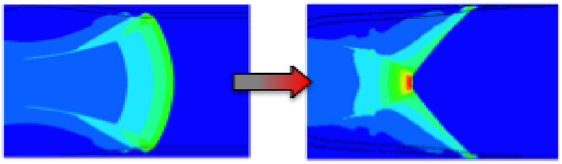
NAVAL POSTGRADUATE SCHOOL

Approved for Public Release



ENHANCED PERFORMANCE FROM INSENSITIVE EXPLOSIVES

Ronald Brown, John Gamble, Dave Amondson, Ronald Williams, Paul Murch, and Joshua Lusk

Physics Department
Naval Postgraduate School, Monterey, CA 93943

Contact: rebrown@nps.edu

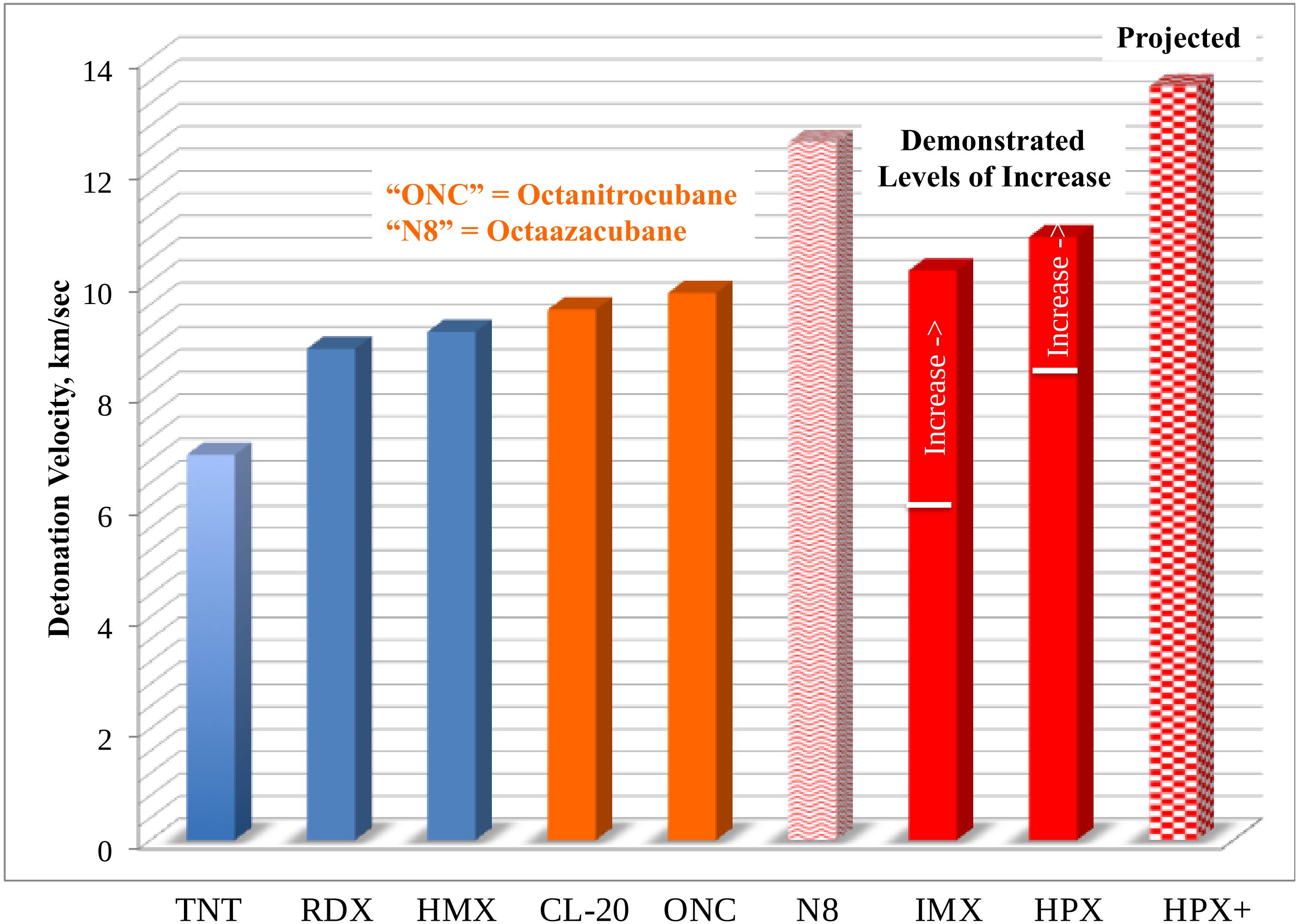
2013 Insensitive Munitions and Energetic Materials Technology Symposium
Paper 16169

Acknowledgement

Dr. Kevin Vandersall
Lawrence Livermore National Laboratory

Technical Staff
ANSYS-AUTODYN
Berkeley, CA

Overview of Achievements Relative to Explosives Chronology



OUTLINE

- Objective
- Background
- Modeling & Validations
- Effect of Detonation Convergence on Energy Partitioning
- Coaxial Initiation Limitations
- Results of Novel Dynamic Compression
- Conclusions

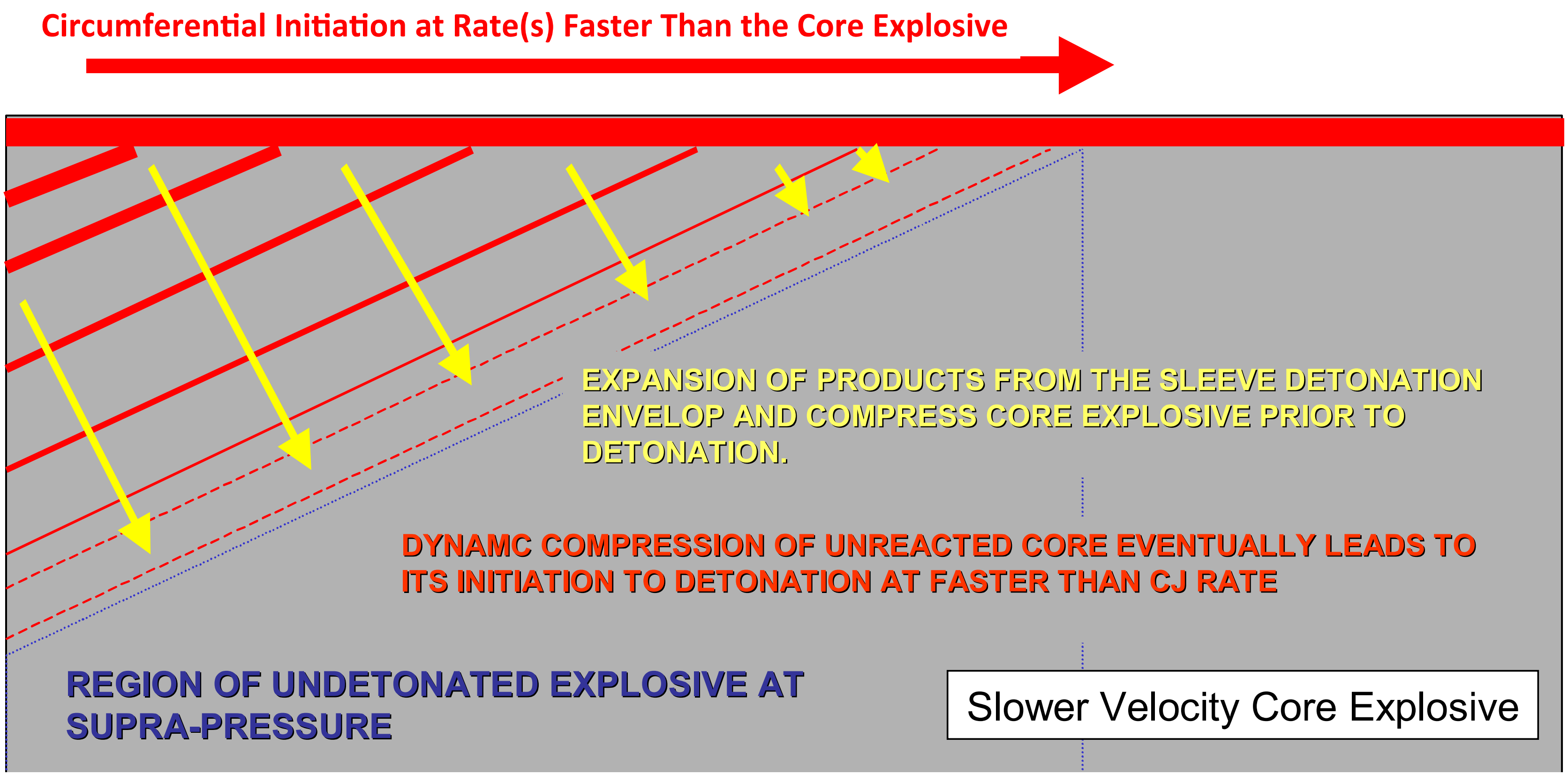
Develop means for enhancing directed energy from explosive weapon systems by exploiting the effects of overdriven detonation.

Explore means for overcoming the limitations of coaxial charges.

Validate prediction techniques.

GOAL & OBJECTIVES

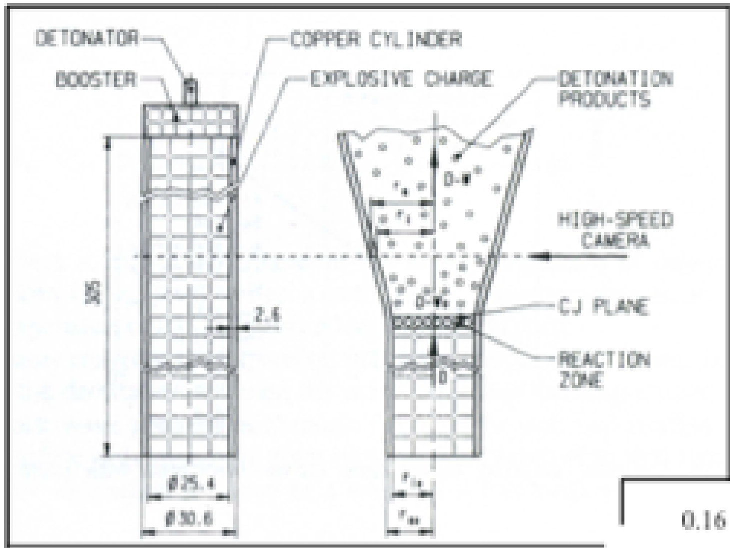
Pre-Compression Leads to Elevated Shocked States & Detonation Condition



Equation of State & Modification
Agreements with
- PBXN-111 PBXN-110/PBXN-111 CYLEX
- PBXN-111 Detonation
- PBHMX spherical implosion

VALIDATION OF PREDICTION TECHNIQUES & TECHNOLOGY BACKGROUND

JWL and JWL-M Equations of State & Concurrence with PBXN-111 CYLEX

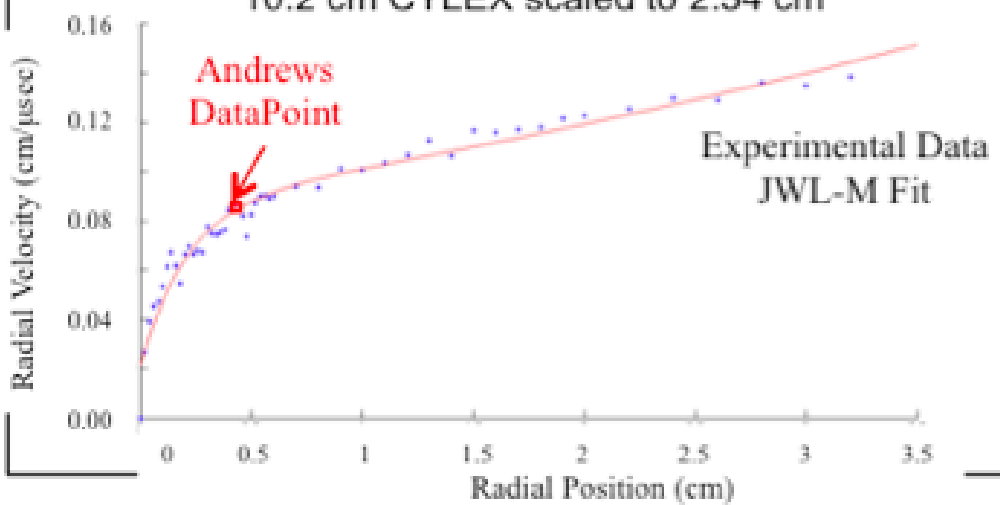


$$P = A\left(1-\frac{\omega}{R_1 V}\right)e^{-R_1 V} + B\left(1-\frac{\omega}{R_2 V}\right)e^{-R2V} + \omega\frac{(E+\lambda Q)}{V}$$

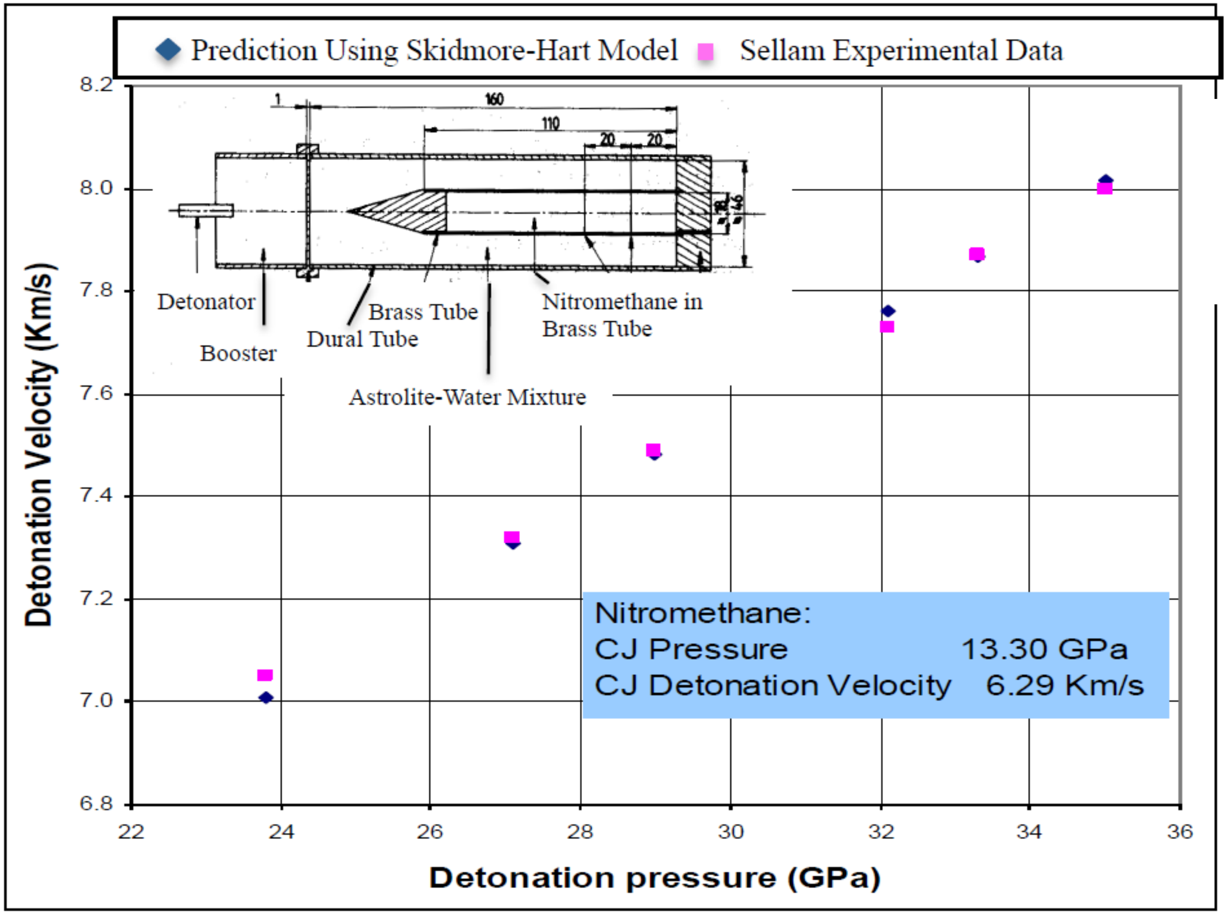
where

$$\frac{d\lambda}{dt} = a\left(1-\lambda^{1/2}\right)p^{1/6}$$

PBXN-111 Experimental Data (Miller)
10.2 cm CYLEX scaled to 2.54 cm



CLASSIC CO-AXIAL EXPERIMENT & AGREEMENT WITH SKIDMORE-HART MODEL

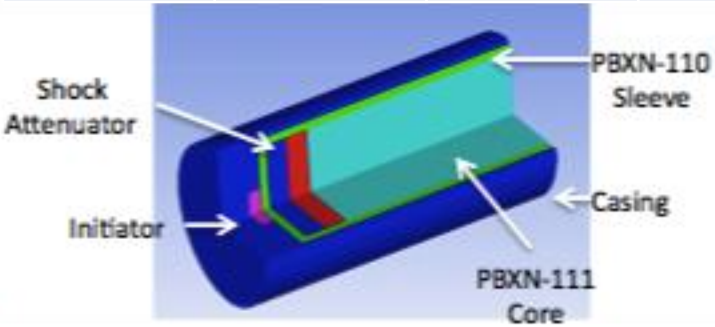


$$\frac{U_{OD}}{U_{cj}} = \left[\frac{P_{OD}}{P_{cj}}\left(2 - \frac{P_{OD}}{P_{cj}}\right)\right]^{1/2}$$

SUSTAINED EFFECT OF CIRCUMFERENTIAL INITIATION ON PBXN-111

(INITIATION BY THIN SLEEVE OF PBXN110 AND PBXN-112)

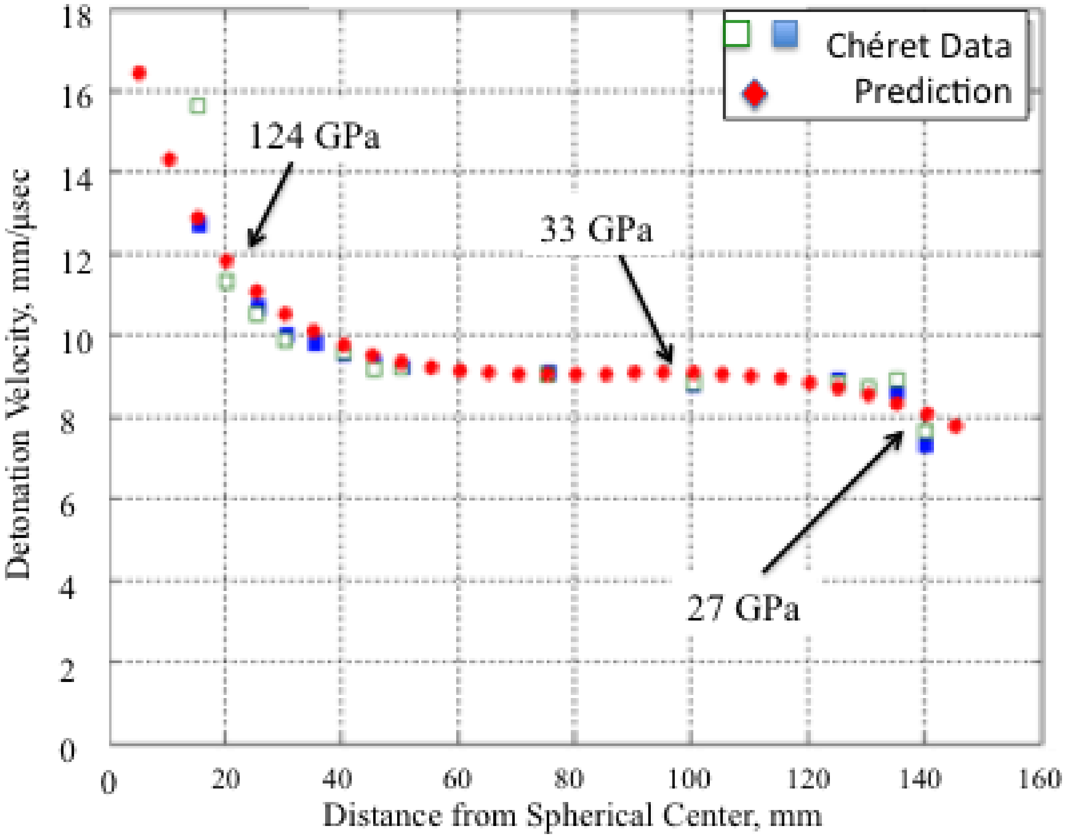
Position	PBXN-	111	PBXN-	110/111	PBXN-	112/111
(mm)	Predict	Exp't	Predict	Exp't	Predict	Exp't
63.5	7.0	6.3	8.3	8.1	8.4	8.3
44.5	6.5	6.0	8.3	8.2	8.5	9.2
Centerline	5.8	5.5	9.7	10.4	9.9	10.2
Average	6.2	5.8	9.1	9.4	9.3	9.5



*Peak Mach Stem Pressure, 66 GPa

HYDRO-CODE PREDICTION COMPARISON WITH REPORTED EXPERIMENTAL DATA: SPHERICAL IMPLOSION

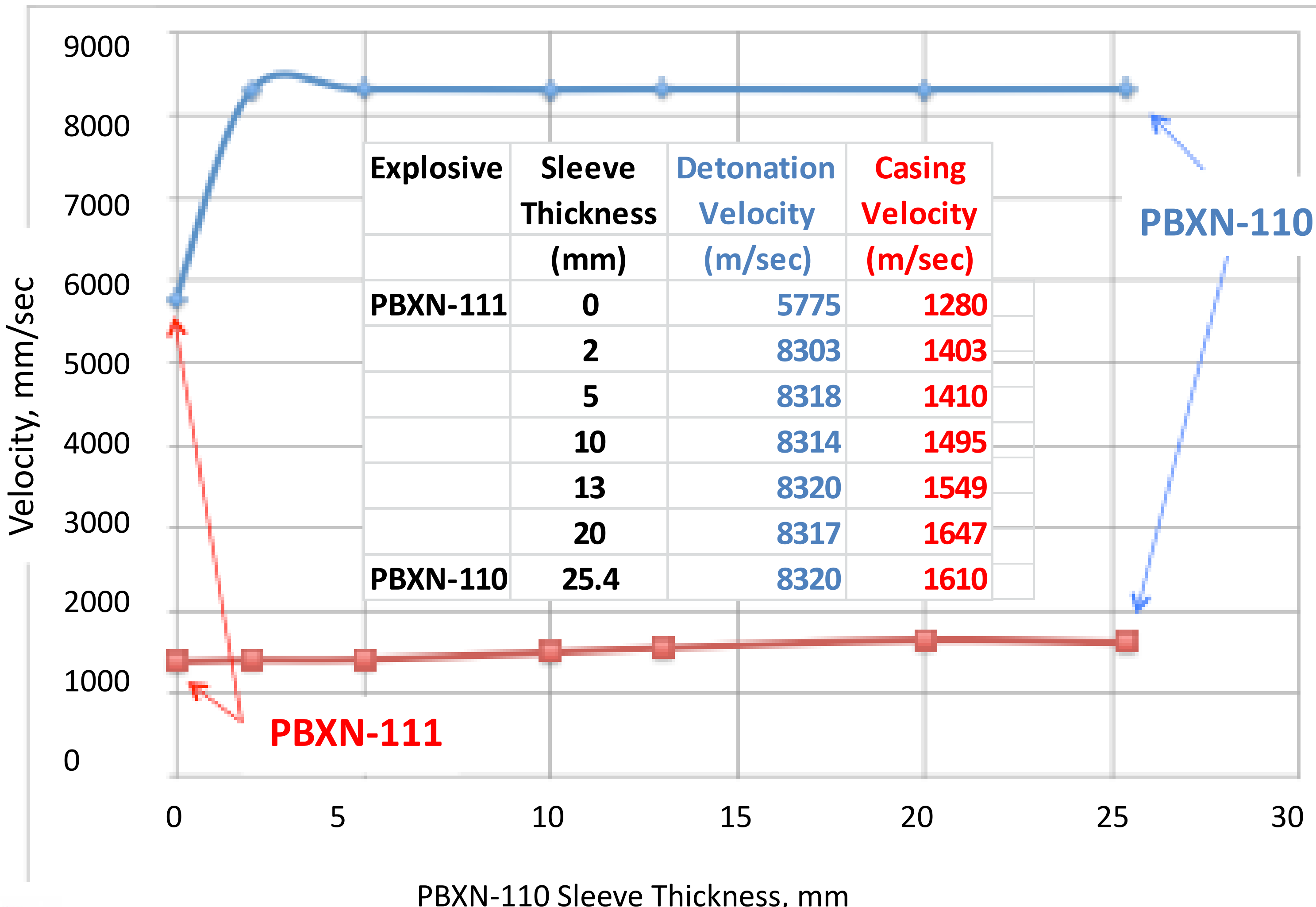
Simulation



NAVAL POSTGRADUATE SCHOOL

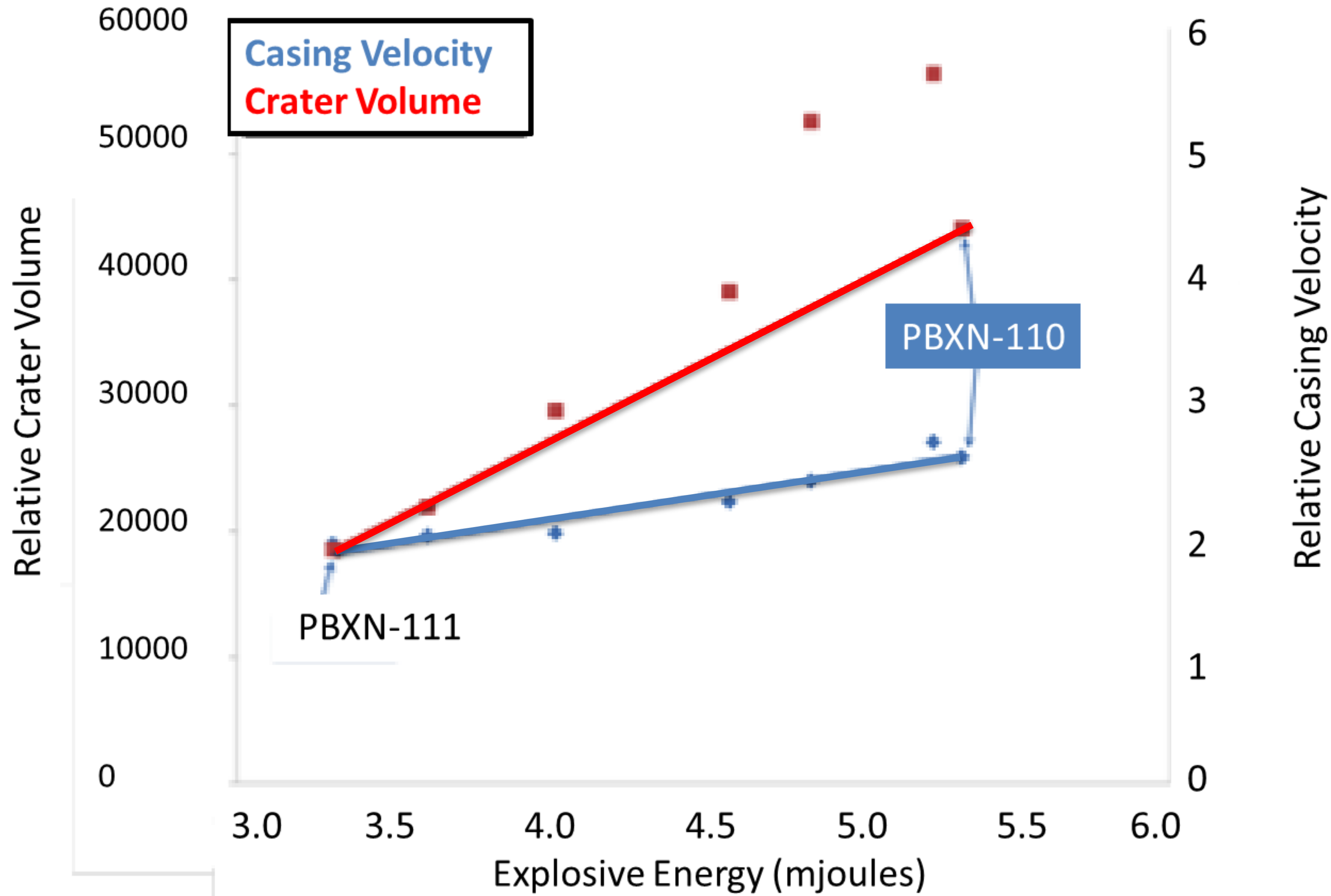
Approved for Public Release

Effect of Sleeve Thickness



Explosive	Sleeve Thickness (mm)	Detonation Velocity (m/sec)	Casing Velocity (m/sec)
PBXN-111	0	5775	1280
	2	8303	1403
	5	8318	1410
	10	8314	1495
	13	8320	1549
	20	8317	1647
PBXN-110	25.4	8320	1610

Relative Energies



Dynamic Compression Technique Results from Circumferential Initiation at ~11 km/sec with core explosives:

- High performance HMX-based explosive ("HPX)
- Extremely insensitive rubber-based explosive ("IMX")

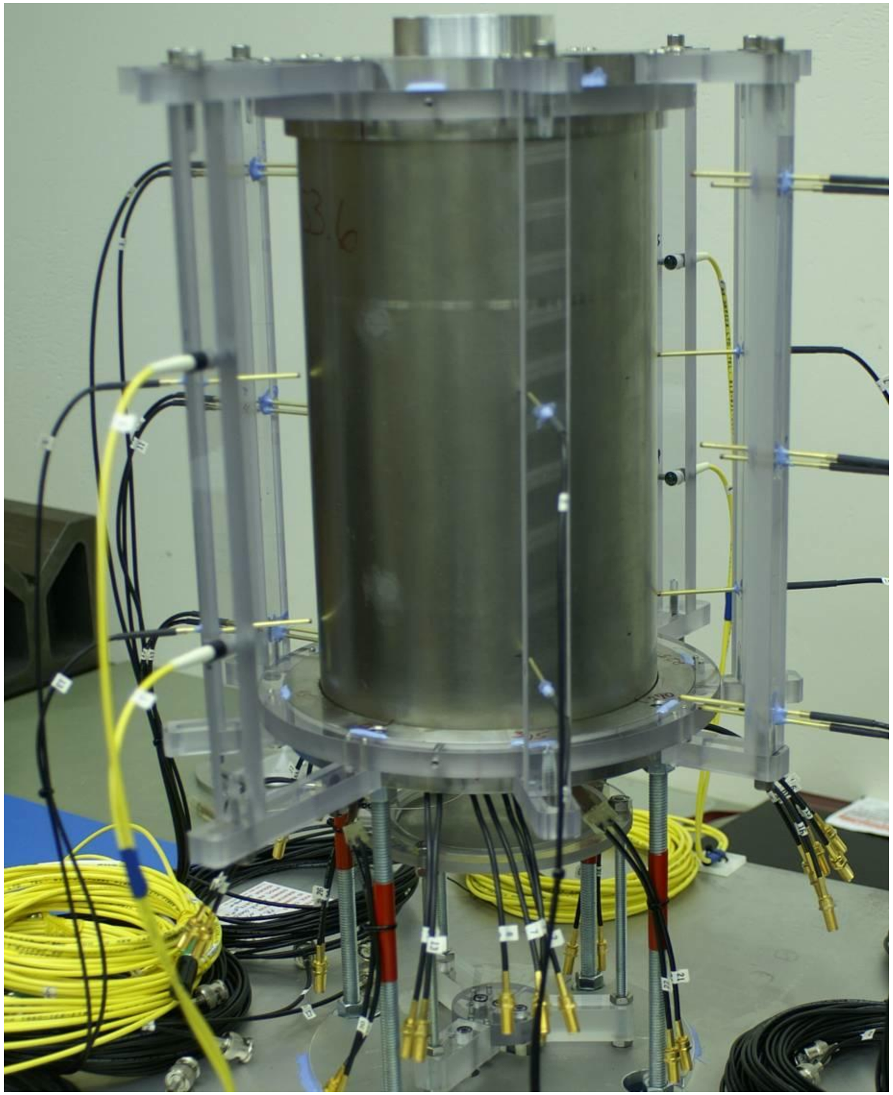
Diagnostics for Measuring

- Convergent front shape
- Detonation velocity
- Cylinder expansion

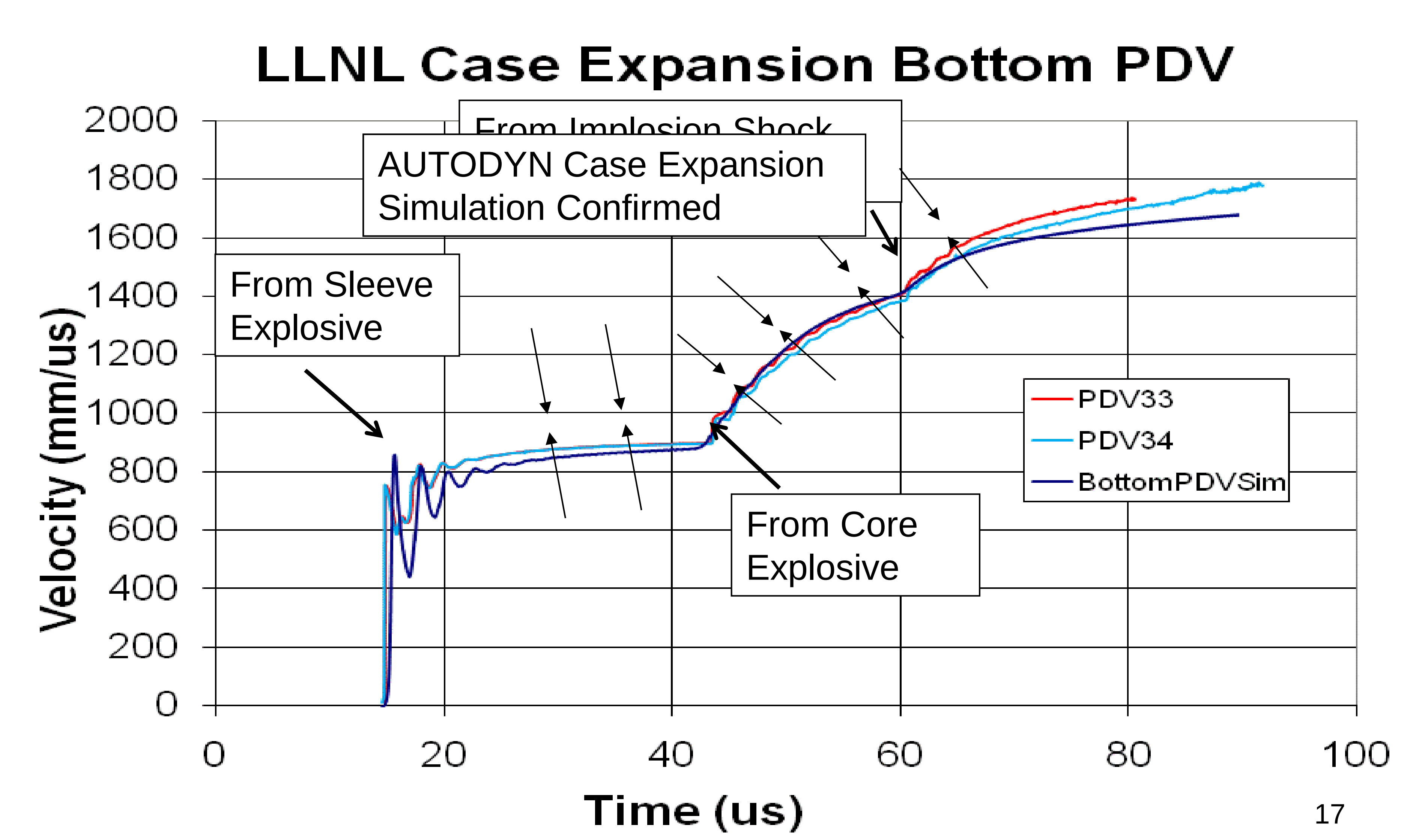
EXPERIMENTS CONDUCTED WITH INITIATING DEVICE THAT OVERCOMES THE COAXIAL CHARGE LIMITATION

CYLINDER EXPANSION

Charge Setup and Exterior Instrumentation



Case Expansion: Simulation vs Experimental

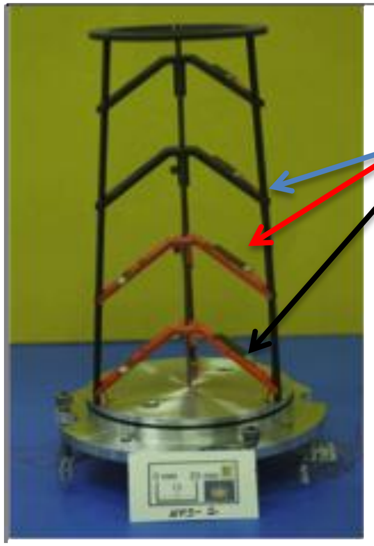


NAVAL POSTGRADUATE SCHOOL

Approved for Public Release

CONVERGENT FRONT GEOMETRY & DETONATION VELOCITY

CONFIRMATION OF PREDICTED FRONT GEOMETRY



Embedded Structure
With Piezoelectric Sensors

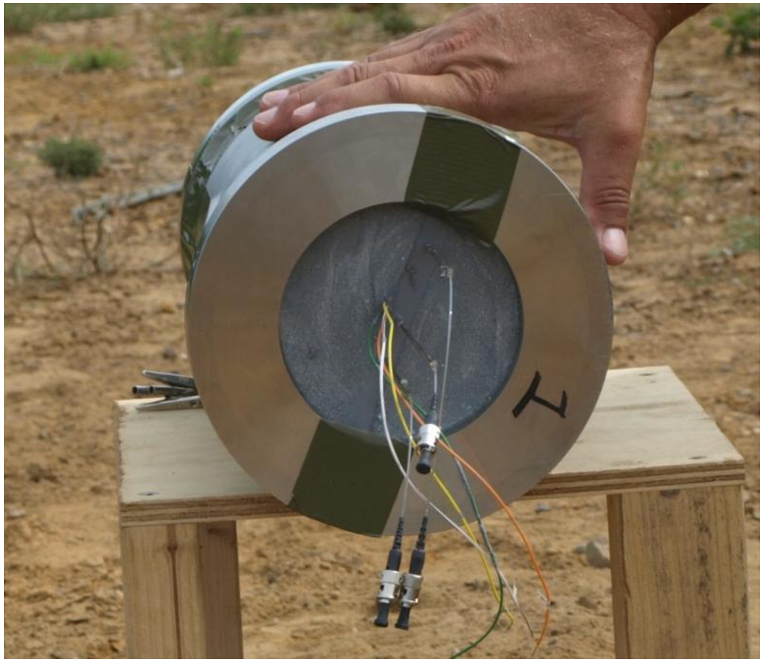
Front Geometry Confirmation

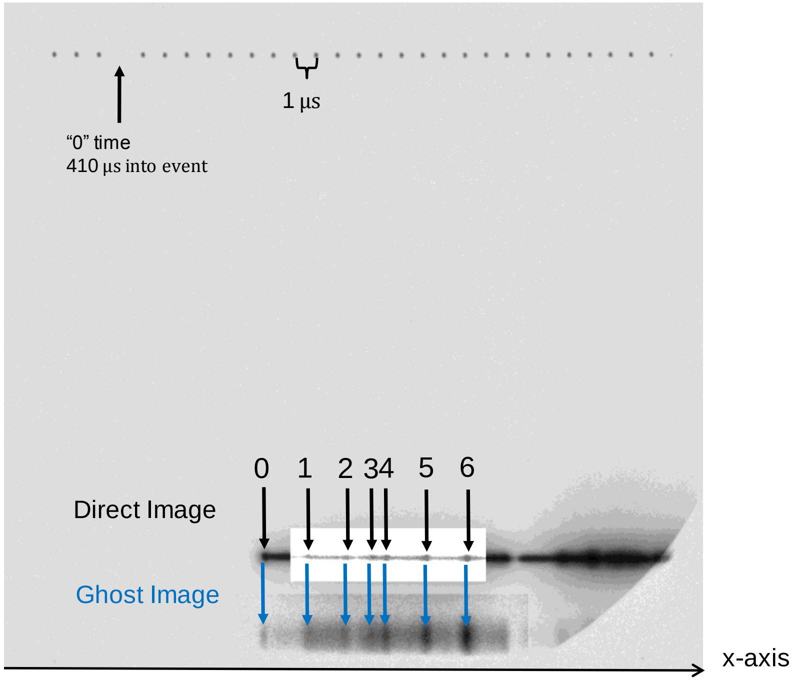
Dataset 1			Dataset 2		
Height (mm)	Distance from Center (mm)	Time of arrival (μs)	Height (mm)	Distance from Center (mm)	Time of arrival (μs)
177.8	20.5	36.4	178.3	20.7	36.9
127.8	21.0	42.2	129.6	20.2	42.5
118.5	40.0	42.3	119.2	40.0	42.4
79.3	21.5	46.7	80.5	20.2	47.2
74.9	31.0	46.9	75.8	29.8	47.1
69.4	41.0	46.9	70.2	39.5	47.0
30.8	21.0	51.2	30.7	20.4	51.9
25.6	31.5	51.5	25.6	31.0	51.7
20.1	41.5	51.4	20.7	39.8	51.7

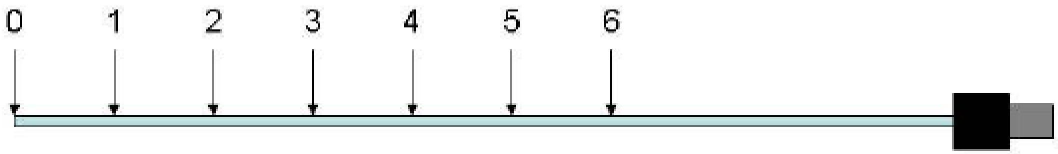
Position 1
Position 2
Position 3

Average detonation velocity (3 experiments and 5 measurement, 10.8 ± 0.1 km/sec

Diagnostics







Holes 1 through 6 are 0.008 inch diameter holes drilled to depth halfway into core
Hole Spacing: 0.787 inches between consecutive locations on center
Hole 0 begining of the probe: flat polish matte finish, blackend with a sharpie

RESULTS OF IMX EXPERIMENTS

Shot Number	Center Fiber Detonation Velocity (km/s)	1.905 cm Fiber Detonation Velocity (km/s)	3.810 cm Fiber Detonation Velocity (km/s)	Average Detonation Velocity (km/s)
1	10.3	10.0	10.1	10.1
2	10.3	10.1	10.6	10.3
AUTODYN	10.9	10.2	10.1	10.3

EXPERIMENT WITH 6.5 in CHARGE

Detonation Velocity Increase from 6.2 to 10.2 km/sec

Detonation Front Angle 52 Degrees

Shot Number	Center Fiber Detonation Velocity (km/s)	1.905 cm Fiber Detonation Velocity (km/s)	3.810 cm Fiber Detonation Velocity (km/s)	Average Detonation Velocity (km/s)
1	10.7	9.5	9.7	10.0
2	10.5	*No data*	10.0	10.2
AUTODYN	10.9	10.1	10.2	10.4

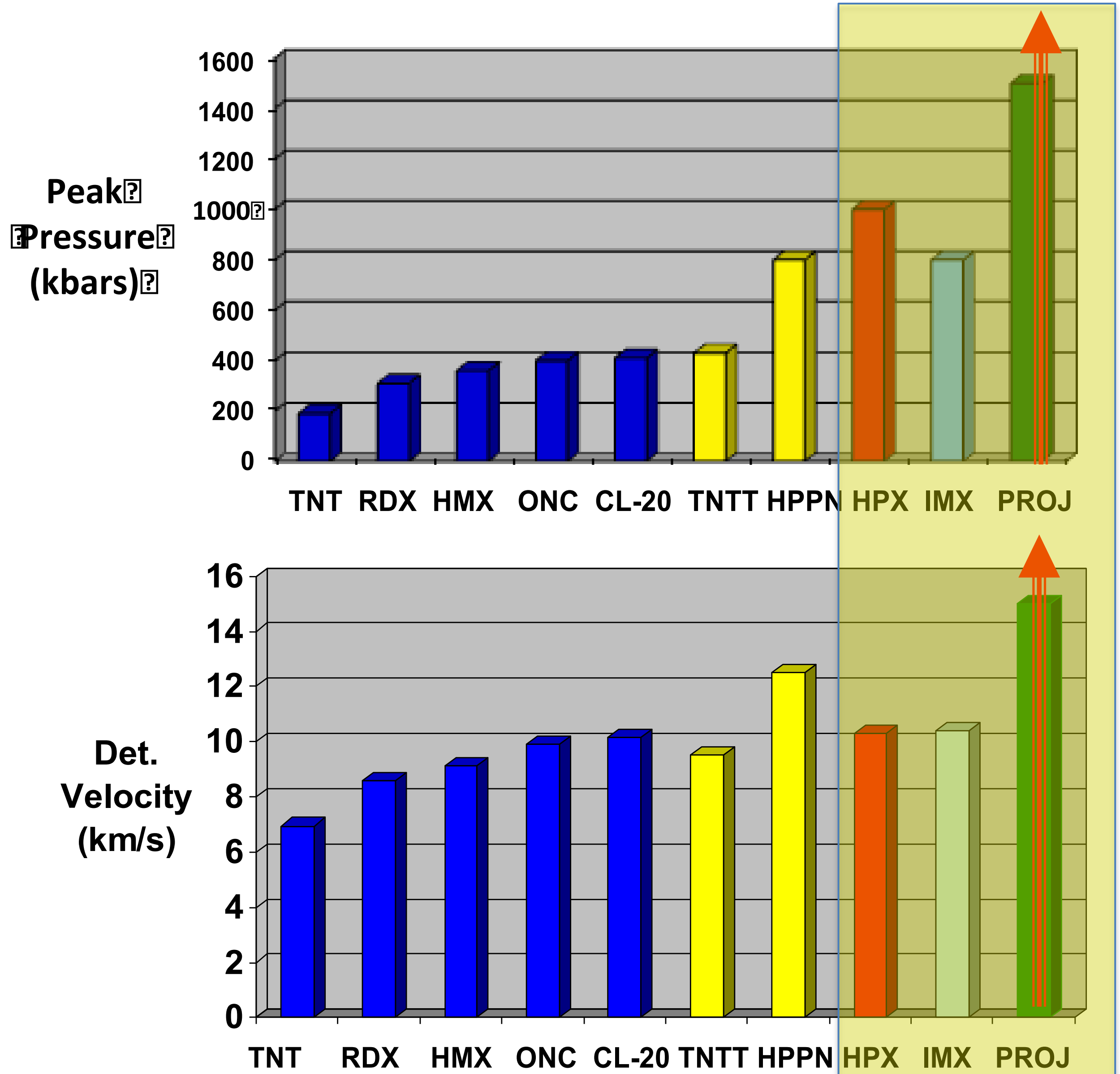
EXPERIMENT WITH 7.0 in CHARGE

Detonation Velocity Increase from 6.2 to 10. km2/sec

Detonation Front Angle 56 Degrees

Pressure gauges saturated

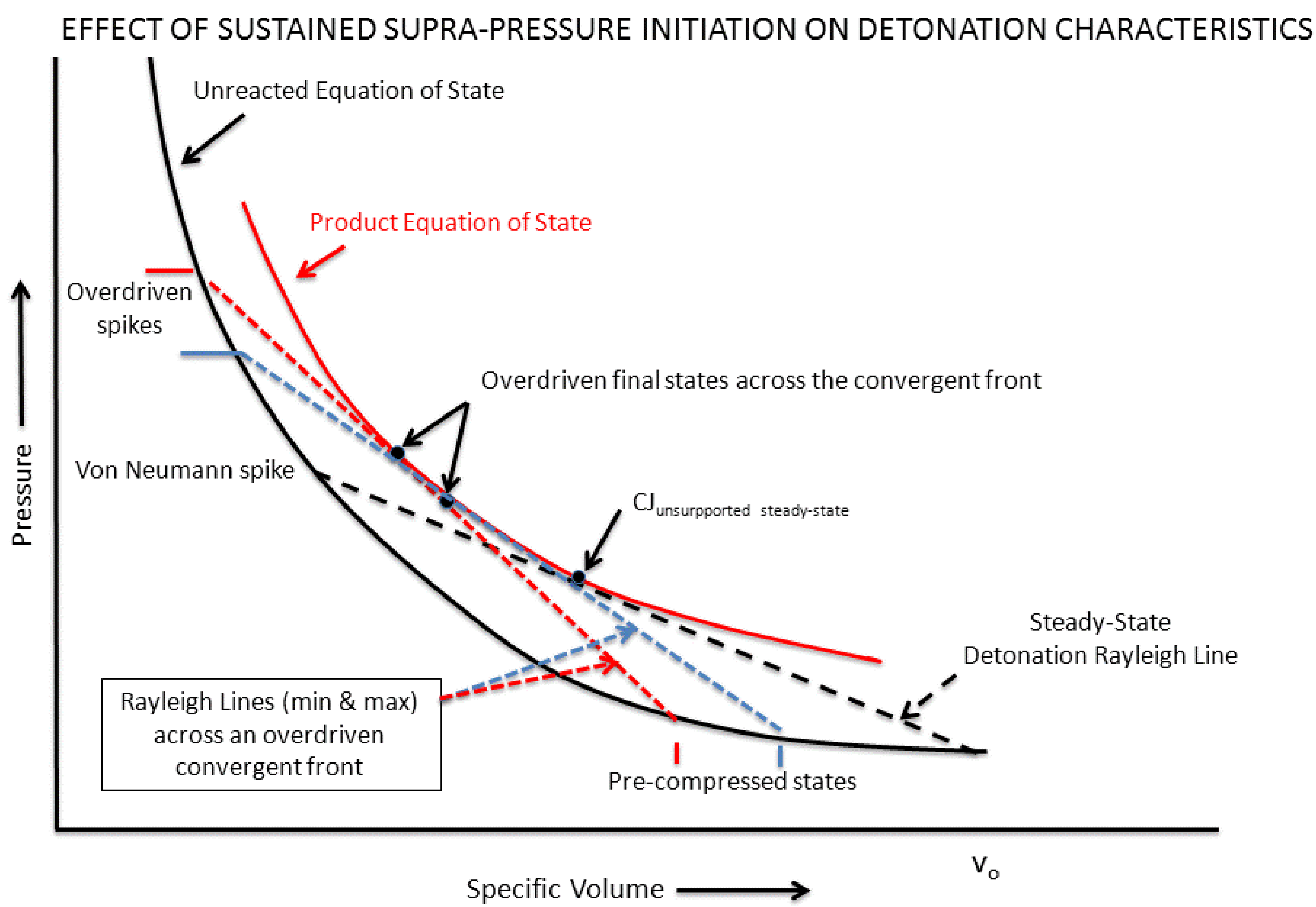
Overview of Achievements Relative to Explosives Chronology



Also PBXN-111
U_D, 5.5 to 8.9
P_{peak}, 12 to 66 GPa

2013 Insensitive Munitions and Energetic Materials Technology Symposium
Paper 16169

New Model for Sustained Overdriven Detonation

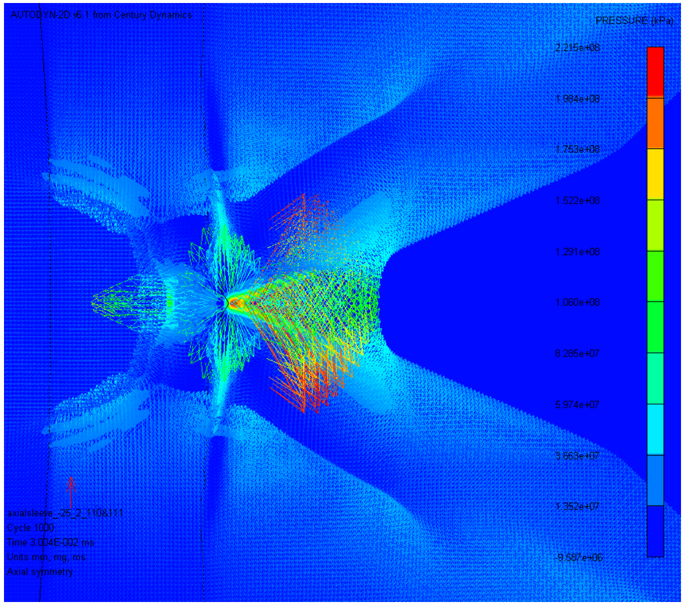


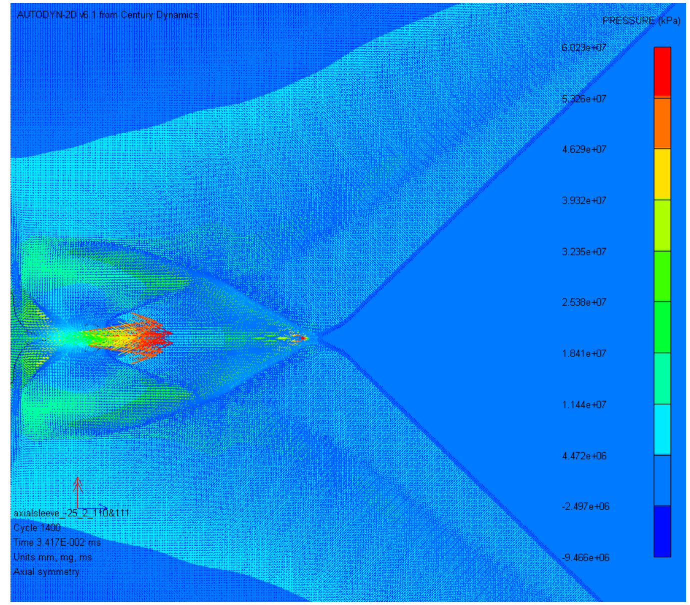
CONCLUSIONS

- Substantial increases in velocity and peak pressure in the detonation of existing explosives by dynamic compression effects from circumferential initiation.
  - Aluminized explosives (PBXN-111)
  - High performance HMX-based explosive ("HPX")
  - Extremely insensitive explosive ("IMX")
- Gains exceed those of on-going and projected chemistry (conventional initiation) and further gains are possible.
- Technology can easily be incorporated into weapon systems.
- Prediction techniques validated across a wide range of applicable conditions.

Immediate Recommendations

- Supra-pressure shock response characterizations of candidate explosives over much greater ranges in order to reach 3+ megabar.
- Techniques for detecting pressures in the megabar range required for continued prediction confidence and to explore effects of the pressure continuum across convergent fronts.
- Additional exploration and extension of detonation theory.
- Exploratory development for enhancing directed energy warheads.





Pressure and vector contours about a convergent mach stem

QUESTIONS