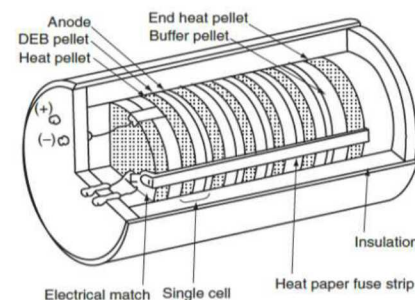
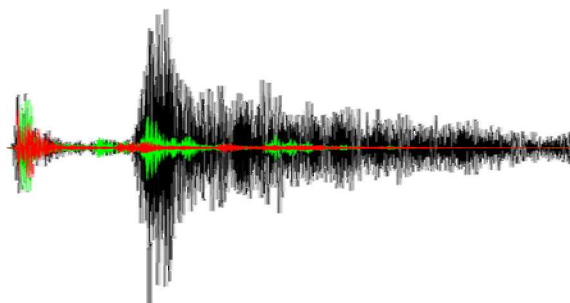


Acoustic and Structural Vibration Monitoring of Thermal Batteries to Detect Events and Margin Change



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Goals and Outline

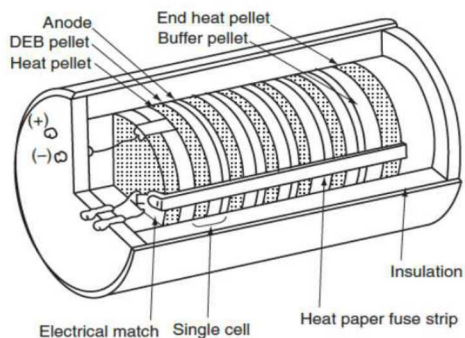
Can we detect changes in performance and understand

- which portion of the thermal battery train that change came from?
- what that change means for the performance of the thermal battery?



Winchester percussion primers

- Characteristic signatures
- Acoustic signal differences created from diverse energies of the firing pin (threshold testing).
 - Was the impact force to the igniter and resulting impulse response as expected or close to the margin?
- Detection of unexpected events
 - Tester alignment issue
 - Behavior near threshold



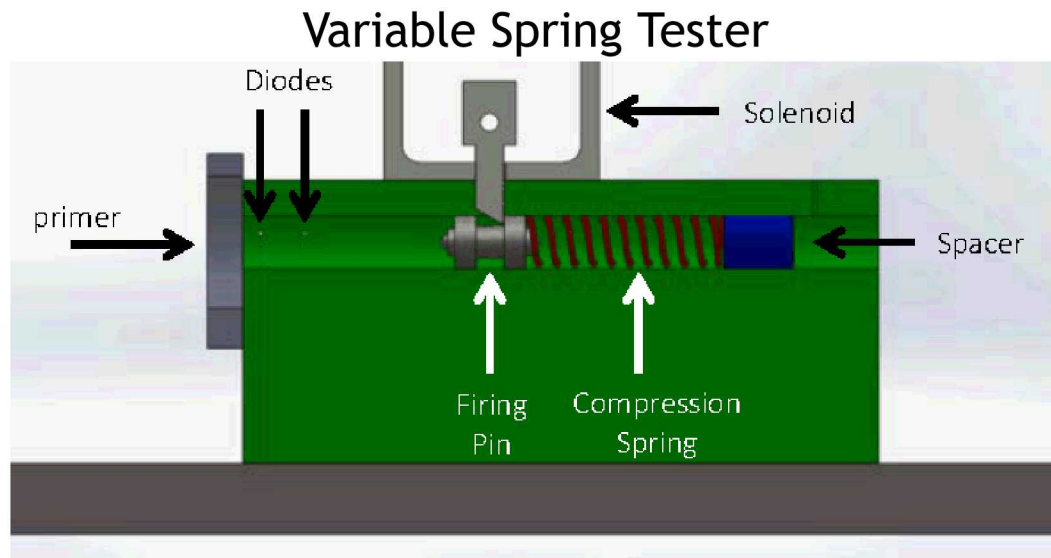
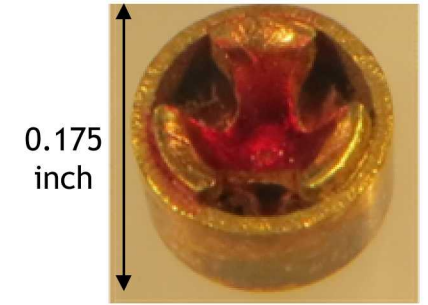
Ca/CaCrO₃ Thermal Battery

- Tailoring choice of sensors, initial data

3

Performance Testing of Percussion Primers: Method

- Kinetic energy of the firing pin can be varied.
- Firing pin velocity measured using diodes.



$$velocity = \frac{\text{distance between diodes}}{\text{time of flight}}$$

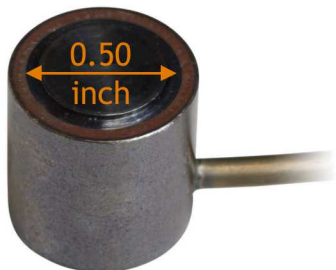
$$Kinetic\ Energy = \frac{1}{2}mv^2$$

m = mass

v = velocity = distance/time

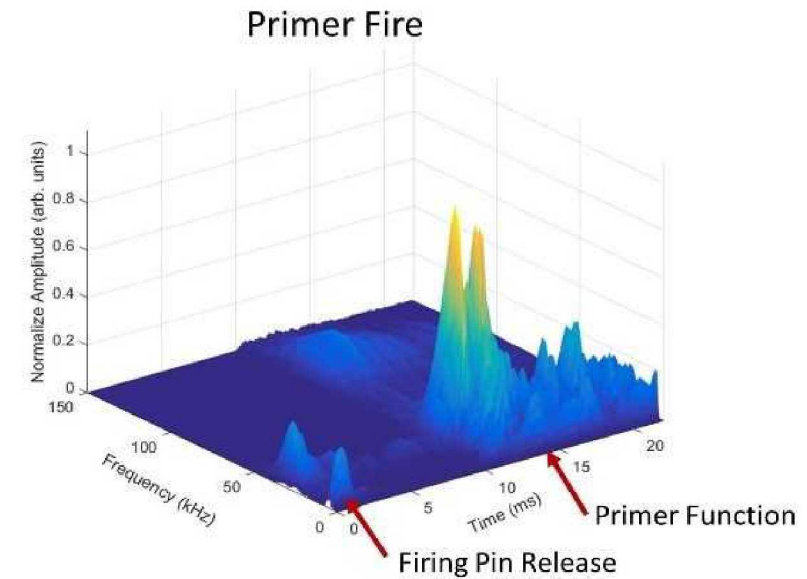
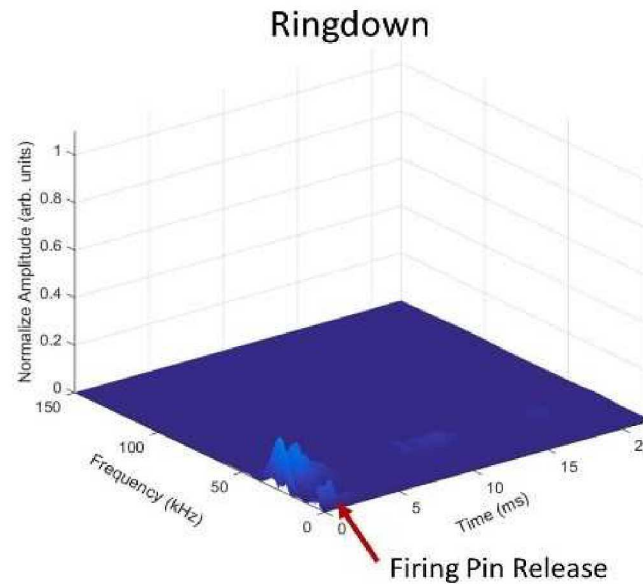
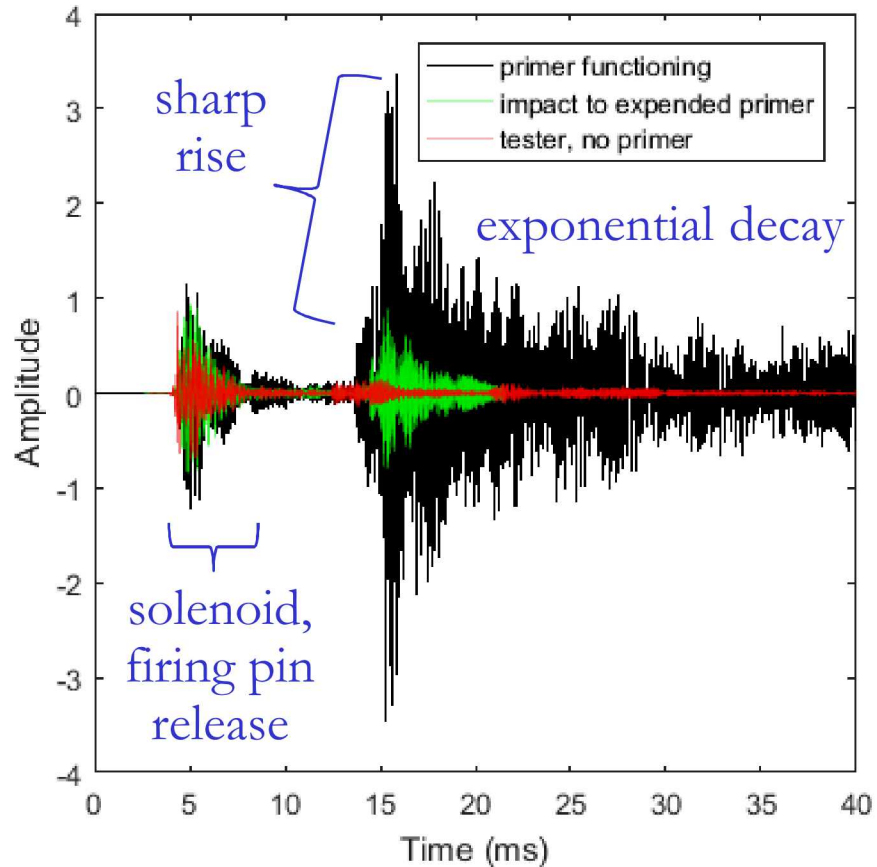
Kinetic energy is a function of $1/\text{time}^2$.

Acoustic signal is a function of time.



S9215 sensor, Physical Acoustics/Mistras Group WD

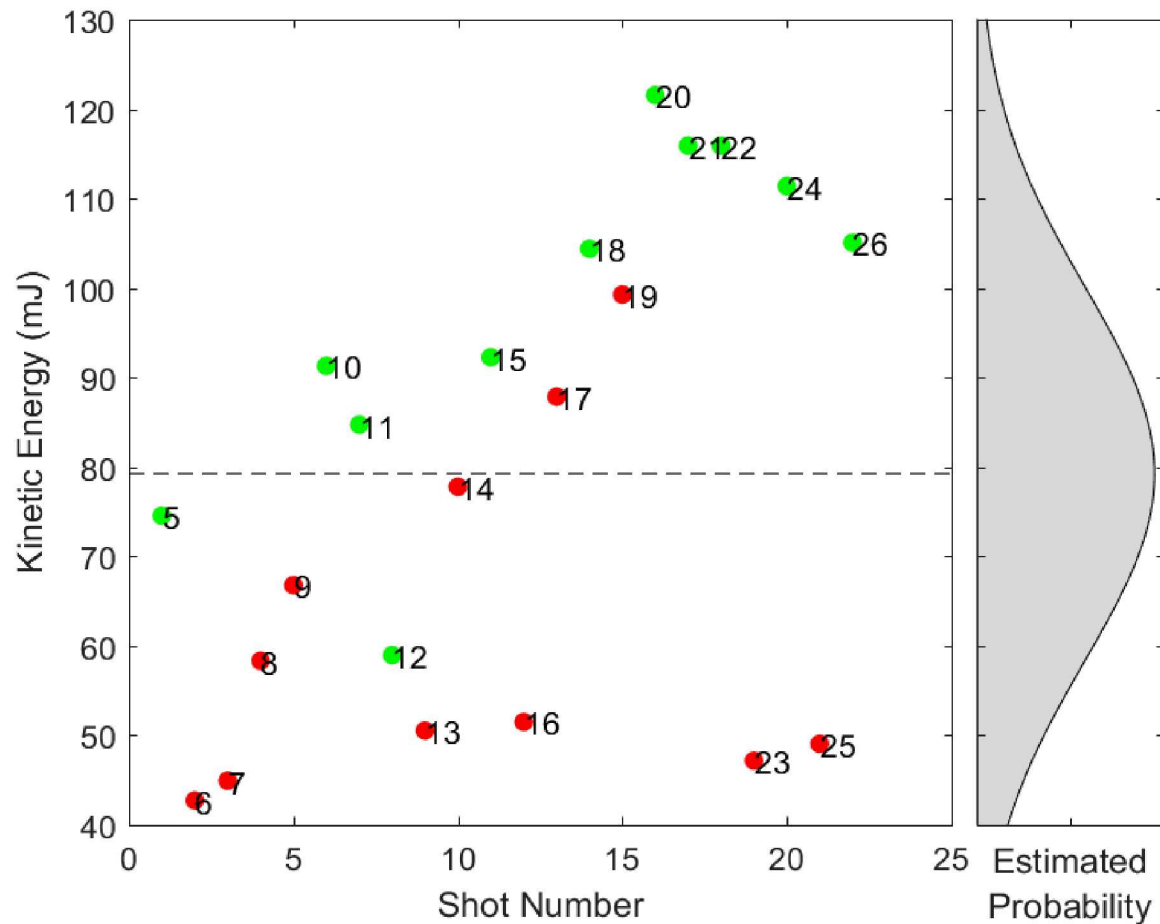
Clear differences in acoustic signatures when primer functions vs not



ringing pattern due to resonance of the structure

additional frequency content when primer fires

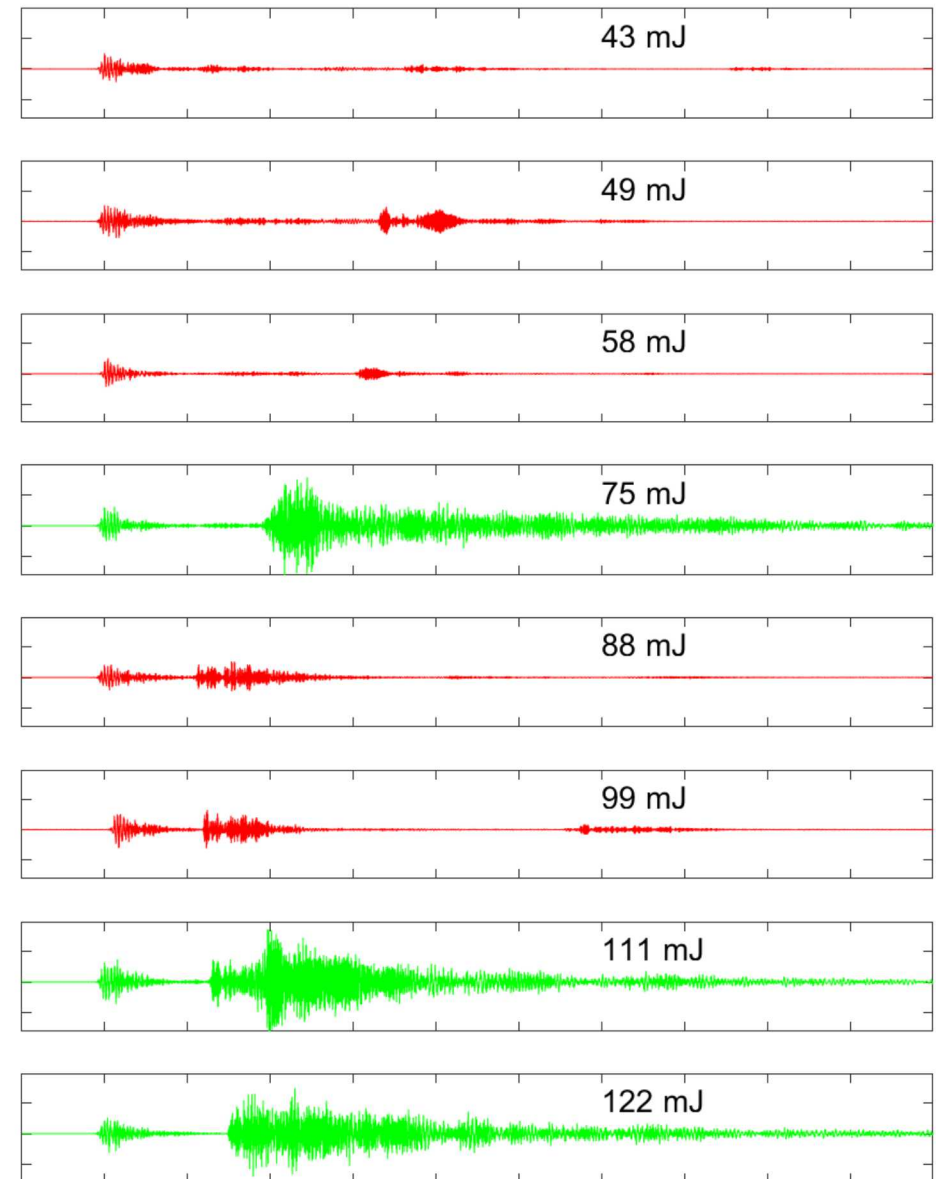
Can Threshold Testing Tell Us More?



Green = functioned, "go"

Red = did not function, "no-go"

numbers on the data points indicate shot number



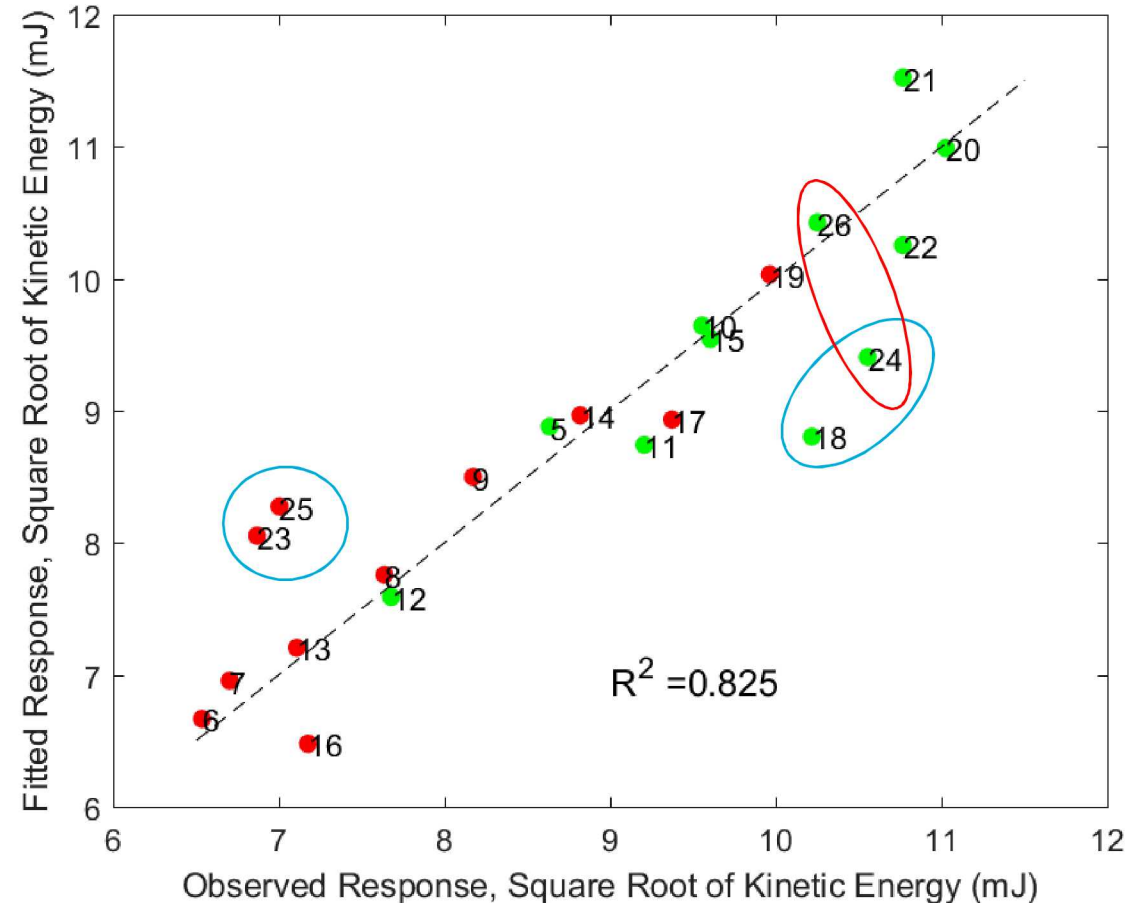
6 | Acoustic data predicts the kinetic energy well

Was the impact force to the igniter and resulting impulse response as expected or close to the margin?

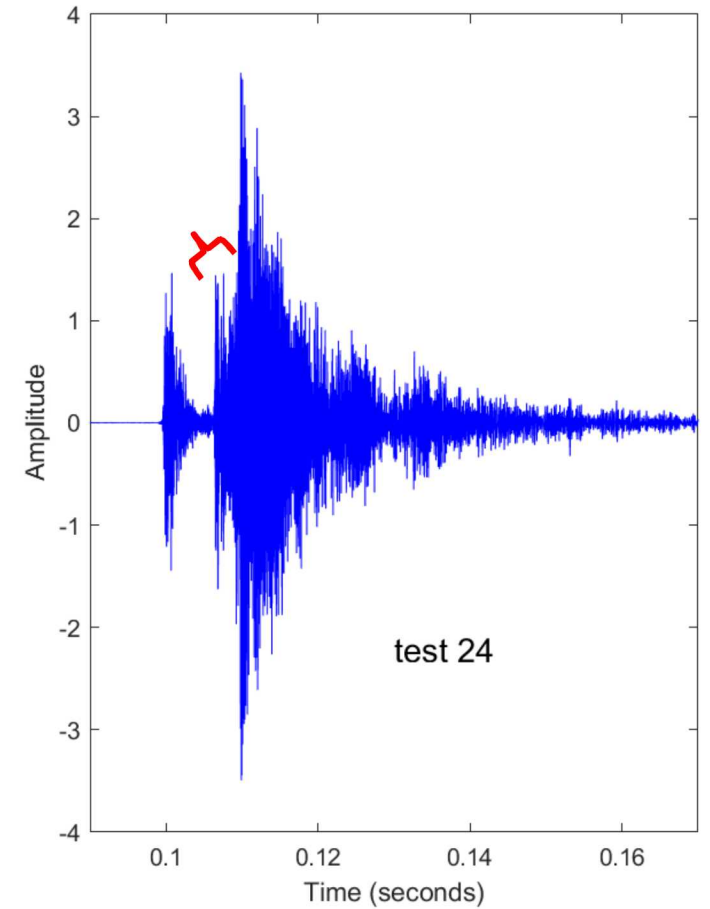
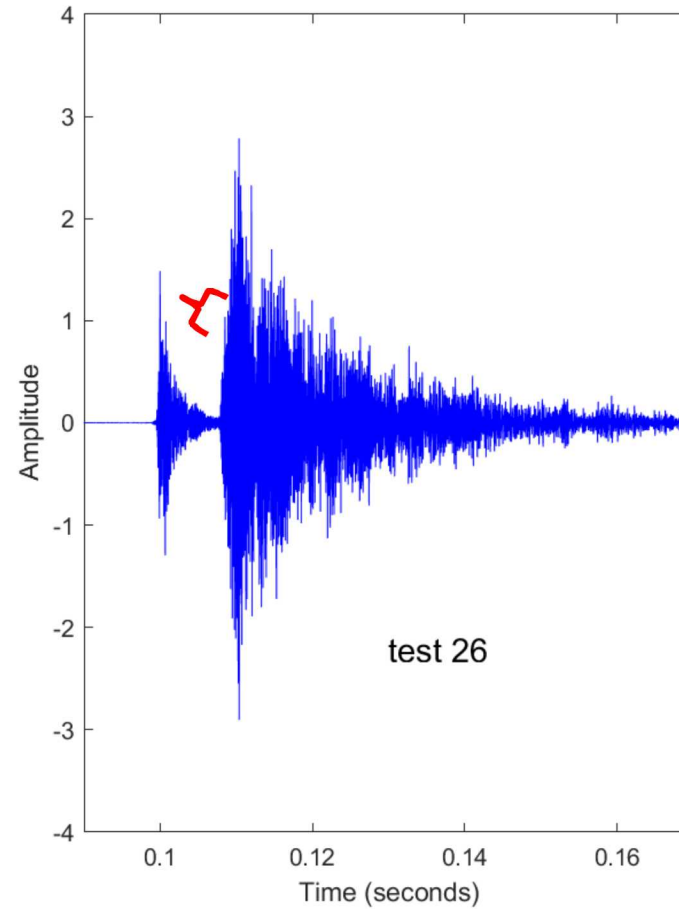
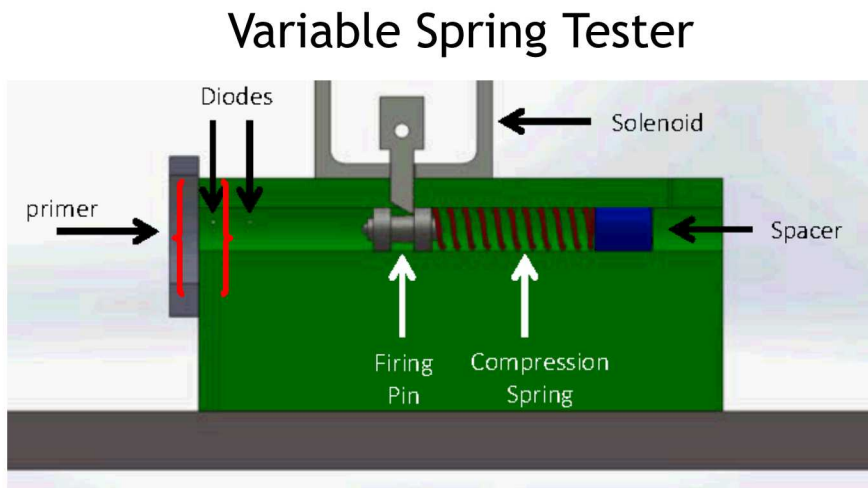
Data Analysis Method

Partial Least Squares (PLS) regression, a multivariate technique that describes the set of explanatory variables and predicting the response ones.

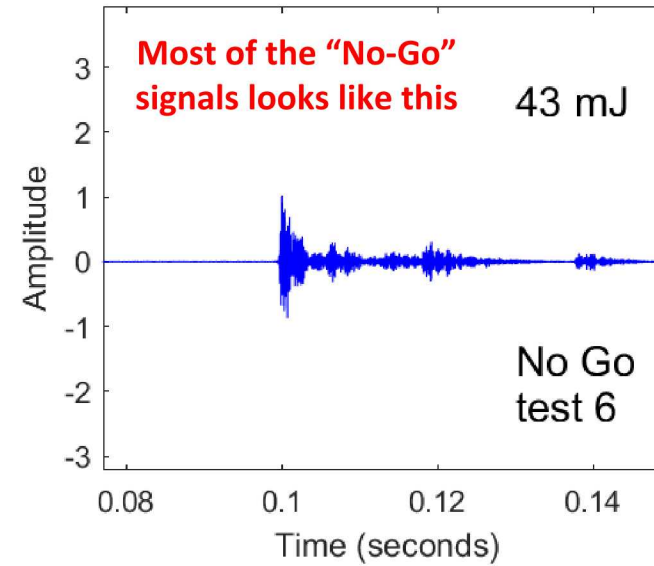
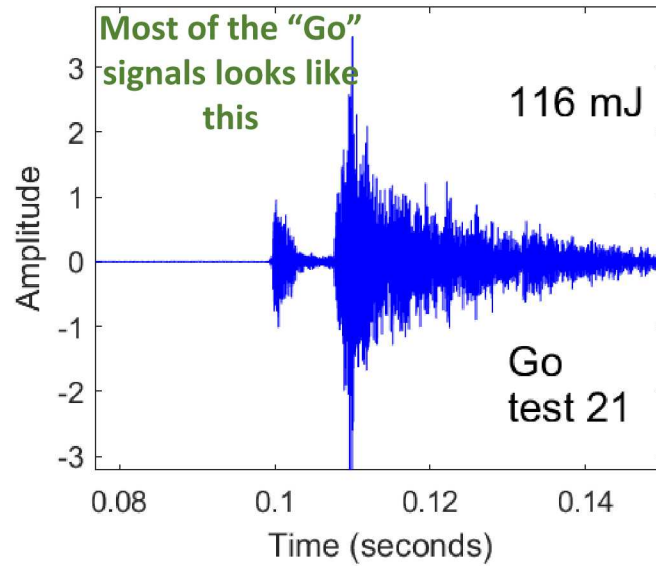
PLS finds a multi-dimensional direction in the observable space that explains as much of the variance in the predicted variable space as possible.



Data points with high residuals contain acoustic data features before the shock output that the other shots do not.



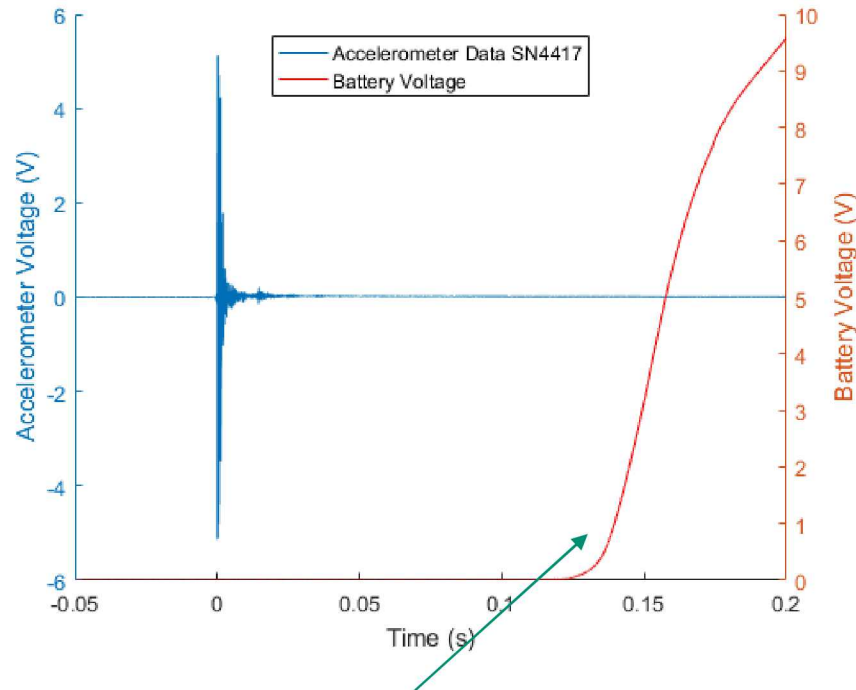
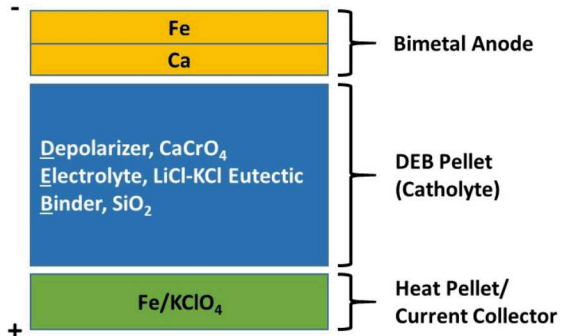
Acoustic signatures far from threshold vs near threshold



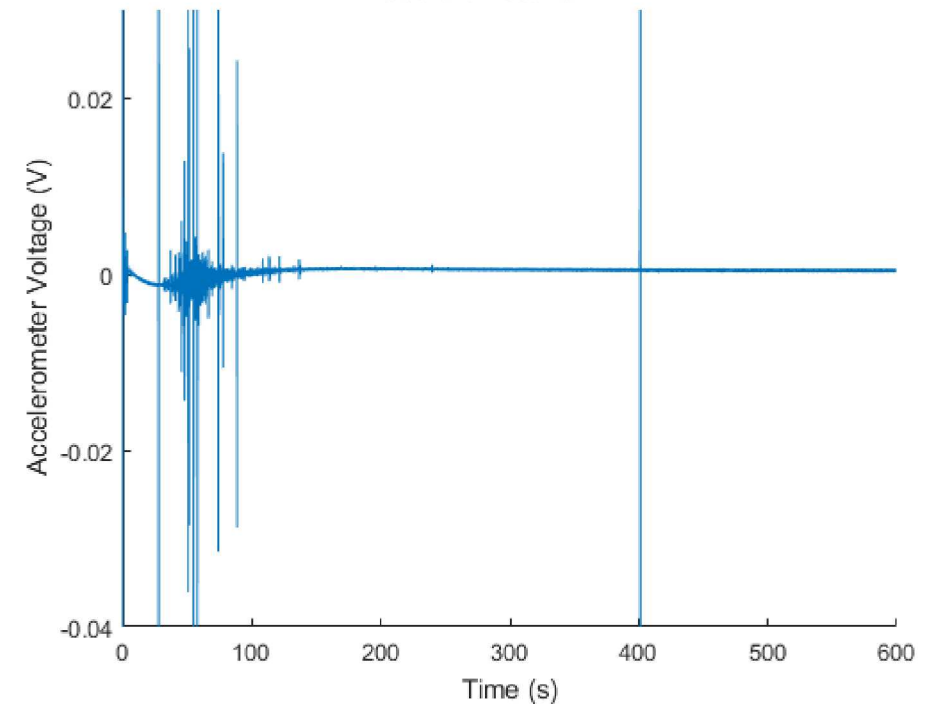
9 Detected primer function and some battery activity in initial tests

- Thermal battery: primer activating center-activated heat pellets.
- 2 sensors, in the process of optimizing to detect different events
- Improvements made to triggering for data collection

Ca/CaCrO₃ pelletized thermal battery



battery voltage began to rise after a delay of a little more than 0.1 seconds



7295B-10 Endevco sensor

Summary

- An initial demonstration of this non-invasive diagnostic has successfully differentiated more than just go/no-go behavior.
- A method was developed for margin determination of percussion primers using acoustic signals.
- Evaluations at the thermal battery level to detect the burning of heat pellets are promising.
 - Choice of sensor to detect different events is key. Ongoing experiments are working this.