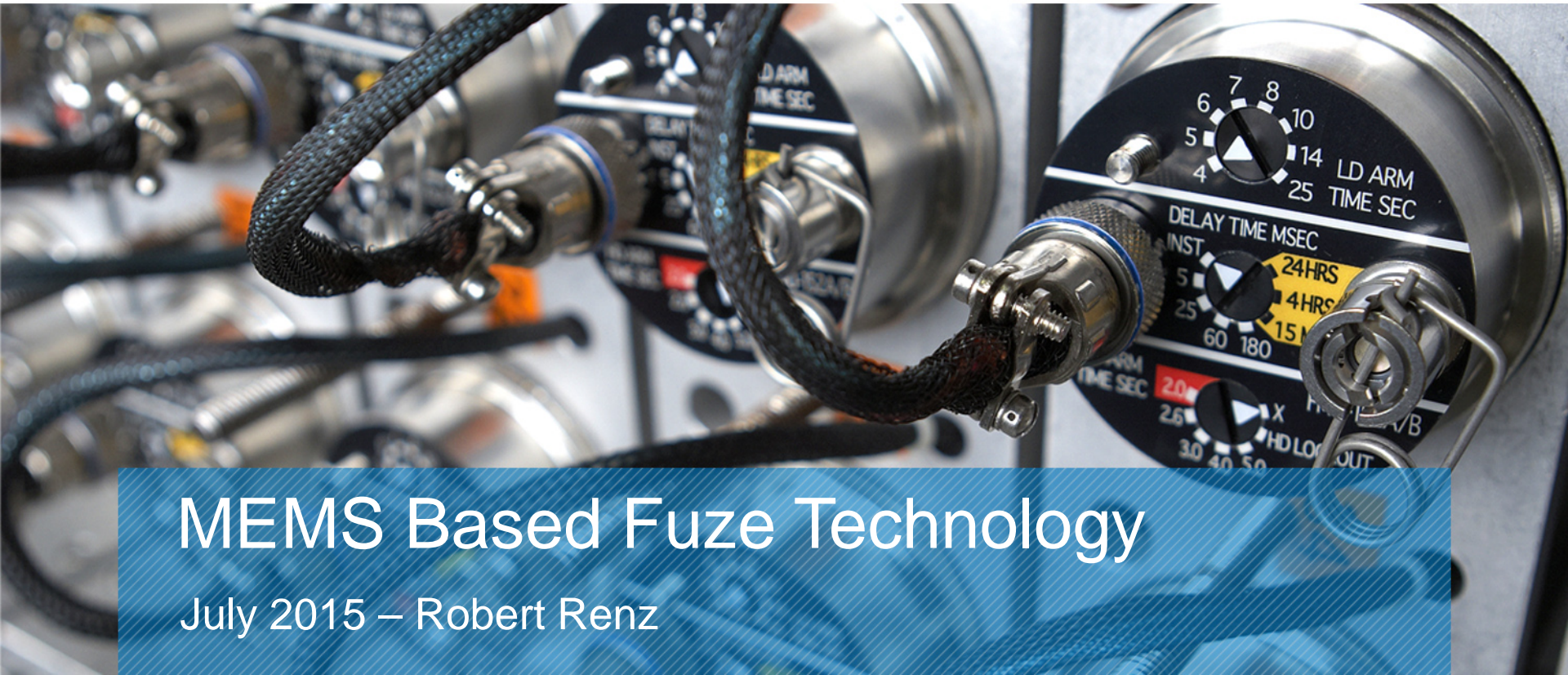


KAMAN

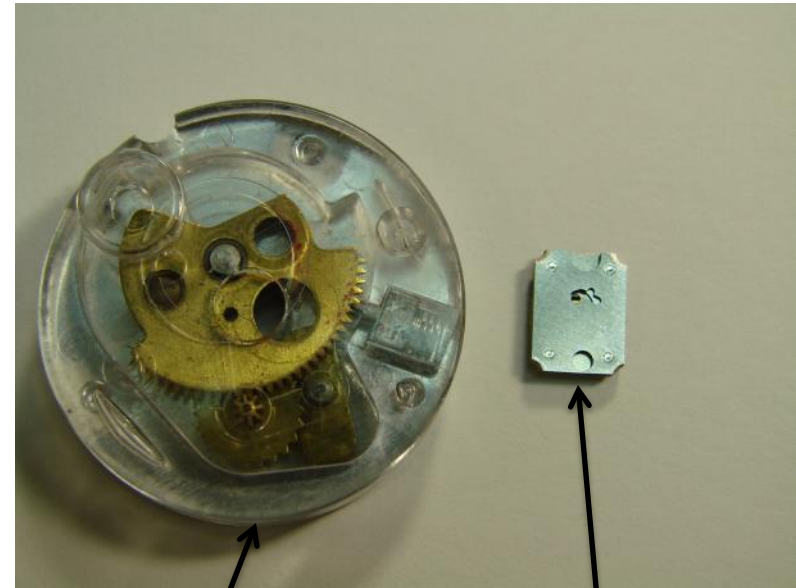
Fuzing & Precision Products



MEMS Based Fuze Technology

July 2015 – Robert Renz

- MEMS Technology Overview
- Kaman MEMS Design Overview
 - MEMS Safe and Arm
 - Fuze Assembly
- Performance Testing Summary
 - Arming Environments
 - Fire Train Testing
 - Live-Fire Gun Testing
- Conclusion



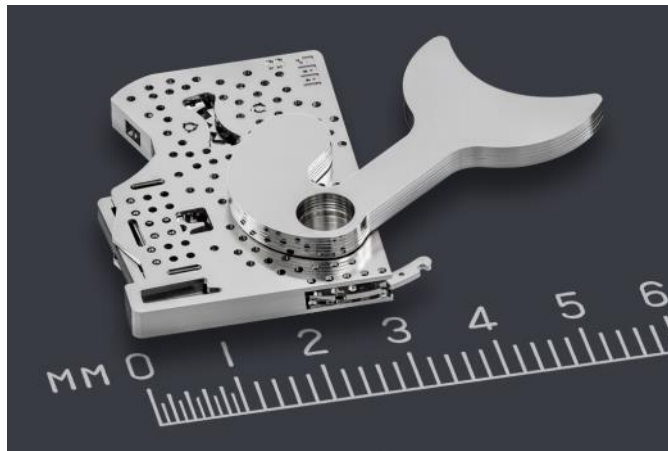
Present M550
40mm Fuze

Kaman 40mm
MEMS Fuze

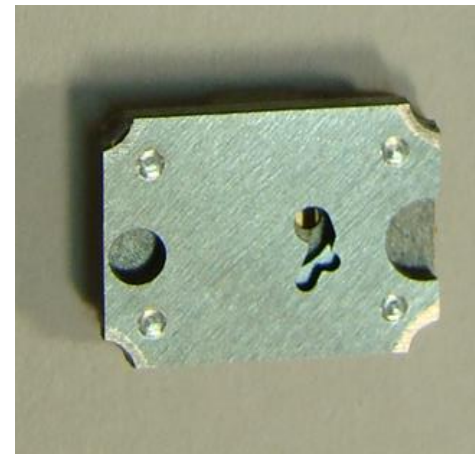
Company Private

Kaman MEMS Technology

- MEMS Safe and Arm Device is constructed of a very strong Nickel-Cobalt metal alloy
- Produced using layer by layer additive technology with tolerance capabilities of ± 2 micron
- MEMS S&A Device is fully assembled and functional coming out of fab process
- MEMS S&A Device is then assembled into a completed fuze using proven micro-dispensing and pick-and-place manufacturing technologies

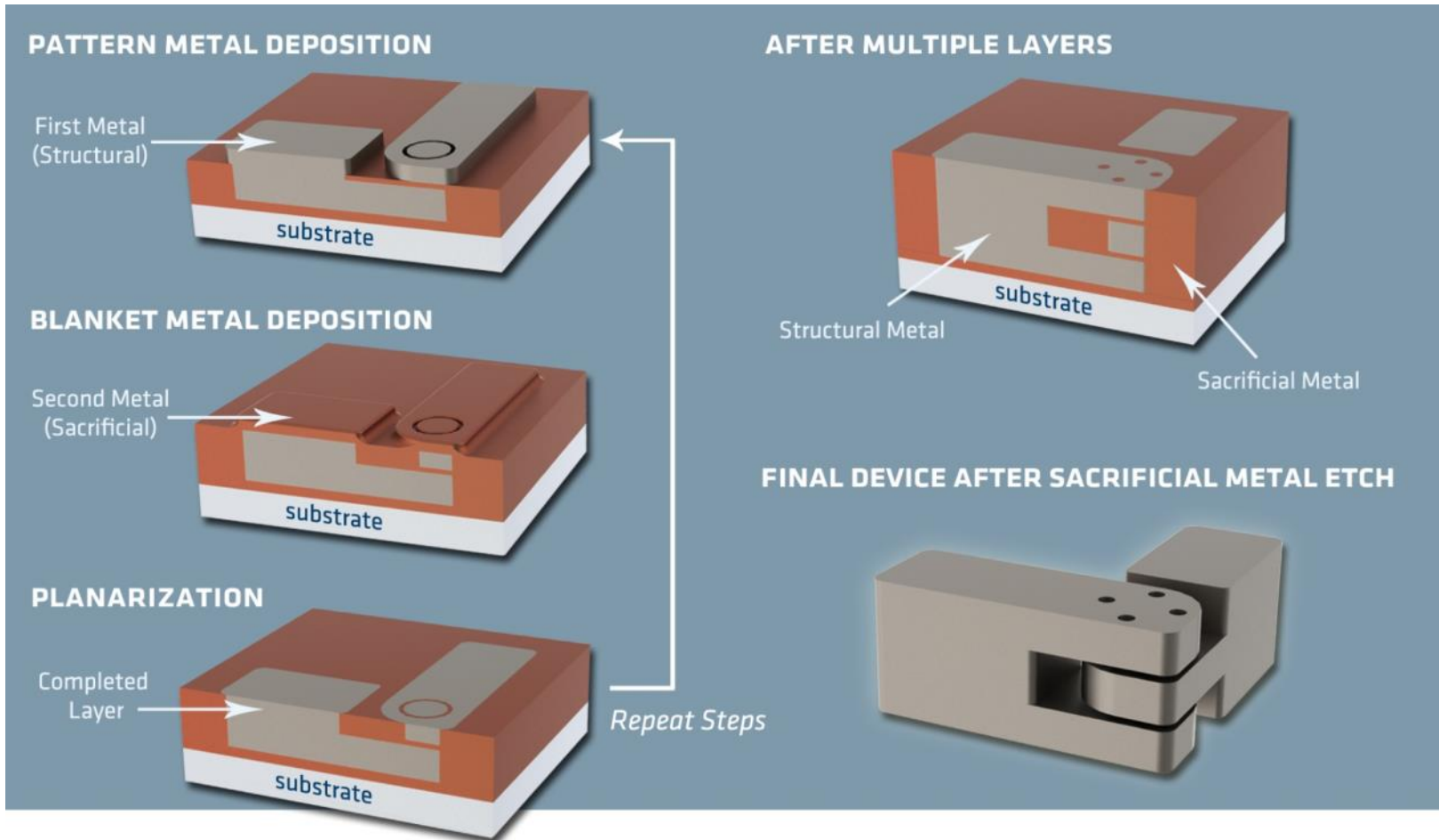


Kaman MEMS Safe and Arm Device



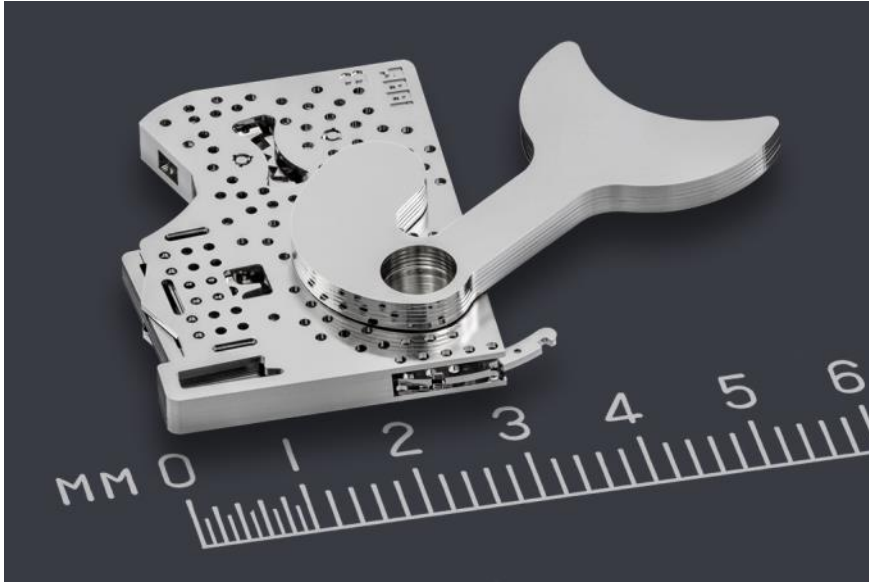
Kaman MEMS Based Fuze

Metal MEMS: How They Are Made

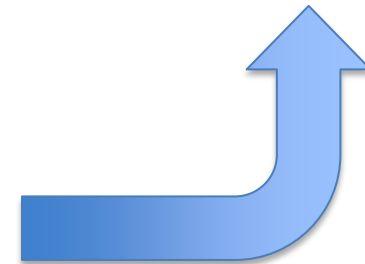
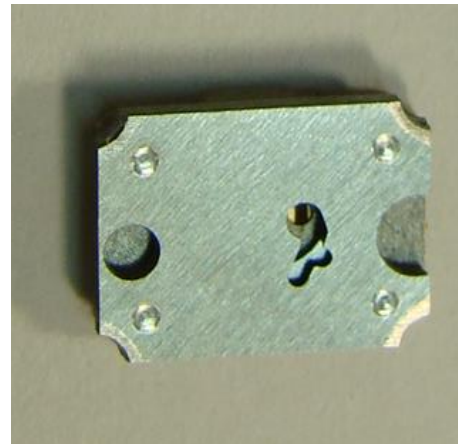
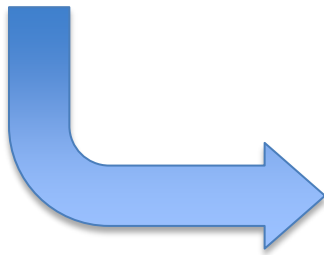
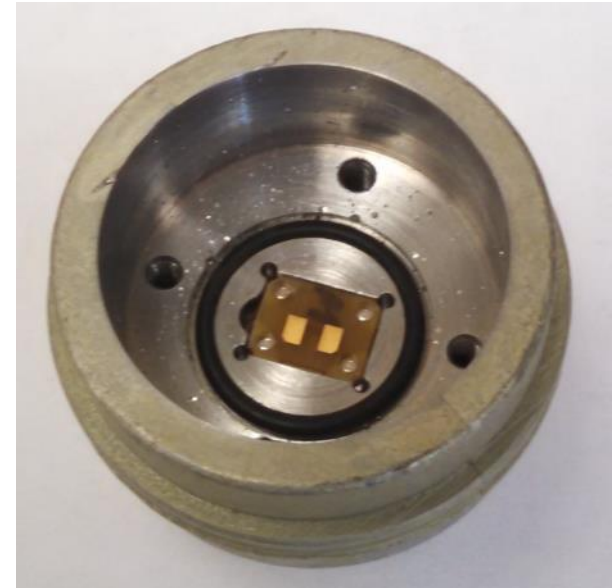


Company Private

Kaman MEMS Safe and Arm Device

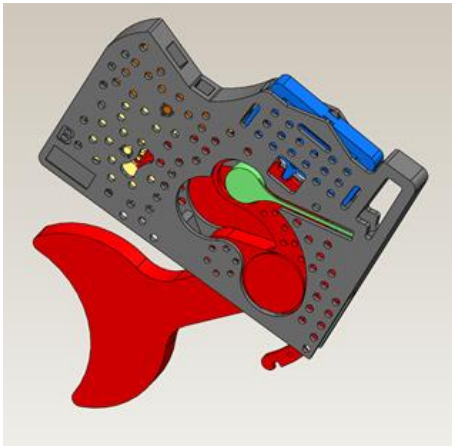


MEMS Fuze Installed in a 40mm Munition

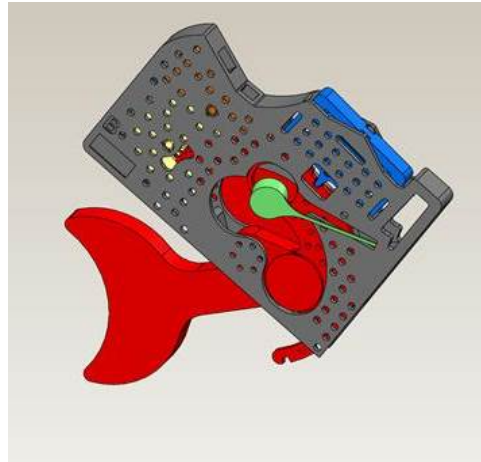


MEMS Fuze Assembly

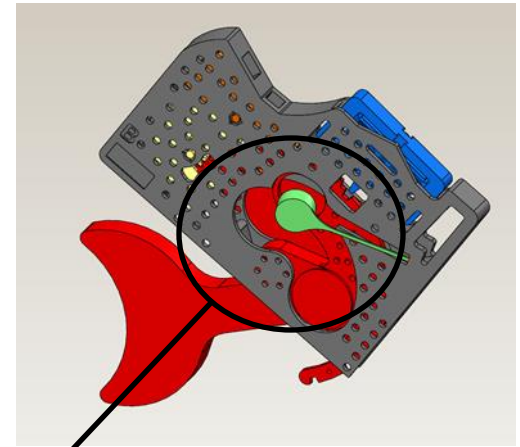
Kaman MEMS Design- Arming Environments



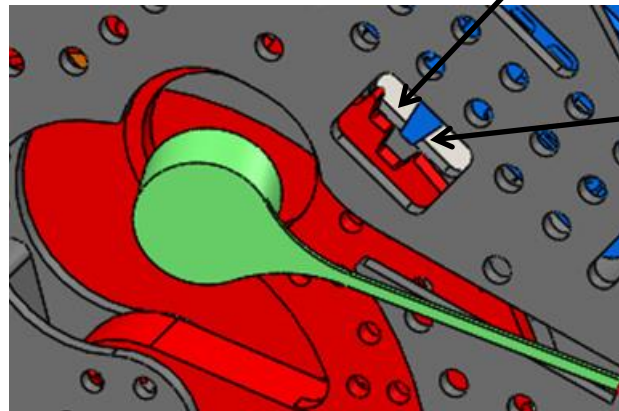
Safe Pre-launch



Set-back lock removed
as round is fired

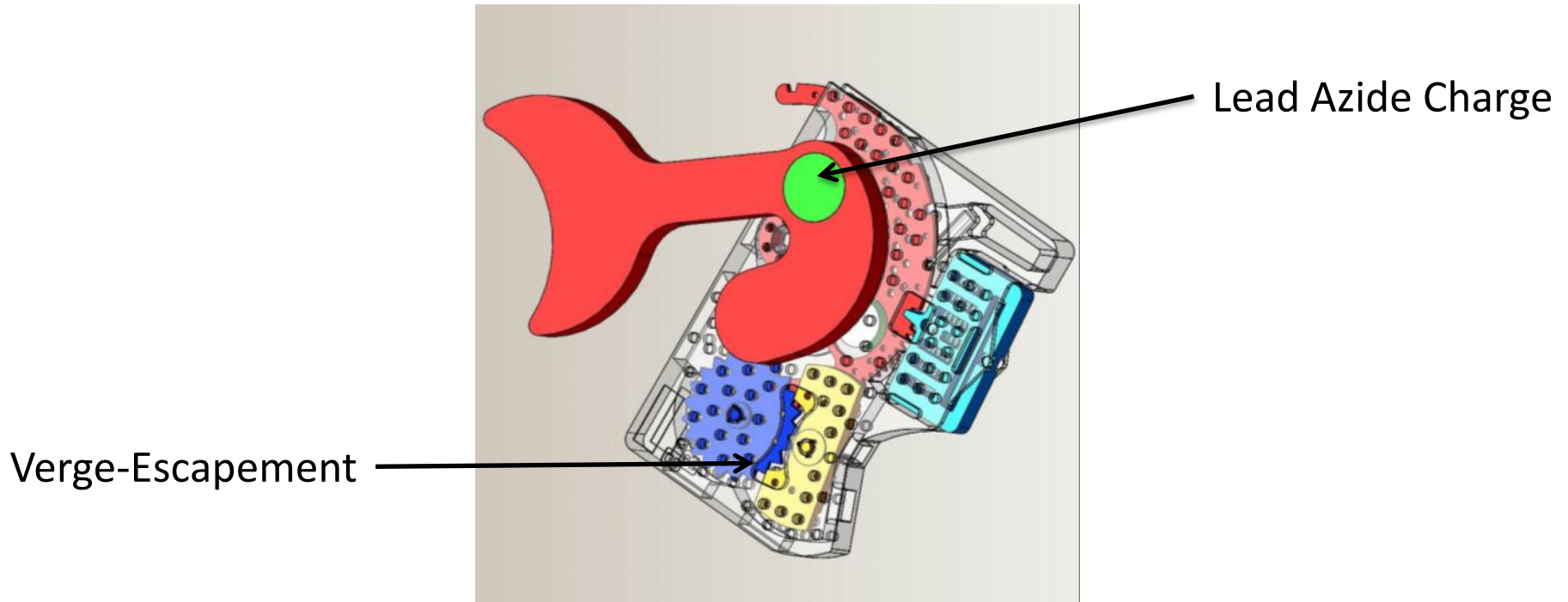


Spin lock removed
as round spins



Note lock tab
disengaged from gear notch

Kaman MEMS Design-Arming Timing Control

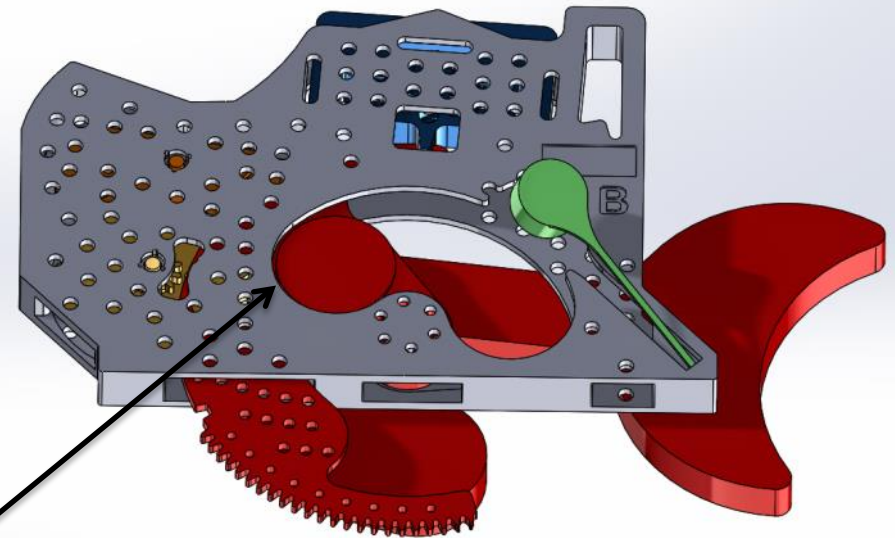
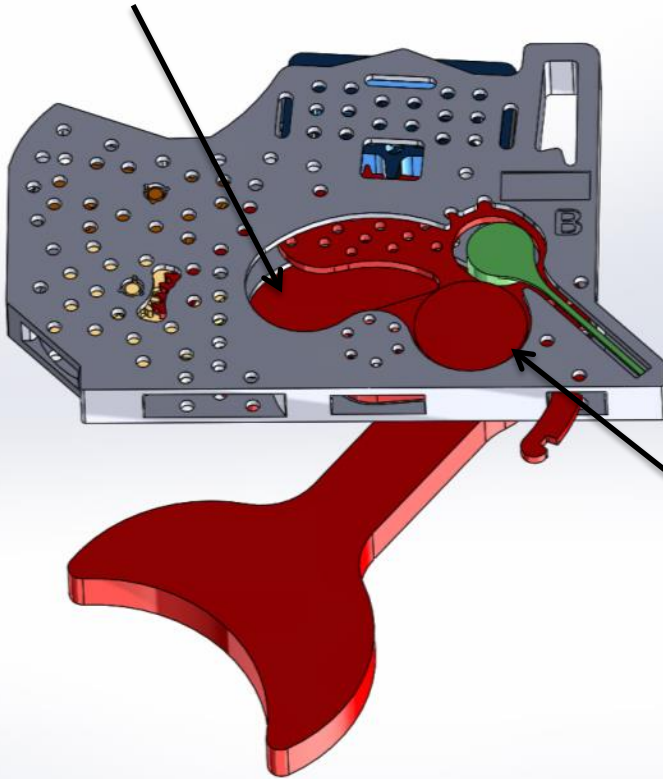


- Verge-escapement manages safe-separation timing
 - Tune-able timing for different ballistic characteristics
 - Timing is dependent on spin rate, number of teeth in verge-escapement, location of the center of rotation, mass of swing arm, length of swing arm

Kaman MEMS S&A In Safe Position

Kaman MEMS S&A In Armed Position

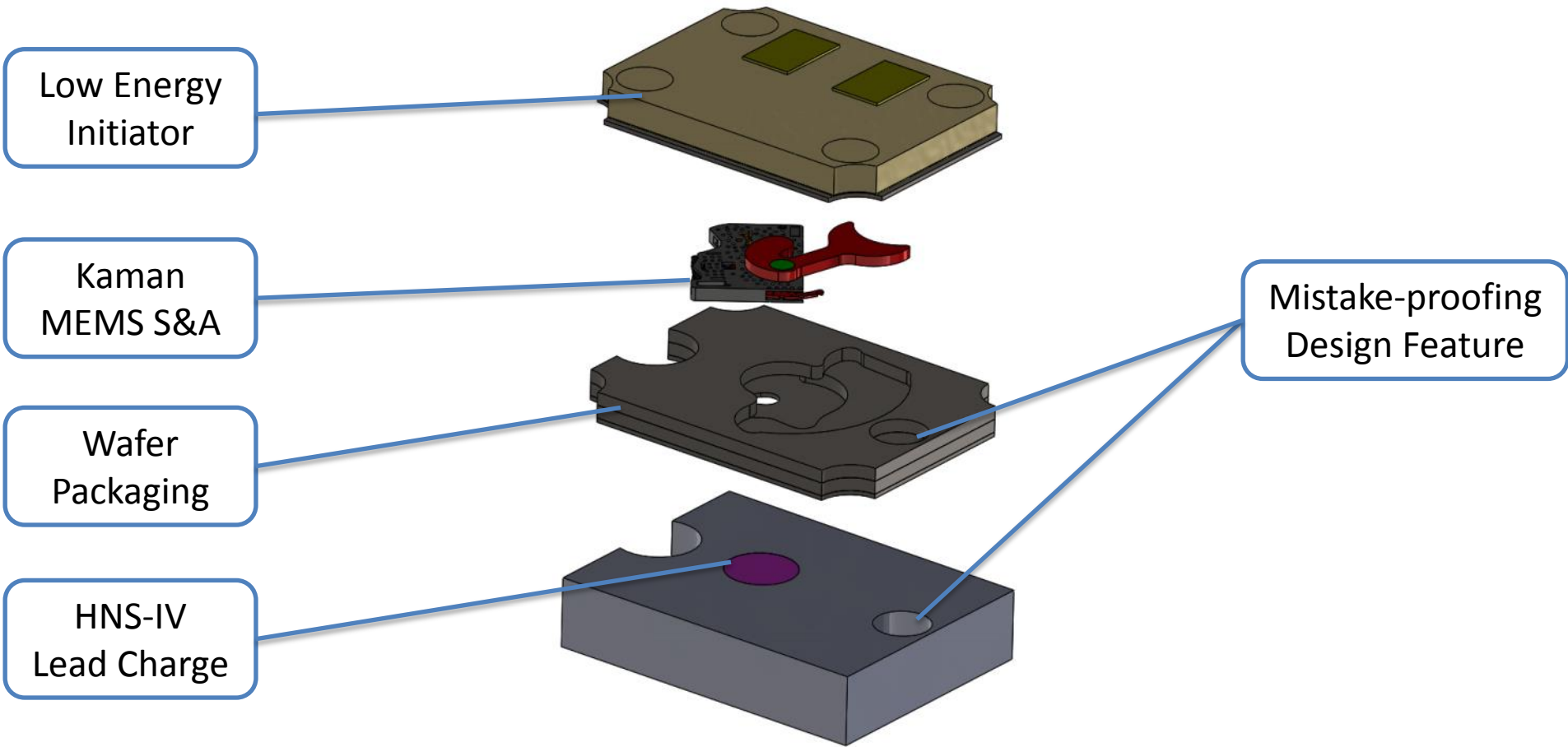
Solid shutter between
ignition and lead charges



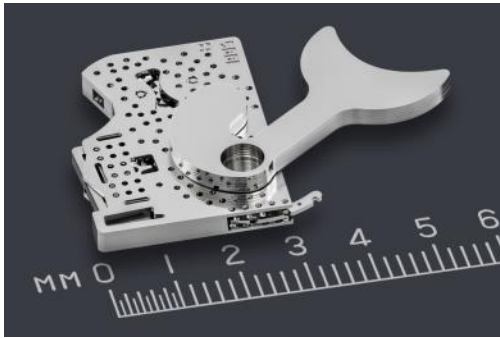
Lead Azide
Charge Cup

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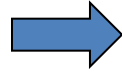
Packaged MEMS Fuze Assembly



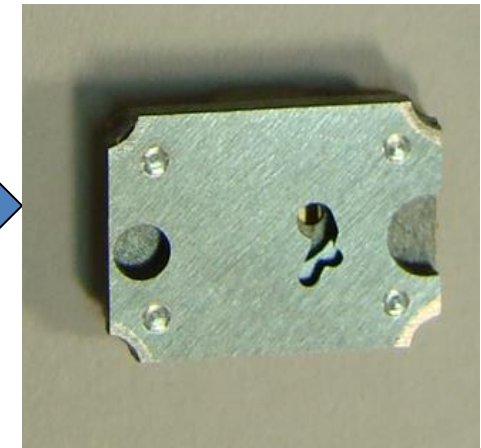
**Strong Focus on Design For
Manufacturability/Assembly (DFMA)**



Kaman MEMS S&A



Assembled on Wafer Level

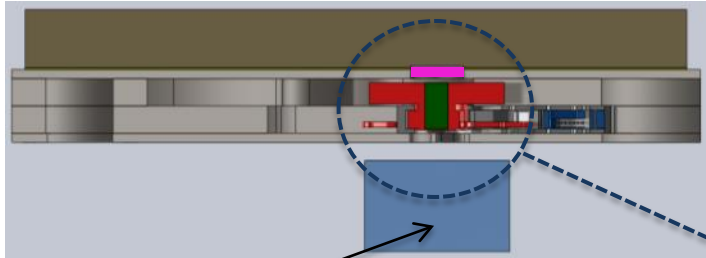


Diced into Individual Fuzes

- Fuzes fabricated on a wafer level laminate fabrication and separated after assembly
 - Utilize semi-automated processes to reduce workmanship centric manufacturing that greatly improves quality
 - Loading occurs with micro-dispensing of slurry based energetics for the primary explosives
 - Assembly is laser welded together
 - Provides path to meet high volume production as well as aggressive cost targets

Kaman MEMS Fire-Train

Fire Train Cross Section

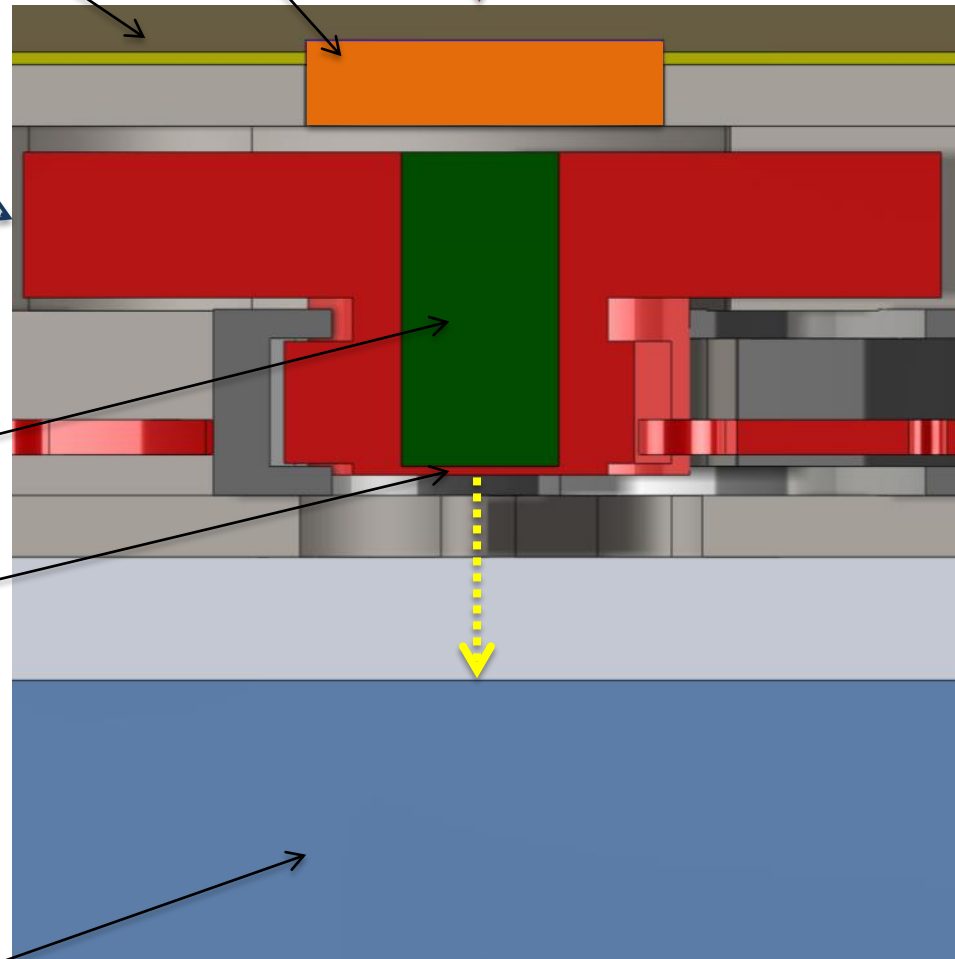


HNS-IV Pellet

Initiator Board

Lead Styphnate

Electrical
Signal



Lead
Azide

Flyer

HNS-IV Pellet

High Explosive

Company Private

- The Fire Train consists of three (3) major components

- The ignition board

- Thin film bridge and spot charge of lead styphnate

- The MEMS based detonation charge

- A slurry loaded lead azide charge is moved in/out of line

- The lead charge

- An approved in-line explosive (HNS-IV) that will interface with the main charge of the warhead

- Modelling of performance properties has been validated through test
- The MEMS was successfully tested as subsystems in the lab environment
 - Spin testing to verify unlock as well as timing variation
 - Set-back lock test to verify go/no-go level
 - Vibration and shock testing to demonstrate arming does not occur and the fuze remains safe and operational
 - Fire train DOE completed, including partial arm steps to confirm no-fire until >95% armed
- Live-fire gun testing completed
 - Rounds fired in 40mm low-velocity gun tests
 - Fuze demonstrated to successfully arm and fire

**40mm MEMS Fuze Design
Demonstrated to TRL-6**

Kaman MEMS Successfully Tested in Live-Fire Rounds

40mm Low Velocity Environment

- MIL-STD 1316E Compliant
 - Out-of-line design
- Setback:
 - ~2,000 Gs set-back
- Spin:
 - > 3,000 RPM
- Arming Delay
 - 80 ms
- Initiation energy
 - 300uJ



Example Application with Kaman MEMS Fuze

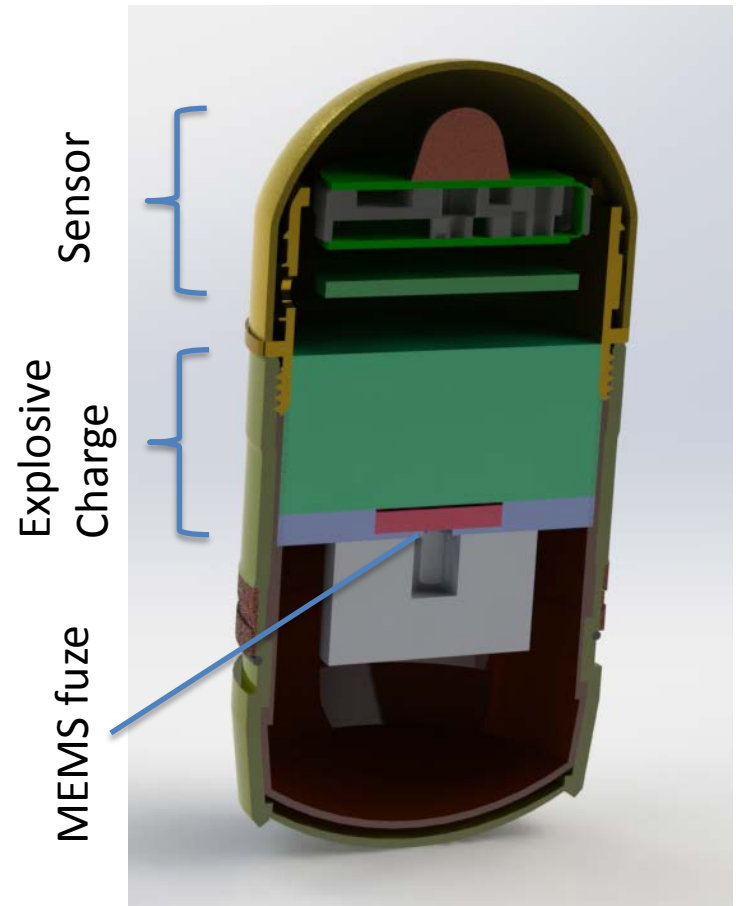
Enabling new capability

Reduced size frees-up space for enhanced capabilities such as *stand off detonation*.

- Proximity sensor
- Power source
- Miniature fuze
- Usable for munitions down to 25mm
- Additional Explosive Charge

Other potential benefits:

- UXO reliability through redundancy
- Integrating HE into smaller rounds



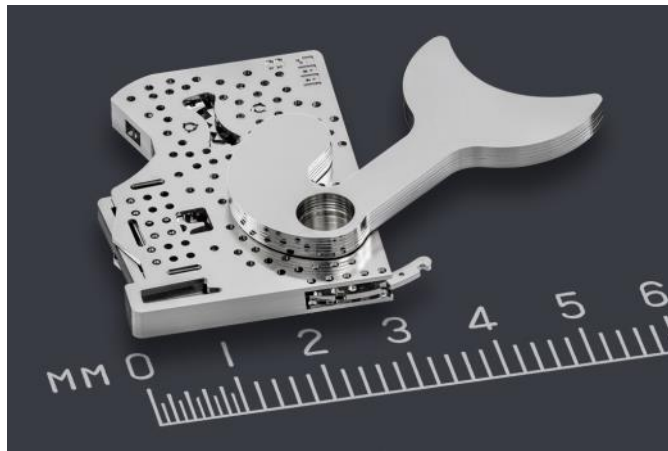
Concept of a 40mm stand-off capable round

Kaman MEMS Family of Designs Nearing TRL-6

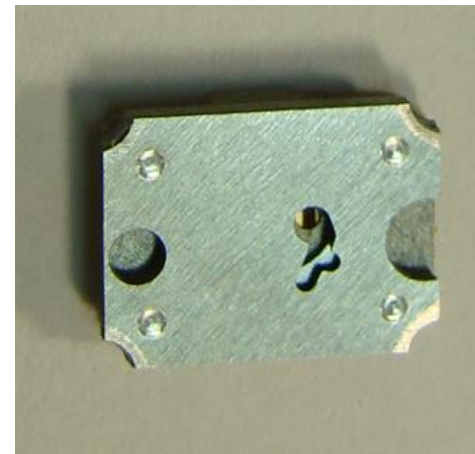
- Non-electric ignition design that utilized impact event
 - Stab primer integrated into MEMS
 - Piezoelectric energy generation to initiate the fire train
- Command-to-arm
 - No verge-escapement
 - Use for non-spinning, low-spin, or unique applications
 - Integrated with additional sensors or electronic circuitry
 - Safety locks can be mechanical, electrical, or a combination of both

Kaman MEMS Fuze Technology Conclusion

- The Kaman MEMS Fuze has been demonstrated to TRL-6 in a 40mm low-velocity round
- Kaman's approach has been to focus on Design For Manufacturability/Assembly (DFMA) as well as Design To Unit Production Cost (DTUPC) to ensure the design meets the quality and cost targets for future weapon systems
- Kaman's MEMS Fuzes make room for enabling technology in existing and next-generation weapon platforms

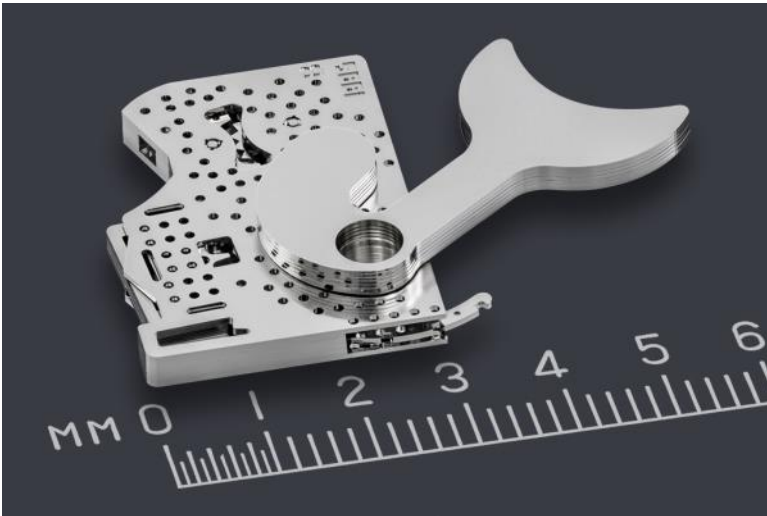


Kaman MEMS Safe and Arm Device

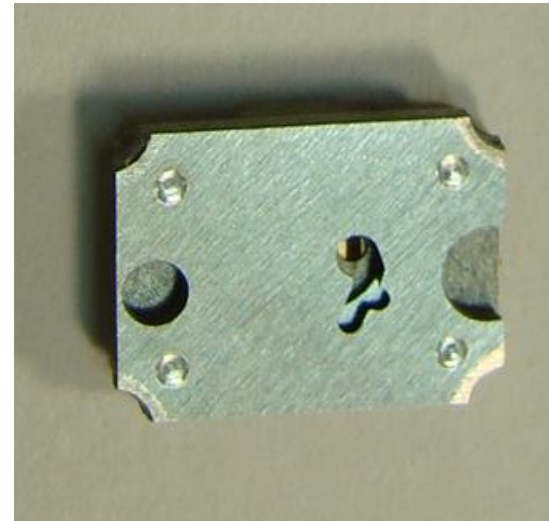


Kaman MEMS Based Fuze

Questions?



Kaman MEMS Safe and Arm Device



Kaman MEMS Based Fuze