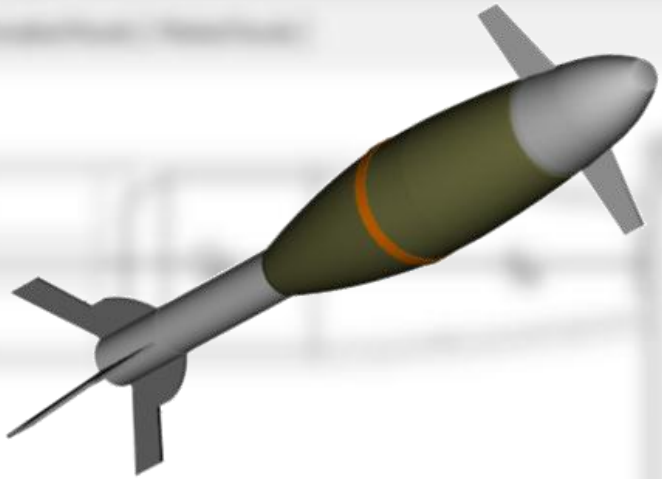


If you can't get a bigger target…

Modeling and Simulation for Guided Mortar Projectiles

May, 2012

Michael J. Wilson, PhD

Arrow Tech Associates

South Burlington, VT 05403

802-865-3460x14

mike@prodas.com

Projectile GNC

Arrow Tech
If you can't get a bigger target...

Requirements

Very Low Cost
<$15K

Survivability
Launch environments
5K+ Gs

Form Factor
Limited space on small airframes

Spin Dynamics
Spin rates from 5 – 250 Hz

GNC Design

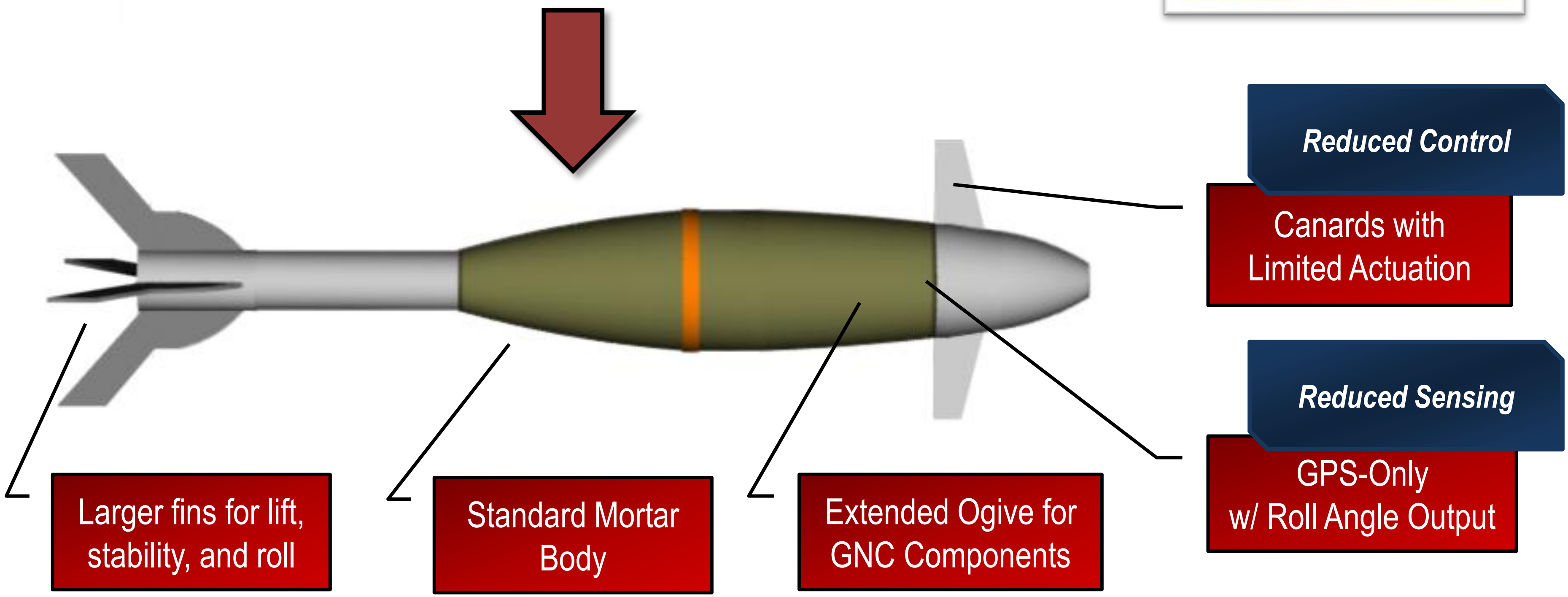
Reduced Sensing — Sensors are inaccurate or nonexistent

Reduced Control — Actuators are simple, axes are coupled

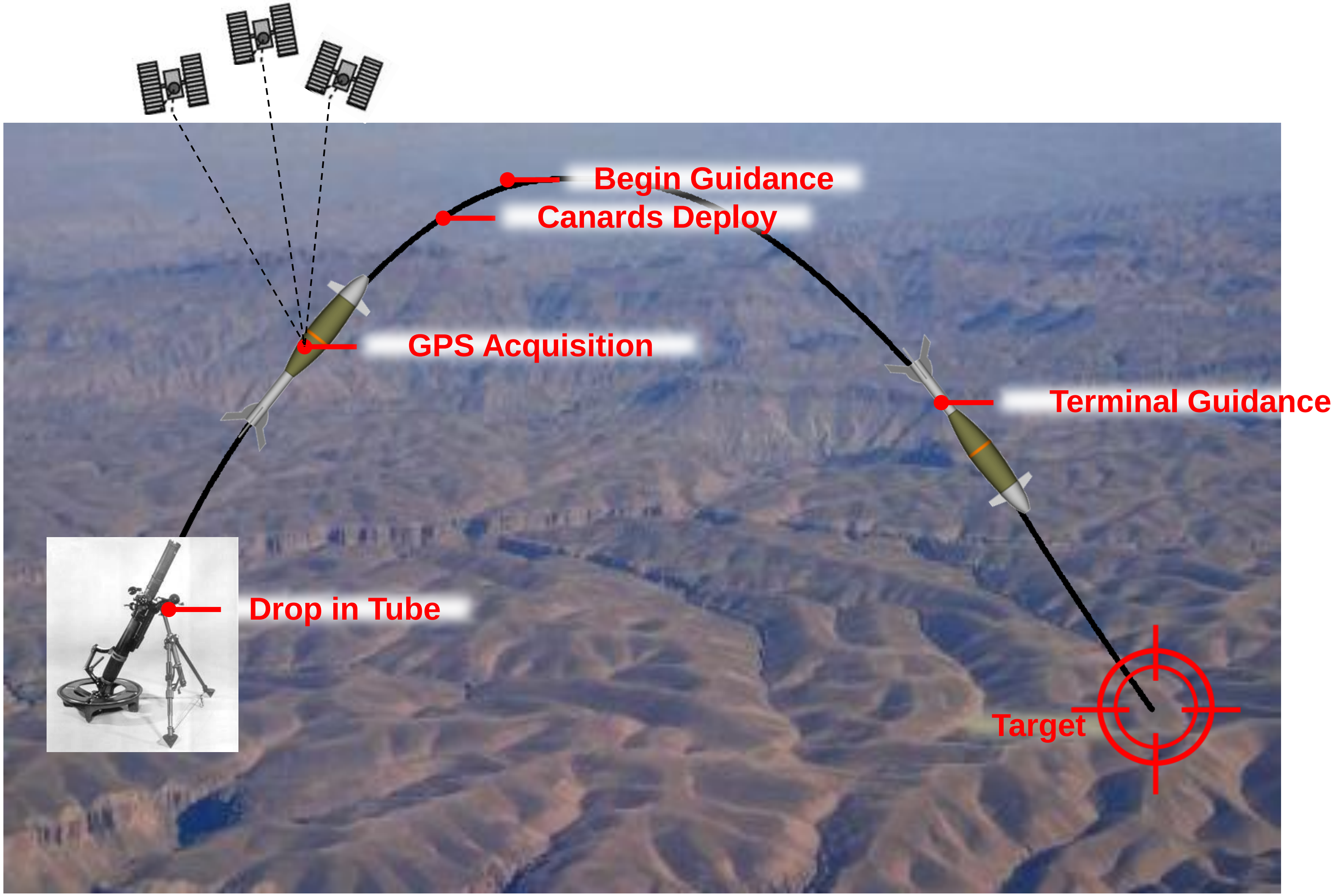
Novel Guidance Algorithms — Must be robust for compatibility with reduced sensing and control

High fidelity modeling and simulation is critical for the success of guided projectiles!

GNC Design - 60mm Guided Mortar

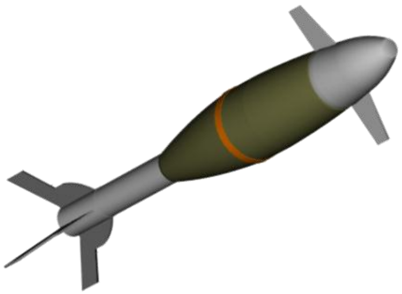


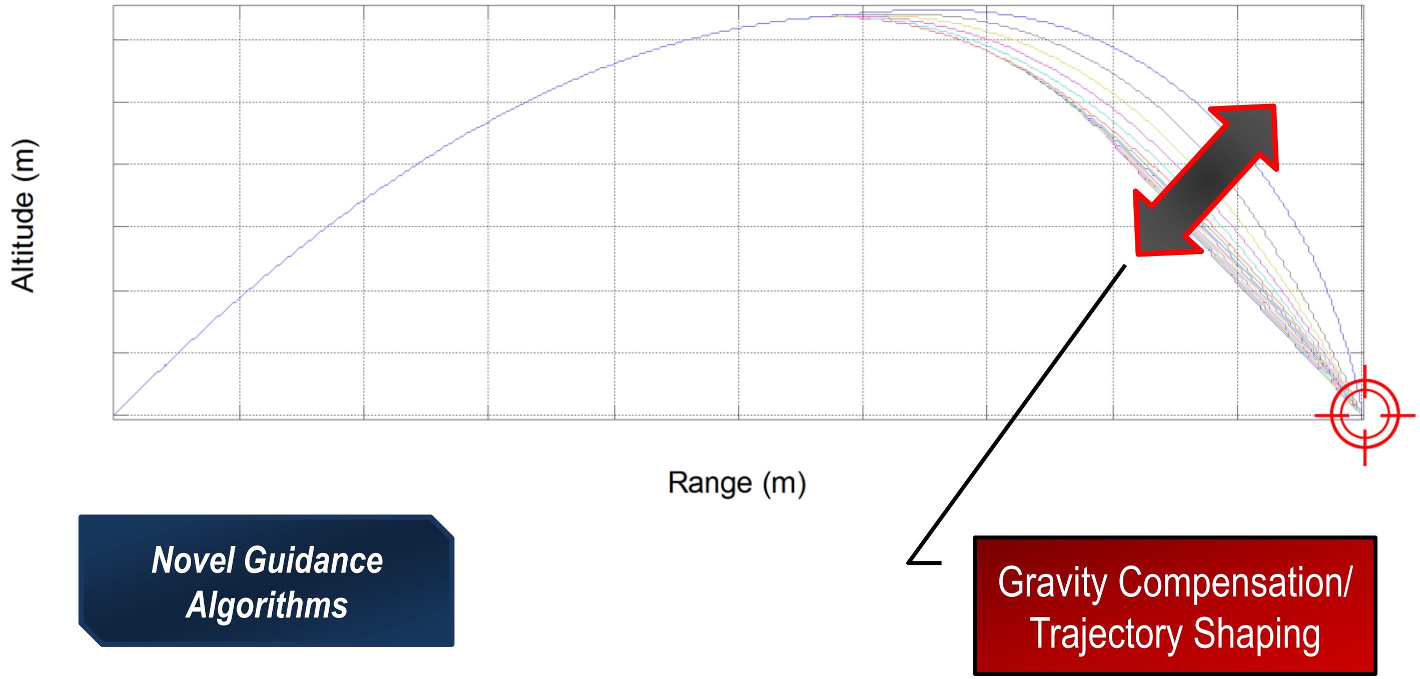
Flight CONOPS



ARROW TECH
If you can't get a bigger target…

- Guidance algorithm must take advantage of ballistic trajectory
- Do not want to fight gravity
- Additional trajectory shaping can improve angle of fall





Novel Guidance Algorithms

Aerodynamic Model

Direct Table Lookup Coefficients

- Extremely versatile – capture any asymmetries and nonlinearities
- Wind tunnel / CFD compatible format
- High angle of attack

$$F_z = \bar{q}A\left(C_z + \frac{pd}{2V} C_{zp} + \frac{qd}{2V} C_{zq} \right)$$

$$m = \bar{q}Ad\left(C_m + \frac{pd}{2V} C_{mp} + \frac{qd}{2V} C_{mq} \right)$$

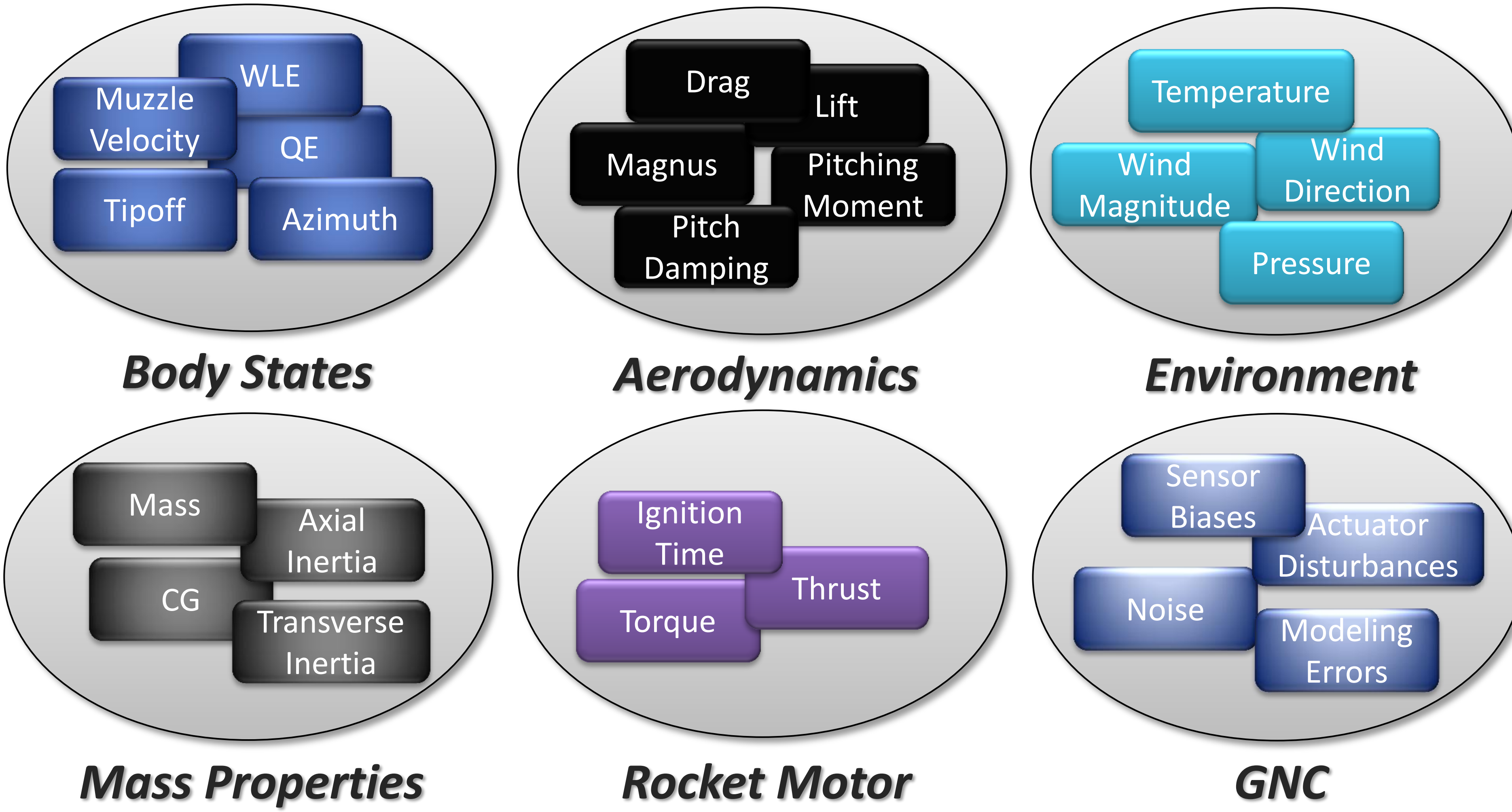
Polynomial Approximations

- Physics-based simplifications
- Spark range / aero predictor compatible format
- Flight test data reduction parameter fits

$$F_z = \bar{q}A\left(-\left[C_{N\alpha} + C_{N\alpha 3} \sin^2 \bar{\alpha} \right] \frac{w}{V} - \frac{pd}{2V} C_{Yp\alpha} \frac{v}{V} + \frac{qd}{2V} C_{Nq} \right)$$

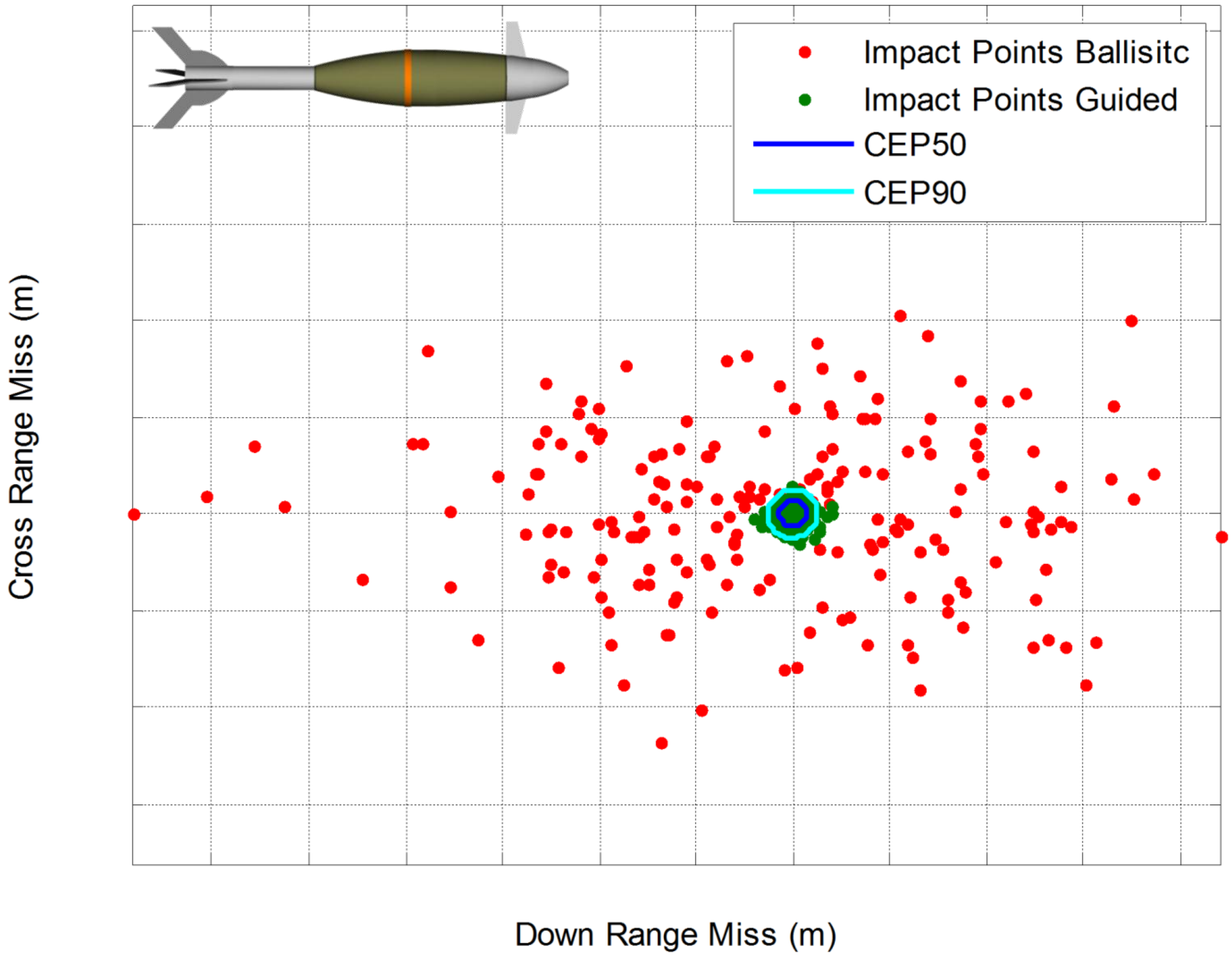
$$m = \bar{q}Ad\left(\left[C_{m\alpha} + C_{m\alpha 3} \sin^2 \bar{\alpha} \right] \frac{w}{V} + \frac{pd}{2V} C_{np\alpha} \frac{v}{V} + \frac{qd}{2V} C_{mq} \right)$$

Error Budget



- **3 Types: Mission-to-Mission, Weapon-to-Weapon, Round-to-Round**

- Monte Carlo trials based on error budget
- CEP50 vs. CEP90
- Randomizing
  - Missions
  - Weapons
  - Rounds



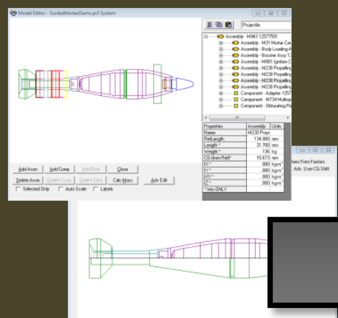
Beyond Concept Development

ARROW TECH
If you can't get a bigger target…

PRODAS Environment

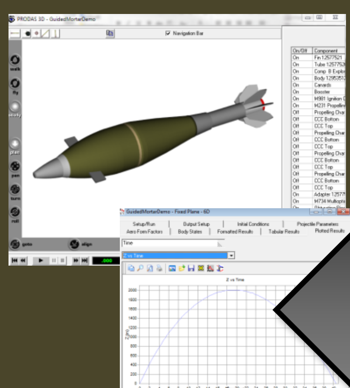
Modeling

- Projectile Modeler
- Aero Prediction
- Mass Properties
- Rocket Motor
- Initial Conditions
- Error Budgets
- MET

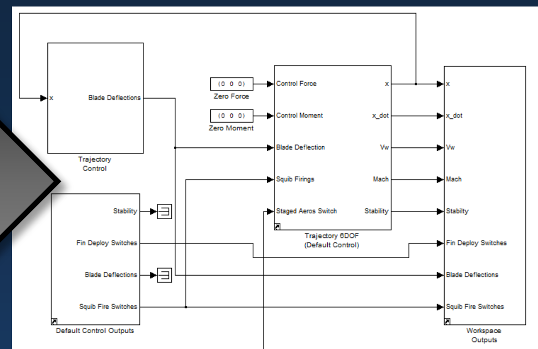


Visualization

- 3D Animations
- Extensive Plotting



MATLAB/Simulink Environment



Development

- Leverage All MATLAB/Simulink Toolboxes and Blocksets
- Focused Effort on GNC Design

Simulation

- Validated 6+DOF Trajectory Engine
- Seamless Data Interface and Execution Between PRODAS and MATLAB

Product Tests

Hardware-In-the-Loop (HIL)

- Use the same simulation to drive the HIL fixture

Embedded Code Generation

- Automatically generate flight code from the Simulink model

Fire Control

- Simulation software is the basis of fire control software