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Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

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# M385A1 Composite Projectile Feasibility Study

20 May, 2008

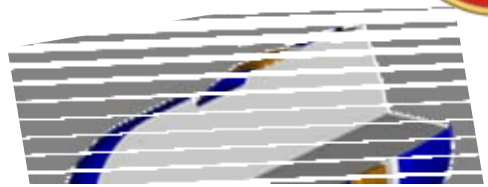
Christopher Summa, 40mm Grenade Ammunition Special Projects

# Objectives

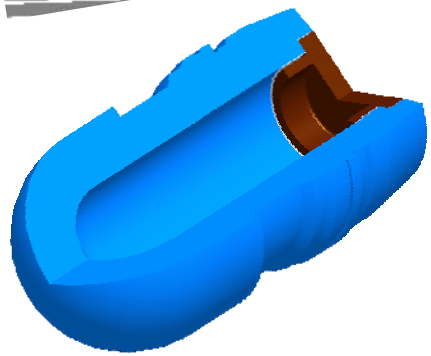
- **Objectives**
  - **Reduce unit cost**
  - **Integrate rotating band to the projectile body**
  - **Obtain ballistic match to M385A1**
- **Requirements**
  - **Color – Blue #35109, FED-STD-595**
  - **Maintain Bore Life – 30,000 rounds**
  - **Survive Linking/De-linking**
  - **Accept Ink Stenciling**
  - **Fire from Mk19 GMG**
  - **Preserve Physical Properties**
    - **Profile, Mass, CG, Moments of Inertia**

# Rationale

- **Current Fabrication:**
  1. Profile machined from aluminum bar stock
  2. Swage copper rotating band
  3. Final machining
  4. Anodize projectile



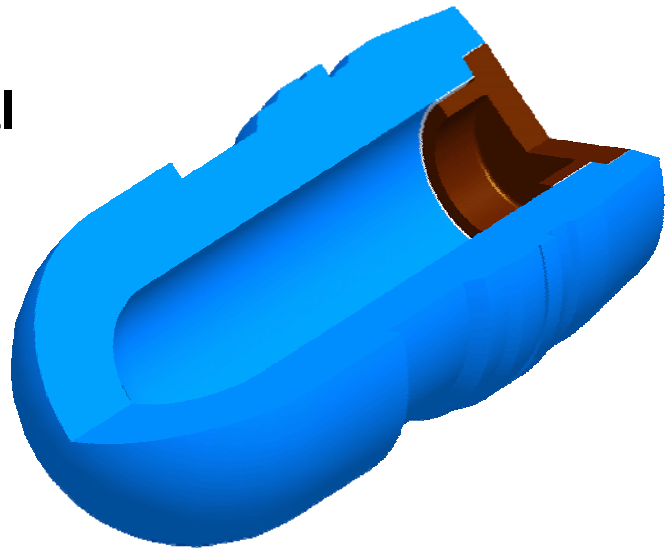
- **Fabrication using composites:**
  1. Injection-mold projectile
     - Colorant in compound
     - Can be either stenciled or engraved
  2. Machine and assemble aluminum gas cap



- **Polymer-Metal Powder Composites:**
  - Can use many commercial-grade injection-moldable polymers with metal powder
  - Can tune density to meet mass requirements
  - Can be machined after molding (ideal for prototyping)

# Feasibility Study: Overview

- **M385A1 Composite Projectile Feasibility Study**
  - **Characterize and down-select materials (Phase 1)**
  - **Mold, assemble, and inspect prototype projectiles (Phase 2)**
    - **Single-cavity mold with parting line along axis**
    - **Core placed on aft side of projectile**
      - **Core necessary to ensure no voids or other mold related defects**
  - **Conduct Live Fire and Environmental Testing (Phase 3)**



# Feasibility Study: Phase 1

- **Material Selection Phase**
  - Ten material recommendations given by Ecomass Technologies
    - 5 thermoplastic polymers combined with 2 different metal fills
  - Performed mechanical properties testing and quasi-static FEA
  - Downselected to 5 materials due to:
    - Chemical incompatibility (-1 material)
    - Insufficient UTS (-4 materials)
    - Mismatching shrink rates (-1 material)
    - Compounding issue (-1 material)
    - Copper-filled materials added (+2 materials)

Materials for Phase 2

Copper + PPA

Copper + Nylon 6/10

Tungsten + PPA

Tungsten + Nylon 6/10

Stainless Steel + Nylon 6/10

# Feasibility Study: Phase 2

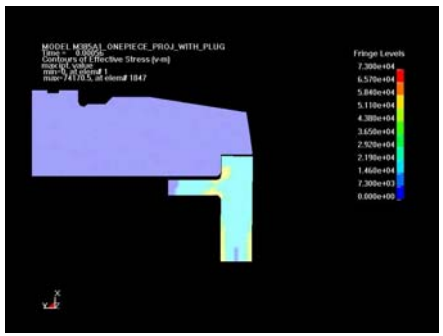
- **Prototyping and Inspection Phase**
  - Gating location in saddle region of projectile
  - Core pin placed in mold cavity to create hollow projectile core
  - 35 projectiles for each material molded (175 total)
    - Inspection shows all are considerably undersized
  - New mold constructed based on previous inspection data and highest shrink rate material – all materials too large would be machined.
  - Equipment malfunction degrades 1 material.
  - Four material groups molded (35 each), delivered to ARDEC (140 projectiles)

Mold Cavity

Untrimmed Part

# Feasibility Study: Phase 3

- **Testing Phase**
  - **Environmental Testing**
    - **High Temperature / High Humidity**
      - **Results inconclusive: growth and shrinking experienced**
      - **Post machining may have affected results**
  - **Live Fire Testing from Mk19 Mod 3 GMG**
    - **Two out of four material groups performed very well**
      - **Experienced no break-up despite being undersized**



FEA of Gas Plug

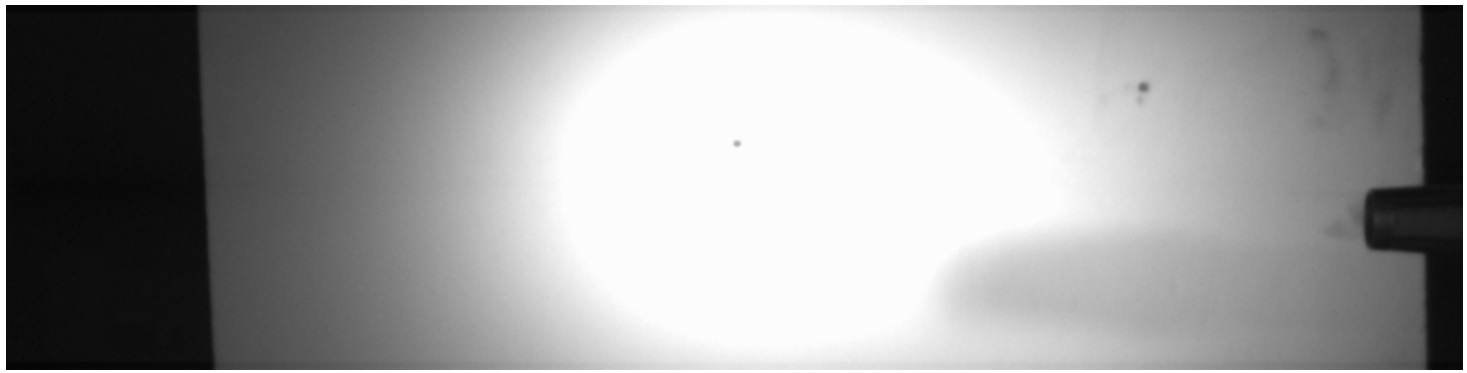
Assembled Projectile


Loaded Cartridge

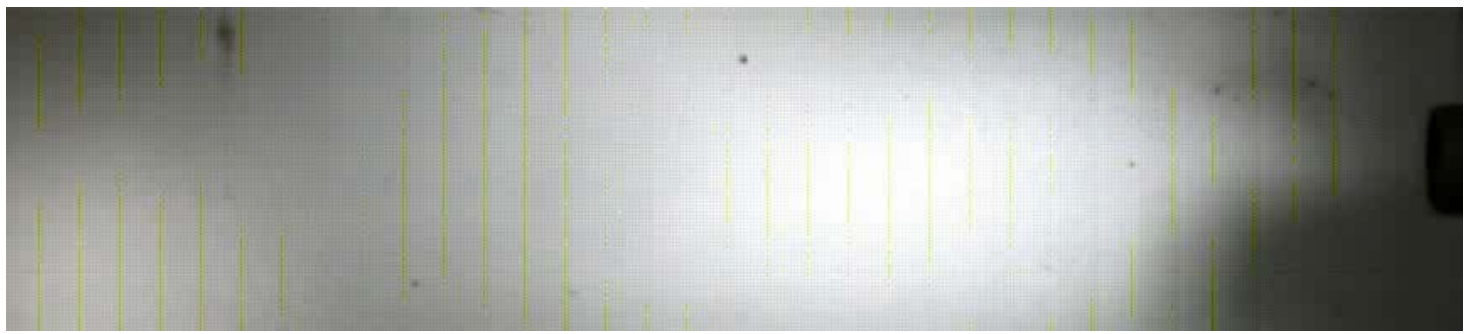
Weapon Setup

# Test Firing Videos

Test firing:

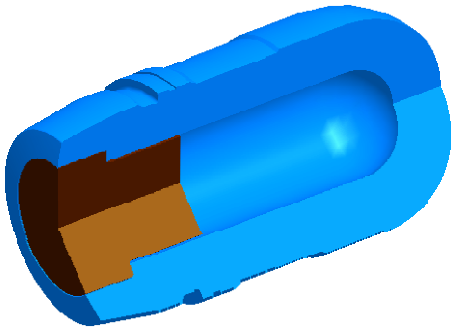


Test firing without gas cap:

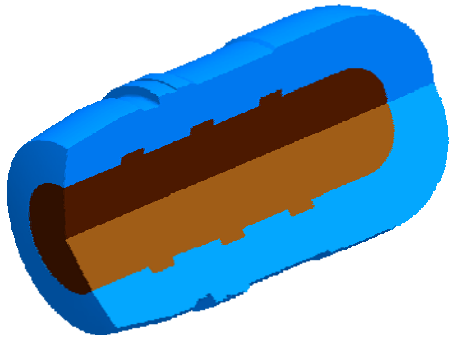


# Phase 3 Conclusions

- Composite projectile is suitable for gunfire
  - Requires more testing to demonstrate ability to rifle
- Composite projectile with hollow core not suitable
- Gas cap or mold-in-mold operation may be implemented in future design



Gas Cap



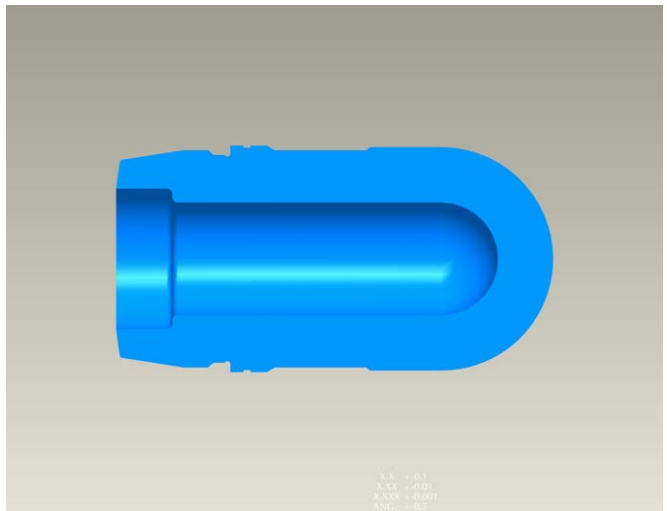
Mold-In-Mold

- Saddle region thickness should be increased to improve strength of part
- Mold modification possible since parts are undersized
- Shape and ballistics of projectile can potentially be made to match those of the tactical cartridge (M430A1 HEDP)
  - Outer profile match not possible with modification to current mold

# Feasibility Study: Phase 4?

- Only use best material from original study (SS + Nylon 6/10)
- Perform in-depth Moldflow analysis to optimize mold design
  - Optimized gating for reduced ovality and core pin deflection
  - Improved dimensional stability (only one shrink rate to monitor)
  - Incorporate gas cap recess into core pin
  - Increase saddle wall thickness similar to M430A1 HEDP
- Modify existing mold based on analysis
  - Unacceptable to construct new mold
- Mold and inspect 100 projectiles
- Live fire testing

- In process of pursuing follow-on contract



# Benefits to 40mm Ammunition and Warfighter

- Reduced cost for training cartridges
- Increased training quantities for the warfighter
- Possible technology spill-over to other 40mm items
- Potential to utilize frangible qualities of material

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# Development of M16A2 Pivoting Coupling

20 May, 2008

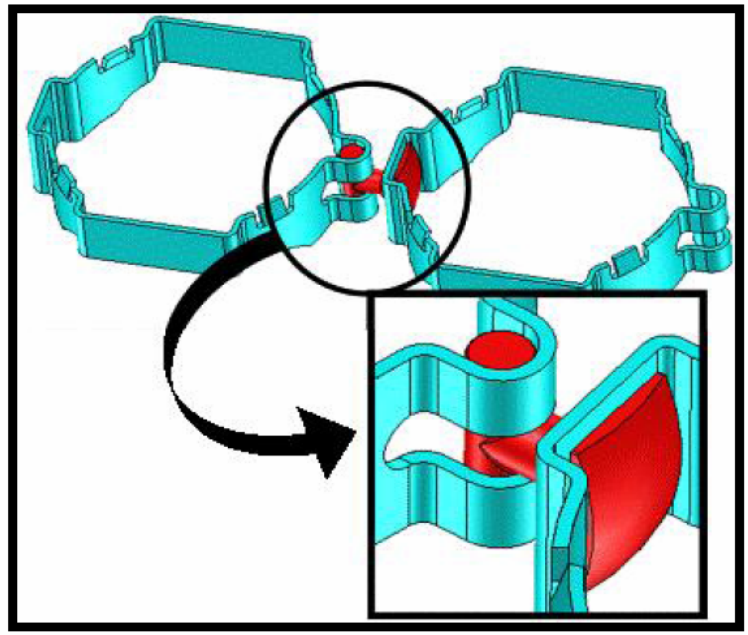
Matthew Millar, 40mm Grenade Ammunition Special Projects

# Background

- Soldiers do not have capability to link MK19 ammunition belts together without use of tools
- Current ammo cannot be re-linked to form full belts
- Limited to fire in belt lengths of 32 before reloading

# Coupling Design Improvements

- Dimensional modification of current coupling to allow snapping action to secure rounds to the belt without deforming the loop
  - Difficult to spot change visually

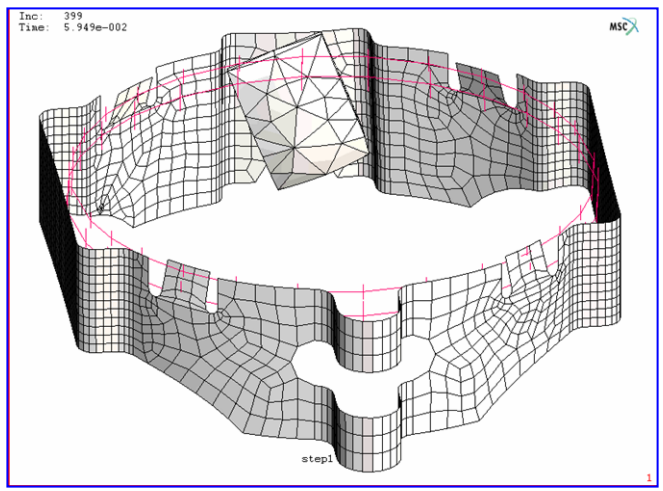


# Coupling Coating (cont)

- Reasons for new coating
  - Identification
    - Gold = NEW
    - Black = OLD
  - Corrosion resistance
    - 96 vs. 48 hours
- New coating will be dulled down to reduce coating shine.

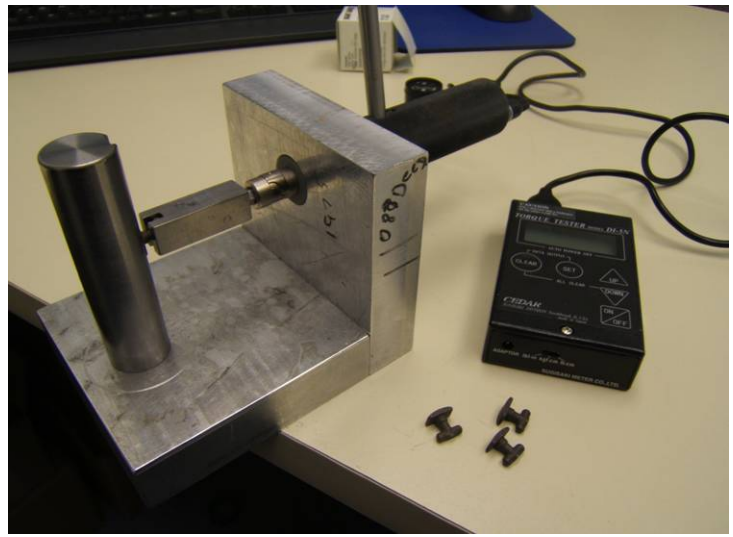
# FEA Analysis

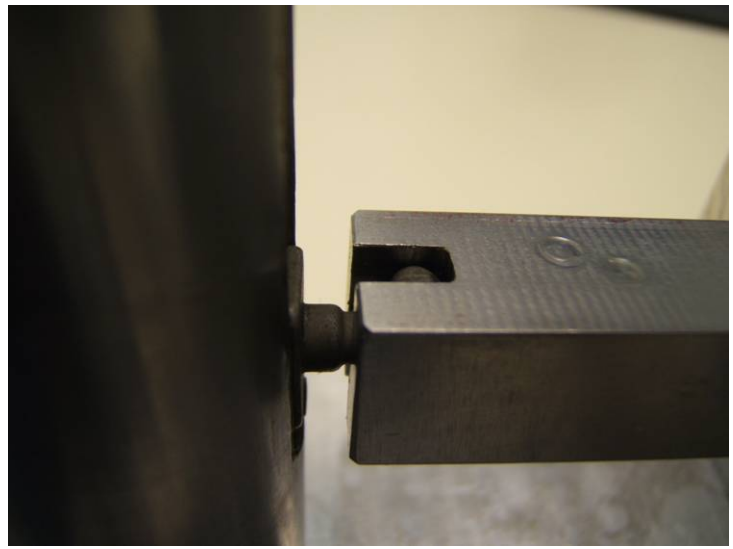
- Investigated mechanical failure during uncoupling/re-coupling
  - Corners of coupling head wear down slightly
  - Loop keyhole opens slightly
- Continued uncoupling and re-coupling did not show any significant decrease in function



# Torque Testing

- Coupling and Uncoupling Test
  - Torque gage used to measure coupling and uncoupling
- Torque greatest during first coupling/uncoupling operation
  - Wear on coupling head
  - Loop keyhole elastic deformation
- Coupling shank experienced twist
  - Test fixture represented “Worst Case”
  - Rigid cartridge vs. “Push-Pull” Motion

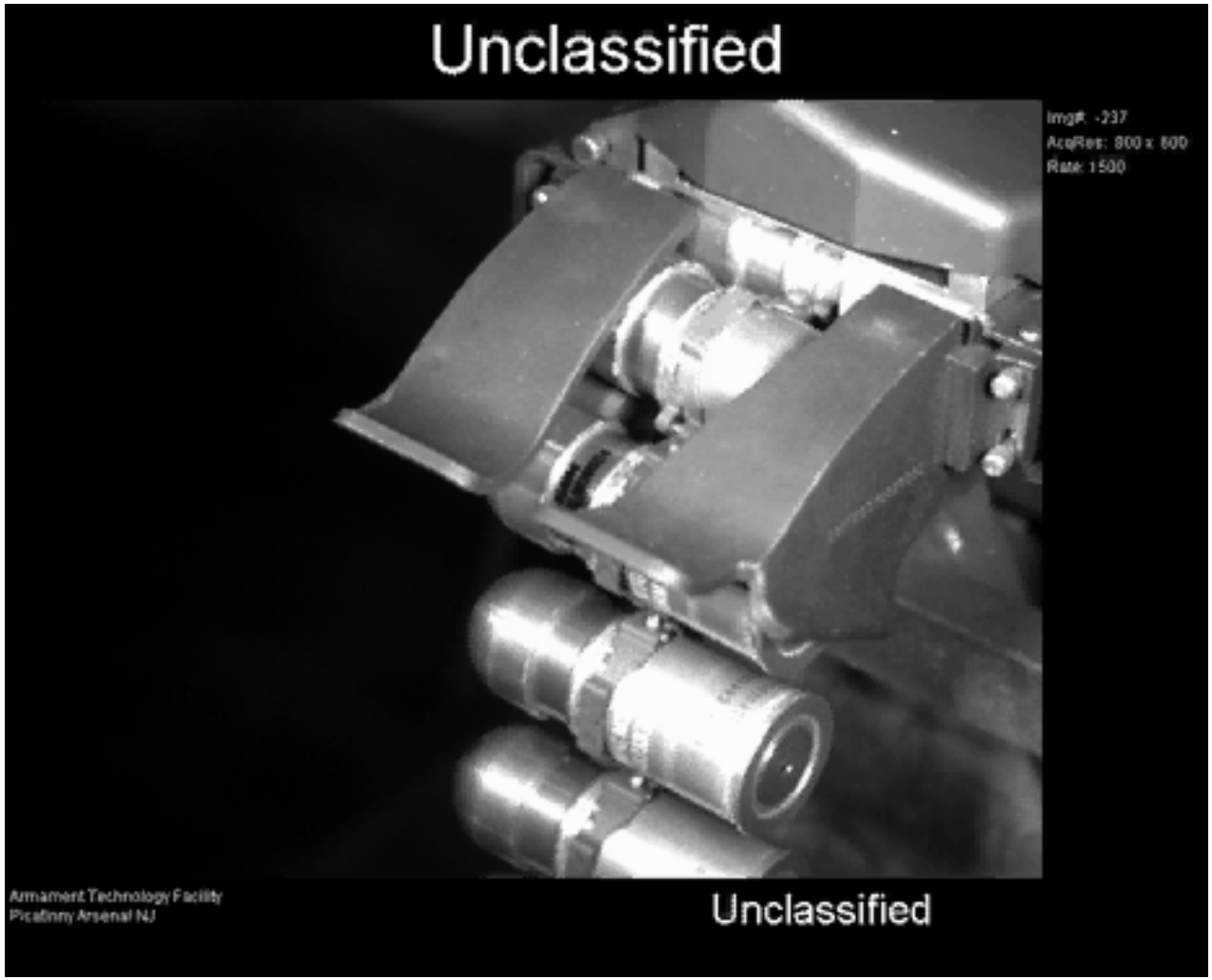




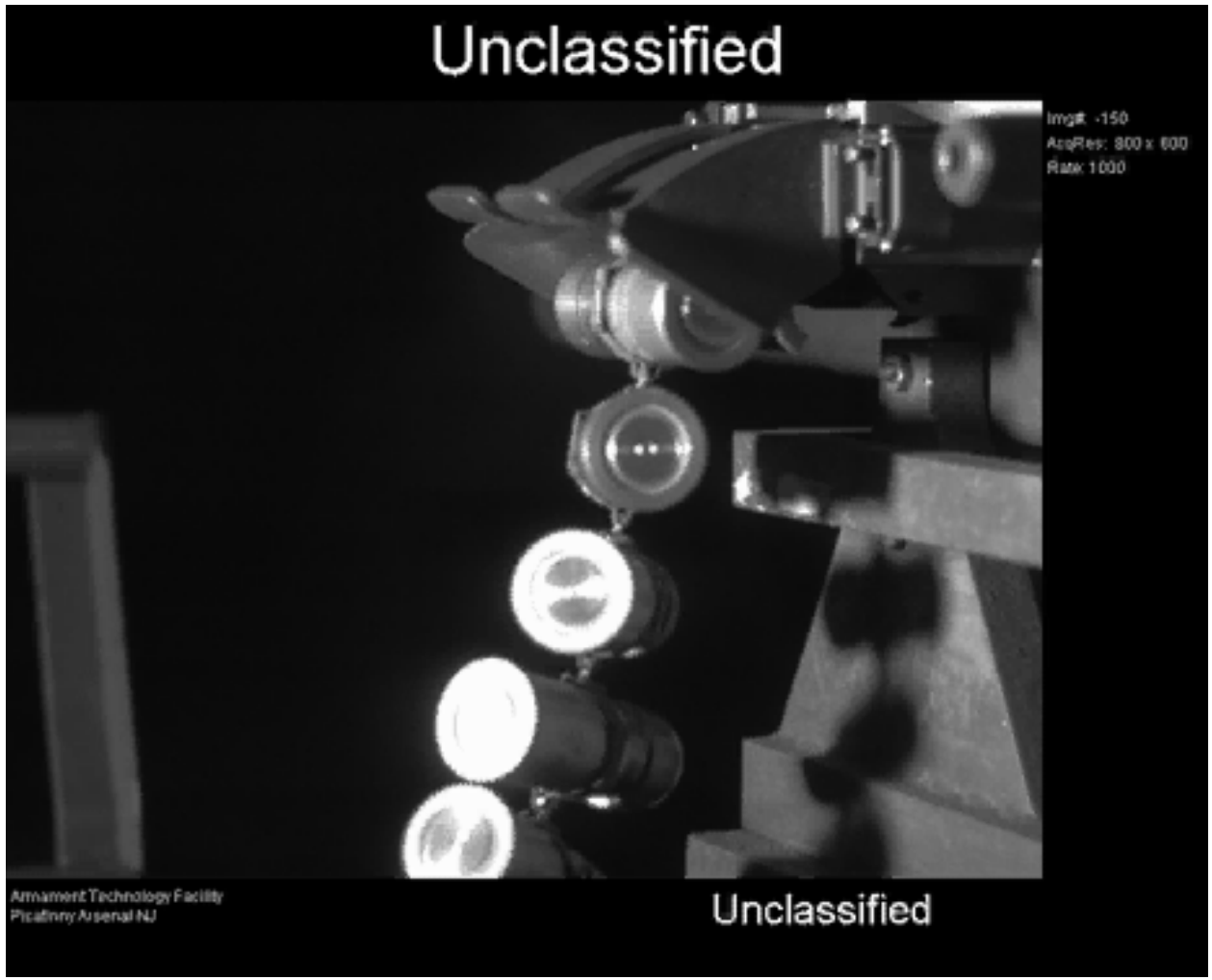
# Armament Technology Facility (ATF) Testing

- 15º Twist
  - Three (3) belts of 24-M385A1 linked cartridges
  - Belts fired in 3-5 round bursts as well as 12 round bursts from MK19
  - No weapon stoppages
- 30º Twist
  - 3-5 round burst
  - Multiple configurations
    - Up to 3 cartridges linked with couplings that had a 30º twist linked consecutively
  - 3 consecutively linked couplings with 30º twist caused weapon stoppages
- Testing ceased at 30º twist.

# ATF Testing: 15º Coupling Twist
# No Weapon Stoppage



# ATF Testing: 30º Coupling Twist Weapon Stoppage



# Vibration Testing

- Vibration Testing at Aberdeen Proving Ground
  - To ensure security of belt during firing from a from moving HMMWV
  - No coupling related weapon stoppages

# War Fighter Payoff

- New coupling reduces logistical burden of requiring Ammo Supply Point (ASP) to re-link ammo
- Ability to re-link or extend belts on-the-fly if desired

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# Electronics and Sensors in 40mm Low Velocity Grenade Ammo

May 20, 2008

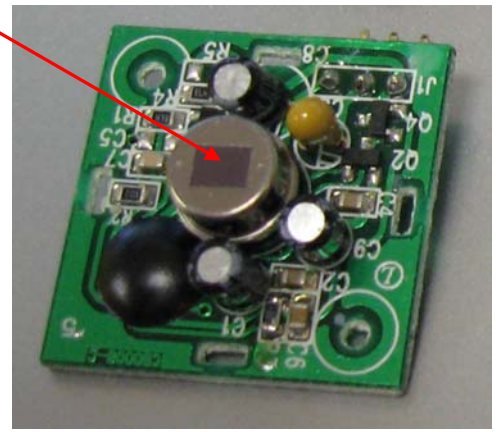
Jason Wasserman, 40mm Grenade Ammunition Special Projects

# Objectives

- To integrate commercial, off-the-shelf electronic components into 40mm Low Velocity Grenade Ammunition

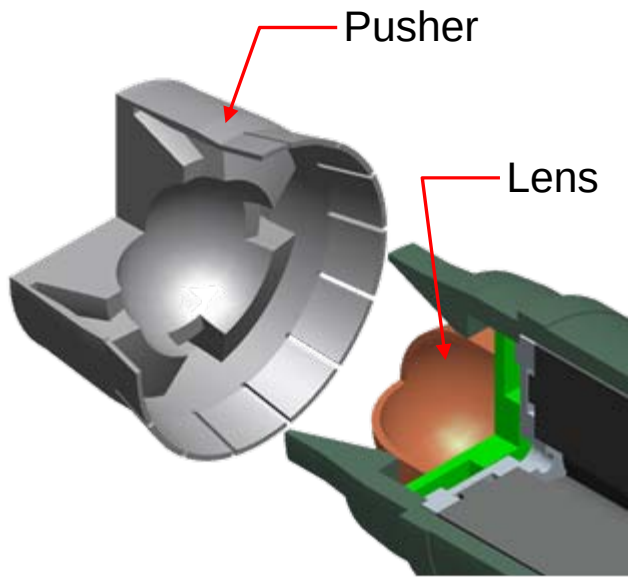
- Overcome the challenges associated with integrating commercial parts without modification

# PIR (Passive Infrared) Sensor




- Challenges
  - Requires a lens that is transparent to IR frequencies and is structurally weak
  - Translucent visual access to exterior of projectile
  - Proper function requires an unpotted sensor

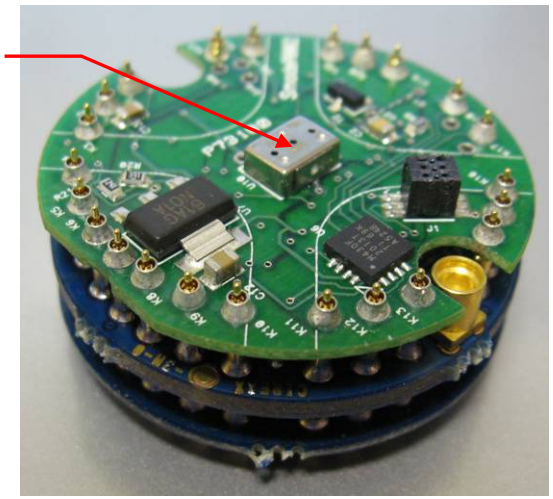
- Solutions
  - Specialized aft geometry to allow the PIR sensor to “see” with a wide field of view
    - “Legs” needed to be strong enough to withstand potential impact loading
  - Specialized pusher utilized to prevent gas leakage from reaching the lens
    - Pusher needed to be robust enough to withstand gun pressures while sensitive enough to detach on muzzle exit to allow the PIR sensor to “see”



# Batteries & Microphone

- Battery Challenges
  - Size vs. usable life tradeoff
  - Orientation specific
  - Retention method
- Solutions
  - 2/3AA size used for acceptable size vs. life tradeoff
  - Must be oriented parallel to axis
  - Specialized “spacers” used to hold batteries together to prevent movement and breaking connections

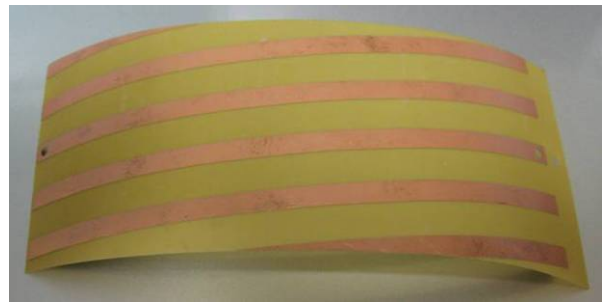

- Microphone Challenges
  - Requires unobstructed, open air access to exterior of the projectile to prevent sound from being muffled or quieted
  - G-load sensitive device
- Solutions
  - Specialized “spacers” used for batteries have built-in channels for microphone and access to exterior of the projectile



# GPS Sensor & Antenna/Wiring

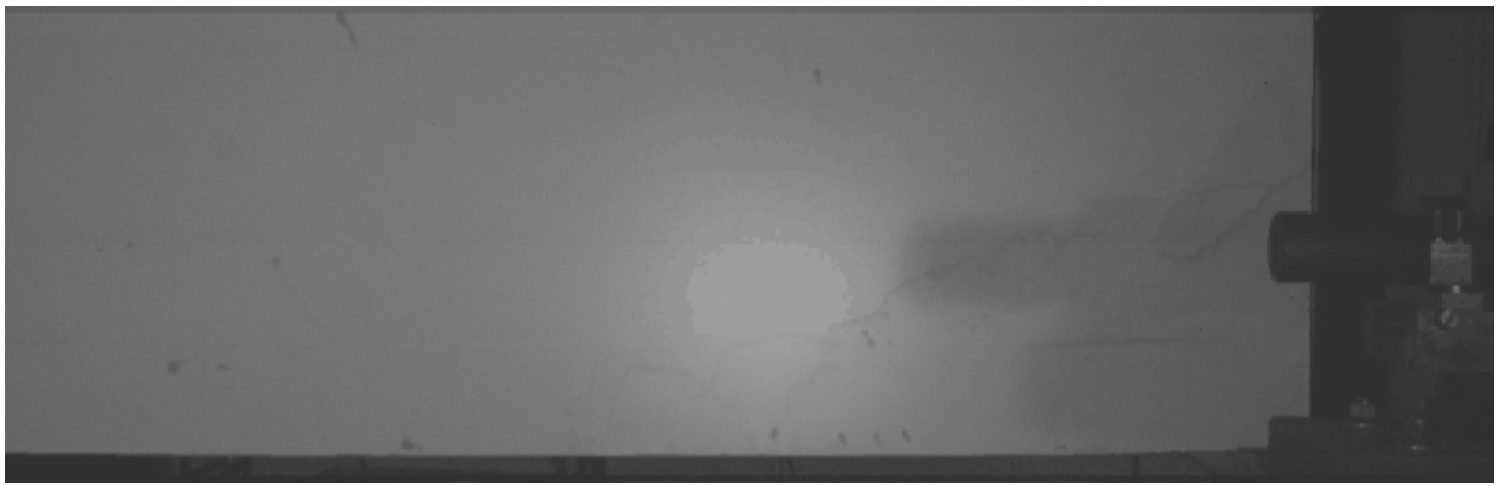
- GPS Sensor Challenges
  - Requires a non-metallic projectile body to prevent the signal from being attenuated
- Solutions
  - High-strength engineering polymer used to retain launch and impact strength without impacting GPS signal


- Antenna/Wiring Challenges
  - Wiring requires space in various spots in projectile body
  - Antenna requires a non-metallic projectile body to prevent the signal from being attenuated
- Solutions
  - Wires are routed in cutouts of battery “spacers” and along the sides of the batteries
  - Antenna is a thin strip wrapped around the outside of the potted electronic assembly prior to inserting into the body



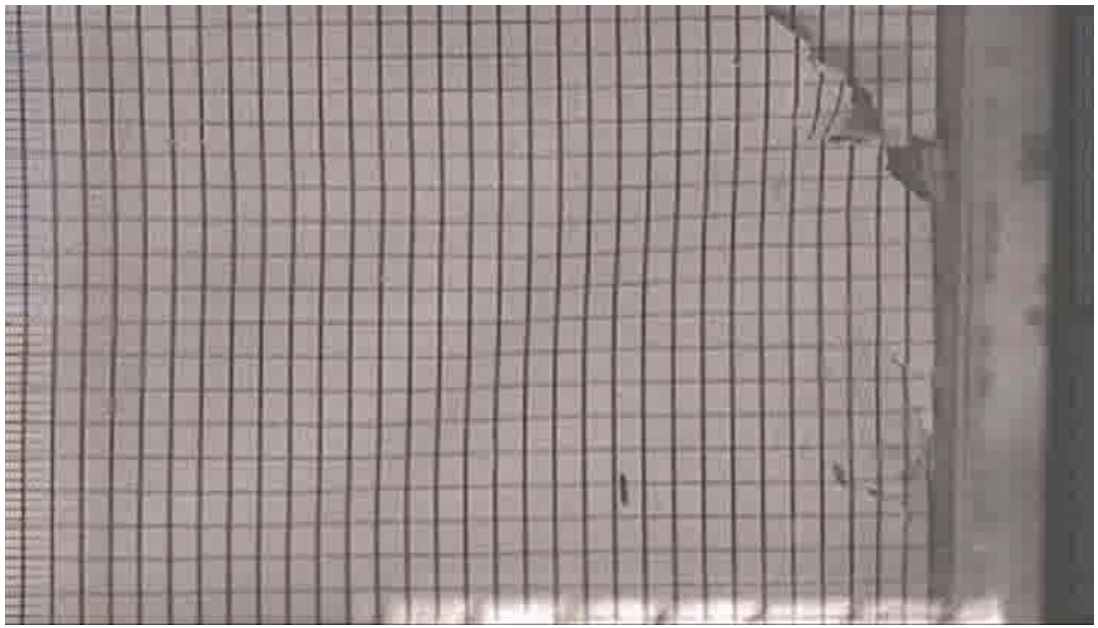
# Launch Survivability

- Projectiles were fired from the ARDEC 40mm Low Velocity Mann Barrel
- Objective was to verify integrity and proper discard of the pusher
- Projectiles were soft caught and had signal verification performed by a wireless connection



# Impact Survivability

- Testing was performed using an airgun to generate the required muzzle velocities
- Projectiles were fired into a rigid steel plate to simulate worst-case scenario impacts
- Projectiles housed a set of sensors attached by a wired connection to a computer to record real-time impact data
- Various nose designs were analyzed and tested



# Path Forward

- Producibility Optimization
  - Reduce time to assemble and pot electronics
  - Procure injection molds
- Live Fire Testing & Demonstration
  - Fire projectiles into various environments and for max range
  - User demonstration

# War Fighter Payoff

- Provides a unique capability for Military Operations on Urbanized Terrain at the squad level
  - Non Line-Of-Sight surveillance of enemy or allies
  - Enhanced Situational Awareness
  - Enhanced Target Acquisition

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# Producibility Improvements of 40mm High and Low Velocity Liners

20 May, 2008

Adam Sorchini, 40mm Grenade Ammunition Special Projects

# Program Objectives

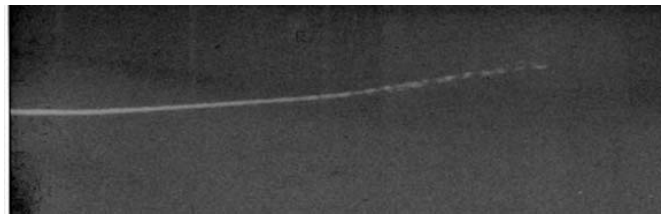
- M433 HEDP One-Piece Liner (Low Velocity – M203 GL)
  - Reduce cost of liner production by combining components
  - Improve efficiency of jet formation
- M430A1 HEDP Non-Fluted Liner (High Velocity – Mk19 GMG)
  - Reduce cost of liner production by simplifying geometry

M433 HEDP

M430A1 HEDP

# Baseline Testing and M&S

- Baseline Testing
  - Performed at ARDEC using production hardware
  - Jet tip formation
    - Spin and no spin
    - Events captured by x-ray
      - Tip velocity
      - Jet straightness
  - Armor penetration depth
    - Spin and no spin
    - RHA steel plates



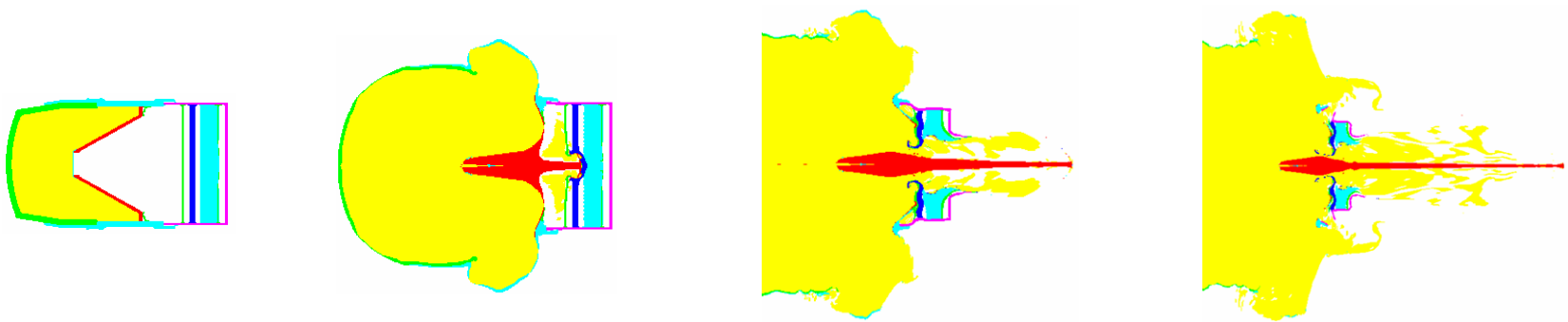
X-Ray of Jet Formation


Penetrated RHA

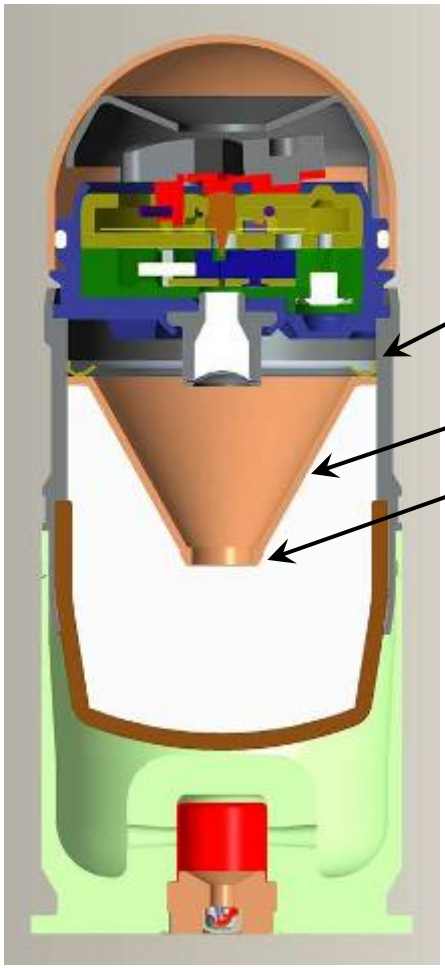
M430A1 Partial Test Projectile

# Baseline Testing and M&S

- Baseline Modeling and Simulation
  - Test data feeds into baseline model
    - Model represents actual performance
  - Baseline model is stepping stone to design improvements

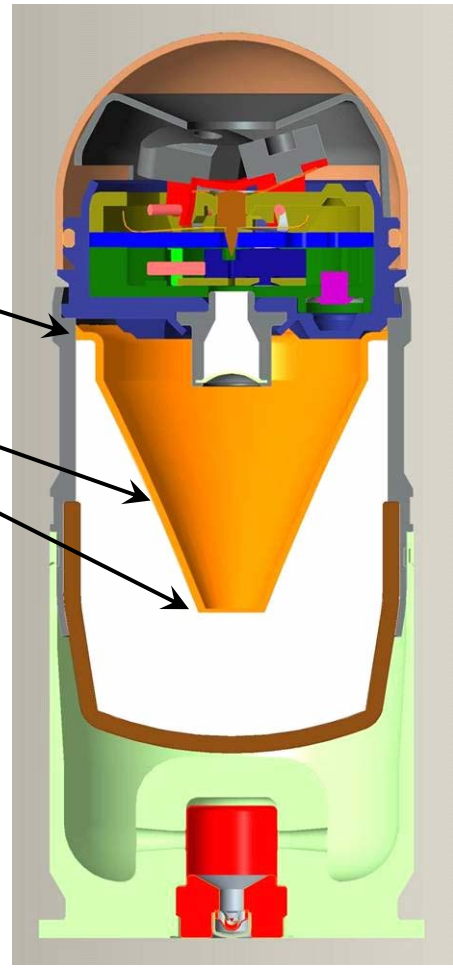


# M433 HEDP One-Piece Liner



## One-Piece Liner Design

1. Retaining Ring replaced by press fit flange
2. Liner elongated and added radius
3. Liner Cap integrated into liner apex

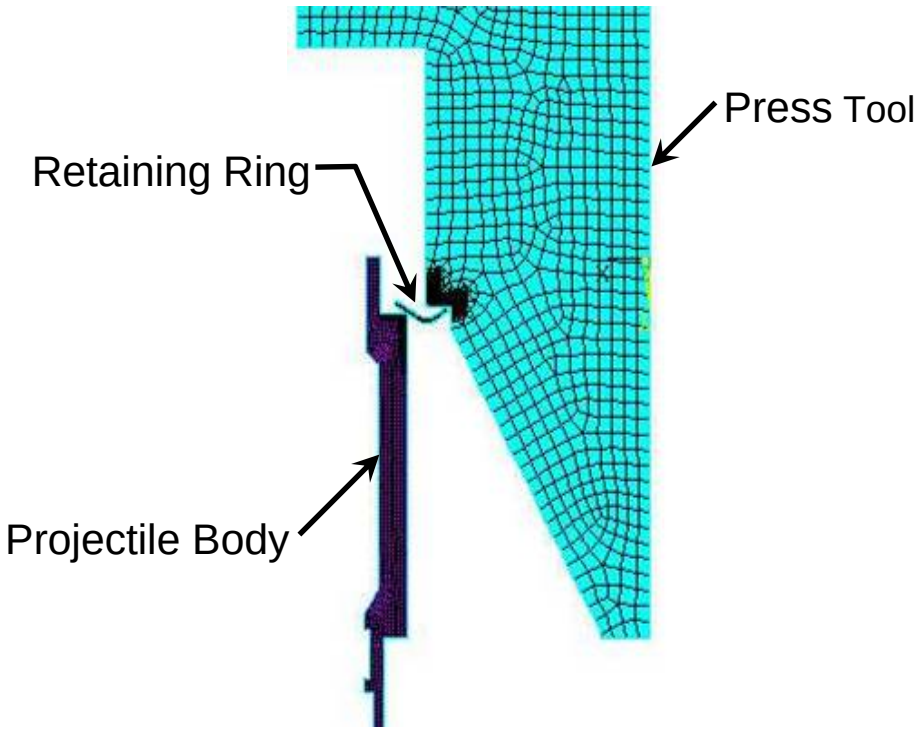


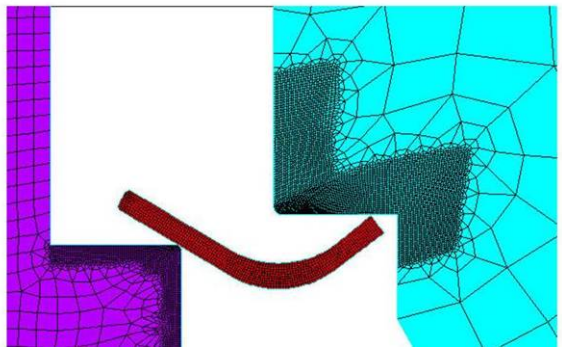
# M433 HEDP One-Piece Liner

- Testing & Design
  - Insertion & Push-Out Testing
    - Baseline retaining ring strength (completed)
    - Simulate integrated retaining ring insertion and push-out strength to compare to current retaining ring performance
  - Integrated Apex Sensitivity Testing
    - Perform armor penetration tests to determine maximum allowable apex thickness
      - Sensitivity to initiation determined by spitback performance
  - Optimize Liner Geometry
    - Adjust TDP based on test data and fabricate test hardware
  - Jet Characterization & Penetration
    - Perform full test array to verify performance

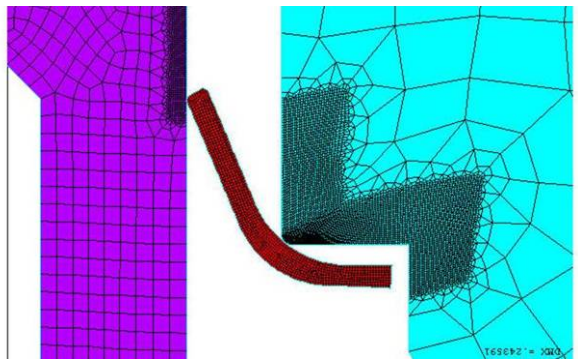
# M433 HEDP One-Piece Liner

- Retaining Ring Insertion & Push-Out M&S
  - Validated by test data



Ring prior to deformation

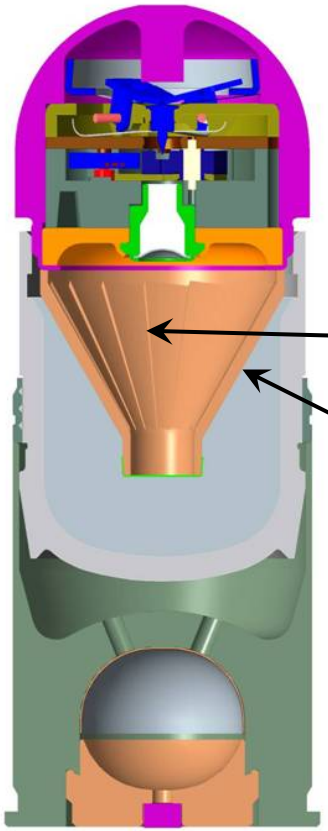


Ring pushed completely in

# M433 HEDP One-Piece Liner

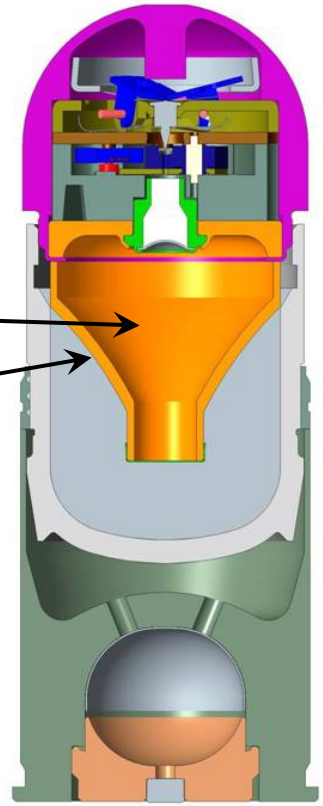
- Manufacturing Progress
  - FCI/Trans-Matic providing manufacturing and design support (subcontracted through DSE, Inc.)
  - Multi-step draw process is used
  - Multiple iterations performed to achieve complex geometry

# M430A1 Non-Fluted Liner



## Non-Fluted Liner Design

1. Flutes in liner removed
2. Slight radius added to liner

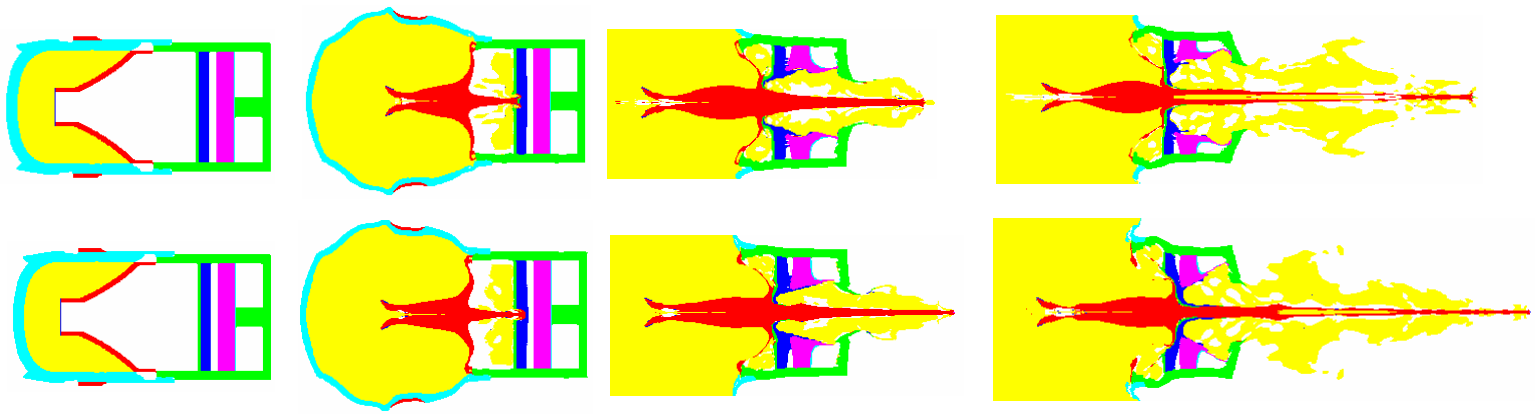


# M430A1 Non-Fluted Liner

- Design Testing
  - Jet Characterization & Penetration
    - Spin and no spin
    - Multiple spin rates to be analyzed due to large spin decay over effective range

Fluted Liner

Non-Fluted Liner



# War Fighter Payoff

- M433 HEDP One-Piece Liner
  - Lower unit cost
    - Fewer pieces
    - Automated assembly
  - Slight increase in performance
- M430A1 HEDP Non-Fluted Liner
  - Lower unit cost
    - Less complexity
    - Higher production rate
    - Easier to measure critical dimensions
  - Performance
    - More consistent
    - Equal at longer ranges
    - Better at short ranges

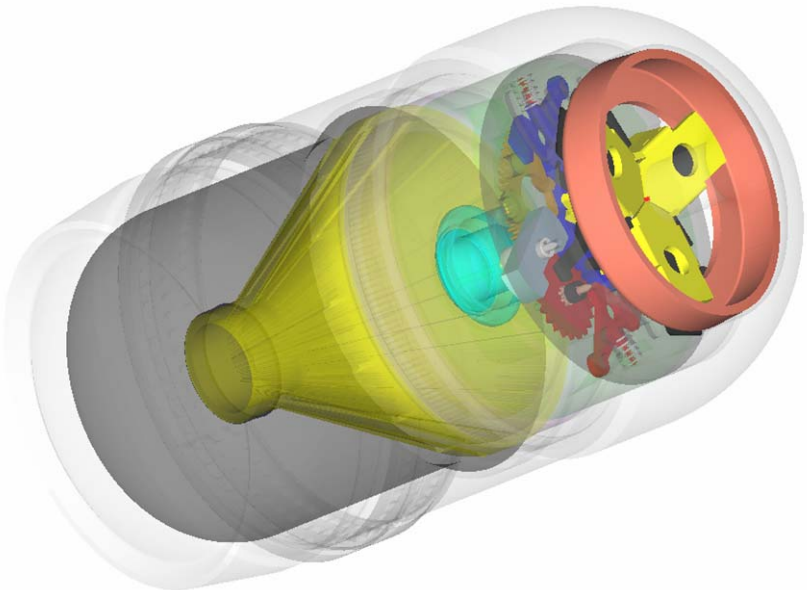
# Background

- 40mm Special Projects Team started program to baseline and improve M430A1 HEDP and M433 HEDP 40mm cartridges
- Baselining the cartridges involved Spark Range testing to quantify exterior ballistic coefficients
- Team showed a desire to identify some contributors to flight dynamics

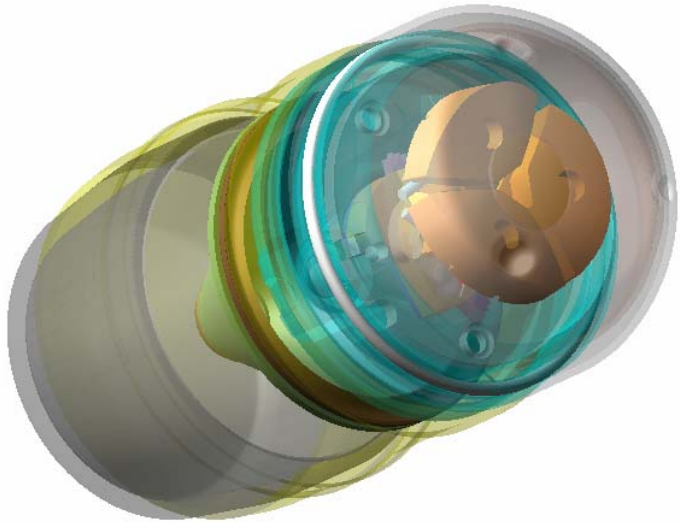
# Objectives

- Produce models that track location of center of mass of M430A1 HEDP and M433 HEDP projectiles throughout their flight and arming cycle of their M549A1 PIBD and M550 PIBD fuzes

# Transparent Views of Projectiles

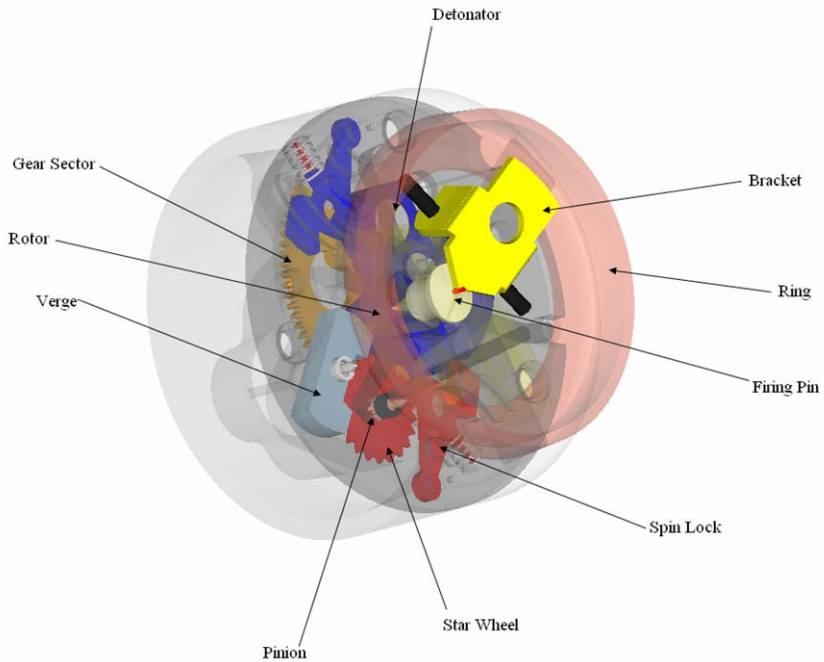


M430A1 HEDP Projectile

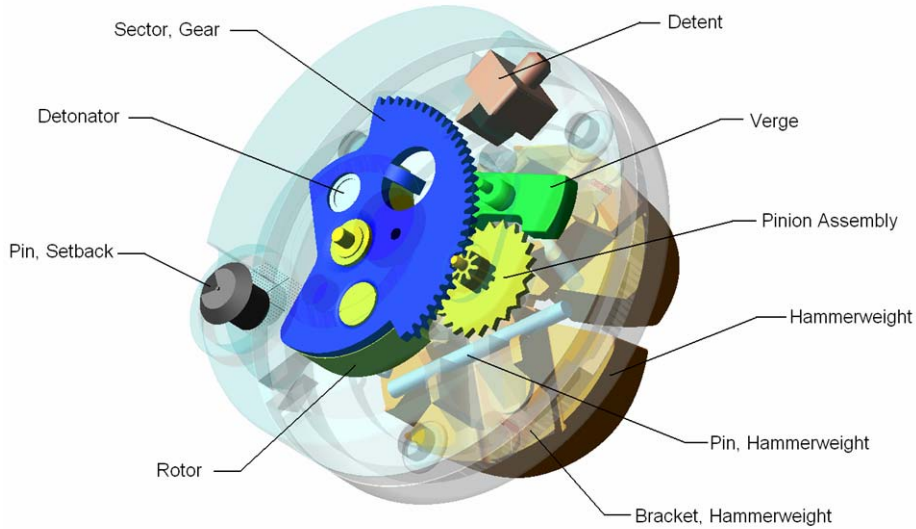


M433 HEDP Projectile

# Detailed Views of Fuzes

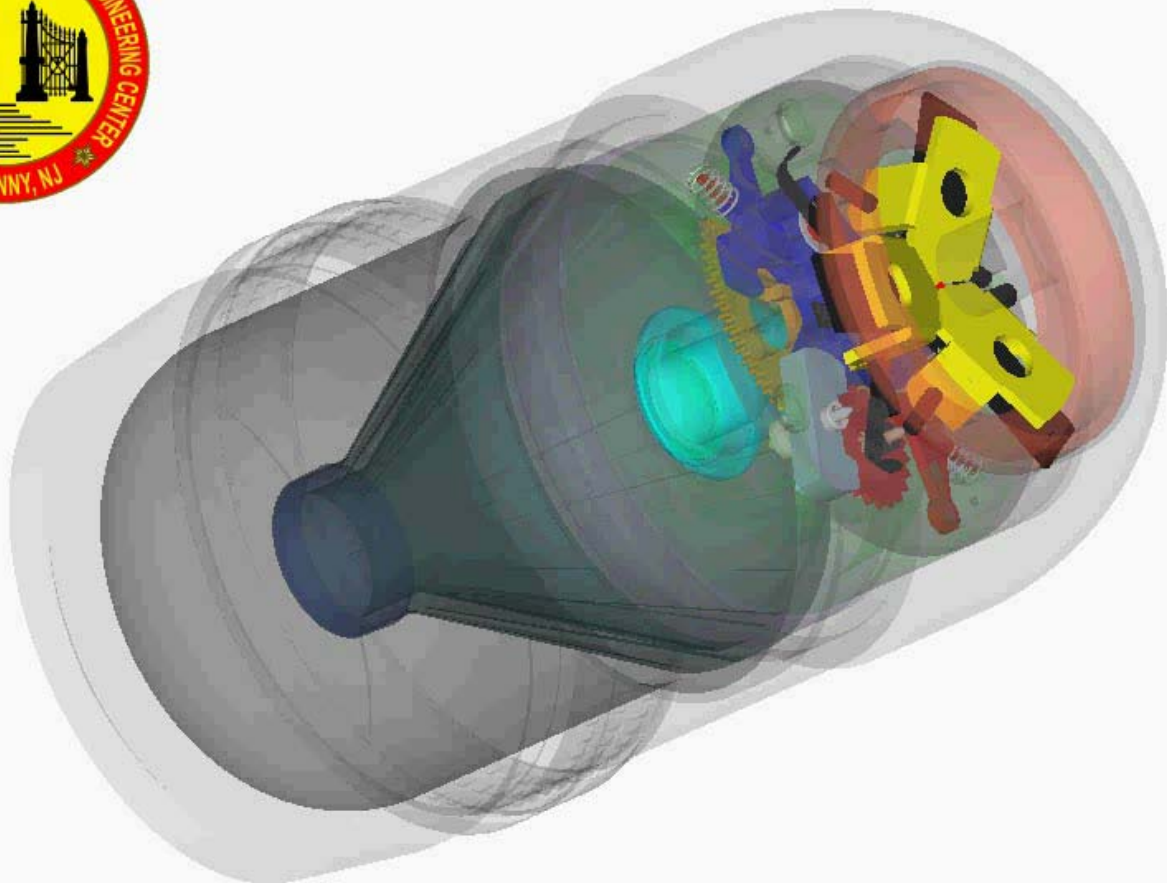



M549A1 PIBD Fuze

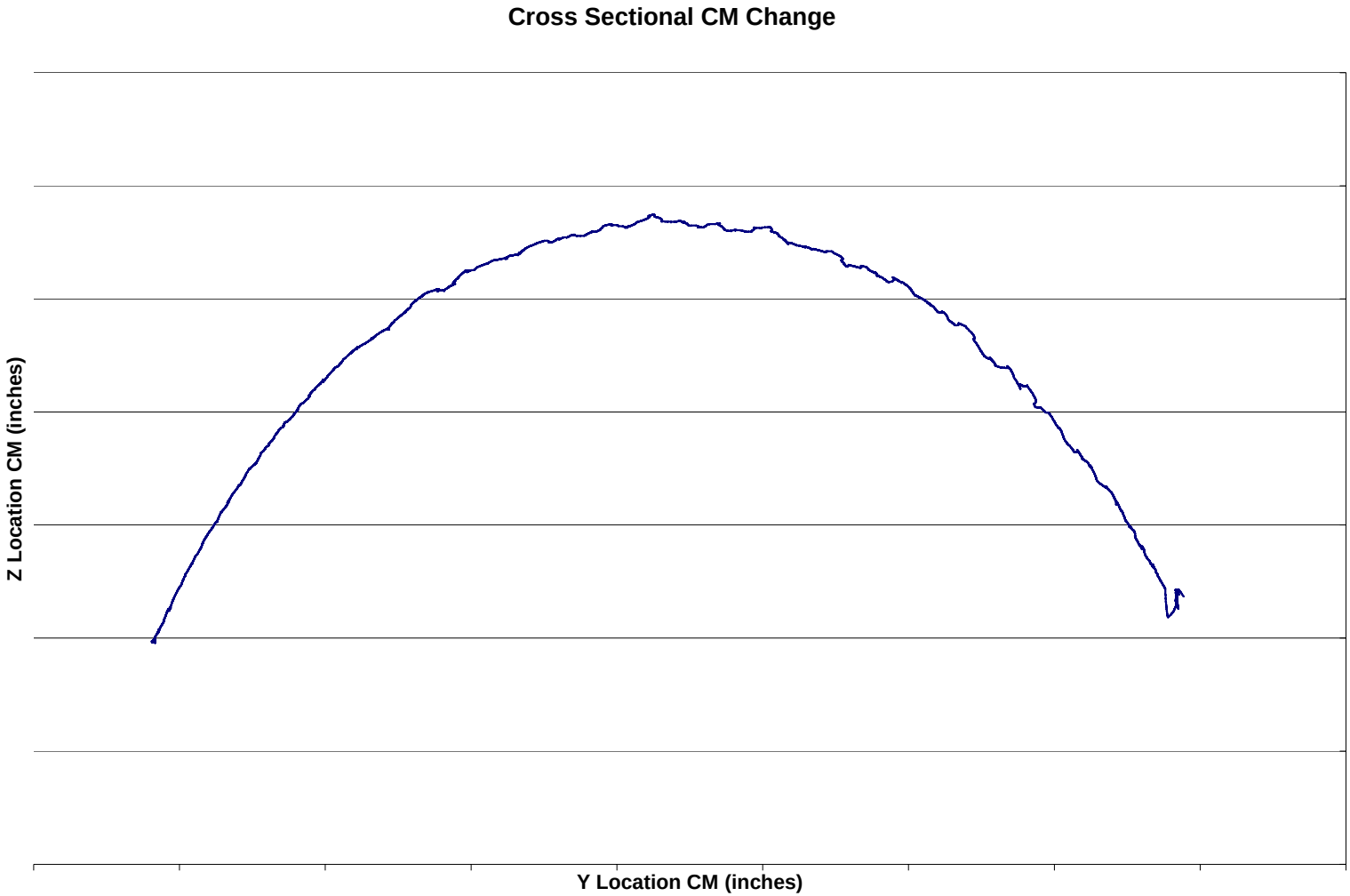



M550 PIBD Fuze

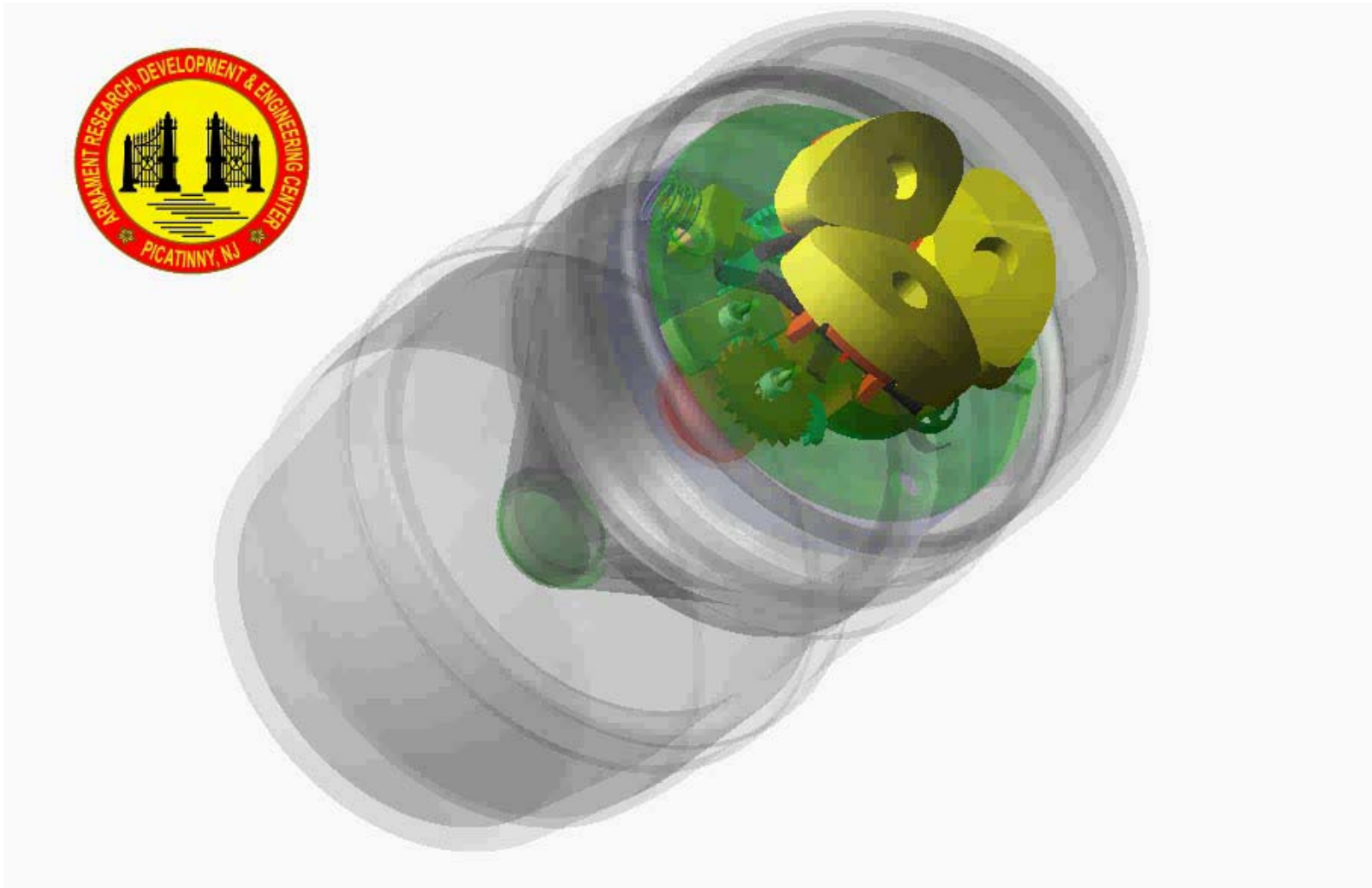
# M430A1 Fuze Arming



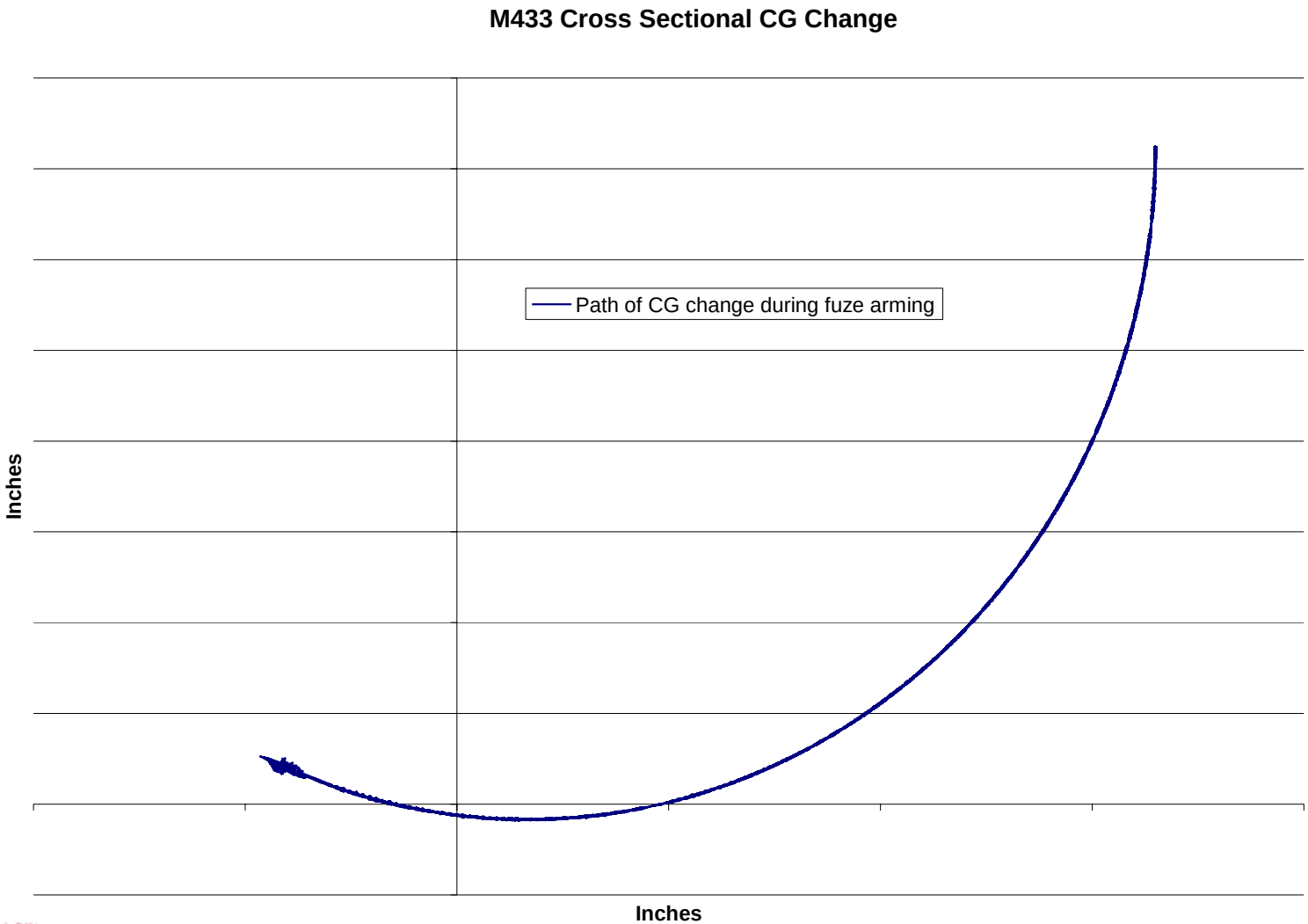
# M430A1 CG Data



# M433 Fuze Arming



# M433 CG Data



# Warfighter Payoff

- Clearer understanding of fuze function
  - Establishes basis for simulating improvements
  - Enhances tool set for failure investigations

# Technical Reports

- For more Information See Technical Reports
  - ARAEW-TR-08001 “Center of Mass Location Changes in M430A1 Throughout Fuze Arming Cycle”
  - ARAEW-TR-06003 “M433 Center of Mass Location Throughout Fuze Arming Cycle”

RDECOM

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

# 40mm Day/Night Practice Cartridge for MK13/XM320/M203 Grenade Launchers

May 20, 2008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40mm Grenade Ammunition Special Projects
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UNITED STATES SPECIAL OPERATIONS COMMAND

PROJECT MANAGER SOLDIER WEAPONS

# BACKGROUND

- **SOCOM identified need in 2003 for 40mm practice cartridge that would facilitate night and day training with EGLM**

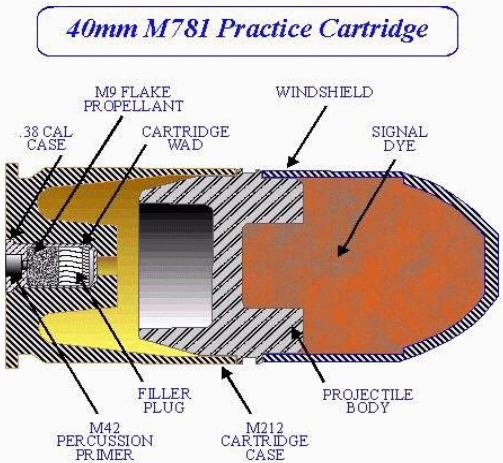
- **SOCOM elected to pursue solution under foreign comparative test program**

# OBJECTIVES
## XM1110 D/N Program

- SHORT TERM (6 months)
  - Provide SOCOM practice round to facilitate night as well as day training w/ MK13/EGLM
    - Low cost
    - Non dud producing
    - Environmentally friendly
- LONG TERM (18+ months)
  - Provide all DOD practice round to facilitate night as well as day training w/ M203 and XM320 grenade launchers
    - Low cost
    - Non dud producing
    - Environmentally friendly

# SOLUTION

- Capitalizing on the success of the 40mm HV D/N Practice Ctg (MK 281 Mod 1) - Rheinmetall Nico of Germany
  - same propulsion system (ctg case/primer/propellant ) as the current M781 practice ctg
  - Chemiluminescent material payload added to the orange powder of the M781 projectile




# PROGRAM HIGLIGHTS

- Key Performance Parameters were established and met (April 2007)
- Successful user trials (IOT) conducted (April 2008)
- Qualification & and ballistic table testing (3QTR 2008)
- Initial fielding of the XM1110 ctg targeted for 2009


# KEY PERFORMANCE PARAMETERS

- Weapon Compatibility
  - Threshold - safely function and fire from M203 grenade launcher without modification to weapon system
  - Objective - safely function and fire from M203, XM320 and MK13/EGLM without modification to weapon system including current range graduations on weapon sight
- Dispersion
  - Threshold - similar ballistics to M433 HEDP Cartridge
  - Objective - ballistic match to M433 HEDP Cartridge
- Signature Visibility
  - Day signature visible at 350 meters. Night signature visible at 350 meters with or without GEN III night vision devices
- Reliability
  - Threshold - reliability > M781 TP Ctg
  - Objective - reliability >= M433 HEDP Ctg
- UXO/ Range Fires
  - None

# TEST PERFORMANCE VIDEO - DAY

# TEST PERFORMANCE VIDEO - NIGHT

# PATH FORWARD

- **SOCOM Milestone C and production release planned for Sept 08**
- **SOCOM initial fielding expected by 4QTR 09**
- **Army and Marine Corps adoption decision expected in early FY09**

# WARFIGHTER PAYOFF

- **SOCOM search for an economical day/night training cartridge is on path to success**
- **Concept of chemiluminescent marker for low velocity 40mm ammo viable solution for night signature**
- **XM1110 has high potential to soon become DOD common practice round with all 40mm low velocity weapons**