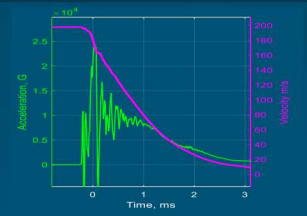
Sandia National Laboratories

SAND2019-9427C

Survivability Studies of Electronics By Gas-Gun Induced High-G Mechanical Shock Conditions II

SHOCK THERMODYNAMICS APPLIED RESEARCH

PRESENTED BY

B. G. Farfan, C. S. Alexander, W. D. Reinhart

U.S. DEPARTMENT OF ENERGY NNSA

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

OUTLINE

- Introduction
- Recapitulation
- New developments
- Better diagnostics
- Improving deceleration
- Conclusion

INTRODUCTION

New tools for electronics survivability tests are needed to better asses aerospace applications …

- Electronics for aerospace is a growing market
- Current tools for accurate survivability test are limited
- High-G and impact dynamics need to be well represented (launch, reentry, etc.)

Previous work has implemented a gas-gun to study electronics under high-G conditions.

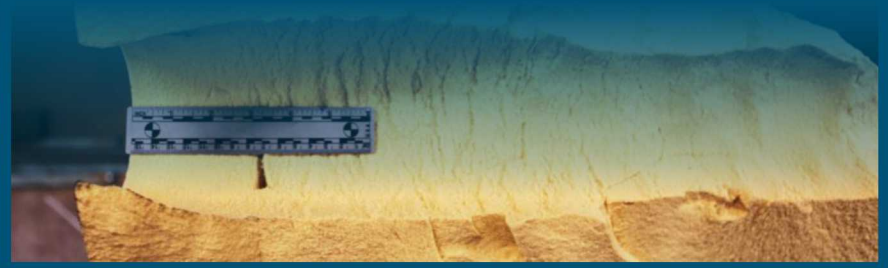
We expanded on previous work to address diagnostic challenges and improve G profiles.

RECAPITULATION

PREVIOUS WORK: **Survivability Studies of Electronics By Gas-Gun Induced High-G Mechanical Shock Conditions**

(69th ARA meeting, Bath UK, 2018)

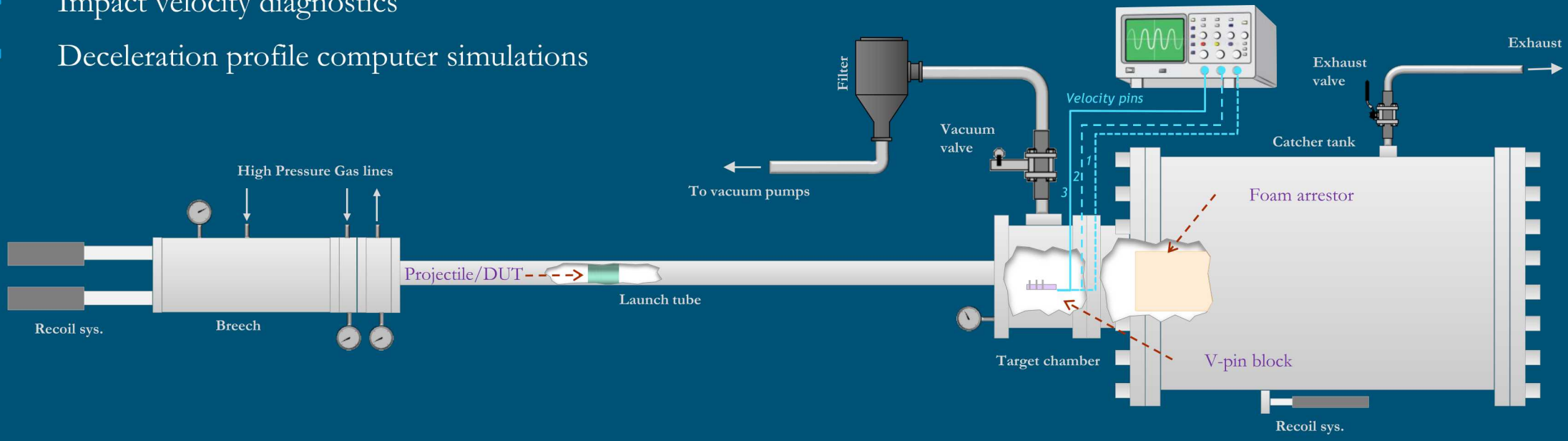
- A Gas-gun was successfully implemented as an electronics survivability test instrument
- Impact velocities representing aerospace application were attained
- High-G levels up to 40 kG were achieved but steeper profiles are desired
- Better diagnostics to assess deceleration profiles are needed
- Foam interfaces projectile instability are an issue that needs to be addressed



RECAPITULATION

The gas-gun approach to mimic impact dynamics representative of aerospace applications …

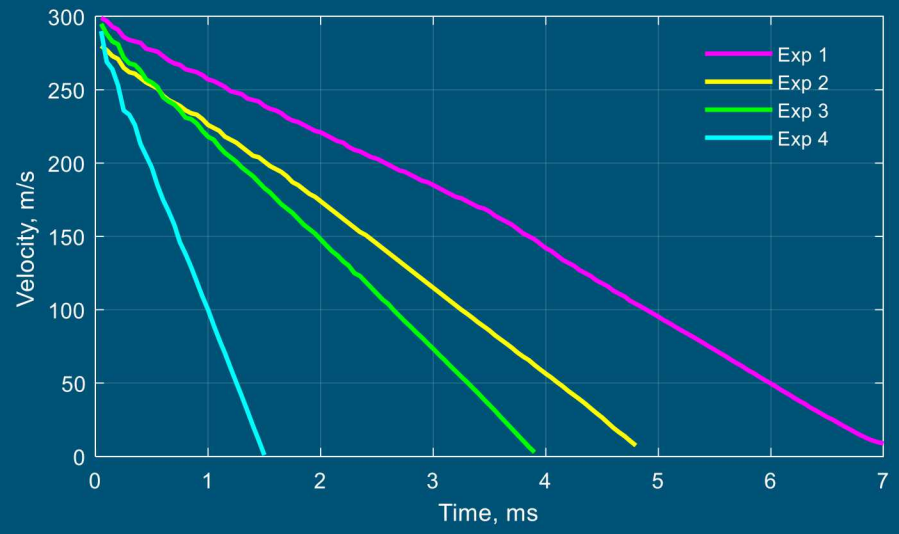
- A 100 mm compressed Gas-gun for projectile acceleration
- Electronics device under test (DUT) embedder in projectile
- A foam arrestor for projectile deceleration
- Impact velocity diagnostics
- Deceleration profile computer simulations

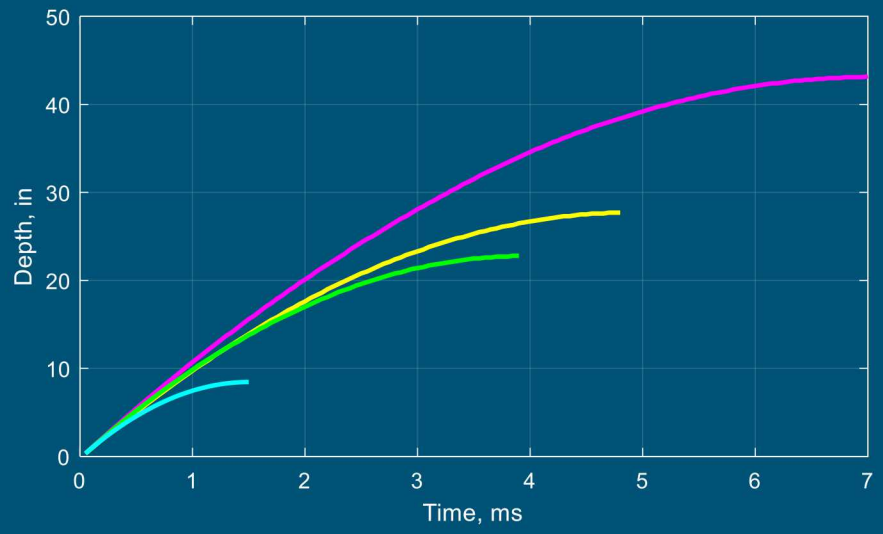


RECAPITULATION

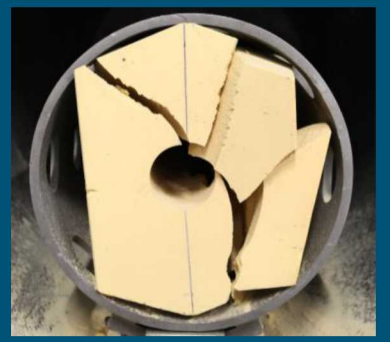
Previous work summary

Shot #	Payload	Foam density (cfp)	Survivability	Projectile path	Penetration experiment (in)	Penetration simulated (in)	Peak acceleration (kG)	Velocity (m/s)
1	Blank	11	NA	Diverged	53	43.2	7.7	302.7
2	Electronics	15	Passed	Straight	33	27.7	9.8	285.4
3	Electronics	20	Passed	Diverged	39	22.8	13	300.2
4	Electronics	40	Failed	Straight	9	8.45	43	300.1



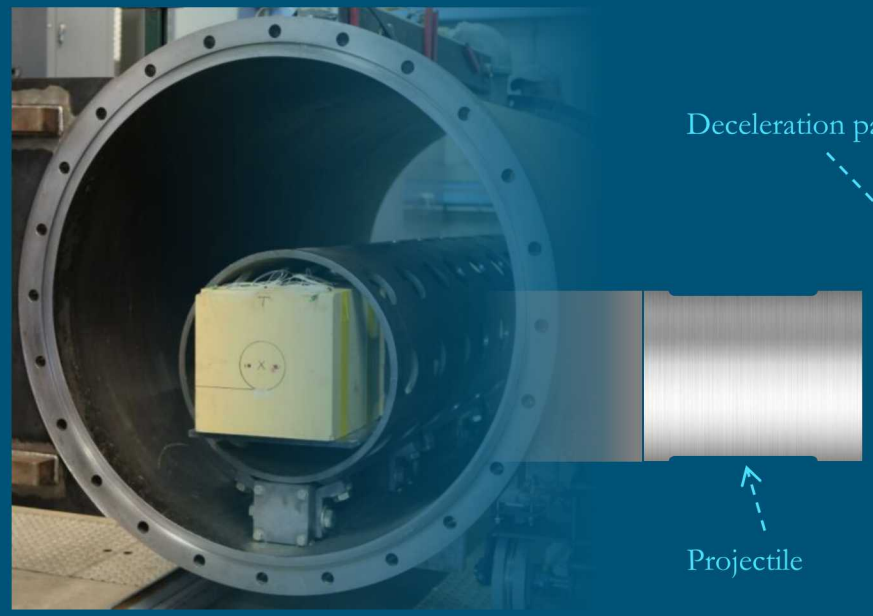


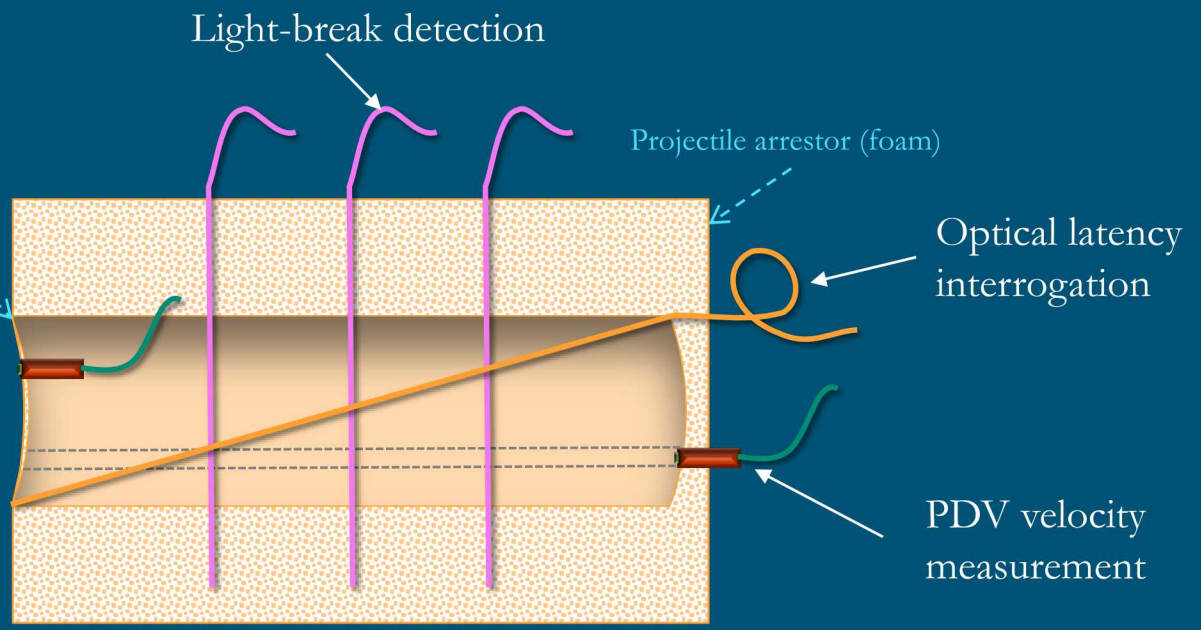
- G-forces were ramped up until electronics failure
- Simulations underestimated penetration depth
- Foam interfaces are not well characterized

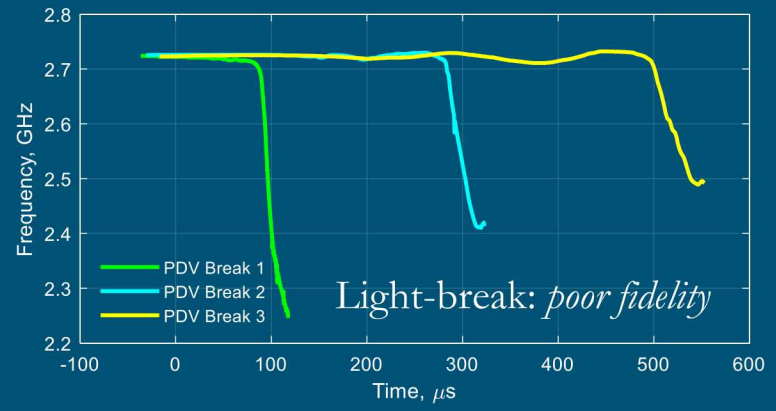


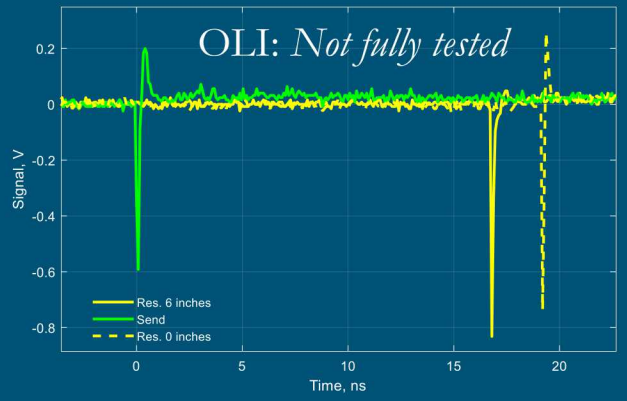
RECAPITULATION

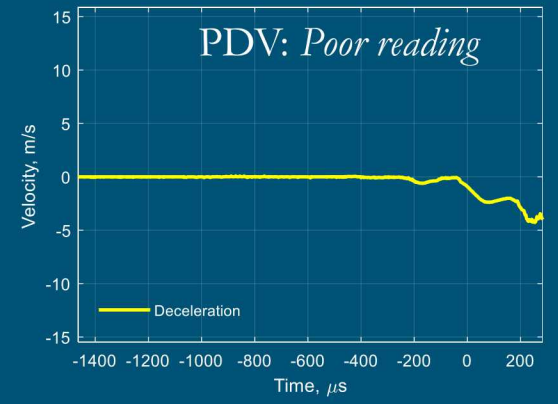
Attempts for deceleration measurements by optical measurement techniques









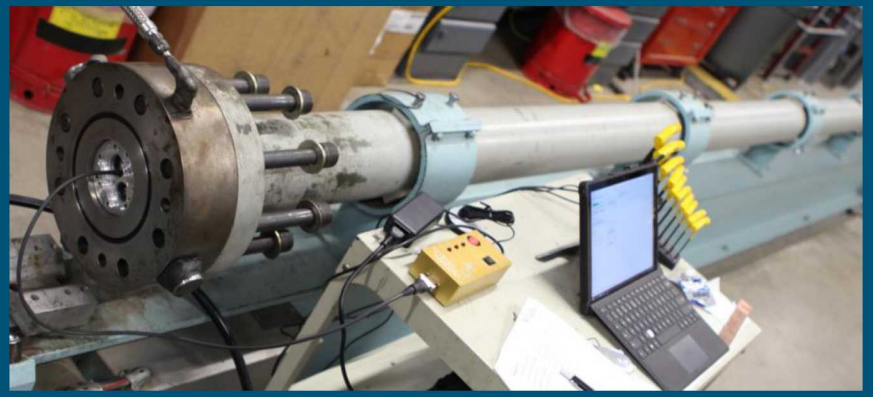


NEW DEVELOPMENTS

We expanded on previous work to address diagnostic challenges and improve G profiles …

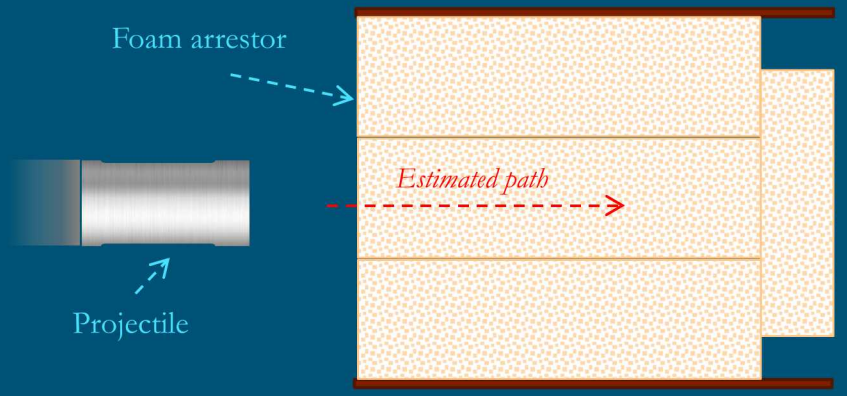
BETTER DIAGNOSTICS:

- New triggering and velocity measurements
- In-situ deceleration measurements
- Higher sampling rates and resolution



IMPROVING DECELERATION:

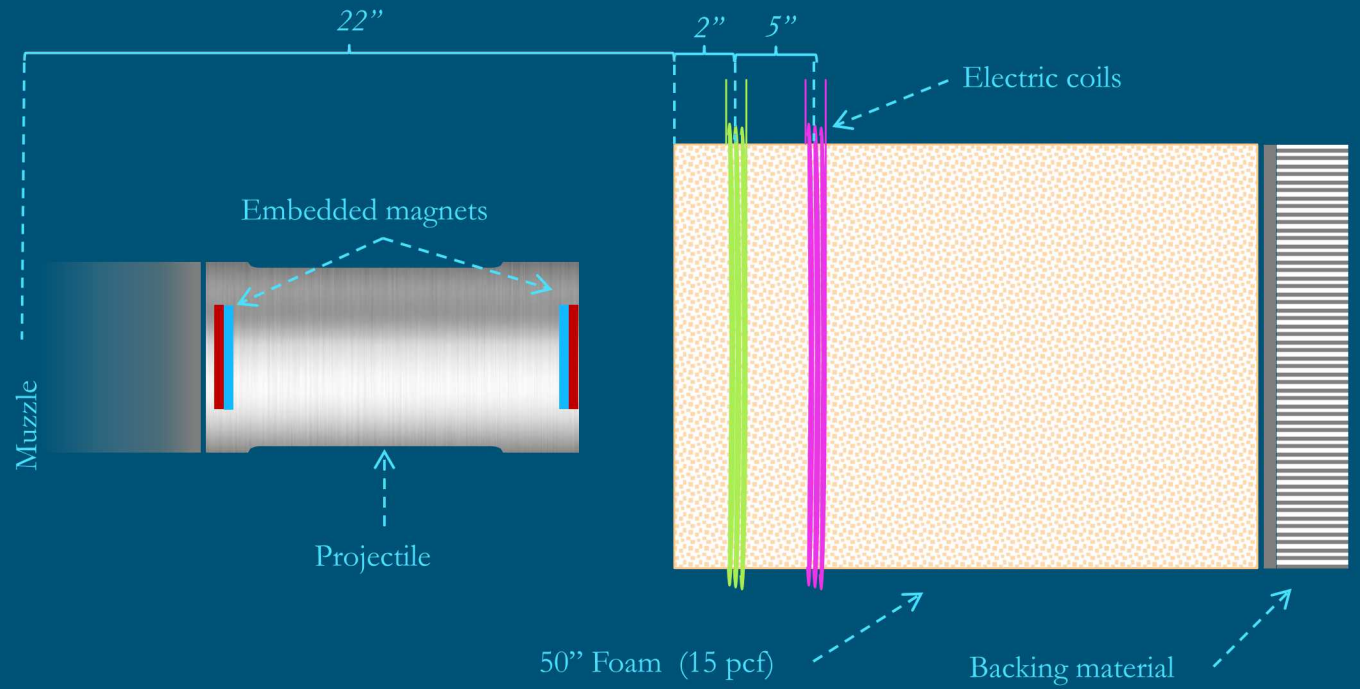
- Overcome foam interface issues
- Steeper deceleration profiles
- Straighter deceleration paths



BETTER DIAGNOSTICS

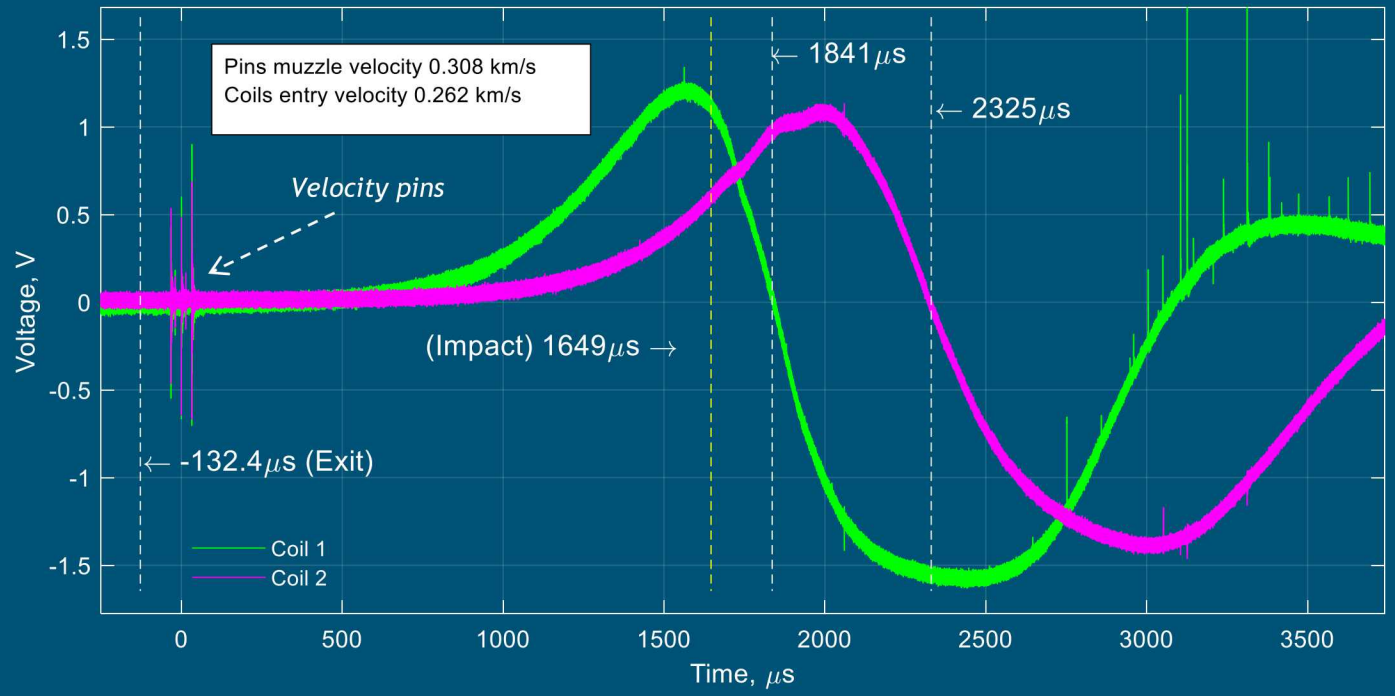
Electromagnetically induced crossing-point signal in foam …

- Voltage signal generated by induced current from the projectile in wire coil around the foam
- By known crossing-point distances of several coils, velocities can be calculated
- Test was done through 26 turns of gauge 30 wire with 2 inch magnets in front and back of the projectile



BETTER DIAGNOSTICS

Electromagnetically induced crossing-point signal in foam …



- Ideal for entry and exit velocity measurements
- Alternative triggering source for proximity instrumentation such as X-rays
- Potential use for deceleration profiles if use of magnets are feasible, however, resolution is low

BETTER DIAGNOSTICS

Onboard data recorder for high resolution in-situ velocity measurement …

- We implemented an onboard data recorder MD01H from Dynamic Systems and Research Corporation (DSR)
- MD01H is a shock hardened data acquisition system designed to survive harsh environments
- Programmable amplification to allow users to select a desired range for their test scenario.

MD01H

DATA RECORDER

- 1-Channel 16kHz Acceleration Data
- 75 kHz Sampling Rate
- 0.84 Second Record Length
- Non-Volatile FRAM Memory
- 1.000" Diameter X 2.580" Length
- Removable Sensor Block

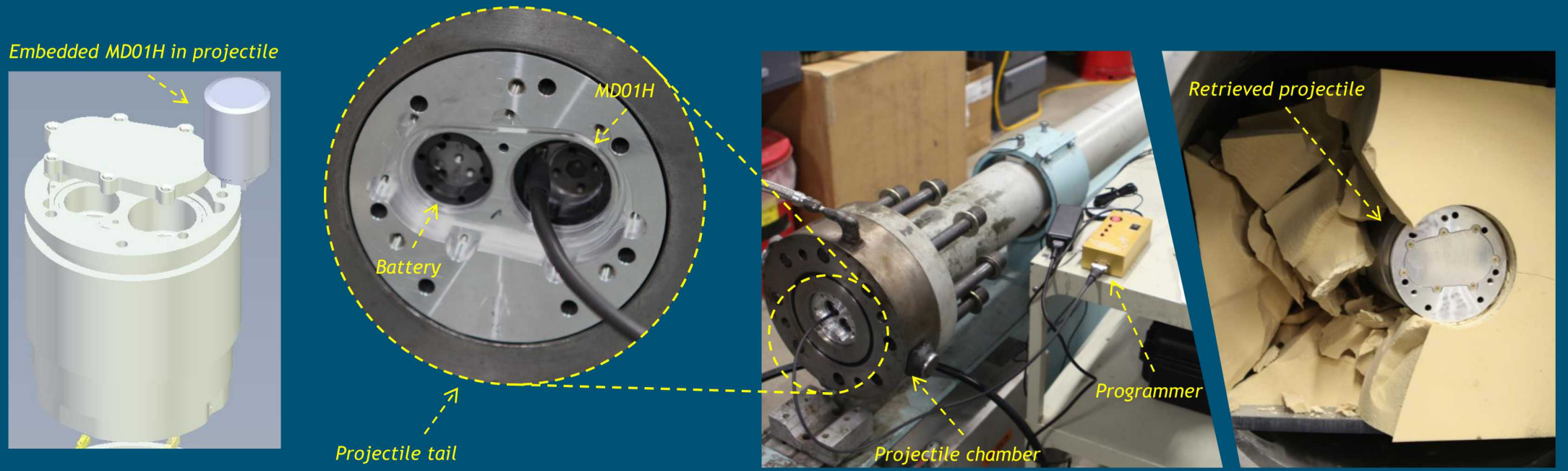
Source: www.dsr.us.com

Source: www.dsr.us.com

BETTER DIAGNOSTICS

Onboard data recorder for high resolution in-situ velocity measurement …

- MD01H and battery system embedded in projectile design that protects electronics for later retrieval
- Programming done after projectile is loaded right before test to expand battery life and avoid mistriggers
- Trigger threshold, accelerometer gain and dynamic range set for predicted outcomes

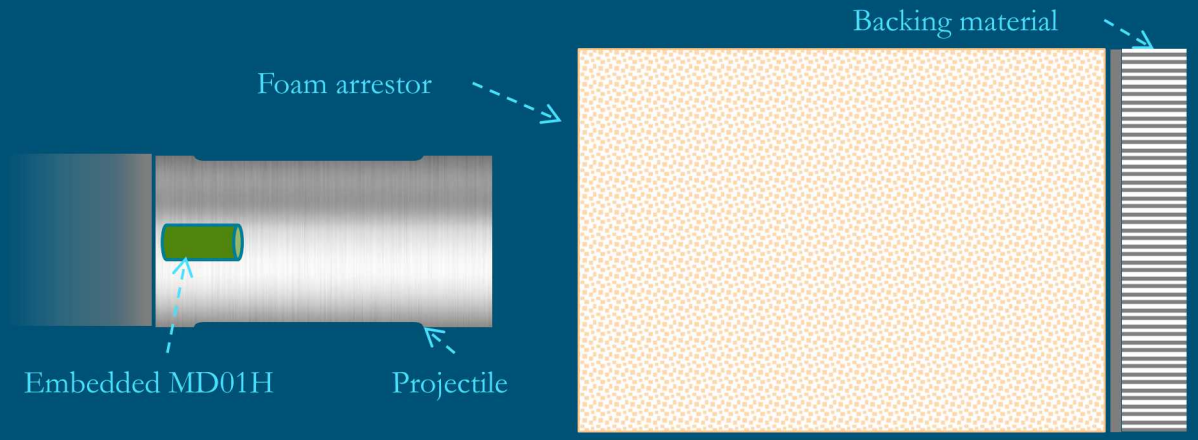


BETTER DIAGNOSTICS

Onboard data recorder experimental series …

- 5 shots were performed using the gas-gun experimental set up as preceding work
- MD01H data recorded was implemented for all shots and survived in all velocities tested
- Different foam densities were used at different velocities to compare performance and validate measurements

Shot #	Foam density (pcf)	Velocity (m/s)	Projectile weight (g)	Penetration experiment (in)	Peak acceleration (kG)	Comments
5	25	305	4745	54	27.8	Projectile diverged towards top and got damaged
6	25	207	4812	31	20.9	Straight shot undamaged projectile
7	30	303	4741	37	37.1	Projectile diverged towards top and got damaged
8	30	197	5214	9.6	24.0	Embedded projectile at foam entry
9	40	262	4806	31.4	45.9	Straight shot extremely damaged projectile

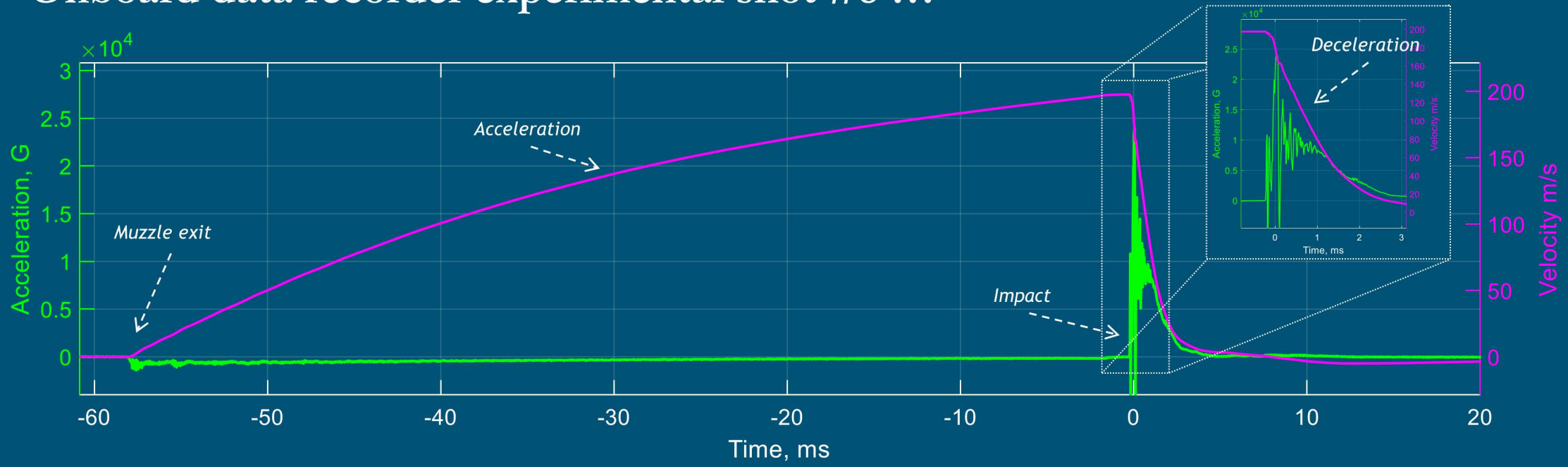


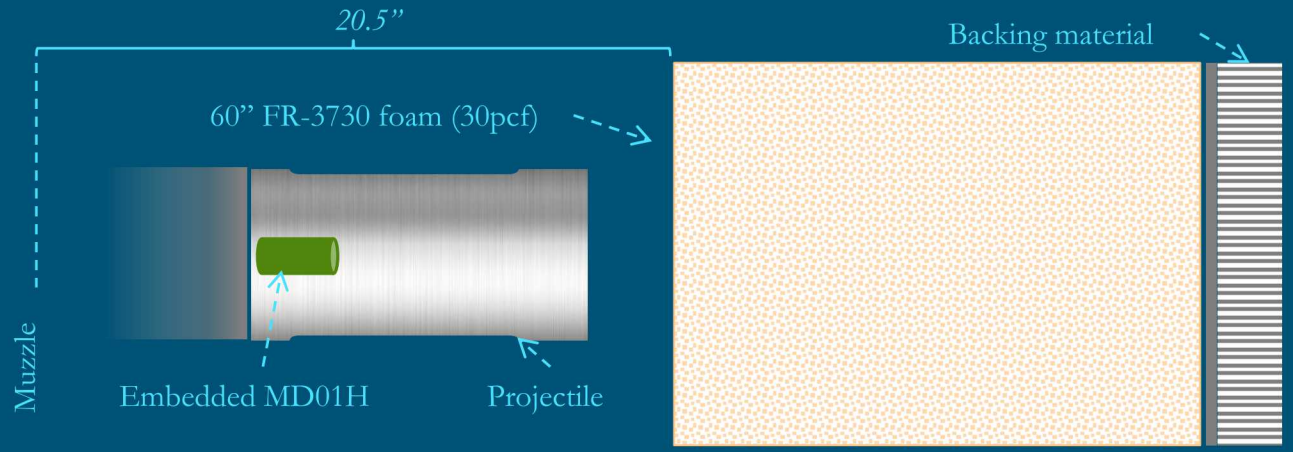
Shot #5

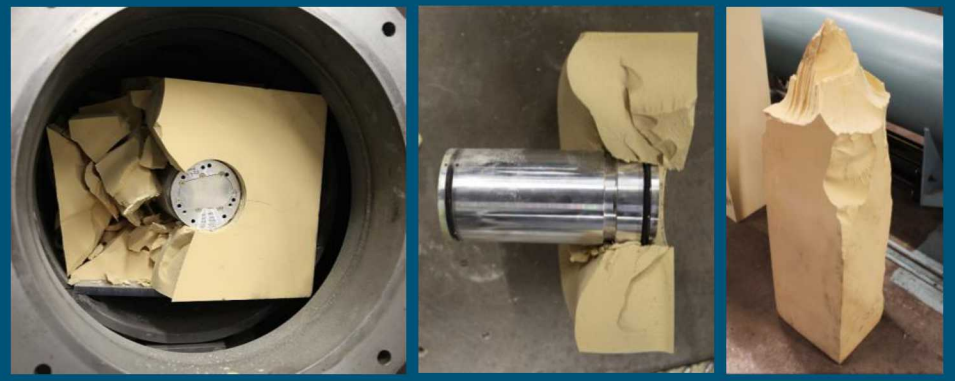
Shot #9

BETTER DIAGNOSTICS

Onboard data recorder experimental shot #8 …

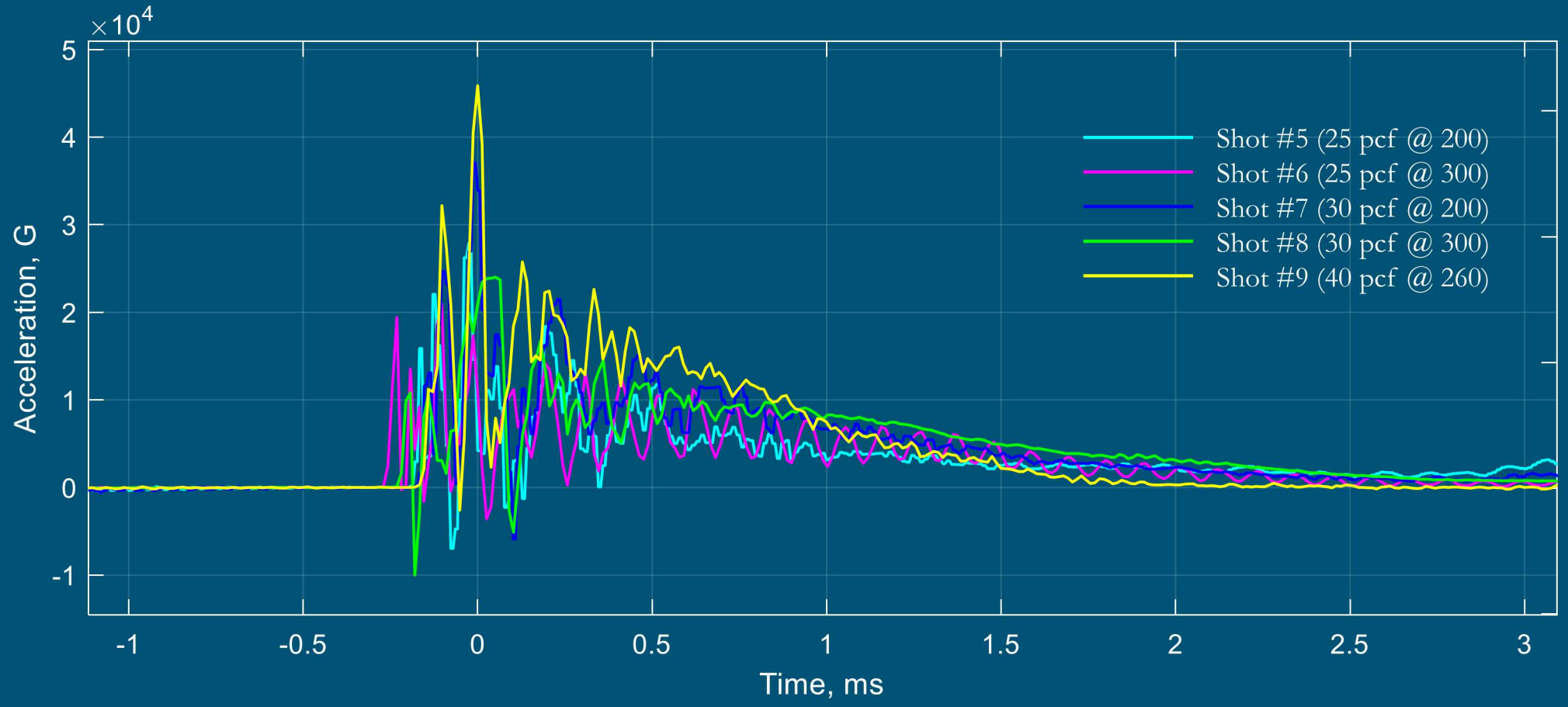






BETTER DIAGNOSTICS

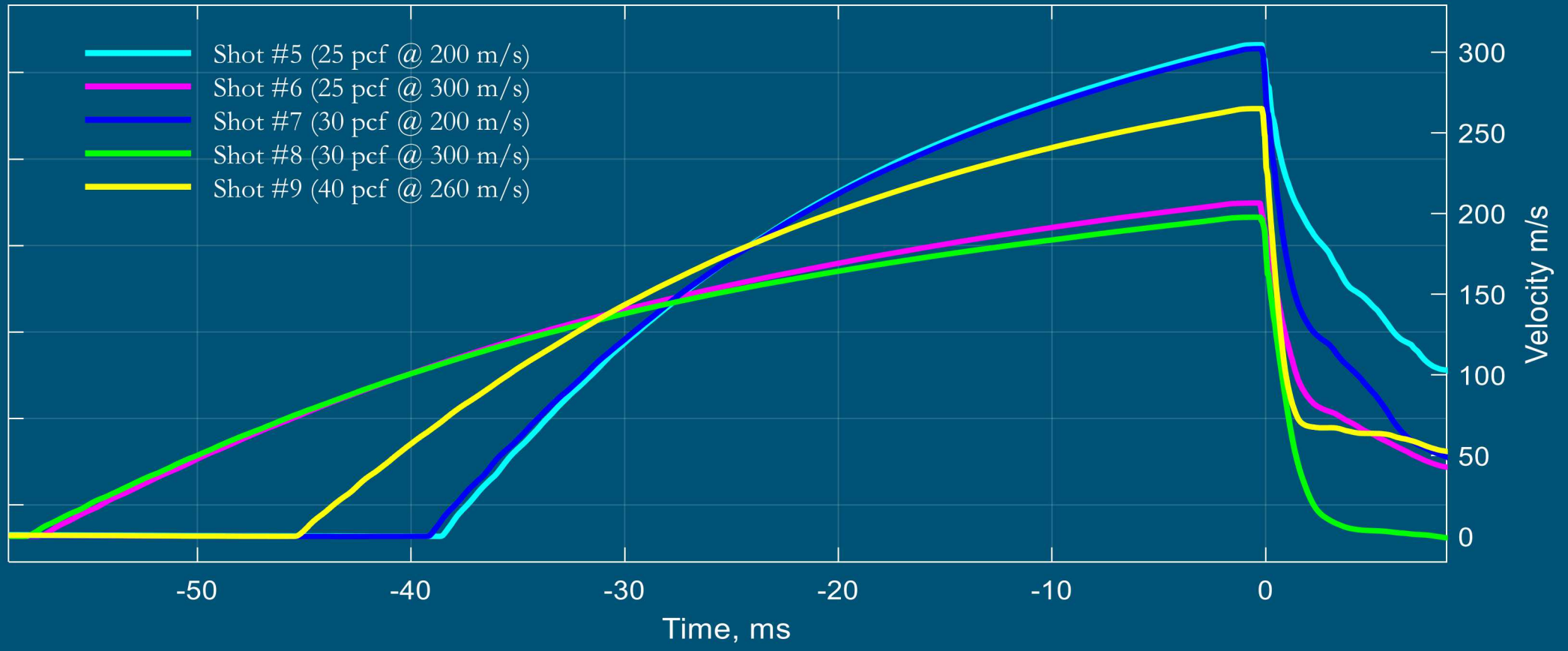
Onboard data recorder experimental series acceleration profiles …



- Recovery of recorder was successful in every shot and instrument did withstand the launching conditions

BETTER DIAGNOSTICS

Onboard data recorder experimental series velocity profiles …

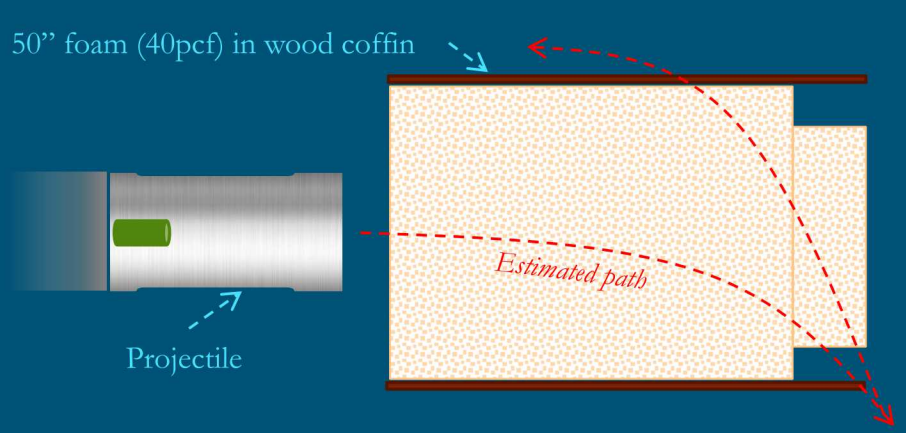


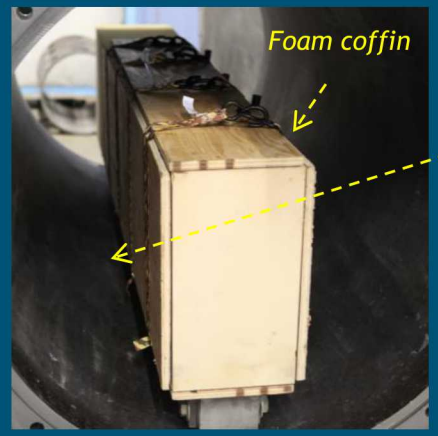
- Data shows decelerating profiles distinguishable for each foam arrestor density

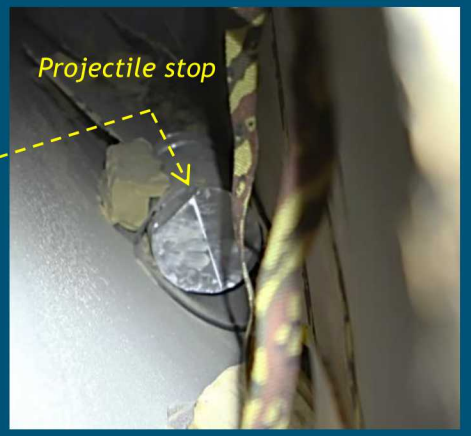
IMPROVING DECELERATION

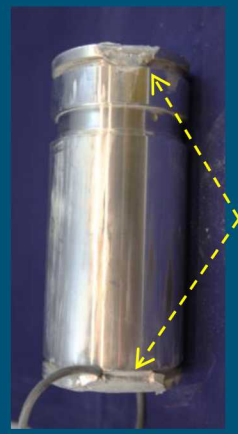
Attempting to create a straightener and smooth penetration path …

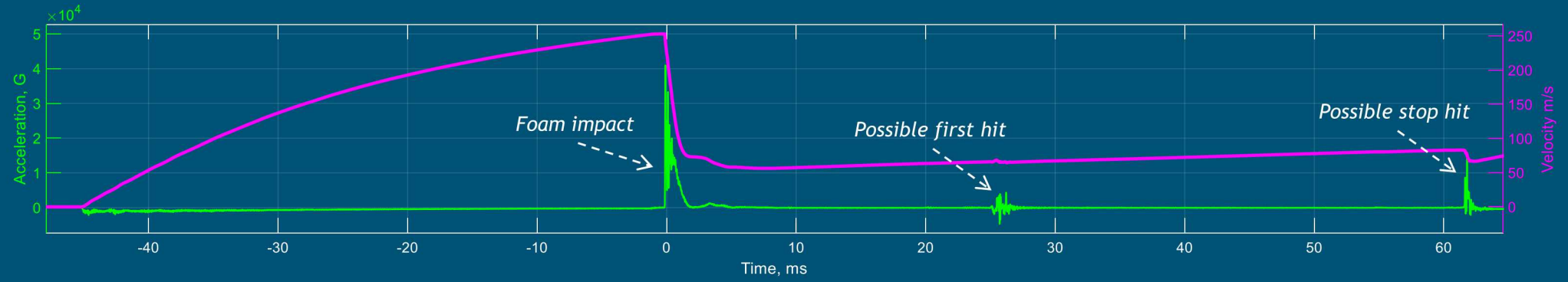
- Some issues with the foam arrestor include unstable projectile paths with the risk of damaging the projectile
- Solid foam arrestor column in plywood coffin was proposed to mitigate this issues and tested on a 40 pcf foam at 260 m/s
- Projectile veered and exited the coffin damaging bouncing inside the catcher tank and damaging the projectile (unwanted G loads)







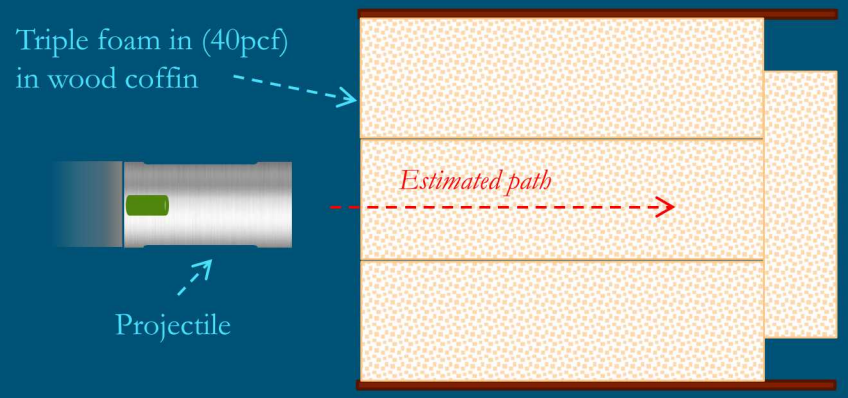


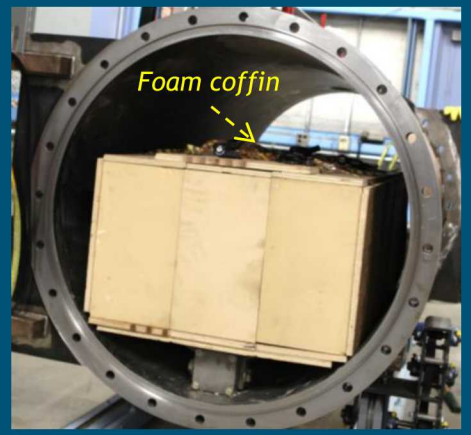


IMPROVING DECELERATION

Creating a straightener and smooth penetration path …

- Foam boundaries were extended by increasing the foam arrestor total volume
- Triple foam arrestor columns in plywood coffin were tested on a 40 pcf foam at 300 m/s



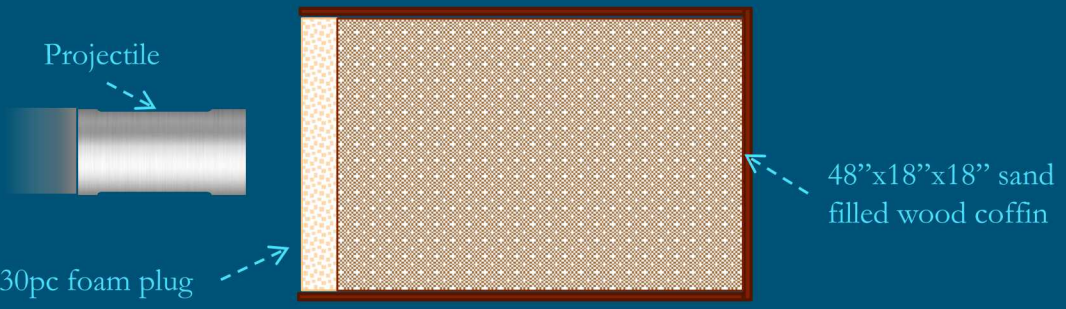


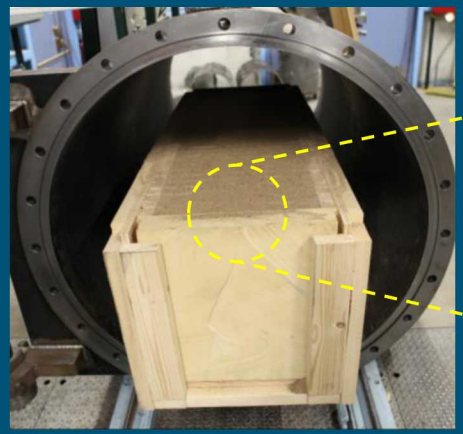
- Projectile followed a straight path and was brought to a smooth stop without further damage of the projectile
- Extending the foam arrestor boundaries away from the projectile path seemed to work well
- Several shot were tested with this configuration with successful results

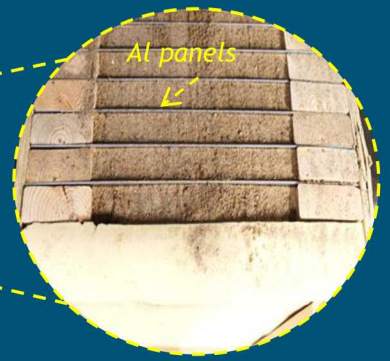
IMPROVING DECELERATION

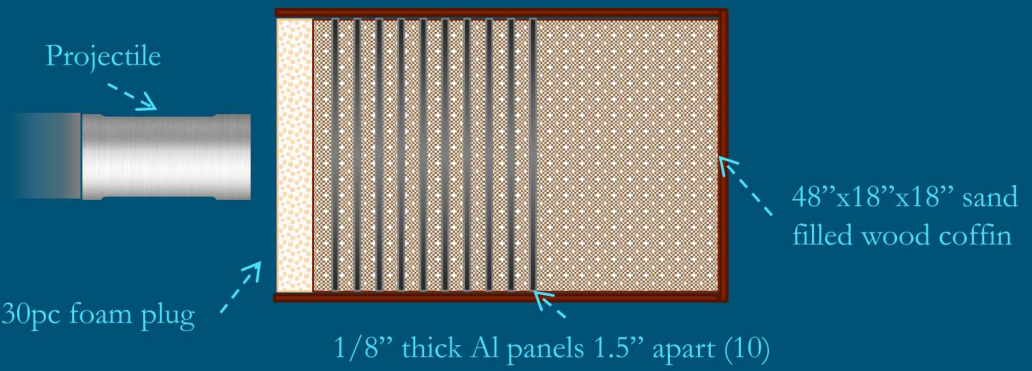
Inducing steeper deceleration profiles …

- Steeper deceleration profiles are desired to improve accuracy of simulated G scenarios for electronics
- Approaches for new profiles needs to gradually steepen up deceleration without exceeding limits
- Sand as an alternative to the foam arrestor was studied in two configuration; plain and aluminum ranforced







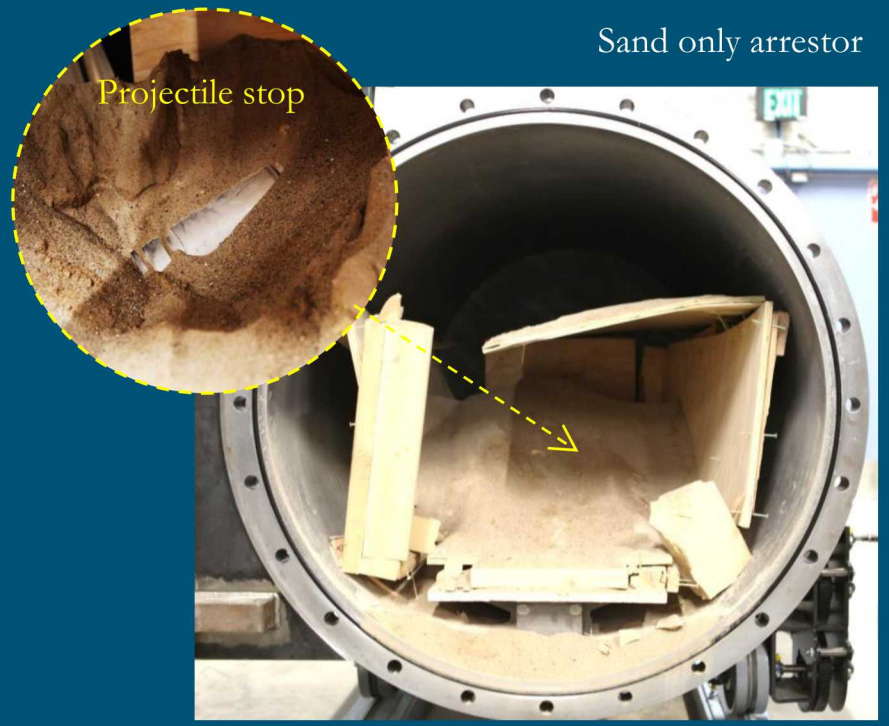


IMPROVING DECELERATION

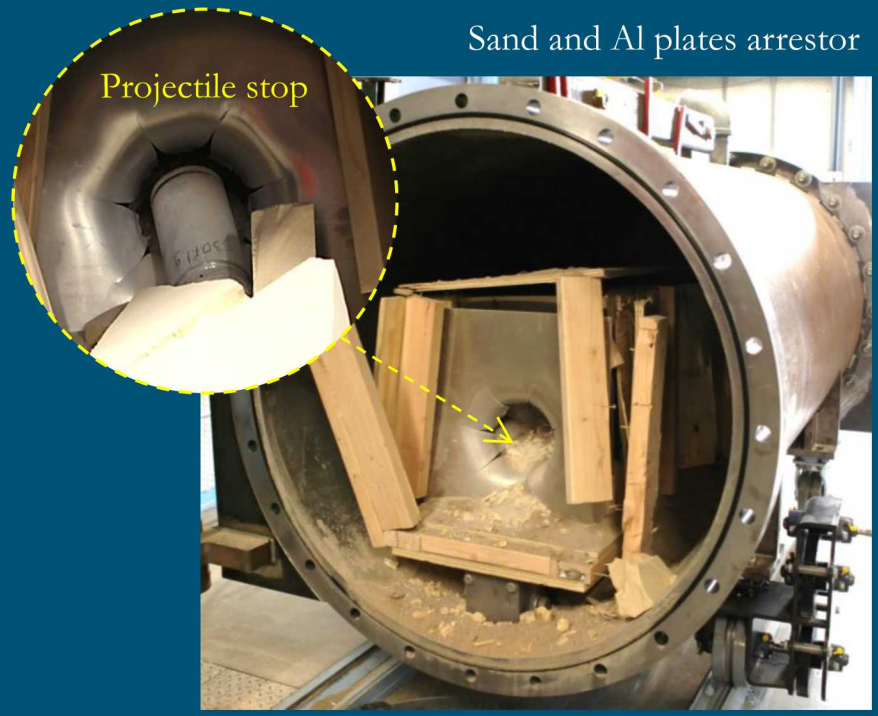
Inducing steeper deceleration profiles …

- Proposed configurations were tested at 300 m/s with the same type of projectile to compare it with foam data
- Both shots were straight with a smooth stop and MD01H data recorded survived and was successfully retrieved

Sand only arrestor



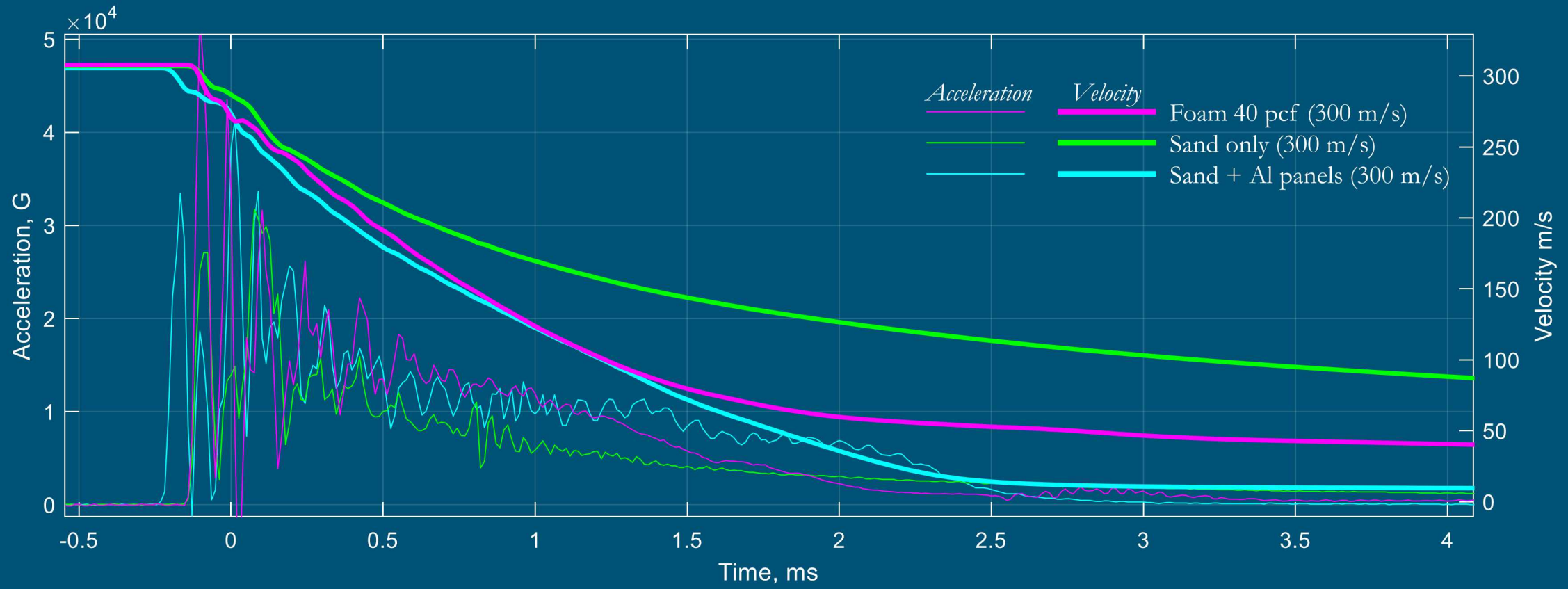
Sand and Al plates arrestor



IMPROVING DECELERATION

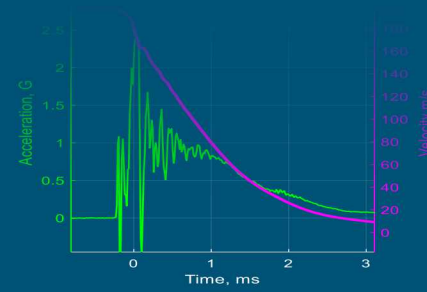
Inducing steeper deceleration profiles …

- Sand only as an arrestor is weaker than our heaviest foam (40 pcf) having a less steep deceleration profile
- The initial deceleration in 40 pcf foam is similar than sand+panels but the latter has a harder stop or steeper profile



CONCLUSIONS

- We expanded on previous work on electronics survivability tests to address diagnostic challenges and improve G profiles
- An electromagnetically induced crossing-point diagnostics was tested and proved to be a useful tool but at low resolution
- We successfully implemented the MD01H data recorded in a projectile designed that protects this diagnostics
- High fidelity data for deceleration profiles were attained
- We improved projectile penetration smoothness/stability by extending the foam boundaries away from projectile path
- Steeper deceleration profiles were attained in a sand medium with aluminum reinforcement plates



Thank you !