Adaptive Imaging and Guided Fuse Technologies

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AAL ...Backroom for the Innovation-Driven Aerospace Organizations of the world...

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Kansas City, Missouri 12 May 2010

Purpose:

Describe to the fuze community the state of the art in adaptive optics and flight control technologies

Outline:

I. Background & Brief Introduction to Adaptive Materials

II. History of Programs

III. New Classes of Adaptive Actuators

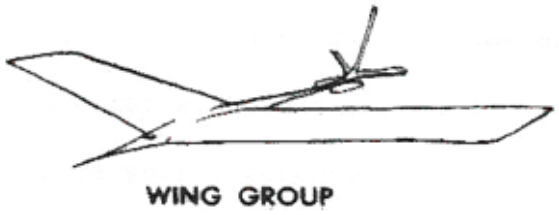
IV. Current & Future Programs Enabled

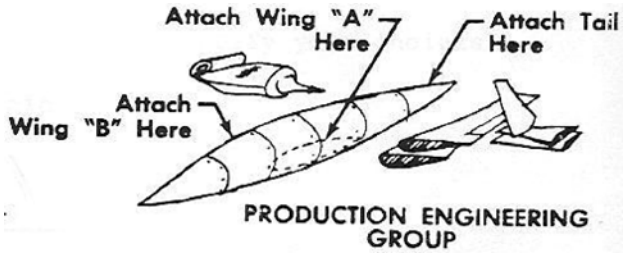
Adaptive Materials

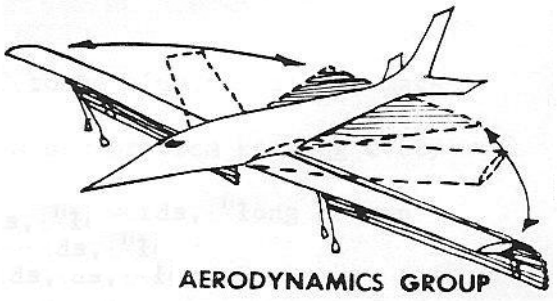
… A Paradigm Shift

Old Paradigm:

Structural deformations indicate that a given loading state is occurring and must therefore be accommodated.





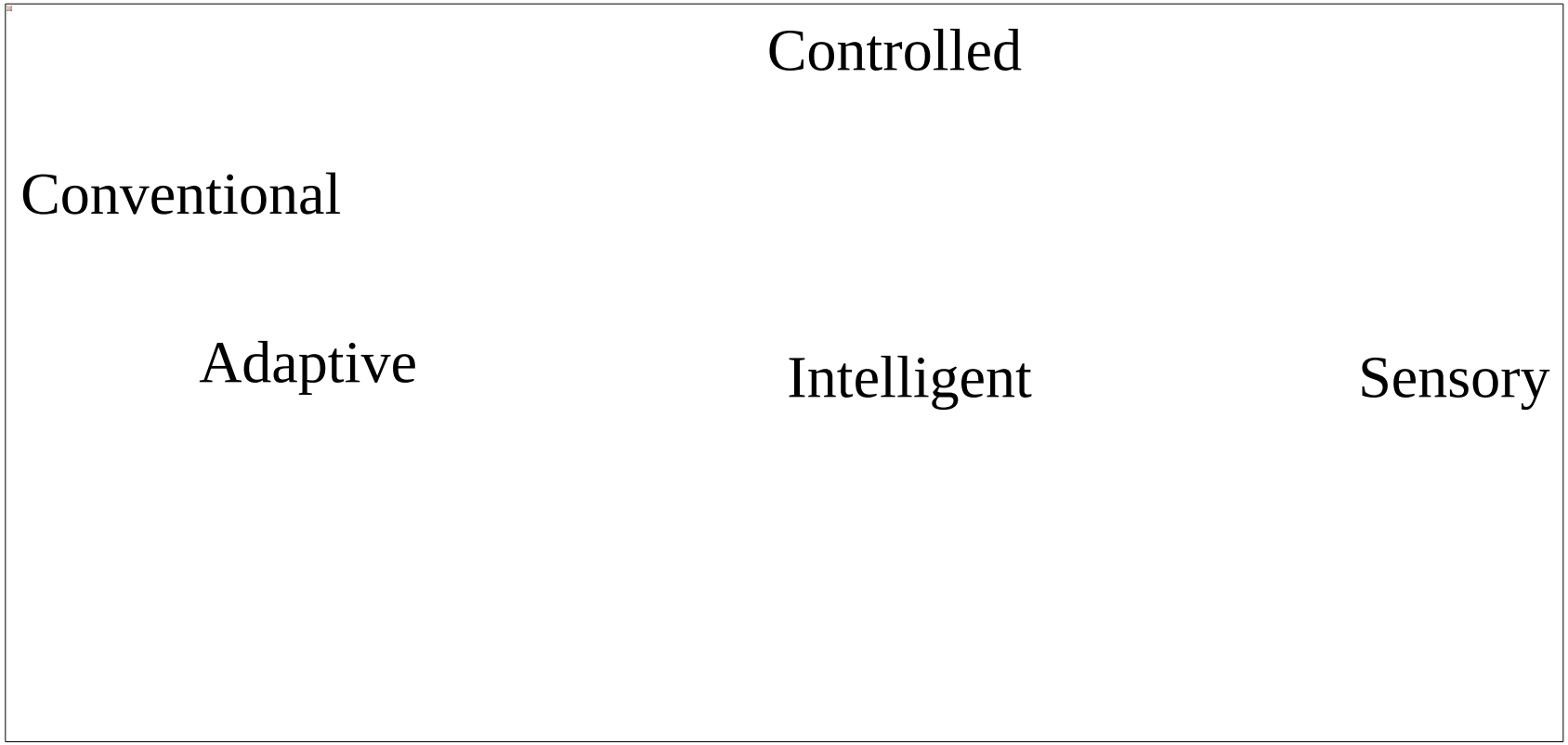


New Paradigm:

Structural deformations can be controlled and can therefore be used to enhance mission effectiveness.

Adaptive Materials: A (Very) Brief Introduction

What are Adaptive Materials & Structures?



Adaptive Aerostructures: A (Very) Brief Introduction

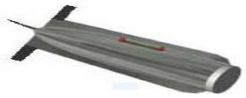
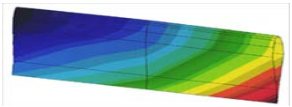
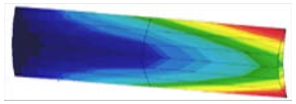
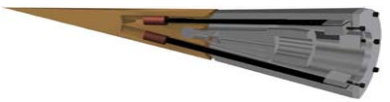
- Most Useful Classes of Adaptive Materials:
  - Shape-Memory Alloy -
    High Deflection, Slow, Lots of Power
  - Variable Rheology Materials -
    Good for clutching and changing stiffness
  - Piezoceramics -
    Very Fast, Low Power
  - Optically Adaptive Materials -
    Newest class, controllable color, luminosity, reflectivity, opacity

Adaptive Flutter Test Surfaces

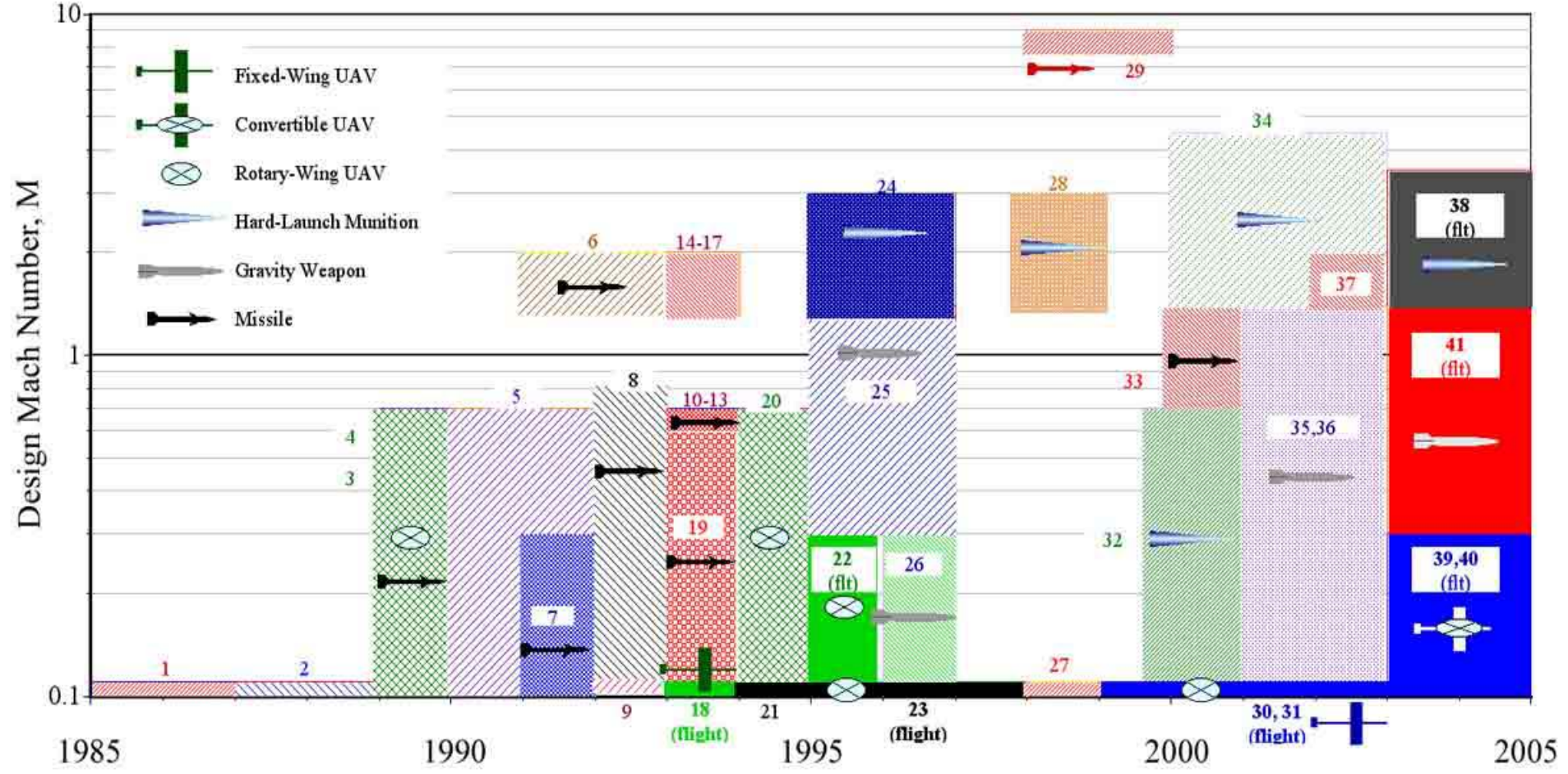
- *Solid State*
- *Order of magnitude less device weight*
- *Order of magnitude less installation weight*
- *Half the acquisition price of the conventional system*
- *Half the installation price and downtime of the conventional system*
- *Exacting Phase Control*
- *Flight Rated to Mach 3*
- *Half the flutter insurance rates*

US & International Patents pending

First 20 years of Programs with Lineage to Flying Adaptive UAVs

Overview of Programs with Lineage to Flying Adaptive UAVs



R. M. Ba

Brief Guided Round History

M712 Copperhead 1975

XM 982 Excalibur & ERGM

Guided Round History

Reducing the caliber...

M 247 Sergeant York 1977 - 1985

Guided Round History

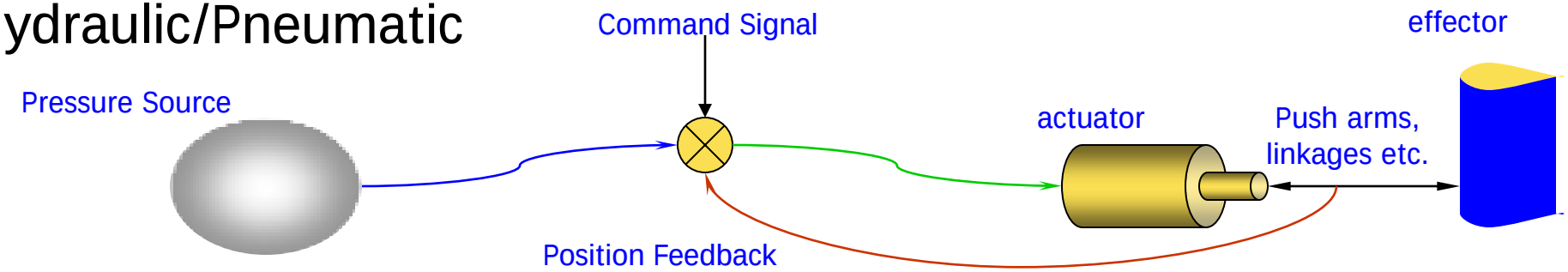
What's needed in a low caliber FCS actuator?

What is needed in such a flight control actuator???

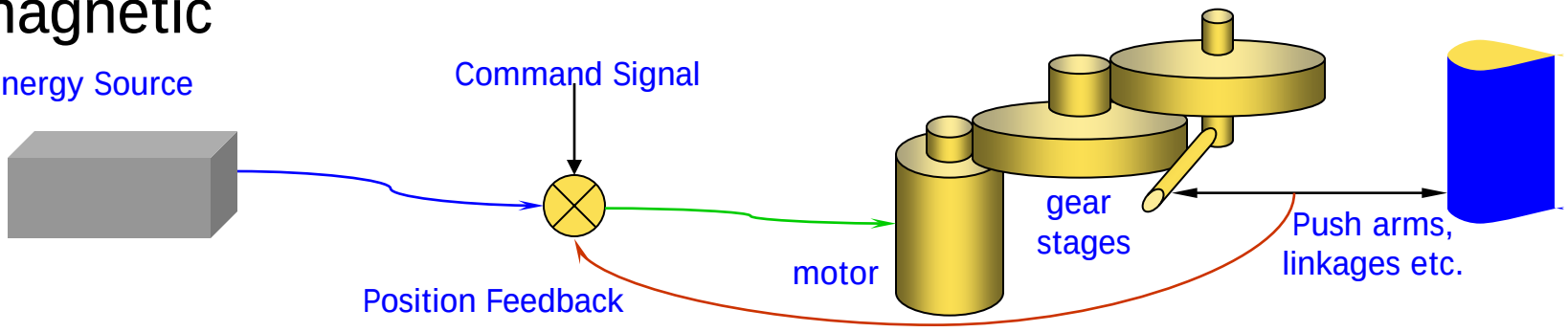
- Setback tolerance: 5,000 - 200,000g's
- Balloting, setforward, ringing impervious
- Compatible with supersonic control effectors
- Not affected by atmospherics (rain, dust, dirt, snow, etc.)
- High feedback command fidelity maintained during all flight phases
- 20 yr storage life
- -40 to +145°F
- Lightweight (<1g), Low Volume (<1cc), Low Power (10's of mW)
- High bandwidth (>200 Hz)
- Production shipset costs in single dollars... at most

Adaptive Materials Actuation… Different

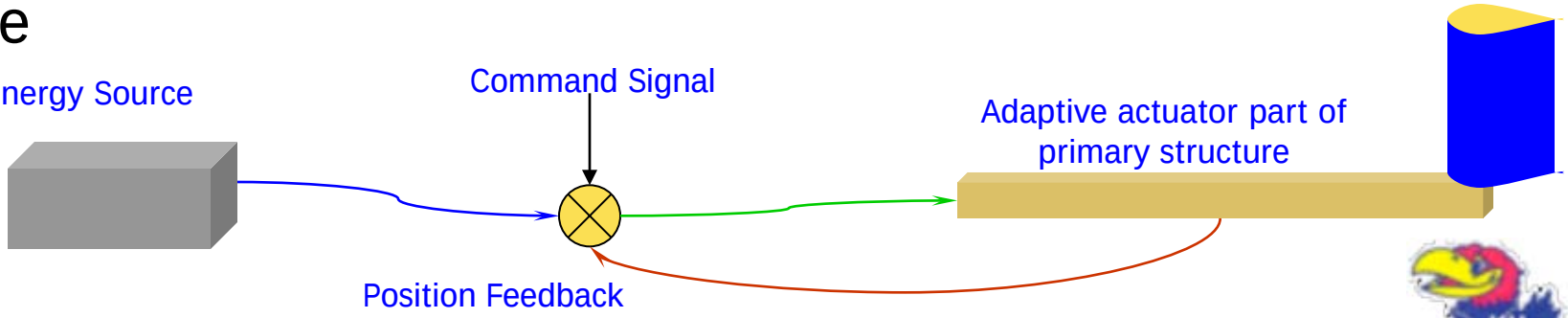
Hydraulic/Pneumatic



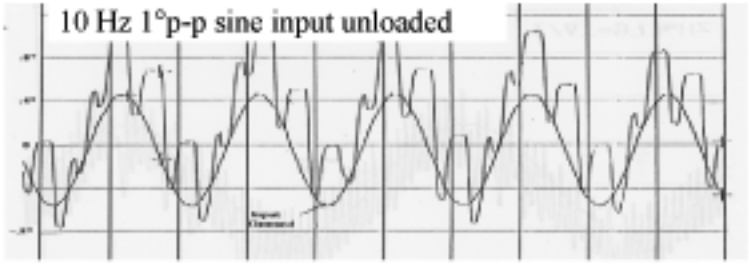
Electromagnetic

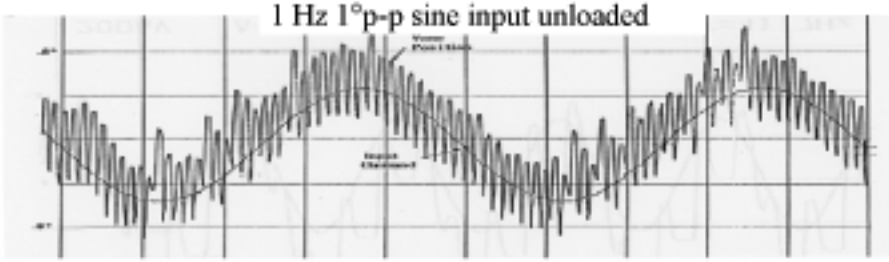


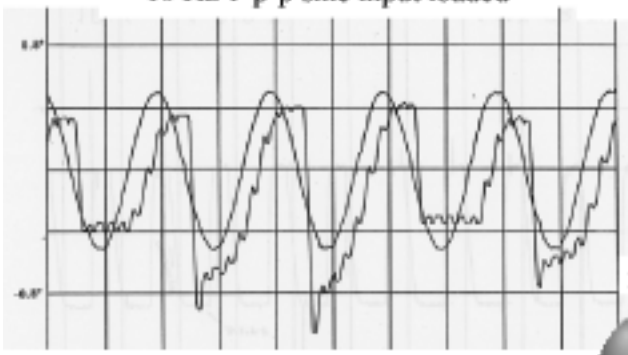
Adaptive

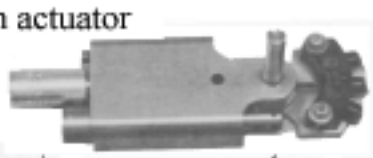


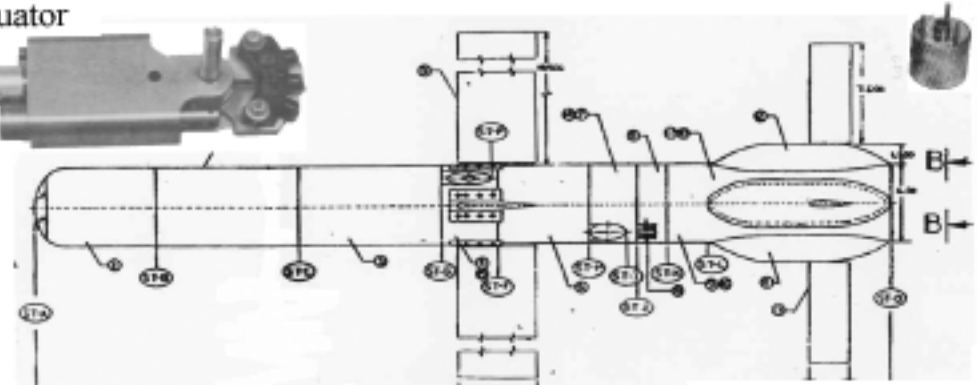
US Army FOG-M FCS…











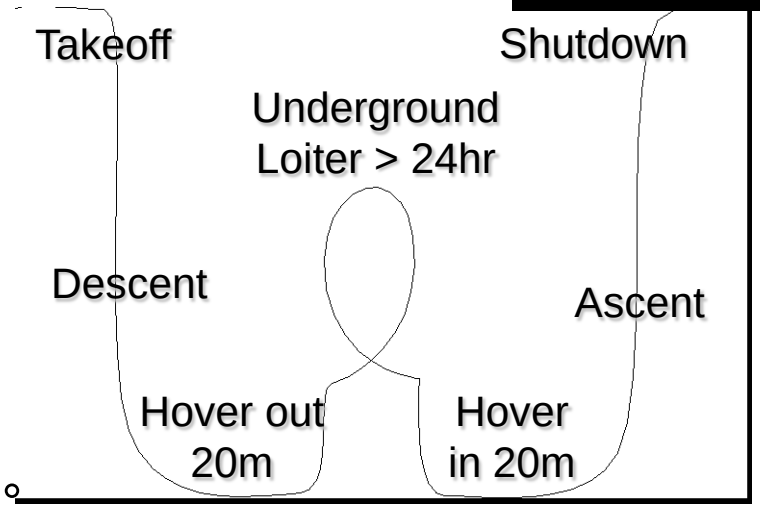
One possible solution... from the MAV world

The 1st Micro Aerial Vehicle (MAV) -- by the DoD CounterDrug Technology Office 1994 - '98

[redacted]

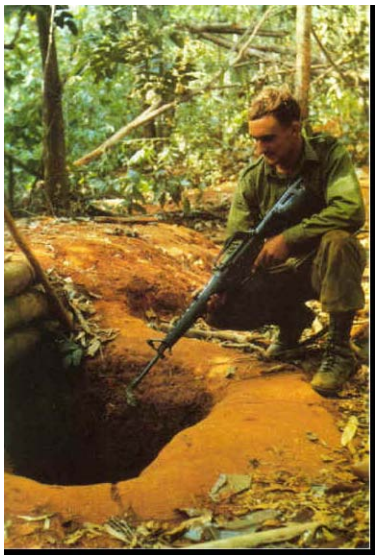
Enabled by Flexspar Piezoceramic Stabilators

Mission Profile:



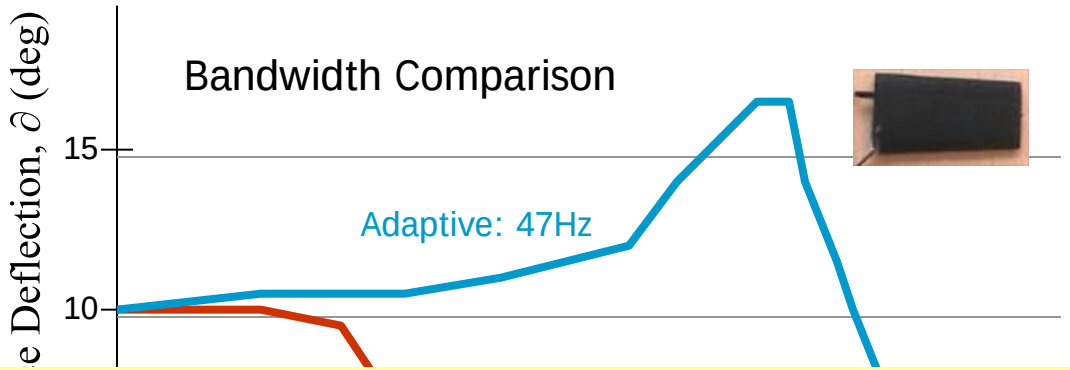
Stabilator Characteristics:

- total mass 5.2g
- actuator mass: 380 mg
- max. static deflections: ±11°
- max power consumption: 14 mW
- pitch corner frequency: 47 Hz
- first natural frequency in pitch: 23 Hz



Advanced UAVs:

Driving the need for Adaptive Actuators -- faster, lighter, stronger



Adaptive Surfaces vs. Conventional Servos

- 96% reduction in power consumption
- 16x increase in bandwidth
- 99.2% decrease in slop
- 12% OWE savings
- 8% MGWTO savings

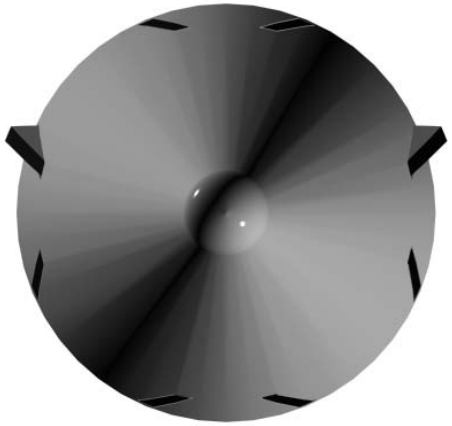
Operating Empty Weight Fraction

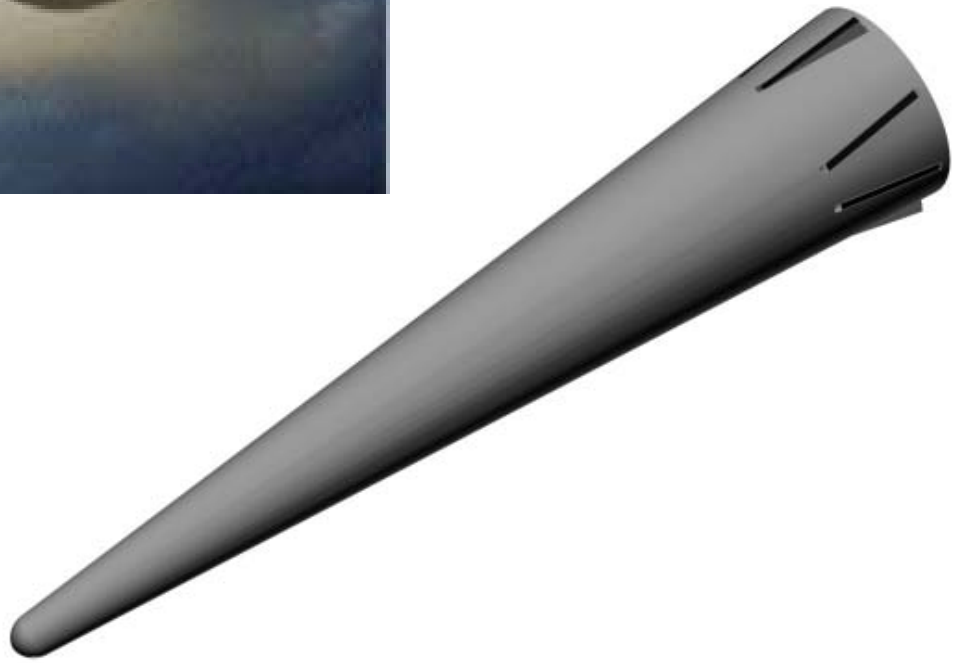
Gravity Weapons

Interceptors

SMDC HITT Program 1997 - 2000

Hypersonic
5ms Response
Pitch, Roll, Yaw control





Guiding Lower Caliber Rounds… More History

Barrel-Launched Adaptive Munition (BLAM) Program 1995 - ‘97

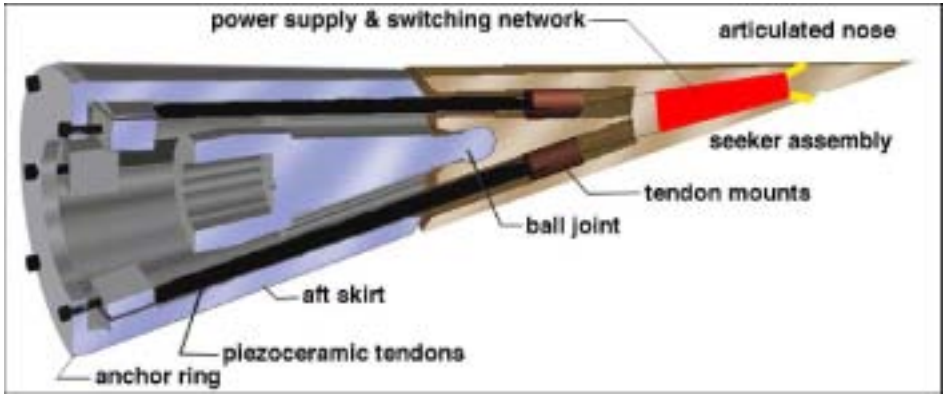
USAF/AFRL-MNAV

- Aerial Gunnery (20 - 105mm)
- Extend Range
- 2g maneuver

(Eglin AFB tests ‘97)

(Mach 3.3 tests ‘96-’97)

- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction



Guiding Small Arms Rounds… More History

Range-Extended Adaptive Munition (REAM) Program 1998 - '99

TACOM-ARDEC (Picatinny-APG) Phase I SBIR

- Guide 50 cal sniper rounds against targets moving up to 100km/hr
- 10cm dispersion @2km under 99% winds, up to 10% grade

Guiding Small Arms Rounds… More History

Range-Extended Adaptive Munition (REAM) IRAD 1999 - 2001

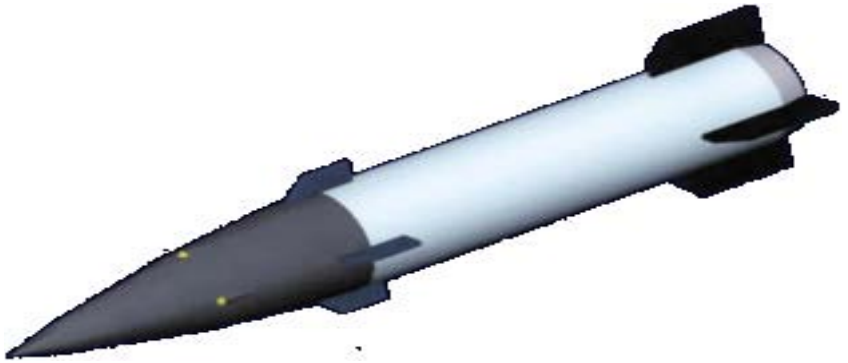
BAT-Lutronix Corp. developed supersonic piezoelectric FCS actuators

Guiding Small Arms Rounds… More History

Shipborne Countermeasure Range-Extended Adaptive Munition (SCREAM) Program 2001 - '03

DARPA-TACOM ARDEC SBIR Phase II

- Change from sniping to countering high jinking rate sea-skimming missiles
- Change from 0.50 caliber to 40mm
- Change from ~2g's of maneuver authority to many tens of g's
- Entire FCS passed 41,000g shock table testing



Guiding Small Arms Rounds… More History

Shipborne Countermeasure Range-Extended Adaptive Munition (SCREAM) Program 2001 - '03

DARPA-TACOM ARDEC SBIR Phase II

SCREAM Actuator Challenges:

- Long actuator bay length
- Difficulty pushing beyond 50,000g's
- Low deflection -- ~ok for sniper, not ok for SCREAM

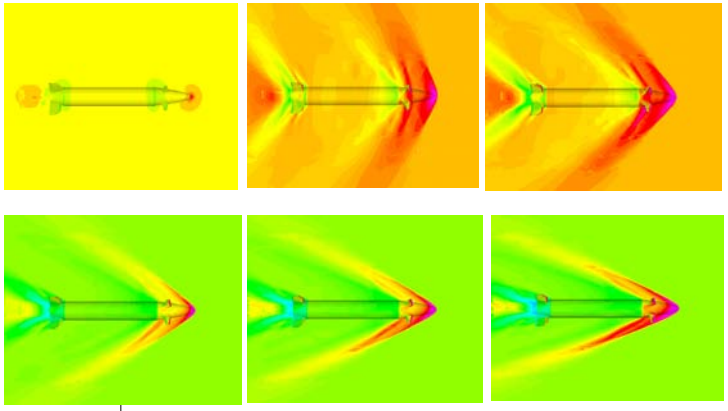
Hmmm…

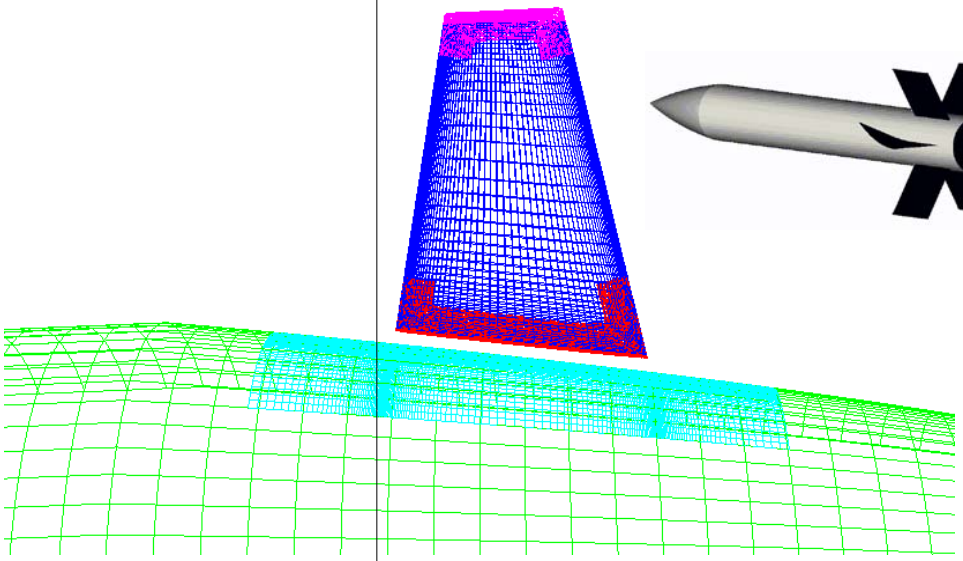
Other Adaptive FCS Efforts

Rabinovitch & Vinson 2000 - present

again... low authority
can't survive balloting, setback unsteady aero...

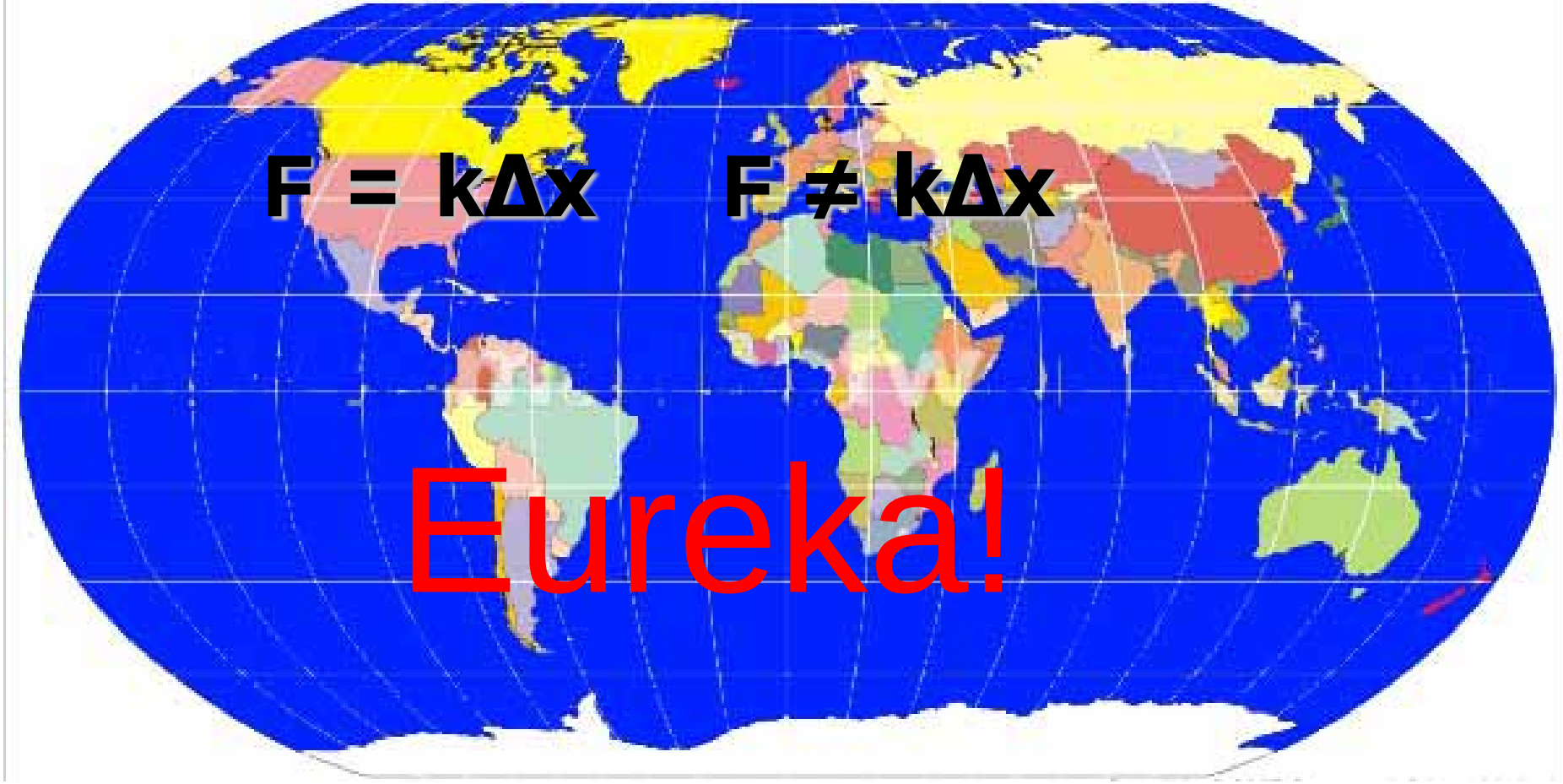
Now Where???





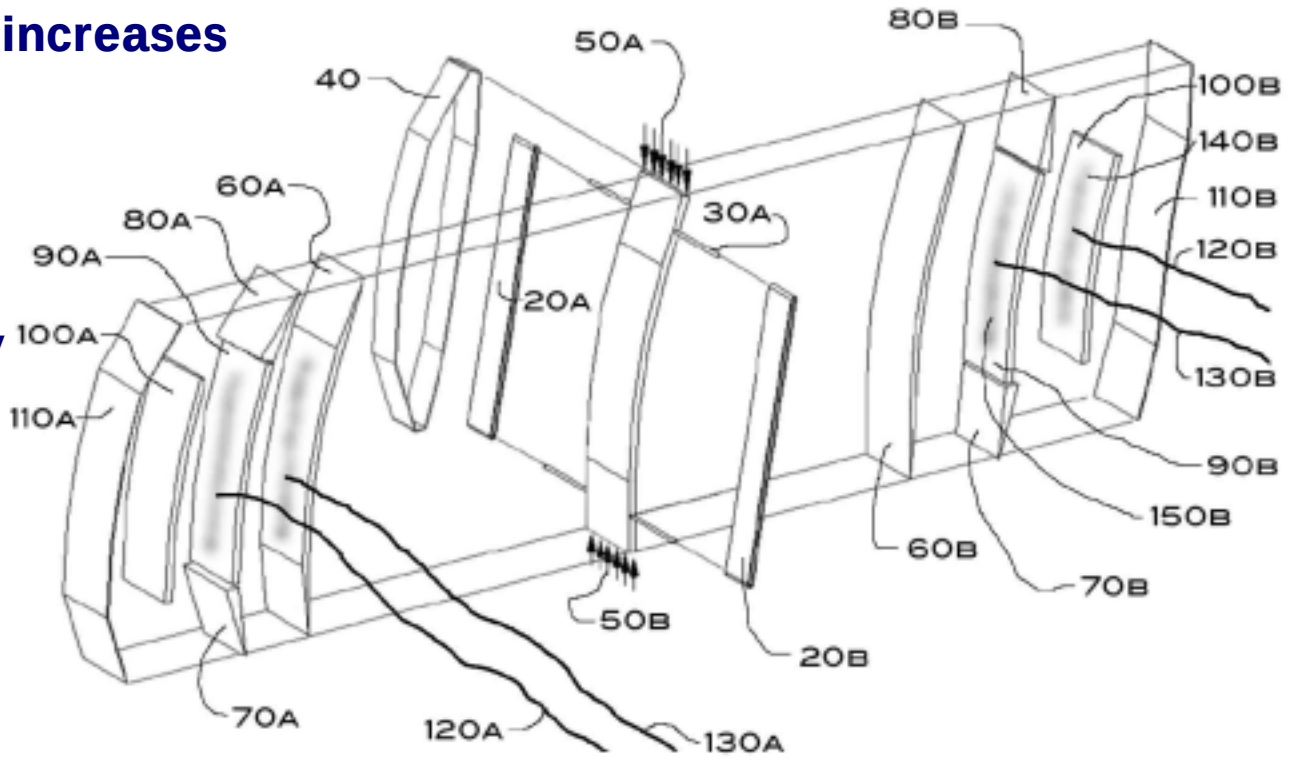
Guiding Small Arms Rounds… The Ephphany!

Discoveries from Europe… 2003 - 2004



PBP Actuators: Real Performance!

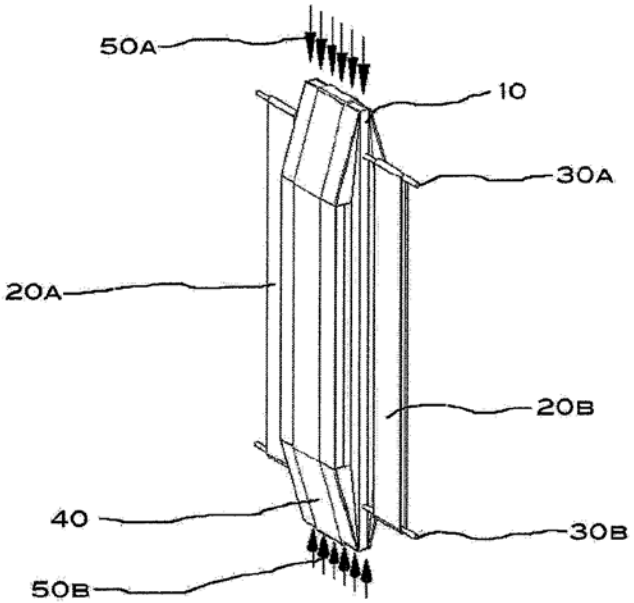
- **Fraction of the weight, size & power consumption of US Actuators (i.e. much smaller actuator bays)**
- **300+% deflection increases**
- **Higher bandwidth**
- **Lower cost**
- **Lower g-sensitivity**

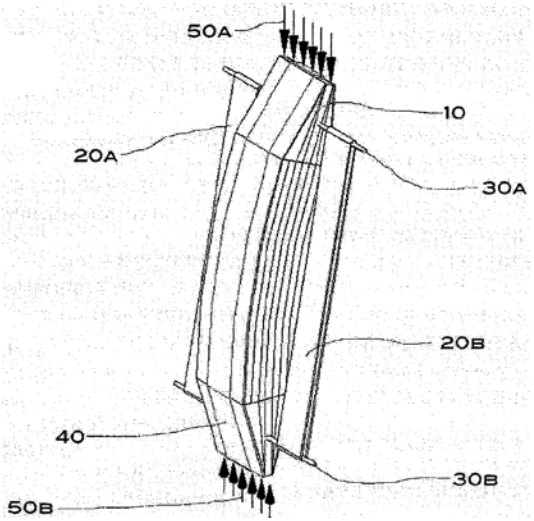


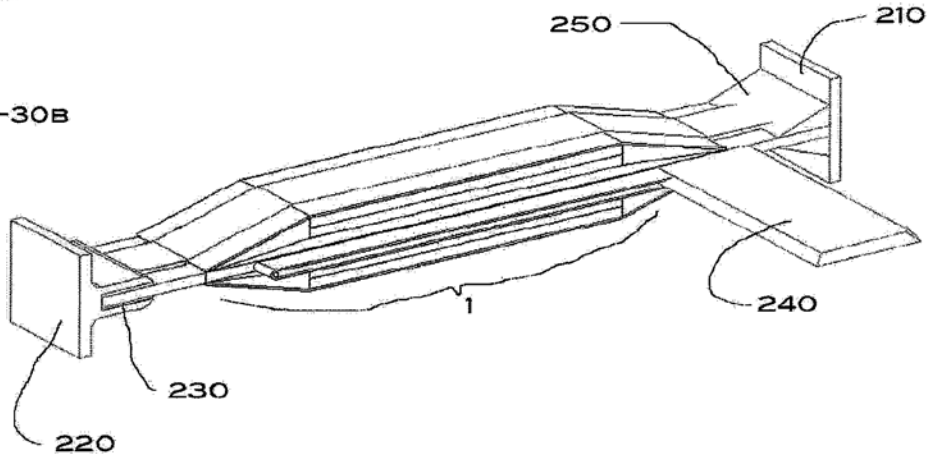
Worldwide patent application: 18 Jan. 2005

PBP Actuators: Real Performance!

Assembled, functioning actuator:

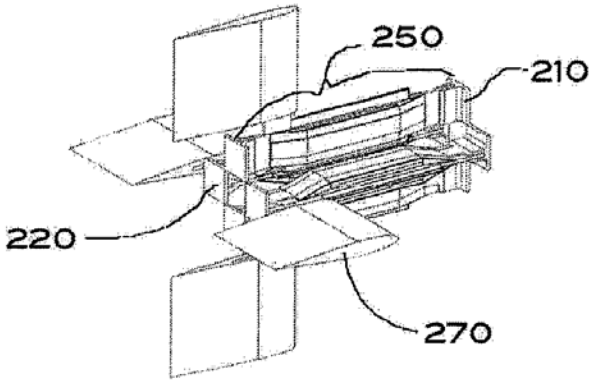


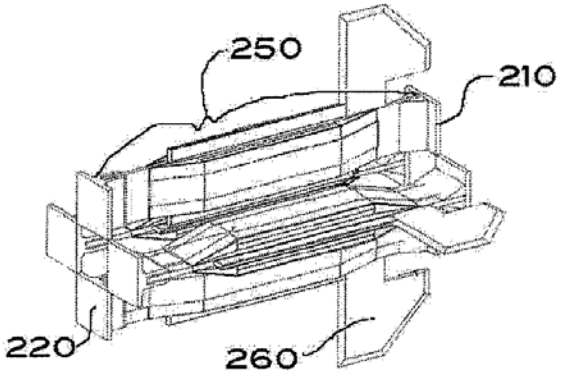


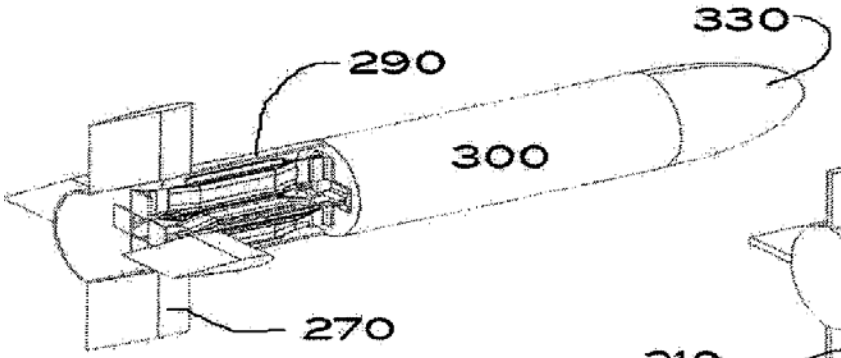


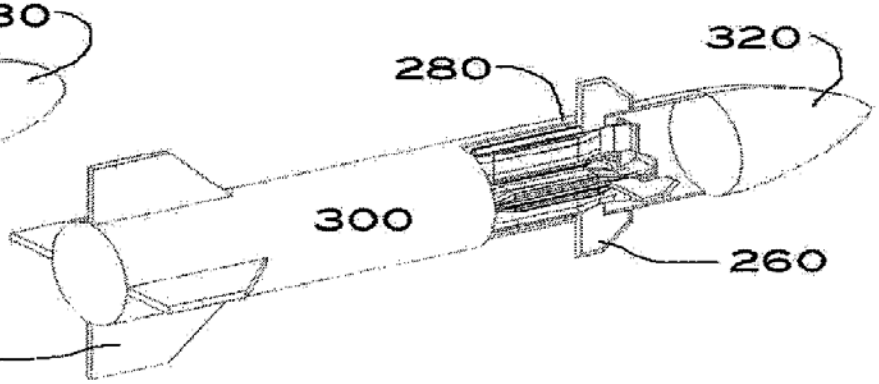
PBP Actuators: Real Performance!

Assembled Hard-Launch Capable Actuator FCS Units:



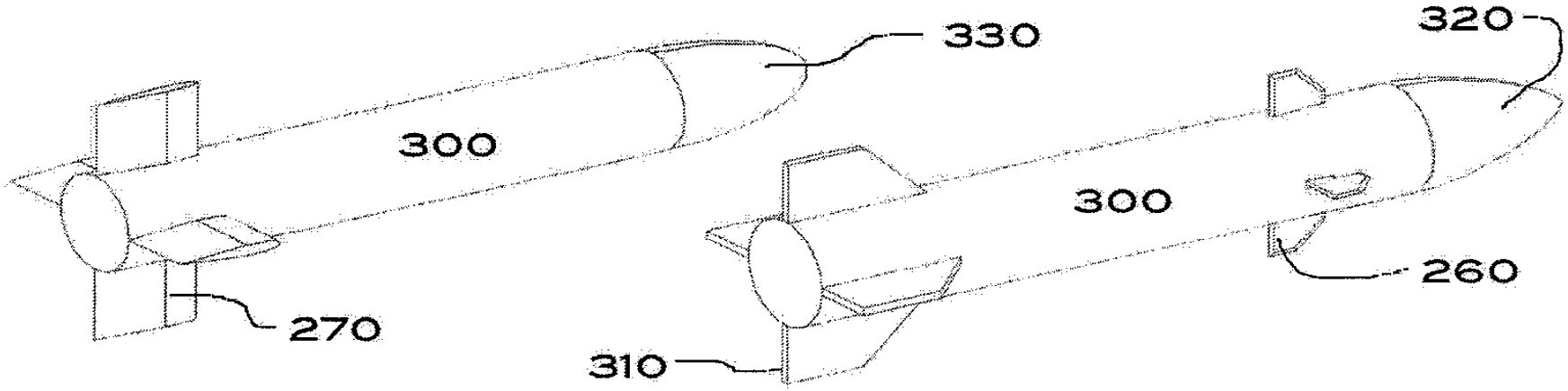






PBP Actuators: Real Performance!

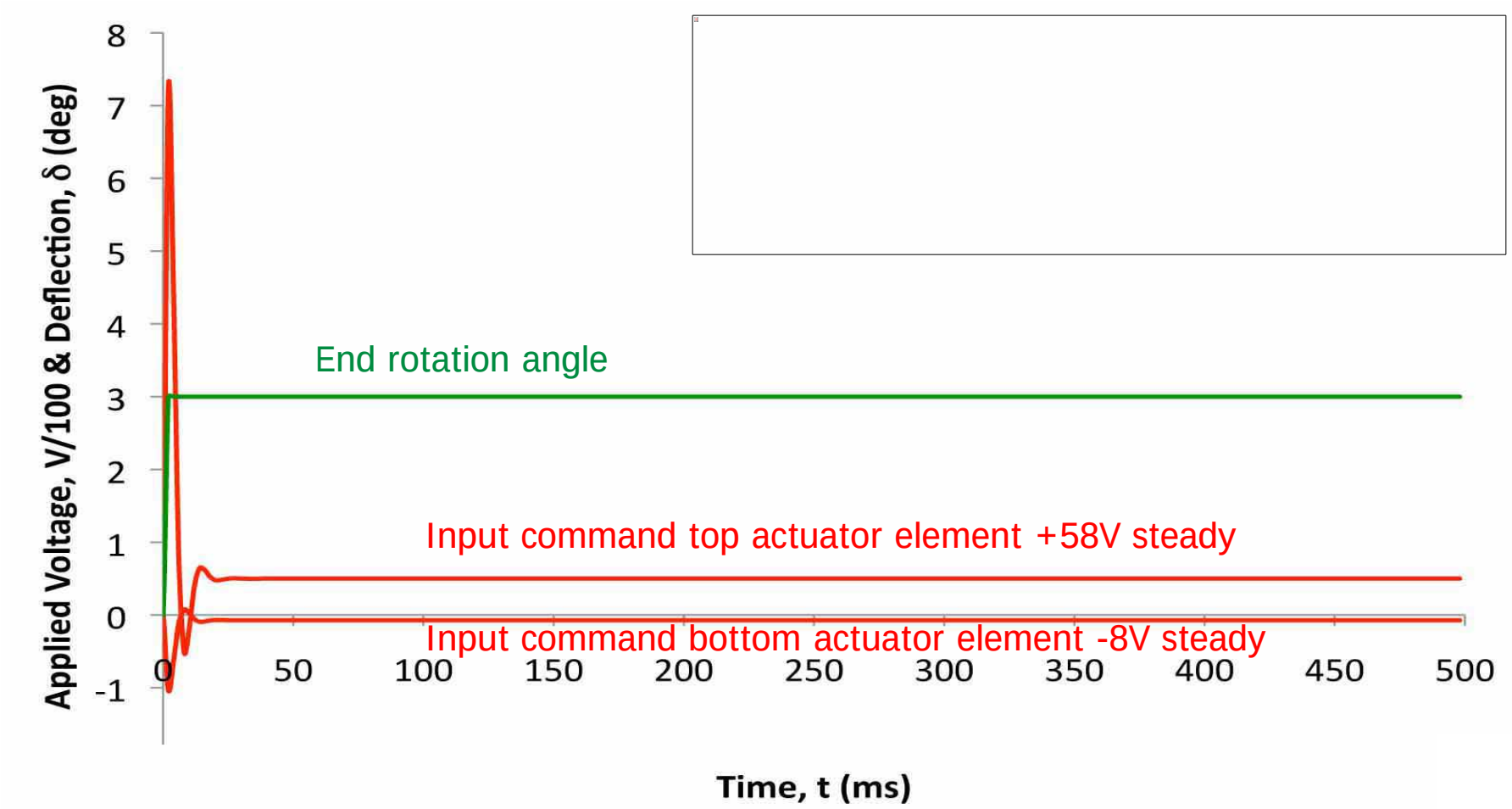
Assembled Hard-Launch Capable Actuator FCS Units:



PBP Actuators: Fastest around…

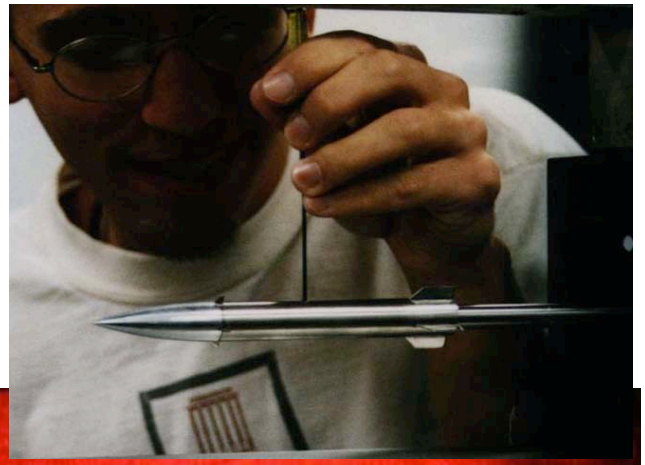
Best performance in the adaptive structures industry:

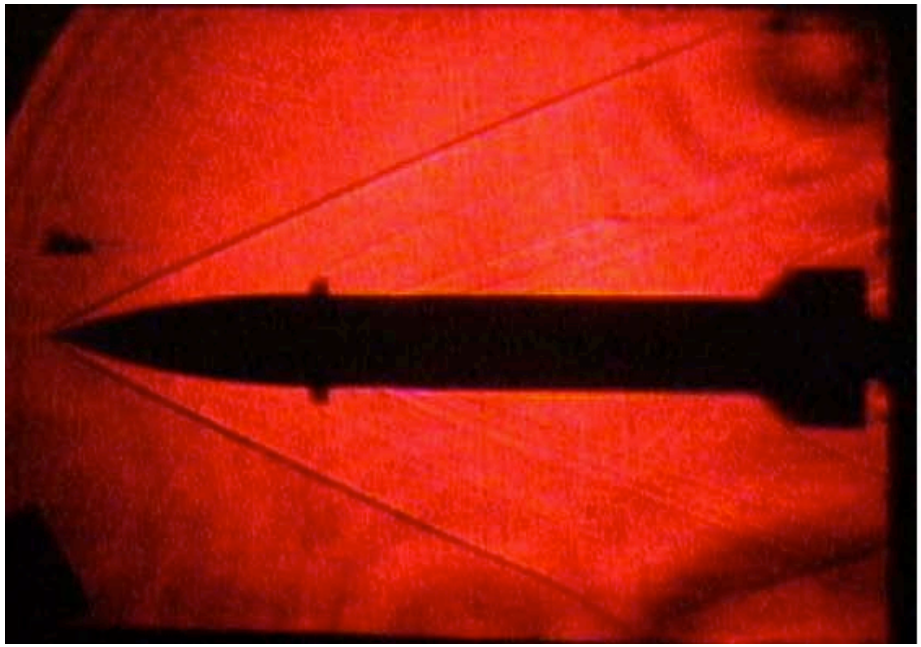
- **1kHz equivalent bandwidth**
- **Driving 0.40/.50 cal Mach 4.5 canards**



PBP Actuators: Real Performance!

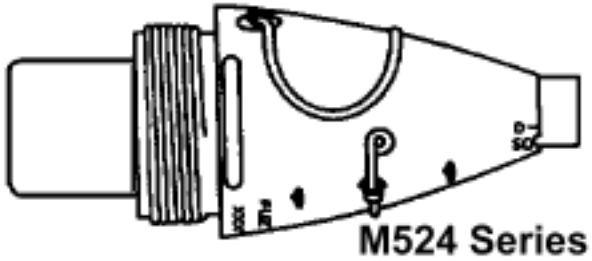
Mach 3 Testing – FCS works well!





PBP Actuators: Moving up in caliber – Easy!

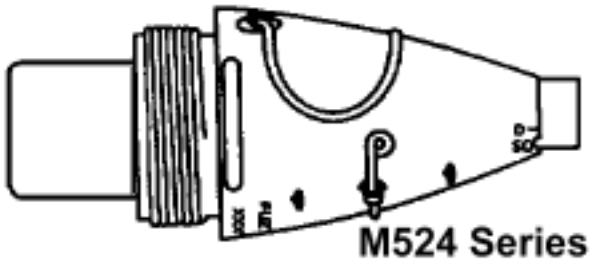
Mortar Fuses



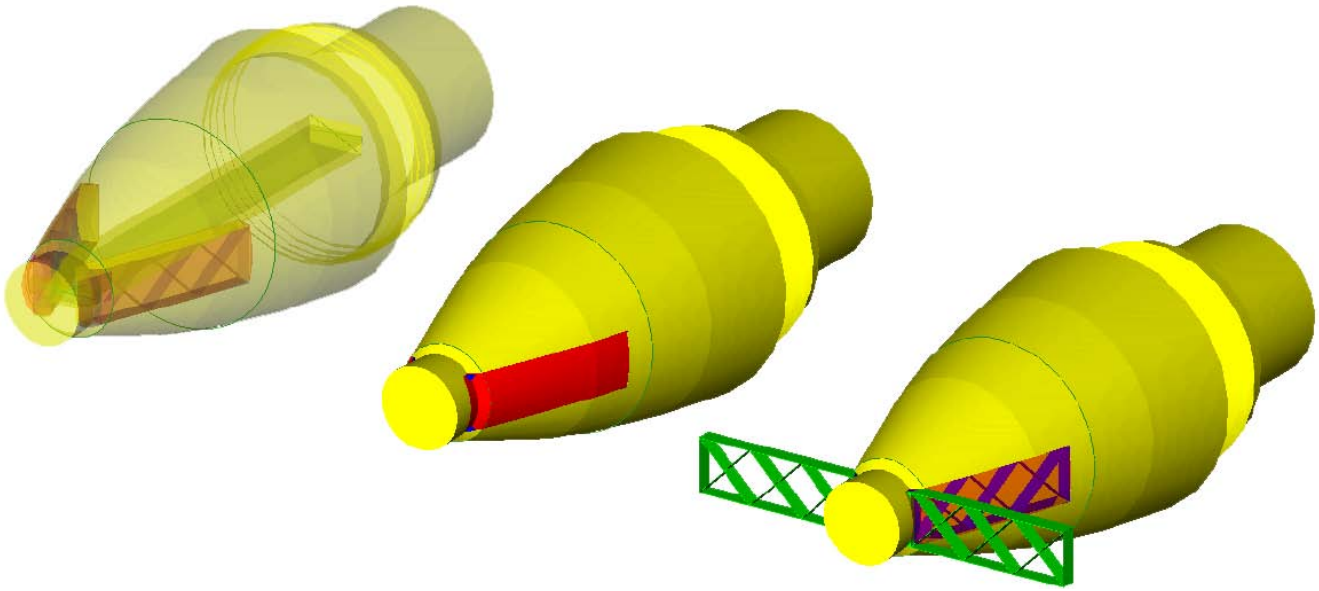
Howitzer Fuses

PBP Actuators: Moving up in caliber – Easy!

Fuse PBP FCS Designs



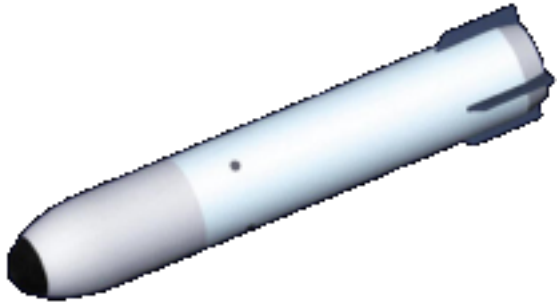
Designs to drive both blade and grid-fin control surfaces full pitch, roll & yaw from apogee for ~8cc volume, through 100 Hz, <1W



Families of Steered Piezoelectric Enhanced Adaptive Rounds (SPEARs)

- Roll Stabilized Recon. SPEAR

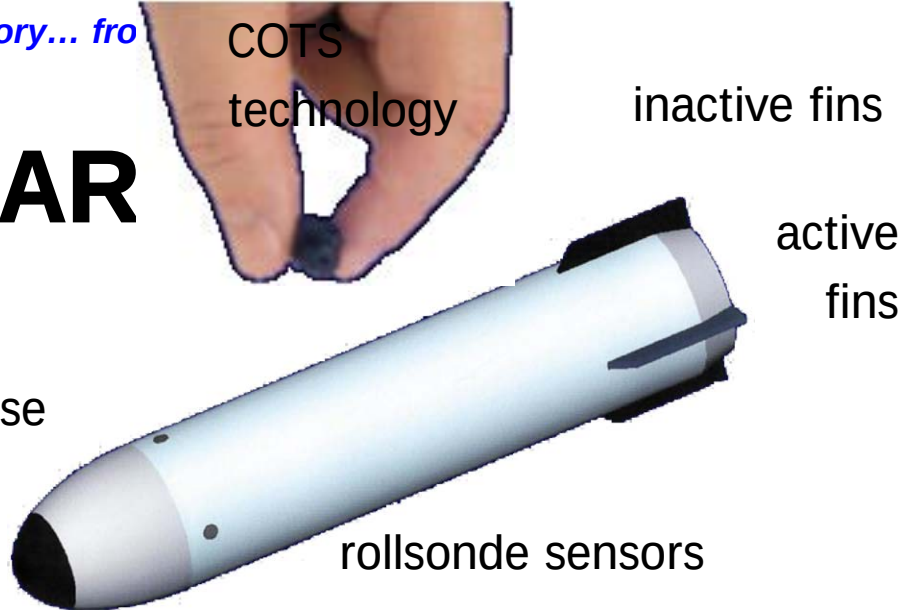
- Full Control Recon. SPEAR



Roll Stabilized SPEAR

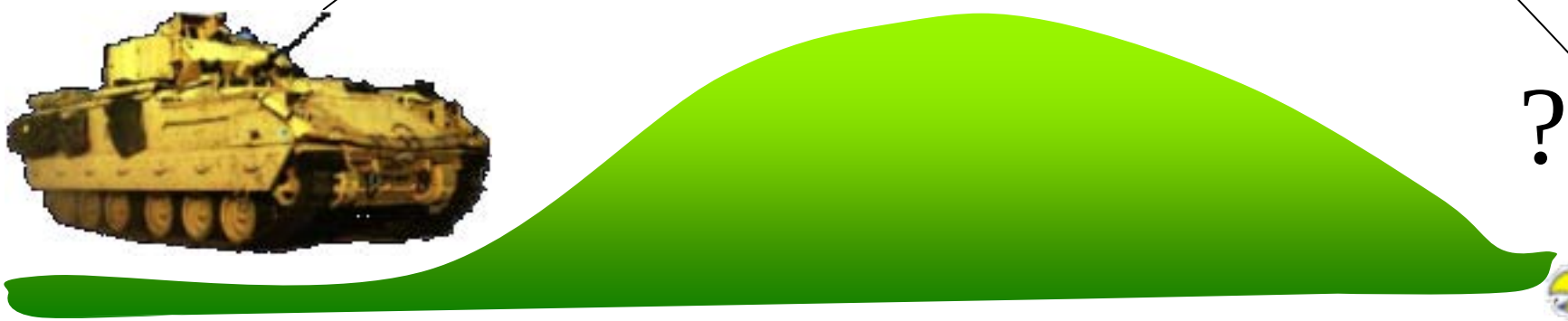
"Look Over the Hill"

Supersonic MAV mission



Tactical Benefits:

- Fastest way to get local reconnaissance images
- Totally impervious to weather/gusts
- ~ $20/round



Roll Stabilized Recon. SPEAR

Necessity of Roll Stabilization

Smooth bore/obturating band launch

20mm:

roll rate > 8rps

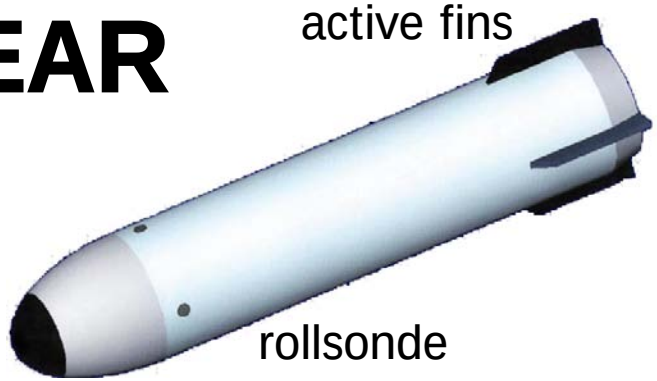
flare

12Ga

Full Control Recon. SPEAR

Full Battlefield

Reconnaissance



Friendly Fire reduction / elimination

40,000 ft (12km)

20mm (16mm) saboted SPEAR

Mach 0.8, 15° launch

Micro Optics Steering w/piezo

±2° through 1kHz

fully proportional

sizable down to 20mm rounds

hardened through 10,000g's

solid state

20+yr life

Questions?

… and a few interesting facts about Kansas…

Hilly, wooded Lawrence, home of the University of Kansas
45 min. West of Kansas City

A very blue dot in a very red state: Lawrence ~ Kansas as Austin ~ Texas

Transportation Hub, Flight Test
Light Aircraft Manufacturing

Avionics

R&D, Flight Test, Aircraft Design
Missiles, Munitions, UAVs

Airline Aircraft Maintenance
Insurance
Spares
Interiors
Avionics
Salvage

Airframe Design, Development, Production