Cost Reducing Material For 40mm Practice Cartridges

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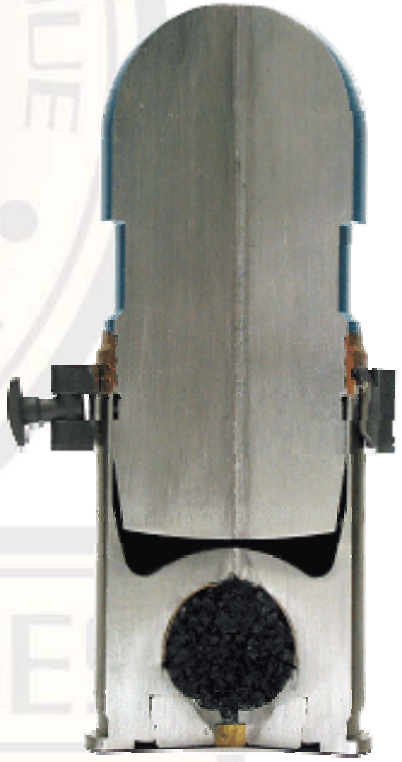
Cost-Reducing Material Substitution

- M385A1 One-Piece Projectile Feasibility Study
  - 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

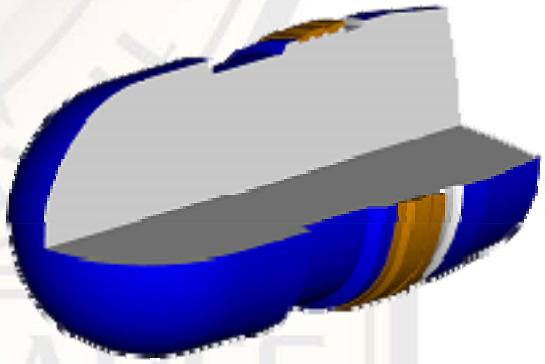
Cost-Reducing Material Substitution

- What is the 40mm M385A1 Practice Cartridge?
  - Check-out round for the Mk19 GMG Mod 3
  - Fired from a linked configuration
  - Muzzle Velocity = 240 m/s
  - Peak Chamber Pressure = 95 MPa
  - Aluminum projectile body with swaged copper rotating band
  - Approximately $6.00 per projectile



Cost-Reducing Material Substitution

- Current Fabrication of M385A1 Projectile:
  - Profile machined from aluminum bar stock
  - Copper rotating band swaged onto projectile body
  - Final machining performed
  - Projectile anodized



Cost-Reducing Material Substitution

- Conception of M385A1 One-Piece Projectile:
  - Desire for integral rotating band
    - Aluminum projectile with integral band
      - Hard anodized aluminum rotating band may erode bore
    - Thermoplastic projectile with integral band
      - Commercial thermoplastic specific gravity too low to match to current projectile weight (245g)
      - Cannot obtain ballistic match

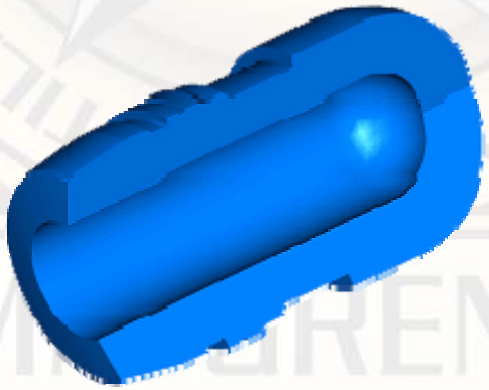
Cost-Reducing Material Substitution

- Advantages of Polymer-Metal Powder Composite
  - Can composite almost any commercial-grade injection moldable polymer with metal powder
  - Machinable & Injection moldable
  - Tunable material density
  - Colorable
  - Emboss/Engrave instead of Stencil Marking

- Functional Advantages
  - Reduce cost with injection molding and insert molding
  - Less effort to design in Ballistic Match
  - Combine components/features to reduce number of parts
- ARDEC Value Engineering submission #20052007

Cost-Reducing Material Substitution

- M385A1 One-Piece Projectile Feasibility Study
  - Prototype Mold
    - Single-cavity with parting line along axis
    - Core placed on aft side of projectile
  - Challenges
    - Preliminary/Static FEA shows minor ballooning in saddle area
    - Core volume increases chamber volume which may reduce MV



Cost-Reducing Material Substitution

- **Outline of Feasibility Study:**
  - **Phase 1**

☑ Contract Awarded	9/05
☑ Ten Materials Recommended	11/05
☑ Uncolored Test Specimens Produced	12/05
☑ Physical Properties Tested	1/06
☑ FEA Analysis Performed	1/06
☑ Colored Test Specimens Produced	2/06
☑ Physical Properties Retested	2/06
☑ Four Materials Graduated to Phase 2	2/06

Cost-Reducing Material Substitution

- Competitive Bidding Process
  - Five companies evaluated based on the following criteria:
    1. Description of Task Fulfillment
    2. Polymer/Metal Powder Selection and Ability to Produce Integrally Blue Compounds
    3. Compound/Injection Molding Experience and Current Products Sold
    4. Mold Fabrication and Adjusting for Different Candidate Compounds
    5. Ability to Dimensionally Inspect Final Projectile
  - Ecomass Technologies awarded contract due to superior marks in all fields.

Cost-Reducing Material Substitution

- **Feasibility Study: Phase 1**
  - **Ten initial material recommendations given by Ecomass**
    - **Based upon stated specifications and requirements for M385A1 practice round**
    - **5 thermoplastic polymers combined with 2 different metal fills**

Polymer Matrix		Metal Powder Fill
• Super Tough Nylon 6/10 (PA6/10) • Co-Polyamide (COPA) • Super Tough Polyphthalamide (PPA) • Polyoxymethylene (POM) • Super Tough Polybutylene Terephthalate (PBT)	+	• Stainless Steel • Tungsten

Cost-Reducing Material Substitution

- **Feasibility Study: Phase 1**
  - Uncolored test specimens for ten materials compounded and molded
  - Material properties tested and quasi-static FEA Analysis performed
    - Properties tested include:
      - Melt Temp
      - Shear Modulus
      - Ultimate Tensile Strength
  - One material cannot be compounded due to chemical incompatibility
  - Four materials dropout due to insufficient UTS
  - Remaining five materials retested with color and reran through FEA
  - Four materials down-selected for Phase II of study

Colored Test Sample – Match to M385A1 spec color

Colored Test Sample – Blue shade typical of M918 TP

Uncolored Test Sample

Cost-Reducing Material Substitution

- Outline of Feasibility Study:
  - Phase 2

☑	Prototype Materials Compounded/Retested	3/06
☐	FEA Analysis Updated	3/06
☐	Final Design Submitted	3/06
☐	AIE Package Submitted	3/06
☐	Rapid Prototype SLA Models	4/06
☐	Construct Prototype Tooling	4/06
☐	Injection Mold Projectiles	5/06
☐	Inspect Projectiles Per Design Drawing	5/06
☐	Final Report from Contractor	5/06

Cost-Reducing Material Substitution

- Feasibility Study: Phase 3
  - Testing
    - Assemble projectiles with M169 cartridge cases
    - Fire belts of 10 from Mk19 GMG at hot, cold and ambient
      - Soft-catch fired projectiles for post inspection
      - Subject projectiles to moisture, temperature, and humidity for discoloration and growth

Mk19 GMG

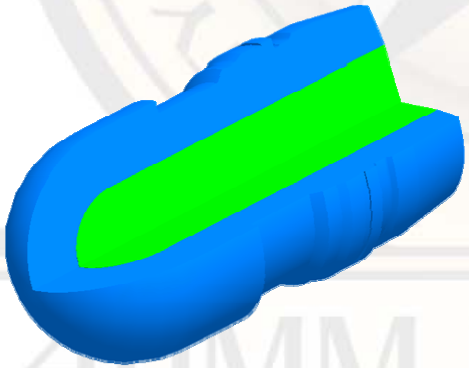
Cost-Reducing Material Substitution

- Post-Feasibility Study
  - Ballistics Mismatch – M385A1, M918 & M430A1
    - Modify M385A1 One-Piece projectile to match profile and physical properties of M918 and M430A1
    - Using M430A1 profile can eliminate issues with one-piece saddle thickness.

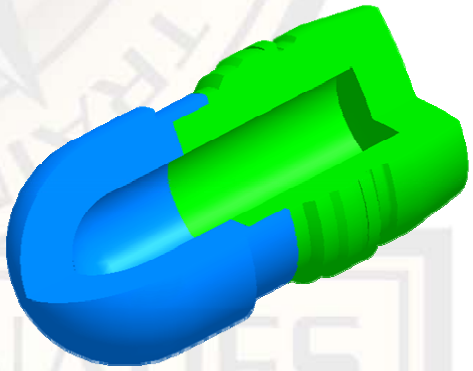
M385A1 M918 TP M430A1

Cost-Reducing Material Substitution

- Post-Feasibility Study
  - Ballistics Mismatch – M385A1, M918 & M430A1
    - May need to use alternative to one-piece design to acquire correct mass, CG, moments of inertia.
      - Multiple Piece
      - Mold-in-mold
      - Structural foam core
  - Chamber volume increase with one piece design
    - Propellant load may need to be adjusted to achieve correct MV.
    - Can also eliminate problem with multiple piece design or added core.



2-piece: body and core



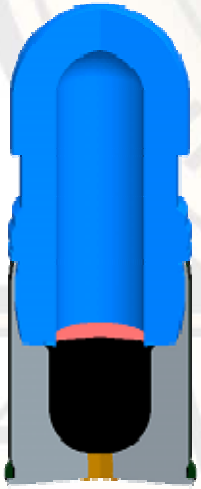
2-piece: capsule

Cost-Reducing Material Substitution

- Post-Feasibility Study
  - If material substitution proves feasible…
    - Material Characterization at high strain rates
    - Pre-Qualification Testing
      - Larger firing samples
      - Full environmental testing
      - Rough handling
  - Production Mold & Qualification Testing
    - Cost savings estimate based on:
      - 300K to 400K rounds per year
      - 5 years production contract
      - 4-cavity mold with slides to eliminate parting line along axis

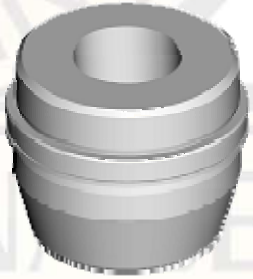
Cost-Reducing Material Substitution

- Follow On Work
  - Mixed Belt M385A1 One-piece with M918 TP
  - Mate M385A1 One-Piece projectile with Single Chamber Cartridge Case (SCCC)
  - M918 Body Insert
  - M781 Projectile Body



M385A1 One-Piece in SCCC

M918 TP Body Insert



M781 TP Body