Weapon System Concepts for a Future Gunship

Michael Canaday
The Gunship IRD Requires a Transformational Capability

Target set:

- Enemy troops in contact with friendlies

Capabilities:

- Situational Awareness
- Precise, responsive, focused weapons effects
- Persistence
- 24-hour operations
- Survivability

Supports two of OSD’s operational goals:

“Denying sanctuary to enemies by providing persistent surveillance, tracking and rapid engagement with high-volume precision strike, … against critical mobile and fixed targets at various ranges in all weather and terrains.”

“Protect and sustain US forces in distant anti-access and area-denial environments.”
AoA PSAS Enabling Technologies

- Hovering UAVs
- Common Operating Picture and Control (COPaC)
- Very Small Missile (VSM)
  - Precise, Responsive, Focused-effects Weapon
  - Prosecute multiple, simultaneous targets throughout the hemisphere under the aircraft
  - 4 inch diameter, 57 inch long; 45 pounds
  - Performance: 15 miles maximum, in 65 seconds
  - Guidance: GPS/INS (in-flight updates) + Laser seeker (optional terminal guidance)
  - Warheads: Lethal and Non-lethal
  - Cost: Approximately $18,000 each
Requirements

- 10 to 15 nmi Range
- 360° Coverage
- Lethal
  - Enemy Personnel
  - Soft Skinned Moving and Stationary Vehicle
  - Armored Moving and Stationary Vehicle
  - Non-Hardened Structures
- Low Collateral Damage
  - Precise with Surgical Effects
- Deep Magazine = Light and Small
  - 45-50 pounds
  - 40-50 inches Long
- Affordable
  - Interservice Common Ammunition
  - Common System Components Across DoD/Commercial
- Selectable Effects
  - Modular Allowing for Guided Non-Lethal/Less than Lethal Munition Options
- Day/Night Capable
- Graceful Degradation
- Small Deployed Footprint
- Automated System

VSM Capabilities are Best Provided by a Weapon System
• VSM Does Not Exist
  – The Capabilities of the VSM are Not Performed by Munitions that Fit the Size and Weight Requirements of the VSM
Mr. Wynne’s Challenge

Demonstrate Capabilities That Can Be Spiraled Into The Current Fleet
Munition / Launcher Size

100mm < MUNITION DIAMETER <127mm

- Munition Volume Too Small for State of the Art Guidance & Propulsion Technology
- Lethal Payload Size Limited
- Munitions Too Heavy for one man lift
- Launch Loads Increase to Obtain Separation Velocities
- Lethality Overkill

120mm AND 105mm DIAMETER MUNITIONS ONLY COMMONLY USED SIZES IN THIS RANGE
Concept Warhead

- Composite (Carbon Fiber) Shell
- Composite (Carbon Fiber) Liner
- Interfaces (Steel)
- Endplates (Al-alloy)
- Center Tube (Al-alloy)
- Explosive (PBXN-110)
- Fragments (W-alloy; 30-grain)
## 120mm vs. 4 inch Diameter Warhead Effectiveness Summary

<table>
<thead>
<tr>
<th>Munition</th>
<th>Accuracy CEP</th>
<th>HOB (ft)</th>
<th>Number of Shots to achieve Pk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Target 1</td>
</tr>
<tr>
<td>Baseline 105mm (M1 MOD)</td>
<td>2 mils 2 mils</td>
<td>0 14</td>
<td>5 3</td>
</tr>
<tr>
<td>VSM Fast (120mm)</td>
<td>1.5 m 4/5</td>
<td>3 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>Slow (120mm)</td>
<td>1.5 m 4</td>
<td>3 1 1 1</td>
<td>3</td>
</tr>
<tr>
<td>AoA VSM (4.0 in.)</td>
<td>1.5 m 4</td>
<td>3 1 2 3</td>
<td>7</td>
</tr>
</tbody>
</table>

- Effectiveness Studies Indicate that 120mm vs. 105mm/4 inch Diameter Warhead Designs Have Superior Performance Against Target Set
Launcher

• Gun
• Missile
• Dispenser

Things to Consider:
– PSAS Must Stay Within Geographic Location of High Priority Mission
  • Orbit is Not Necessary for Gun Fire Control - Allows for Short Range Use of Unguided Rounds
  • Less Expensive Munitions Can Be Used if Less Guidance Control Authority is Required (GPS Guided Artillery Rounds)
– Gun Launch is a Well Proven Method of Deploying Munitions from Inside Aircraft
– VSM-Like Munitions are Launched Out of Guns and Missile Launchers
– Rocket Propelled Munitions Cannot Be Safely Ignited Inside of Aircraft
  • What if They Don’t Leave?
– Rocket Exhaust Plumes Burn Aluminum
– Fully Maneuvering Rocket Propelled Munitions are Expensive - Use Only When Needed
– Unguided Munition are Cheap – Use IF You Can

VSM must be developed in the context of an overall PSAS Combat System
## 105-mm GUN vs. 120-mm MORTAR

### 105-mm Howitzer
- Weight 100 rounds 4200 lbs
- Recoil Load: ~10,900 lbs
- Gun Recoiling Weight 1,465 lbs
- Muzzle Pressure: 3,560 psi
- Legacy System
- Little Guided Technology Ongoing
- Lethal Payload Size
- Current System Too Much Gun
- FCS 105mm Gun is Separate Loaded

### 120-mm Breech Loaded Mortar
- Weight 100 Rounds 3200 lbs
- Recoil Load: ~5,600 lbs
- Gun Weight 1,315 lbs
- Muzzle Pressure: 1,620 psi
- Leading FCS Fire Support Weapon
- Stryker Brigade Combat Team Fire Support Weapon
- A Lot of Guided Munition Development Work Ongoing
- Lethal Payload Size
- Low Gun Loads
- Lighter Ammunition

**120mm DIAMETER MUNITION OFFERS BEST OPTIONS**
M102 Howitzer 120mm Conversion Demo

- Fire Baseline 105mm M1 Howitzer Rounds and 120mm M931 Mortar Rounds from Modified M102 Howitzer
- Verify Functionality of 120mm Breech Loaded Mortar Concept, Establish Baseline Launcher for Unguided, Guided, and UAV Munitions
- Blast Overpressure Comparison
  - Reduce Blast Pressure on Aircraft Surfaces
- Recoil Force Comparison
  - Reduce Load on Aircraft
- 120mm Characterization
  - Range
  - Initial Flight Stability
  - Interior Ballistics
M102 Howitzer 120mm Conversion Demo

- Bore Barrel ID to 4.732 inches (120.2mm)
- Breech Ring - Machine Larger Radius
- Breech Block - Machine Larger Radius
- Extractors - Machine Pockets To Fit 120mm Case
M102 Howitzer 120mm Conversion Demo

- Flight Stability of Mortar Round is Satisfactory
- Further Testing Recommended in Simulated Crosswind
• Purpose: Investigate in Detail the Performance of the VSM with 1100 fps Initial Launch Velocity
• 1100 fps found to be best velocity for weight, length of munition
• Look at Range Achieved for Various Flight Times Using Three Launch Methods:
  – Side
  – Top
  – Forward
• Expand Study to Include Lighter Munition (15 pound Warhead vs. 20 Pound Warhead) Capable of Meeting 15 nmi/65 second Requirement
• Investigate Low Level CONOPS and Ground Launch Range of Munitions
Configuration 2

Side Launched
Initial Velocity = 1100 fps
AOF = -90 deg

VSM Configuration Trade Studies
Range Studies
VSM Configuration Trade Studies
Range Studies

VSM/15 lb Warhead
Ground Launch Initial Velocity = 1100 fps
Terminal Velocity = 500 fps

-90 Deg Angle of Fall
-70 Deg Angle of Fall
AC-130 Spiral Launcher Approach

120mm Breech Loaded Cannon Launching System
• 120mm Launcher/Munition interface
  – Lightweight Launcher and Ammunition
  – Lower Recoil Loads and Blast Overpressure
  – Safe Reliable Munition Separation
  – Multiple Service User Base
• Retains AC-130 Like Capabilities as Well as Embracing New Capabilities
  – Pylon Turn Not Necessary for Fire Control
  – CoPac Develops Instantaneously Computed Solution
• Multiuse
  – Conventional Unguided Ammunition
  – One or Two DOF Guidance as Well as Fully Maneuvering Munitions
  – Soft and Hard Launch of Munitions
• Automated Handling and Loading System
  – Tightly Integrated with CoPAC
  – Providing Health and Status of Ammunition and Launcher
PSAS Launcher

PSAS Launcher Concepts:

• Must address LO Platform Requirements

• Autoloaded Trainable Gun Launcher

• Fixed Tube Bank Launcher

• VSM works in either type
**Munition Approach**

- Modular Open System Design
- Member of a family of munitions
- Lightweight
- Multiple Warhead Types
  - Blast Frag Penetrator
  - EFP
  - Combination Blast/Frag-EFP
  - High Pressure Low Blast Radius Warhead
  - Less-than-Lethal
- Remote Data Control Interface
- GPS/INS Guidance
- Terminal Guidance Technologies Available
  - Semi Active Laser Seeker
  - GPS Only

Modular Munition Design and Standard Interfaces Allows Affordability
120mm Warhead Penetration Demo

• 5 Shot Series from Airgun
• VSM Warhead Design
  – Inert
  – 4340 Steel Case
  – 20 pound
  – 120mm diameter
• 900 fps Impact Velocity
• Targets:
  – 10.5 5000 psi Reinforced Concrete; Normal Impact
  – 7 inch 5000 psi Reinforced Concrete; 30° Obliquity
  – .5 inch RHA; Normal Impact
  – .5 inch RHA; 30° Obliquity
  – 1 inch RHA; Normal Impact
## 120mm Warhead Penetration Demo

<table>
<thead>
<tr>
<th>Target Material</th>
<th>Target Thickness, in.</th>
<th>Obliquity, degrees</th>
<th>Impact Vel, ft/s</th>
<th>Complete Perforation</th>
<th>Exit Vel, ft/s</th>
<th>Projectile Assembly Weight, lb</th>
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<tbody>
<tr>
<td>RHA Steel</td>
<td>1</td>
<td>0</td>
<td>892</td>
<td>No</td>
<td>n/a</td>
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<tr>
<td>RHA Steel</td>
<td>0.5</td>
<td>0</td>
<td>888</td>
<td>Yes</td>
<td>556</td>
<td>21.80</td>
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<tr>
<td>RHA Steel</td>
<td>0.5</td>
<td>30</td>
<td>896</td>
<td>Yes</td>
<td>655</td>
<td>22.01</td>
</tr>
</tbody>
</table>

Penetration Hole in 0.5-in. RHA Steel

Bulge in 1-in. RHA Steel Plate, Exit View

Target Damage, Shot PGM-S03 .5” RHA 30° Obliquity
### 120mm Warhead Penetration Demo

<table>
<thead>
<tr>
<th>Target Material</th>
<th>Target Thickness, in.</th>
<th>Obliquity, degrees</th>
<th>Impact Vel, ft/s</th>
<th>Complete Perforation</th>
<th>Exit Vel, ft/s</th>
<th>Projectile Assembly Weight, lb</th>
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</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>10.5</td>
<td>0</td>
<td>910</td>
<td>Yes</td>
<td>194</td>
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<tr>
<td>Concrete</td>
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<td>45</td>
<td>914</td>
<td>Yes</td>
<td>242</td>
<td>22.27</td>
</tr>
</tbody>
</table>

**Entrance Hole, Test PGM-C01**
10.5” 5K RC

**Exit Hole, Test PGM-C02**
7” 5K RC 30° obliquity
120mm Warhead Penetration Demo

7 inches 5000 psi Reinforced Concrete
45° Obliquity
Summary

Very Small Munition:
• 120mm Diameter
• Launchers:
  – side firing gun capable of firing standard 120mm mortar ammunition
  – PSAS Concept Launcher
• Provides 360° Coverage from either AC-130 or PSAS
• A Viable Spiral for AC-130
• Meets PSAS Roadmap Objectives
BACKUPS
M102 Howitzer 120mm Conversion Demo

- Standard M931 TP Cartridge

- M931 After Conversion
- Conversion Applicable to All M930 Series Ammunition
M102 Howitzer 120mm Conversion Demo

- Blast Overpressure of 120mm was Approximately 35% Lower than 105mm
- 120mm Mortar Rounds Shot at Highest Charge
  - Further Reduction in Blast Possible from Lower Propellant Charge Configuration
M102 Howitzer 120mm Conversion Demo

- Recoil Force of 120mm was Approximately 30% Lower than 105mm
- Recoil Mechanism Can be Optimized for 120mm Gun
  - Further Reduction in Recoil Force
  - Lighter Weight Gun Components
- Lower Charge Propellant Should Reduce Recoil Loads

Recoil force curves from high speed video derivation, force vs. time

105mm

120mm

LEGEND
Recoil mass
Recoil stroke
Avg. recoil force
M102 Howitzer 120mm Conversion Demo

- 120mm Muzzle Velocity -> 1218 ft/s
  - Maximum Muzzle Velocity from M120 Mortar -> 1040 ft/s
- 120mm Range: 10° QE -> 3400 m Average; 33° QE -> 7300 m Average
  - Maximum Predicted Range for 120mm -> 8100 m
  - Maximum Range from M120 Mortar -> 7270 m
M102 Howitzer 120mm Conversion Demo

- Design Pressure of Gun System Below Elastic Strength Pressure
- Optimize Gun Dimensions to Reduce Weight and Footprint
- Optimize Recoil Mechanism to Reduce Recoil Load
120mm Warhead Penetration Demo

Concrete Target and Oblique RHA Test Setup

Normal Impact RHA Steel Target Setup
120mm Warhead Penetration Demo

10.5 inches 5000 psi Reinforced Concrete
0° Obliquity
120mm Warhead Penetration Demo

.5 inches RHA
30° Obliquity
VSM Configuration Trade Studies
Initial Velocity

• Purpose: Investigate Length and Weight Payoff of Utilizing Higher Gun Launch Initial Velocity vs. Carrying More Rocket Propellant in Munition.
• Fixed Performance: Munition to Achieve 15 nmi in 65 seconds
• Allow Necessary Weight and Length to Vary Given Different Initial Velocities
• Considerations:
  – G Load on Munition
  – Recoil Loads
  – Chamber Pressure
  – Munition Length
  – Munition Weight
VSM Configuration Trade Studies
Initial Velocity

Initial Velocity Trade

- Launch G
- Breech Pressure
- Length
- Weight

Graph showing the relationship between initial velocity (fps) and various trade-off parameters (G and Pressure, Length, Weight).
VSM Configuration Trade Studies

Initial Velocity

• Higher Initial Velocity Allows Munition to Loose Weight and Length for Same Given Range Performance
• Limiting Factors
  – Chamber Pressure
  – G Loads on Munition – 7500 G is not Difficult for Mortar Ammunition Components
• 1100 fps Yields Acceptable Levels for All These Parameters:
  – 51-pound Munition
  – 45 inches Long
  – 21,000-psi Chamber Pressure
  – 7200 G
• Lower Mortar Propellant Increments will Permit Lower G Launch, and Munition Weight and Length Benefits will be Achieved, Needs Further Investigation
VSM Configuration Trade Studies
Range Studies

- Side Launching Munitions Offers Some Performance Advantages Over Top and Forward Launch
- Top Launch has Best Extended Range Advantage, but has Some Difficulty Getting Under AC
- New Control Algorithms Being Examined for Better Offside Performance from Side Launched Munitions
- Low Altitude CONOPS are Feasible with this Munition
- VSM would have Tremendous Application as a Ground Combat Fire Support Munition
- The Range and Response Time Requirements must be Examined in the Context of the Overall PSAS Combat System
VSM Configuration Trade Studies
Range Studies

Configuration 1
Side Launched
Initial Velocity = 1100 fps
AOF = -90 deg

Downrange (nmi)
Cross range (nmi)
10 nmi radius
15 nmi radius
240-296 s
180-240 s
120-180 s
65-120 s
0-65 s
0-65 s
15 nmi radius
10 nmi radius
VSM Configuration Trade Studies
Range Studies

Configuration 1

Top Launched
Initial Velocity = 1100 fps
AOF = -90 deg
VSM Configuration Trade Studies
Range Studies

Configuration 1

Forward Launched
Initial Velocity = 1100 fps
AOF = -90 deg
VSM Configuration Trade Studies

Range Studies

Top Launched
Initial Velocity = 1100 fps
AOF = -90 deg

Configuration 2
VSM Configuration Trade Studies
Range Studies

Configuration 2

Forward Launched
Initial Velocity = 1100 fps
AOF = -90 deg
VSM Configuration Trade Studies
Munition / Aircraft Separation Study

• Purpose of Study: Develop a Simulation that will Allow Modeling of Munition Flyout from AC
• Six Degree of Freedom (6-DOF) Simulation
• Ejection Speed (Study Variable)
• Parameters:
  – C-130 Slip Stream and Prop Wash is Modeled
  – Munition is Unguided Through Separation
  – Munition Initial Conditions Based Upon:
    – Aircraft Velocity (240 kts)
    – Launcher Position Relative to Aircraft (X’, Y’, Z’)
    – Two Launcher Angles Relative to Aircraft: Azimuth Ψp, Elevation θp
    – One Munition Angle Relative to Launcher: Azimuth Ψm
VSM Configuration Trade Studies
Munition / Aircraft Separation Study

Global (Aircraft): \(X, Y, Z\)
Local (Launcher): \(X', Y', Z'\)
Launcher Azimuth: \(\Psi_\rho\)
Launcher Elevation: \(\theta_\rho\)
Munition Azimuth: \(\Psi_m\)
VSM Configuration Trade Studies
Munition / Aircraft Separation Study

- **Initial Velocity: 100 fps**
- **Initial Velocity: 250 fps.**
- **Initial Velocity: 30 fps Good Trajectory**
- **Initial Velocity: 30 fps Bad trajectory**
• Initial Studies of Munitions Indicates that Lower Launch Velocities (200-500) will not have Difficulty Separating from AC

• Oscillation of Munition During Low Velocity Launch May be an Issue for Guidance System

• Further Development of Simulation Warranted Using AFSOC Owned AC-130 Flow Field Model Developed by Auburn University

• Results Should be Verified in Actual Flow Field
VSM Configuration Trade Studies
Motor Configuration

• Study of Pintle Motor Configuration Examined to Investigate Potential of this Type of Motor

• Possible Pintle Motor Trade-offs:
  – Fly During “Cruise” with Low Mass Flow Rate Allowing for Possible Higher Terminal Velocities
    • This Allows for More Propellant to be Left to Throttle Up With
  – Fly During “Cruise” with High Mass Flow Rate Allowing for Possible Shorter Time-of-Flights
    • This Leaves Little Propellant for Throttling Up, but can Possibly Give Better Time-of-Flights than a Boost/Sustain Motor

• This is only a rough cut! This pintle motor design will need some optimization to determine what the best burn conditions are for the specified mission (i.e. higher terminal velocities and shorter time-of-flights may be possible to achieve).
VSM Configuration Trade Studies
Motor Configuration

Pintle vs. Boost/Sustain Motor
15 nmi Case
Initial Velocity = 1100 fps

Time (sec)
Velocity (ft/s)

Boost/Sustain
Pintle
VSM Configuration Trade Studies
Motor Configuration

• Rough Cut Analysis Indicates that the Configuration is Promising
• May Need to Be Soft Launched
• Less Mature Technology
• This Pintle Motor Design will Need Some Optimization to Determine What the Best Burn Conditions are for the Specified Mission
• With this Technology it may be Possible to Achieve:
  – Higher Terminal Velocities
  – Shorter Time-of-Flights