

Aeromechanics and Flight Control

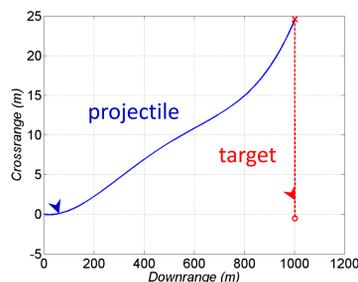
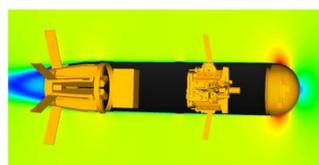
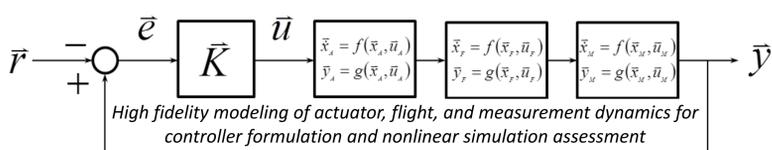
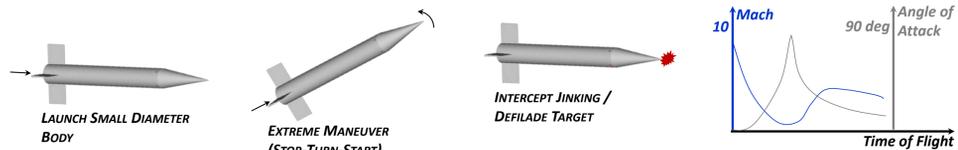


S&T Campaign: Sciences for Lethality & Protection
Aeromechanics and Flight Control

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Research Objective

- Understanding and controlling flight behaviors of novel atmospheric flight vehicles across omnisonic speeds
- Discovery of control mechanisms to overcome scientific barriers to maneuverability (e.g., aerodynamic lift-to-drag, guidance components, jet limitations) for extended lethal range, intercepting agile targets, and engaging defilade targets



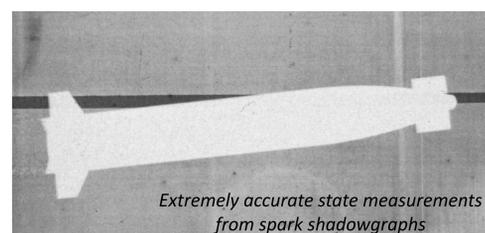
ARL Facilities and Capabilities Available to Support Collaborative Research



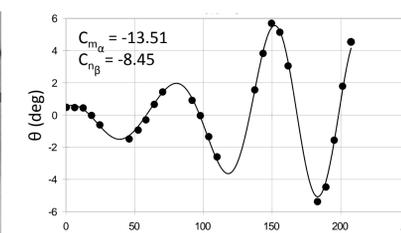
Unique launch and flight range facilities



Spark range experiments



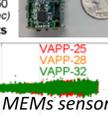
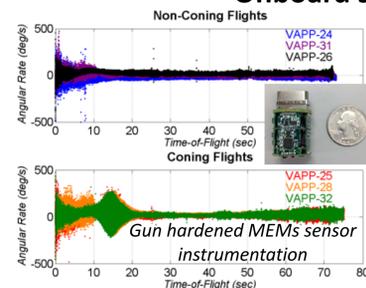
Extremely accurate state measurements from spark shadowgraphs



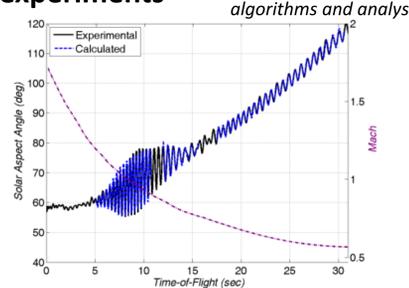
Parameter estimation algorithms and analysis

Capabilities for Understanding Flight Behaviors

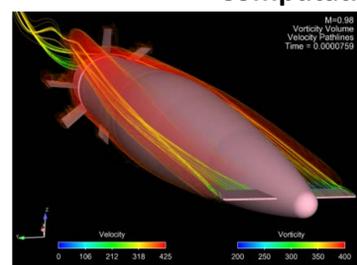
Onboard sensor experiments



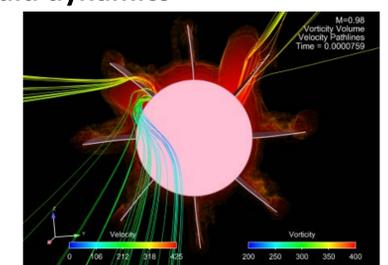
Gun hardened MEMS sensor instrumentation



Computational fluid dynamics



Three-dimensional, time-resolved access to complex flow-fields through High Performance Computing resources

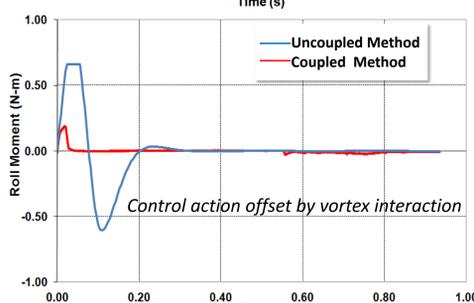
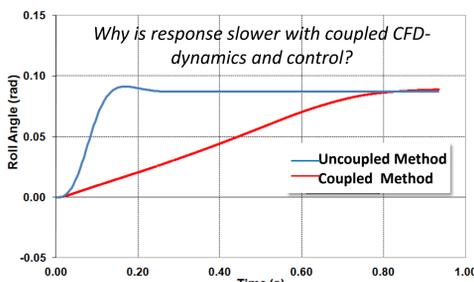
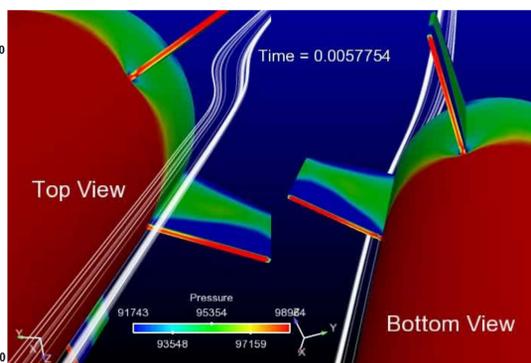
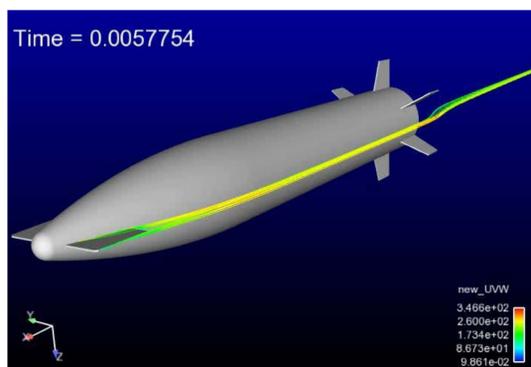


Challenges

- Rapid, accurate prediction of maneuvering flight physics and experimental validation
- Nonlinear control laws with limited feedback and simple actuators
- High angle-of-attack, unsteady and separated flows, turbulence, wakes, shock-shock, shock-boundary layer and vortex interactions, nonlinear dynamics and stability

Roll Control Investigation using Coupled Computational Fluid Dynamics and Flight Dynamics and Control Simulations
Flight Control Algorithm based on Aeromechanics

$$\begin{aligned} \dot{\mathbf{x}} &= [\dot{\phi} \quad \dot{\alpha} \quad \dot{\delta}_1 \quad \dot{\delta}_2]^T \\ \mathbf{u} &= [\delta_1^{CMD} \quad \delta_2^{CMD}]^T \\ \mathbf{A} &= \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -1/\tau & 0 \\ 0 & 0 & 0 & -1/\tau \end{bmatrix} \\ \mathbf{B} &= \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1/\tau & 0 \\ 0 & 1/\tau \end{bmatrix} \\ \mathbf{C} &= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \\ \mathbf{D} &= \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \end{aligned}$$



Recent Journal Publications

Fresconi, F., DeSpirito, J., Celmins, I., "Flight Performance of a Small Diameter Munition with a Rotating Wing Actuator," accepted to *Journal of Spacecraft and Rockets*, 2014.
 Fresconi, F., Rogers, J., "Flight Control of a Small Diameter Spin-Stabilized Projectile Using Imager Feedback," accepted to *Journal of Guidance, Control, and Dynamics*, 2014.
 Bhagwandin, V., Sahu, J., "Numerical Prediction of Pitch Damping Stability Derivatives for Finned Projectiles," *Journal of Spacecraft and Rockets*, Vol. 51, No. 5, pp. 1603-1618, 2014.
 Celmins, I., Fresconi, F., Nelson, B., "Actuator Characterization of Man Portable Precision Maneuver Concepts," *Defence Technology*, Vol. 10, Issue 2, June 2014, pp. 141-148.
 Fresconi, F., Celmins, I., Ilg, M., Maley, J., "Projectile Roll Dynamics and Control with a Low-Cost Maneuver System," *Journal of Spacecraft and Rockets*, Vol. 51, No. 2, pp. 624-627, 2014.
 Fairfax, L., Fresconi, F., "Position Estimation for Projectiles using Low-cost Sensors and Flight Dynamics," *Journal of Aerospace Engineering*, Vol. 27, No. 3, pp. 611-620, 2014.
 Dykes, J., Costello, M., Fresconi, F., Cooper, G., "Periodic Projectile Linear Theory for Aerodynamically Asymmetric Projectiles," *Journal of Aerospace Engineering*, Vol. 228, pp. 2094-2107, 2014.
 Sahu, J., Heavey, K.R., "Parallel CFD Computations of Projectile Aerodynamics with a Flow Control Mechanism," *Computers and Fluids*, Vol. 88, pp. 678-687, 2013.
 Dykes, J., Montalvo, C., Costello, M., Sahu, J., "Use of Microspoilers for Control of Finned Projectiles," *Journal of Spacecraft and Rockets*, Vol. 49, No. 6, pp. 1131-1140, 2012.
 Fresconi, F.E., Harkins, T., "Experimental Flight Characterization of Asymmetric and Maneuvering Projectiles from Elevated Gun Firings," *Journal of Spacecraft and Rockets*, Vol. 49, No. 6, 2012, pp. 1120-1130.
 Cooper, G., Fresconi, F.E., Costello, M., "Flight Stability of an Asymmetric Projectile with Activating Canards," *Journal of Spacecraft and Rockets*, Vol. 49, No. 6, 2012, pp. 130-135.
 Fresconi, F.E., "Guidance and Control of a Projectile with Reduced Sensor and Actuator Requirements," *Journal of Guidance, Control, and Dynamics*, Vol. 34, No. 6, 2011, pp. 1757-1766.
 Fresconi, F., Cooper, G.R., Celmins, I., DeSpirito, J., Costello, M., "Flight Mechanics of a Novel Guided Spin-Stabilized Projectile Concept," *Journal of Aerospace Engineering*, 226, 2011, pp. 327-340.
 Fresconi, F., Cooper, G.R., Costello, M., "Practical Assessment of Real-Time Impact Point Estimators for Smart Weapons," *Journal of Aerospace Engineering*, 24, 2011, pp. 1-11.
 Fresconi, F., Plostins, P., "Control Mechanism Strategies for Spin-Stabilized Projectiles," *Journal of Aerospace Engineering*, Vol. 224, 2010, pp. 979-991.
 DeSpirito, J., Siltou, S., Weinacht, P., "Navier-Stokes Predictions of Dynamic Stability Derivatives: Evaluation of Steady-State Methods," *Journal of Spacecraft and Rockets*, Vol. 46, No. 6, 2009, pp. 1142-1154.

Complementary Expertise/ Facilities/ Capabilities Sought in Collaboration

- Control mechanisms, nonlinear control algorithms and assessment tools for controlling high maneuverability flight bodies across omnisonic speeds
- Low cost/highly accurate experimental techniques for investigating maneuvering flight