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Precision Guided Miniature Munitions

Navigation and Guidance Concepts

40th Annual Guns-Ammunition-Rockets-Missiles Conference

Session 6, Mortars and Artillery

April 28, 2005

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Case 4670

Mission Need

- *Provide small unit of operations with organic Precision Strike capability against High Value Targets*
- *Accelerate Enemy Defeat*
- *Reduce Collateral Damage*
- *Improve Deployability & Logistics*
- *RF Guided Muntion (RFGM)*
  - *Provide a low cost precision means for ground forces to engage C3 targets, enemy FOs, and some radars*
  - *Completes the sensor-to-shooter chain for IO targets operating from 30MHz to 3GHz*
- *Optically Designated Attack Munition (ODAM)*
  - *Ground or air laser designation of high value targets*
  - *Covert Programmable Optical Tag*

Current Mortar Munitions have <0.1%. first shot direct hit on target. RFGM and ODAM guidance system capable of correcting trajectory improves first-shot hit on the target to 90%.

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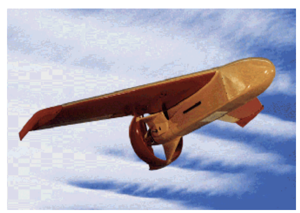
G&C Legacy

AN/ALQ-214
IDECM

APKWS 2.75
Rocket

Precision Guided Mortar
Munitions (PGMM)

SKYEYE® R4E-50



SKYEYE® R4D

VTOL OAV

9" MAV

OBLIQUE WING

MINI SNIFFER

EAGLE ARV

QF-4 Drone

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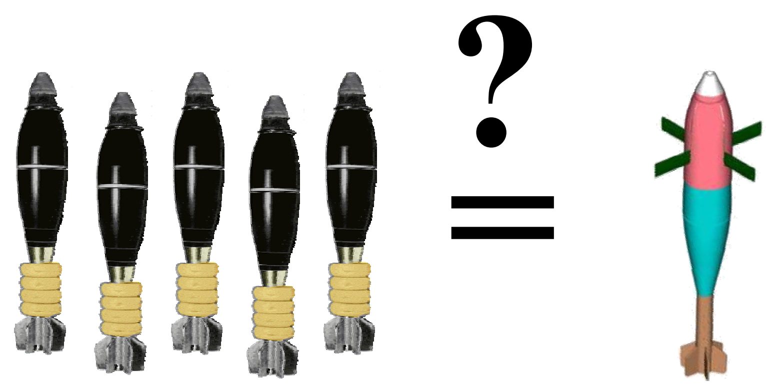
RF Guided Munitions

What is RFGM?

- ***Replacement fuze/guidance package that effectively converts current, ballistic 81 mm mortar munitions into precision RF guided munitions***
- ***Screw-on mod-kit***
- ***Affordable, Easy to use***
- ***Frequency range 30MHz to 3GHz***
- ***Accuracy not dependent on visual observation***
- ***Fire and Forget***
- ***First shot kill***
- ***Passive, all-weather***
- ***Technology that is scalable to other munitions***



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RF Guided Munitions
Technical Challenges

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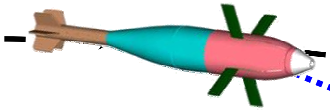

Launch Cue → **Geo-locate** → **Maneuver toward target** → **Detonation**

- Initial detection, discrimination and geolocation
- Leverage technology developed in Wolfpack/MANPACK

<20m accuracy (CEP) with << 0.3λ aperture

- ≥ 0.5g capability and stable control
- Not accomplished for this size munition;
- Leverage PGMM/BAT

3m Airburst using GOTS proximity fuze

System Integration

- Miniaturize to a 81mm mortar round
- Cost effective
- Match maneuver, target, and munitions capability

Existing technology	Extension of existing technology	Seedling analysis indicates feasible

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Optically Designated Attack Munition (ODAM)

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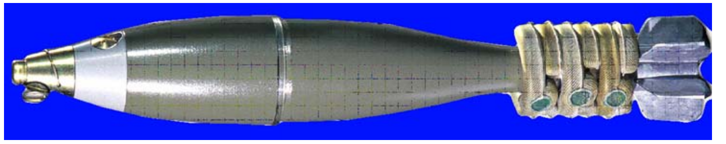
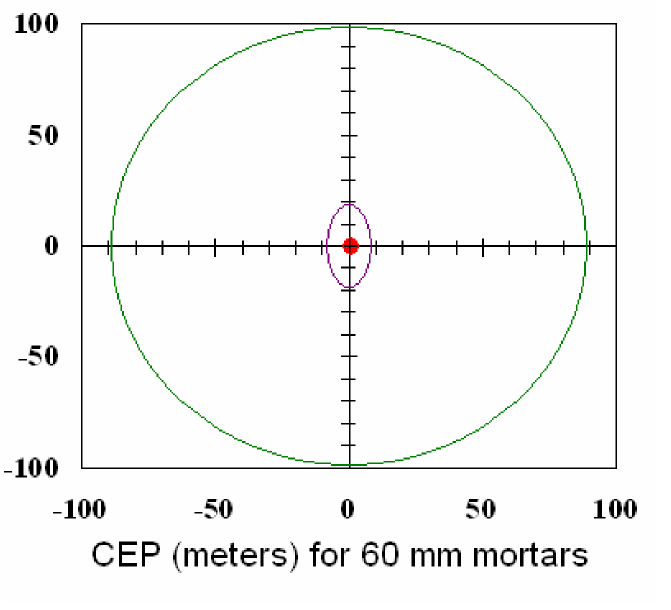
What is ODAM?

- ***Replacement fuze/guidance package that effectively converts current, ballistic 60 mm mortar munitions into optically designated 60 mm attack munitions***
- ***Rapid path to an affordable (<$300/unit) manufacturable end product.***
- ***No megapixel steering array***
- ***No cooled detectors***
- ***Visible light tag for daytime***
- ***Optimize for: Rugged, simple, and cheap***





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Seeker Types – System Integration

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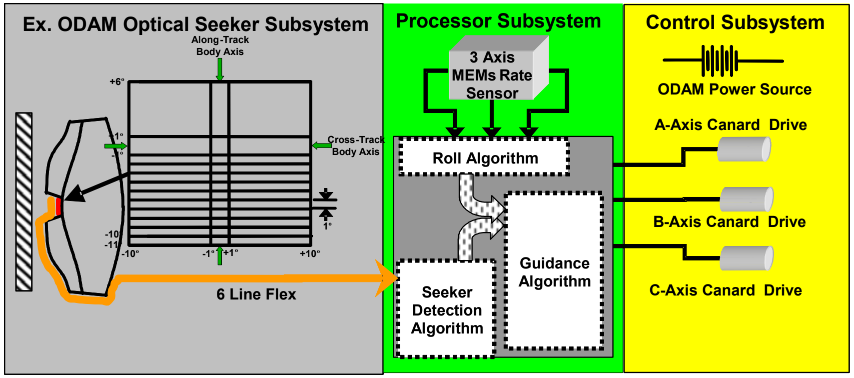
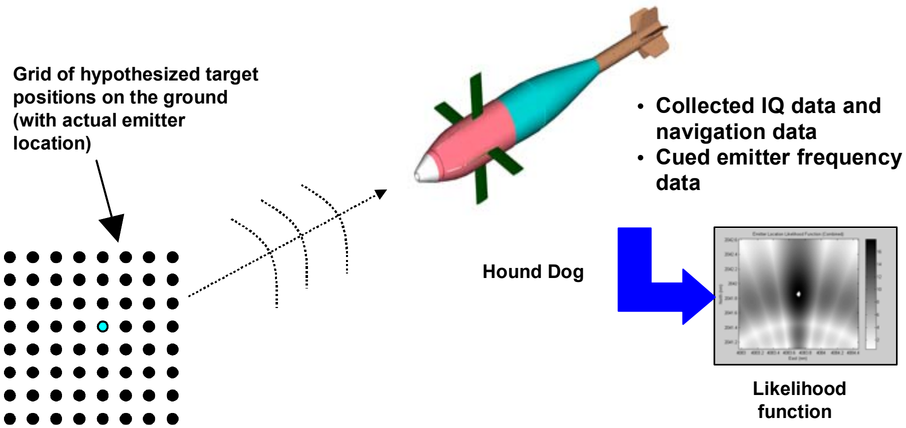
Seeker type strongly impacts system design.

- **Sensor integration must be considered when designing guidance and control system ⇒ including CAS design and aero-mechanical integration**

ODAM
High Resolution Optical Array Seeker

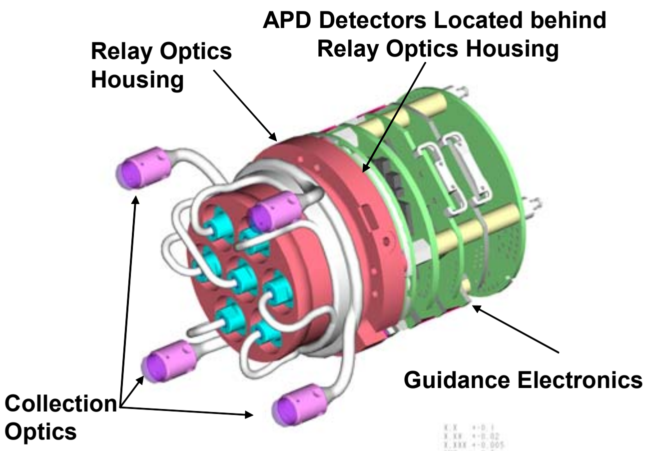


RFGM
High Resolution RF Antenna Array Seeker



Hound Dog method uses both phase and amplitude information from all the antenna elements and then determines emitter geolocation metric by computing the probability likelihood surface of the potential emitter location as a function of its hypothesized location.

APKWS
Distributed Semi Active Laser Seeker



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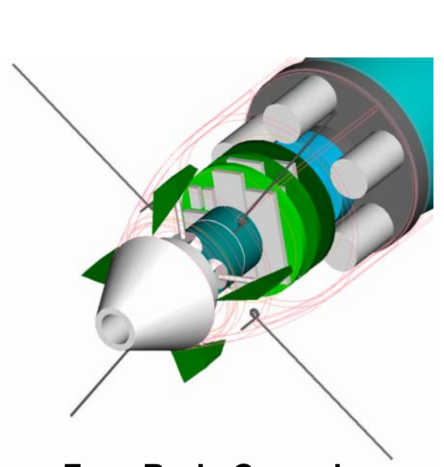
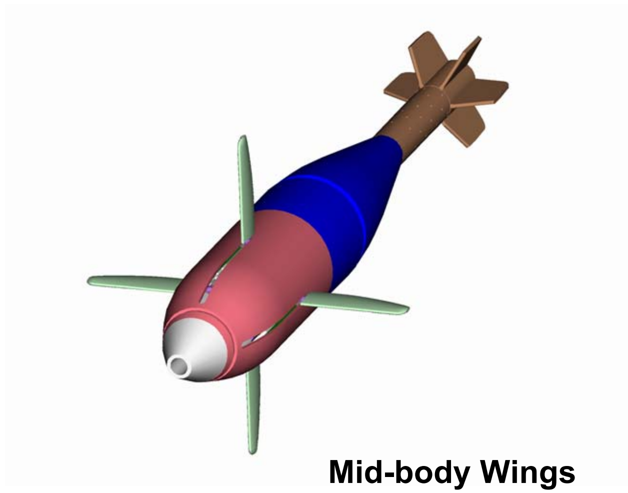
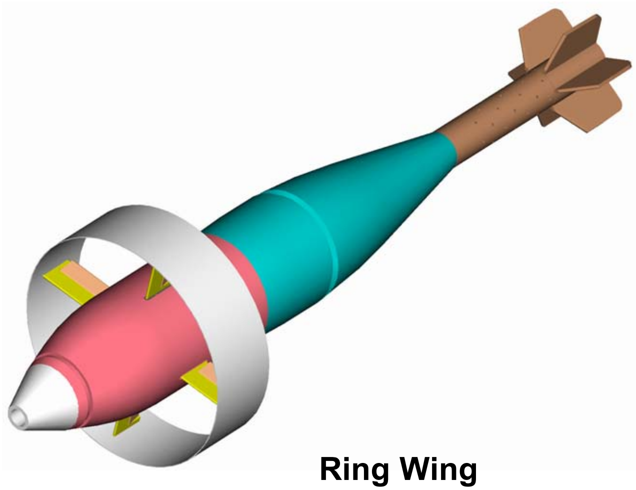
Aerodynamics







Two distinctly different aerodynamic design concepts were evaluated to determine basic feasibility of aero-mechanical implementation.

Concept type 1: Mid-body guidance. Approach using Mid-body wing surfaces to generate added normal force and provide steering.

Concept type 2: Fore-body guidance. Moment approach using canards mounted forward to generate normal force and controlled pitch moment effecting steering.

Each method is considered at the integrated system level versus specific design criteria.

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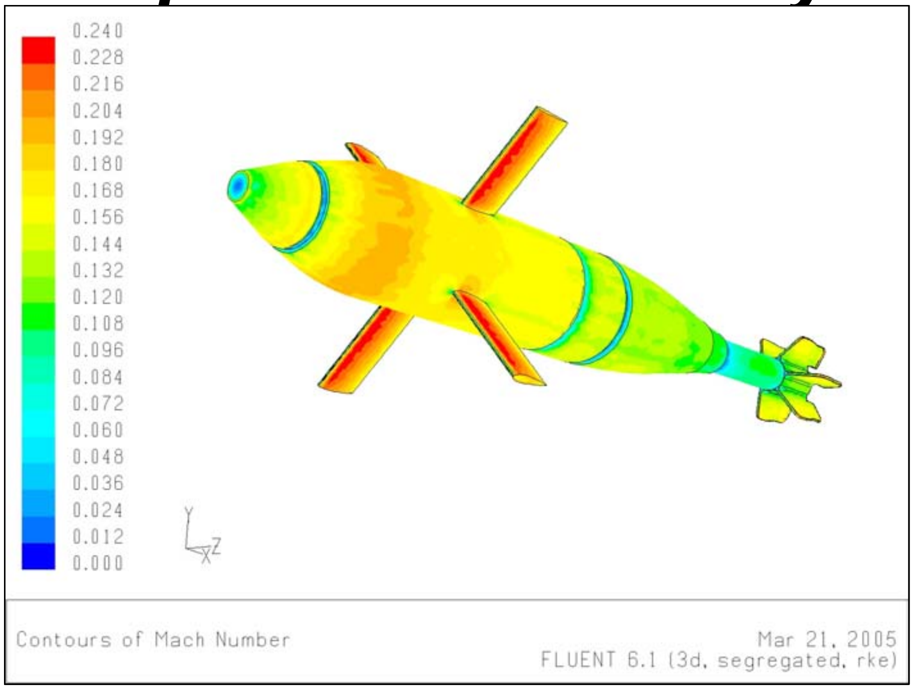
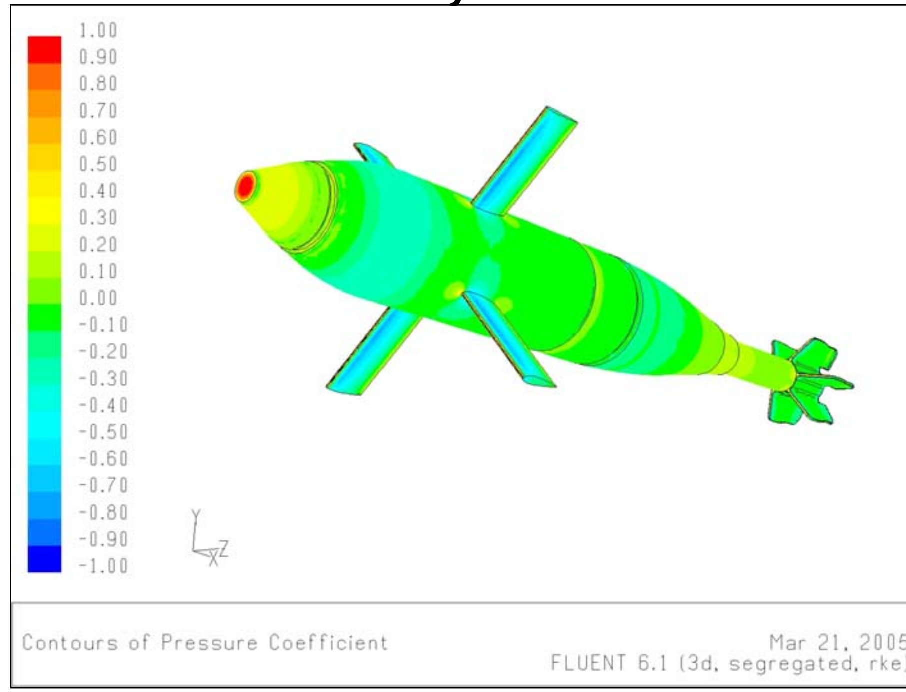
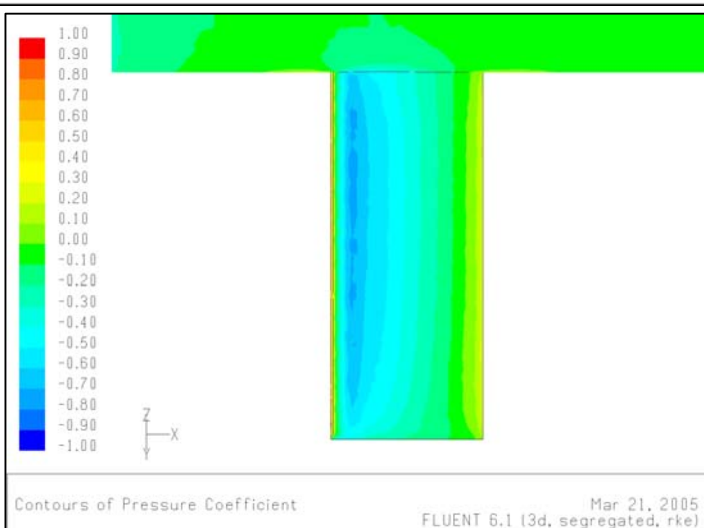
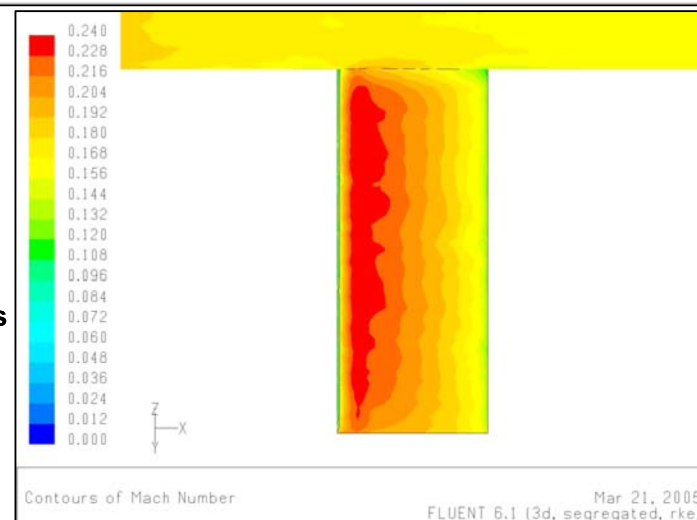
Computational Fluid Dynamics Results, RFGM







Pressure and Mach Contours on Wing



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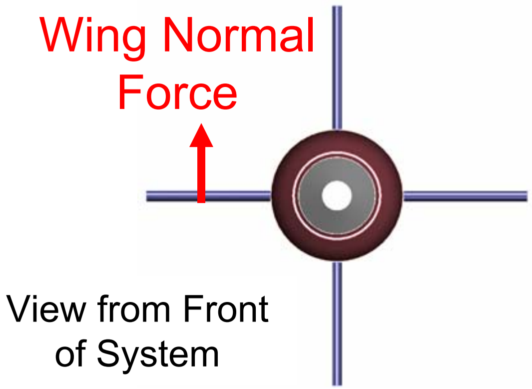
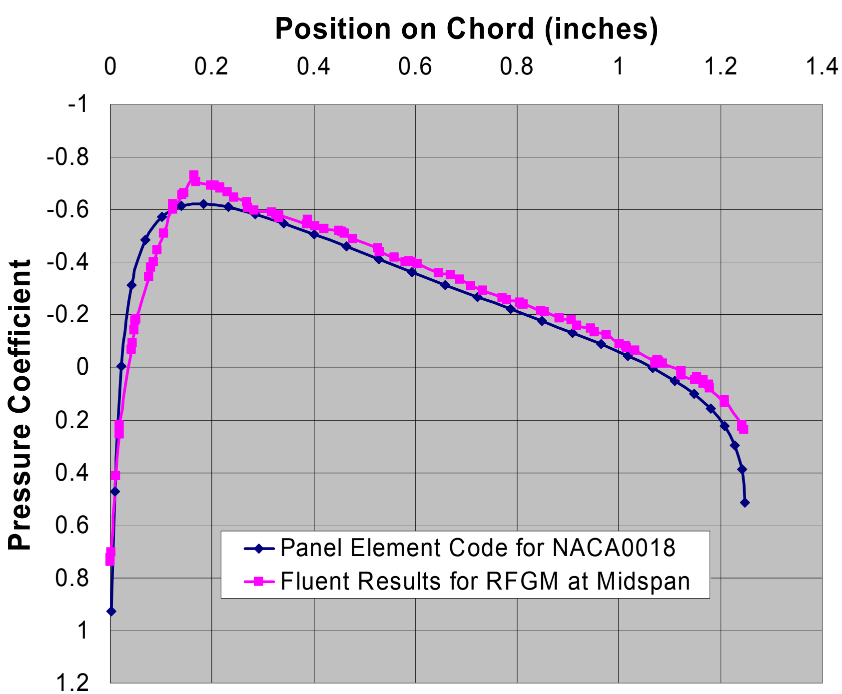
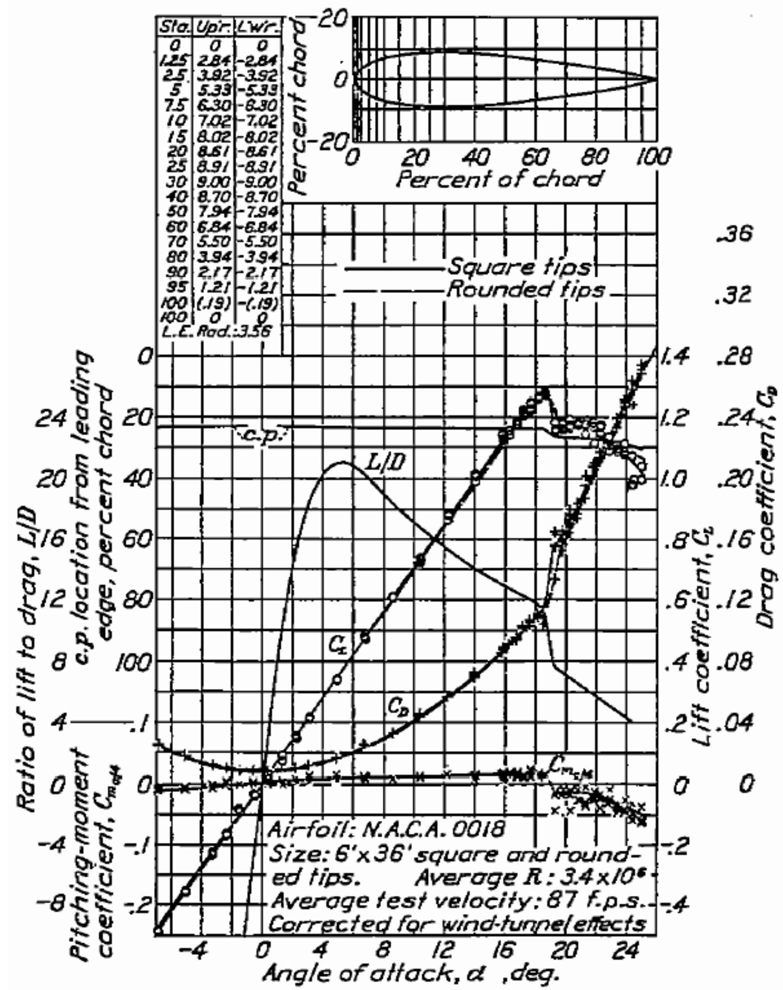
Aerodynamic Calculations – RFGM mid body wings







Sta.	Upr.	Lwr.
0	0	0
1.25	2.84	-2.84
2.5	3.92	-3.92
5	5.33	-5.33
7.5	6.30	-6.30
10	7.02	-7.02
15	8.02	-8.02
20	8.61	-8.61
25	8.91	-8.91
30	9.00	-9.00
40	8.70	-8.70
50	7.94	-7.94
60	6.84	-6.84
70	5.50	-5.50
80	3.94	-3.94
90	2.17	-2.17
95	1.21	-1.21
100	(.19)	-(.19)
100	0	0
L.E. Rad.: 3.56		

"Tests of N.A.C.A. 0009, 0012, and 0018 Airfoils in the Full-Scale Tunnel" NACA Report No 647

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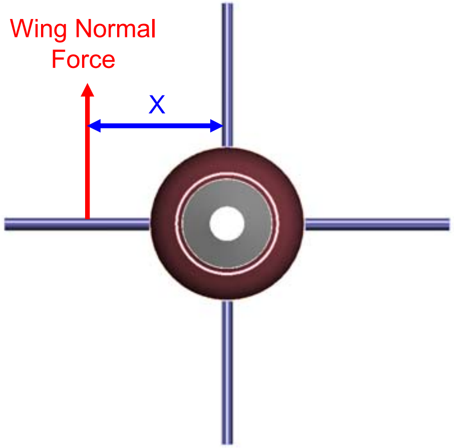
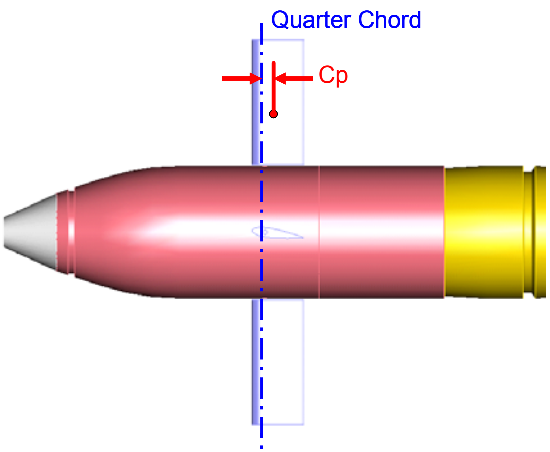
Computational Fluid Dynamics Results, RFGM

Results are utilized in 6 DOF modeling of performance as well as structural design

X (inches from centerline)		Mach	
		0.2	0.6
Wing AoA	3°	3.13	3.02
	10°	3.27	3.08



Cp (inches from quarter chord)		Mach	
		0.2	0.6
Wing AoA	3°	0.023	0.063
	10°	0.026	0.084



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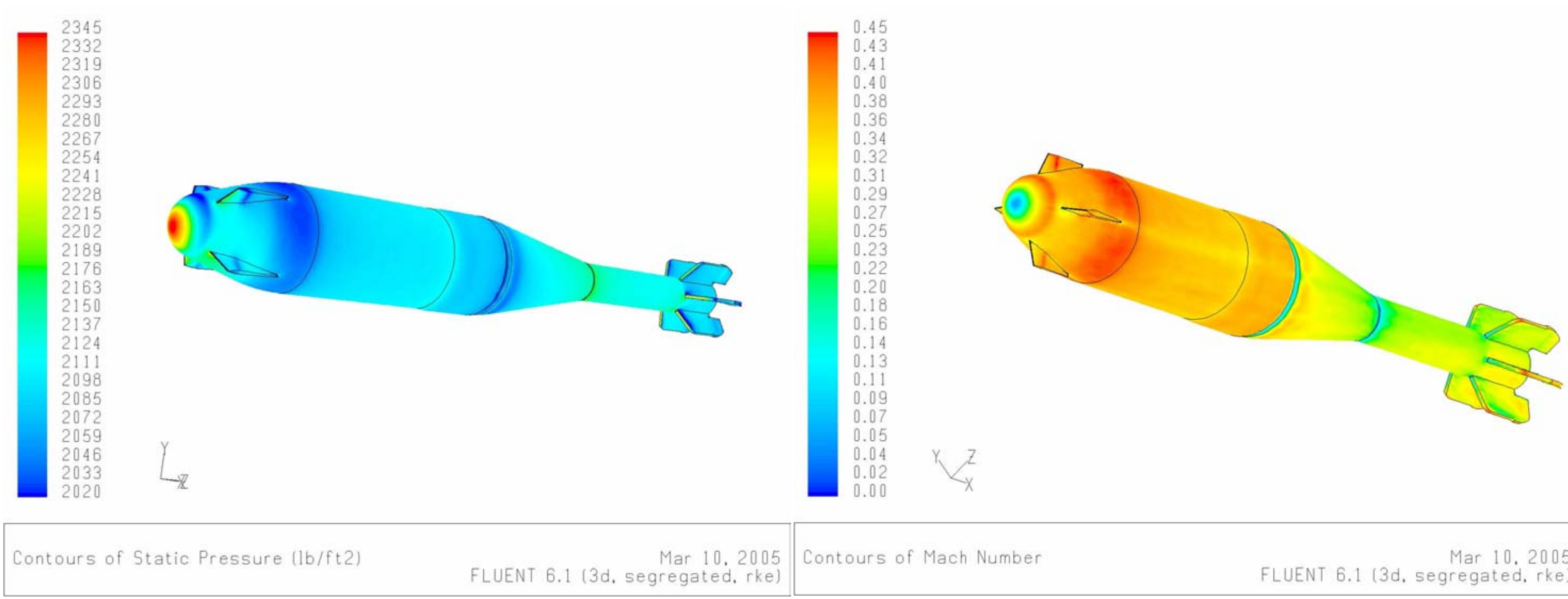
Computational Fluid Dynamics Results, ODAM



Pressure and Mach Contours on ODAM Projectile with canards installed and under various flight conditions. Data extracted is utilized for canard sizing to achieve required maneuverability, structural design of canard surfaces, guidance and control system development.

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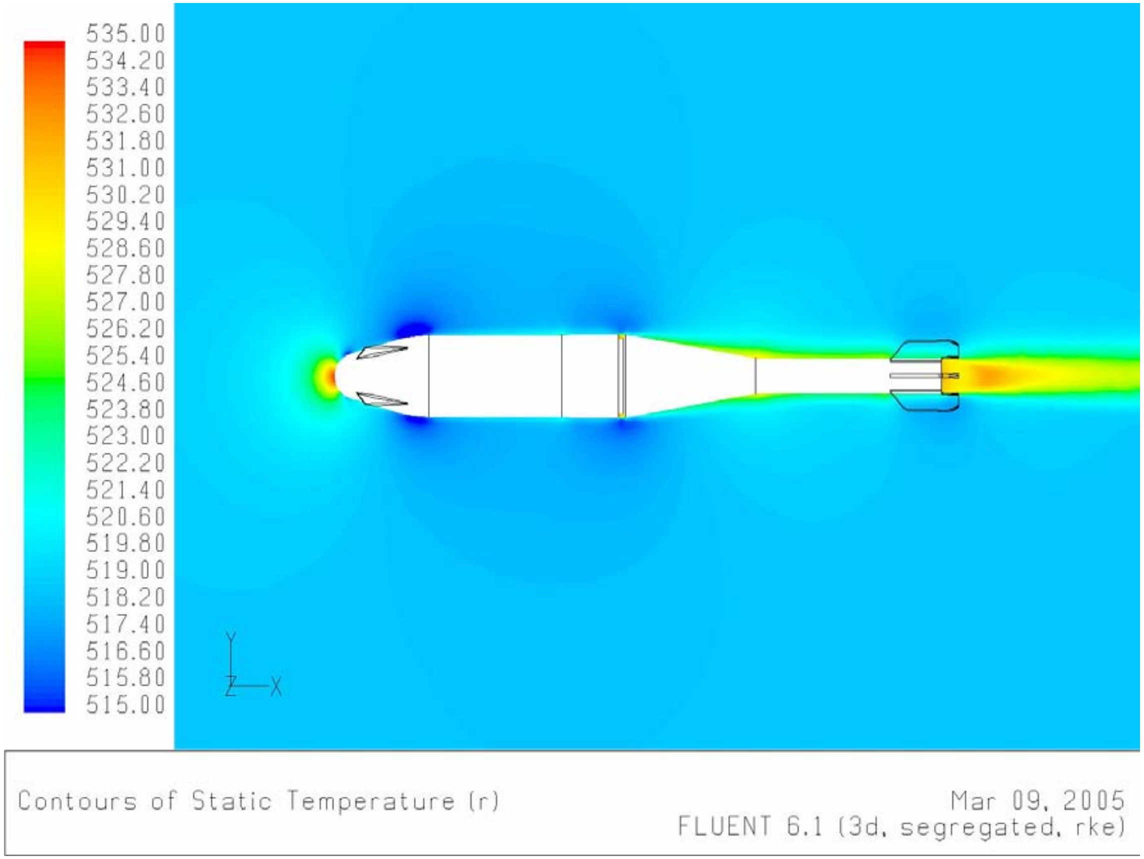
Aerodynamic Calculations – Temperature



- **CFD has proven extremely useful in computation of other related aerodynamic phenomena of interest to ODAM development**
  - **A thorough understanding of thermal heating of optical window on nose is required for seeker performance**

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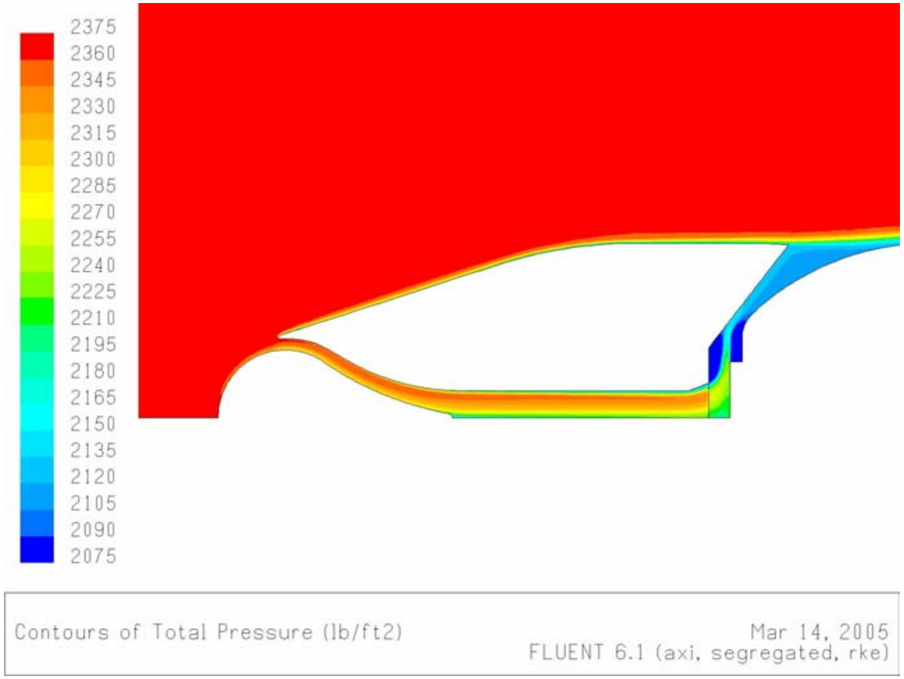
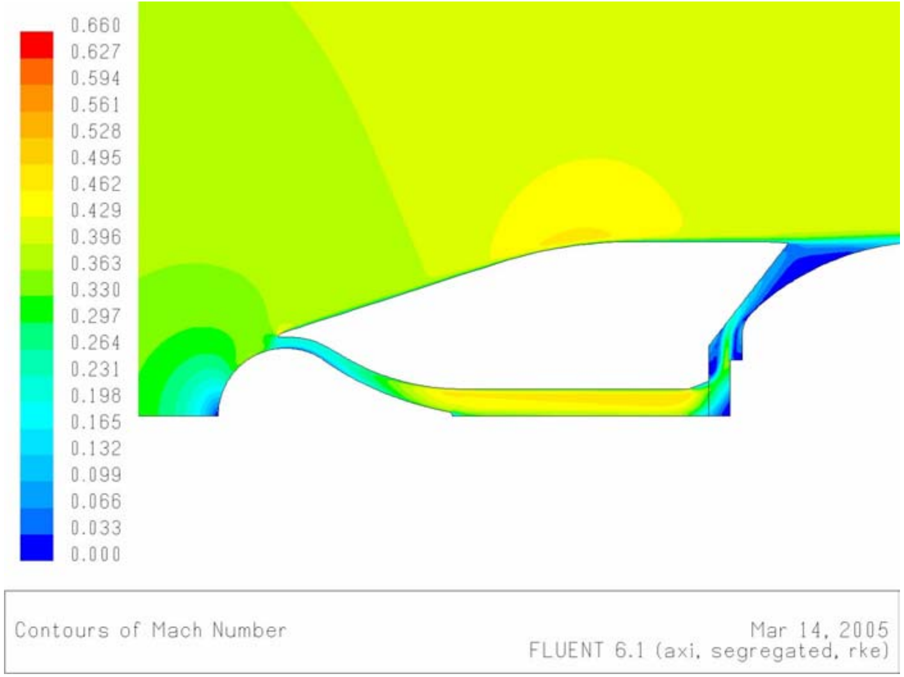
Computational Fluid Dynamics Results, ODAM





- **CFD has been utilized in computation of inlet performance during design phase in order to ensure integration of critical fuze components is properly accounted for.**

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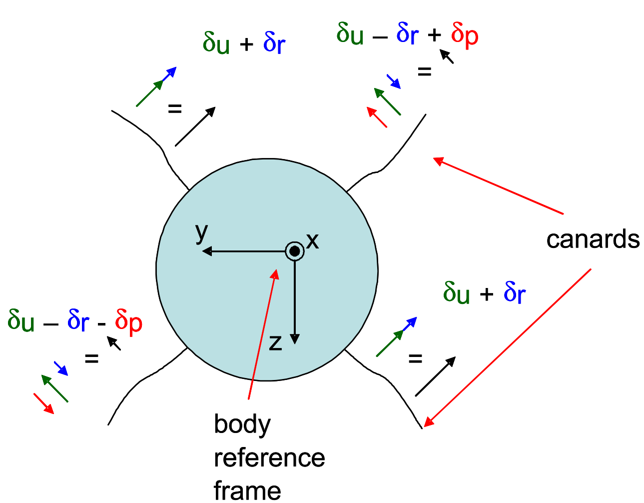
Precision Guided Miniature Munitions

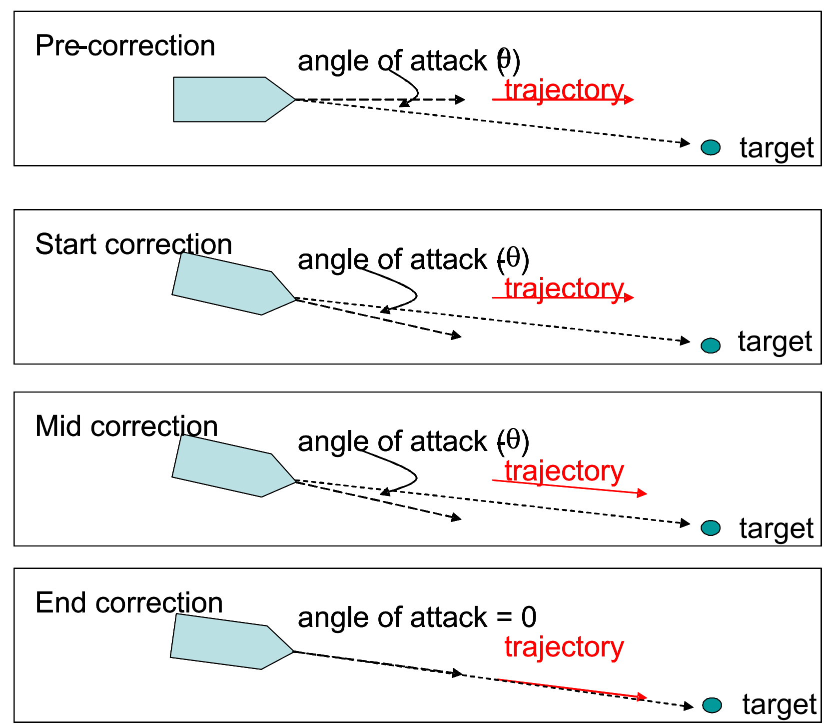
CAS - Command Requirements

- **Tied directly to aerodynamic performance requirements**
- **Spin control requires differential mode**
  - **Drive $\varphi_B \rightarrow 0$**
- **Pitch control requires common deflection**
  - **Maximize F_N in direction of target**
- **Control surfaces are torque balanced.**
  - **I.e.: Hinge located @ wing $C_P \rightarrow$ minimizes motor torque requirements**

Munitions View (Nose forward)



δp – roll correction
δu – up (down) steering correction
δr – right (left) steering correction



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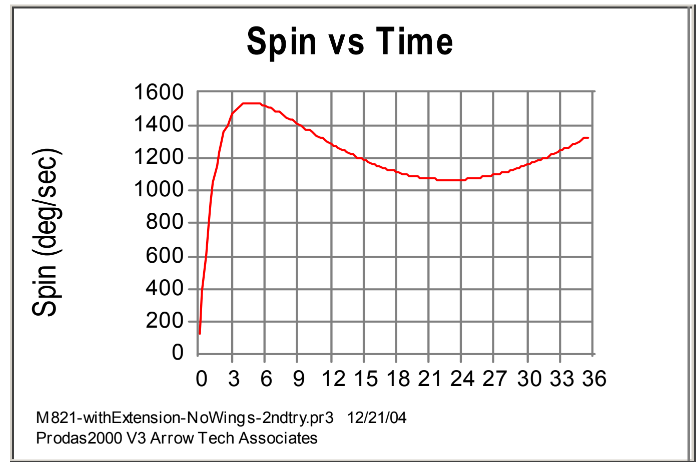
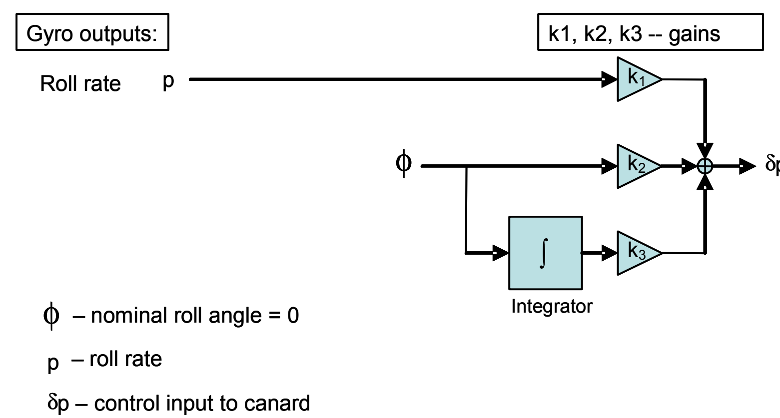
CAS Requirements

- Control roll & pitch of projectile
- Integrate steering commands with aerodynamic control surfaces
- Both RFGM and ODAM projectiles constantly spin
  - Spin generated via 5° tail fin cant
    - Fosters requirement to despin and maintain despun orientation throughout flyout and while maneuvering to target.
      - Complicates guidance process
      - CAS must despin, maintain specific orientation, and maneuver simultaneously
- CAS must exert fine grain control of aerodynamic surfaces to prevent over control



PID Controller



- Zero roll is maintained by using a Proportional-Integral-Derivative (PID) control loop.
- The "proportional" and "integral" inputs come from the pitch and yaw rate gyros.
- The "derivative" term comes from the roll rate gyro. These three terms are combined to estimate the instantaneous roll rate component and steer the canards appropriately to offset this effect

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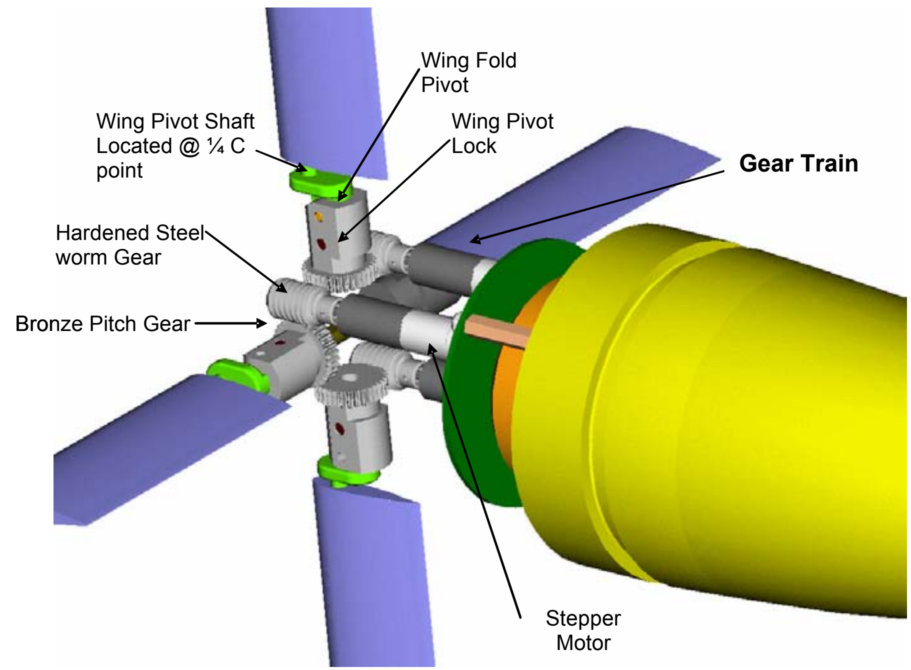
Precision Guided Miniature Munitions

CAS – Motor / Control Options

- Several potential motor / drive options are available ranging from 1 to 4 motors.
  - Trade study initiated to down select to preferred option
- 3 Motor → RFGM / ODAM ⇒ Selected for Phase 1configuration
  - 1 common axel (pure pitch)
  - 2 Independent axels (roll & pitch)
- 4 Motor
  - Each supports both roll & pitch
- 2 Motor
  - Requires $1_{in} \rightarrow 2_{out}$ transmission (prototype of simplified version developed with $1_{in} \rightarrow 4_{out}$ and limited testing performed)
- 1 Motor
  - Requires higher complexity transmission with shaft independent shifting function
    - Variant of $1_{in} \rightarrow 4_{out}$ previously developed with addition of complex shifting function added

RFGM CAS Design
Antennas integrated within wing



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Summary

- **Precision Guidance of Miniature Munitions is viable.**
  - **RFGM ⇒ 81 mm round incorporates mid-body wings**
  - **ODAM ⇒ 60 mm round incorporates fore body canards**
- **Aerodynamics are readily calculated using current CFD techniques**
  - **Well understood force, moment, and damping is required in order to design guidance system**
    - **Some aspects are complex and require more than traditional level of design treatment ⇒ spin terms such as Magnus force and moment along with coupled aerodynamics parameters**
- **Advances in miniature, affordable sensors such as the IMU incorporated into RFGM provide enabling technology for solution of complex guidance and control problem**
- **Guidance and Control must be highly integrated with seeker / sensors in order to provide best system level solution**

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Questions?

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