RDECOM

PAX-11
A High Performance Booster For IM Applications

Prepared by:

Melissa Mileham, Robert Hatch, and Paul Braithwaite

ATK Aerospace Systems, Brigham City, UT, USA

Kenneth E. Lee

U.S. Army Armament Research, Development, and Engineering Center, Picatinny, NJ, USA

Prepared for:

2010 Insensitive Munitions/Energetic Material Technical Symposium

October 11-14, 2010 – Munich, Germany

ATK

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Acknowledgments

- **Appreciation is extended to:**

Dr. Kenneth E. Lee of ARDEC

- Overall technical guidance of this advanced technology initiative
- Financial support

Mr. Leslie Bracken of ATK Aerospace Systems

- Program management and task oversight

Outline

- Background
- Introduction
- Qualification Plan
- Characterization Testing
- Performance Considerations
- Summary and Conclusions

Background

- **New main charge explosives often use ingredients with large critical diameters (AP, NTO, etc.)**
  - Approach results in improved IM behavior
    - Especially effective in sympathetic detonation/impact tests
- **Unfortunately these new explosives are also often more difficult to reliably initiate**
  - Use of new less powerful boosters compounds the problem
  - Initiation problems can be offset by increasing booster size or by using a more powerful booster explosive
- **To address the challenge associated with initiation of new insensitive main charge fills, ARDEC and ATK Aerospace Systems are qualifying a new high-performance booster explosive, PAX-11**

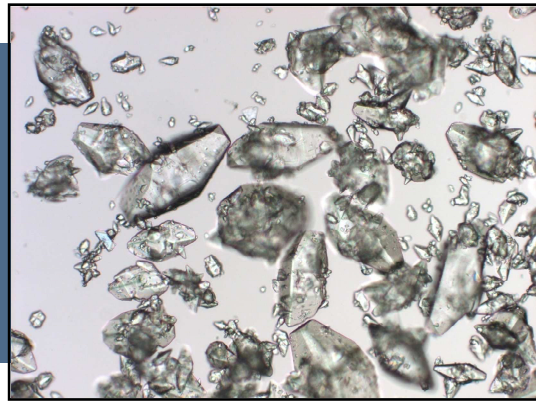
Introduction

- **A small number of energetic solids have been used in a wide range of explosives for many decades**
  - Melt pour, cast cure, and pressed compositions
  - Historically RDX, HMX, and TATB have been primary materials
  - CL-20 has been evaluated more recently due to its higher performance

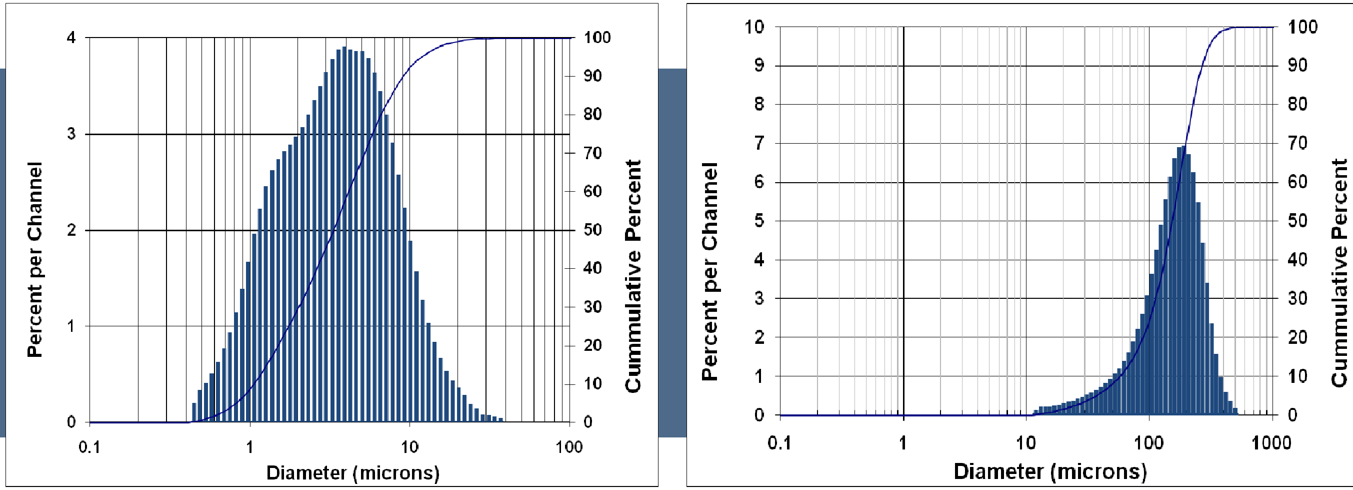
	CL-20	RDX	TATB	HMX
Chemical Formula	$C_6H_6N_{12}O_{12}$	$C_3H_6N_6O_6$	$C_6H_6N_6O_6$	$C4H_8N_8O_8$
Density (g/cc)	2.04	1.82	1.94	1.91
Heat of Formation (kJ/mol)	377	70	-140	75
Calculated P_{cj} (GPa)	48.0	35.2	31.1	39.4
Calculated V_d (km/s)	10.05	8.98	8.11	9.30

Introduction (cont)

- **CL-20 is synthesized and crystallized at ATK Aerospace Systems**
  - Crystal shape has been improved steadily over the past decade
  - Material is readily ground to uniform distributions



CL-20 Crystals at 100X



Typical Ground and Unground Particle Size Distributions

Qualification Plan

- **A 36-kg batch of PAX-11 was produced for qualification**
  - Primary focus of the current effort is to qualify PAX-11 for use as a booster explosive
- **Tests examine a broad range of properties**
  - General categories are summarized in the table to the right
  - Influence of temperature, time, and humidity are evaluated
  - Some tests are performed over a one-year period to evaluate aging
  - Tests are conducted per AOP-7 or appropriate MIL-SPEC or STANAG

Qualification Test Category
Stability
Thermal Characterization
Compatibility with Common Materials
Ignition Temperature
Explosive Response
Electrostatic Sensitivity
Impact Sensitivity
Friction Sensitivity
Shock Sensitivity
Other Sensitivity
Chemical, Physical, and Mechanical Properties
Performance Properties
Products of Combustion/Detonation
General Characterization

Thermal Testing

- **VTS, DSC compatibility, and DSC after elevated temperature aging are all good**
  - Additional DSC data will be gathered for material aged for 12 months at 50 ℃

VTS Results	
Material	**5-gram Samples (mL/g)**
PAX-11	0.018
RDX (Class 5)	0.036
LX-14	0.023

Compatibility of PAX-11 With Common Materials	
Material	**DSC Onset Temp. (℃)**
PAX-11	233
PAX-11/Aluminum	233
PAX-11/4340 Steel	229
PAX-11/Red Oxide Primer	230
PAX-11/Anodized Aluminum	217

DSC Results After Elevated Temperature Storage Through Six Months

Material	DSC Onset Temp. At Start (℃)	50 ℃				60 ℃				
		1 mo	3 mo	6 mo	9 mo	1 mo	2 mo	4 mo	6 mo	8 mo
PAX-11	233	234	231	236	237	229	231	221	233	228
LX-14	270	270	270	270	280	270	270	270	270	268
CL 5 RDX	208	208	208	208	231	208	208	208	208	211

Characterization

- **Good results for exudation, growth, and compressive strength**

Exudation				
Sample	**Initial Wt. (g)**	**Final Wt. (g)**	**Weight Loss (g)**	**Weight Loss (%)**
1	123.8086	123.7777	0.0309	0.0250
2	123.7582	123.7270	0.0312	0.0252
3	123.7816	123.7505	0.0311	0.0251

Irreversible Growth			
Sample	**Initial Volume (cc)**	**Final Volume (cc)**	**Volume Change (%)**
1	13.0377	12.9982	-0.3
2	13.0176	12.9982	-0.15
3	13.0504	12.9982	-0.4

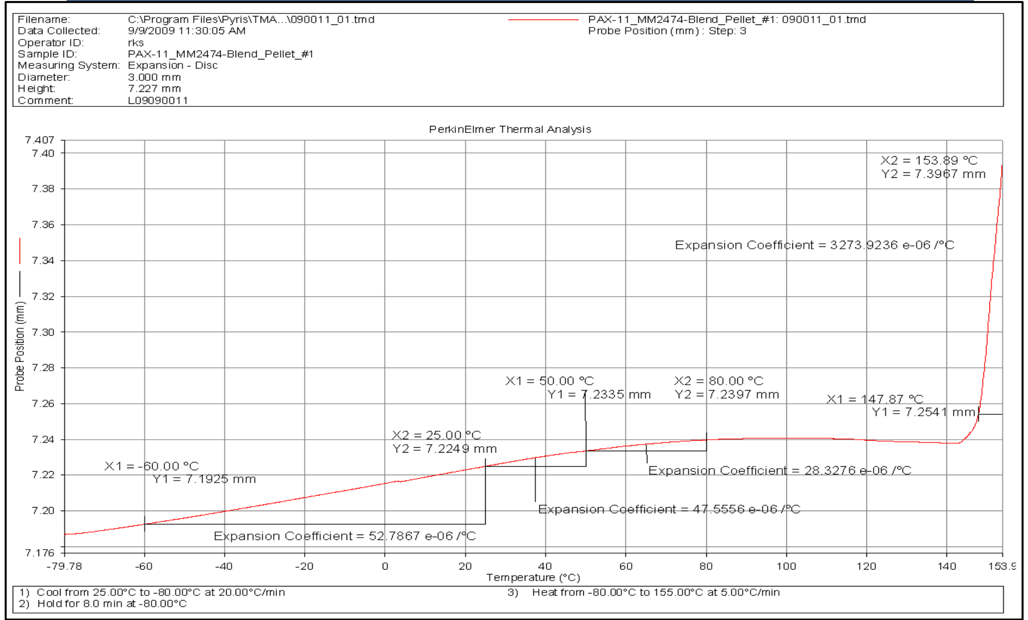
Compressive Strength		
Test Temp. (°C)	**Strain at Max Stress (%)**	**Maximum Stress (ksi)**
-45	2.93	7.12
23	3.00	2.22
65	3.18	1.03

Additional Testing

- **Majority of tests have been completed per the qualification test plan**
  - VCCT cook-off
  - TCLE
  - CL-20 polymorph analysis on aged PAX-11
  - Small-scale ESD
  - Small-scale burn
- **Ongoing tests are being completed per schedule!**

Small-Scale Burn Results

Sample	Weight (g)	Time to Burn (s)	Length of Burn (s)	Event Description
1	100.49	16.74	6.095	Rapid Burn
2	100.11	6.00	5.445	Rapid Burn
3	10.05	20.0	3.385	Rapid Burn
4	10.0	20.0	2.755	Rapid Burn



TCLE Results

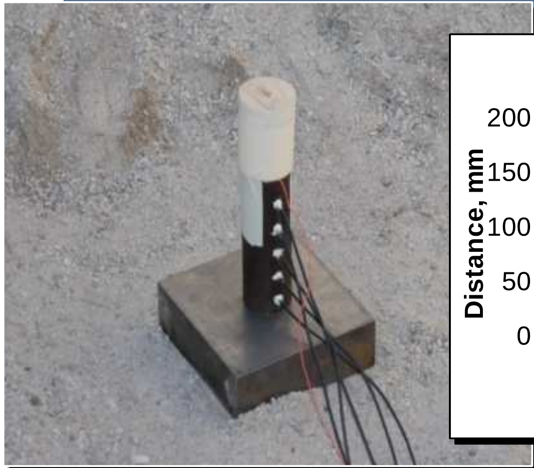
Theoretical Performance

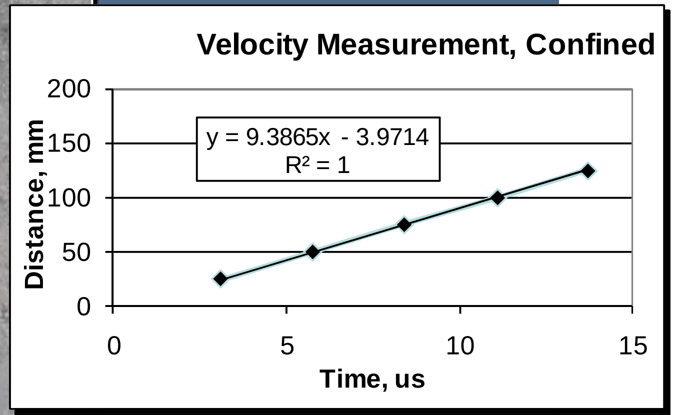
- **Theoretical performance of PAX-11 is significantly higher than legacy booster explosives**
- **Higher performance is predicted for all major indicators:**
  - V_D, P_{CJ}, T_{CJ}, Expansion Energy
- **High performance opens the door for the use of smaller sized boosters to initiate insensitive main charge fills**

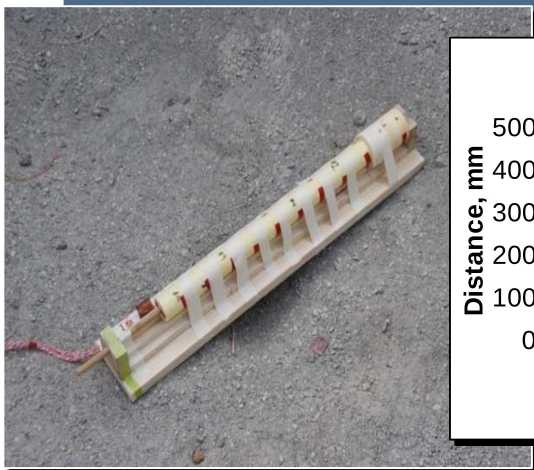
Formulation	PAX-11	PBXN-5	PBXN-7
Nitramine	CL-20	HMX	RDX/TATB
Density (g/cc)	1.94	1.86	1.85
P_{cj} (GPa)	41.66	35.00	28.69
V_d (km/s)	9.47	8.86	8.04
CJ Temperature (°K)	4597	4027	3525
Energy at V/V_o = 6.5 (kJ/cc)	10.16	8.94	7.20

Detonation Velocity

- **Confined and unconfined detonation velocity measurements were performed per MIL-STD-1751A**
  - Results for both tests were well above 9 mm/µsec
  - Testing confirmed high predicted detonation velocities







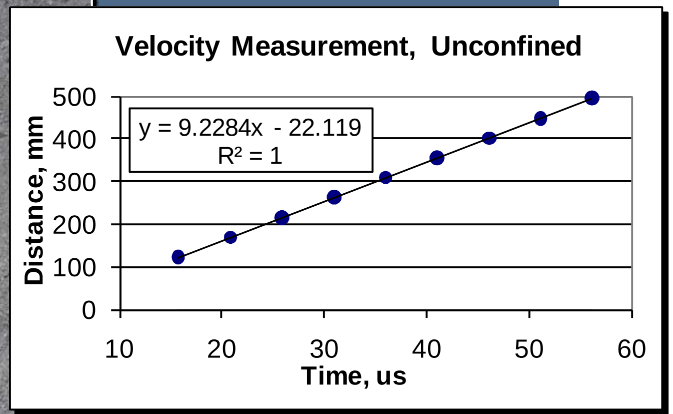
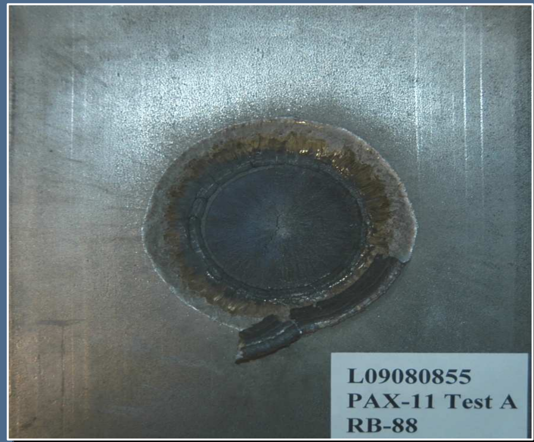
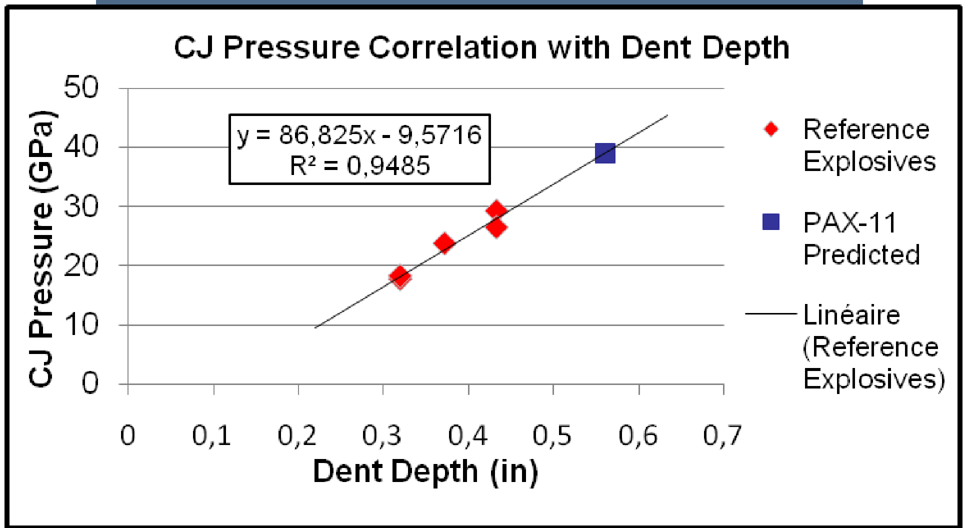


Plate Dent Testing

- **Plate dent test predicts very high P_{CJ}**
  - Test article was an NOL pipe
  - Predicted pressure is above range of calibrated explosives but correlates well with theoretical predictions





TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RDECOM

Critical Diameter Testing

- **Critical diameter testing was conducted using pressed pellets of PAX-11**
  - L/D of 4 to 1 was used
  - Pellets ranged between 0.20 and 0.50 inches in diameter
  - All pellets were unconfined
  - All pellets fully detonated with measured velocities above 9 mm/µsec

Witness Plate From PAX-11 Critical Diameter Test

Critical Diameter Test Results for PAX-11		
Diameter (in)	**Length (in)**	**Average Velocity (km/s)**
0.20	0.812	9.103
0.25	1.005	9.009
0.50	2.061	9.056

RDECOM

Summary

ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER PICATINNY ARSENAL

- **PAX-11 is a high-performance, CL-20-based explosive which was developed to outperform legacy booster explosives such as PBXN-5 and PBXN-7**
  - Higher performance allows minimization of booster charge while maintaining reliable initiation of even the most insensitive main charge explosives
- **Qualification testing is ongoing**
  - PAX-11 has demonstrated good stability after aging in elevated temperatures for all tests completed to date

ATK