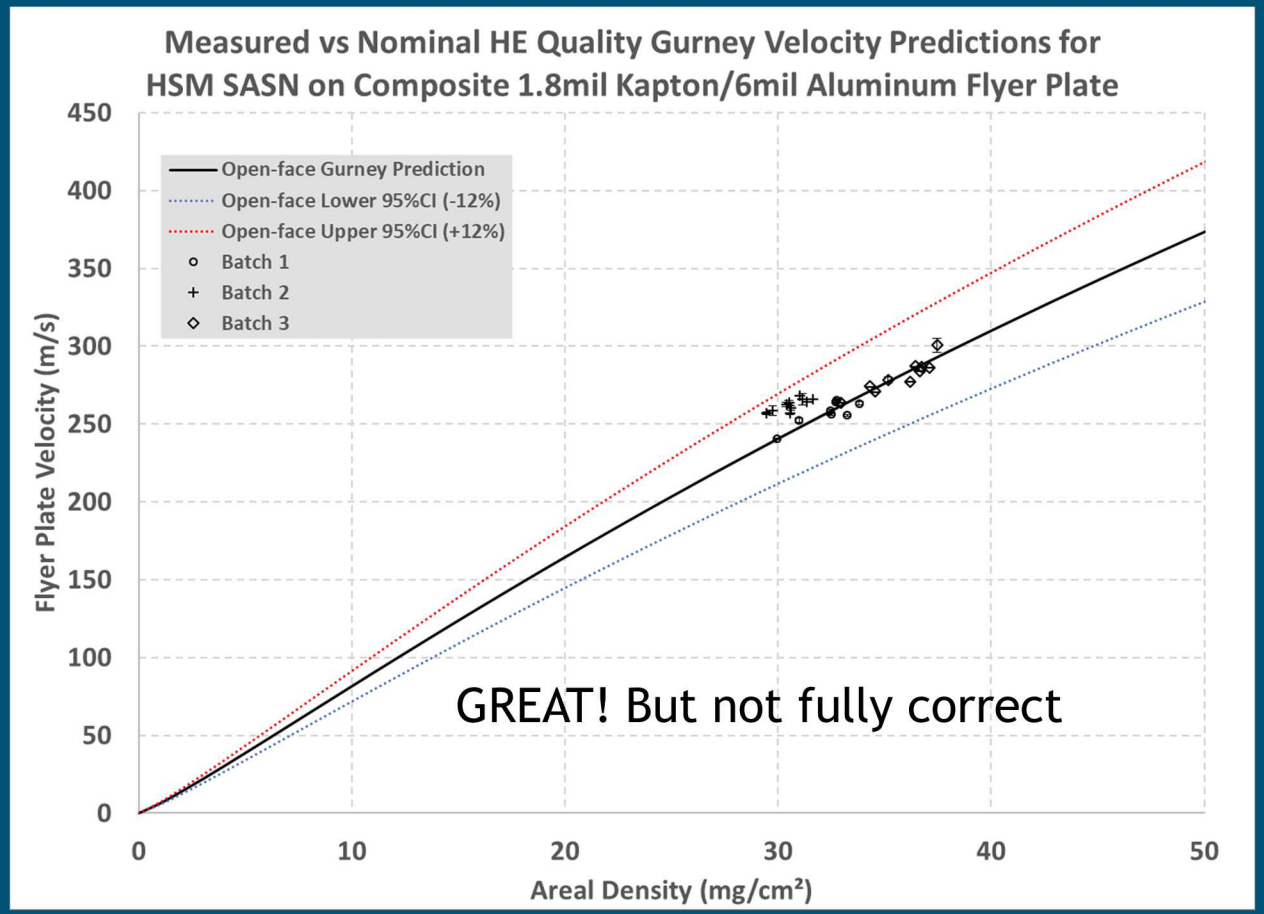
Application of Gurney Analysis

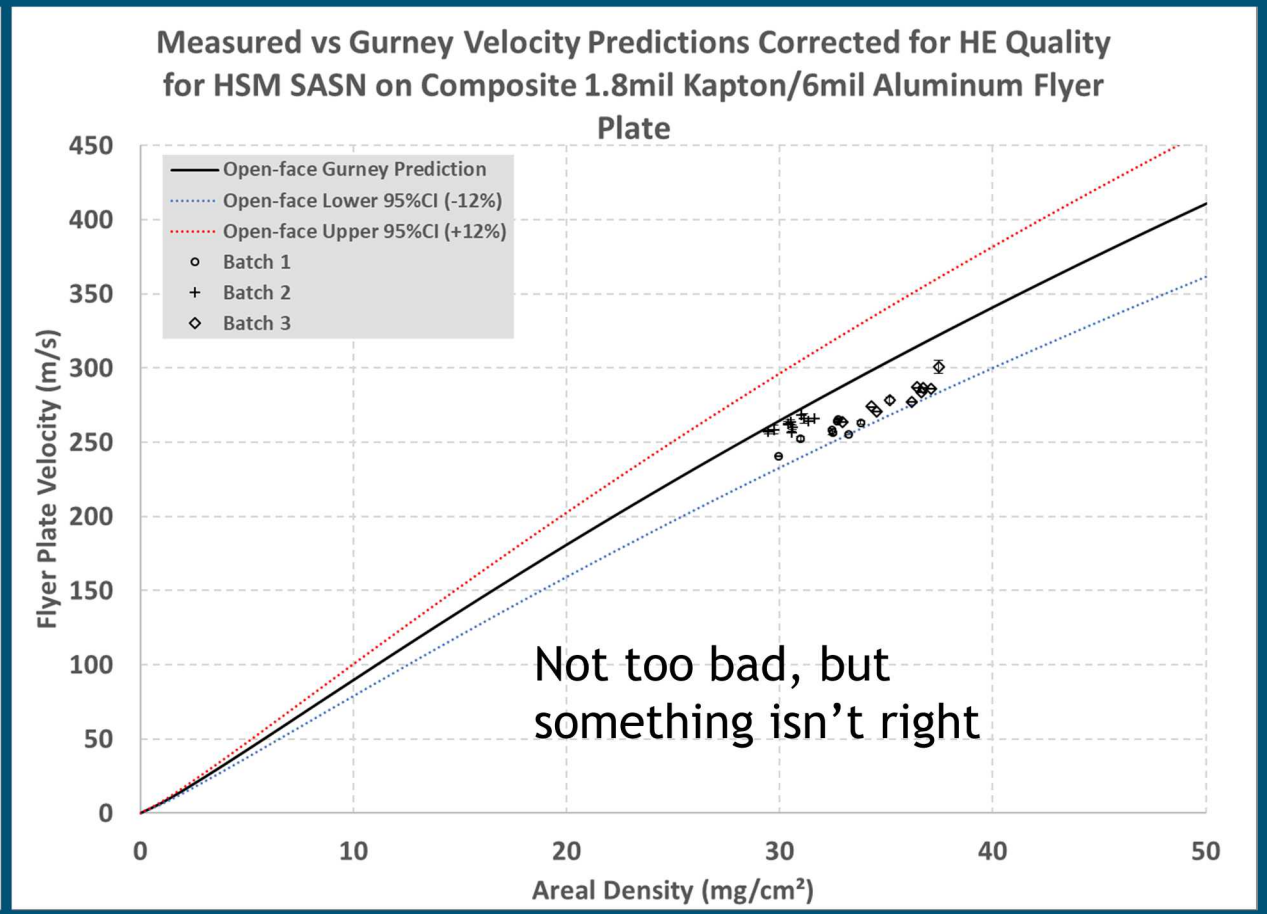
- What was different?
  - Less massive flyer plates: M=47.3 mg/cm² vs 70.7 mg/cm²
  - Composite flyer plate
  - Air gaps smaller on this test series: 2.3mm average vs ~5mm average

- HE Quality was:
  - Batch 1=111%
  - Batch 2=109%
  - Batch 3=109%

vs TP69
Batch 1=98%
Batch 2=103%

Application of Gurney Analysis





Summary

- Discussed the pertinent Gurney models and how they are adapted for use with LIHE
- Showed process improvements
  - High shear mixing
  - Kapton substrate
- Applied asymmetric Gurney equation to data due to reaction products effect
  - Open-face Gurney equation would work given no reaction products effect
- Predicted terminal velocity for different flyer configuration
  - Asymmetric Gurney equation did not work
  - Open-face Gurney equation works fairly well
  - Other phenomena limiting applicability of current models

Gratitude

- Tim Covert
- Dan Dow
- John Liwski
- Mike Willis
- Barry Ritchie

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