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Optimizing 5.56 Tracer Ammunition Dispersion

Jeff Siewert
Arrow Tech Associates
NDIA

Andy Boman
Orbital ATK
NDIA

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Outline

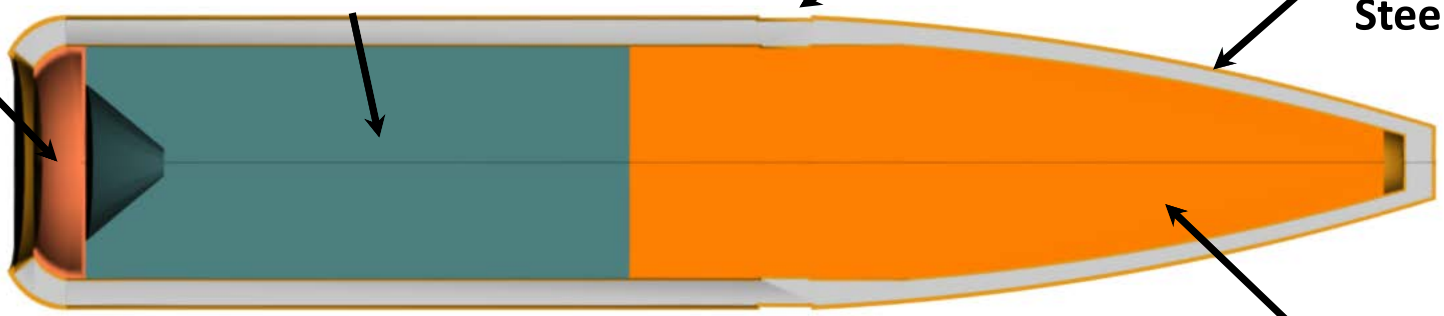
- Introduction
- Tracer Bullet
- Error Budget Approach
- Significant Factors Identified
  – PA Tilt / CG Offset
  – Moving Parts
  – Tracer Drag Offset
  – Barrel Influence on Muzzle Exit Yaw Rates
- Conclusion

Introduction

- While Tracer ammunition has a trajectory match to its ball counterpart, tracer is known to exhibit a higher fall of shot dispersion than ball
- An engineering approach has been used to identify factors unique to tracer bullets which cause an increase in dispersion

Tracer ammunition enables a shooter to make aiming corrections, optimizing tracer dispersion will improve the shooters aiming capability

Tracer Bullet Overview



<u>**Unique Design Elements**</u>

- No boat tail
- Long jacket
- CG closer to normal force center of pressure than Ball
- Copper plated steel jacket
- Solid tracer pellet

<u>**Influence on Dispersion**</u>

- **Tracer jump sensitivity is much higher than Ball**
  - CG close to normal force center of pressure
  - Large transverse moment of inertia
- **High radial stiffness, relatively low bending stiffness, and forward CG location increase sensitivity to non-straight barrels**
- **Drag offset due to trace burn**

Error Budget Pareto

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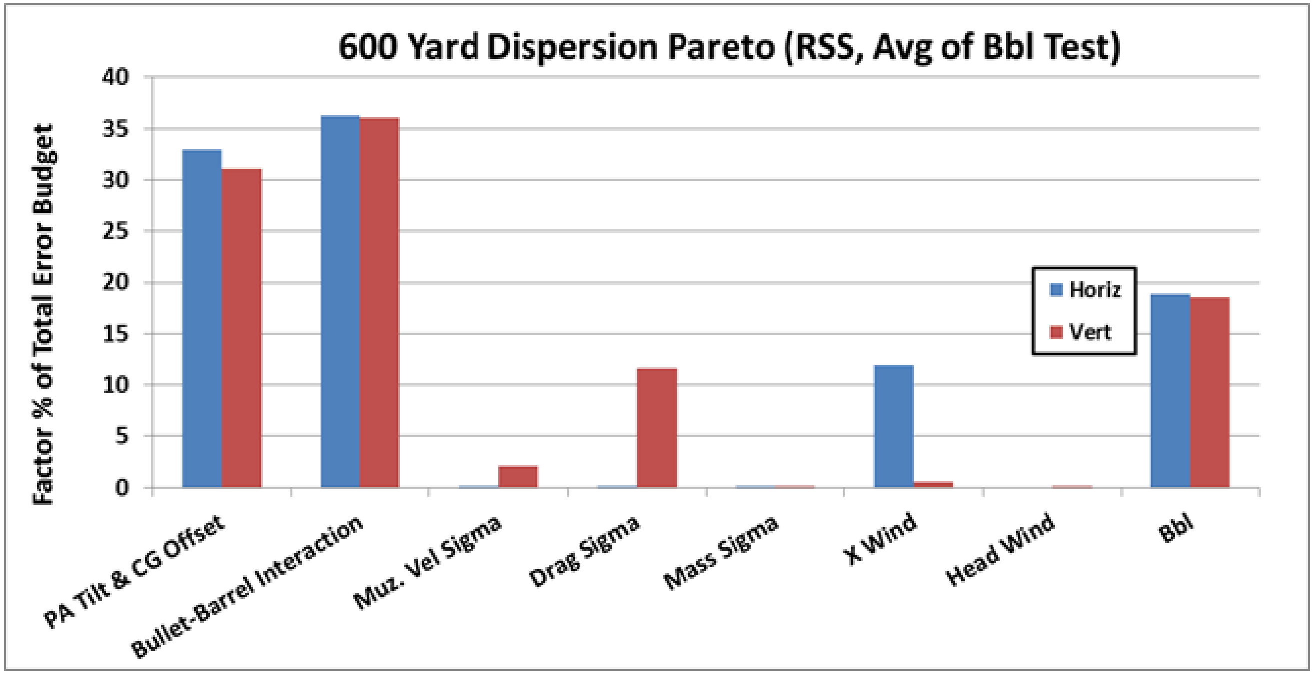

Inputs:

- Historical Dispersion
- Bullet mass imbalance - principal axis tilt / center of gravity offset
- Initial yaw and pitch rates
- Muzzle velocity sigma
- Drag sigma
- Weight sigma
- Wind velocity sigma

Factors Identified via Error Budget

- Bullet mass imbalance
- Drag Sigma
- Bullet-Barrel Interaction

Other Factors believed to contribute to dispersion performance

- Moving parts, slug moving independently from jacket

Structured approach to identify and prioritize causes of dispersion

Mass Imbalance
Process Contributors

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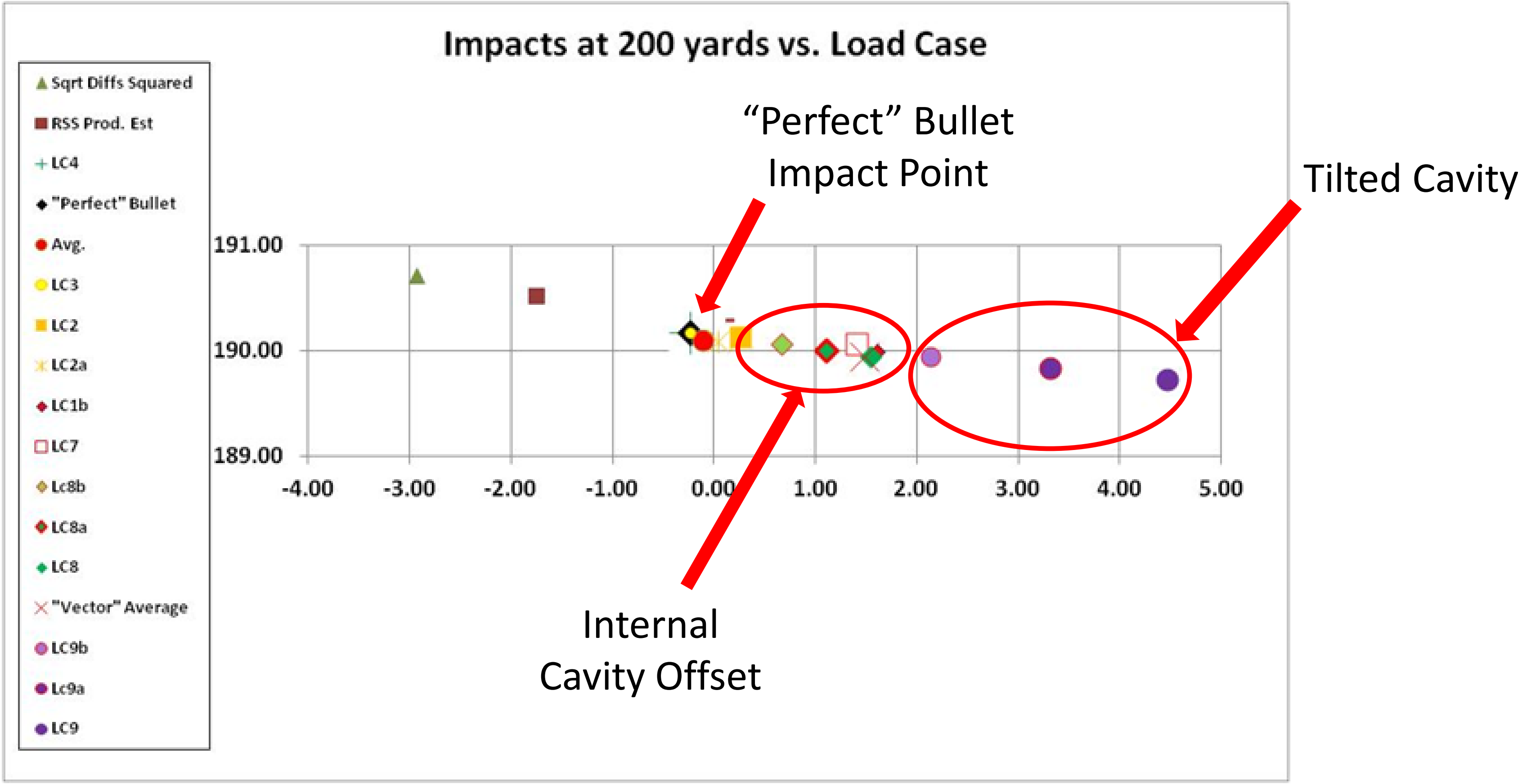
Process Sensitivity of fall of shot to bullet mass imbalance

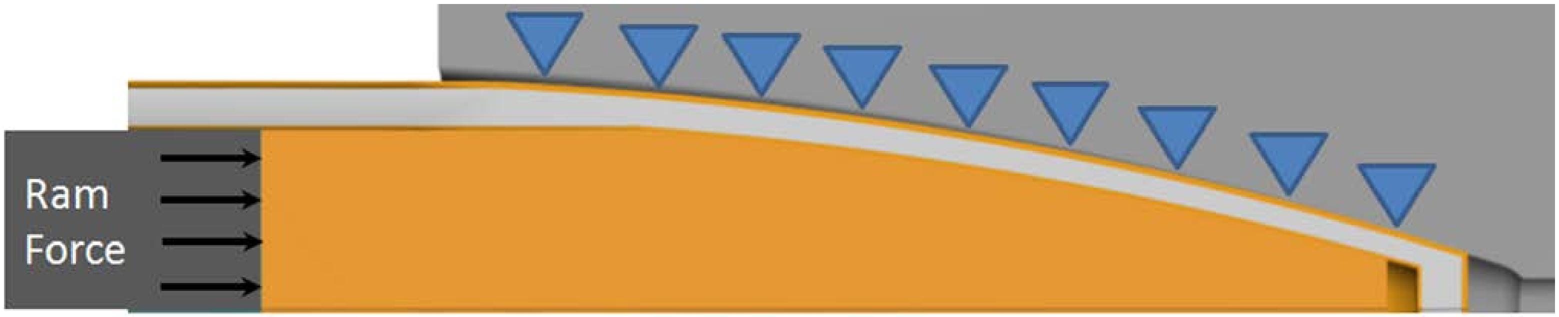


- **Driving Manufacturing Process Contributor**
  - Jacket Wall thickness variation, i.e. internal cavity offset from OD, known to be cause of mass imbalance
  - Study found tilted internal cavity much worse case

Mass Imbalance:
Firing Boundary Conditions

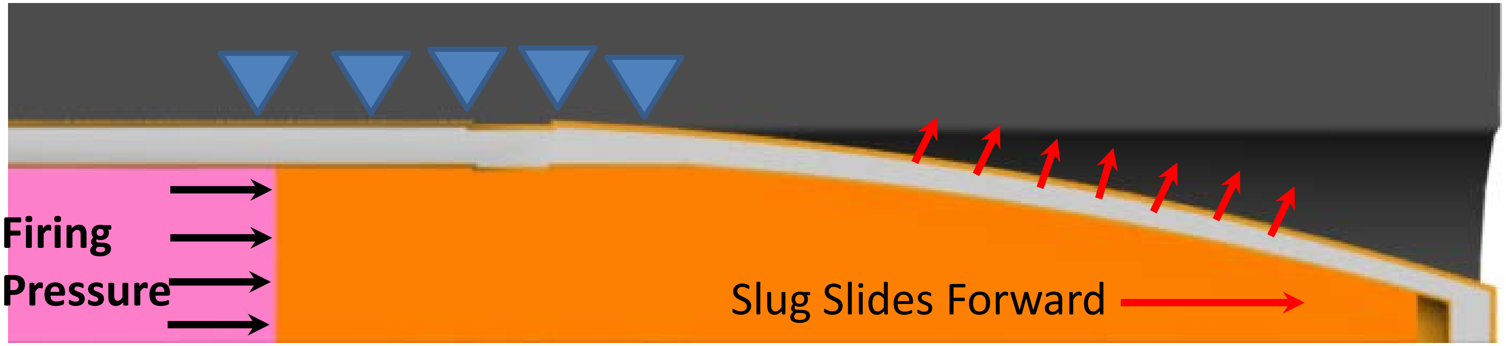
Manufacturing

Die supports jacket during consolidation and limits ogive radial deflection



Firing

Ogive is unsupported and free to deflect outward during firing



Slug movement independent of jacket during firing due to internal pressurization can cause mass imbalance by ogive radial deflection

Moving Parts

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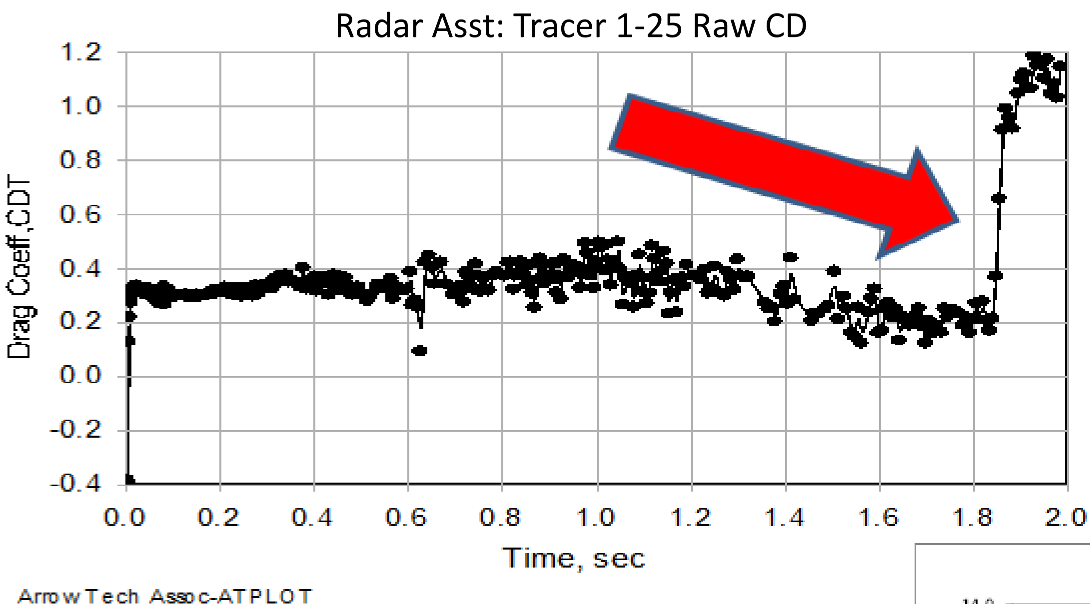
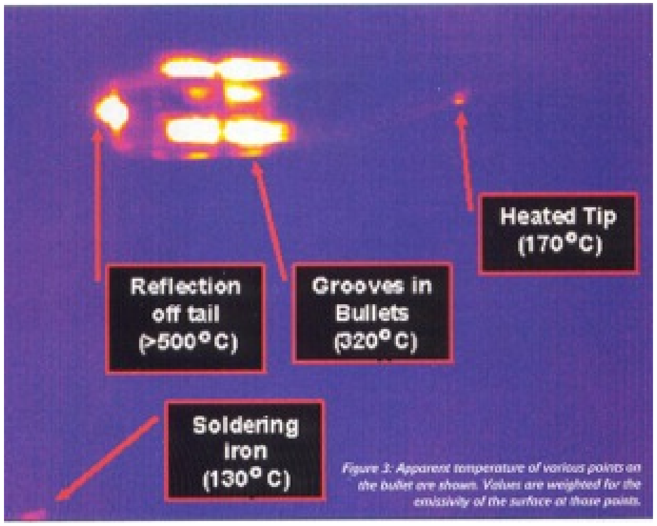
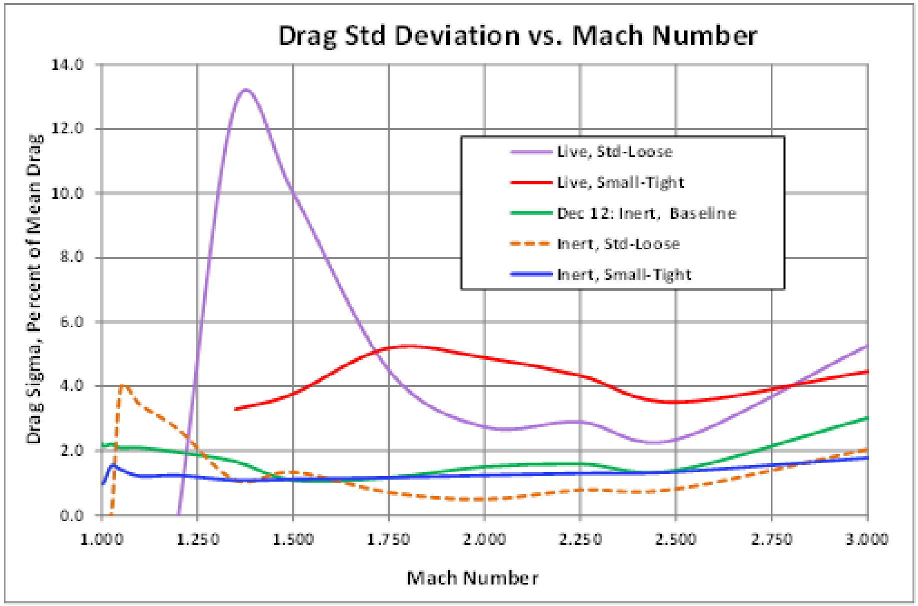


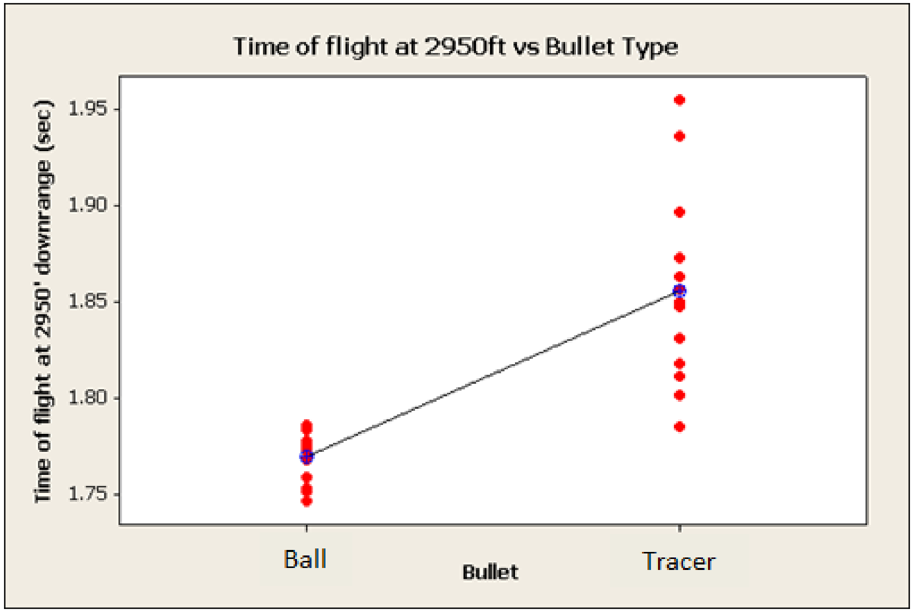


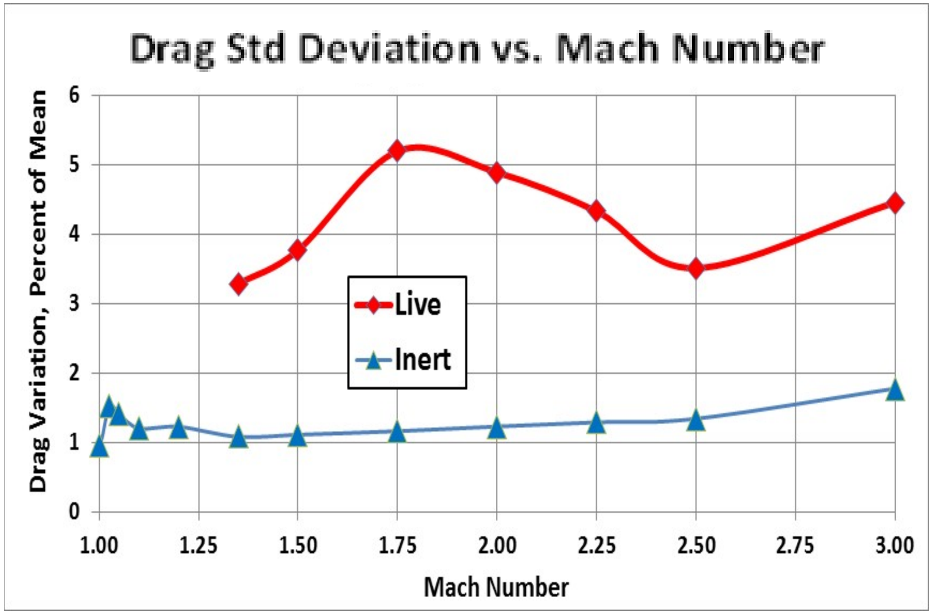
- **Slug constrained in jacket by:**
  - **Residual contact stress between jacket and slug**
  - **Consolidated tracer pellet**
- **Contact stress reduced by:**
  - **Thermal expansion of jacket, caused by firing and tracer burn, reduce contact constraint**
  - **Loss of tracer pellet**
- **Study found key slug/jacket characteristics improved residual contact stress**



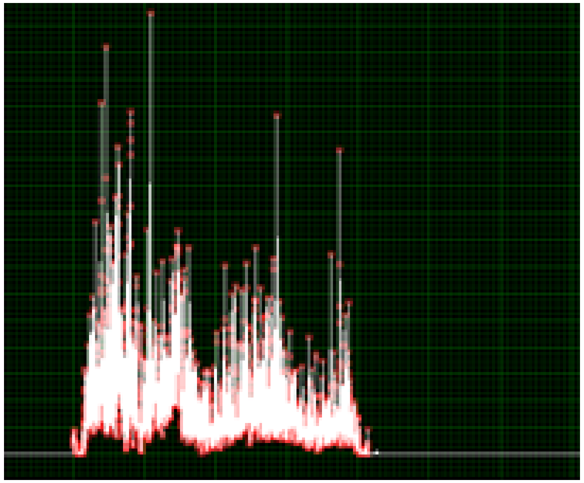
Dispersion degraded by loose slug; factors to improve identified

Tracer Drag Offset



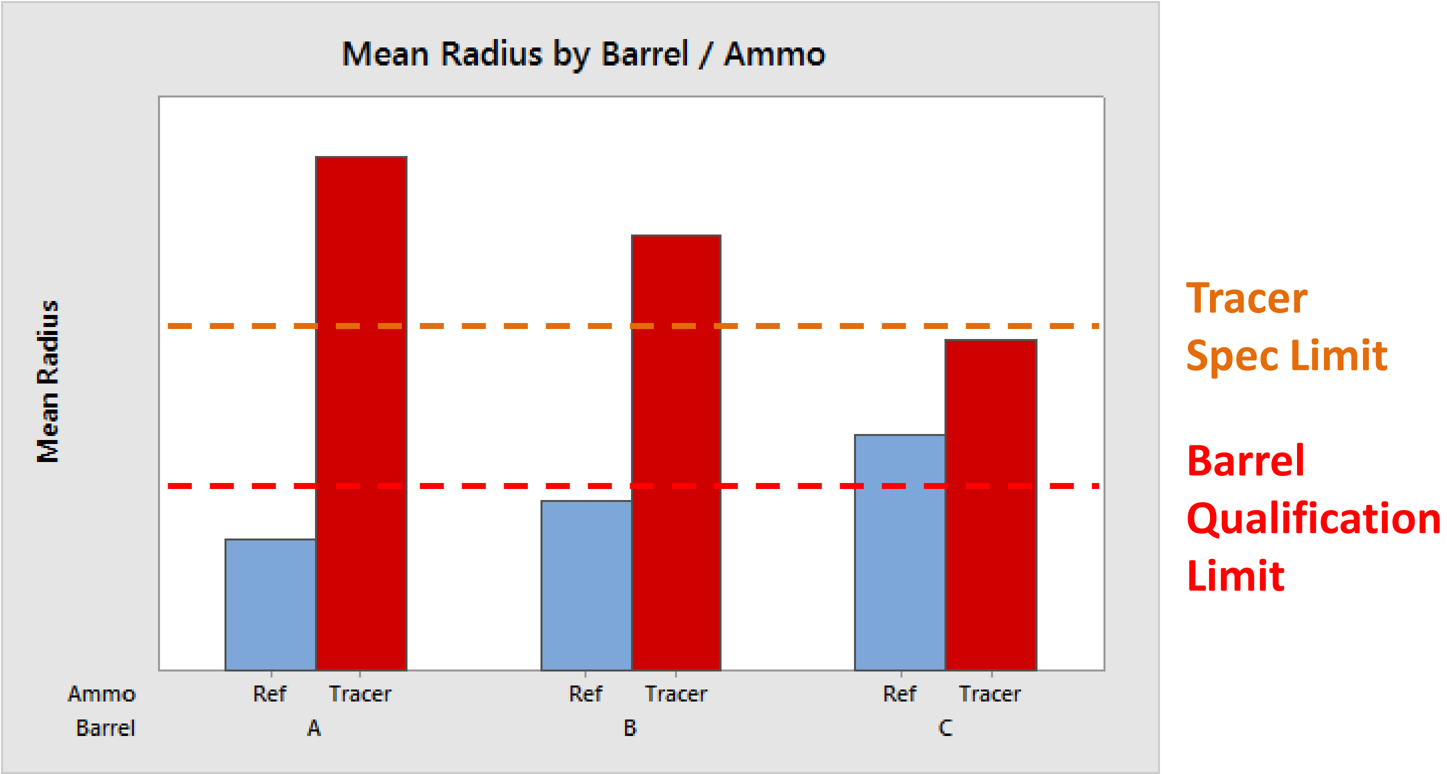


- Time of flight variability significantly greater with tracer when compared to ball
- Believed to be caused by inconsistent tracer burn
  - Validated by luminous intensity data captured during laboratory burn testing
  - Increases drag sigma, large contributor to vertical dispersion


Luminous Intensity of Trace burn

Inconsistent tracer burn increases dispersion of tracer bullets at extended ranges

Muzzle Exit Yaw Rates: Bullet-Barrel Interaction



Ref = Ball reference is used to qualify barrels for 5.56 dispersion testing

- Barrels A & B qualified for testing w/ref., failed Tracer test; barrel C failed to qualify w/ref., passed Tracer test
- Barrel Characterization suggests tracer is more sensitive to barrel straightness, while Ball has a higher sensitivity to jump to rifling

Barrel features that influence dispersion need to be repeatable, represent fielded weapons

Conclusion

- **A structured engineering approach was used to identify and prioritize factors unique to 5.56mm tracer ammunition dispersion.**
- **The effort has lead to opportunities for continual improvement and optimization of tracer ammunition**

Optimizing tracer dispersion will advance the Warfighter