M80A1 Dispersion Reduction

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Zach Krogstad
Steve Redd
Dustin Triebel
Jeff Siewert

Northrop Grumman
Alliant Techsystems Operations LLC
Arrow Tech
Project Manager MAS Maneuver Ammunition Systems
DEVCOM Armaments Center
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Background

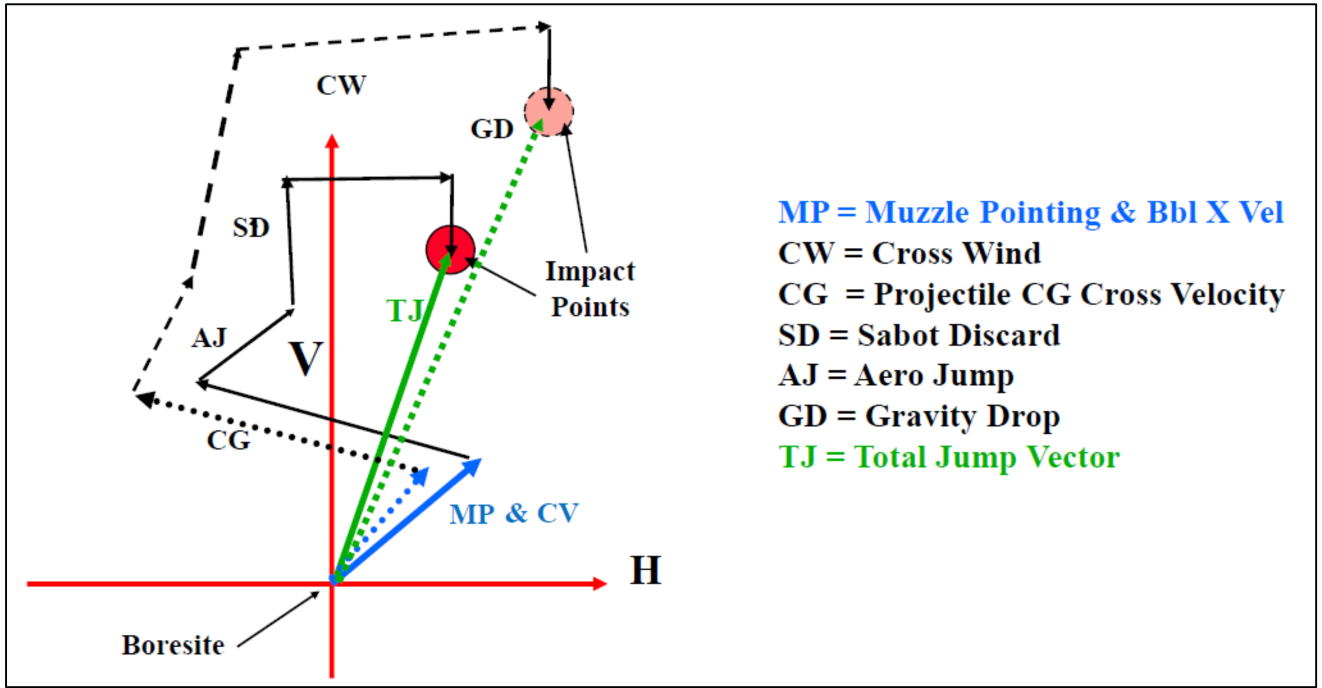
- Two packing configurations exist for M80A1
    1. Linked (machine guns)
    2. Carton (rifles)
- Ammunition dispersion requirements differ
    - Rifle packing requires smaller dispersion
- In order to increase flexibility in manufacturing, PM-MAS initiated an effort to improve the ammunition dispersion of M80A1
- Armaments Center, Northrop Grumman, and Arrow Tech collaborated to *prioritize the error sources that contribute to ammunition dispersion*

Linked M80A1

Carton-packed M80A1 (in rifle magazine)

Ammunition Dispersion

- Ammunition dispersion is composed of various effects
- The unpredictable magnitude and direction and of these effects causes a random “miss distance” from the boresight with each shot
- The project goal was to assign priority to the error sources
  - Efficient approach to improvement

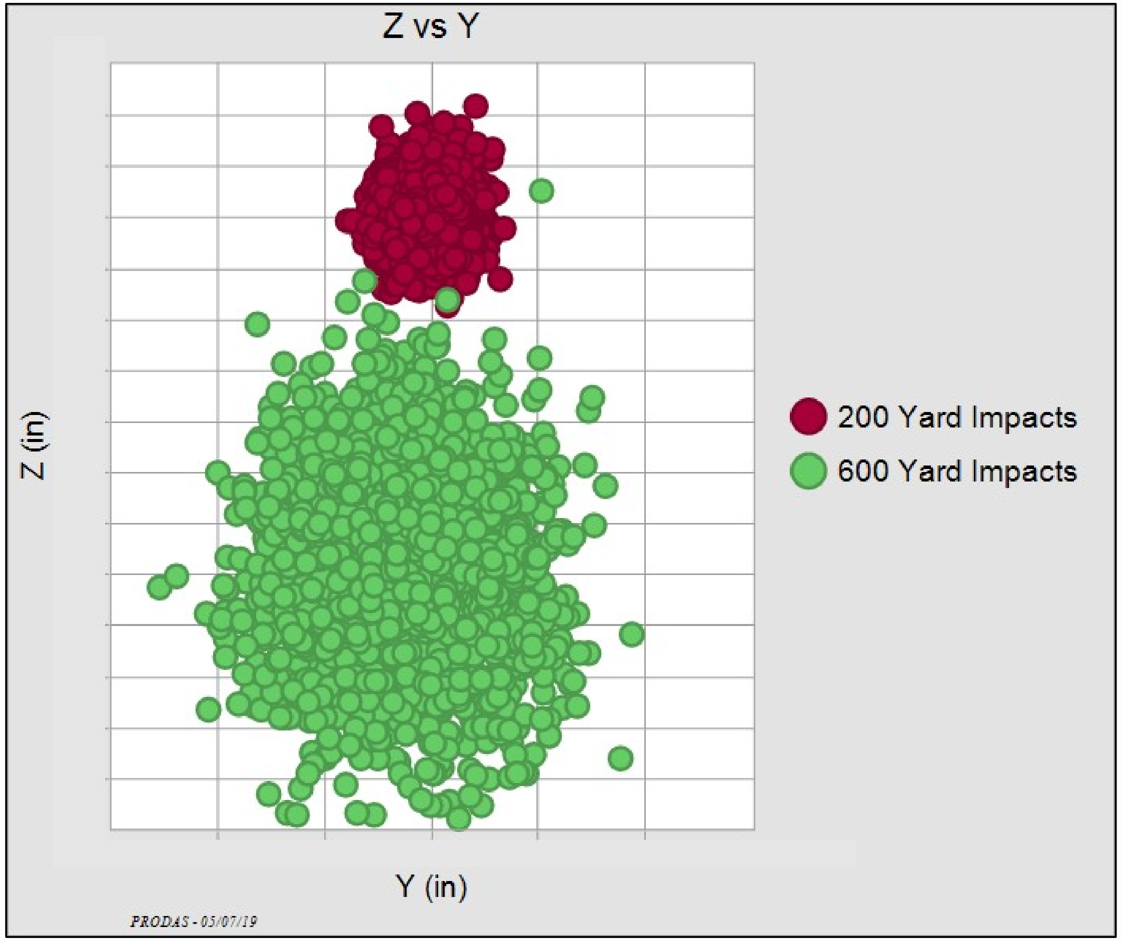


General Approach

PRODAS

1. **6DOF w/ Trades**
   - *Inputs:*
     - Mean and SD of:
       - Drag
       - Muzzle velocity
       - Angular rates
       - Etc.
   - *Outputs:*
     - Group size vs. range
     - Quantify and rank error budget factors

2. **Body Fixed 6DOF**
   - *Inputs:*
     - "Load case" CG offset
     - "Load case" principal axis tilt
   - *Outputs:*
     - Dispersion sensitivity
     - Ranking of typical manufacturing variances



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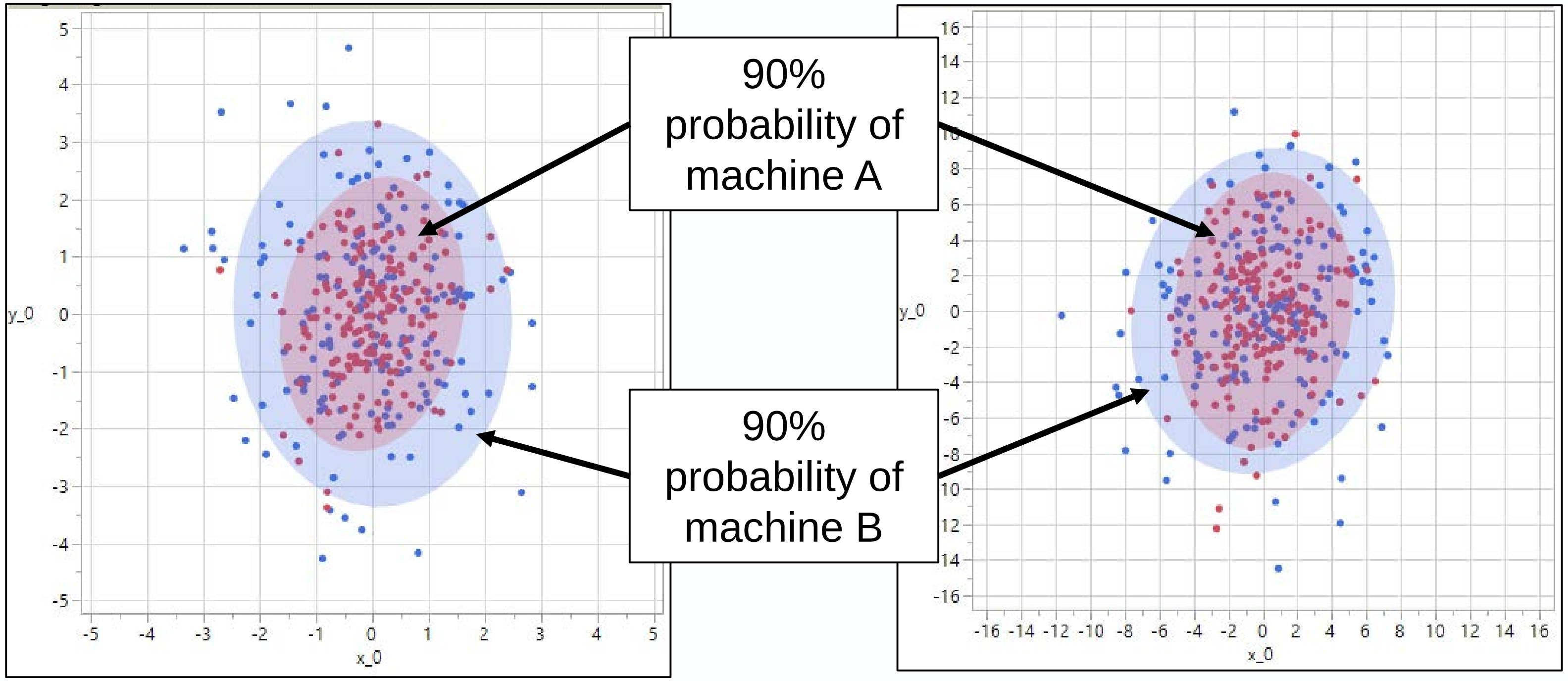
Tests Conducted

1. BAM by BAM
2. Radar
3. DOE
4. Dimensional inspection
5. Load case study
6. Spin balancing
7. X-ray with soft catch

All tests listed provided inputs to error budget construction

BAM BY BAM

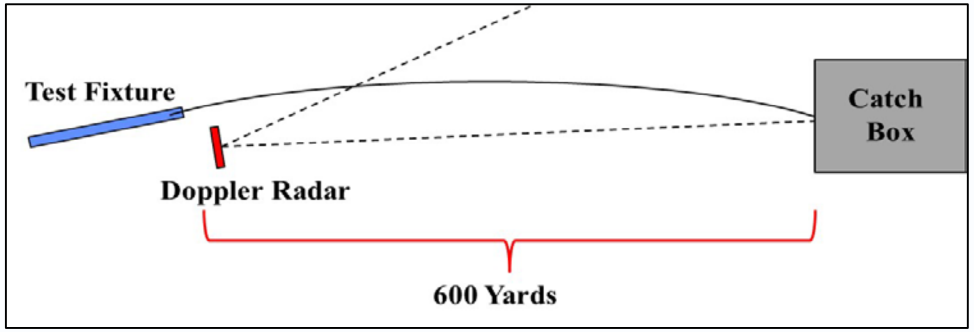
- Compile baseline dispersion data for M80A1
- Identified differences between bullet assembly machines (BAMs)

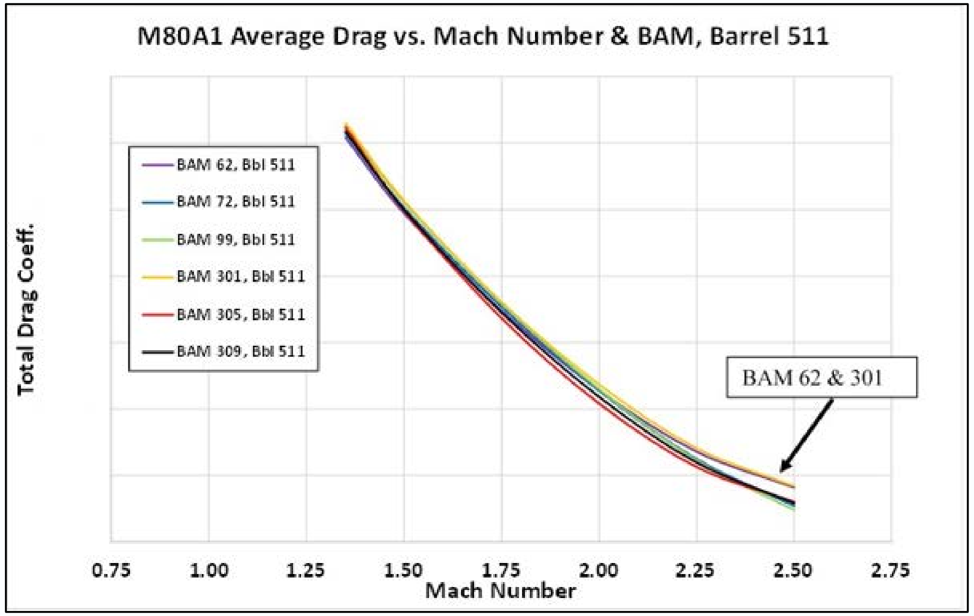


Noted that the best and worst performing BAMs were generally consistent

RADAR

- Tests conducted using Doppler radar
- Tests samples from multiple bullet assembly machines
- Drag vs. Mach number extracted from Doppler radar data, compared by BAM and barrel





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DESIGN OF EXPERIMENTS

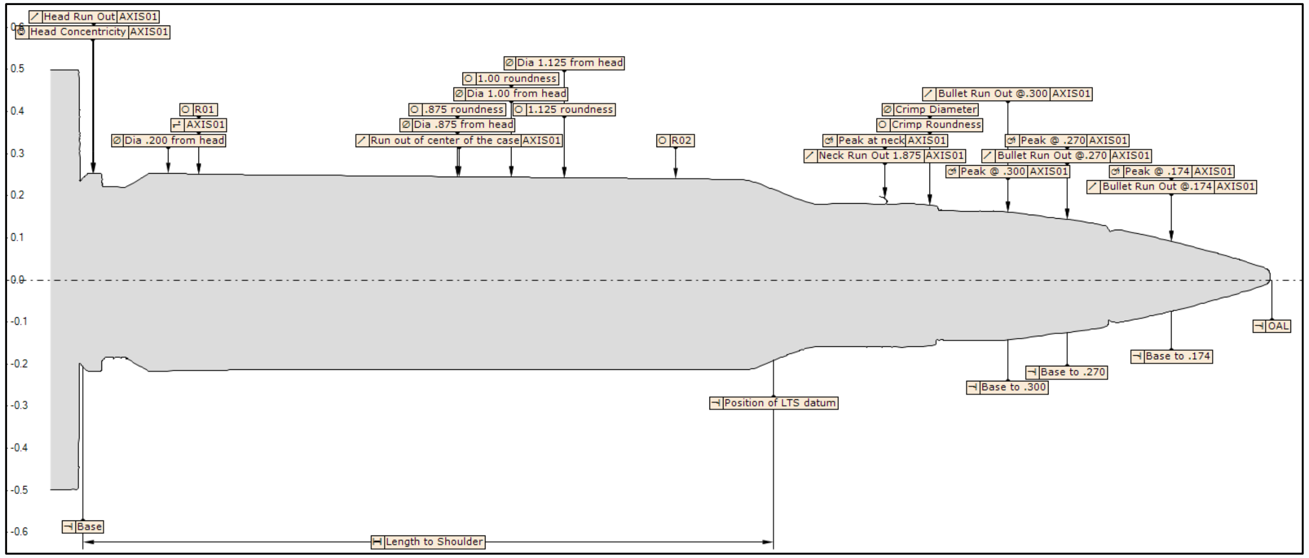
Contributing factor	Explanation	Selected Features
Mass asymmetry	Results in CG offset and PA tilt, angular rates at muzzle exit	Cannelure concentricity
Radial stiffness	Resistance to engraving in the rifling, sensitivity to curved barrel	Cannelure diameter Multiple cannelures
Asymmetric engraving	Affected by jump to the rifling	Cartridge overall length
Muzzle blast interaction	Affected by reverse flow of gas around the heel of the bullet at muzzle exit	Heel radius

- 6 factors, 2 or 3 levels each
- Optimized design utilized for this experiment

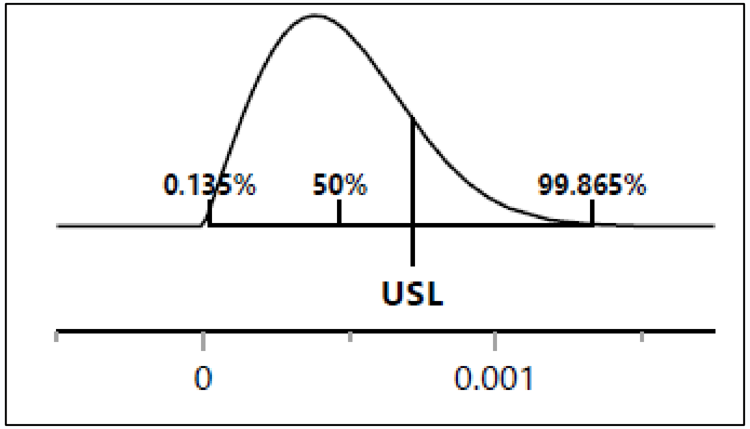
Factors	Level 1	Level 2	Level 3
Cannelure Diameter	L	H	-
Cannelure Concentricity	L	H	-
Bullet Heel Radius	L	H	-
Double Cannelure	No	Yes	-
Barrel	A	B	-
Cartridge Overall Length	L	M	H

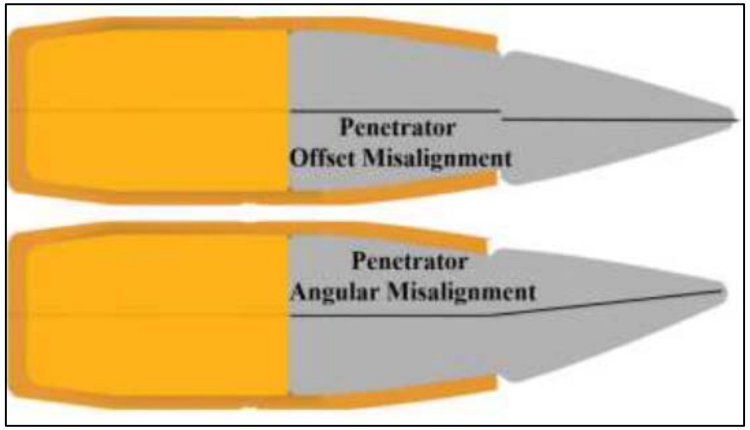
DIMENSIONAL DATA

- Optical inspection machine used to capture dimensional data from bullet and cartridge samples
- Used to model physical parameters of M80A1 cartridges



Load Case Study

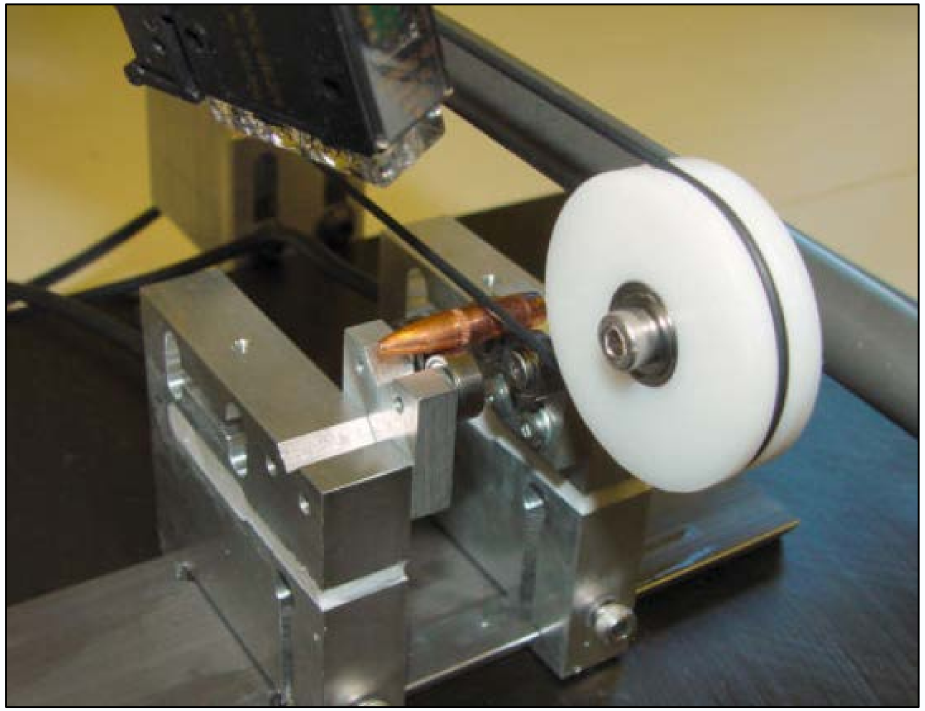




- Various dimensional data were collected to determine the effect of common manufacturing variances
  - Examples: tip runout, boattail runout
- Mean plus 1 standard deviation were determined for each variance
- These values were input into physical models and simulated to determine the sensitivity of the variances
  - Answers the question: “How bad is tip runout relative to other forms of runout?”

Spin Balancing

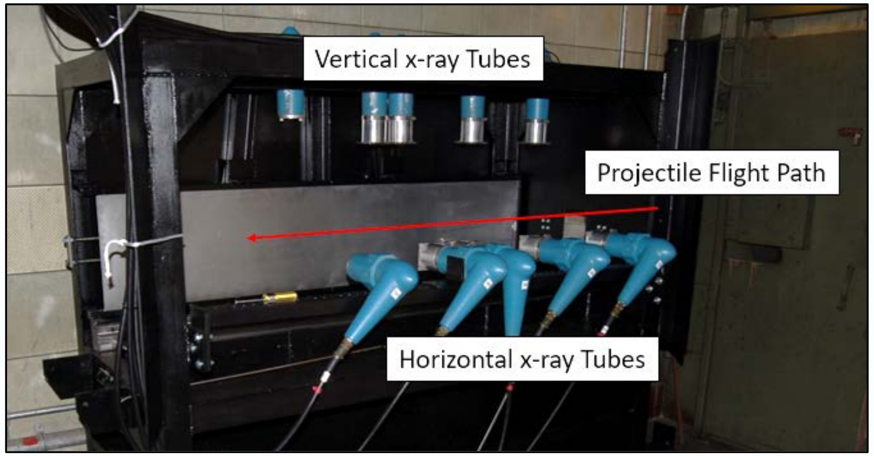
- Dynamic spin balance machine used to quantify bullet mass imbalance
- Mass imbalance used to derive CG offset and principal axis tilt

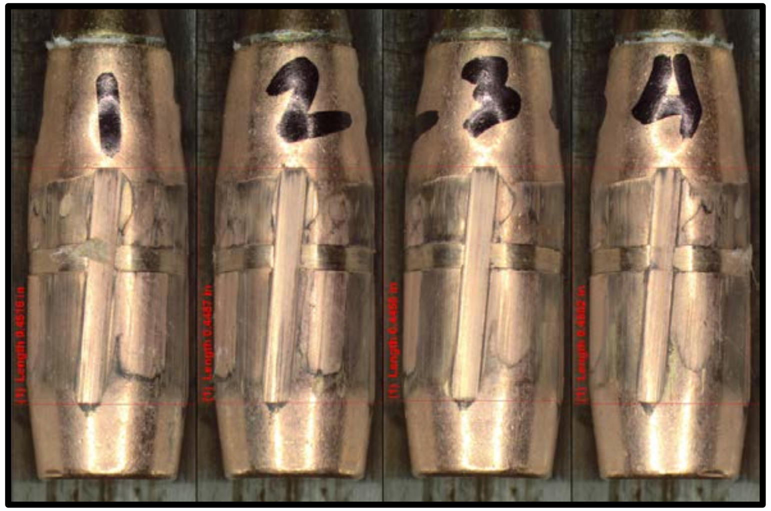


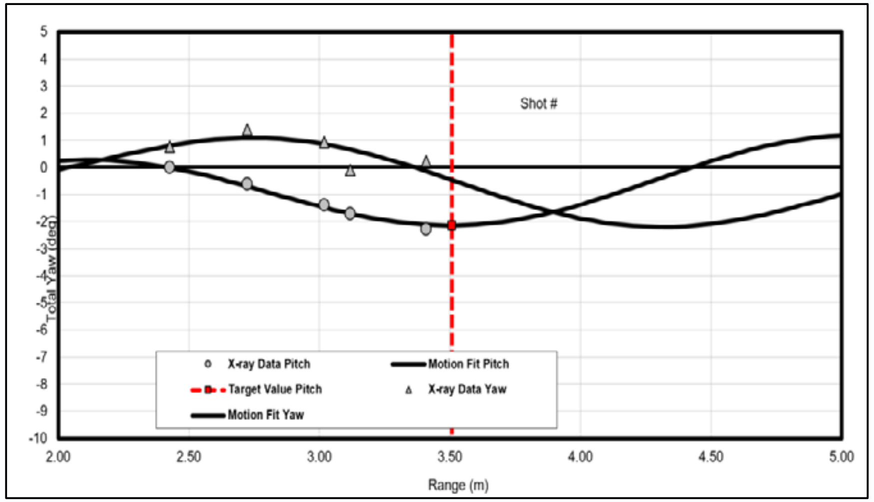
X-Ray and Soft Catch

- Shot samples through orthogonal x-ray to determine mean and standard deviation of muzzle exit yaw rates

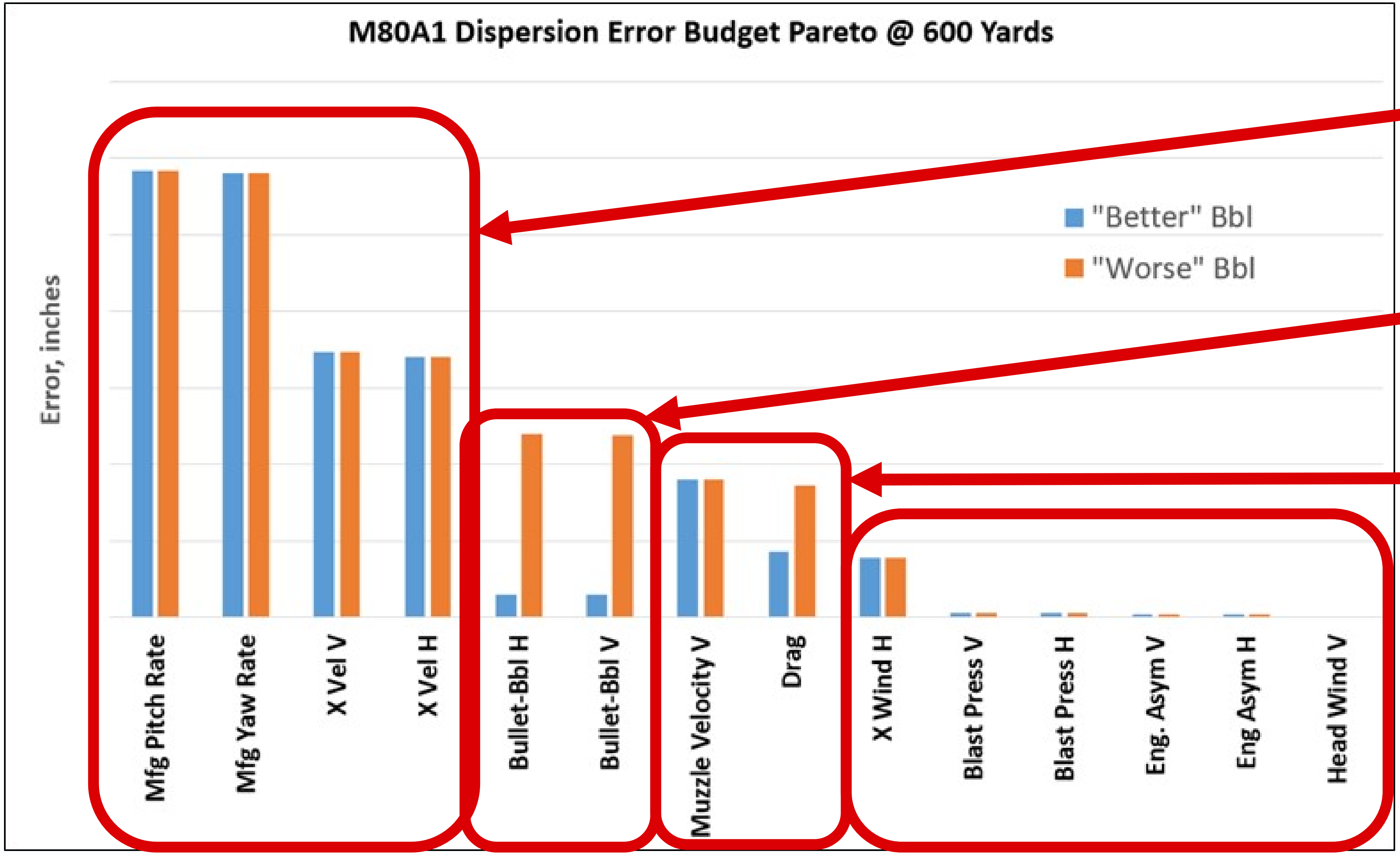
- Fired projectiles into bullet catcher to assess asymmetric engraving







M80A1 Error Budget



- Bullet quality matters a lot (variability)
- Barrel interaction is significant
- MV variation and drag effects are present but not main drivers
- Everything else is fairly small

Conclusion

- M80A1 dispersion is most sensitive to variation in bullet manufacturing
- Future efforts may involve M80A1 bullet manufacturing improvements
- DOE revealed potential gains from minor design changes (deeper cannelure)
  - More testing is required
- Potential paths to improvement:
  - Reduce mass asymmetry (tip runout)
  - Reducing variation in processes (only use best BAM)
  - Minor design changes (cannelure optimization)