Scorpion Technology Program Overview

DARPA

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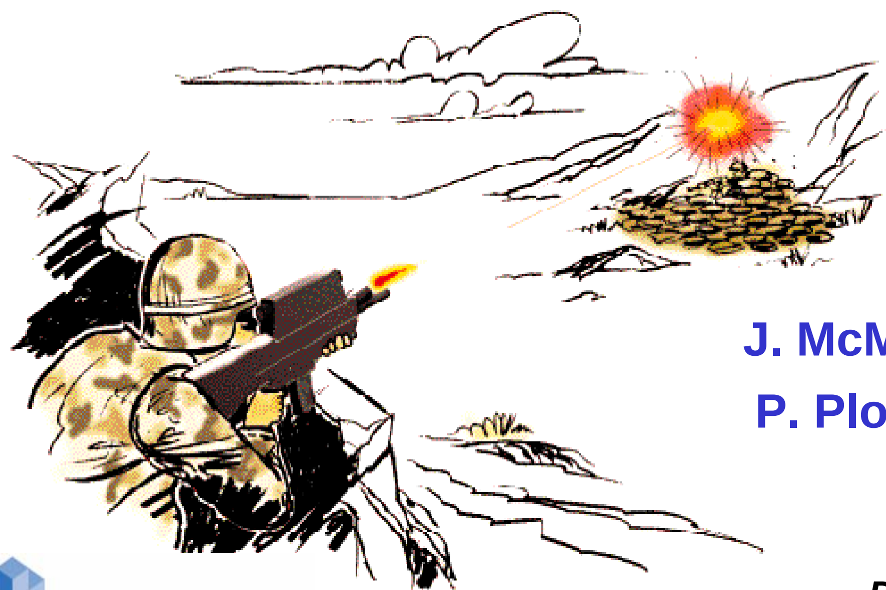
MICRO ADAPTIVE FLOW CONTROL
MAFC

NDIA Fire Power Symposium

Parsipanny, NJ, 12 June 2007

“Micro Adaptive Flow Control Applied to a Spinning Projectile”

SCORPION
Self-**Cor**recting **P**rojectile for **I**nfantry **O**peratio**n**

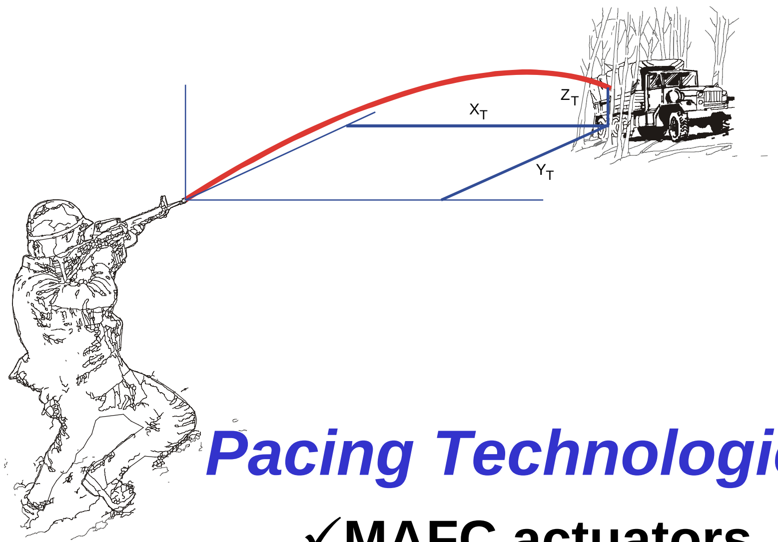


J. McMichael, A. Glezer and A. Lovas, *GTRI*
P. Plostins, G. Brown and J. Sahu, *USARL*

in collaboration with:
Mike Heiges, Kevin Massey, GTRI
Dave Lyon, Dave Hepner, Tom Harkin, USARL
Mark Allen, Brian English, Chris Rinehart, Georgia Tech

SCORPION Objectives

GOAL: Demonstrate a Guided Spinning Projectile using MAFC Technology



***Objectives*:**

1. **Demonstrate MAFC control authority and guidance algorithm for a medium caliber munition**
2. **Provide a suite of validated advanced design tools**
3. **Establish technology transitioning pathways for tactical systems**

Pacing Technologies:

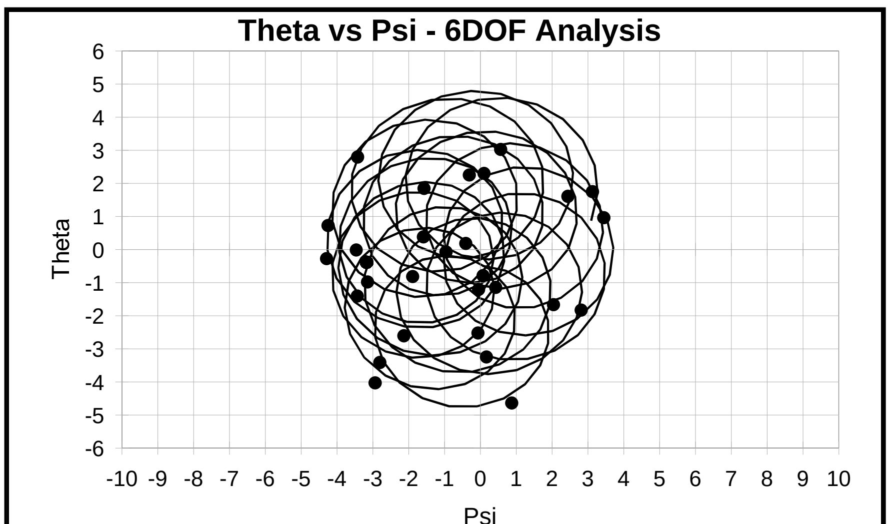
- ✓**MAFC actuators**
- ✓**Flow control concept for spinning projectiles**
- ✓**Flight control algorithm**
- ✓**Initialization and INS for spinning projectile**
- ✓**Compact, g-hardened electronics and packaging**
- ✓**Design Tools: Integrated CFD and Flight Dynamics**

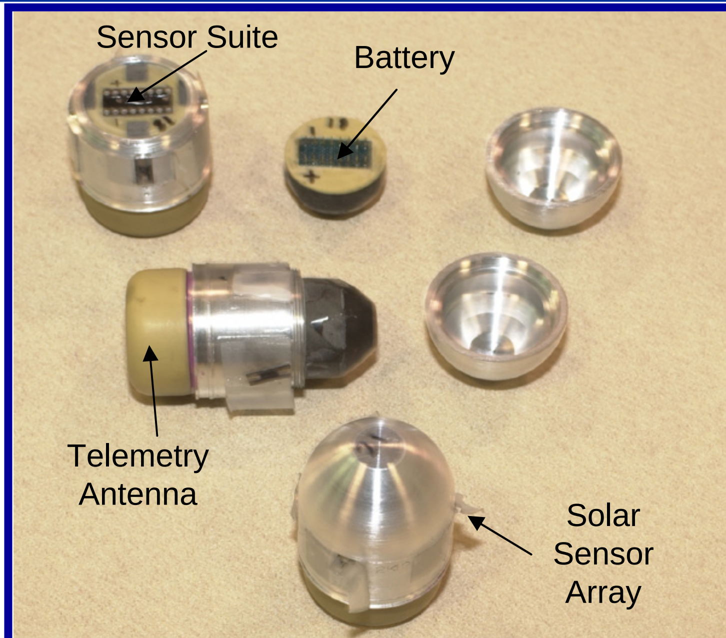
Aerodynamics Flight Tests

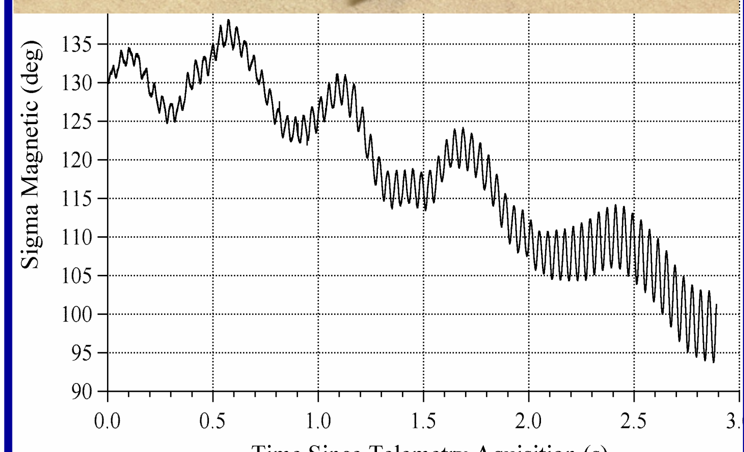
Grenade **Simulator**

Predicted Mass properties
Mass: 171 grams
cg from nose: 44 mm
Iaxial: 354.7 g*cm²
Itrans: 806.4 g*cm²

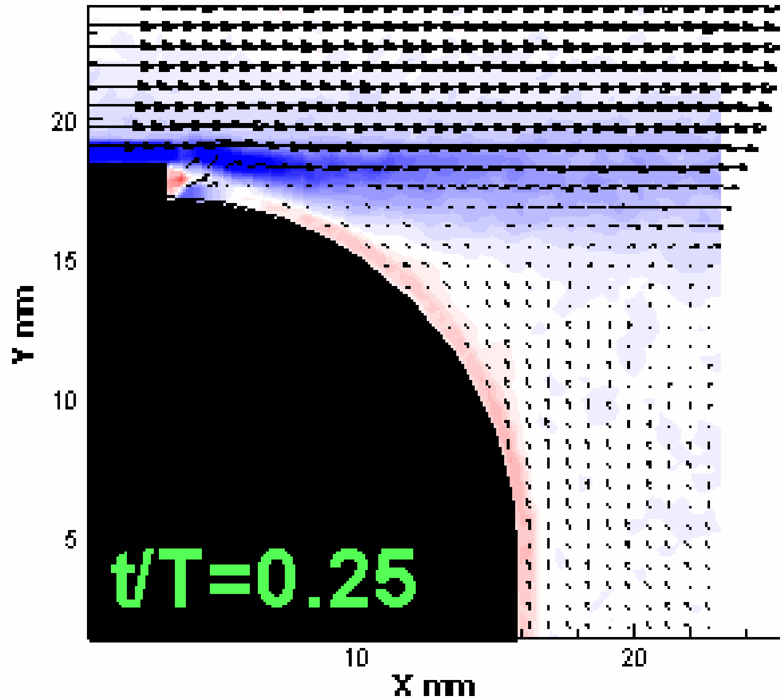
Classic Spin Stabilized Yaw Helix Looking Down Range







Transient Flow Behavior

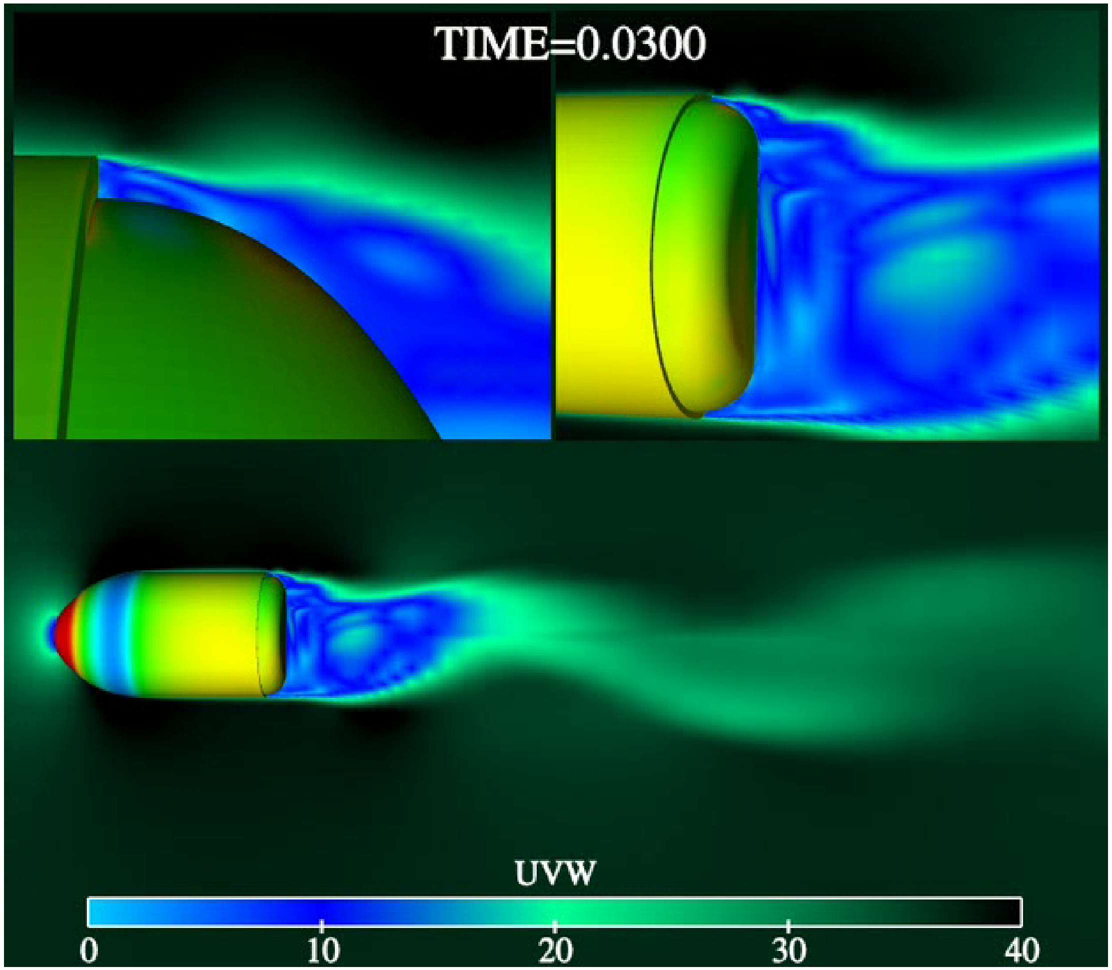


Phase-locked PIV images acquired over first 12 milliseconds

(T_{act} = 1 msec)

- Actuator runs for 6 cycles
- Starting vortex shed on first cycle
- Flow turning nearly complete after a few cycles
- Global effects completely developed in 1-2 convective time scales

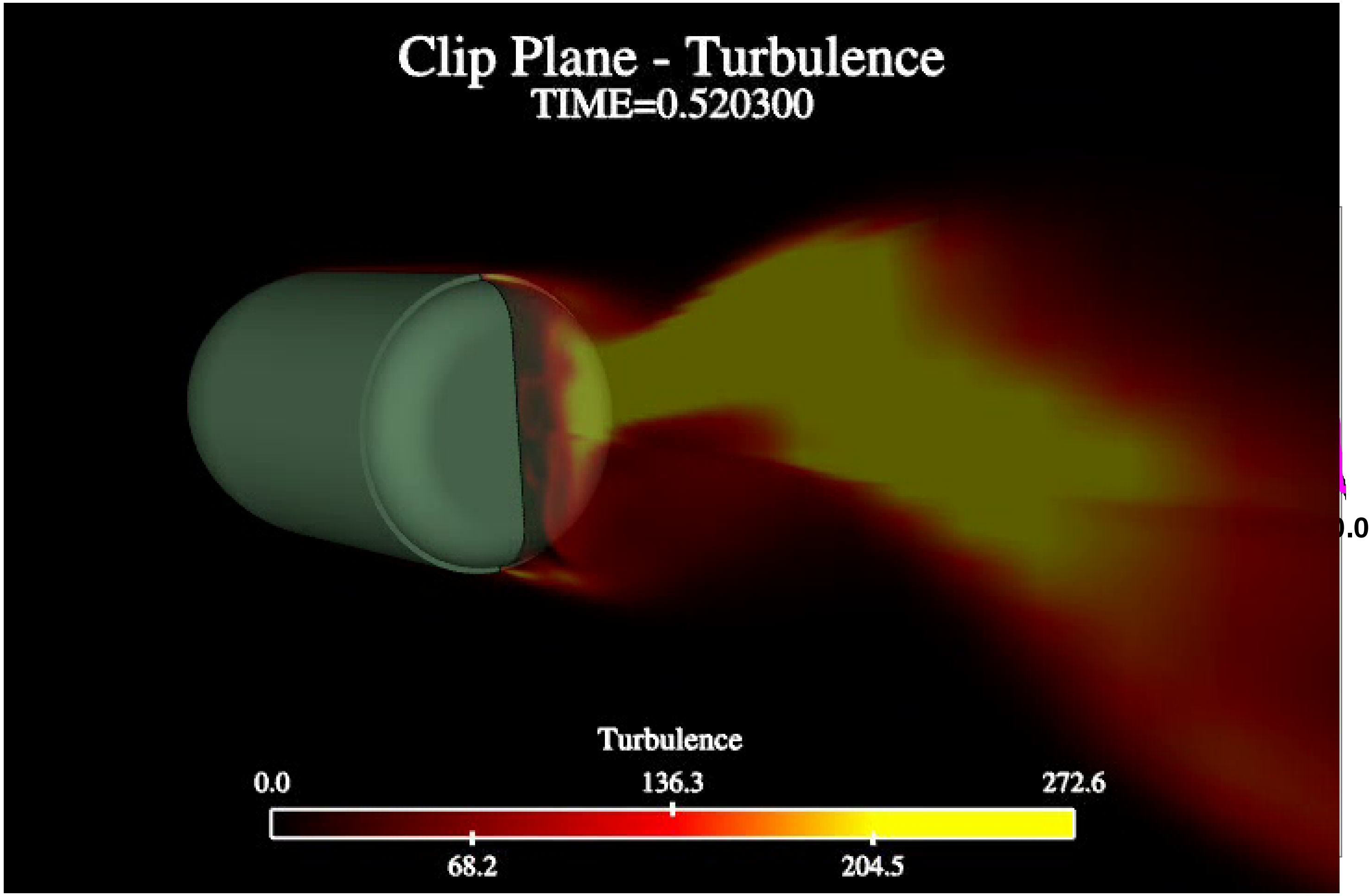
Continuous Synthetic Jet Circulation Control



D = 80 mm
U_0 = 37 m/s
α= 0°
Uj = 31 m/s
Without Spin
f= 1000 Hz

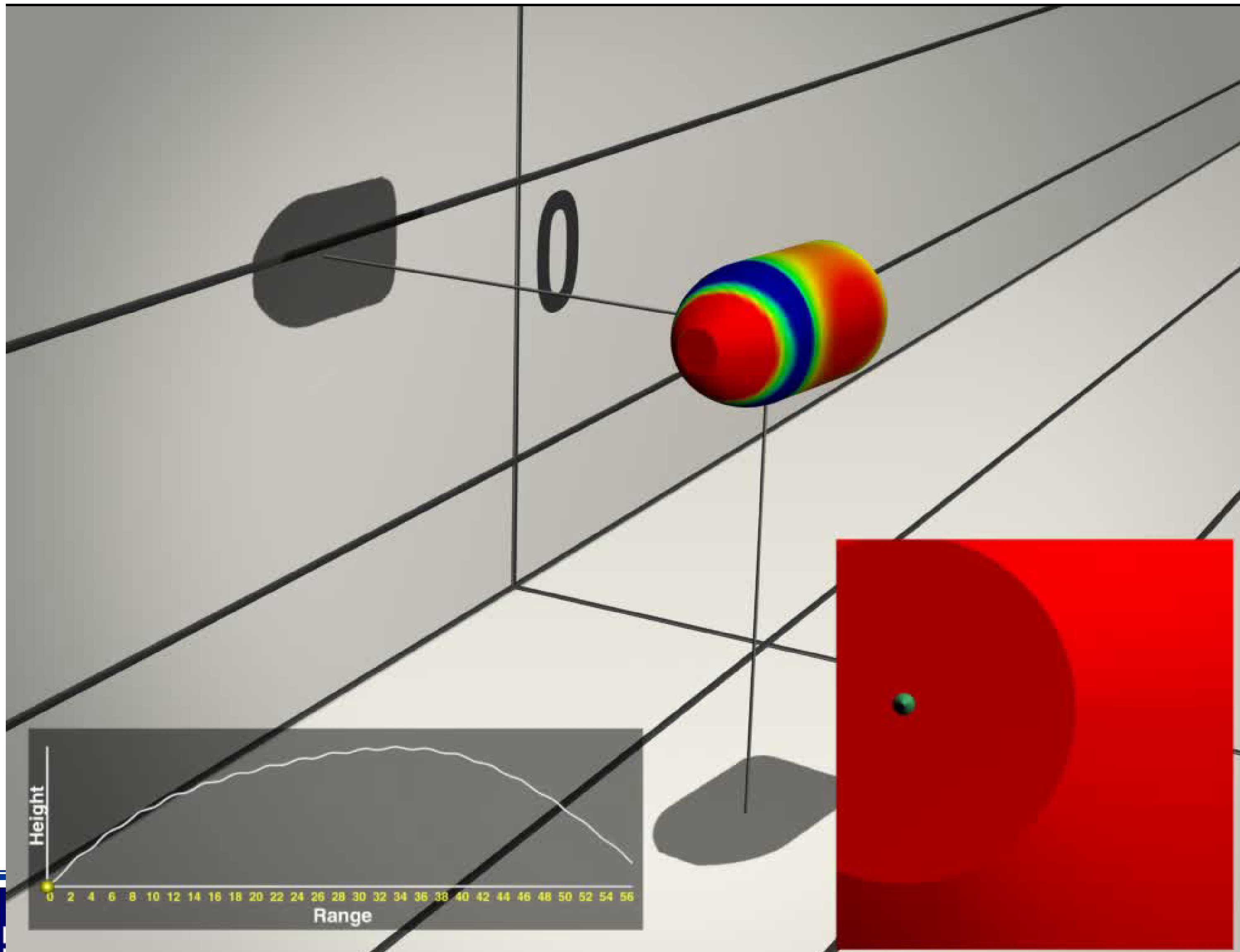
Simulation by
Jubaraj Sahu, ARL

Coupled CFD-SIXDOF Simulation Aerodynamic Force, Fy (Side Force)

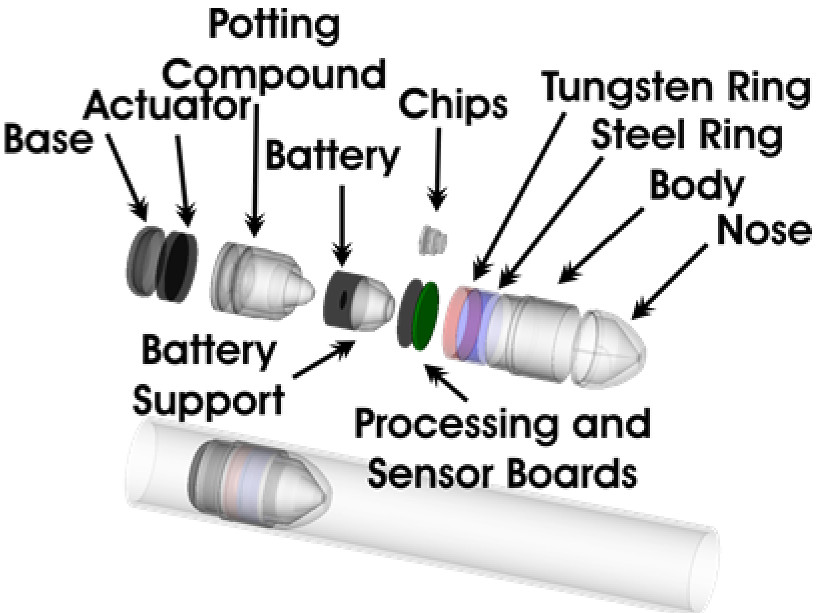


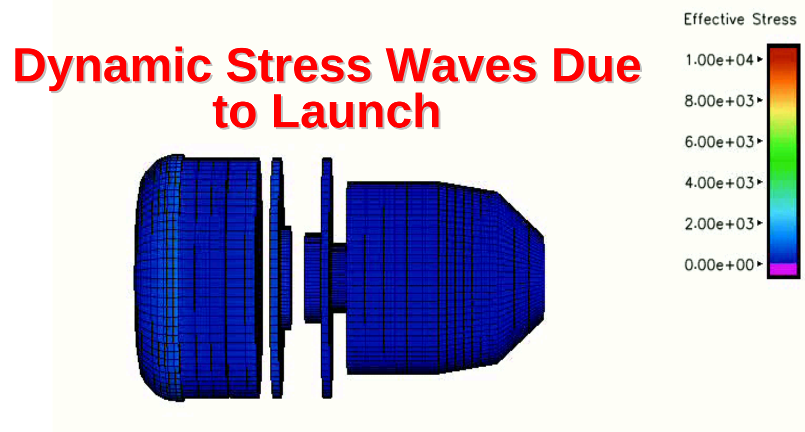
Range, m

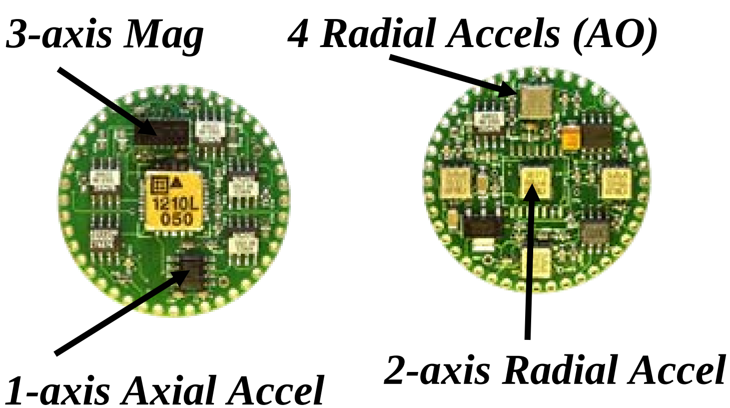
Virtual Fly-Out Visualization



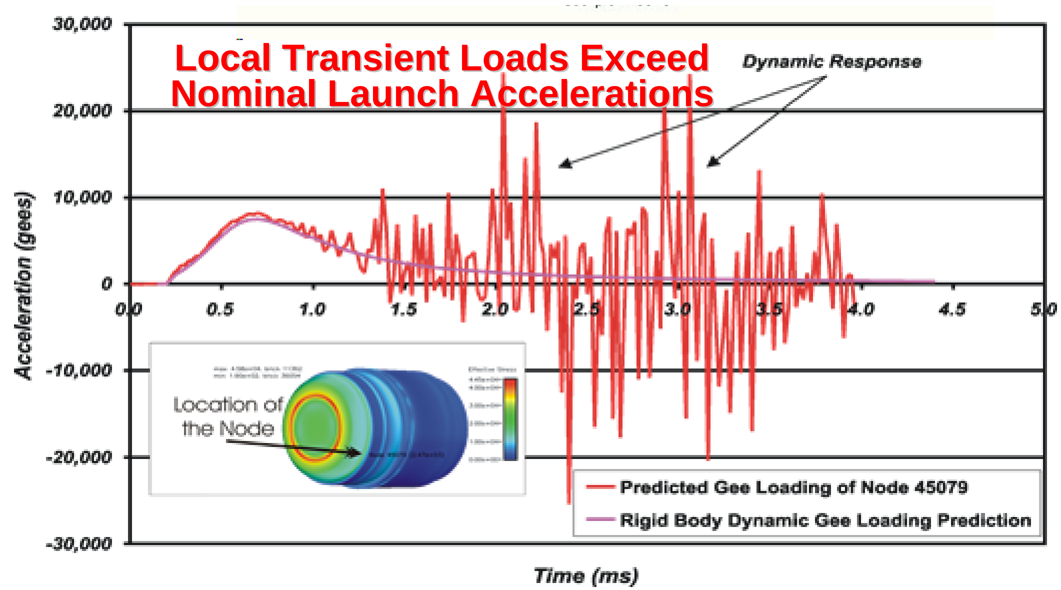
Full 3-D Dynamic Structural Analysis of SCORPION Projectile During Launch





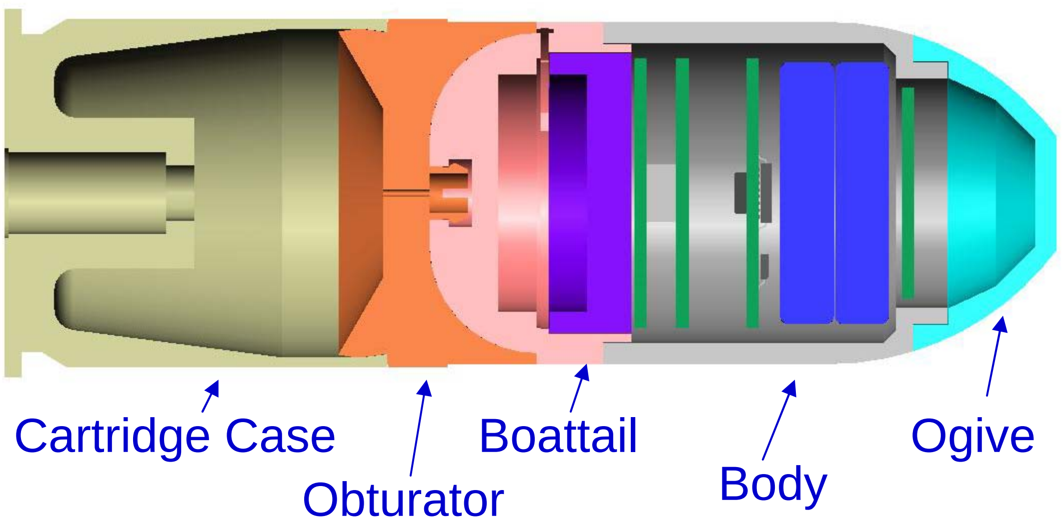


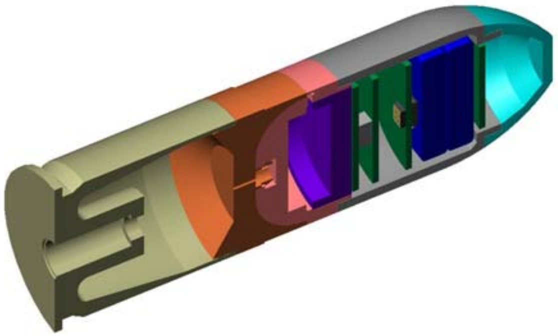
Dynamic Response During Launch

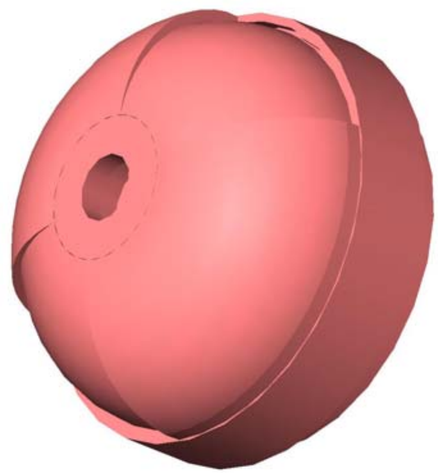


Georgia Tech Research Institute

Scorpion Assembly
Open Loop Test

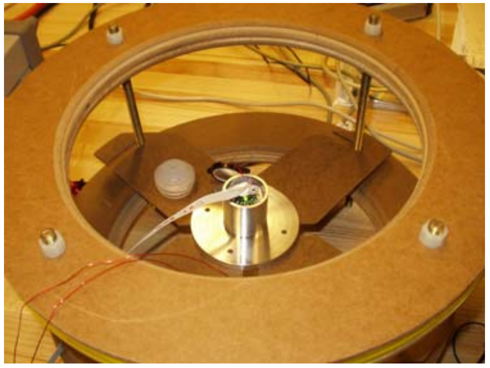




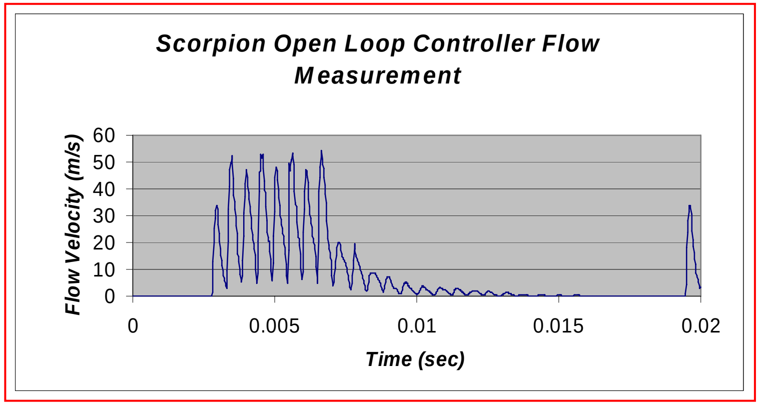


strake-like fences

Control Electronics Calibration and High-G Ground Experiments



Spin simulated to initiate maneuver

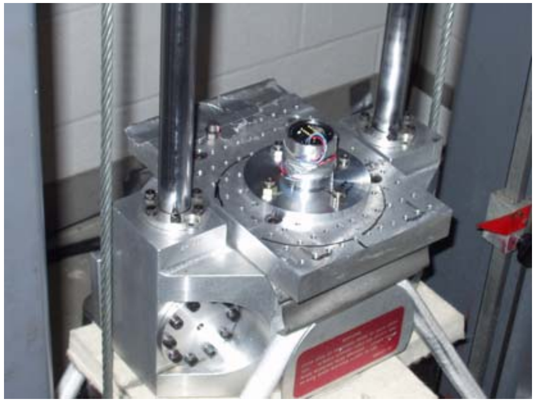


Hot Wire Flow Measurements

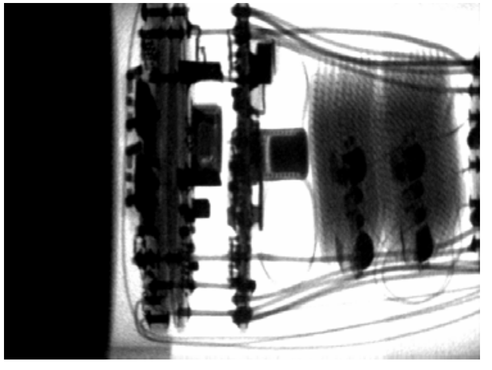
Assembled Jet Velocity 34 m/s

Simulating Magnetic Field

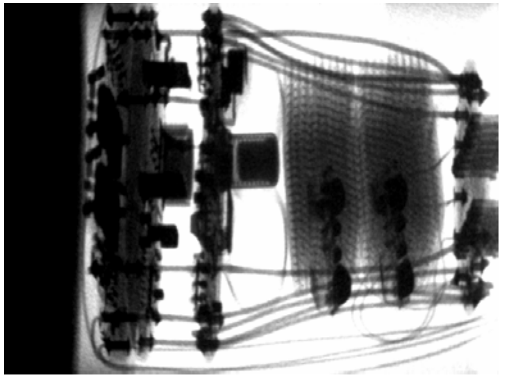
- **Developed High-G packaging to survive launch acceleration. GTRI-supplied electronic boards.**
- **Unit functioned appropriately after shock**



High-G Shock (8,000 G's)

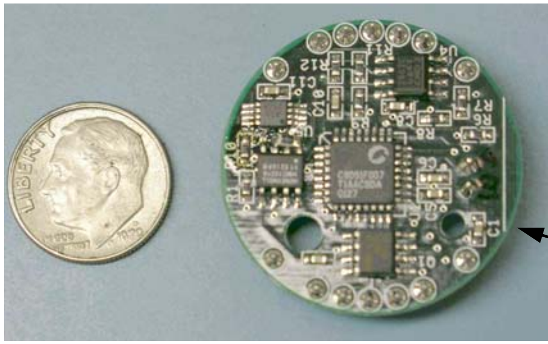


Before Shock

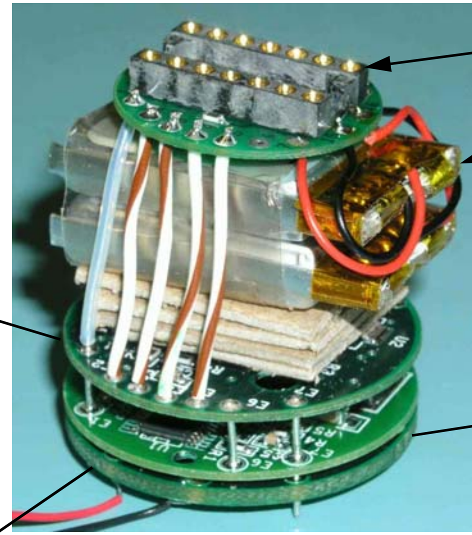


After Shock

Open Loop Electronics and Control System Assembly



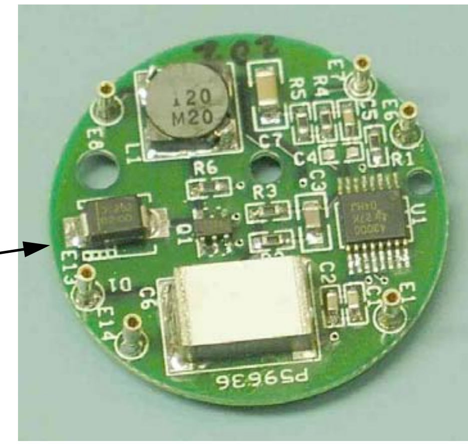
Processor Board



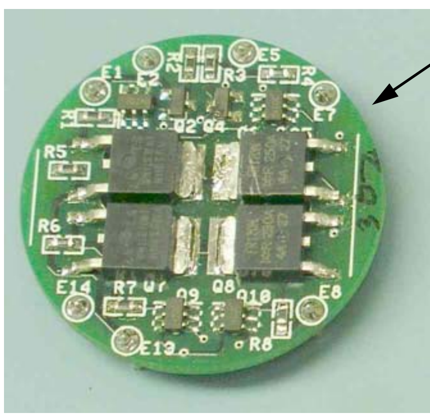
Interface Connector

Battery

Open Loop Electronics Assembly



Boost Converter

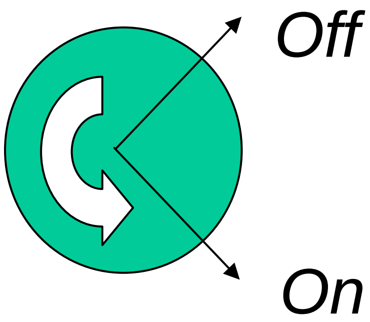


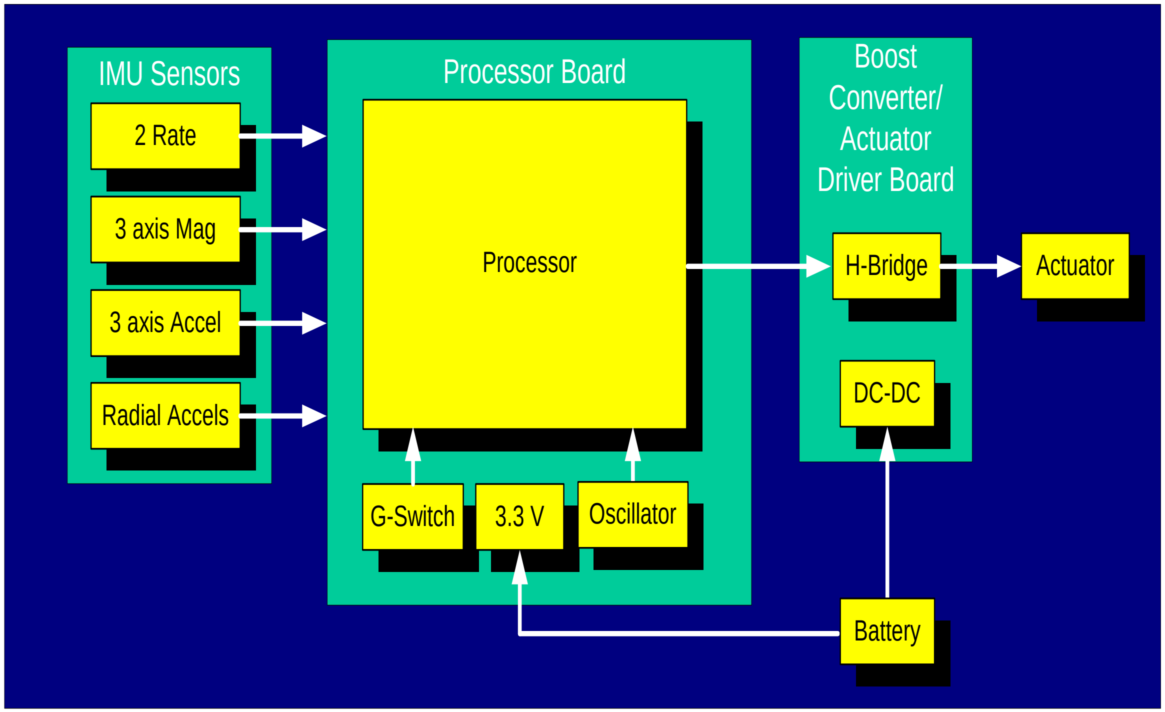
Driver Board

Flight Hardware

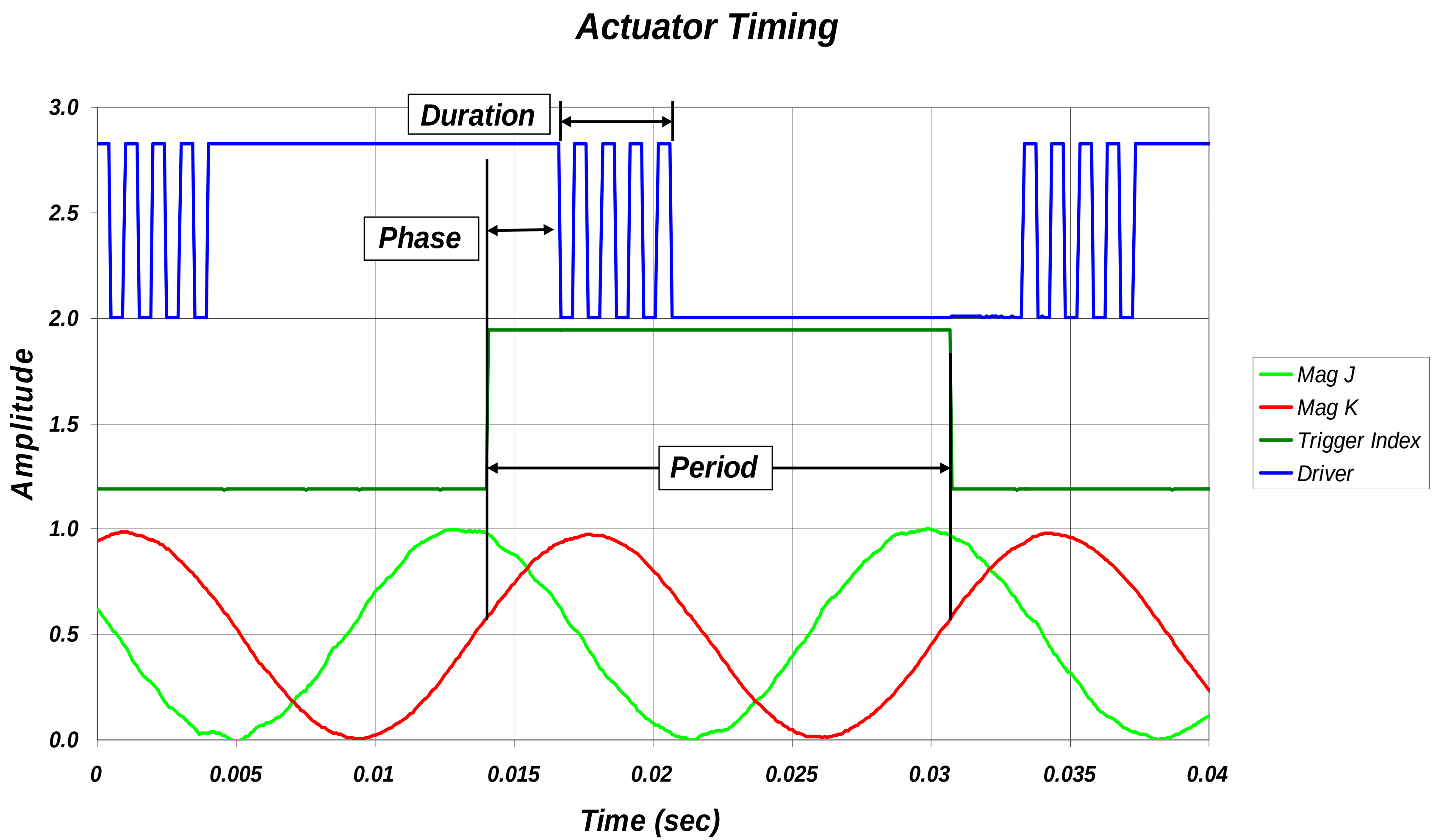
Divert Flight Test Firing Protocol

- After launch, wait 0.5 seconds, then activate at maximum voltage at same roll angle each revolution.
- Activate for 1/4 revolution (about 4 diaphragm cycles) such that force generated will be horizontal (left or right, as selected)
- On approximately 4 ms, and off 12 ms each revolution



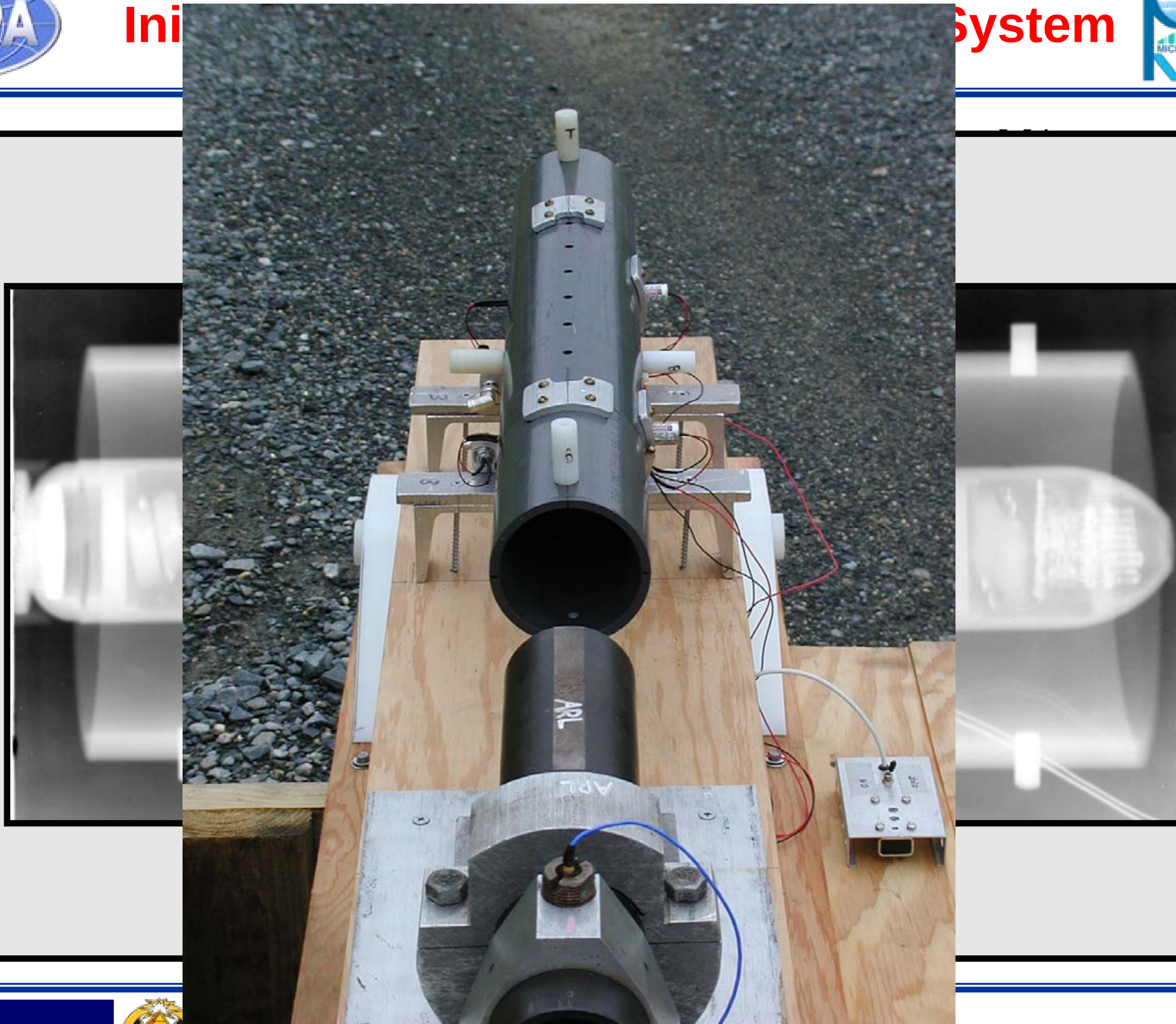


Divert Flight Test Firing Protocol

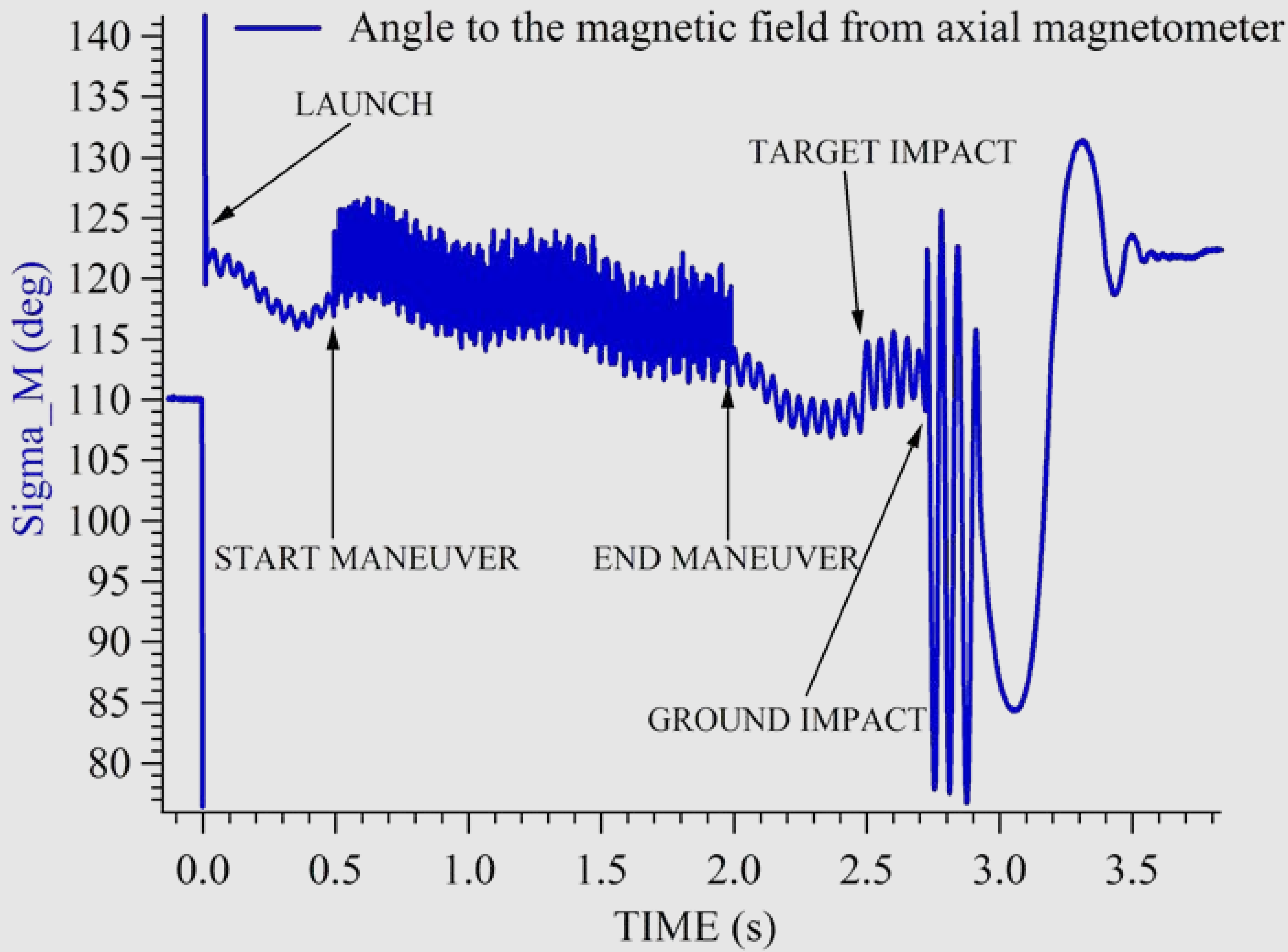


Ini

System



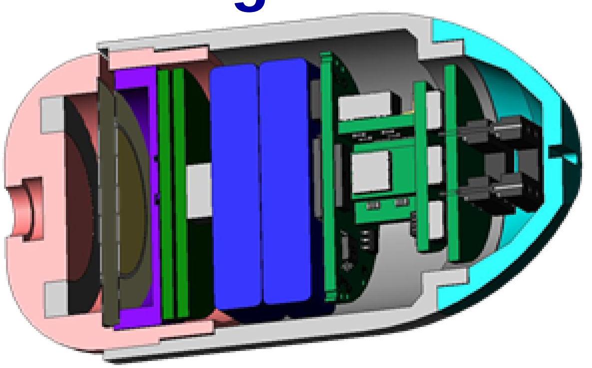
SCORPION ONBOARD SENSORS

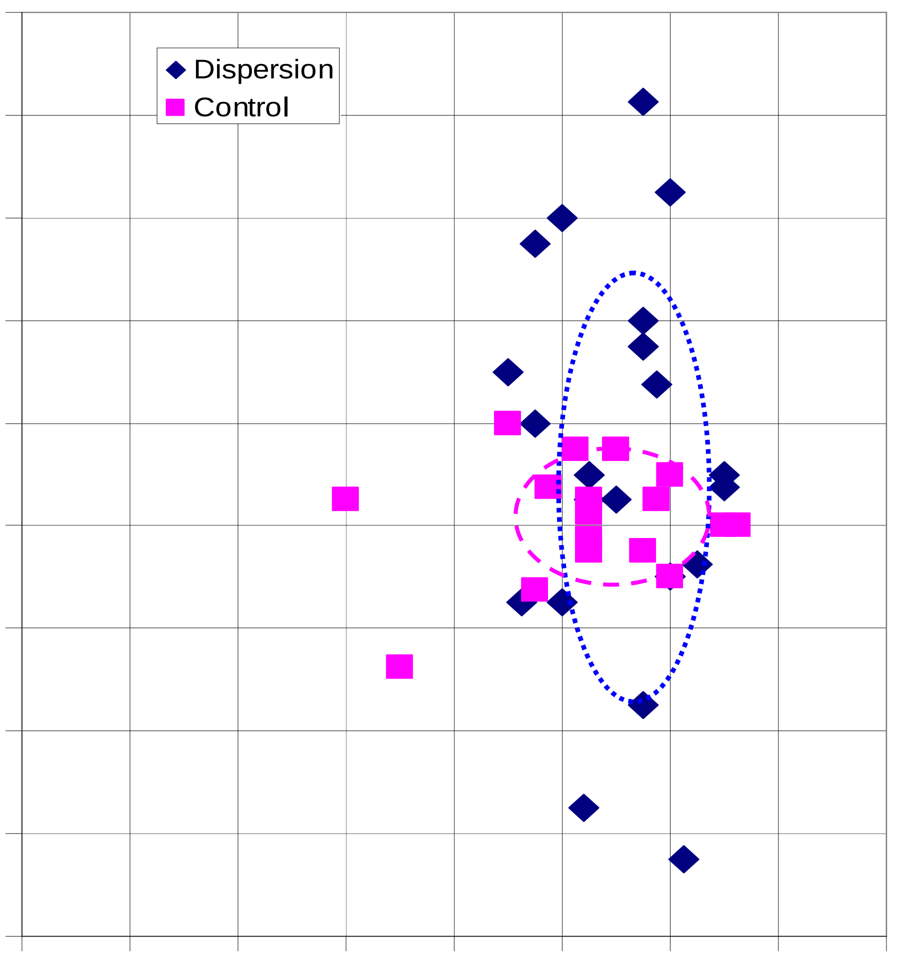


Holes in the Target!!!

Scorpion Test Results With Closed Loop Muzzle Velocity Control

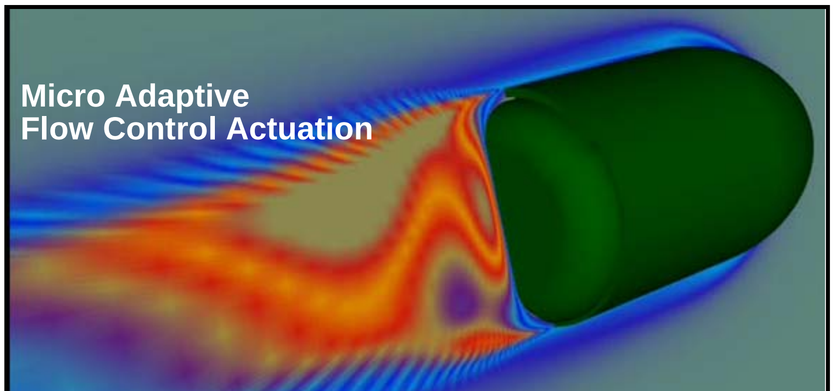
Flight Configuration



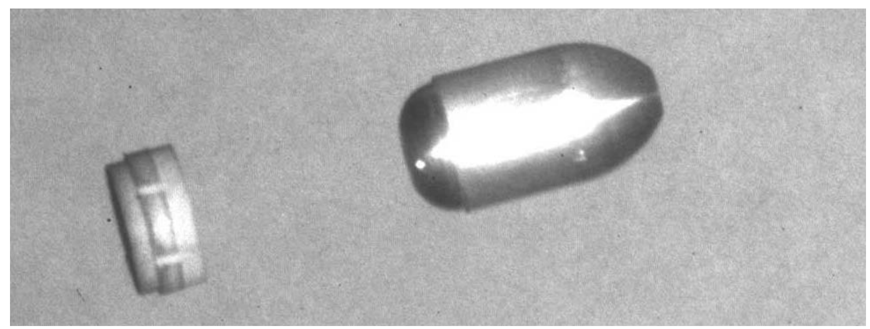


Scorpion Technology Program Accomplishments

- 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



DARPA Georgia Institute of Technology



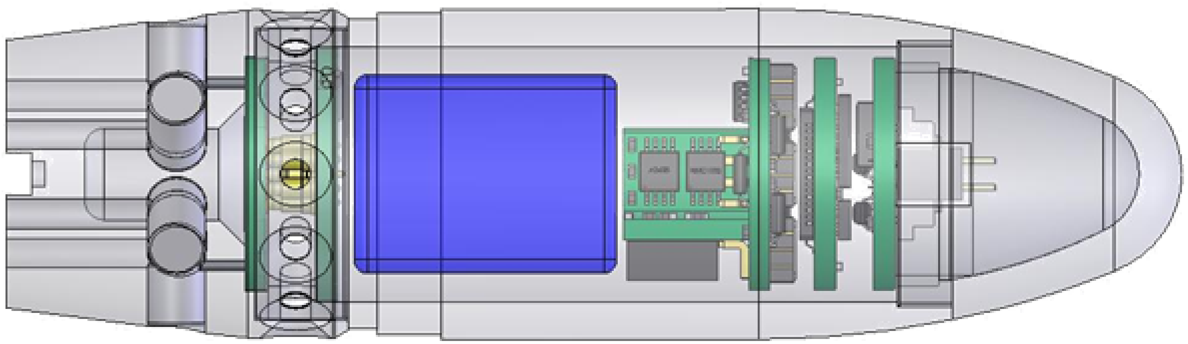
Experimentally Demonstrated Novel Aerodynamic Control Methodology Capable of Diverting Medium Caliber Munitions

Georgia Tech Research Institute ARL

25mm Scorpion

Control Mechanism Module

Inertial Sensor and Control Module

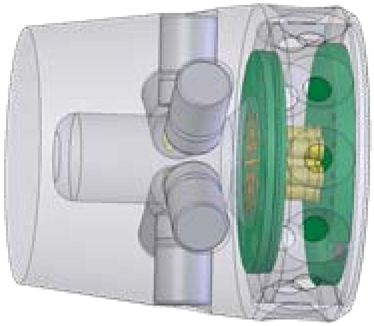


25mm Scorpion Projectile

Georgia Tech Research Institute

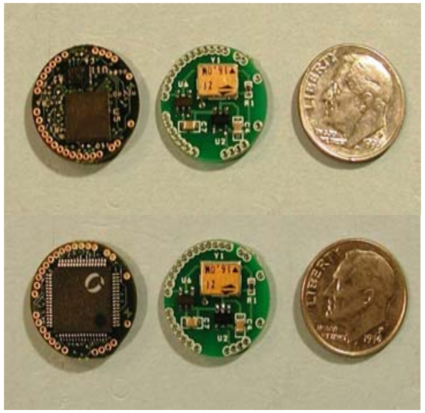
ARL

Integrated Inertial Sensor and Control Electronics

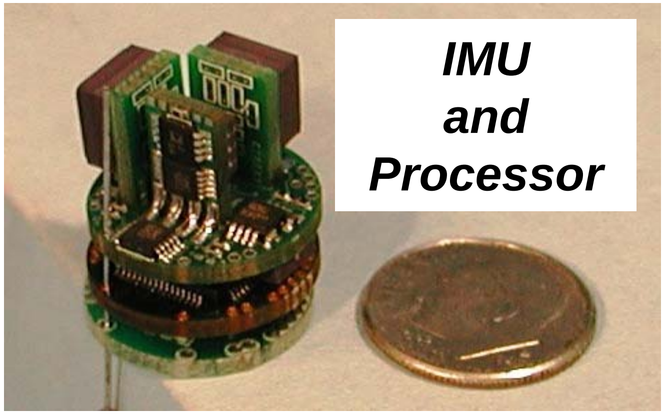


Removable Micro-Squib Control Mechanism Module

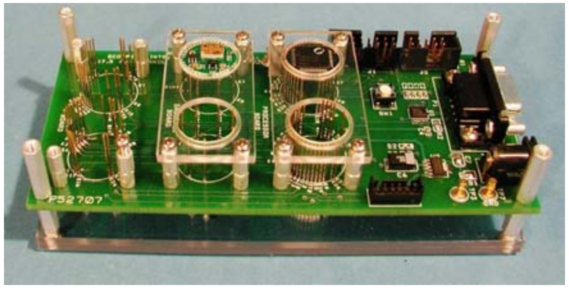
Tightly Integrated IMU and Processor



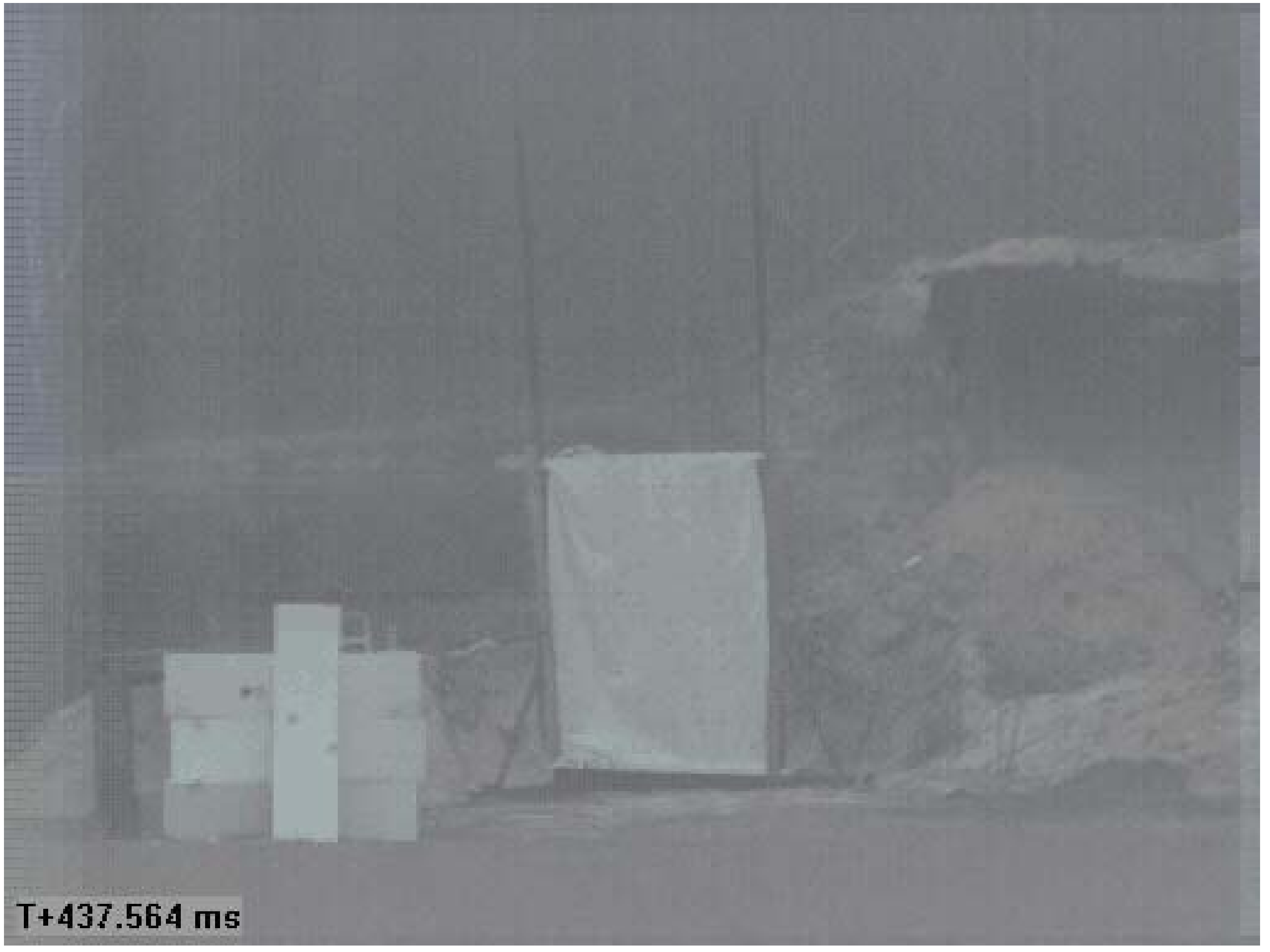
17mm IMU (ARL) tightly integrated with processor (GTRI), power management (ARL/GTRI), interface hardware (GTRI), and control mechanism module (ARL)



Interface Electronics

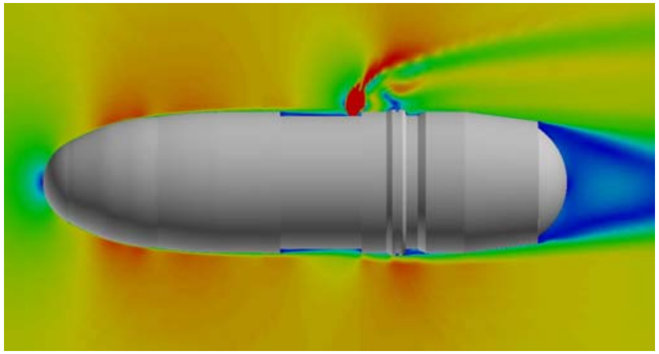


25 mm Divert Video

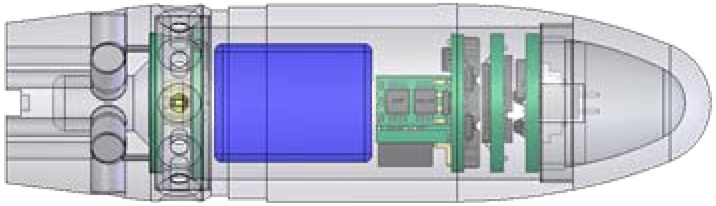


Milestones

- **25 mm Scorpion Completed**
- **25mm instrumented projectile**
- **Driver board design**
  - Addresses 6 actuators (limited by size)
- **Single actuator maneuver**
- **Multiple actuator initiation**
- **Projectile recovery**
- **Reduced state flight software**
  - Utilizes magnetometer and axial accelerometer
  - Algorithms need to develop and mature
  - Tradeoff between functionality (research instrumentation and control guidance…) and practicality (size, processor capability, & time/cost).



25mm ACSW With Combustion Actuator



Scorpion Technology
Future Technology Insertions

- Designated and Moving Targets
- Munition Dispersion Control
- Designated and Moving Targets Long Term

XM307ACSW

Long Term

Dispersion Control
Laser Designation
Point Burst Kill
Multiple Burst Optimization
Swarming Munitions

Other Transition Opportunities

Sub-munition flight control
Smart Fuzing
Warhead dynamic orientation
BDA platform stabilization
Subsonic micro-missile roll control

Future R & D Areas

Laser Designation
Micro-Technology for Prox - Fuzing