

Modeling & Simulation

Gun Launch Dynamics & Aeroballistic Analysis via Onboard Laser Diode

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- **Background/Need**
- **Concept**
- **Implementation**
- **Range Setup & Options**
- **Data Acquisition & Post Processing**
- **Aerodynamic Coefficients**
- **Summary**

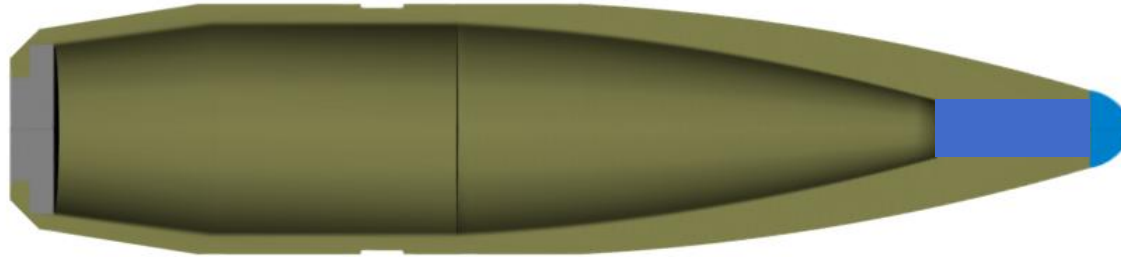
- **Early insight into gun launched dynamics (tip-off rates, direction, first max yaw angle, body motion) is critical to precision weapon development**
 - Gun Launch disturbances have a large effect on dispersion & guidance
 - Unexpected large tip-off rates
 - Requires instrumented rounds (D-Fuze) or ranges (Spark Range, Yaw Cards)
 - Characterizes body motion during gun travel, muzzle egress and flight
- **Aerodynamic analysis can also take time and be costly to program efforts if not planned for within program scope**
 - Wind Tunnel Testing (model and tunnel facility costs ~\$100K-\$200k)
 - CFD Analysis (time consuming and not always accurate)
 - Spark Range Testing (facility cost, duration)
 - Flight Testing / Data Analysis (range and onboard instrumentation cost)

- **How can we quickly obtain gun launch dynamic information?**
- **Onboard Laser Diodes.....**
 - Retrofit a small caliber bullet or large caliber projectile with a “laser pointer”
 - Requires a simple machining process to mount hardware (longitudinal alignment is key)
 - Motion of projectile will be emitted onto witness plate(s)
 - By simply recording the image(s) we can rapidly obtain launch dynamics
 - Angular motion, alpha, beta
- **One step further – Aerodynamic Analysis**
 - Add Radar for time and position
 - Record meteorological data
 - Develop and include a post-processor
 - Utilize spark range and yaw card data reduction techniques to determine aerodynamics

Like Spark Range and Yaw Card Testing, Advantages Are:

- **Actual Testing Conditions**
 - Full scale projectile
 - Actual Reynolds Number
 - Real time body motion
- **Low Cost & Effective Solution**

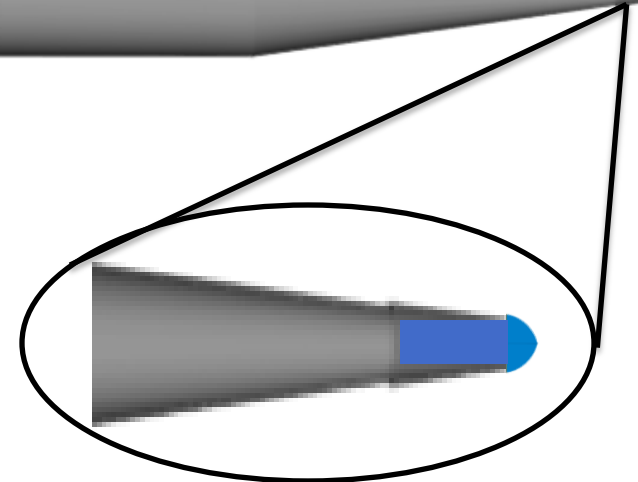
Laser Diode Mounted to: Small or Large Caliber Rounds



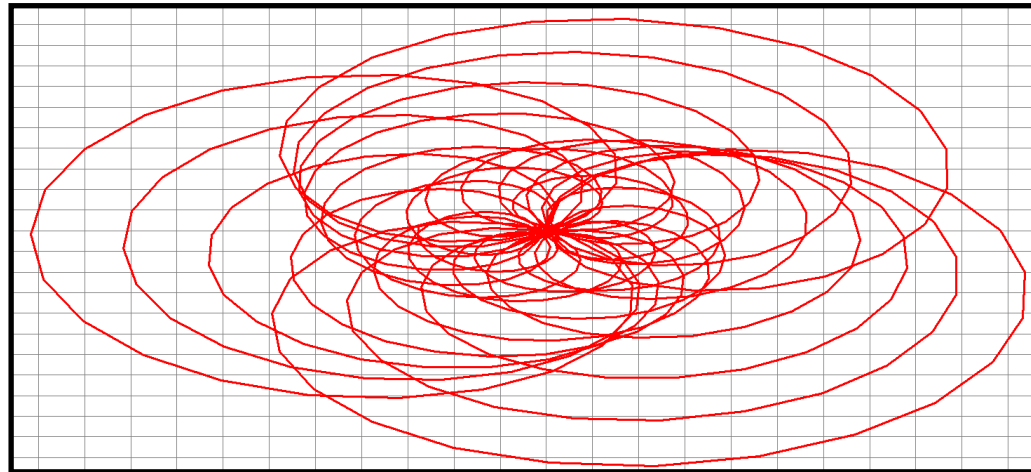
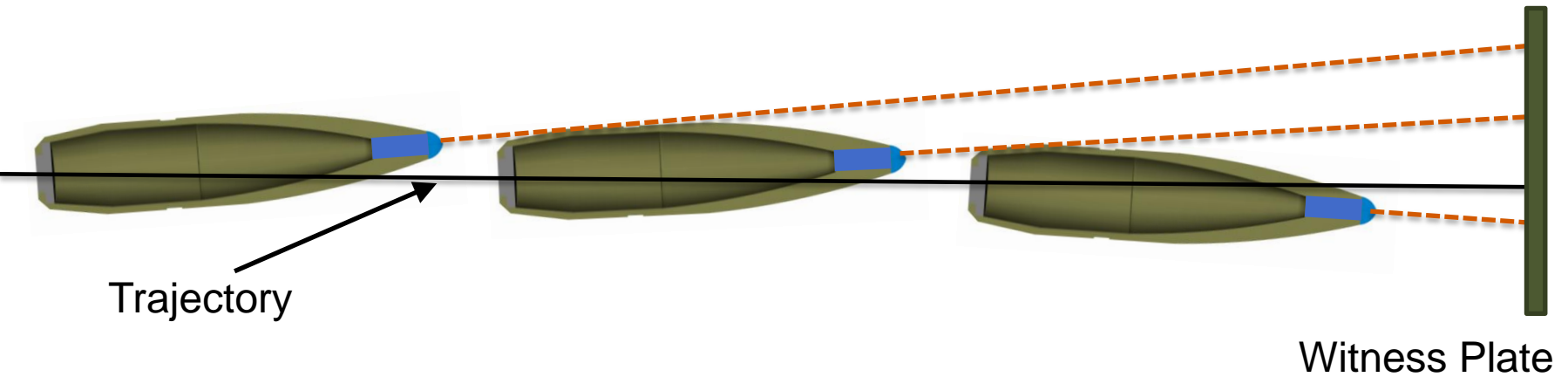
0.50cal bullet



105mm Round



Miniature Diode Emits Trace of Projectile Motion

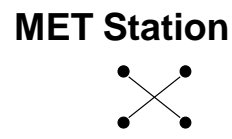


Rotated View of Witness Plate

Varying Levels of Test Instrumentation

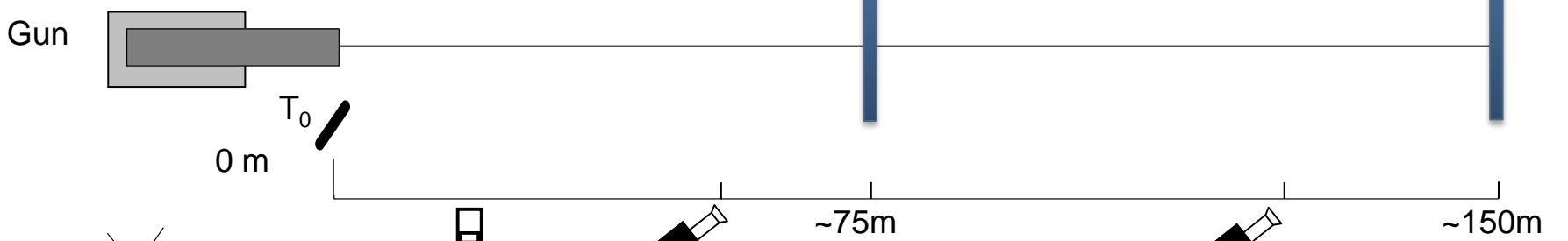


- Optional Gun Instr.**
- Piezoelectric Chamber
 - Piezoelectric Breech
 - Piezoelectric Muzzle

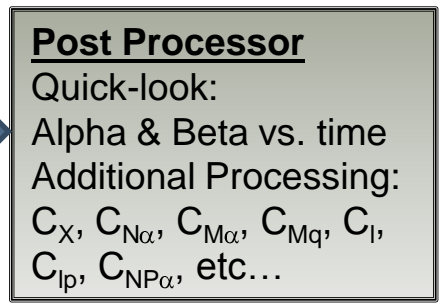
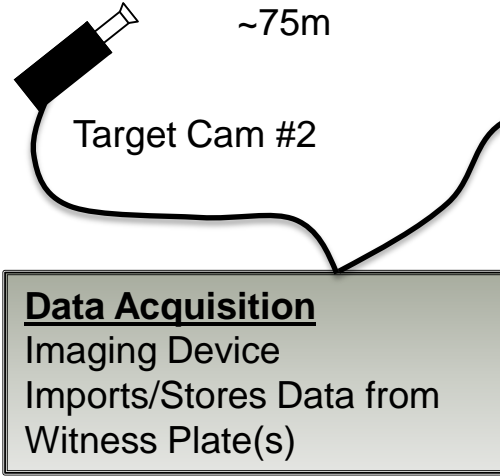
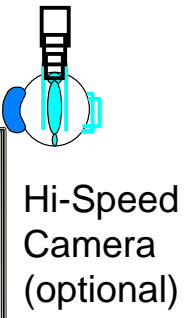


- Ground Met**
- Air Temp
 - Relative Humidity
 - Dew Point
 - Wind Direction
 - Wind Speed

If light source is sufficient the range can either be indoors or outdoors



- Optional Downrange Radar**
- Compliments aeroballistic analysis
 - Muzzle velocity
 - Range velocity
 - Time
 - Distance

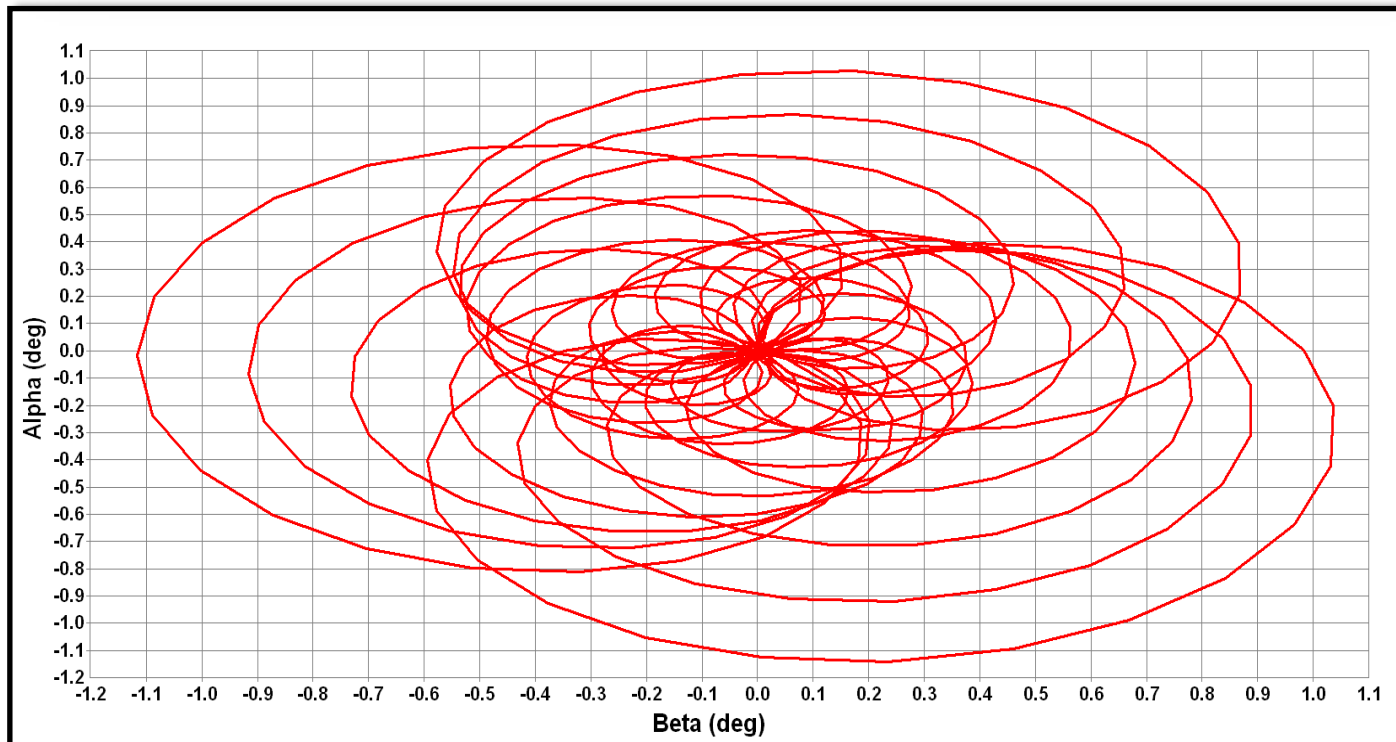


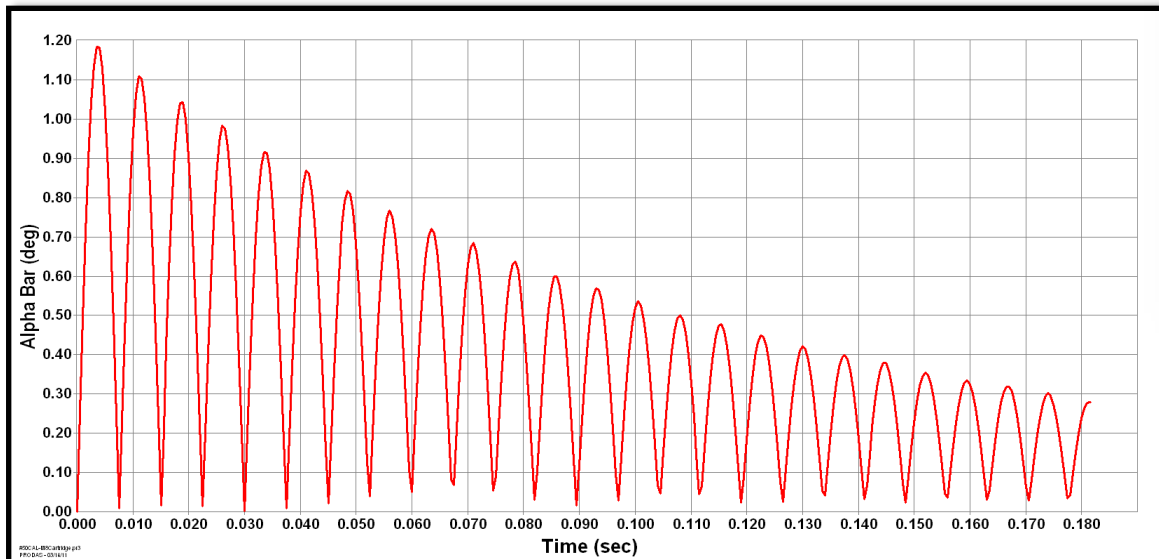
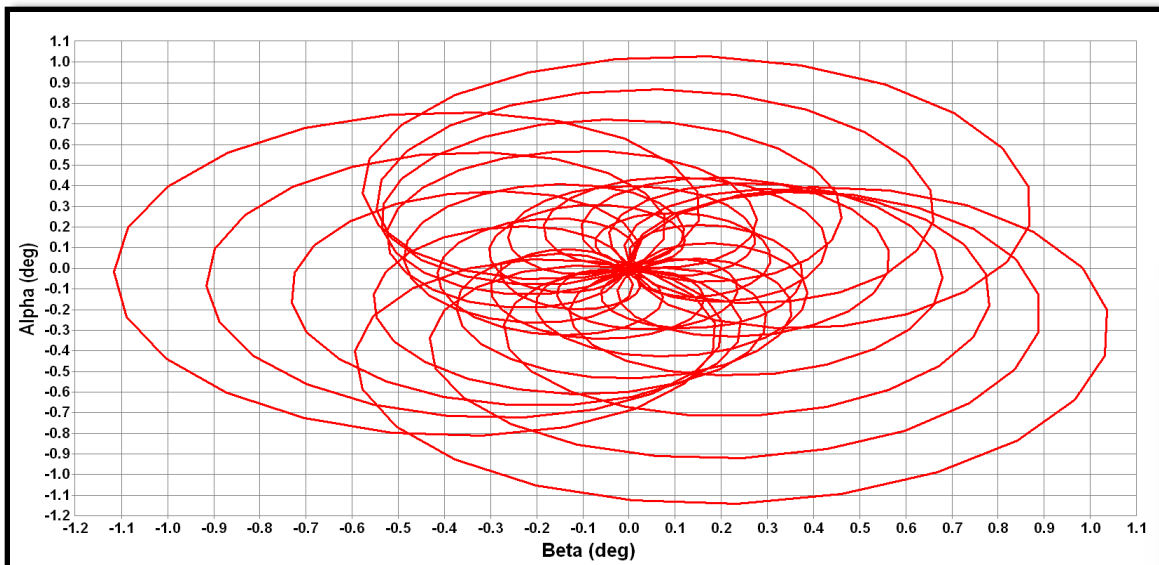
Data Acquisition Plots (Rapid Return/Simple Instrumentation)





Use of OnLaD, Witness Panel(s), Hi-Speed Camera(s), and minimal data acquisition allow the projectile motion to be captured. This permits a quick, cheap and effective method to determine:

- Max Tip-Off Angle
- Tip-Off Direction
- Does Body Motion Grow?

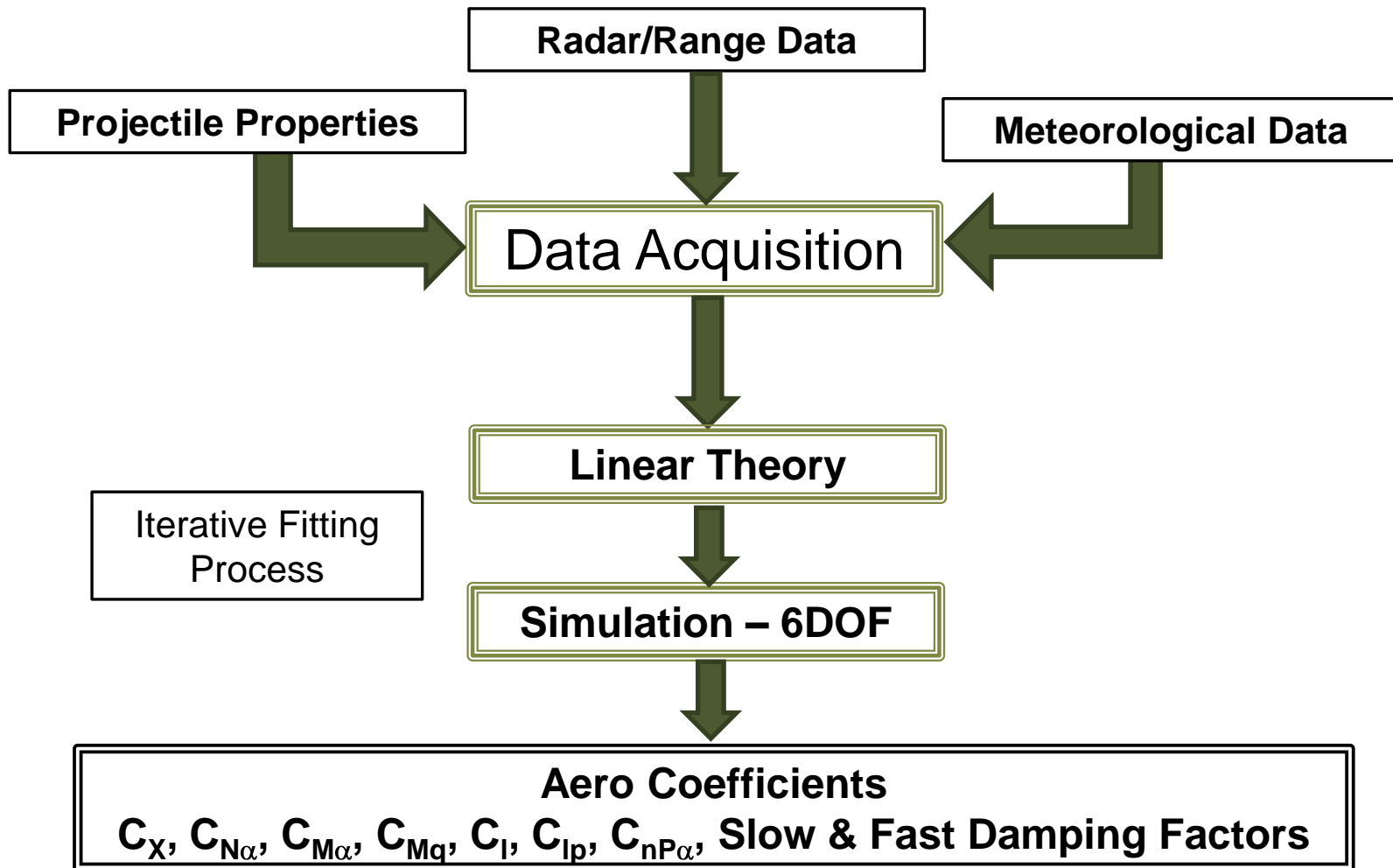




Use of Radar Provides Velocity & Positional Data:

- Tip-Off Rates (q, r)
- Roll Rate, p (via asymmetric optic shape , , etc..)
- Pitch Damping, $Cm\dot{q}$
- Etc...

Adding In Post Processing Capability



- **Miniature laser diodes are cheap (<\$200-\$300)**
- **Test units, specifically small caliber bullets, are cheap and easy to retrofit with OnLaD**
- **Test range can be an enclosed tunnel (spark range with reduced instrumentation) or an open range (light source must accommodate) to reduce facility cost**
- **Development of data acquisition & post processor is an upfront cost/investment**
 - Companies such as ArrowTech & Aberdeen Research Laboratory have extensive experience and robust post processing techniques
- **Range instrumentation dictates level of data post processed**
 - Gun launch dynamics easily obtained
 - Aerodynamic coefficients obtained via addition of radar
- **Low cost method to quickly determine flight characteristics up front**