# MEMS S&A FOR MUNITIONS

To:

JOINT ARMAMENTS CONFERENCE

EXHIBITION & FIRING DEMONSTRATION

Small Arms Session

MAY 19, 2010

Dale Spencer

Kaman Precision Products

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# 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

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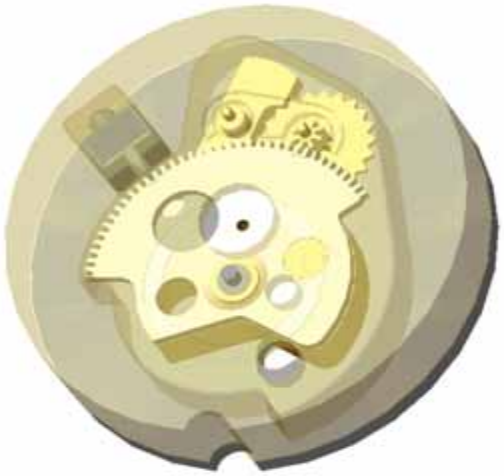
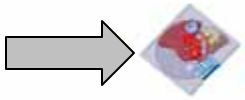
# Kaman MEMS Overview

- **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***

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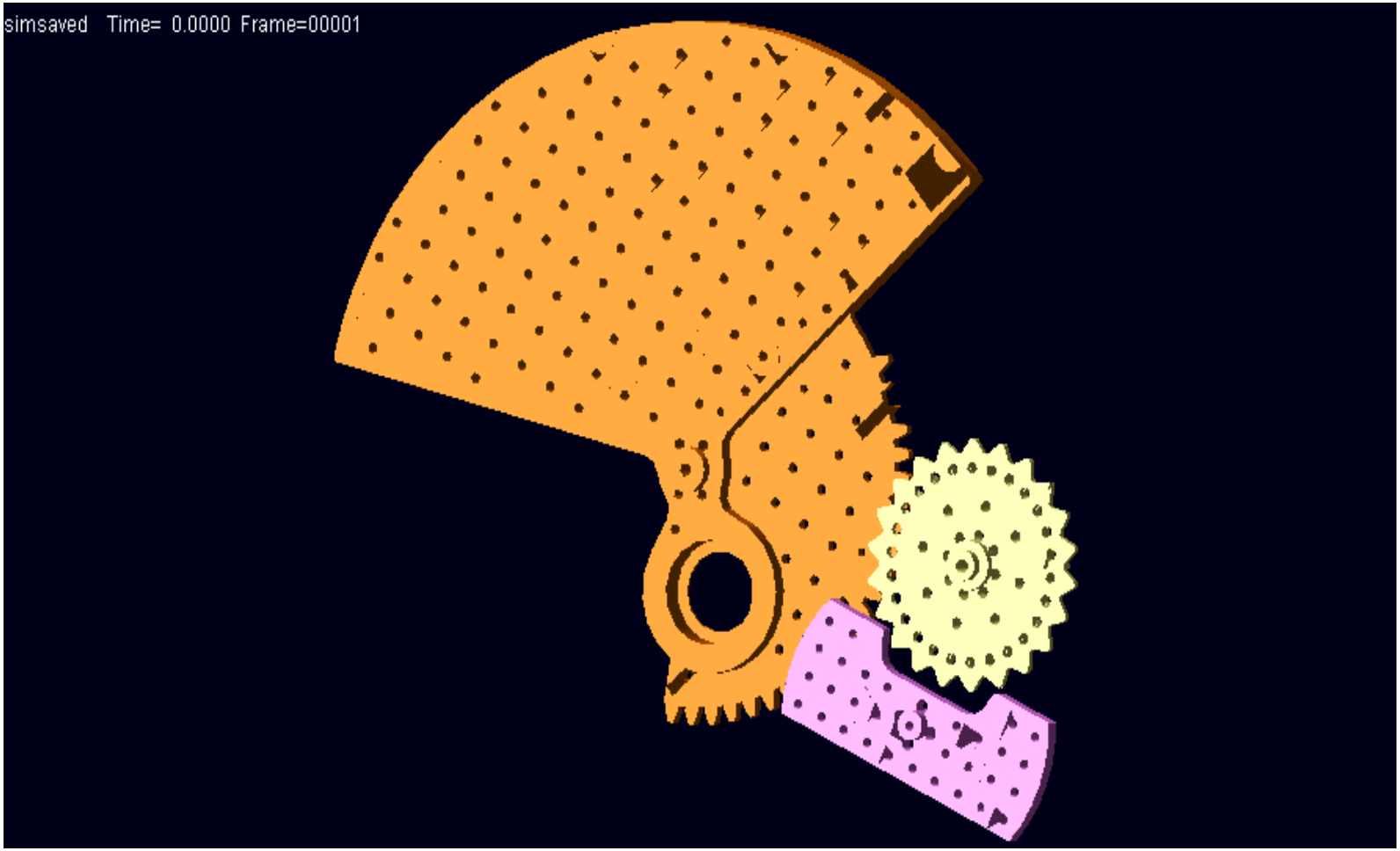
# Verge Escapement Simulation

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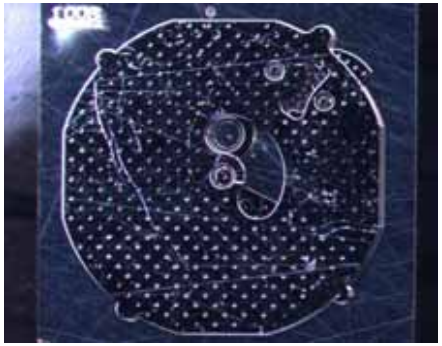
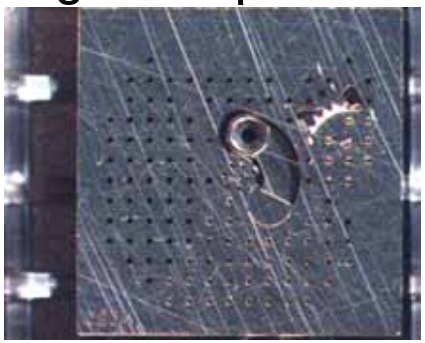
# Self-Assembled (In-Situ) MEMS S&A Development History

P1 Demonstrated Moving Parts



P1 CY 2006

P2 Demonstrated Verge Escapement

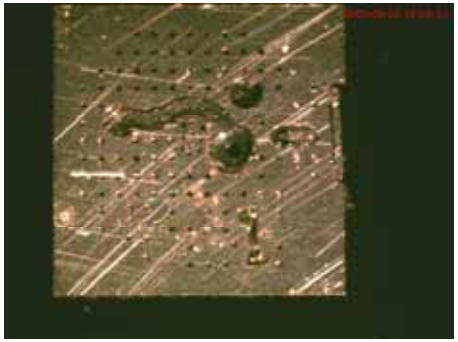


P2 CY 2007

P3 Demonstrated Spin Lock

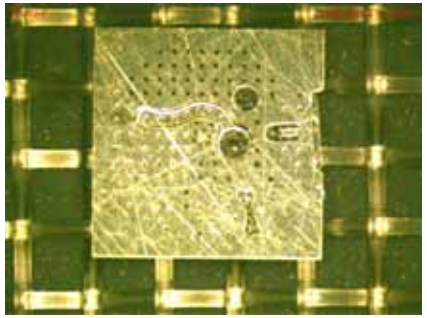
P3 Q1 CY 2008

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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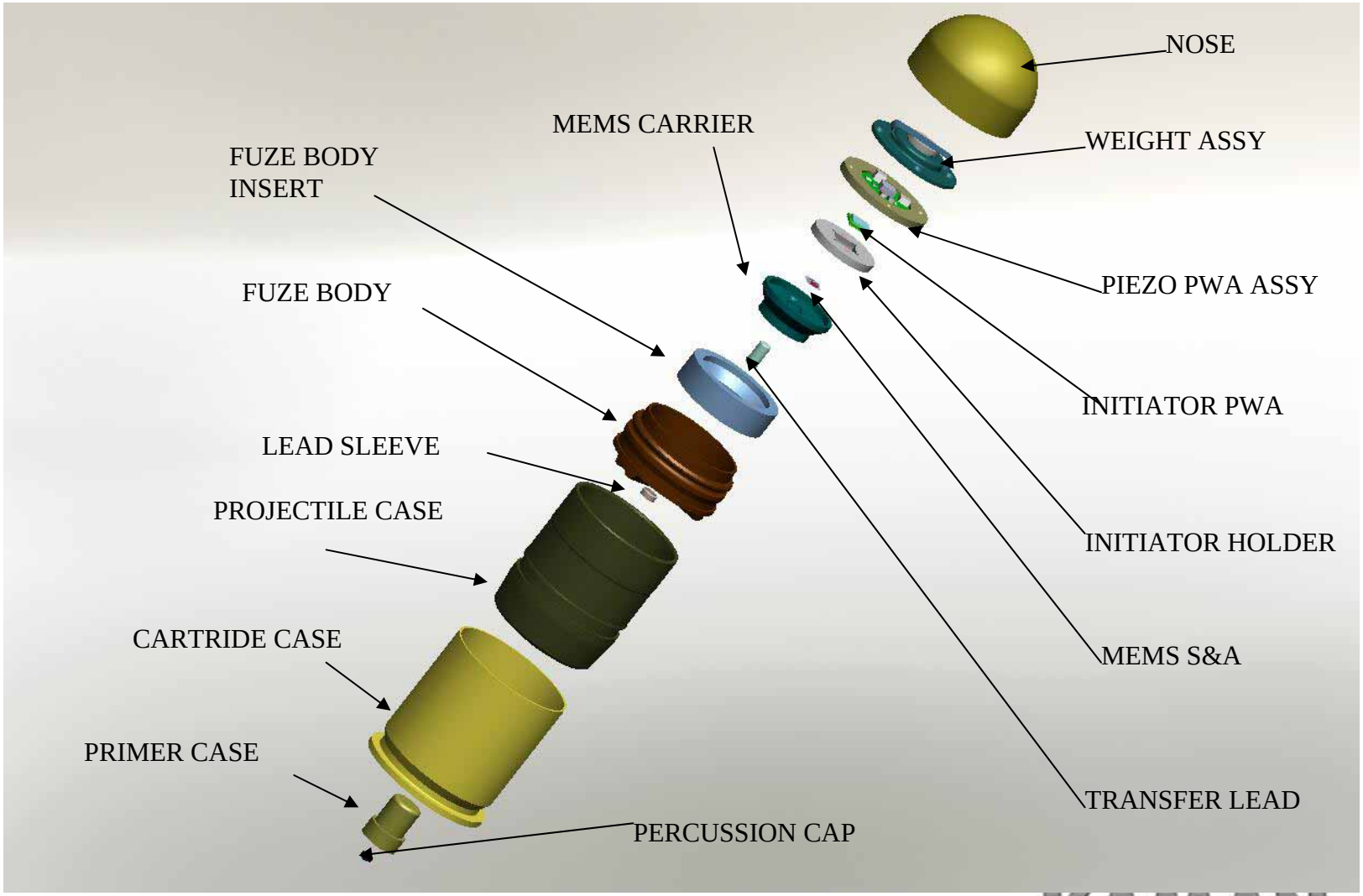
# Current Concept for TOSA-159 Demonstration

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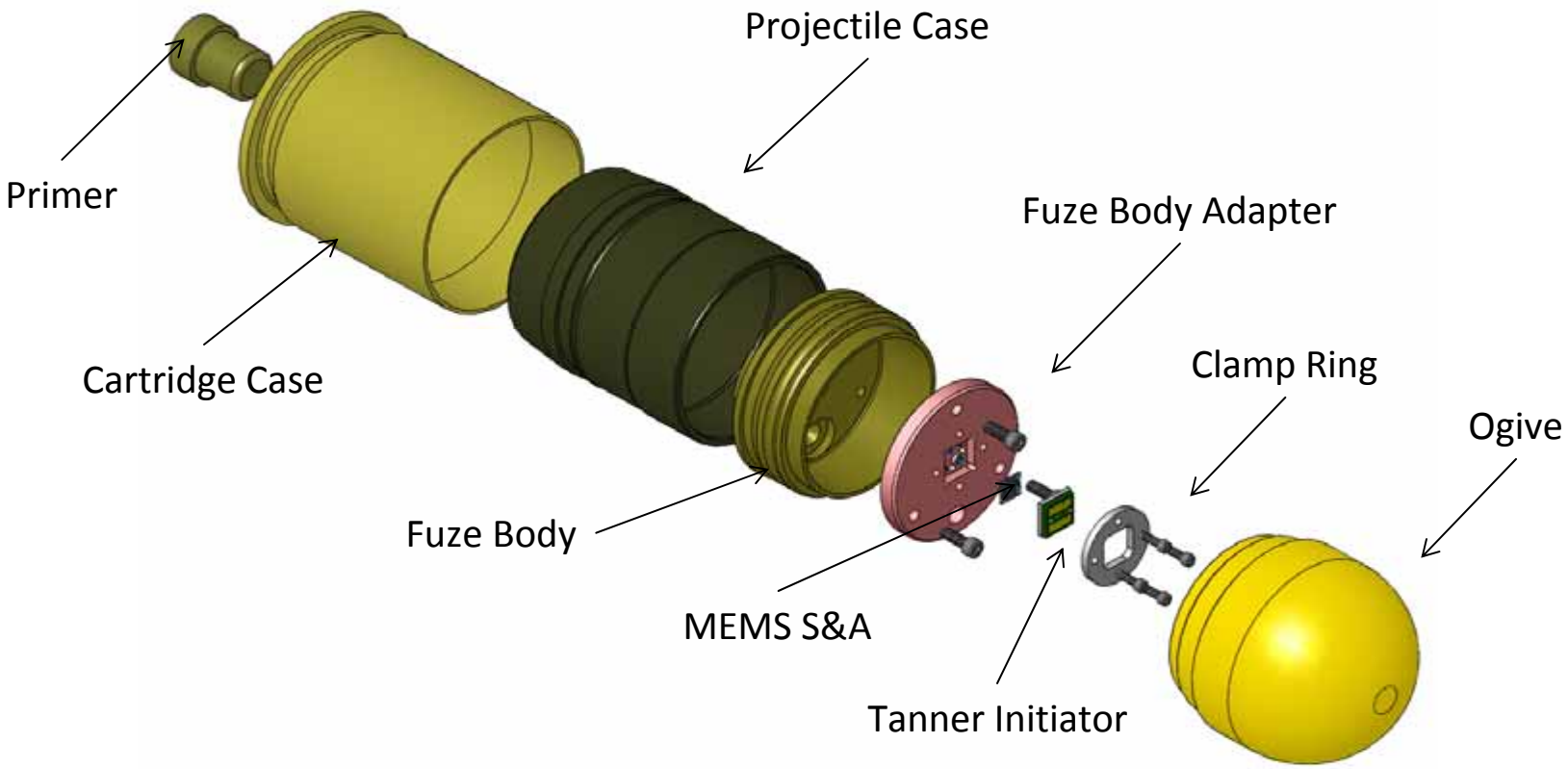
# Actual Demonstration Conducted in Dec 09

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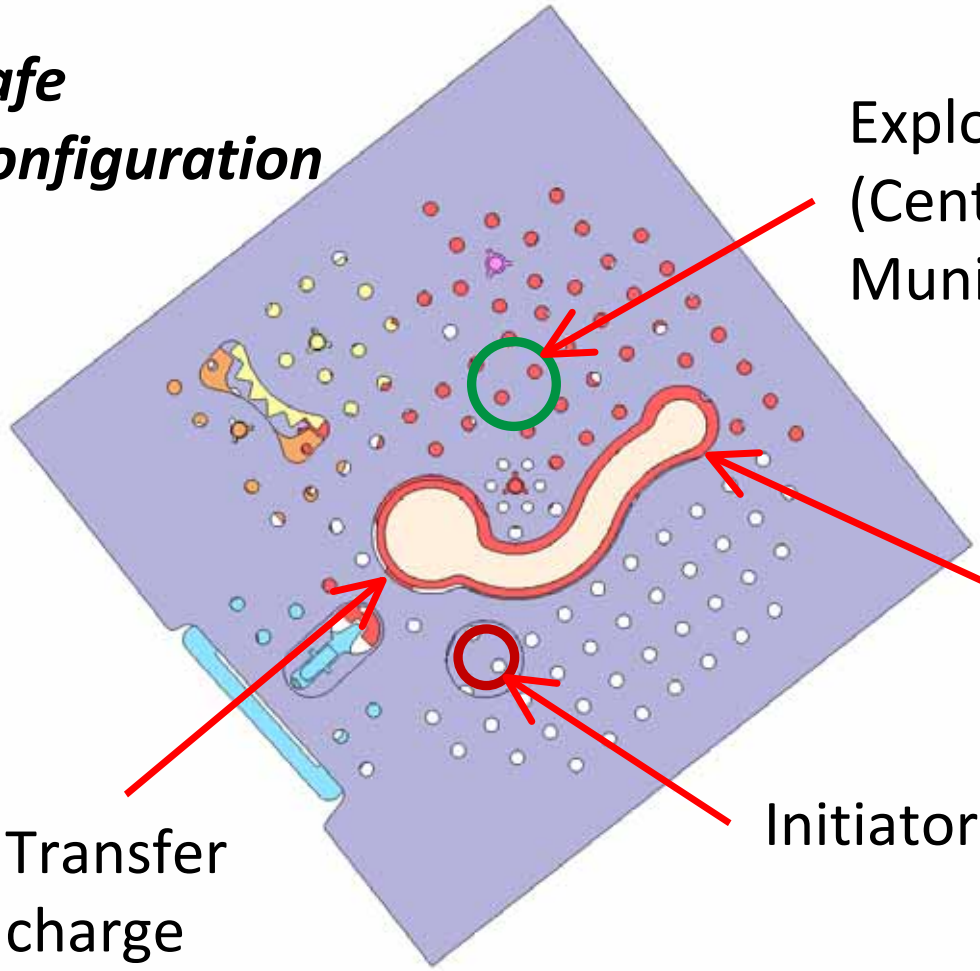
# MEMS S&A Out-of-Line
# " Safe" Configuration

***Safe Configuration***

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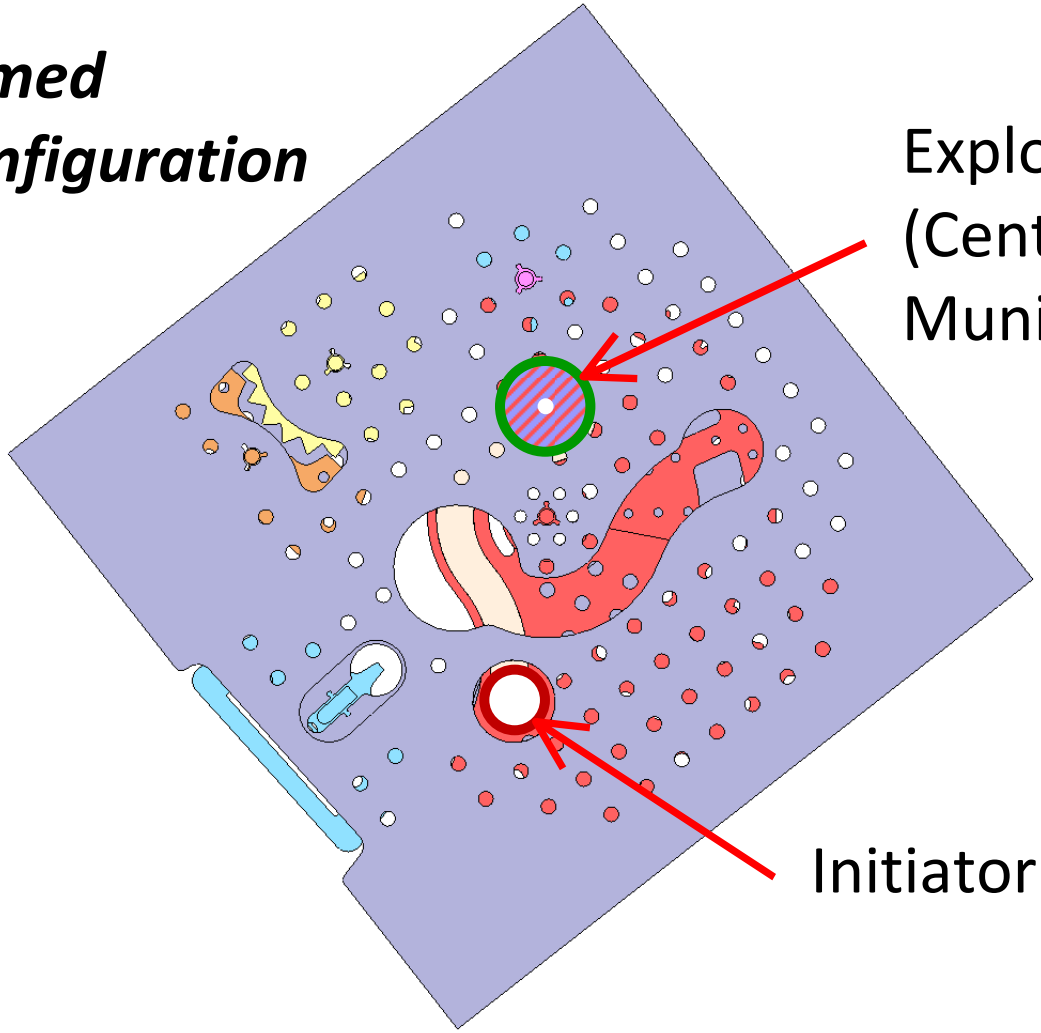
# MEMS S&A Out-of-Line "Armed" Configuration

***Armed Configuration***



Explosive train (Centerline of Munition)

Initiator

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# 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

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# TOSA 159 Studies

- **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**

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# 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

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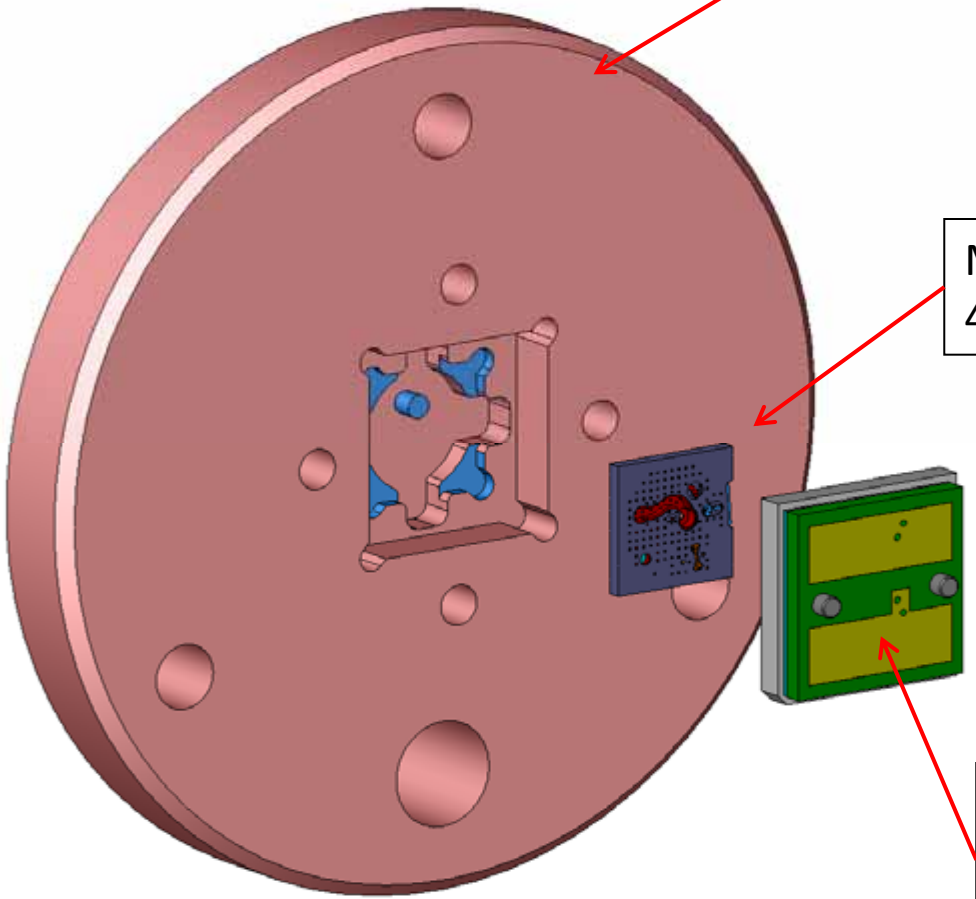
# Exploded View of Assembly

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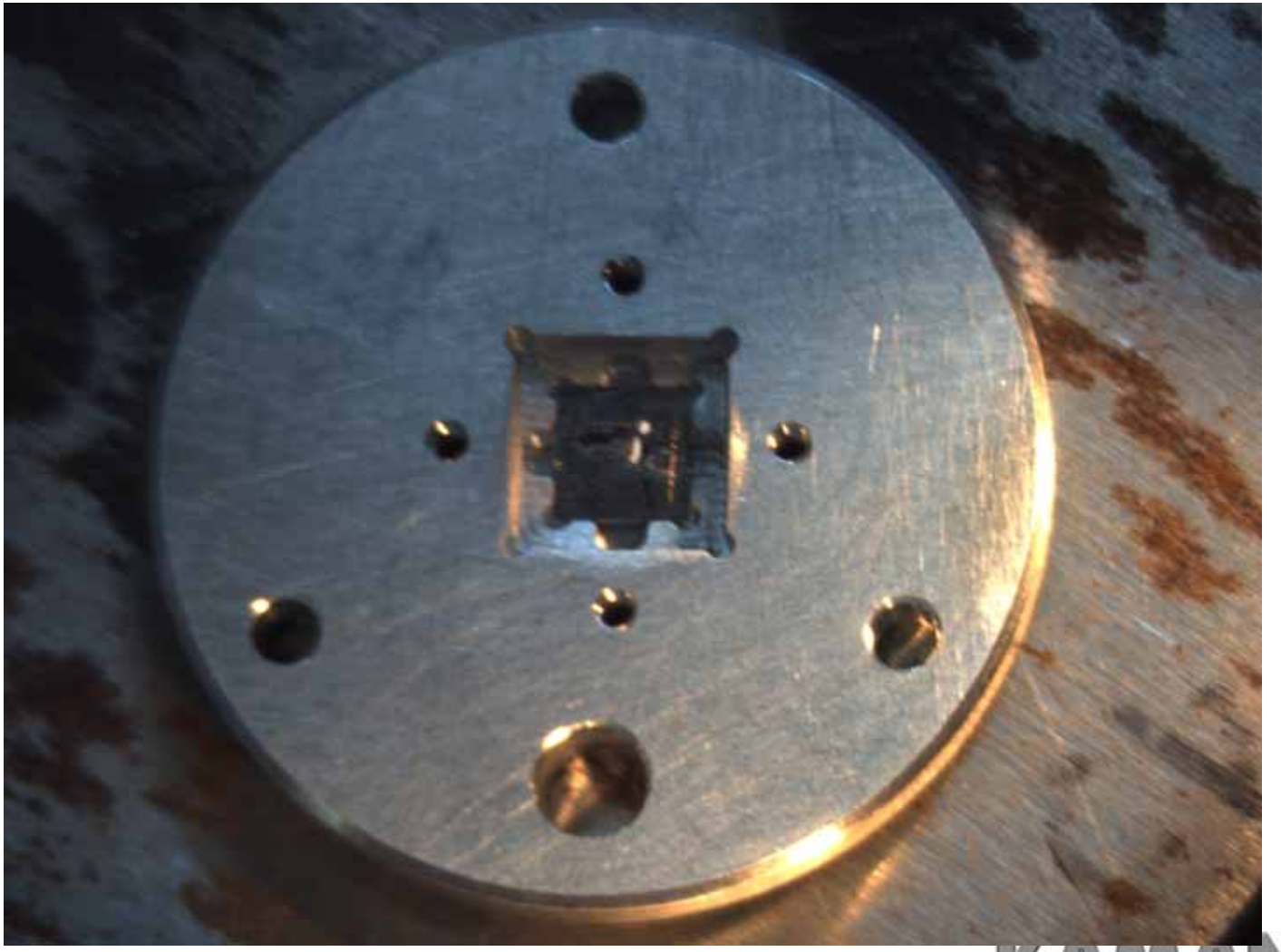
# Loaded Armed MEMS Device in Carrier



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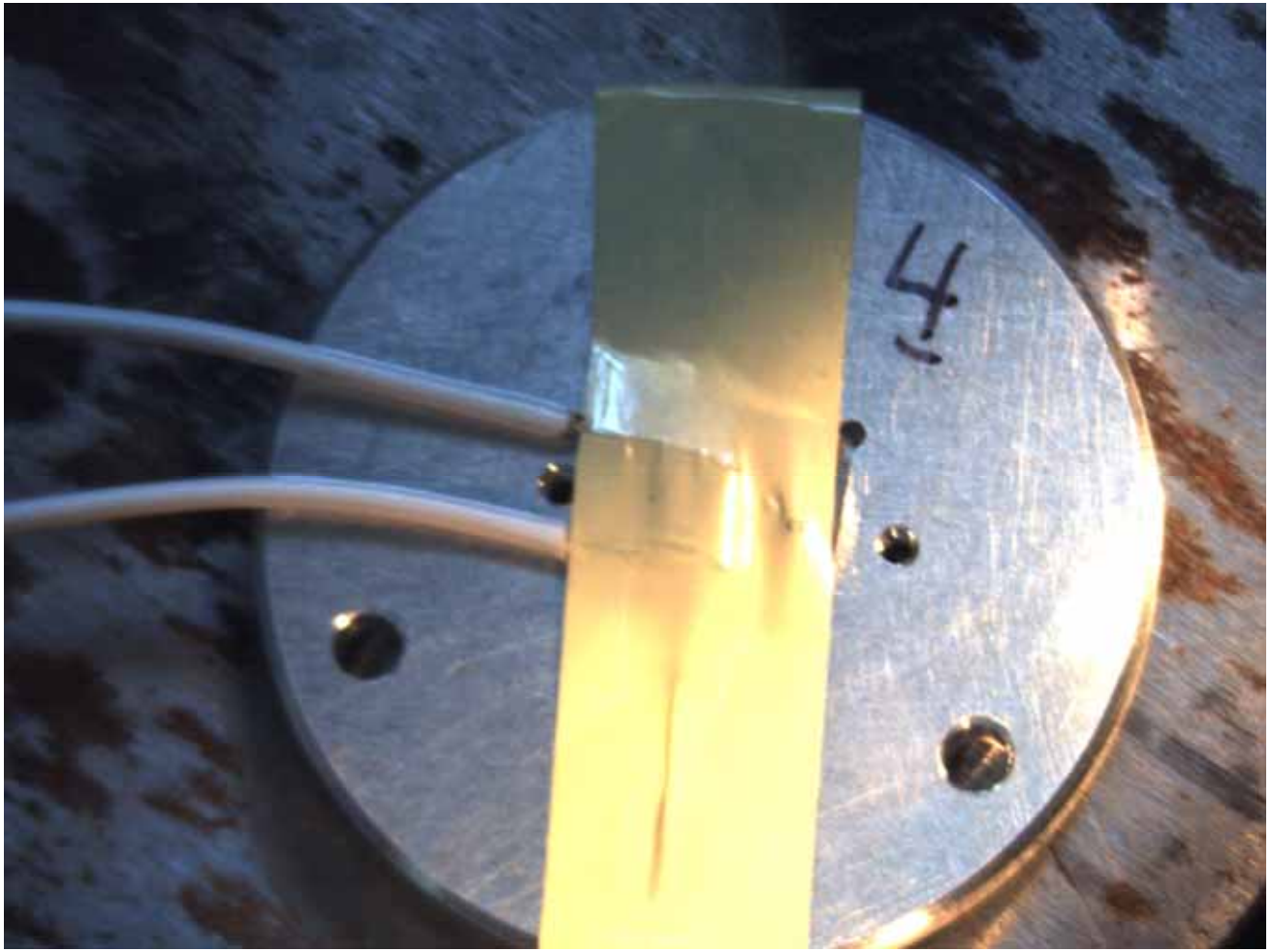
# MEMS Device w/ Initiator Ready for Firing Test

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# Close-up of Carrier after Explosive Test

Witness Dent

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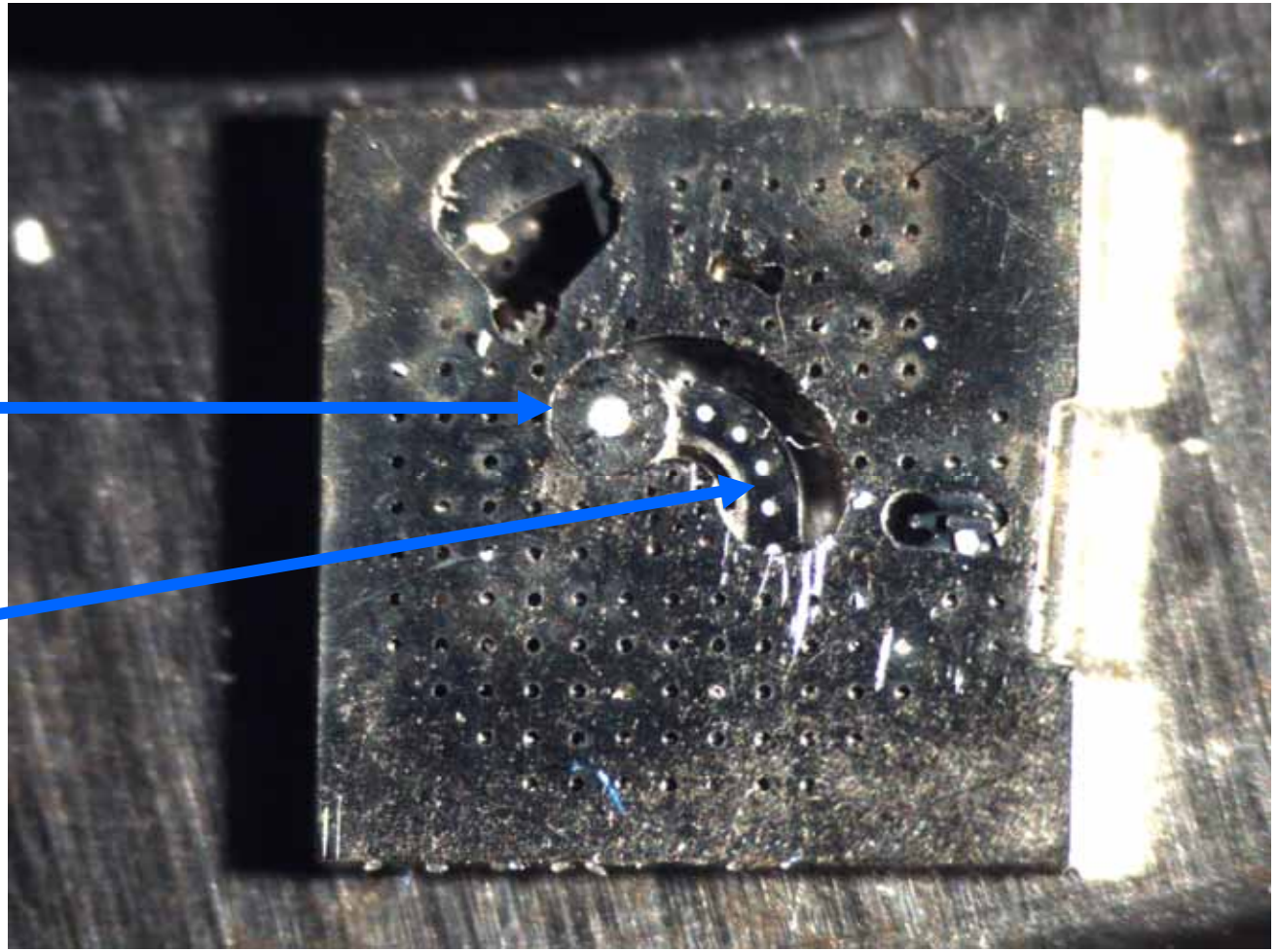
# Output side of MEMS Device in Armed Condition (Set Back Lock Removed)

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# Close-up on Witness Dent

Close-up on Witness Dent

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# Undamaged N5 Booster Pellet

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# 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.

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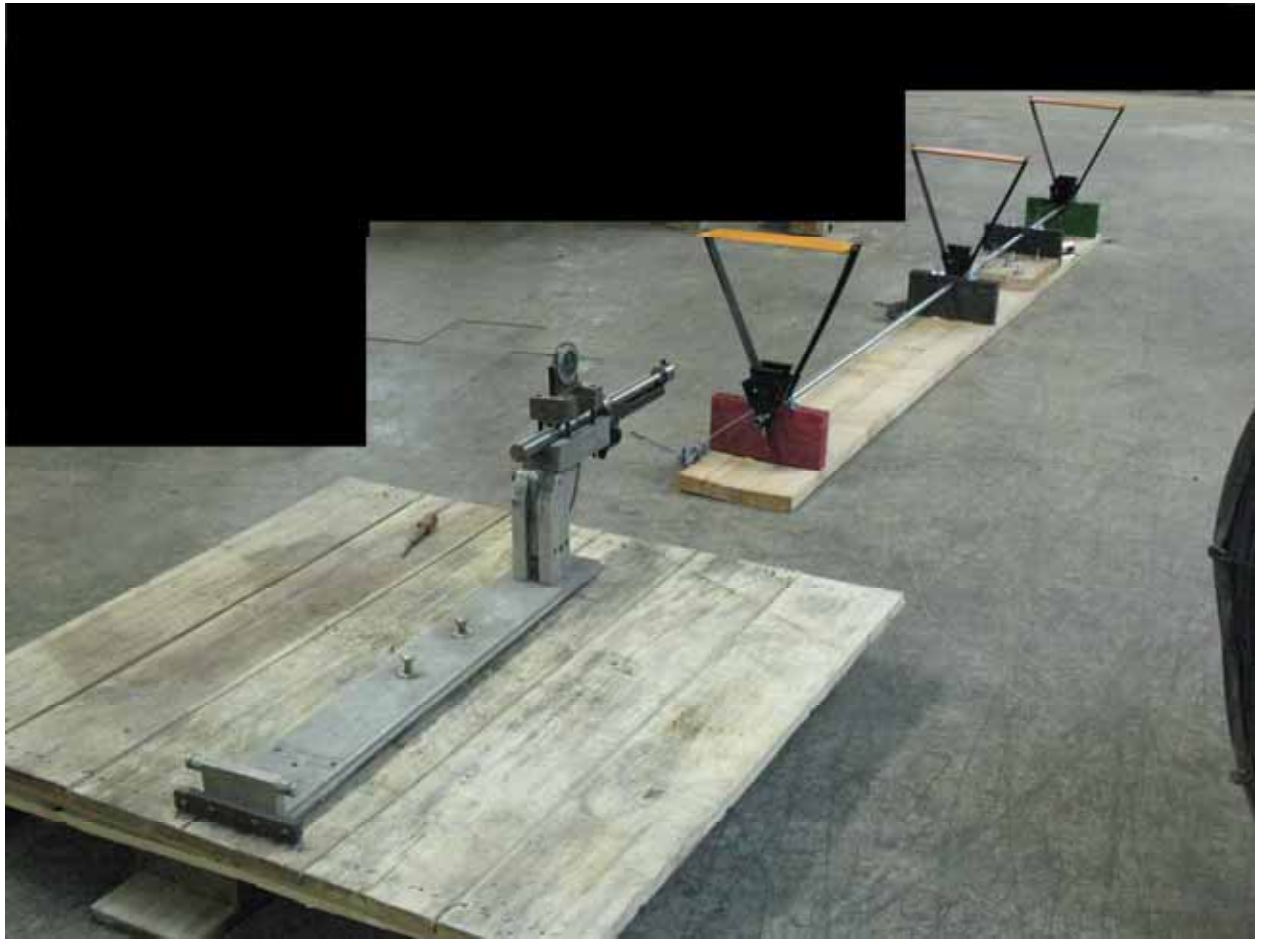
# 40mm Gun Demo Set Up



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# 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

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# 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

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# M203 Test Firing, Con't.

- Next seven fired and soft recovered succesfully, 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.

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# 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

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