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

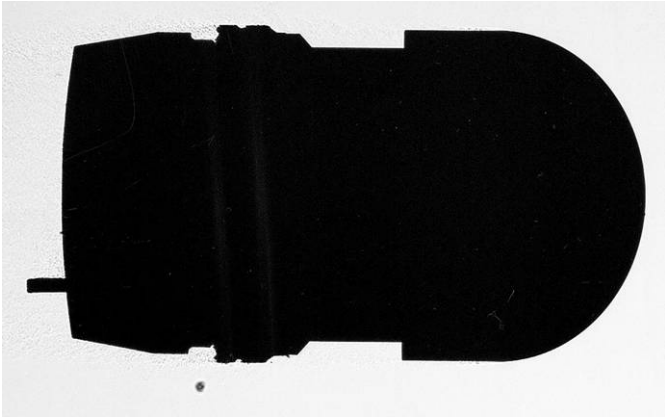
Reason for Baselining

- 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

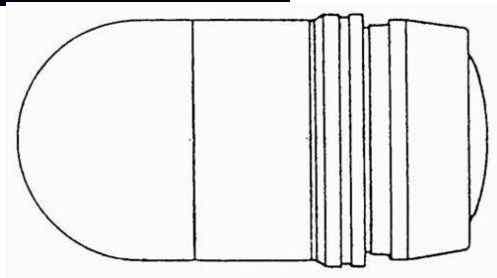
ARL Spark Shadowgraph Range



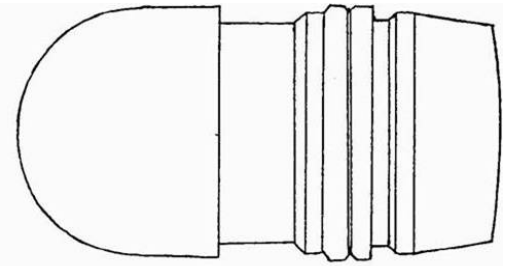
M385A1 TP Spark Shadowgraph

Spark Range Testing

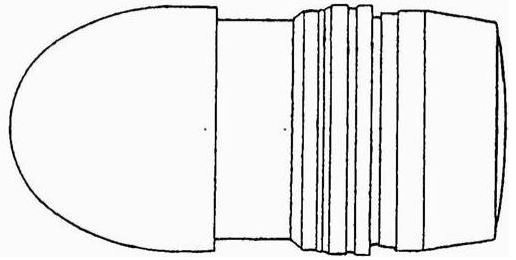
- Previous 40mm spark range testing performed on high velocity cartridges
  - "BRL-MR-3788 Aero Characteristics of 40mm Ammo for the Mk19 GMG", Robert McCoy & Andre Sowa, November 1989
  - M384 & M385 no longer in service
  - M430 now M430A1 and M385E4 now M385A1



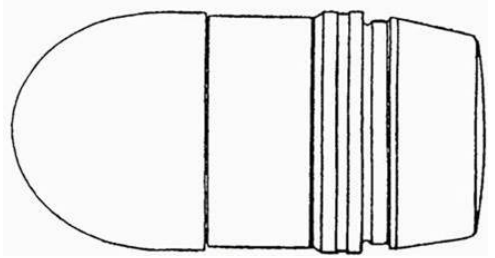
M430 HEDP



M385E4 TP



M385 TP



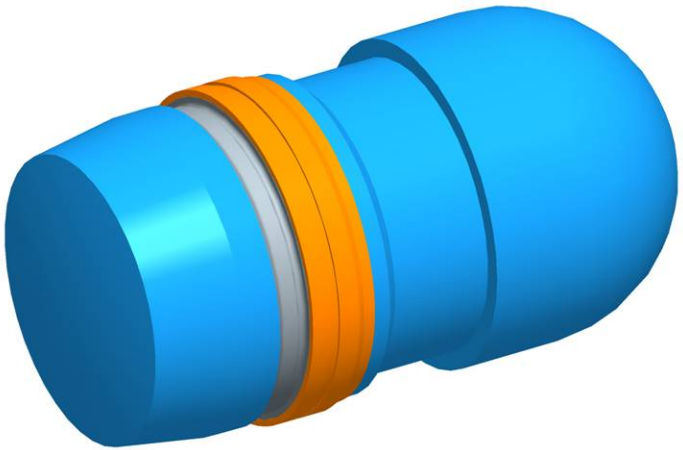
M384 HE

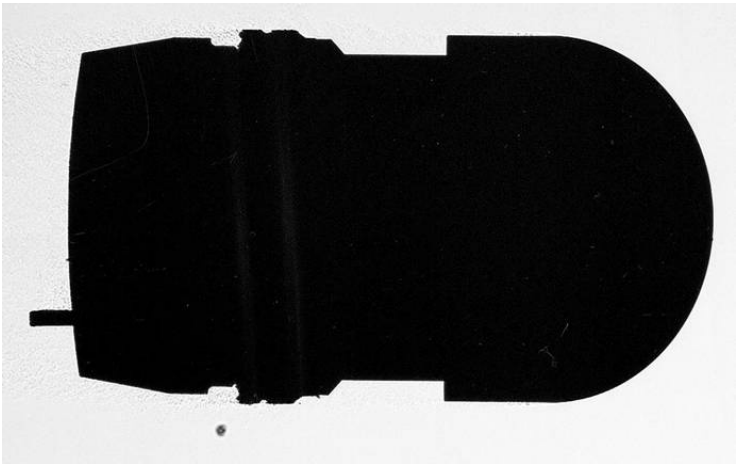
Spark Range Testing

- 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

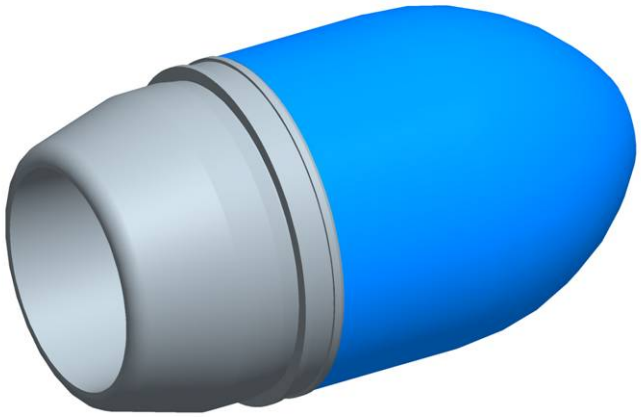
- M385A1 TP (High Velocity)
  - Large gyroscopic stability factor (>4 vs. >1.8)
  - Weak pitch damping coefficient





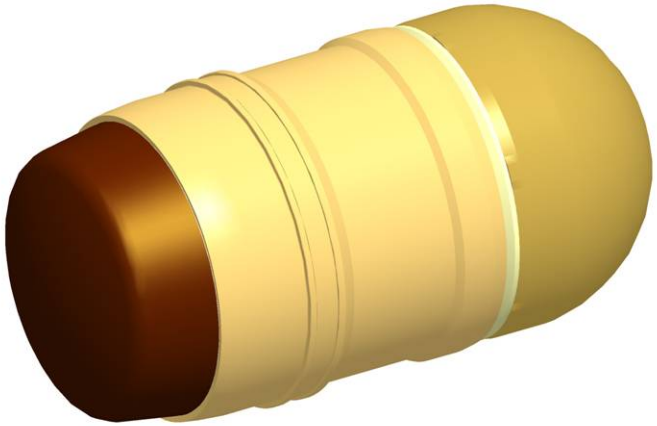
Spark Range Testing

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



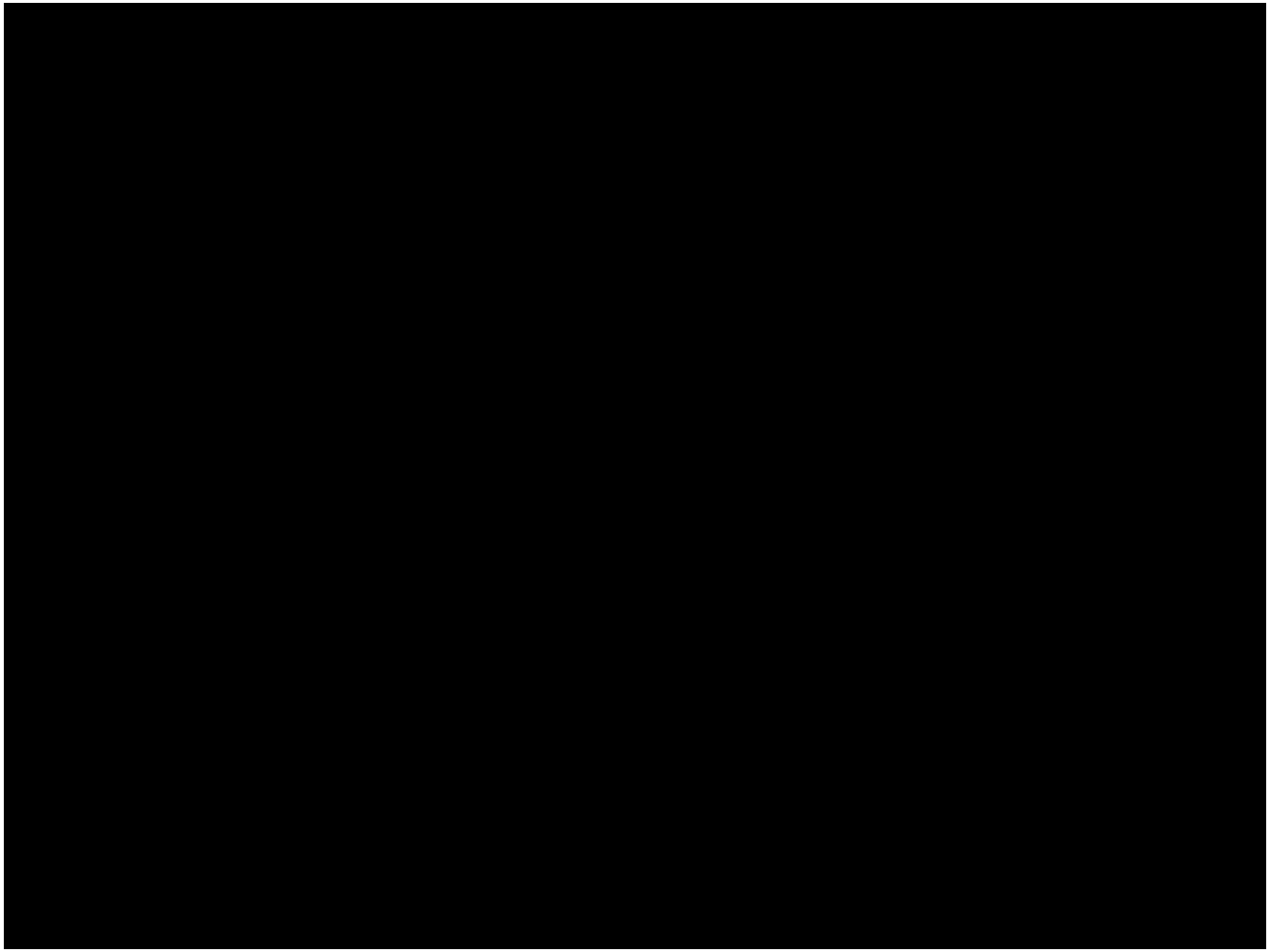
Spark Range Testing

- 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**

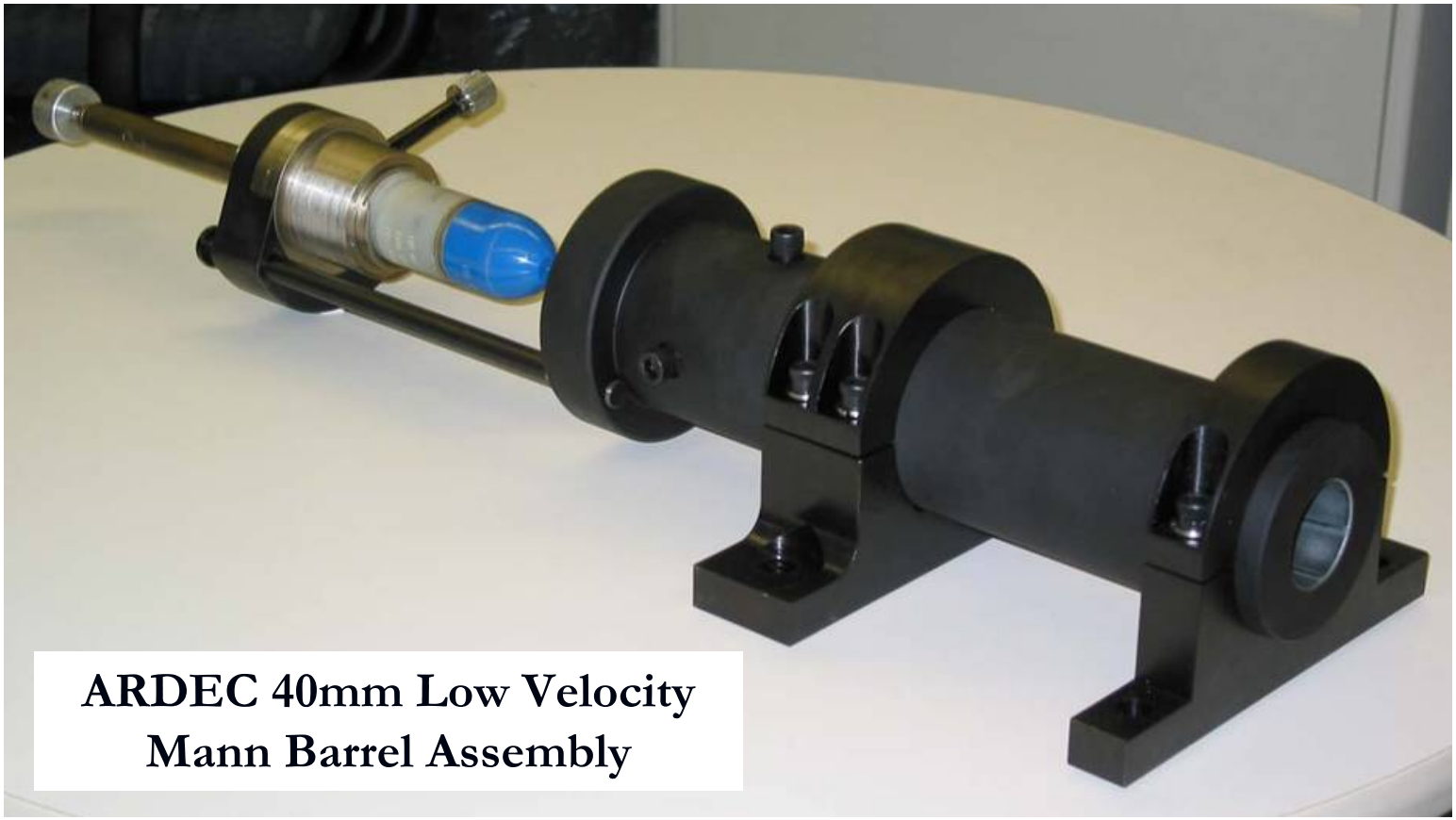
Firing Tables Testing

- 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

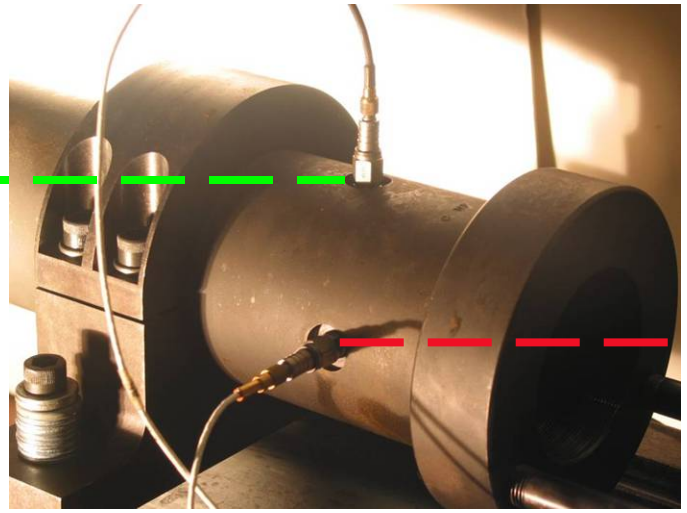
EPVAT with Soft Recovery

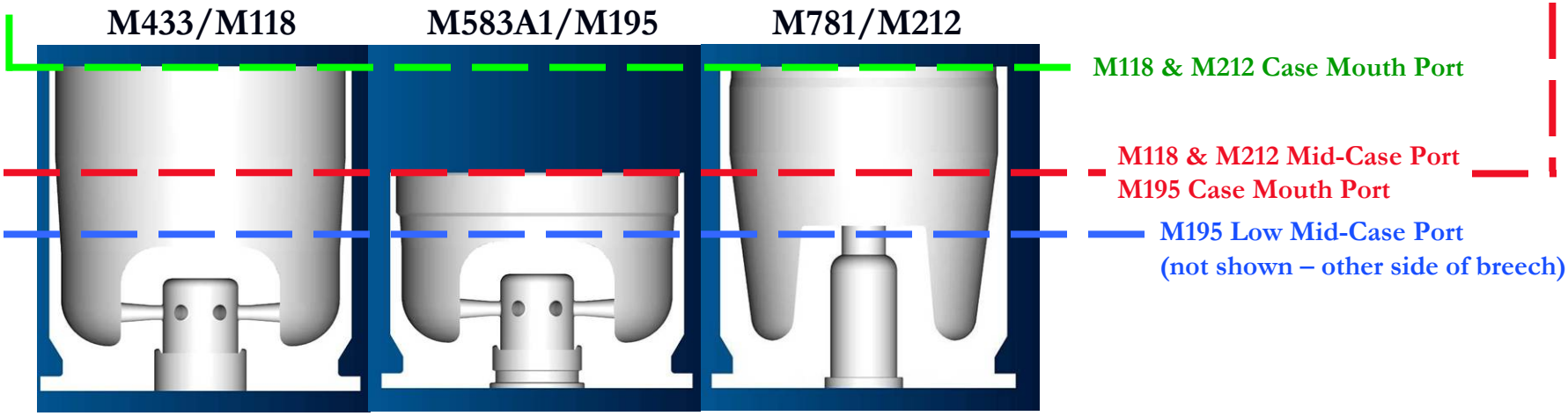


ARDEC 40mm Low Velocity Mann Barrel Assembly

EPVAT with Soft Recovery

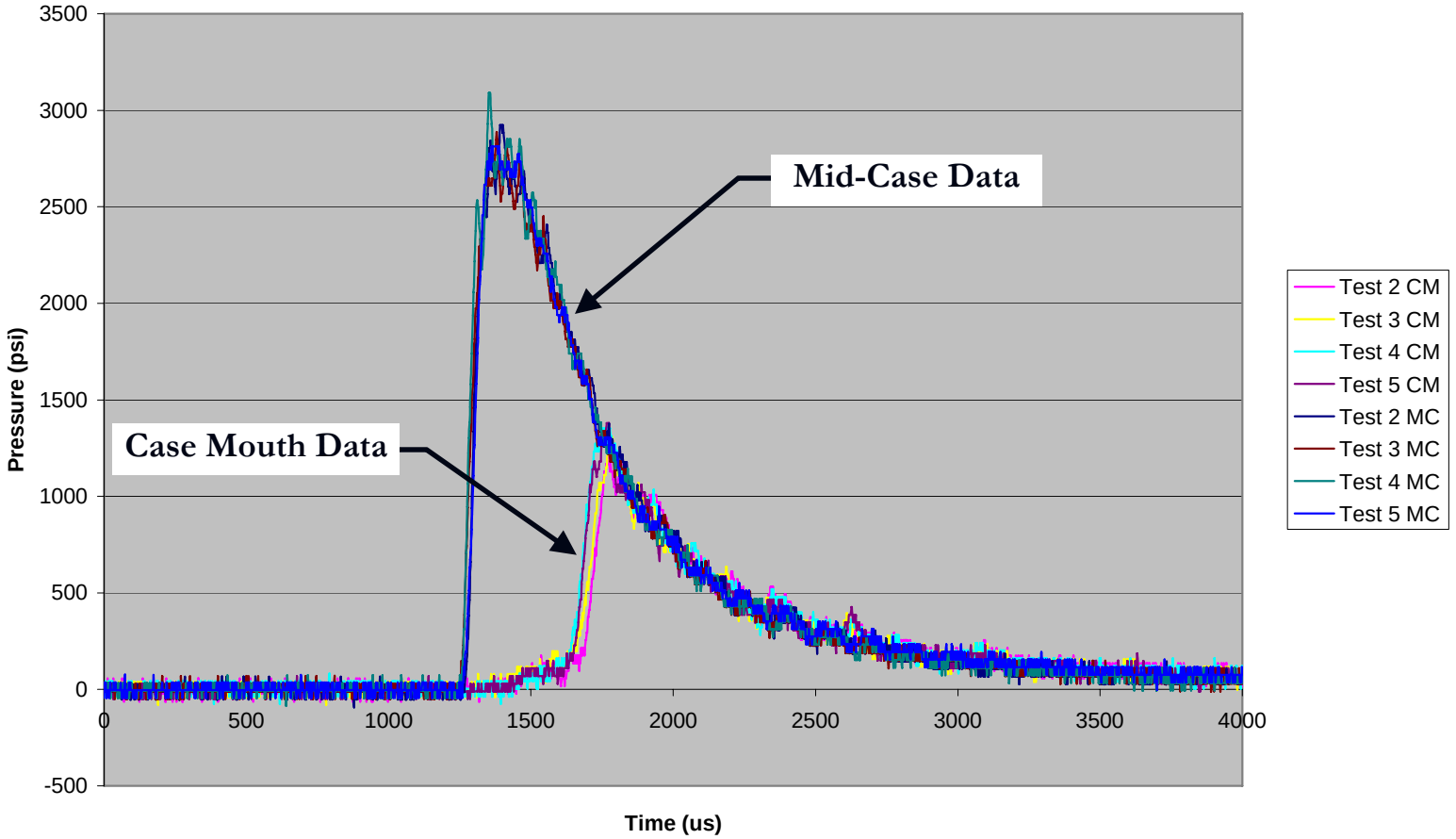
Low Velocity Pressure Port & Cartridge Case Diagram





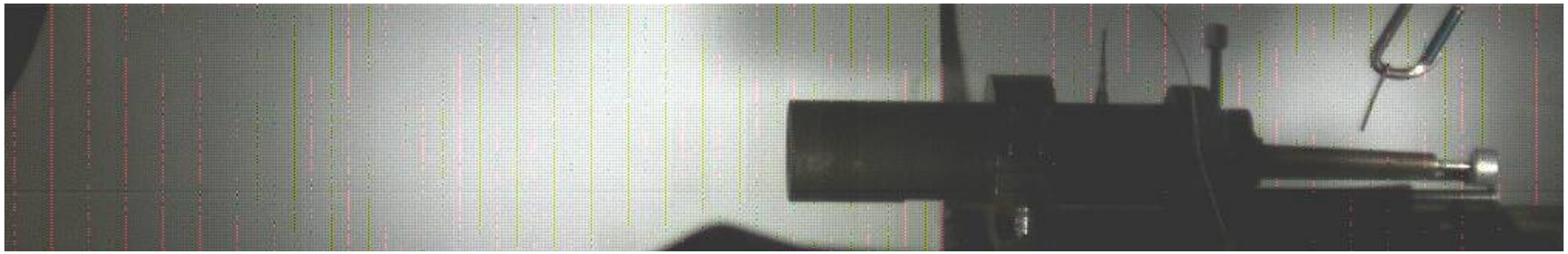
EPVAT with Soft Recovery

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



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

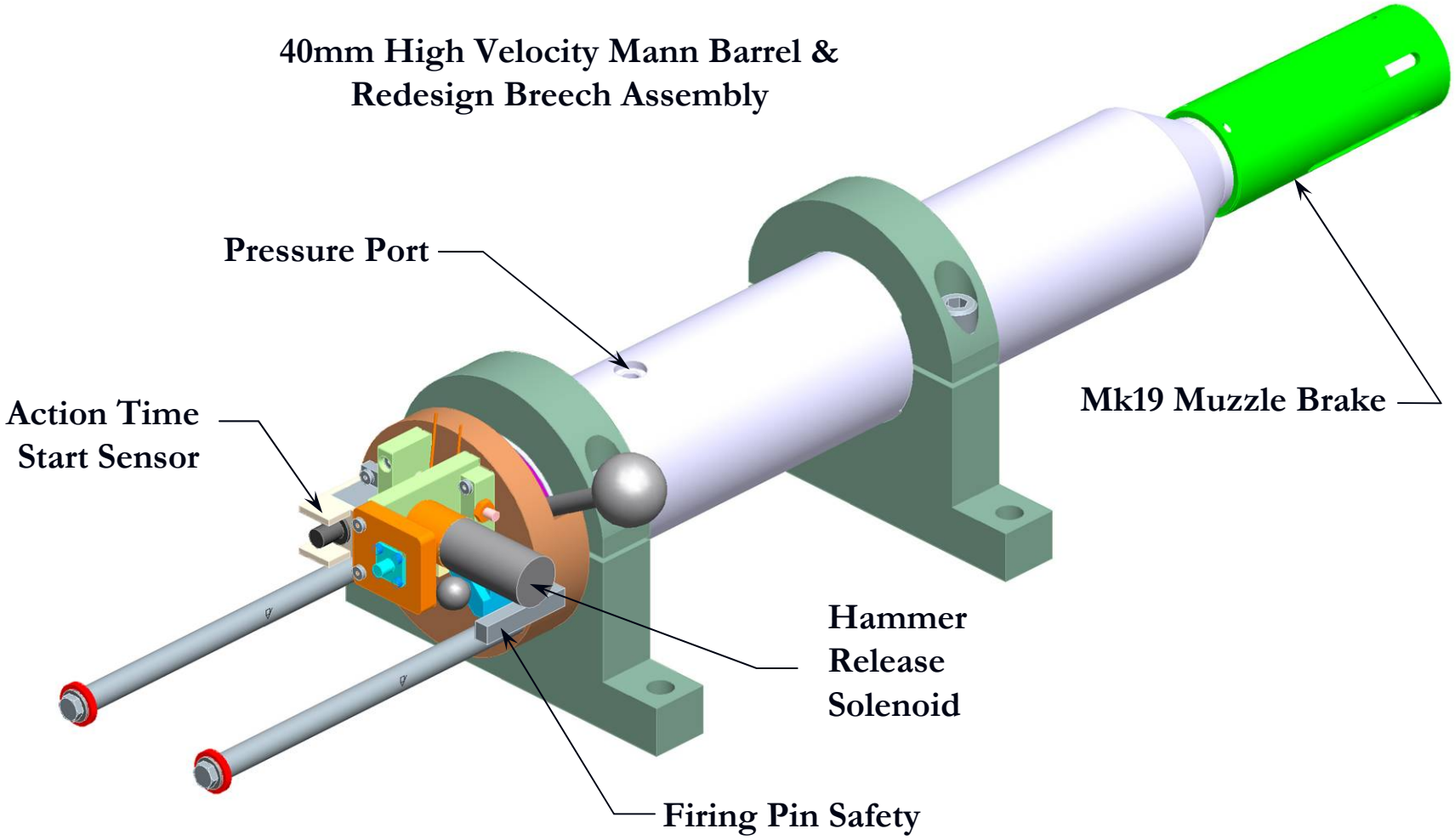
EPVAT with Soft Recovery

- 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



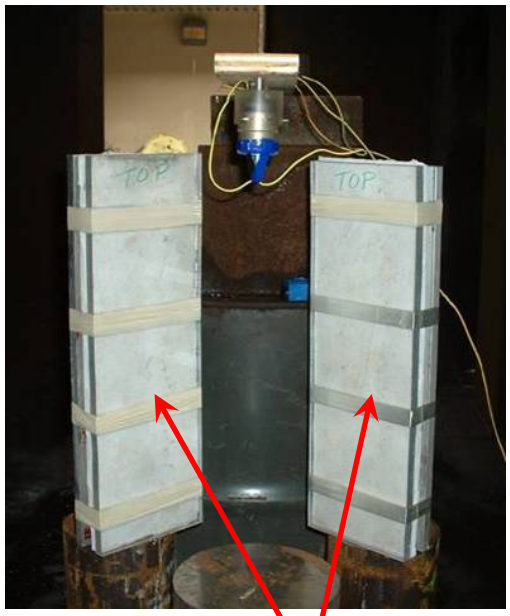
Warhead Testing

- 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



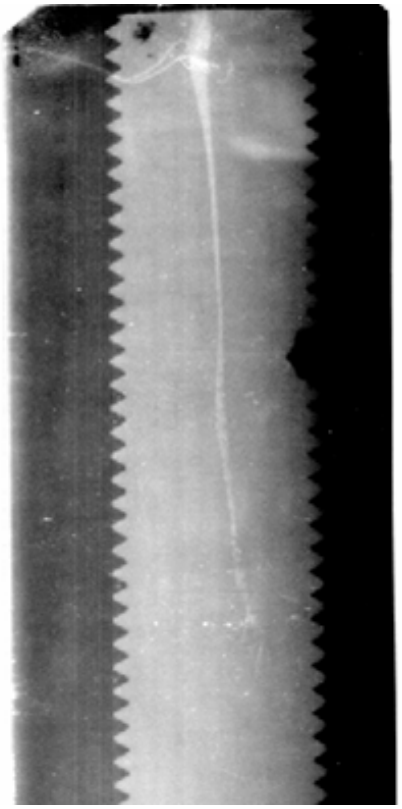
Orthogonal X-Ray Film Packs

Penetrated RHA

Spin Fixture

Fiber Optic Spin Rate Pickup

X-Ray of Jet Formation



Warhead Testing

- Fragmentation Performance Characterization

Detonation Chamber

Projectile in Balloon in Saw Dust

Separation Apparatus

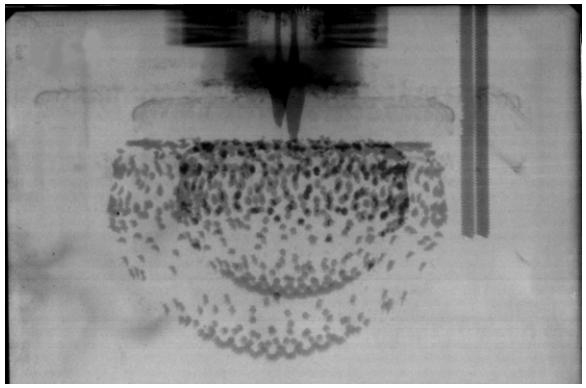
Vacuum

Ferrous

Non-Ferrous

Warhead Testing

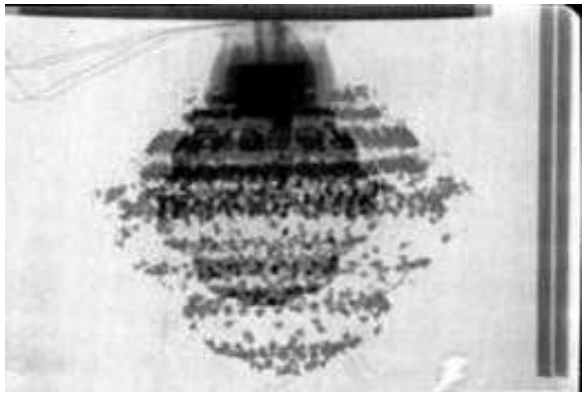
- Fragmentation Performance Characterization



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