MEMS S&A FOR MUNITIONS

To:

JOINT ARMAMENTS CONFERENCE
EXHIBITION & FIRING DEMONSTRATION
Small Arms Session
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Kaman Precision Products
The Team

- ARDEC Fuze Division
  - Sponsor, TOSA 159
  - EDF-11

- Kaman Precision Products:
  - Fuze Systems Engineering
  - Project Management

- Draper Laboratory:
  - MEMS Design & Analysis Engineering

- MicroFabrica: MEMS Manufacturer
  - MEMS Foundry
Kaman MEMS Overview

• **Concept:** Demonstrate the ability to produce a Runaway (Verge Escapement) Safe and Arm device with a self assembled, In-Situ, Micro-Electro Mechanical System. Thereby demonstrating the feasibility of MEMS S&As for Munition Applications.

Devices shown to relative scale

40mm S&A ~Ø32 mm

MEMS S&A
~5x5 mm
Verge Escapement Simulation
Self-Assembled (In-Situ)
MEMS S&A Development History

P1 Demonstrated Moving Parts
P1 CY 2006

P2 Demonstrated Verge Escapement
P2 CY 2007

P3 Demonstrated Spin Lock
P3 Q1 CY 2008
Loaded w/EDF-11

P4 Set-Back Lock
Tested Q2 CY 2009

P5 In Fabricated 11/09
Out-of-Line Exp Train
Update Set-Back Lock
Rotor Armed Lock

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Current Concept for TOSA-159 Demonstration
Actual Demonstration Conducted in Dec 09
MEMS S&A Out-of-Line
“Safe” Configuration

Safe Configuration

Explosive train (Centerline of Munition)

Initiator ‘landing pad’

Transfer charge

Initiator

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MEMS S&A Out-of-Line
“Armed” Configuration

Armed Configuration

Explosive train (Centerline of Munition)

Initiator
What the benefits are (versus existing funded efforts)

• **Size**
  - Present 5mm x 5mm x0.5mm = 12.5 mm³
  - Exclusive of Detonator of ~ same size
  - Thought to be the smallest 2 environment sensing S&A in World.

• **Reliability**  -- Fully Self-Assembled

• **Arming Accuracy**  -- Exceeds Close in Arming distance requirement in Lab Tests

• **Broad Application**  -- Medium Caliber, Small Caliber potential, Cannon Fired Sub-Munitions, Rockets, Small Missiles, Spinning and Non-Spinning

• **Cost**  -- Ultimately a lower cost approach
TOSA 159 Studies

- **Sensitivity Study** -- MEMS Verge Escapement design of interest has a good sensitivity
- **Non-Spinning Munition** -- MEMS Verge Escapement suitable
- **De-Spun Munition** -- MEMS Verge Escapement based device could be constructed that would act after sensing De-Spin
- **Volume Requirements** -- Two orders of magnitude reduction in comparison to Mortar Fuze Rotor assembly ~0.5 Cubic inches reduced to ~.008 Cubic inches
Preliminary Testing -- Test Objectives

• Demonstrate Feasibility of:
  ☑ Micro-Detonator Explosive Transfer to EDF-11 Loaded Explosive Transfer Charge
  ☑ Demonstrate Transfer via MEMS Explosive Transfer channel of EDF-11 detonation to MEMS Explosive Output Cup
  ☑ Demonstrate Explosive Output from Explosive Cup

➢ Demonstrated Out-of-line sufficiency for design with N5 lead pellet, a safety requirement
Exploded View of Assembly

- Fuze Body Adapter
- MEMS S&A (Phase 4 device shown)
- Initiator Assembly (Phase 4 assembly shown)
Loaded Armed MEMS Device in Carrier
MEMS Device w/ Initiator Ready for Firing Test
Close-up of Carrier after Explosive Test
Output side of MEMS Device in Armed Condition (Set Back Lock Removed)
Close-up on Witness Dent
Undamaged N5 Booster Pellet
Results

• **Demonstrated** Micro-Explosive Train propagation from Micro-Det across to Explosive Output Cup, and then high order output of cup via flyer plate into aluminum holder. ~33% first round P4 ~50% second round P5

• Demonstrated Out-of-line sufficiency for design with N5 lead pellet, a safety requirement.
40mm Gun Demo Set Up
M203 Demo Preliminary Firing

• Objectives
  - Demonstrate the integrity of the Test Round, especially MEMS fixturing in Test Vehicle
  - Demonstrate survivability of MEMS S&A, Micro-Detonator and Micro-Explosive Train
  - Demonstrate Range set up
  - Demonstrate Suitable Ballistics of Test Vehicle
  - Demonstrate Arming in Flight and Post Firing Detonation
M203 Demo Preliminary Firing

• 9 rounds Fired
  – Three Type A Set-Back Lock
  – Six Type B Set-Back Lock
  – All rounds fired, disassembled, inspected, reassembled, subjected to firing stimulus

• First two (9 and 8) took out velocity screens
  – Ogive collapsed
  – No test, gunners error
M203 Test Firing, Con’t.

- Next seven fired and soft recovered successfully, no velocity data
  - Round 6, armed in flight detonator fired no transfer to lead charge
  - Round 5, not fully armed in flight, armed on lathe and successfully detonated high order
  - Remaining rounds were neither fully armed in flight nor successfully detonated.
2010 Plans

• Program Continuing
  – Presently funded under Kaman IR&D
  – P6 MEMS and Micro-Detonator Build
  – Awaiting 2010 Sponsor funding

• 2010 Goals
  – Explosive Train Demo of better than 90%
  – Improved Gun fired demonstration