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40mm Grenade Ammunition Panel Papers

21 May, 2009

40mm Grenade Ammunition Special Projects Team

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ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

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Development of a 40mm Mann Barrel System for both High and Low Velocity Ammunition

21 May, 2009

Adam Sorchini, 40mm Grenade Ammunition Special Projects

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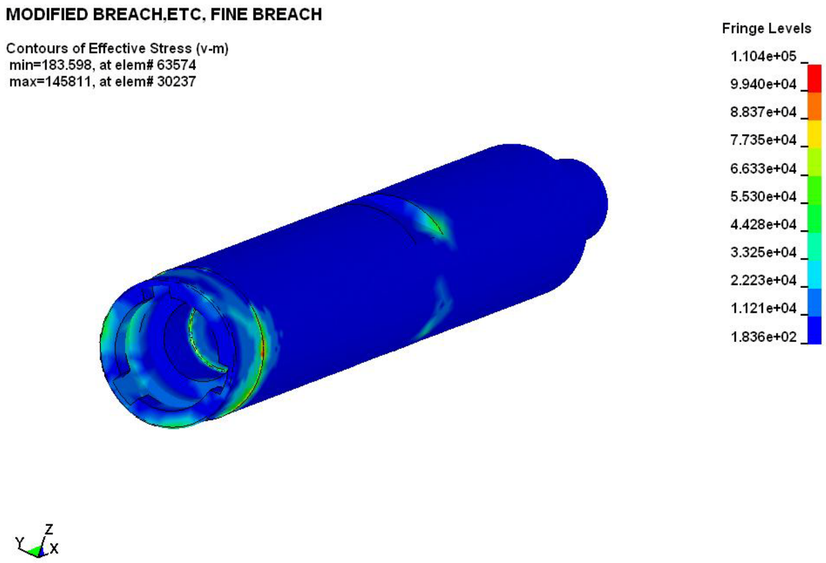
Program Objectives

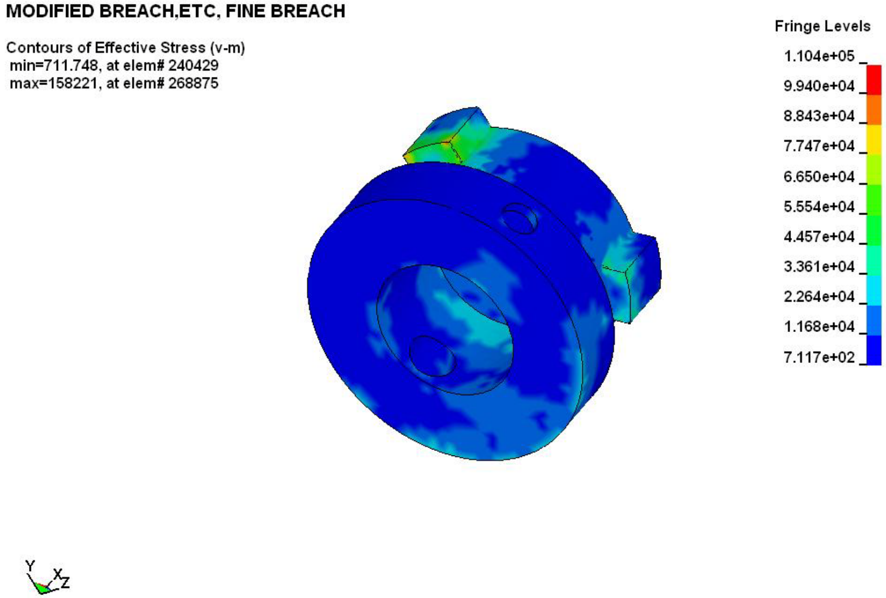
- Develop 40mm test fixture for both High and Low Velocity ammunition
- Design electronically controlled breech system for remote initiation
- Ensure that new Mann barrel system interfaces with current data acquisition system to record EPVAT (Electronic Pressure, Velocity, and Action Time)

Previous Designs

- Previously version of Mann barrel breech used pinball style plunger to initiate primer
- Pin on rope/pulley system was used to release plunger remotely
- Previous breech used interrupted thread to interface with barrel requiring custom fitting

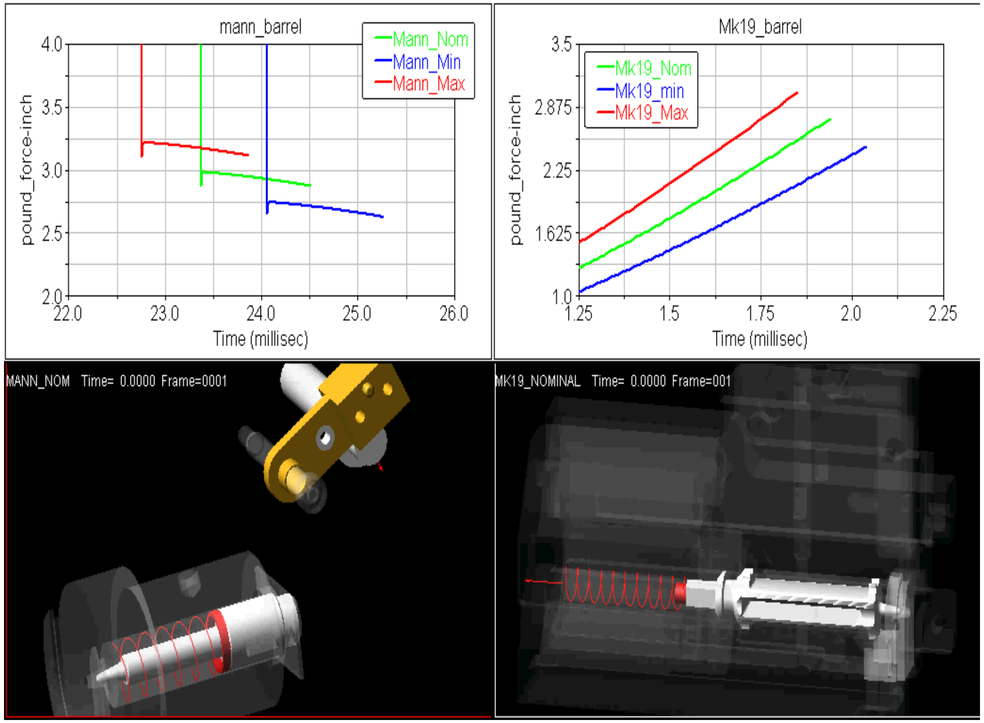
- Mann barrel is rated up to a max pressure of 20 ksi with failure at ~60 ksi
- Breech lugs see highest stress concentrations on lug corners





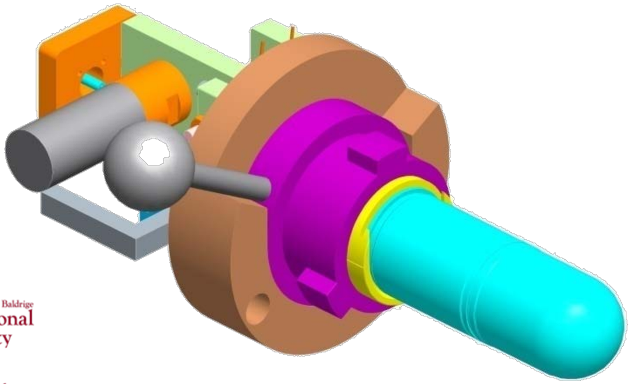
Modeling & Simulation

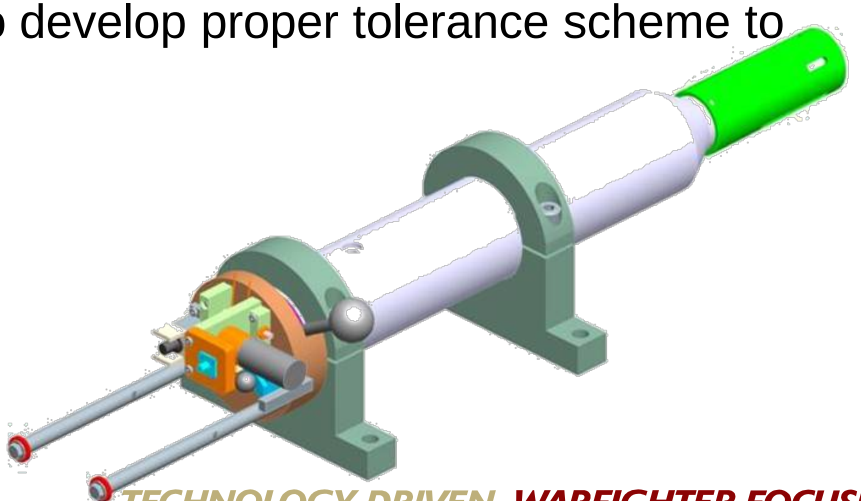
- Used ADAMS to refine the Mann barrel firing energy to match the MK19 and M203 weapons
  - Matched value of energy at primer initiation
  - By changing the firing pin and firing pin spring, the breech is easily converted from a high velocity system to a low velocity system



Initial Prototype

- Mann Barrel System with electronically controlled breech system
  - Design based on Cannon Cal Mann barrel breech
  - Solenoid released hammer
  - Action Time start signal triggered by hammer fall
  - Multiple pressure ports
- Lugged breech configuration allows for interchangeability and eliminates the need to custom fit breeches to barrels
- Tolerance and Fits
  - Collaborated with fabricator to develop proper tolerance scheme to achieve desired fitments





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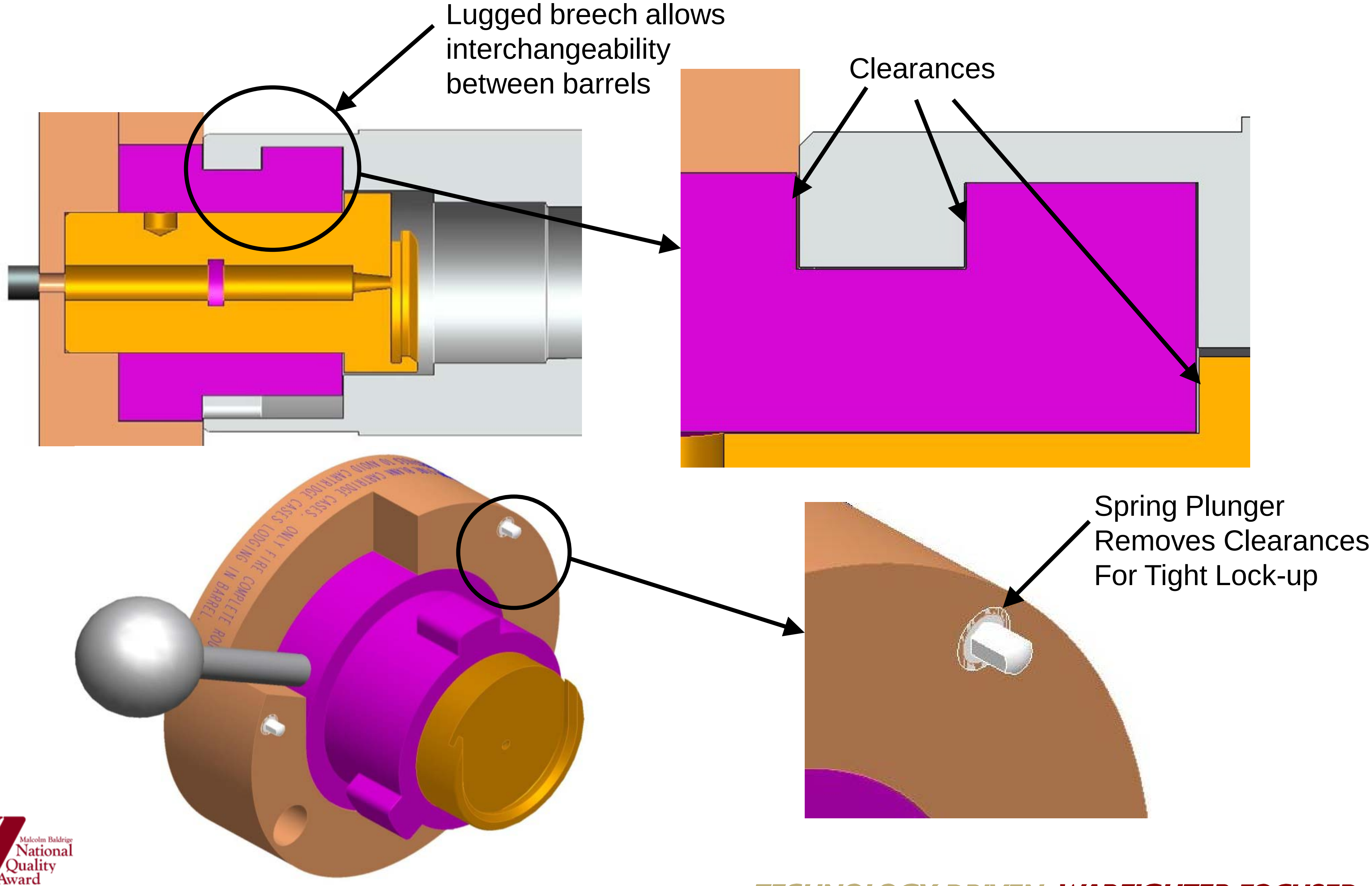
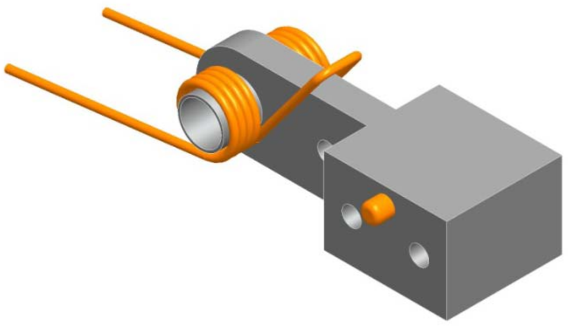
Next Generation Mann Barrel Breech Lock-Up

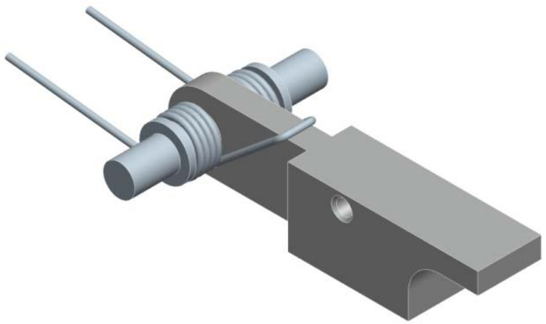


Next Generation Mann Barrel Hammer & Spring Design

- New hammer and spring system provides improved consistency over plunger system
  - More consistent primer initiation
  - More accurate Action Time Start signal
  - Commercially available spring (AR15/M16A1 hammer spring)
- Upgrades to system:
  - New two-piece axle design allows for easier installation
  - New hammer design allows operator to cock hammer easily
  - Assembly simplified



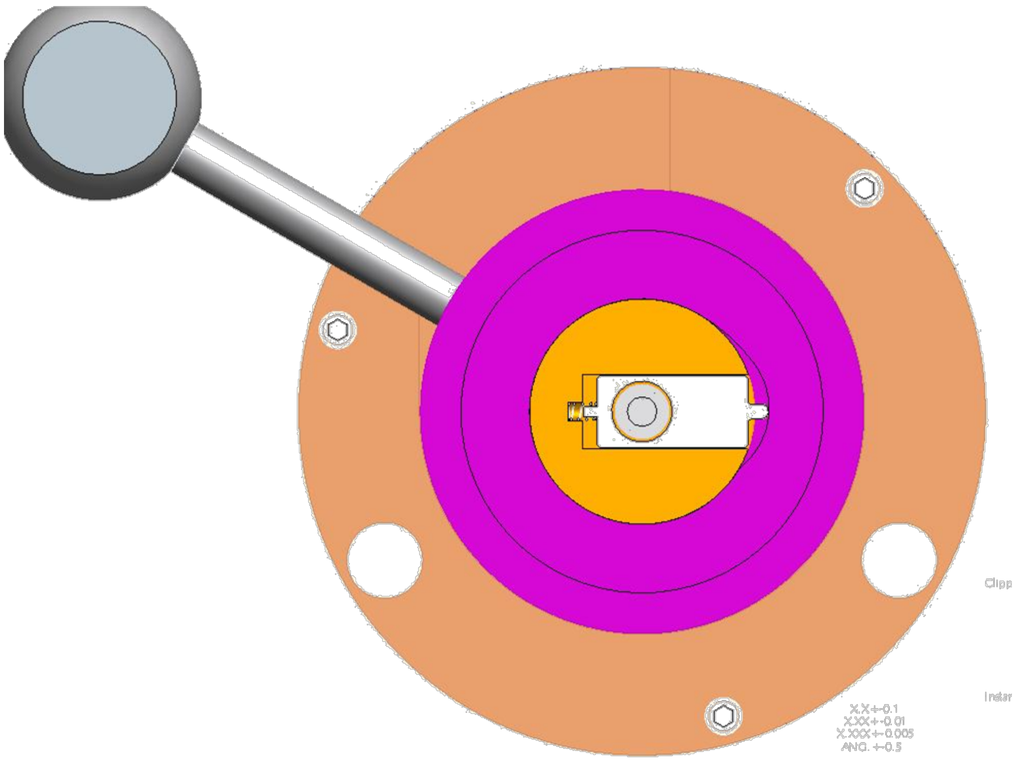
Original Hammer Design



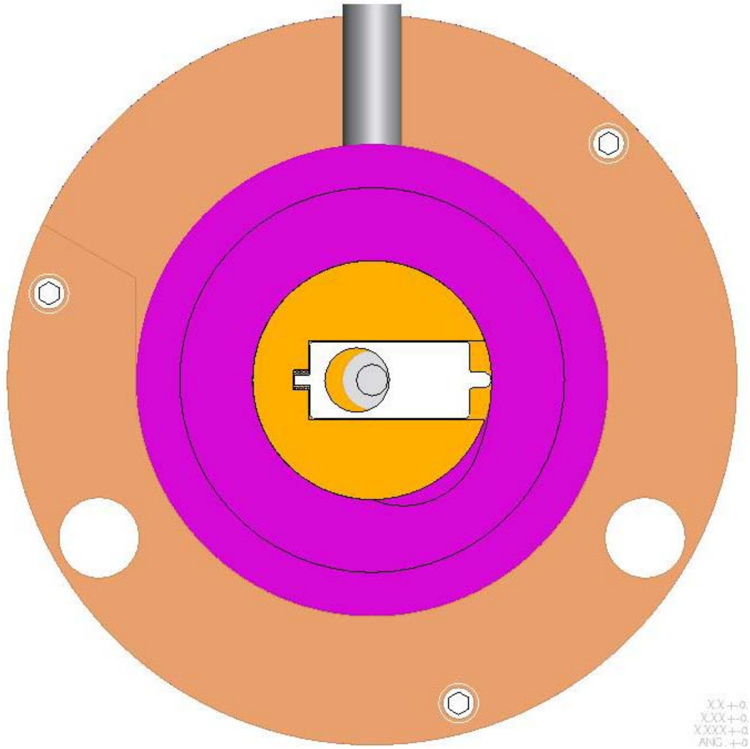
User Friendly Hammer & Two-Piece Axle System

Next Generation Mann Barrel Safety Upgrades

- Upgrade to system includes internal safety interlock
  - Cartridge cannot be initiated until breech is locked
  - Manual safety necessary but secondary



Locked



Unlocked

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Path Forward

- ARDEC currently refining the Mann barrel to maximize user friendliness and safety
- Long term plan to introduce system into production for lot acceptance testing
- Considering ways to determine difference between breeches equipped for high or low velocity ammunition
- Perform 1,000 round endurance test
- Comparison test of Mann barrel to MK19

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Development of a 40mm High Velocity Single Chamber Cartridge Case (SCCC)

21 May, 2009

Matthew Millar, 40mm Grenade Ammunition Special Projects
Peter Martin, 40mm Grenade Ammunition Special Projects

Single Chamber Cartridge Case Program Objectives

- Replace standard dual chamber M169 cartridge case with single chamber case
  - Reduces cost
  - Reduces number of critical/major defects and inspections at the system level
  - Does not degrade current performance

SCCC Benefits

- Eliminate gun stoppage
  - Excessive base plug movement
- Eliminate bolt face erosion
  - Leaking of hot propellant gases past the base plug
- Safety
  - Inability to fire de-bulleted cartridge case into barrel
  - Eliminates base plug ejection during cook-off situation
- Reduce cost
  - Elimination of base plug and closing cup
  - Easing manufacturing processes
  - Reduce critical/major defect inspection

SCCC Program Approach

- Phase I – Design Development
  - Evaluation of case material, primer, propellant confinement methods
  - Finite Element Analysis (FEA) to support design, material, and process development
  - Process and quality assurance criteria
  - Evaluate design, material, and process and quantify variables
- Phase II – Design Validation
  - Evolve manufacturing process
  - Advanced performance analysis/assessment
- Phase III – Production Verification
  - Comprehensive verification tests for transition to production

SCCC Material Selection

Objectives:

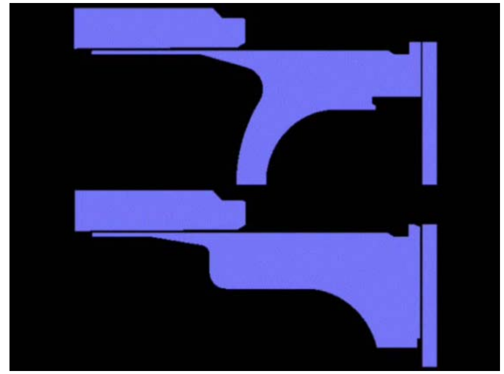
- Establish producible SCCC configuration
- Select and define SCCC material ensuring strength, quality, and Affordability
- Establish a reliable, repeatable high volume manufacturing process ensuring availability, and affordability

- Material candidates (6061, 6061 PT, 6066, 6070)
  - Stress/Strain under pressure
  - Crimp/Pull test
  - Thermal effects
  - Weapon interface

- 6061-T6 chosen as case material
  - Cost, formability, strength

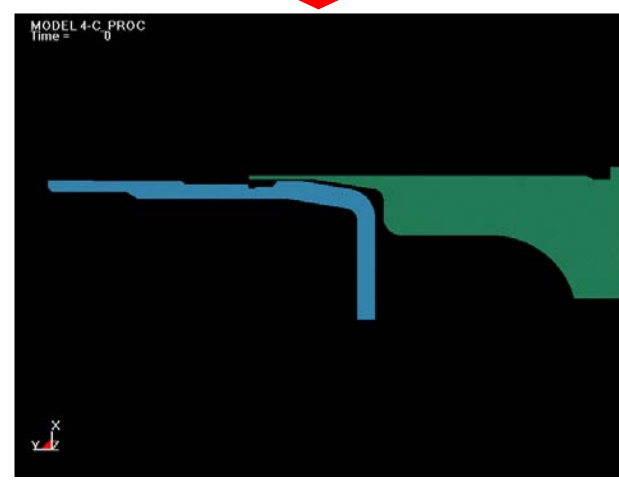
SCCC Modeling and Simulation

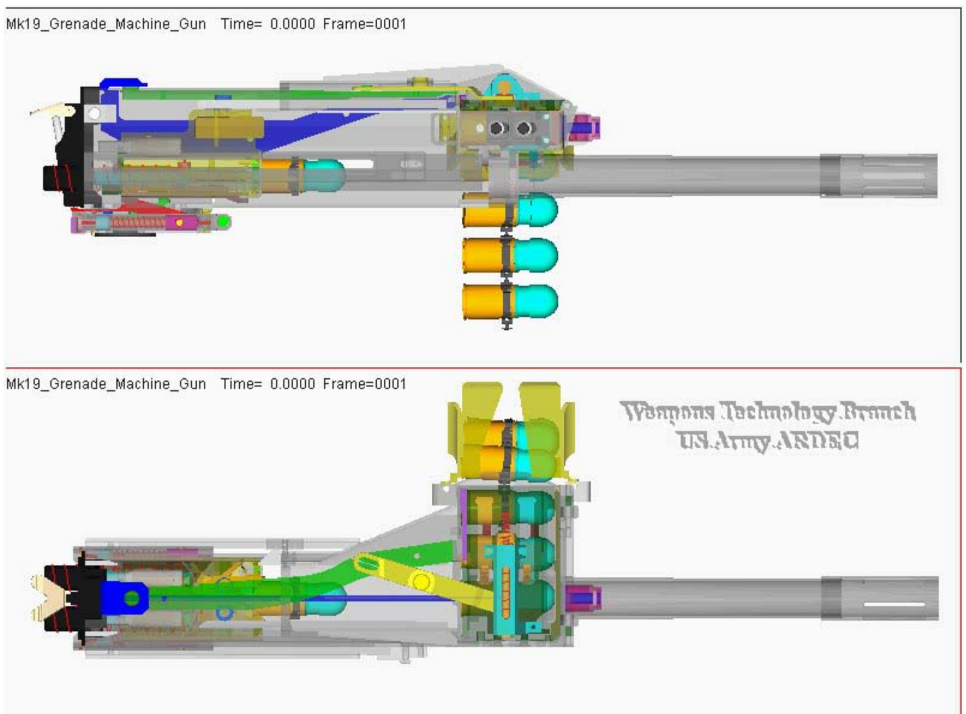
- MK19 weapon function and interface simulation
- Completed FEA with candidate materials



FEA on Unsupported Area of Case

Bullet Pull Analysis





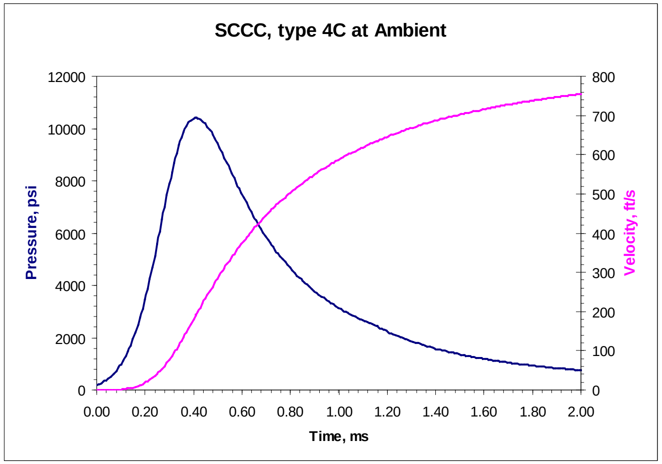
MK19 Simulation

SCCC Propulsion Modeling and Simulation

- Objective
  - Determine appropriate propellant for SCCC
  - Determine charge weights
  - Model pressures and velocities

- Propellant Candidates
  - M9 Flake, Mil-P-50206
  - M2 Single Perf, Mil-P-60989
  - M9 Flake, Mil-P-48127

Producibility and Availability

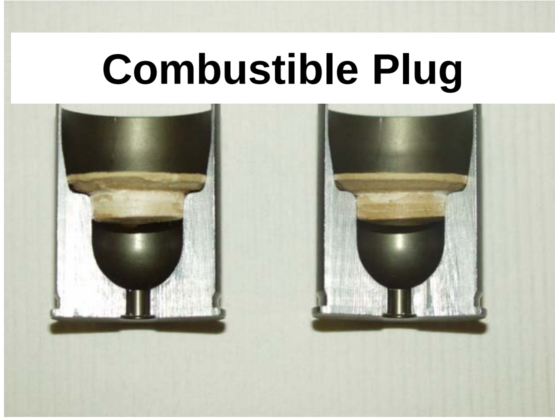


IB Analysis

Propellant	Charge Wt, g	Pressure, psi	Velocity, ft/s	% prop burnt
M9 Flake, Mil-P-50206 (D=0.034", L=0.005")	**3.00**	**11952**	**769**	**100**
	3.25	**13478**	**807**	**100**
M9 Flake, Mil-P-48127 (D=0.058", L=0.006")	**3.25**	**10057**	**766**	**100**
	3.50	**11239**	**804**	**100**
M2 Single Perf, Mil-P-60989 (D=0.039", L=0.048", web=0.016")	**3.00**	**3495**	**358**	**38**
	4.00	**3423**	**435**	**39**

Propellant Confinement Method

- Objective
  - Confine the propellant in the cavity from cartridge case loading until firing
  - Closure disc adhere to anodized aluminum
  - Ease of assembly / support high volume production
  - Immune to environmental/aging effects
  - Compatible with propellant
- Candidates
  - 5 adhesive discs & 1 combustible plug
    - Various facestock and adhesive



- Down-selected candidates
  - Cost, adhesive strength, ease of assembly, compatibility

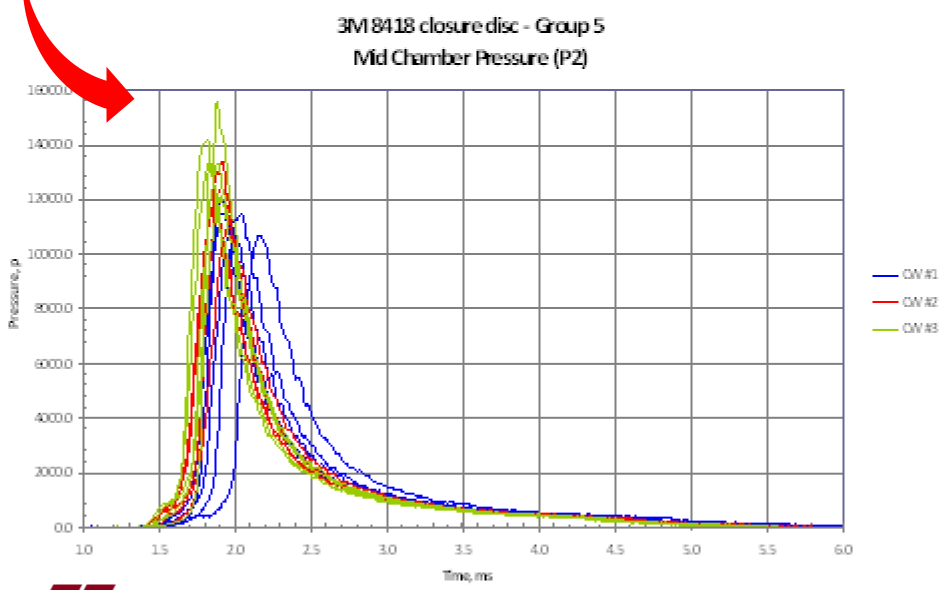
DISC MATERIAL
Aluminum
7830
8414
Chic A
Chic B
NC
7871

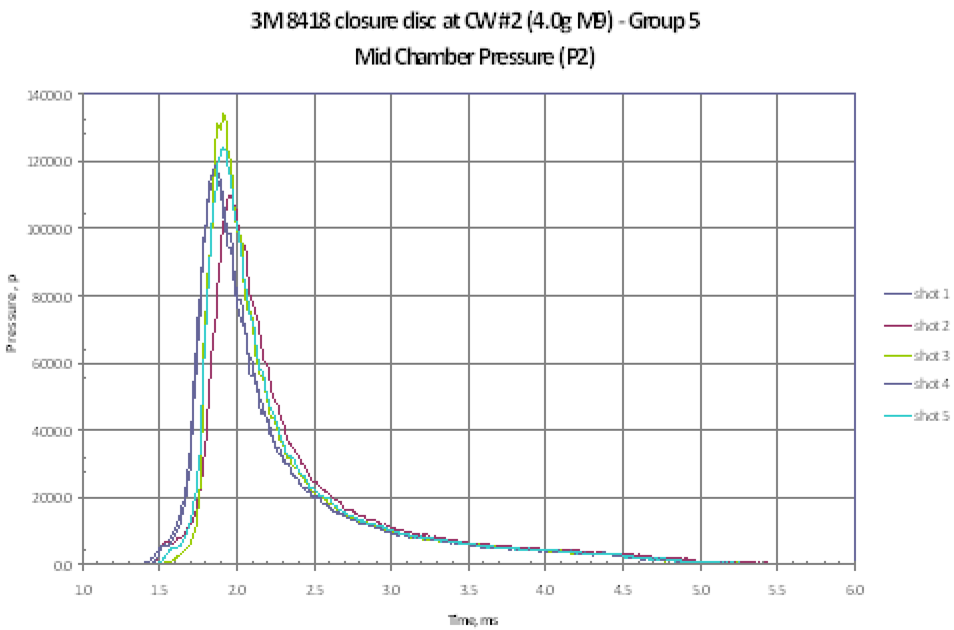
Ignition System

- Objective
  - Repeatable output and sensitivity
  - Output to support combustion of propellant
- Primer Candidates
  - W209 (shotshell primer) & Fed215 (large rifle magnum)
    - W209 more sensitive & higher energetic output
    - Similar profiles and action times
    - Fed215 more production oriented
- Closed bomb analysis - primers are interchangeable when used with the same propellant

Charge Establishment

- Established baseline performance of M169 case using Mann Barrel
- Initial propellant charge weight for SCCC determined from IB code
  - Charge weights constant for two closing discs
  - Charge weight adjusted for combustible plug energy
- Cases loaded to ±5% of initial IB code weight
  - Fired at hot (+165ºF), cold (-65ºF), and ambient (70ºF)
- Test showed signs of unburned propellant
  - IPT is investigating ways to improve propellant efficiency





Path Forward

- Optimize propulsion system efficiency
  - Alternate primer
  - Alternate propellant
- Down select to best propulsion system and confinement method & continue maturity
- Continue into next phase of testing
  - Environmental
  - Rough handling
  - MK19 integration
  - Qualification
  - Production transition

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M385A1 Composite Projectile Feasibility Study

21 May, 2009

Christopher Summa, 40mm Grenade Ammunition Special Projects

Overview

- **Objectives**
  - Reduce unit cost
  - Integrate rotating band to projectile body
  - Meet existing requirements of M385A1

- **Method**
  - Replace aluminum with injection molded plastic/metal powder composite
  - Reduce manufacturing/assembly operations

Feasibility Studies

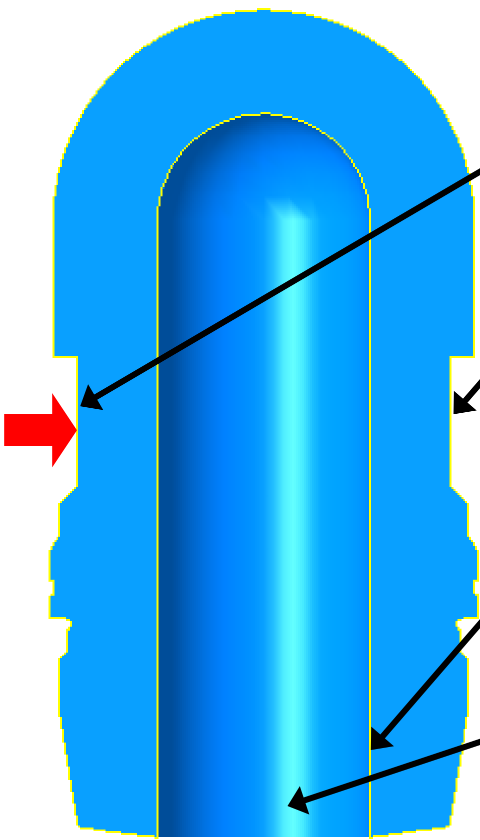
- Phase 1: Characterize and down-select materials
- Phase 2: Mold, assemble, and inspect projectiles
- Phase 3: Conduct live fire and environmental testing

- Results of Phases 1-3:
  - Some success test firing from Mk19 Mod 3 GMG
  - Gas cap required for projectile to survive launch
  - Improvement potential for part strength and dimensional stability

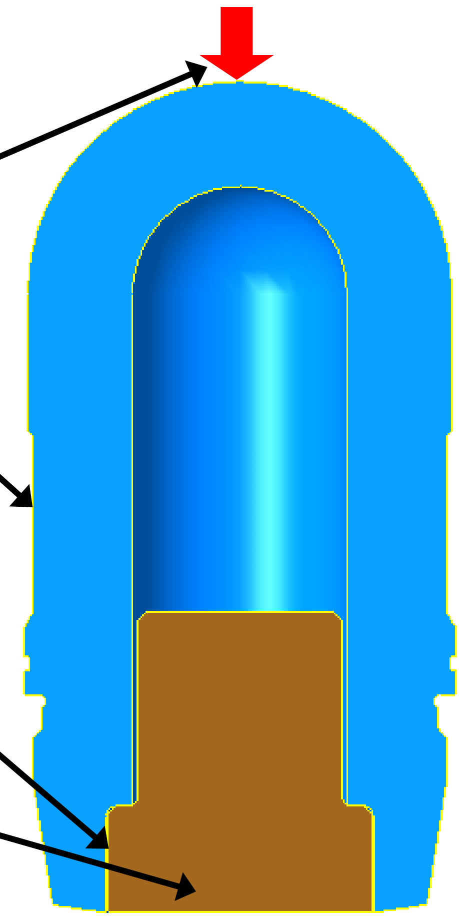
- Phase 4: Follow On Effort
  - Projectile Design Changes
  - Mold Optimization Analysis
  - Mold Modification
  - Produce/Inspect Projectiles
  - Inspection
  - Test Firing at ARDEC

Projectile Design Changes

<u>Previous Design</u> <u>New Design</u>



1. Moved gate location from side to top
2. Saddle region thickened to match M430A1 HEDP (tactical cartridge)
3. Gas cap recess added to mold core pin
4. Steel gas cap assembled to aft of projectile



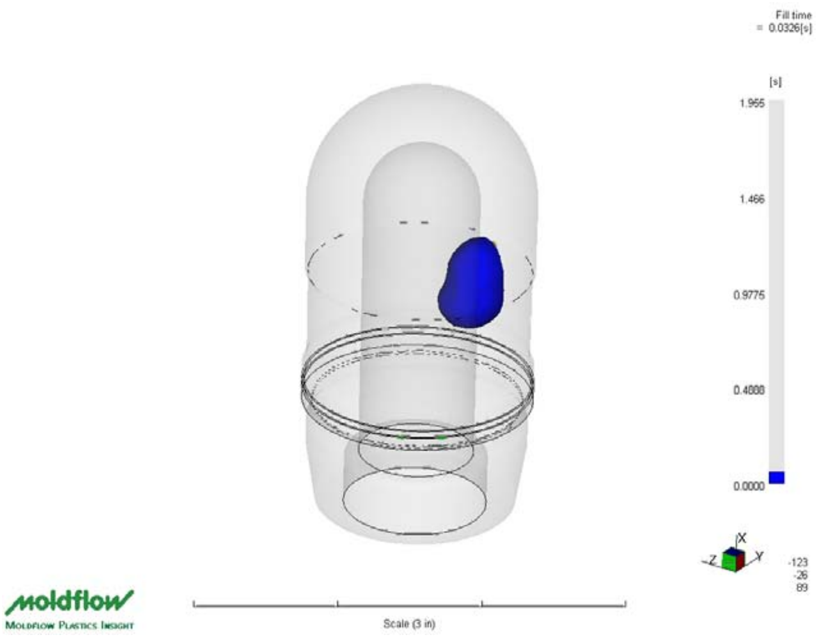
Material: PA 6/10 with Stainless Steel Fill

Mold Optimization Analysis

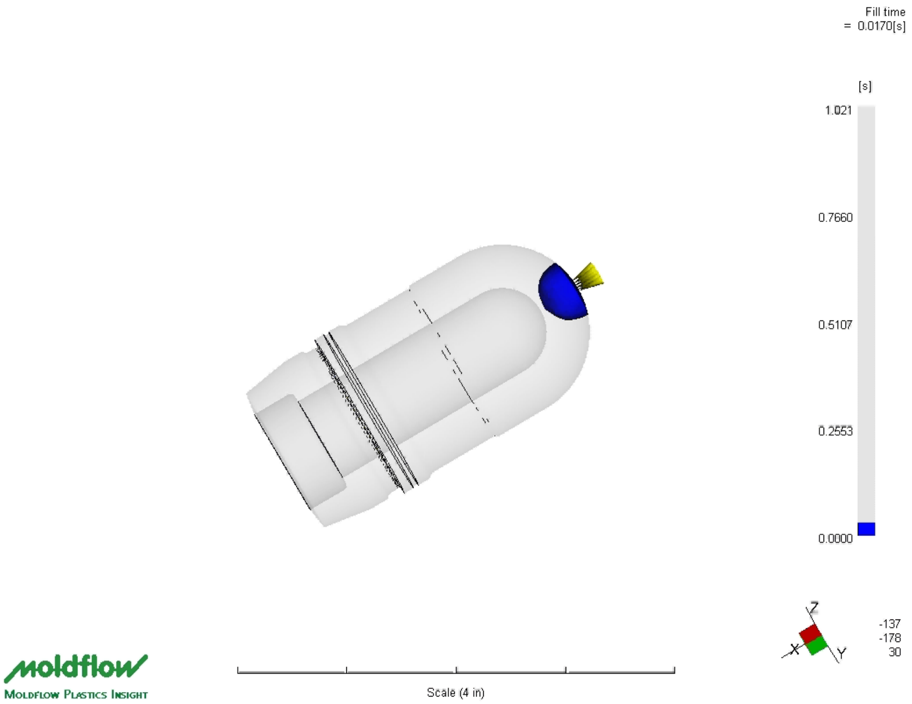
- Mold flow analysis baselined on original geometry
- Analysis calibrated to actual projectile dimensions from original effort
- New projectile geometry implemented into analysis
- Used fill material similar to PA 6/10 with SS
  - Better characterized than actual material
- Gate configuration, size, and location optimized
- Full round top gate superior to existing side fan gate:
  1. Reduced core pin deflection
  2. Part geometry more stable
  3. Less part ovality

Mold Optimization Analysis

Side Fan Gate

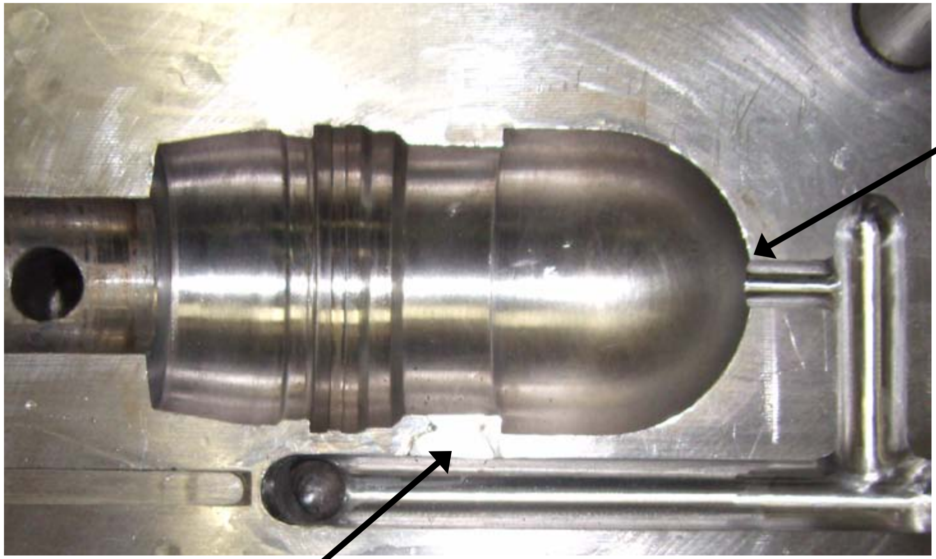


Top Gate



Mold Modification

- **Top gate implemented before other modifications**
- **Examined shrink rate with top gate on current geometry**
- **Modified existing mold cavity and core pin**



Path Forward

- Contractor to mold & inspect 100 projectiles
- Test Firing
  - Performed at Armament Technology Facility (ATF) located at ARDEC
  - Hot, Cold, Ambient cartridge conditioning
  - Unlinked & linked belt configuration (single shot and burst) from Mk19 Mod 3 GMG
  - EPVAT Testing from Mann Barrel
    - Muzzle Velocity
    - Pressure
    - Action Time
- PM to decide future of composite projectile program
  - Technology applicable to other cost reduction programs

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Producibility Improvements of 40mm High and Low Velocity Liners

21 May, 2009

James Grassi, 40mm Grenade Ammunition Special Projects

Program Objectives

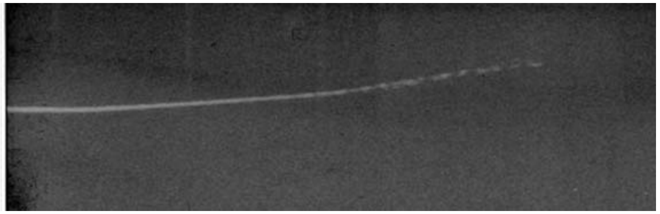
- M433 HEDP One-Piece Liner (Low Velocity – M203 GL)
  - Reduce cost of liner production by combining components
  - Improve penetration reliability
- M430A1 HEDP Non-Fluted Liner (High Velocity – Mk19 GMG)
  - Reduce cost of liner production by simplifying geometry


M433 HEDP


M430A1 HEDP

Baseline Testing and M&S

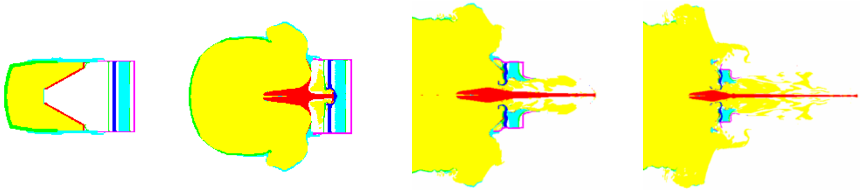
- Baseline Testing
  - Performed at ARDEC using production hardware
  - Jet tip formation
    - Spin and no spin
    - Events captured by x-ray
      - Tip velocity
      - Jet straightness
  - Armor penetration depth
    - Spin and no spin
    - RHA steel plates
- Baseline Modeling and Simulation
  - Test data feeds into baseline model
    - Model represents actual performance
  - Baseline model stepping stone to design improvements



X-Ray of Jet Formation

Penetrated RHA

Test Projectile

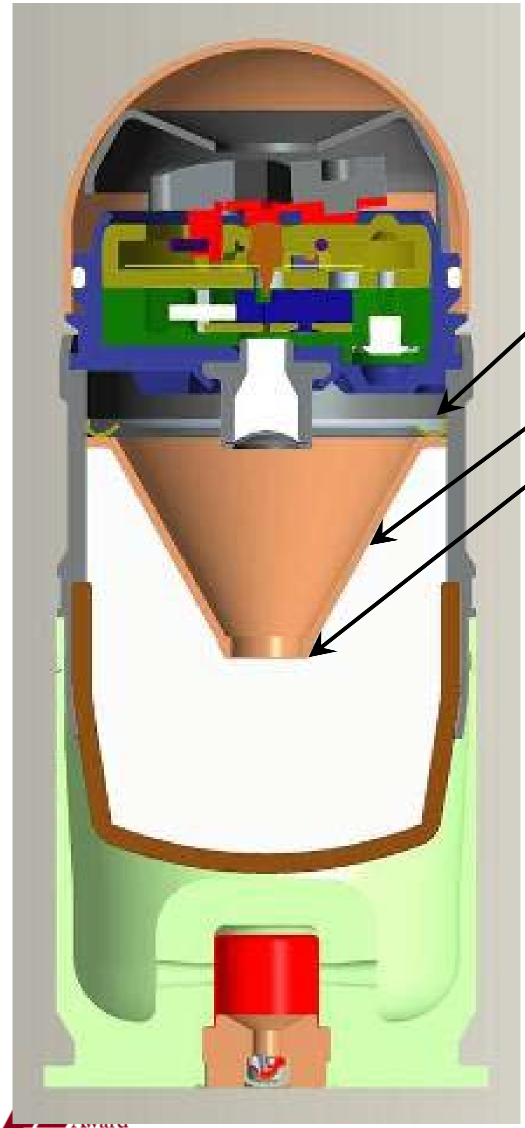


Jet Formation Simulation

M433 HEDP One-Piece Liner Program Overview

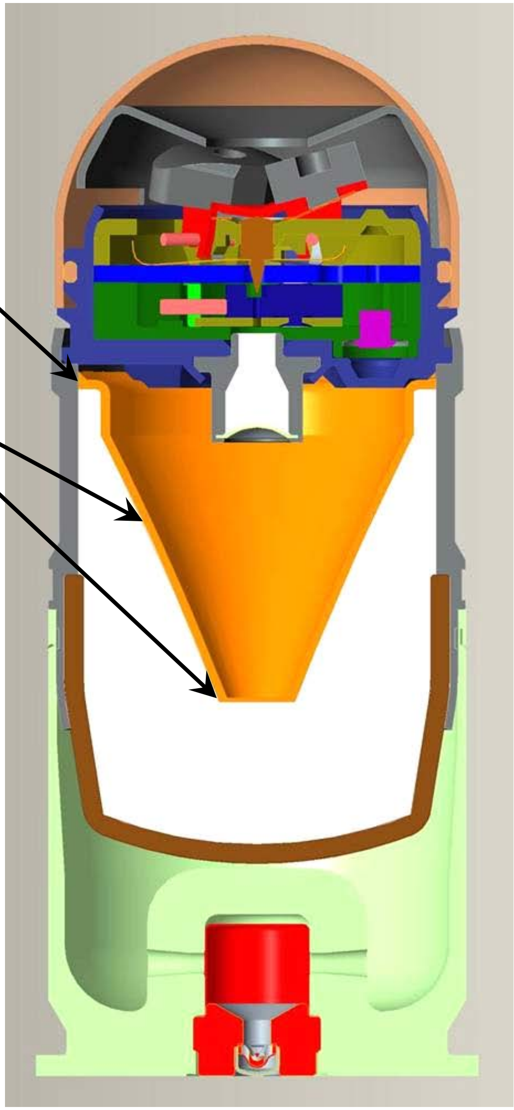
- ARDEC **Warheads** designed liner based on validated simulation
- ARDEC **Ammo** integrated apex cap & retaining ring features
  - Analysis showed slight jet velocity loss with integrated apex cap at full wall thickness
- Phase 1 - fabricate liners with varying apex cap thickness & perform static armor penetration test
  - Objective: determine max allowable apex thickness
- Integrated Product Team
  - PM-MAS
  - ARDEC (Ammo & Warheads)
  - DSE (Prime Contractor)
  - FCI & Trans-Matic (Liner Mfg Sub-Contractor)
  - American Ordnance (Projectile Assembly)

M433 HEDP One-Piece Liner



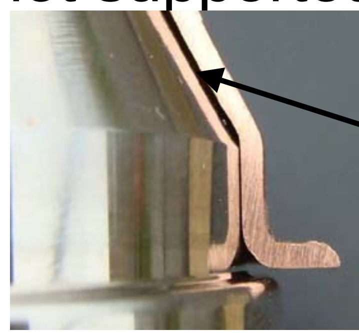
One-Piece Liner

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



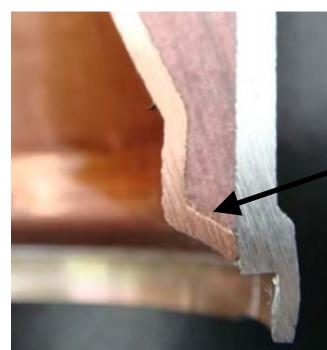
M433 HEDP One-Piece Liner

- Challenges
  - Required multiple iterations on both liner & explosive press tooling
  - Flange not forming up as expected and leaving void under flange (flange not supported)



Explosive Tooling Gap

Contact should be farther out radially to eliminate annular depression



Flange Not Forming As Anticipated

M433 HEDP One-Piece Liner Results & Path forward

- Phase 1 Results
  - Slightly greater penetration
  - Can function with full apex cap wall thickness
  - Requires optimization of flange design to improve loading

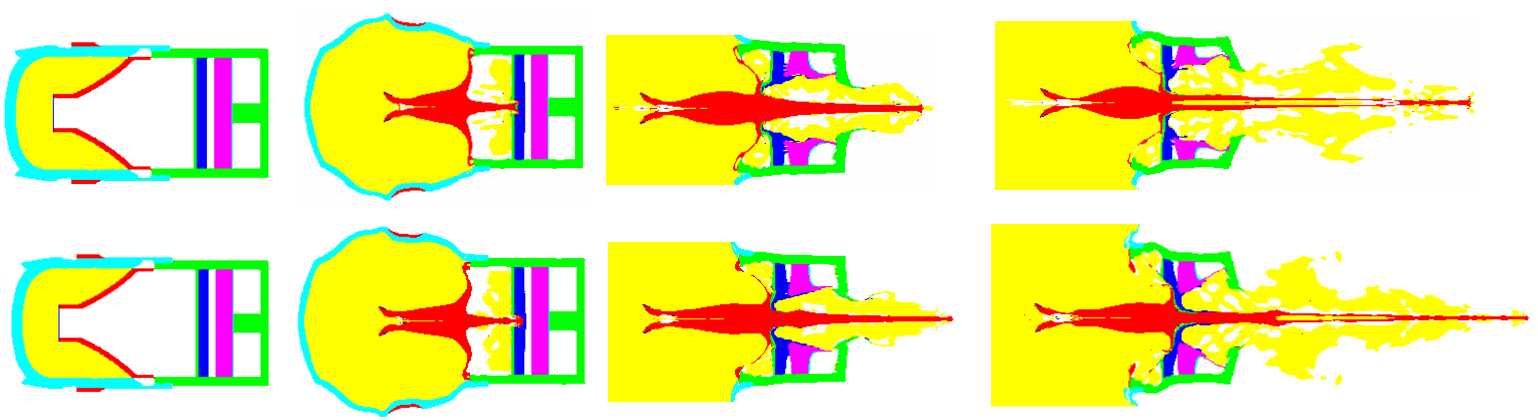
- Path forward
  - Conduct Phase 1B contract
    - Fabricate optimized liners
    - Jet characterization & penetration lab tests
    - Gun launch projectiles against armor plate

M430A1 HEDP Non-Fluted Liner

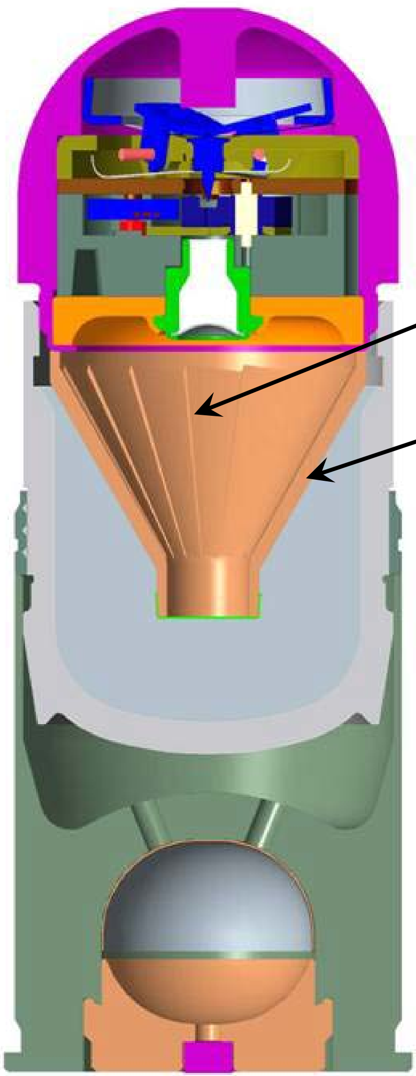
- ARDEC **Warheads** designed liner & ARDEC **Ammo** teamed with contractors to integrate producibility enhancements
- Phase 1 - fabricate liners & perform static shaped charged jet characterization & armor penetration test
  - No spin
  - Multiple spin rates analyzed due to large spin decay over effective range

Fluted Liner

Non-Fluted Liner

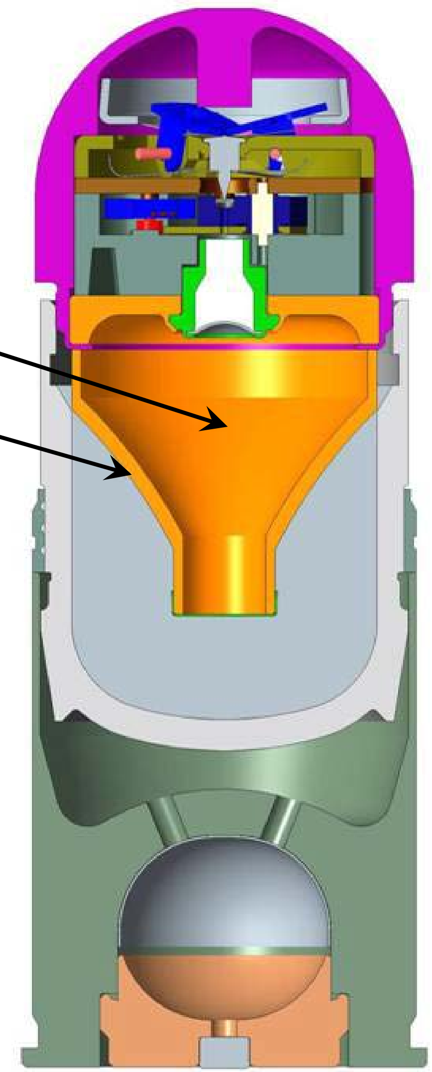


M430A1 HEDP Non-Fluted Liner



Non-Fluted Liner

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

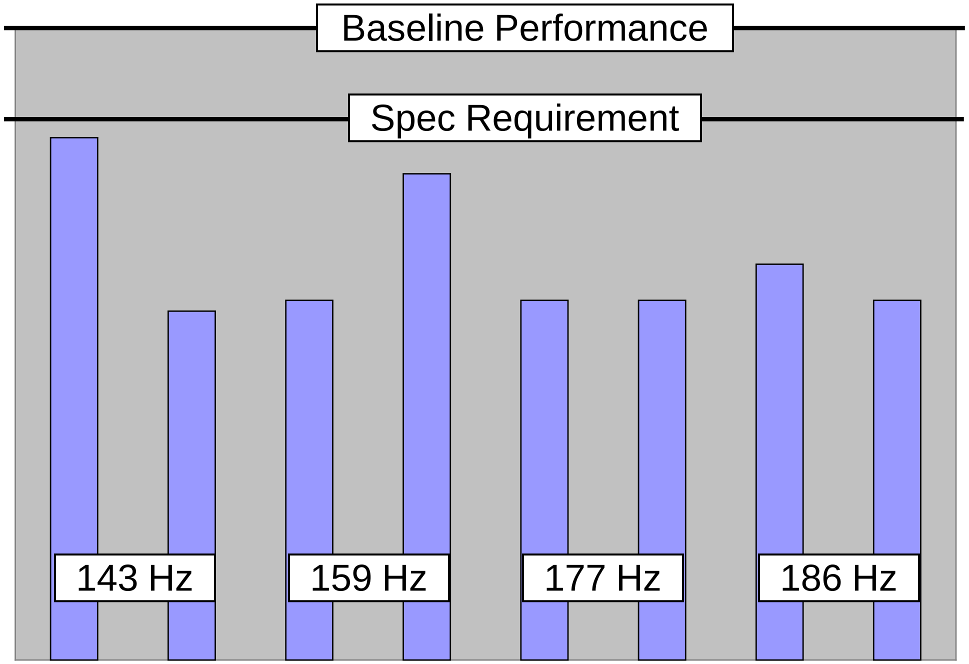


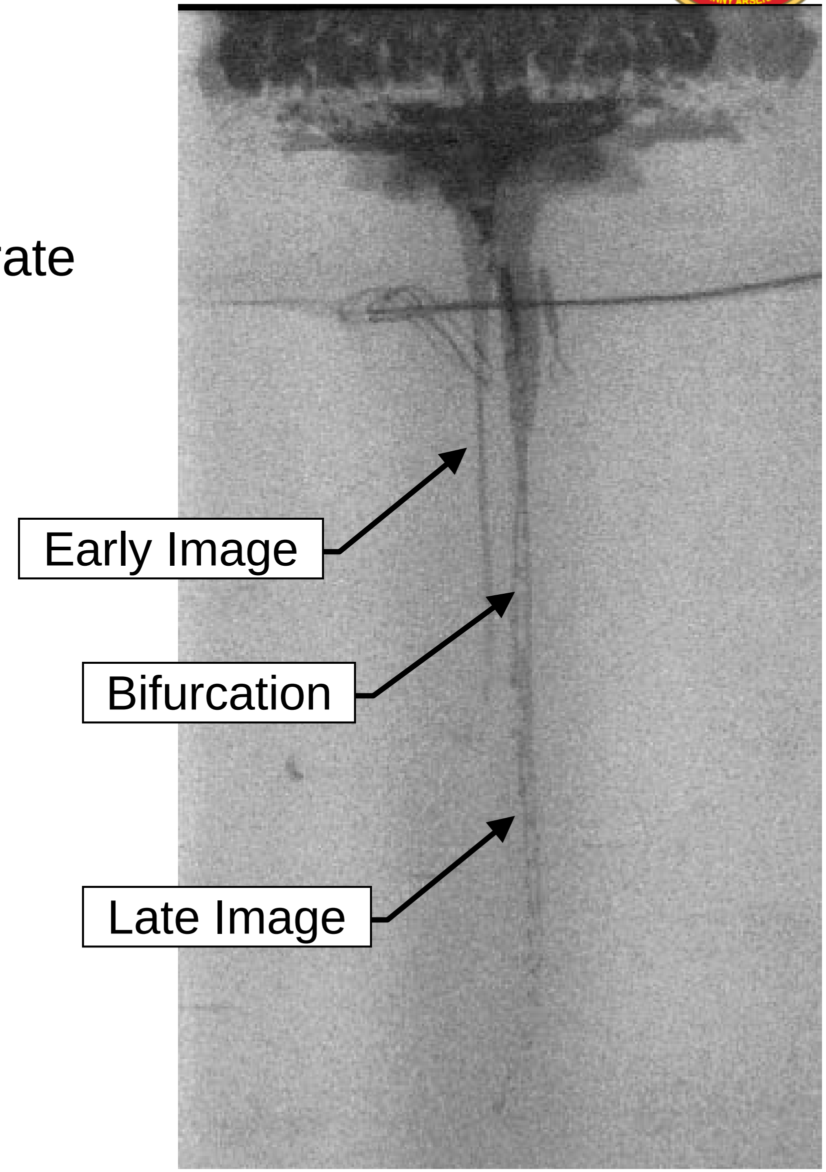
M430A1 HEDP Non-Fluted Liner

- Integrated Product Team
  - PM-MAS
  - ARDEC (Ammo & Warheads)
  - AMTEC (Prime Contractor)
  - FCI & Trans-Matic (Liner Mfg Sub-Contractor)
  - American Ordnance (Projectile Assembly)
- Producibility Study & Fabrication
  - IPT adjusted dimensioning scheme for producibility
  - Tightened material specification
  - Looked at grain structure uniformity
  - Reduced learning curve due to One-Piece Liner Program
    - No issues with tooling, part fabrication or explosive loading

M430A1 HEDP Non-Fluted Liner

- Test Results
  - Poor penetration
  - Bifurcation regardless of spin rate including no spin condition





M430A1 HEDP Non-Fluted Liner

- Path Forward
  - M&S of Liner using inspection data to reproduce bifurcation (2D & 3D simulations)
  - Copper material & grain size study

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Study of Advanced Lethal Mechanisms in 40mm Grenade Ammunition

21 May, 2009

Jason Wasserman, 40mm Grenade Ammunition Special Projects

Objectives

- Close-In Anti-Personnel Lethality Study
  - Characterize the lethality of sub-projectiles given various parameters
  - Analyzed both mission oriented and independently
  - Study intended to establish cartridge design parameters for 40mm low velocity system
- Enhanced Fragmenting Grenade Study
  - Scalable technology for high and low velocity grenade ammunition
  - Dramatically increase lethality over currently fielded high and low velocity system

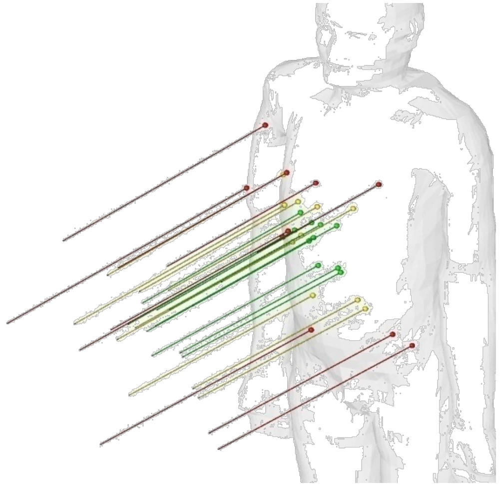
Close-In Anti-Personnel
Overview

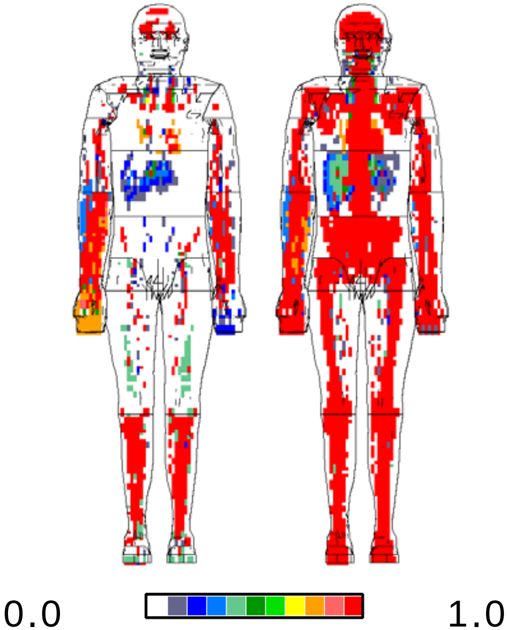
- Analyze how various parameters affect sub-projectile lethality
  - Determine added benefit over currently fielded systems
    - 12 Ga. Shotgun and M576 Multiple Projectile Ctg (Spherical shot based systems)
  - Determine optimal design requirements for increased lethality
  - Analyzed Parameters
    - Sub-projectile Shape, Size, Material, Quantity
    - Range, Muzzle Velocity, Pellet Spread, Aim Error

Close-In Anti-Personnel

Lethality Analysis

- ARL using ORCA to determine individual sub-projectile lethality
- Calculations made assuming randomly placed pellets given dispersion parameters
- Lethality is calculated as mission-oriented
  - Inability to carry out assigned task in a prescribed time frame
    - Stand, Aim, and Fire

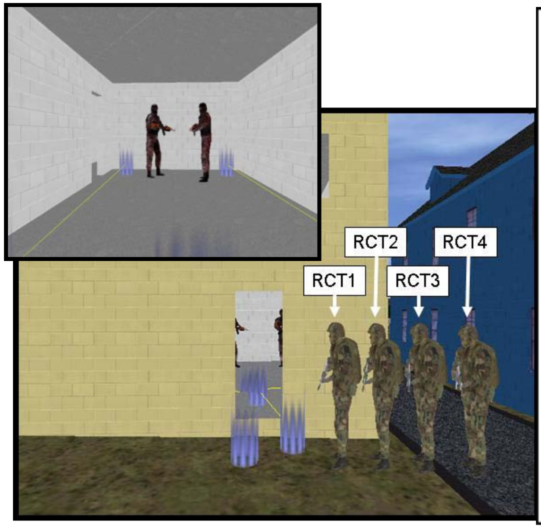


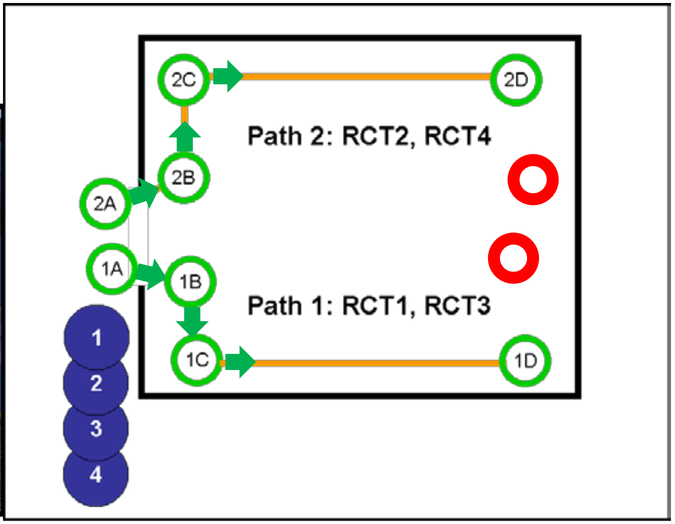


Close-In Anti-Personnel

Infantry Warrior Simulation (IWARS)

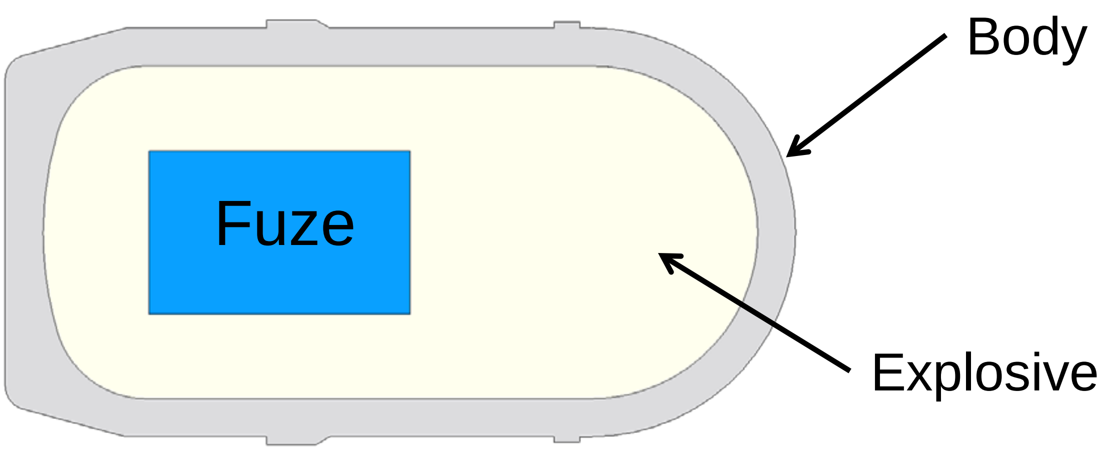
- Used to determine system effectiveness in a realistic Close Quarter Battle situation
  - Evaluates loss of fire team under various scenarios
- Baselined against fielded shotgun system and M4 carbine
- Able to include various protective gear, number of enemy combatants, and tactics





Enhanced Fragmenting Grenade

- Design Parameters
  - Designing complete new cartridge system
    - Started with generic shape to develop ideal flight properties
    - Potential new propulsion system for heavier projectile
  - Using fuze envelope from MEMS S&A program
  - Lethal mechanism based on work done in cannon caliber



Enhanced Fragmenting Grenade

- Producibility Study
  - Working with contractor to develop production methods
    - Placing preformed fragments
    - Optimizing packing factor
    - Material selection
    - Assembly procedures prior to explosive loading

RDECOM

Path Forward

- Close-In Anti-Personnel
  - Anticipate study to conclude by October 2009
  - IPT to determine feasibility of forming a cartridge development program
- Enhanced Fragmenting Grenade
  - Lethality analysis
  - Prototype fabrication
  - Lab testing for fragmentation performance