U. S. ARMY COMMON LOW-COST INSENSITIVE MUNITION PROGRAM
IMX-101 REPLACEMENT FOR TNT EXPLOSIVE

155mm M795 IM Projectile

Mike Ervin*, Virgil Fung, Brian Alexander, Alberto Carrillo
BAE SYSTEMS Ordnance Systems, Holston Army Ammunition Plant

Anthony Di Stastio*, Philip Samuels, Sanjeev Singh
ARDEC, Picatinny Arsenal, NJ

Charlie Patel
OPM - Combat Ammunition Systems, Picatinny Arsenal, NJ
U. S. Army CLIMEx Program Strategy and Goals

Common Low-cost Insensitive Munitions Explosive (CLIMEx)

Program Strategy

To accelerate candidate explosive fill formulations and compositions that satisfy the selection criteria into test material using representative manufacturing facilities.

Program Goals

1. Selection of one single common explosive fill for all artillery and mortar products.

2. Selection of two explosive fills, one that is common for replacement of TNT and another that is common for the replacement of Composition B.
CLIMEx Program – Selection of IM Explosive

Execution of the CLIMEx Program by PM CAS involved the evaluation of multiple explosive technologies (melt-cast, cast-cure, and cast-cure injection) and numerous IM candidate explosives from the Industrial Base and foreign sources.

“Funnel” framework to progressively screen candidates

Filter 1 Criteria
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

Filter 2 Criteria
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJ)

BCA Criteria
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

IM Explosive Fill for TNT or Comp B Replacement

Munitions Fill Types

Arena Test & Qualification

Execution of the CLIMEx Program by PM CAS involved the evaluation of multiple explosive technologies (melt-cast, cast-cure, and cast-cure injection) and numerous IM candidate explosives from the Industrial Base and foreign sources.
CLIMEx Program – Selection of IM Explosive

• M795 155mm Artillery Munition selected as the initial test vehicle for identifying a common IM replacement for TNT in artillery systems.

• CLIMEx Criteria for candidate IM explosive fills:
  ❖ Must be significantly less sensitive than TNT explosive, if not fully IM compliant.
  ❖ Must maintain lethality, as compared to the TNT baseline, with minimal or no degradation.
  ❖ Overall IM solution needs be affordable.
  ❖ Must be producible within the National Technology & Industrial Base to include ingredients, formulation, and LAP. Ideally a “drop-in” replacement for TNT in LAP activities.
CLIMEx Program – Selection of IMX-101 Explosive

**IMX-101 Explosive**

- Selected as IM replacement to TNT in U. S. Artillery systems
- Developed and produced by BAE Systems at Holston AAP
- Utilizes standard LAP infrastructure for melt-cast explosives
- LAP of M795 Rounds performed at Picatinny Arsenal & Iowa Army Ammunition Plant
- Subjected to comprehensive IM and performance test criteria to include BI, FI, SCO, FCO, SD, SCJI (50mm & 81mm), etc

Energetics Material Qualification Completed for IMX-101

Molten IMX-101  Flaked Final Product
Making the IM Mission Possible

- Achieving the IM Mission Required New Technologies
- Energetic and Critical Materials for IM / EM Applications
  - DNAN
  - NTO
  - TATB
  - High Bulk Density NQ
  - FEM RDX and HMX
  - DMDNB
  - “Special Grade” RDX
  - R8002 Energetic Plasticizer
- All Materials Produced on a True Production Scale at HSAAP
# IM Melt Cast Explosives from Holston AAP

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMX-101</td>
<td>DNAN &amp; NTO based formulation. Selected by the Army as the common TNT replacement. Applications include 105mm, 120mm, &amp; 155 mm munitions.</td>
</tr>
<tr>
<td>IMX-104 (aka OSX-7)</td>
<td>Contains DNAN, NTO, and RDX in various grades. Selected by the Army as the common Comp B replacement in IM Mortar systems (60mm, 81mm, &amp; 120mm) and various submunitions.</td>
</tr>
<tr>
<td>OSX-8</td>
<td>Contains DNAN, NTO, and HMX in various grades and provides excellent IM and energetic performance properties. Being evaluated in 60mm Mortar (Europe) and 120mm HET Tank Ammo (FMS).</td>
</tr>
<tr>
<td>OSX-12</td>
<td>An aluminized version of IMX-104 which offers excellent IM properties combined with high blast energetic output.</td>
</tr>
<tr>
<td>PAX-21</td>
<td>DNAN based melt-cast explosive which is currently qualified and fielded in the U. S. Army 60mm Mortar system.</td>
</tr>
<tr>
<td>PAX-41</td>
<td>DNAN based melt-cast explosive which is currently qualified and fielded in the U. S. Army Spider Munitions system.</td>
</tr>
</tbody>
</table>
M795: System Enhancements for IM

Venting Technology for Cook-off Environments

- IM explosive alone cannot meet cook-off criteria in 155mm Artillery
- Total system analysis and design will provide complete IM Solutions

Evaluated and Incorporated Venting Solutions

- Standard Lifting Plug Will Not Pass (Type III)
- Partial Venting (Type IV)
- Meltable Fuze Plug (Type V)
IM Test Results: Fast Cook-Off (FCO)

Test Conditions: Mil-Std-2105C, Liquid Fuel Fire, Witness Plate & Pressure Gauge

IMX-101 Passed with Type V Response
IM Test Results: Slow Cook-Off (SCO)

Test Conditions: Mil-Std-2105C, Precondition Temp at 145F, Heating Rate of 50F / Hr, Witness Plate & Pressure Gage

SCO Test Set-up

IMX-101 Passed with Type V Response
IM Test Results: Fragment Impact (FI)

Test Conditions: Mil-Std-2105C, Impact Velocity of 6,000 ft/sec, Army Fragment, Witness Plate & Pressure Gage

IMX-101 Passed with Type V Response

FI Test Set-up
IM Test Results: Bullet Impact (BI)

Test Conditions: Mil-Std-2105C, .50 Caliber AP Bullet, Witness Plate & Pressure Gage

BI Test Set-up

IMX-101 Passed with Type V Response
IM Test Results: Sympathetic Detonation (SD)

Mil-Std-2105C, Diagonal Configuration, Witness Plate & Pressure Gages

SD Test Set-up

IMX-101
Passed with
Type III Response

Donor side witness plate

III

Acceptor side witness plate
**IM Test Results: Shaped Charge Jet Impact (81mm)**

**Mil-Std-2105C, Unconditioned Jet, Witness Plate & Pressure Gages**

![Test Set-up with 81mm SCJ](image)

*Example*

- **IMX-101 Passed**
- **NO Detonation**
- **High-order Detonation**
## Summary of IM Test Results

M795 Filled with IMX-101 Demonstrated Full IM Compliance!!

**Passed SD**  
**Passed SCJI**

<table>
<thead>
<tr>
<th>IM Test:</th>
<th>FCO</th>
<th>SCO</th>
<th>BI</th>
<th>FI</th>
<th>SD</th>
<th>SCJI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing Criteria</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>III</td>
<td>III</td>
</tr>
<tr>
<td>M795 Baseline (TNT)</td>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
<td>FAIL</td>
</tr>
<tr>
<td>IMX-101</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
</tbody>
</table>

**VI** No Sustained Reaction  
**V** Burn  
**IV** Deflagration  
**III** Explosion  
**II** Partial Detonation  
**I** Detonation
Maturity of M795 IM Design

Safety Confirmation from Development Test Command

• Produced 132K lbs of IMX-101
• Loaded over 1,000 M795 projectiles
• Transition to production for FY10 Army procurement

<table>
<thead>
<tr>
<th>Test</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial firing tests</td>
<td>√</td>
</tr>
<tr>
<td>12m Drop</td>
<td>√</td>
</tr>
<tr>
<td>Initial Safety Test</td>
<td>√</td>
</tr>
<tr>
<td>Sequential Environmental Safety &amp; Performance</td>
<td>√</td>
</tr>
<tr>
<td>Shock Attenuating Lifting Plug</td>
<td>√</td>
</tr>
<tr>
<td>Worn Tube</td>
<td>√</td>
</tr>
<tr>
<td>Explosive Ordnance Disposal (EOD)</td>
<td>√</td>
</tr>
<tr>
<td>High Humidity &amp; Temperature (16) / Fungus (8)</td>
<td>√</td>
</tr>
<tr>
<td>Solar Radiation</td>
<td>√</td>
</tr>
<tr>
<td>Long Term Storage - Uncontrolled</td>
<td>√</td>
</tr>
<tr>
<td>Final Reduced Qty Firing Table Confirmation</td>
<td>√</td>
</tr>
<tr>
<td>Arena Testing (Fragmentation)</td>
<td>√</td>
</tr>
<tr>
<td>Initiation Reliability</td>
<td>√</td>
</tr>
<tr>
<td>IM Testing (BI/FI/SCO/FCO/SD/SCJI)</td>
<td>√</td>
</tr>
</tbody>
</table>
Conclusions

• U. S. Army CLIMEx program was successful in identifying IMX-101 Explosive as a common insensitive replacement for TNT.
  • IMX-101 qualified by US Army as main charge explosive

• IM M795 155mm Munitions demonstrated far superior IM properties in all test categories with no barriers (BI, FI, SCO, FCO, SD, SCJI).
  • Formal IM tests completed – scores expect to be presented at IM&EM in October 2010

• Initial explosiveness & fragmentation performance of the IM M795 with IMX-101 indicates equivalency to the legacy TNT filled M795.
  • Arena tests completed – Analysis in process

• LAP of M795 Rounds using standard processing equipment was successfully developed and demonstrated with excellent cast quality.
  • Safety Confirmation for projectile from DTC
Conclusions (cont.)

• IMX-101 explosive is effectively a “drop-in” replacement for TNT in melt-cast LAP operations.

• BAE Systems at Holston AAP has robust manufacturing processes and essentially unlimited capacity for both the IM ingredients (i.e. DNAN, NTO, etc) and melt-cast formulations.

• The marvelous achievement of the CLIMEx program is a strong testimony of the dedication and teamwork of PM-CAS and its industry partners.
On-going Activities

• Finalizing Technical Data Package for the IM M795 Munitions (FY-2010)

• Production and fielding of the IM M795 Munitions (FY-2011)

• Evaluation of IMX-101 Explosive in 105mm HE Ammunition

• Qualification of IMX-104 Explosives as a common replacement for Comp B in various mortar and artillery systems.
Questions
Highlights of Other Testing - IM M795 Munitions

- Successful loading trials at Picatinny Arsenal (>150 projectile in recent LAP with “Zero” defects in cast quality).
- Completed firing trials at top service charge under extreme service conditions.
- Firing Table confirmation tests completed which validated a ballistic match to the legacy, TNT filled M795 Munitions.
- Completed Safety Test Series [ITOP 4-2-504(1)] to include drop tests in various orientations, tactical vibration sequence, and temperature extremes followed by confirmation of cast quality.
- Firing of the “abused” M795 Munitions evaluated in the Safety Test series under extreme service conditions.