Aerodynamics Branch

MICRO-ADAPTIVE FLOW CONTROL APPLIED TO A SPINNING PROJECTILE

Dr. Jubaraj Sahu
U.S. Army Research Laboratory

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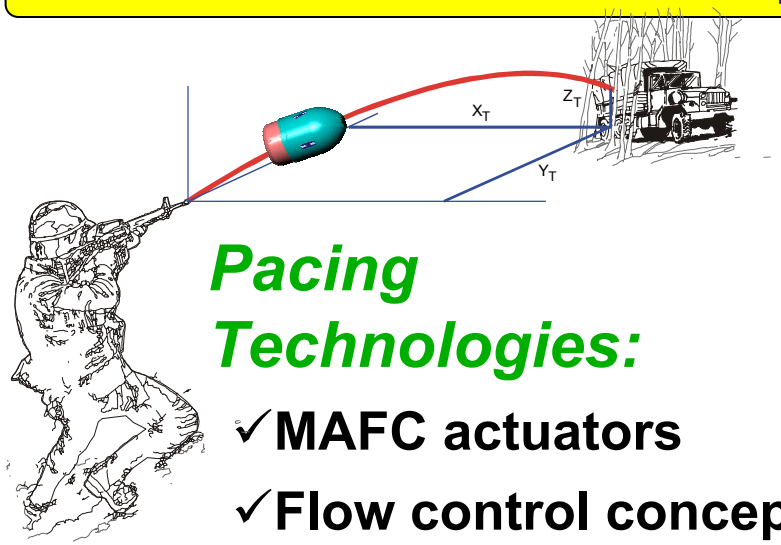
Weapons & Materials Research Directorate

SCORPION

Self-CORrecting Projectile for Infantry OperatioN

GOAL: Demonstrate a Guided Spinning Projectile Using MAFC Technology



Pacing Technologies:

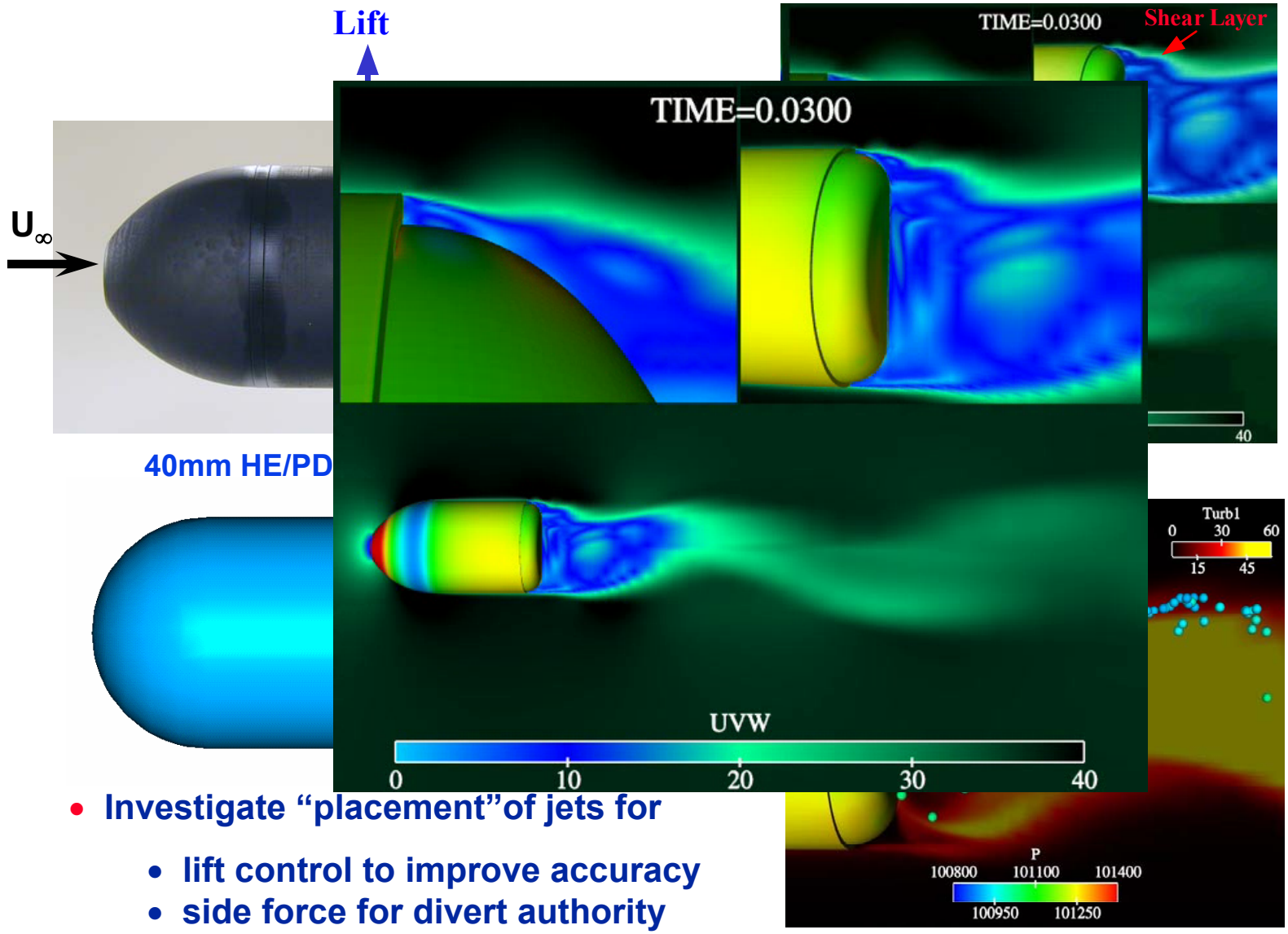
- ✓MAFC actuators
- ✓Flow control concept for spinning projectiles
- ✓Flight control algorithm
- ✓Initialization and INS for spinning projectile
- ✓Compact, g-hardened electronics and packaging
- ✓<u>Design tools: integrated computational fluid dynamics (CFD) and flight dynamics</u>

Objectives:

1. Demonstrate microadaptive flow control (MAFC) authority and guidance algorithm for a medium-caliber munition at subsonic speeds.
2. Provide a suite of validated advanced design tools.
3. Establish technology transitioning pathways for tactical systems.

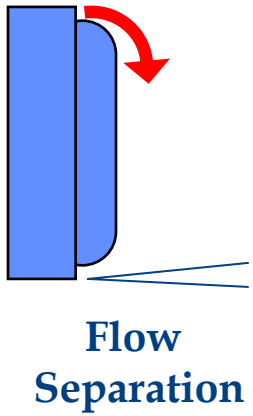
Micro-jet CFD Flow Visualization

U_∞ = 37 m/s, α = 0°, Ujet = 31 m/s, f= 1000 Hz, no spin



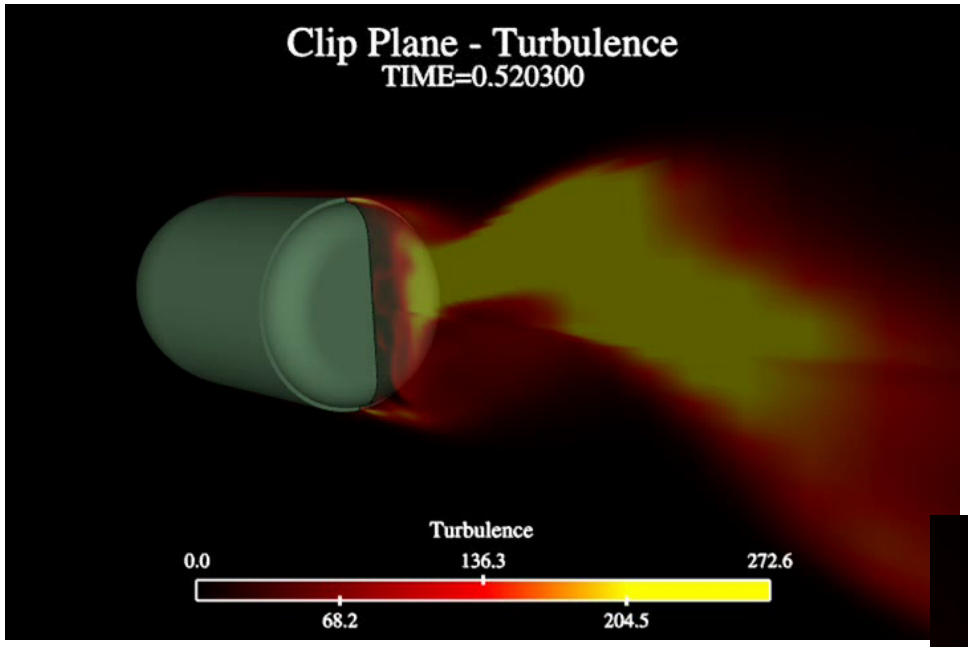
Asymmetric Flow Separation

- Investigate "placement" of jets for
  - lift control to improve accuracy
  - side force for divert authority



Particle Traces Visualization

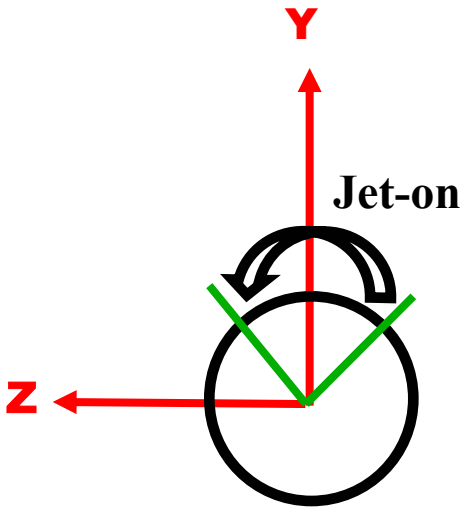
U = 82 m/s, α = 0°, Ujet = 31 m/s, f = 1000 Hz, Spin = 67 Hz

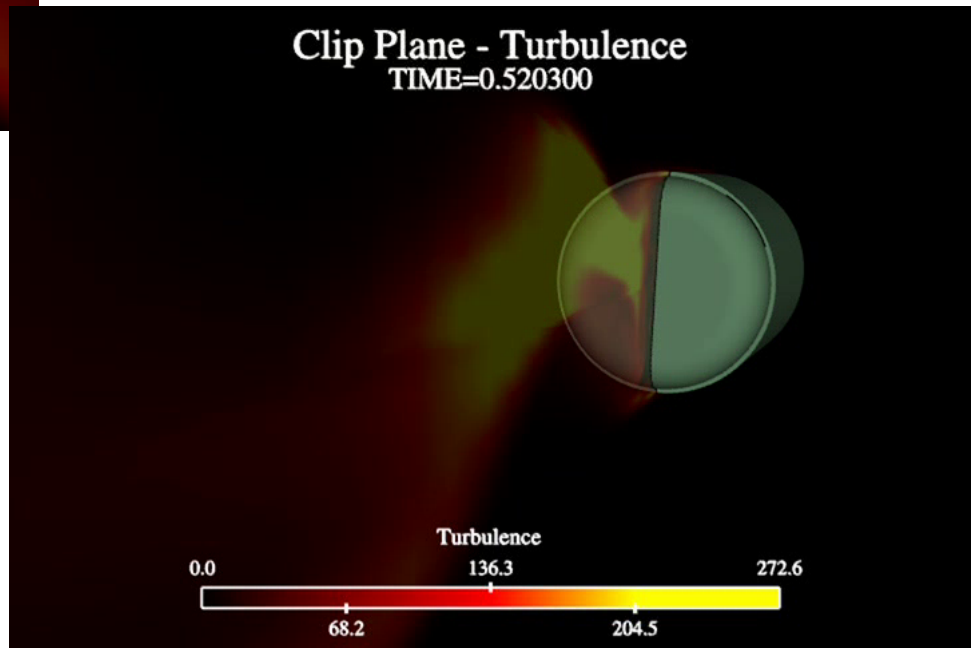


For Two Spin Cycles

1st cycle: Red

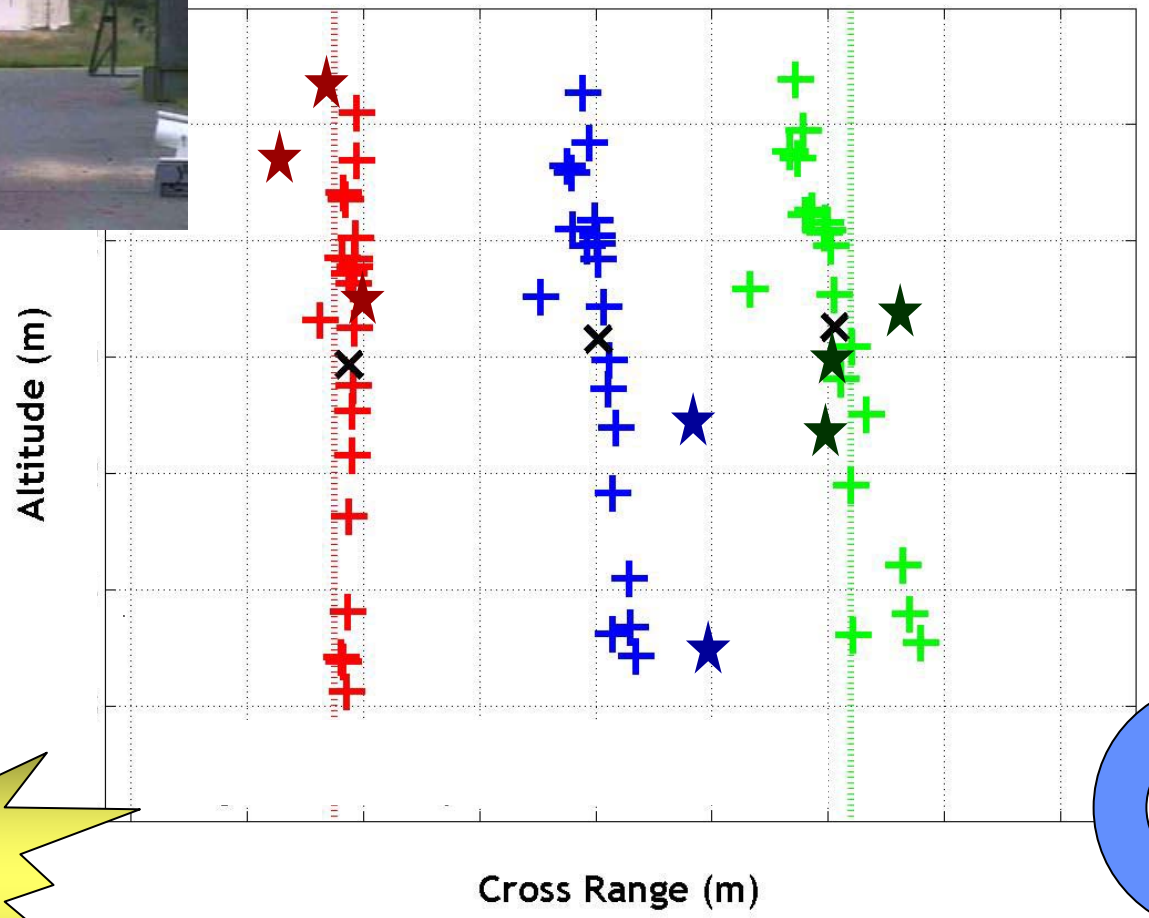
2nd cycle: Blue





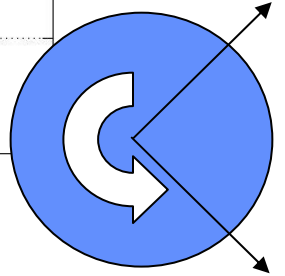
SCORPION Open-Loop Test
Flight Test Results Compared With Simulated Impacts

Experimental Muzzle Velocity Distribution Used for Simulation



Experimental Impacts

- Right Divert Command
- No Command
- Left Divert Command

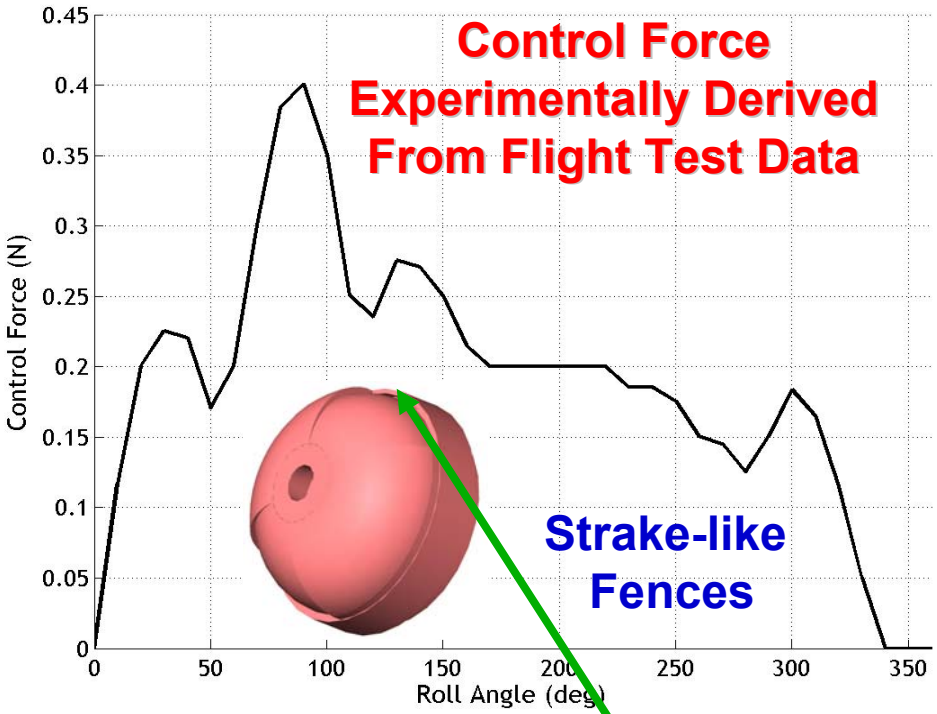


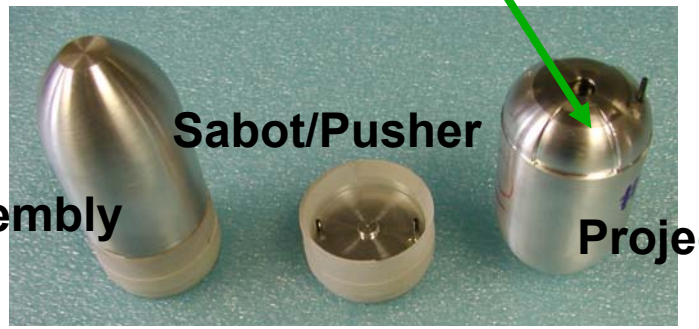
ONLY a few jet cycles are available

Activate for 1/4 revolution (about 4 jet cycles) such that force generated will be horizontal (left or right, as selected).

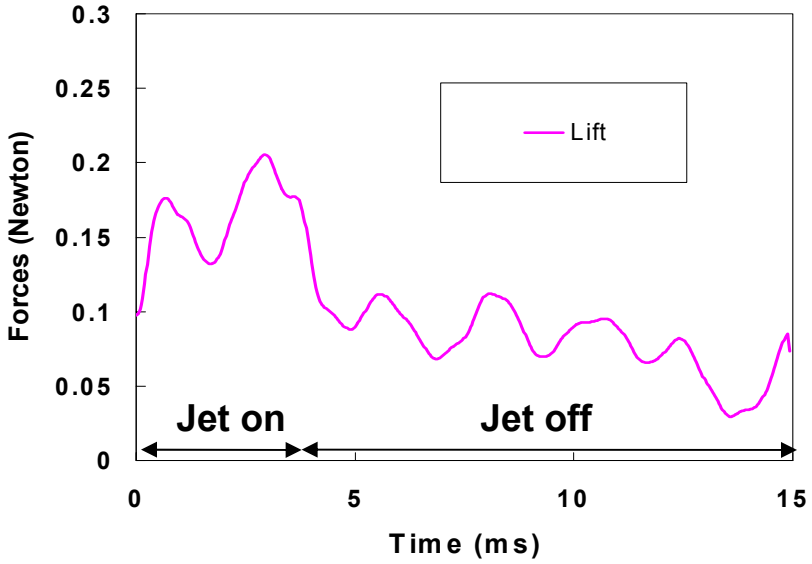
Flight Data Confirms Control Force

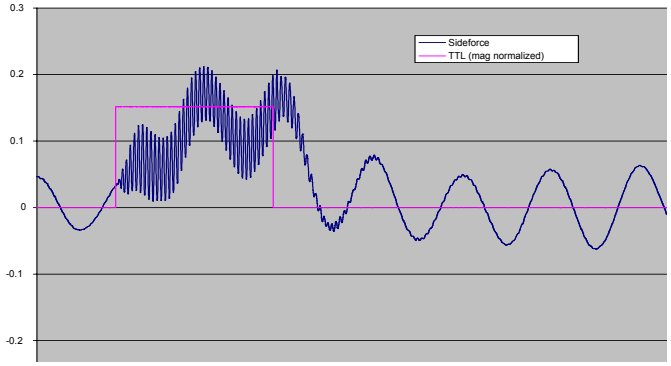
Georgia Institute of Technology





ARL Unsteady CFD (Spinning)

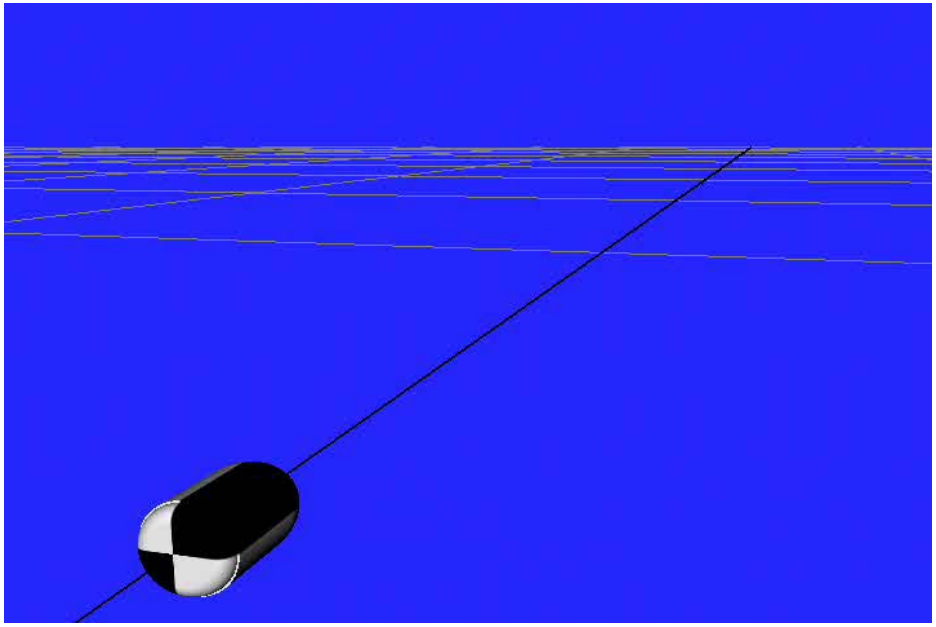




GTRI Wind Tunnel Experiments (Non-spinning)

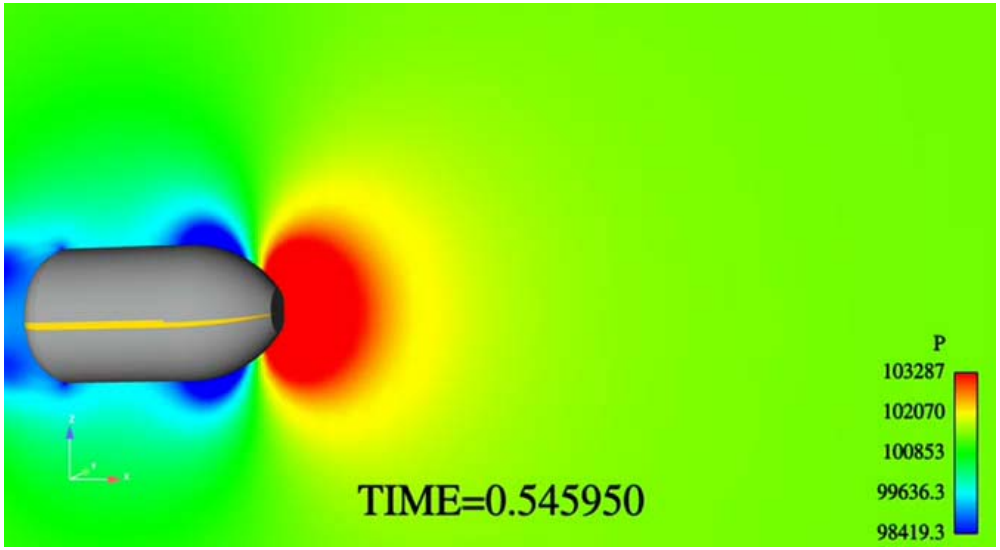
UNSTEADY AERODYNAMICS/FLIGHT DYNAMICS

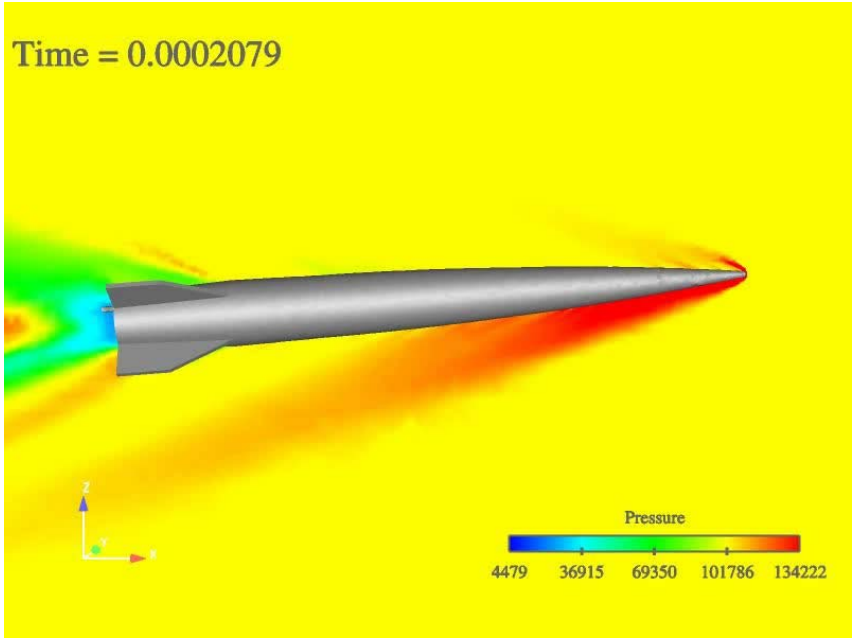
DOD HPCMP Grand Challenge Project



GOAL: Virtual Fly-Out of Projectiles

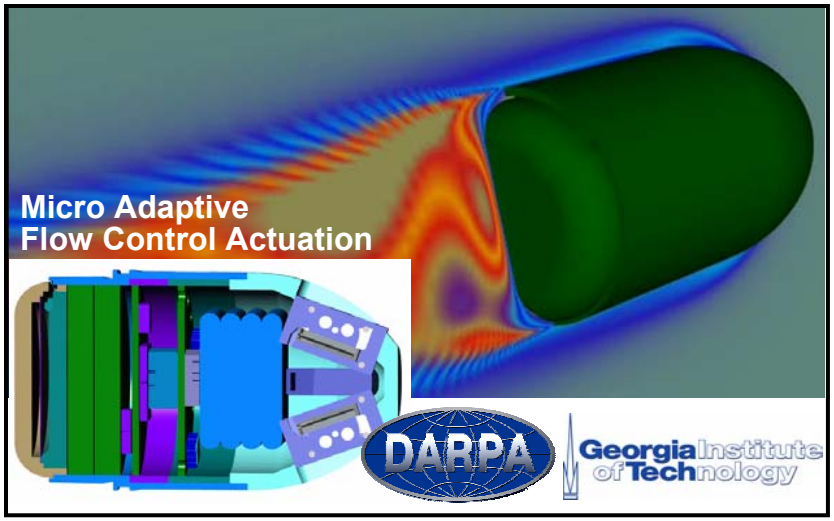
Coupled CFD/Rigid Body Dynamics (RBD) Simulations of in-flight spinning and finned projectiles

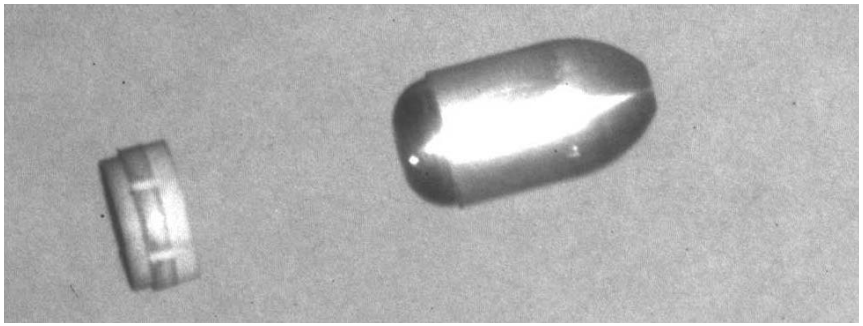




Guided Medium Caliber Munitions

- Demonstrated Micro-Adaptive Flow Control for divert of subsonic guided 40 mm grenade
- Demonstrated Multi-disciplinary physics modeling – flew munition through the computer using High Performance Computing
- First divert ever of a spin stabilized munition system at 60 hertz spin rate
- Developed a miniature, G hard, on board flight control system
- Demonstrated initialization at muzzle exit – Velocity - Orientation
- Demonstrated open loop divert
- Demonstrated closed loop guidance to the target on major error source - Velocity
- Cut on target dispersion due to muzzle velocity variation to one third of the system value





Experimentally Demonstrated Novel Aerodynamic Control Methodology Capable of Diverting Medium Caliber Munitions

Technologies developed in this research were critical in the design of flight control systems required for subsequent flight tests that demonstrated the ability of MAFC to divert the trajectory of a spinning projectile in flight

SCORPION CFD VIDEO