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*Title:* Gas Gun Experiments to Measure the Shock Compression Behavior of High Performance Propellant (HPP)

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*Intended for:* Shock Compression of Condensed Matter Conference



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SCCM Abstract

*high performance*  
**GAS GUN EXPERIMENTS TO MEASURE THE SHOCK COMPRESSION BEHAVIOR OF AN  
AMMONIUM-PERCHLORATE/ALUMINUM-BASED PROPELLANT**

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, L. L. Gibson and D. E. Hooks Shock & Detonation Physics Group, WX-9 Los Alamos National Laboratory  
Los Alamos, NM USA 87545 Gas-gun driven plate impact experiments were performed on High  
Performance Propellant (HPP) to measure the shock compression behavior and Hugoniot. HPP is a  
proprietary blend of ammonium-perchlorate, aluminum, and plastic binder. A small amount of FeO<sub>2</sub> gives the  
propellant a rust color. The primary diagnostic was embedded magnetic particle velocity gauges. The  
Hugoniot was determined by performing multiple experiments using different impactors and a range of  
impact velocities. Impact stresses ranged from 0.3 GPa to 15 GPa. Even at the highest stress no reaction was  
observed; none was expected. At low stress HPP exhibits viscoelastic behavior with rounded wave profiles.  
Hugoniot data can be described using a model based on a Murnaghan isotherm with a small amount of  
porosity.

(HPP)

# Gas Gun Experiments to Measure the Shock Compression Behavior of High Performance Propellant (HPP)

N. J. Sánchez, R. L. Gustavsen, L.L.  
Gibson, & D. E. Hooks

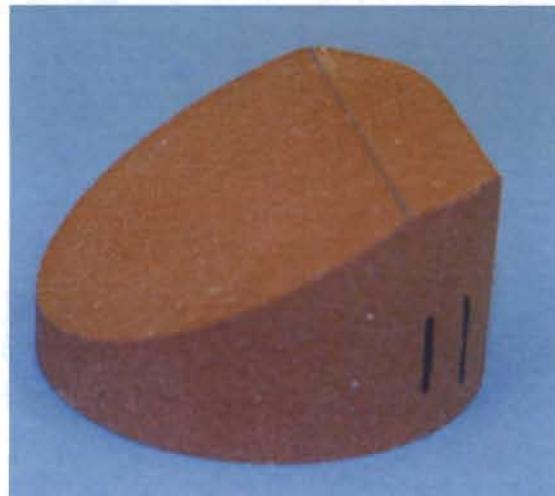


Funding Provided by the Joint  
DOD/DOE Munitions Technology  
Development Program (JMP)

## Goals of this study

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HPP composition: Ammonium-Perchlorate/Aluminum & plastic binder

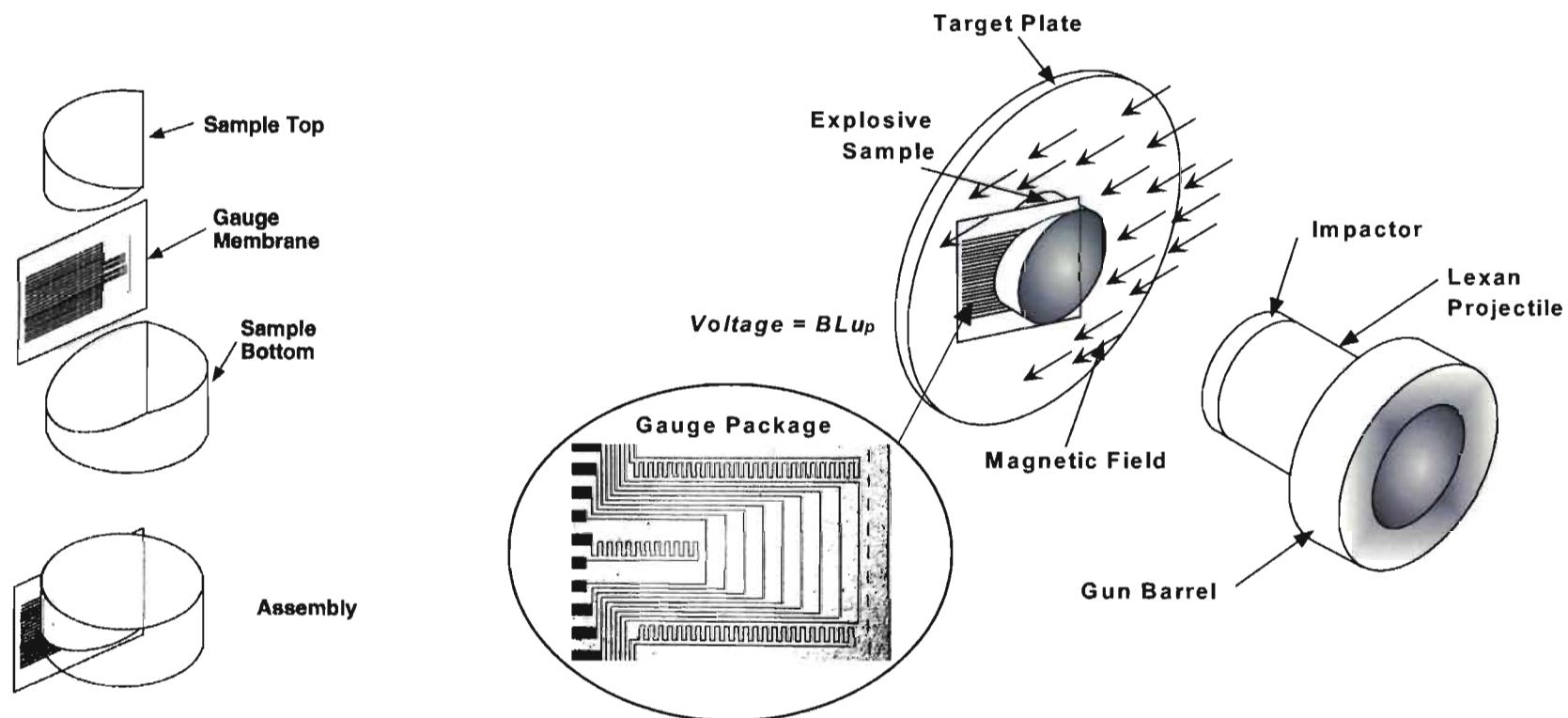


HPP test wedge

- Measure a possible shock to detonation transition (Safety)
- Measure Hugoniot (P-V curve reached by shocks) Equation of State
- Provide “wave profiles” at high pressure (mechanical response)

## Gas gun driven plate impact experiments were used to measure shock properties of HPP

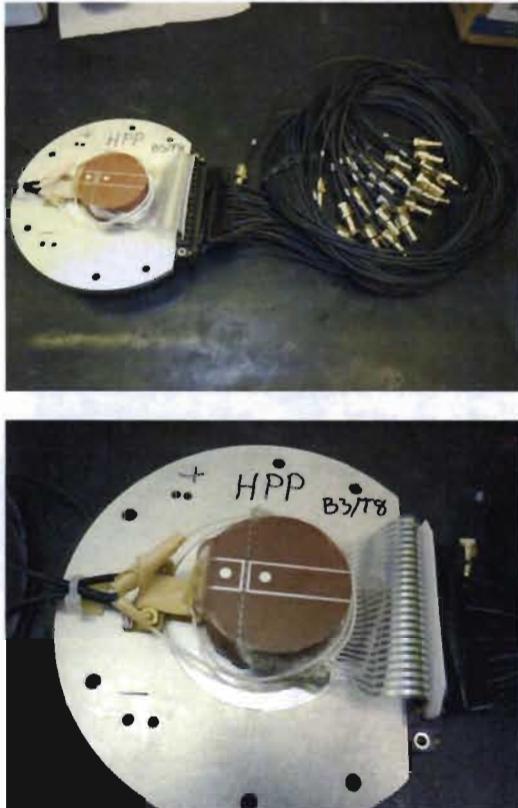
- Magnetic gauges based on Faraday's Law of Induction measure in-material motion



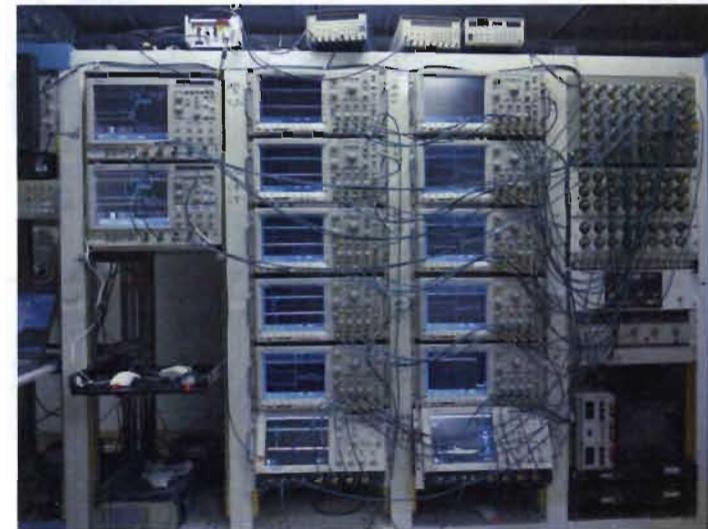
$$V = U_p \times B$$

## Finished HPP target

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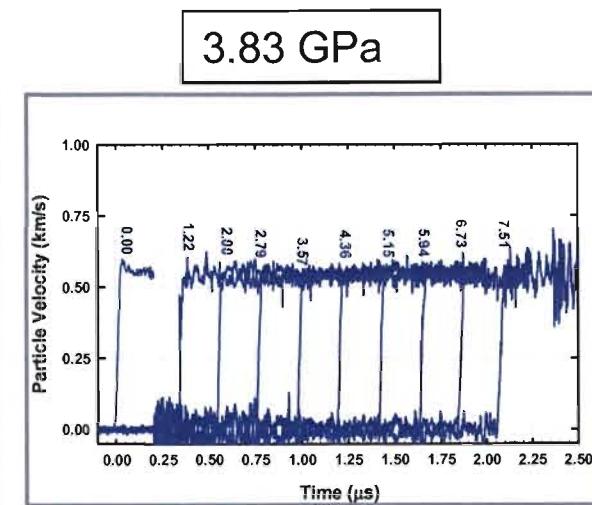
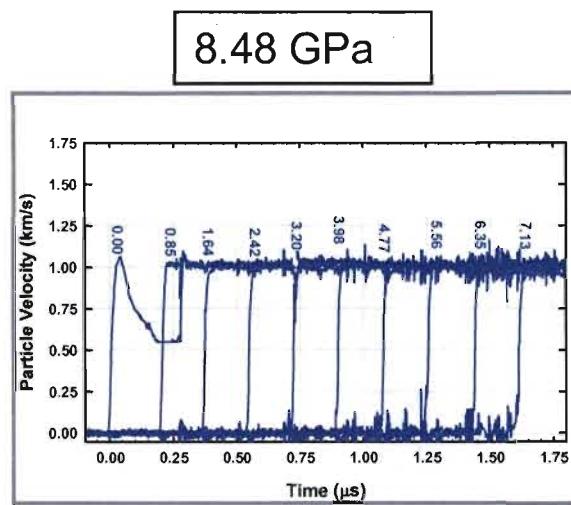
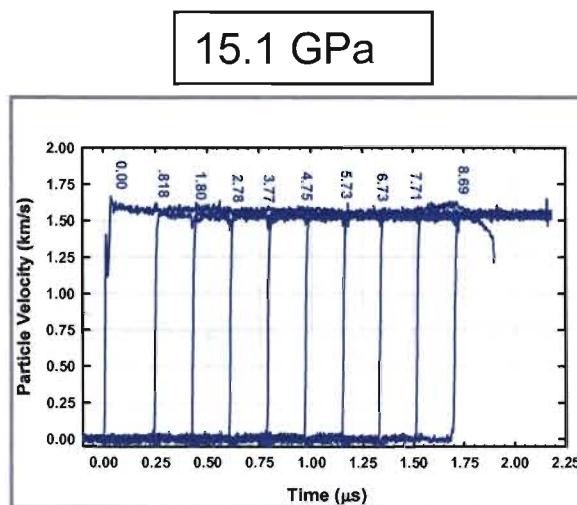


Large amount of data collection



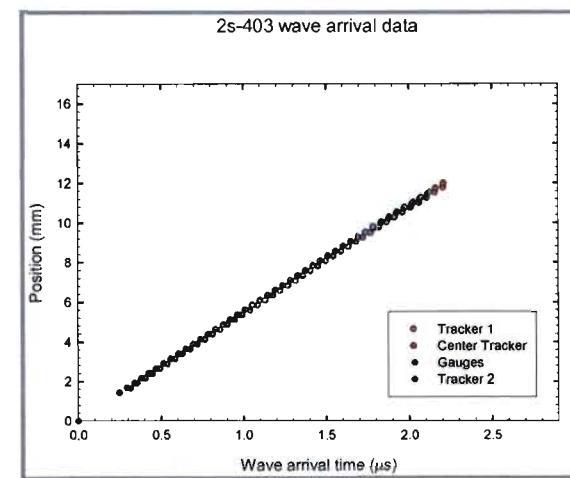
Target assembly was difficult due to the eraser like texture of HPP

# In-situ wave profiles provide material response at high pressure

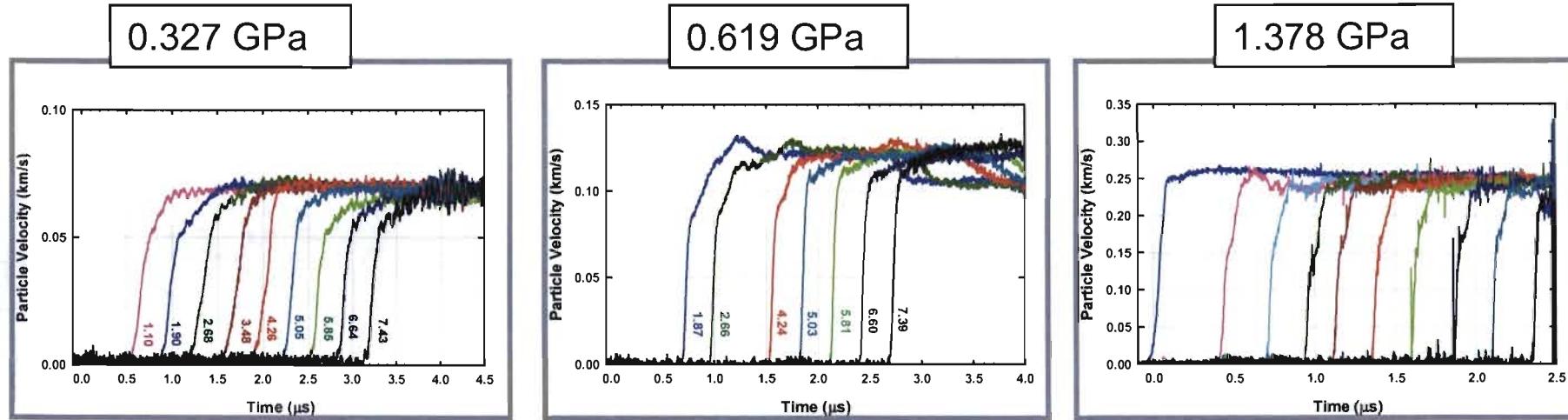


HPP inert up to 15 GPa

Particle velocity ( $U_p$ ) & shock velocity ( $U_s$ ) are measured for Hugoniot data



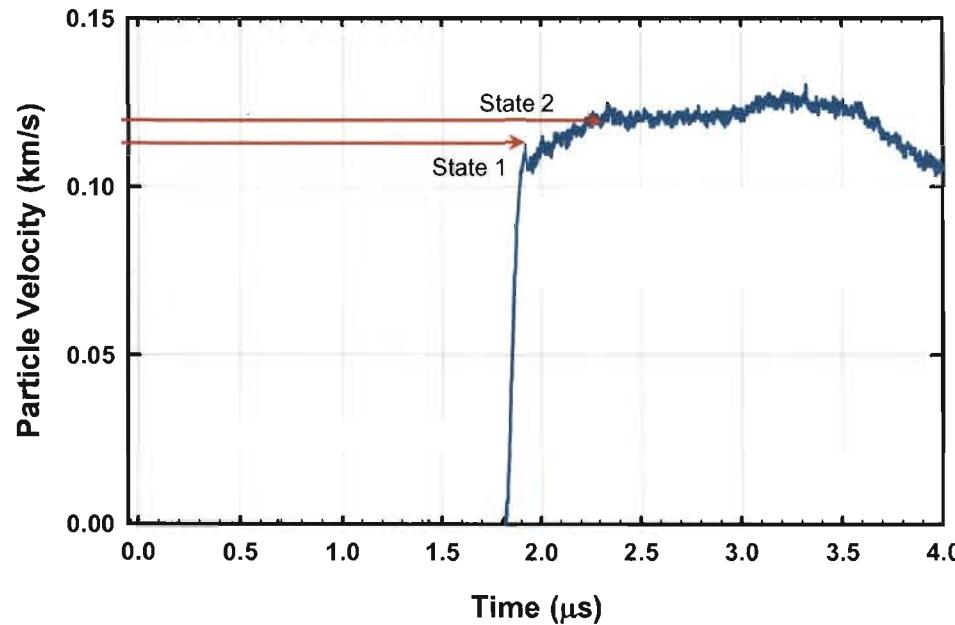
## Viscoelasticity was observed at low pressures



Rounded wave profiles indicate viscoelastic behavior

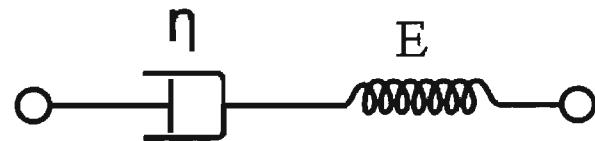
# Viscoelastic materials exhibit both viscous & elastic characteristics when undergoing deformation

- Slow transition from state 1 to state 2 caused by viscous damping

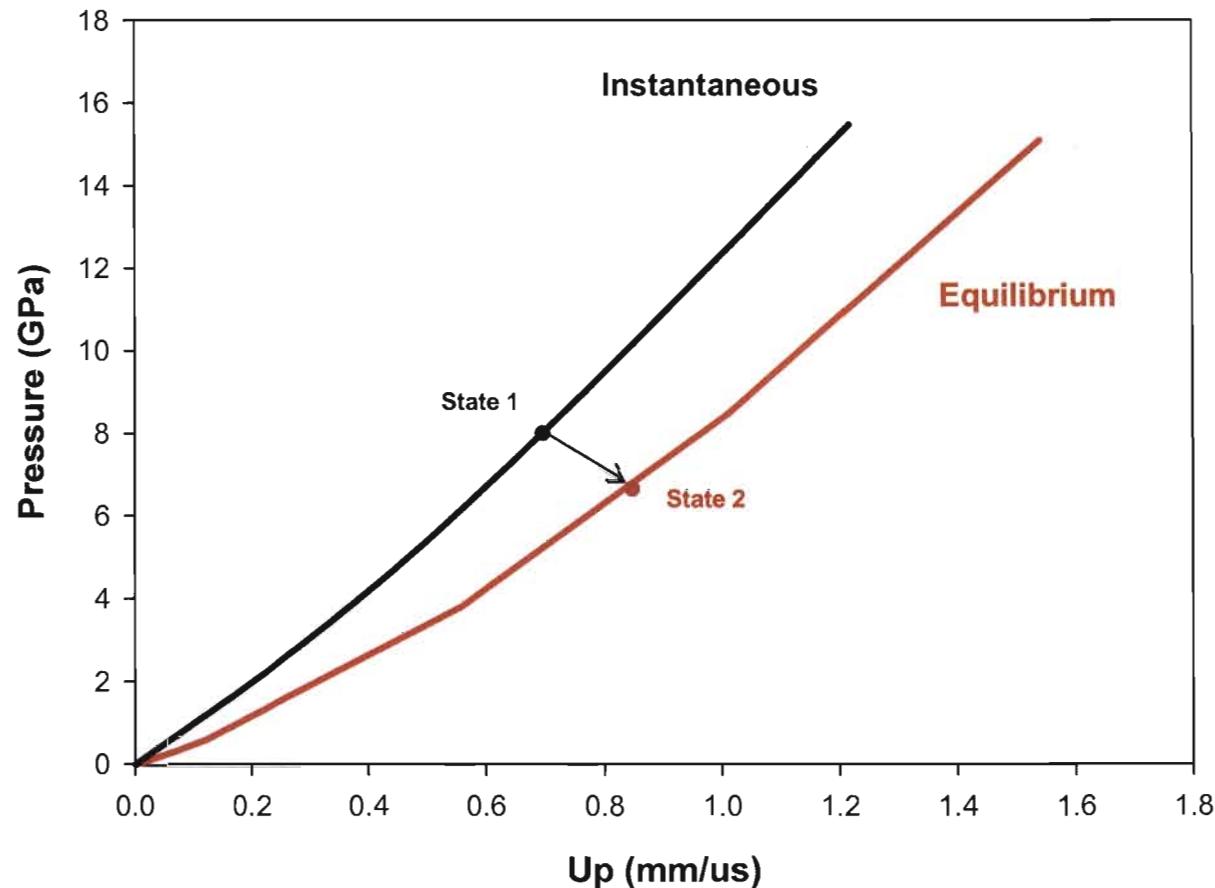


## ▪ Maxwell Model

$$\frac{d\epsilon_{Total}}{dt} = \frac{d\epsilon_D}{dt} + \frac{d\epsilon_S}{dt} = \frac{\sigma}{\eta} + \frac{1}{E} \frac{d\sigma}{dt}$$



## Viscoelastic materials are difficult to model because they have an instantaneous Hugoniot & equilibrium Hugoniot



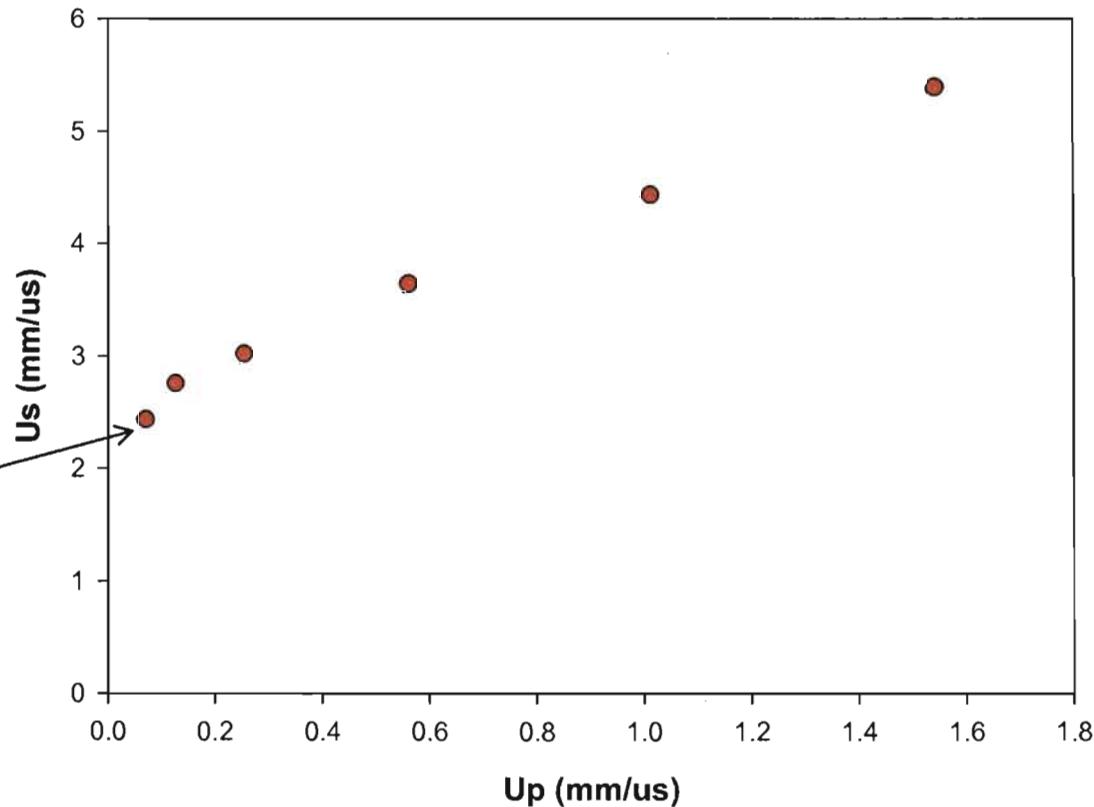
## Hugoniot seems to soften at low pressure due to crush out of voids

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HPP Hugoniot

Is the nonlinear behavior real?

Symmetric Impact to verify gauges were reading correctly



# Equation of State for porous energetic materials

Constructing a complete thermodynamic potential function based on the Helmholtz Free Energy

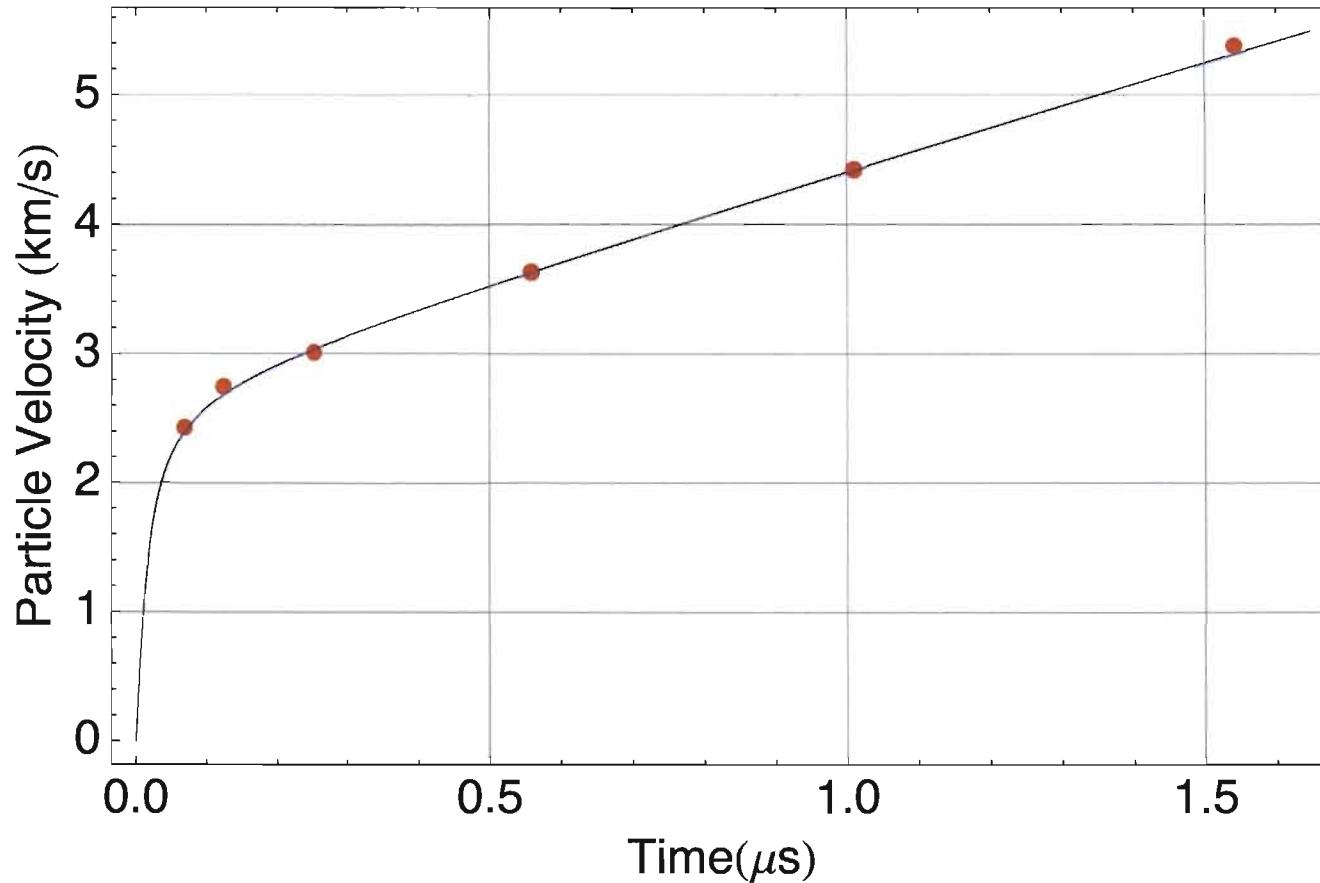
$$F(T, V) = C_V \left[ (T - T_o) \left( 1 + \frac{\Gamma}{V} (V_o - V) \right) + T \ln \left( \frac{T_o}{T} \right) \right] + \frac{K_{To} V_o}{N(N-1)} \left[ \left( \frac{V_o}{V} \right)^{N-1} - (N-1) \left( 1 - \frac{V}{V_o} \right) - 1 \right]$$
$$K_T = K_{To} \left( \frac{V_o}{V} \right)^N$$

Transforming it to the form of  $E(P, V)$

$$E(P, V) = \frac{P}{\Gamma} - \frac{\Gamma}{V} C_V T_o (V_o - V) - \frac{K_{To}}{N \Gamma} \left[ \left( \frac{V_o}{V} \right)^N - 1 \right] + \frac{K_{To} V_o}{N(N-1)} \left[ \left( \frac{V}{V_o} \right)^{1-N} - (N-1) \left( 1 - \frac{V}{V_o} \right) - 1 \right]$$
$$E = \frac{1}{2} P (V_{oo} - V)$$

## Analytic function fits the data well

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## Summary

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- Concluded that HPP is inert up to 15.1 GPa
- Provided in-situ wave profiles for mechanical response at high pressure
- Provided an equation of state at high pressures

# Questions?

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