Baselining of the 40mm Family of Ammunition

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Overview

- Reason for Baselining
- Spark Range Testing
- Firing Tables Testing
- EPVAT with Soft Recovery
- Warheads Testing
- System Effectiveness Modeling & Simulation
- Benefits & Warfighter Payoff
Reason for Baselining

- 40mm Family of Ammunition
  - Low Velocity – M203 GL & XM320 GL
  - High Velocity – Mk19 GMG

- Why Baseline?
  - Establish robust ballistic & warhead performance database
    - Improve support to the User
    - Identify strengths and weaknesses of system
  - Improve engineering capability
    - Production Support
    - Ammo-Weapon Interface Issues
    - Producibility Enhancements & Technology Upgrades

- Objective – Provide the Warfighter Superior Capability
  - Enhance design, performance, reliability, quality & availability
Spark Range Testing

- Spark Shadowgraph Range
  - Orthogonal cameras placed at fixed intervals along trajectory
  - Photographs positional and angular orientation of the projectile
  - A “spark” provides back lighting & shadow

- 6-DOF motion models used to reduce data.
  - Provides aero coefficients, stability parameters and other characteristics
  - Parameters needed for projectile design, diagnostic studies and corrected aeroballistic models

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Spark Range Testing

- Previous 40mm spark range testing performed on high velocity cartridges
  - “BRL-MR-3788 Aero Characteristics of 40mm Ammo for the Mk19 GMG”, Robert McCoy & Andre Sowa, November 1989
  - M384 & M385 no longer in service
  - M430 now M430A1 and M385E4 now M385A1
Spark Range Testing

- Perform Spark Range Testing at ARL and Eglin AFB on both Low & High Velocity projectiles
  - M433 HEDP (M203 GL) - Complete
  - M781 TP (M203 GL) - Complete
  - M430A1 HEDP (Mk19 GMG) – Firing Now
  - M918 TP (Mk19 GMG) – To Be Fired
  - M385A1 TP (Mk19 GMG) - Complete

- Low Velocity testing with both 12” & 9” M203 GL barrels
Spark Range Testing

- M385A1 TP (High Velocity)
  - Large gyroscopic stability factor (>4 vs. >1.8)
  - Weak pitch damping coefficient
Spark Range Testing

- M781 TP (Low Velocity)
  - Large gyroscopic stability factor (>6 vs. >1.8)
  - Weak pitch damping coefficient
  - Small Transverse Moment of Inertia
Spark Range Testing

- M433 HEDP (Low Velocity)
  - Weak pitch damping coefficient
  - Very high pitch/yaw angle at muzzle exit resulting in high drag (up to 14 degrees!)
  - Adhesive on boattail affects flight in random manner
Spark Range Testing
Spark Range Testing
Spark Range Testing

- Testing yielded validated PRODAS models for flight simulation

- Projectiles will not damp out initial pitch/yaw
  - Must minimize influences on projectile
  - Mitigate or eliminate adhesive on M433 HEDP boattail
  - Flexure of M203 GL and host weapon impact projectile exit (jump)
Firing Tables Testing

- Testing performed by ARDEC Firing Tables Team at Aberdeen Test Center
- Firing M433 HEDP & M781 TP cartridges from M203 GL (both 12” & 9” barrels) & XM320 GL.
- Testing performed:
  - Physical Characteristics of Ammunition - Completed
  - Muzzle Velocity vs. Propellant Temp Test - Completed
  - Ballistic Match & Firing Tables Test - Completed
  - Maximum Range Aeroballistic Test - Completed
  - Maximum Trail Quadrant Elevation Test - Completed
Firing Tables Testing

- Ballistic Match, Firing Tables & Max Range Tests
  - Firing Tables & Unit Effects Tables available for both M433 HEDP & M781 TP in the 12” & 9” M203 GL and XM320 GL
  - M781 TP considered ballistically matched to the M433 HEDP out to 300 meters
Firing Tables Testing

- Shorter barrel lengths do reduce muzzle velocity, but temperature change have minor effect
- Currently planning for High Velocity Firing Tables Test with M430A1 HEDP & M918 TP
  - Ballistic Match & Firing Tables
  - Maximum Range
  - Sight Accuracy
EPVAT with Soft Recovery

- EPVAT - Electronic Pressure, Velocity & Action Time is scarce for 40mm Grenade Ammo
  - High Velocity P-t data from Mk19 during development
  - HV action time taken from M129 GMG during LAT
  - No Low Velocity data on record
  - No established method for EPVAT testing during production or development

- Fired Low Velocity EPVAT from Mann barrel & soft recovered projectiles
  - Mann barrel designed by ARDEC & fabricated by Colt
  - Test ammo fabricated from production hardware
EPVAT with Soft Recovery

ARDEC 40mm Low Velocity Mann Barrel Assembly
EPVAT with Soft Recovery

Low Velocity Pressure Port & Cartridge Case Diagram

M433/M118
M583A1/M195
M781/M212

M118 & M212 Case Mouth Port
M118 & M212 Mid-Case Port
M195 Case Mouth Port
M195 Low Mid-Case Port
(not shown – other side of breech)
EPVAT with Soft Recovery

M433 Case Mouth & Mid-Case Ports at 70°F
Pressure VS Time

-500 0 500 1000 1500 2000 2500 3000 3500

0 500 1000 1500 2000 2500 3000 3500 4000

Pressure (psi)

Time (us)

Test 2 CM
Test 3 CM
Test 4 CM
Test 5 CM
Test 2 MC
Test 3 MC
Test 4 MC
Test 5 MC

Mid-Case Data
Case Mouth Data
EPVAT with Soft Recovery

- Used high speed digital video to capture action time & muzzle velocity
- Action time is from plunger stop to complete projectile exit

Mann Barrel Firing of 40mm M433 HEDP Projectile
EPVAT with Soft Recovery

- Poor engraving on all cartridges
- Residual adhesive on M433 HEDP & M781 TP

M433 HEDP

No Evidence of Contact with Rifling Groove

Residual Adhesive

Cold (-65°F)  Hot (+165°F)  Ambient (+70°F)
EPVAT with Soft Recovery

- Recorded Case Mouth & Mid-Case P-t data at hot, cold & ambient temperatures for all cartridges
  - M433 HEDP, M583A1 Whitestar Parachute & M781 TP
  - Measured Case Mouth & Mid-Case simultaneously on M433 HEDP at Hot, Cold & Ambient with no noticeable difference versus single port measurement
- Residual adhesive on boat tail is irregular shaped
  - Bad for Flight
- Poor rotating band engraving yields blow-by
  - Bad Efficiency + Muzzle Exit Influence
EPVAT with Soft Recovery

- High Velocity EPVAT planned for July/Aug 2007
- Currently fabricating High Velocity Mann Barrels & redesigned Breech Assembly
  - Breech to be used on both HV & LV Mann Barrels
  - Plan to fabricate Low Velocity Mann Barrels that accept redesigned breech
EPVAT with Soft Recovery

40mm High Velocity Mann Barrel & Redesign Breech Assembly

Pressure Port

Action Time Start Sensor

Hammer Release Solenoid

Firing Pin Safety

Mk19 Muzzle Brake
Warhead Testing

- Testing performed by ARDEC Warhead Branch
- Characterize fragmentation & shaped charge penetration performance
  - M433 HEDP – Completed
  - M430A1 HEDP – Completed
- Typical LAT’s test for penetration, but do not test for fragmentation performance
- Results run through CASRED for Probability of Incapacitation
  - Compared to historical data on file
Warhead Testing

- Penetration Performance Characterization

No-Spin Fixture

Penetrated RHA

X-Ray of Jet Formation

Spin Fixture

Orthogonal X-Ray Film Packs

Fiber Optic Spin Rate Pickup
Warhead Testing

- Fragmentation Performance Characterization

Detonation Chamber

Projectile in Balloon in Saw Dust

Separation Apparatus

Vacuum

Ferrous

Non-Ferrous

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Warhead Testing

- Fragmentation Performance Characterization

X-Ray of Fragmentation

M433 HEDP

Fragment Recovery

M430A1 HEDP
Warhead Testing

- Testing showed no change in lethality from historical data
- Improvement in penetration is easily achievable
- Exhibited good fragmentation break-up
- Fragmentation effects can be improved
- Modeled & simulated shaped charge & fragmentation performance
  - Validated by testing
System Effectiveness M&S

- Model the collection of system parameters & errors in order to run them through a Monte Carlo type simulation
  - Output is Probability of Hit & Probability of Incapacitation given a Hit
  - Study applied to M433 HEDP & M430A1 HEDP
- Intent is to determine improvements with highest return on investment
Benefits & Warfighter Payoff

- **Benefits**
  - Robust ballistic & warhead performance database
  - Manage risk by proactively resolving problems
  - Solid basis for determining improvements with highest return on investment

- **Warfighter Payoff**
  - Ensuring a superior product that is reliable & safe
  - Improved ballistic & lethal performance