Fully Resettable MEMS Safe/Arm with Lock and Slider Position Feedback

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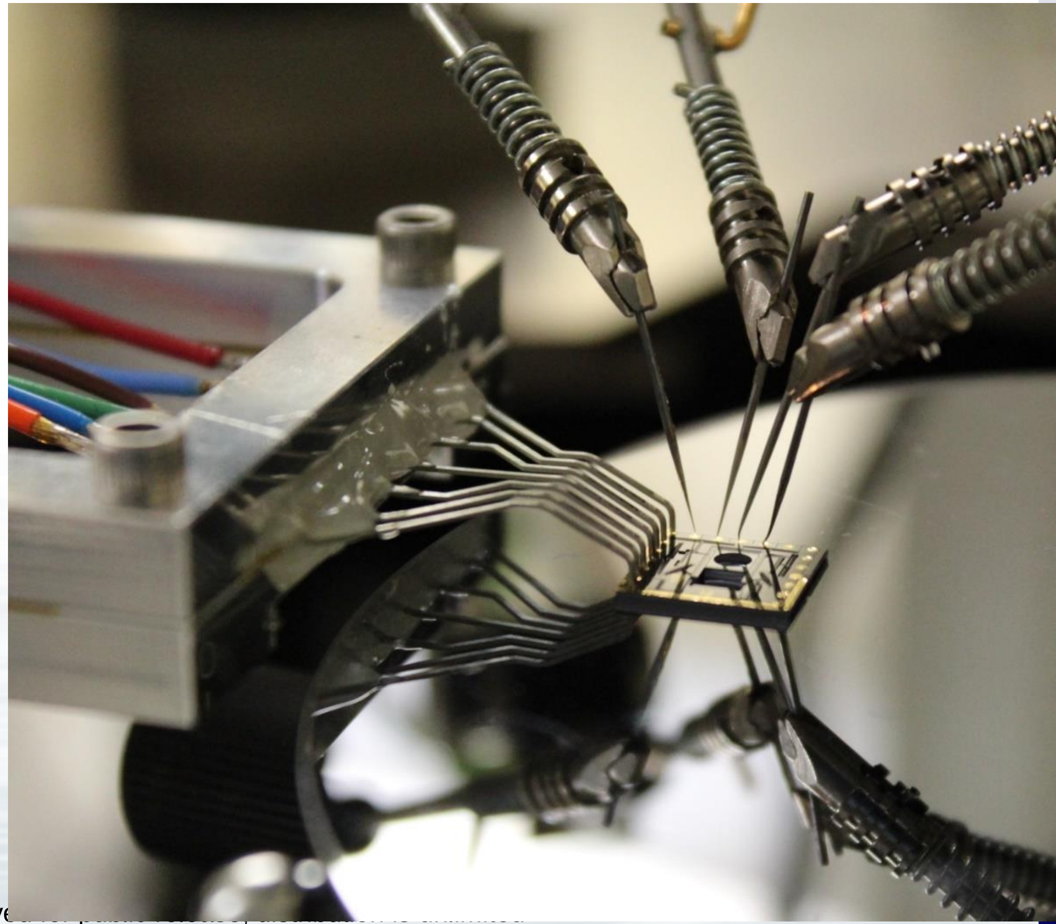
Outline

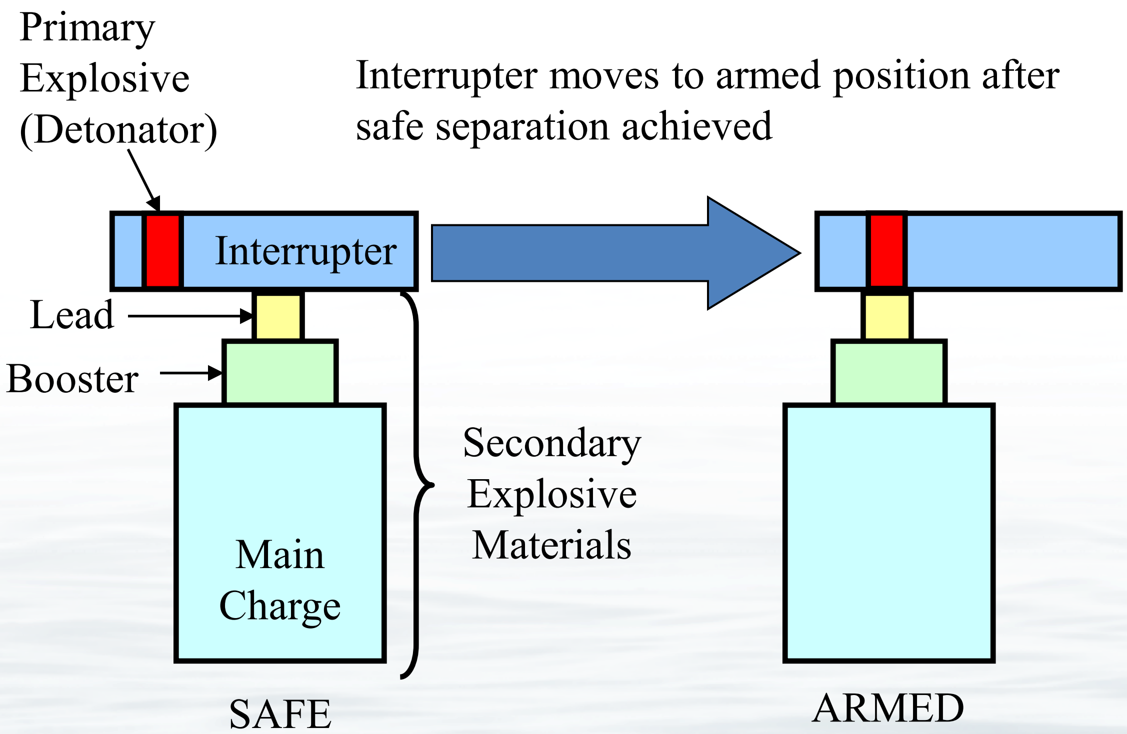
- Generic Safe/Arm Architecture
- MEMS and Fuzing Background: Why MEMS?
- MEMS vs ESAD
- Detailed MEMS Design
- Component Position Monitoring
- Summary



Safe/Arm Safety Architecture Background

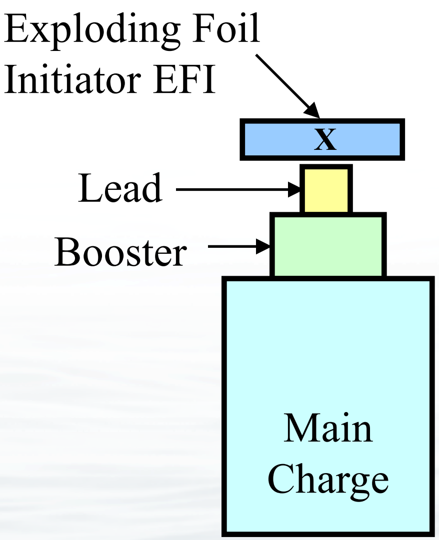
Interrupted

- "Out-of-line"
- Electro-mechanical
- Pure mechanical



Non-Interrupted

- "In-line"
- Electronic Safe Arm Device (ESAD)
- High voltage system



Electronic based system, no moving parts required

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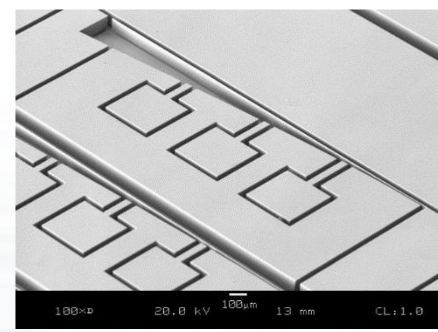
MEMS: Why Use Them?

- New or more accurate function
  - Small size creates new possibilities
    - Features size ~1 micron
    - Embedded sensing
    - Complex mechanics
  - Low power requirements
    - Energy harvesting
    - RFID tags/embedded sensors
- Cost reduction
  - Batch fabrication enjoy benefits of economy of scale
  - Leverage IC foundries…infrastructure in place
- Reliability
  - Silicon has attractive mechanical properties (compared to conventional engineering materials)
- Assembly-free complex mechanisms

Sandia Dust Mite

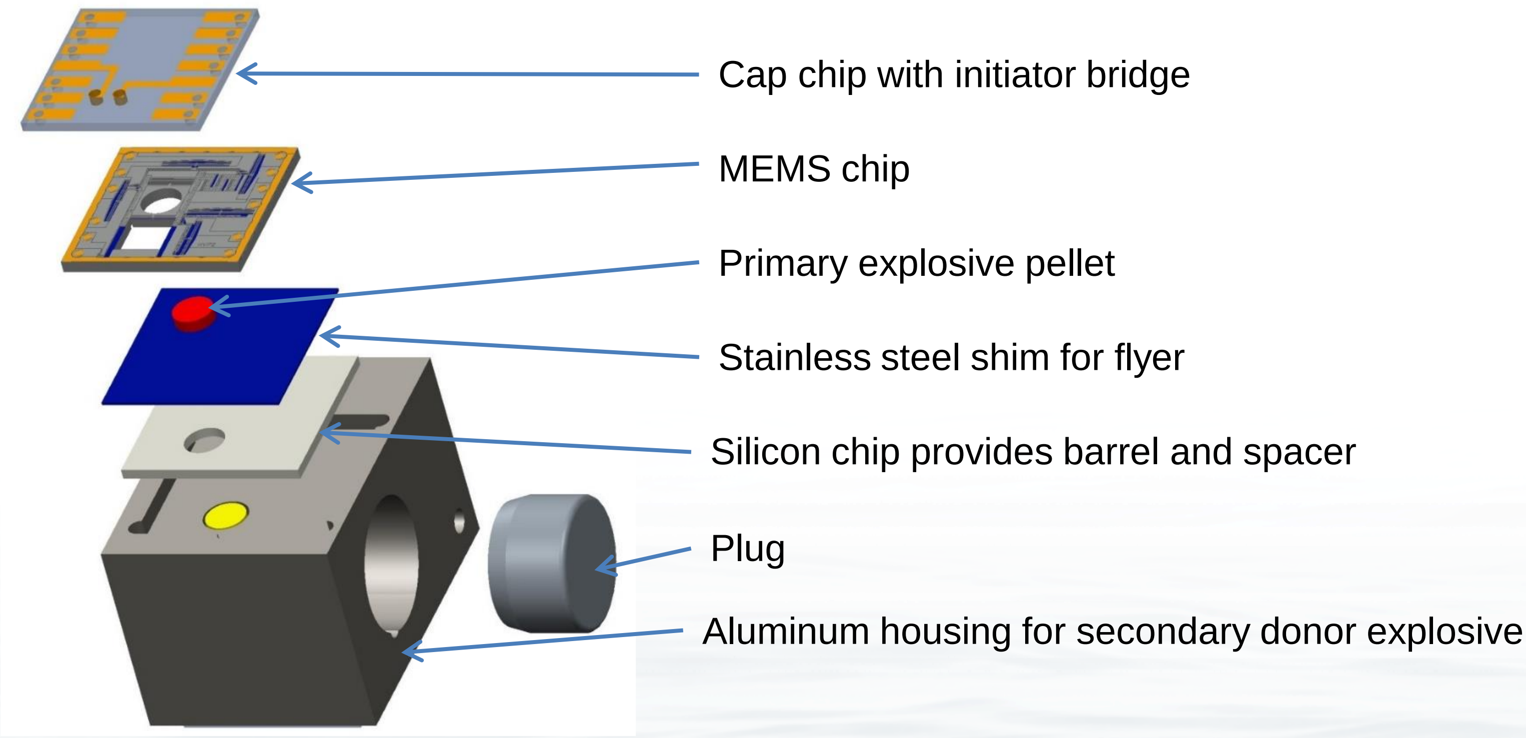


NSWC curved electrode actuator

Fuzing: MEMS vs ESAD

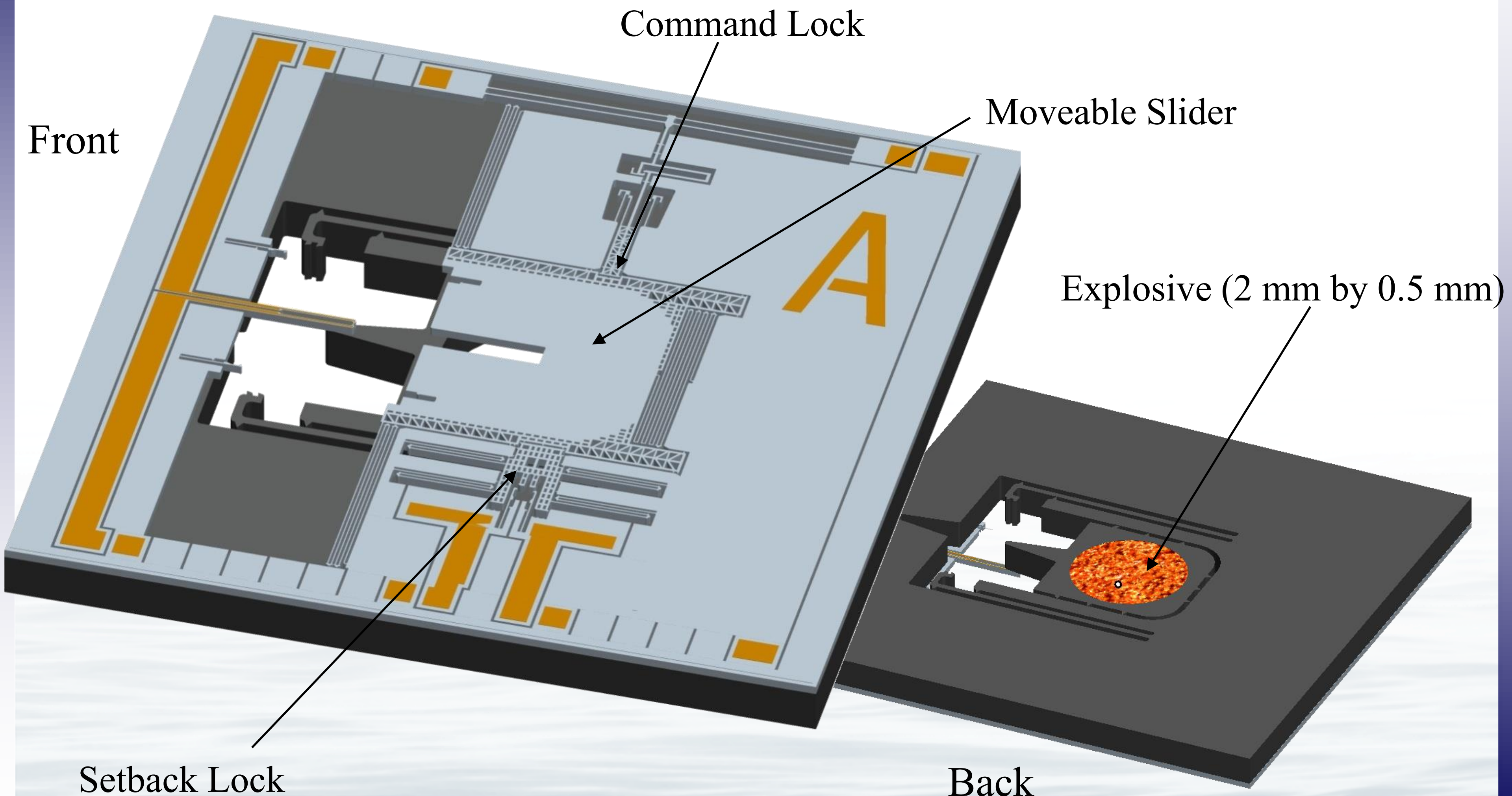
- Size: MEMS
  - A MEMS fuze design is typically smaller, especially in less complex systems (smaller, simpler munitions). As complexity is added, the differences in safe/arm technology contributes less to overall fuze size.
- Reliability: ESAD
  - ESADs have more data in this area, but MEMS also have the potential for high reliability
- Technical Maturity: ESAD
  - ESADs are fielded, while MEMS fuzes are in the prototyping stage
- Cost: MEMS
  - At low volumes, the cost is similar (<1,000 units per year). At higher volumes, MEMS has the potential to be less expensive.
- Power: MEMS
  - MEMS fuzes are typically lower power, especially if an inertial arming environment is available (such as spin). In addition, the MEMS fuze can hold the armed state without drawing any power. No high voltage generation is needed for MEMS.

Typical MEMS Safe/Arm Assembly

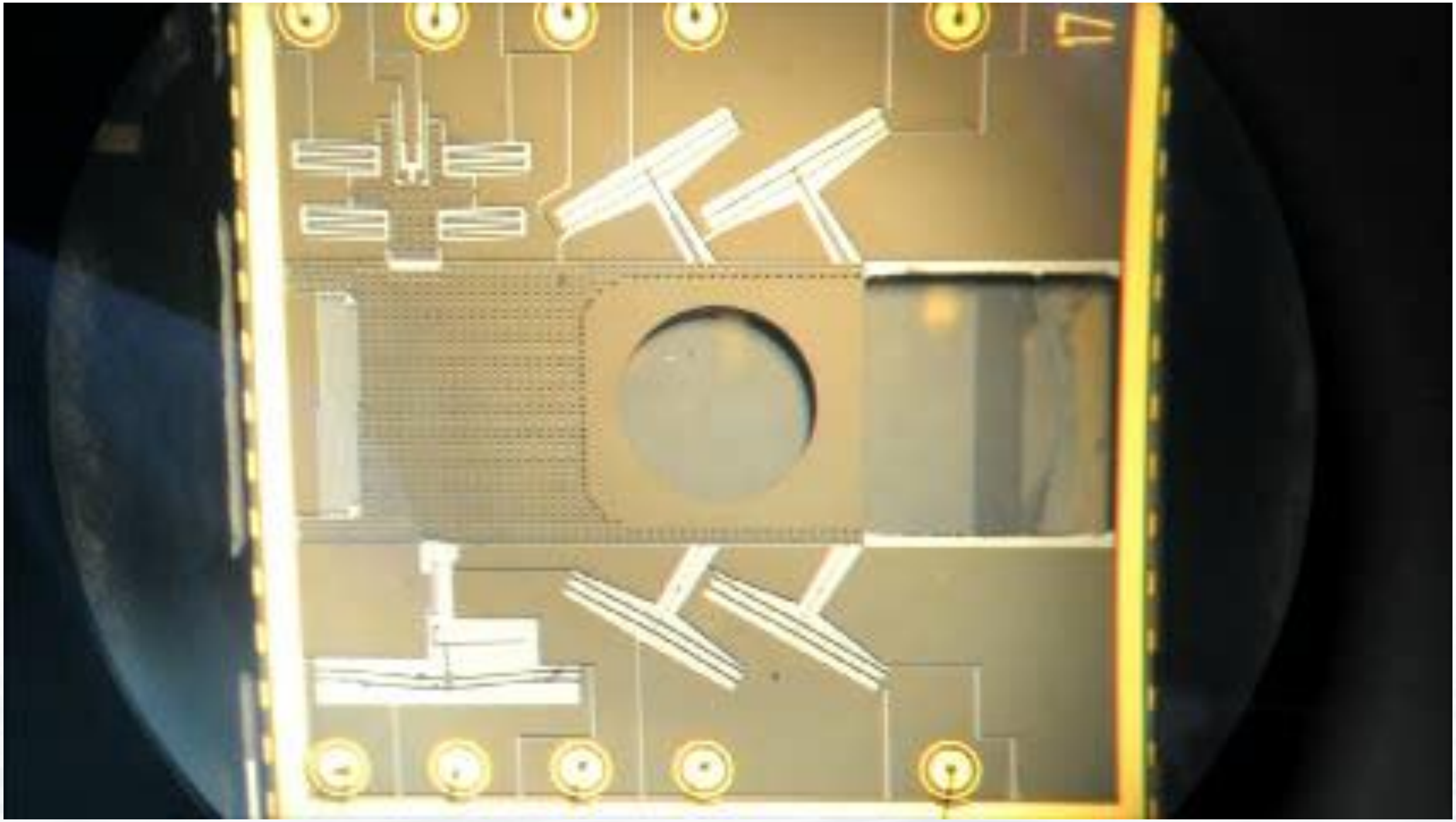


MEMS with Explosives

Micro-Electromechanical Safe Arm Device: 9 x 9 mm



MEMS Command Arming in 40 ms



Resettable MEMS Fuze

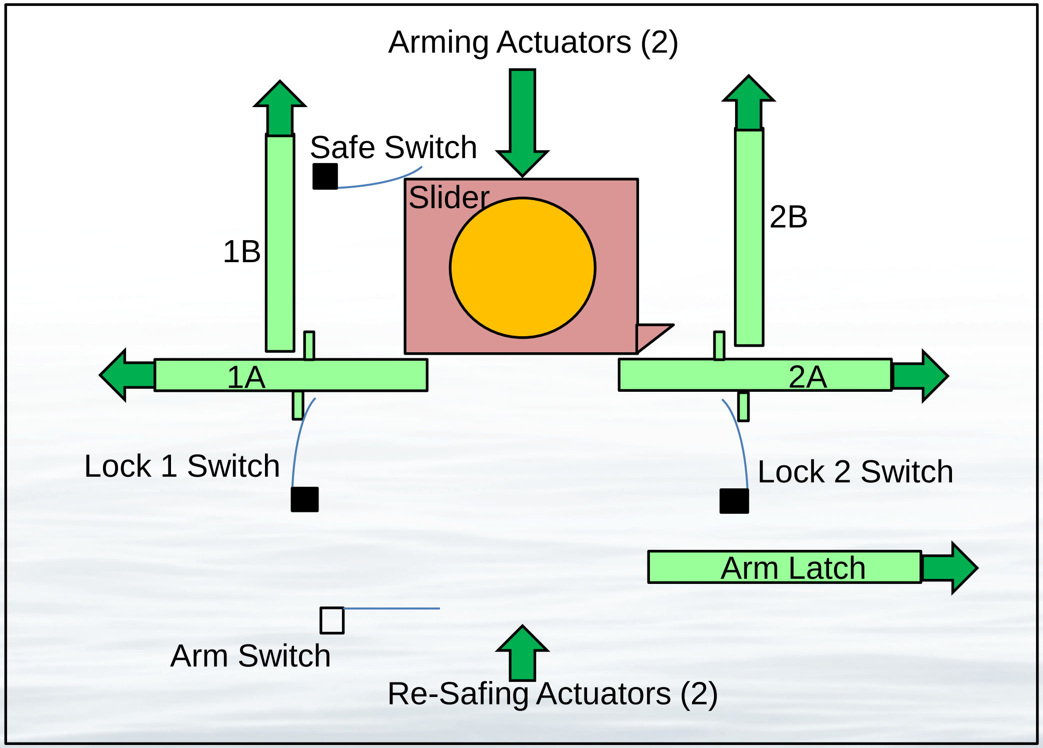
- Slider Locks (2)
  - Command actuated to unlock, latched in unlocked state with no power
  - Command actuated to lock, remain in locked state with no power
  - Each lock features a queryable switch that is closed in the lock state and open in the unlocked state
- Slider
  - Command actuated to arm; latches in armed position with no power
  - Command actuated to safe
  - Two switches on slider: one in safe position and one in armed position
- Safe/Arm Indication
  - Safe State
    - Both lock switches are closed
    - Slider safe position switch closed
    - Slider arm position switch open
  - Arm State
    - Both lock switches are open
    - Slider safe position switch open
    - Slider arm position switch closed
    - <u>OR</u> any switch state not matching Safe State conditions (unsafe state)

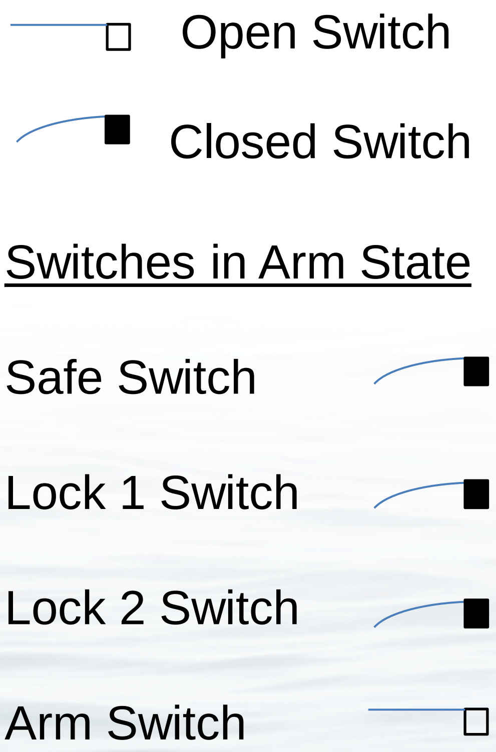
Advantages of Component Position Monitoring

- Enhances safety by providing information on status of device
  - Feedback from lock switches to show if locks are in place or not
  - Feedback from safe position switch to show position of slider
- Enhances reliability of device
  - Opening and closure of lock switches to show lock function
  - Closure of arm switch to properly time initiation of explosive
- Provide additional capability
  - Allow arm-disarm function testing prior to final assembly with safety assurance from feedback
  - Allow arm-disarm if required by system

Resettable Fuze Schematic: Safe

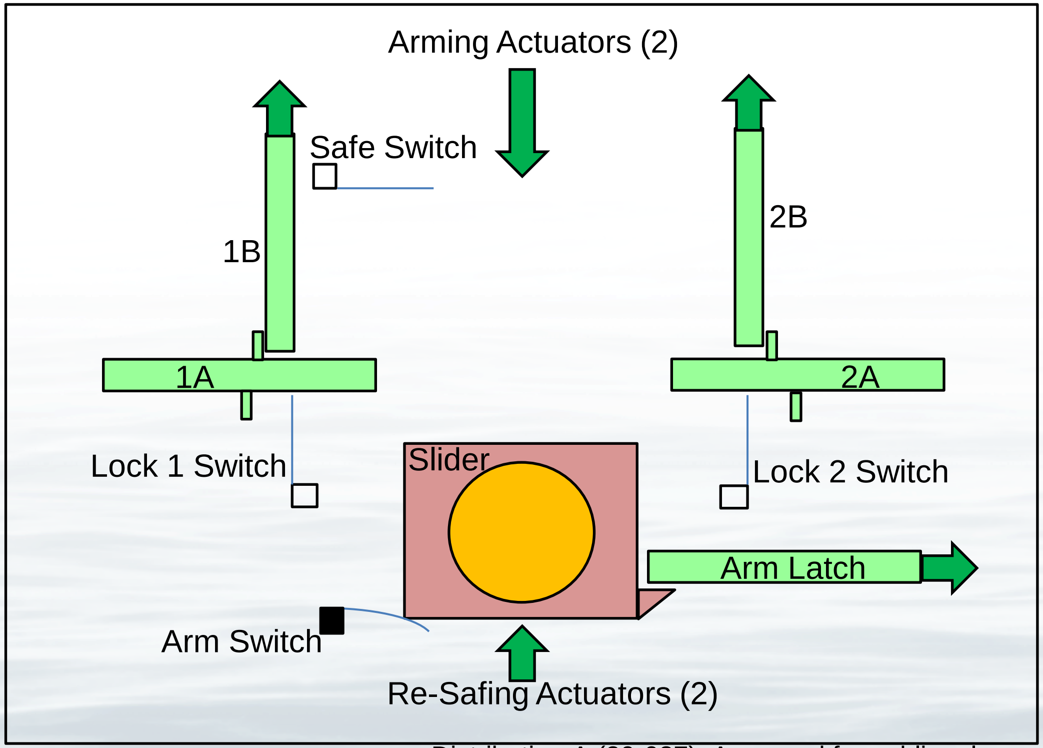
- Total # of actuators: 9
  - Two actuators to remove locks
  - Two actuators to hold locks
  - Two actuators to arm
  - One actuator to unlatch slider
  - Two actuators to disarm



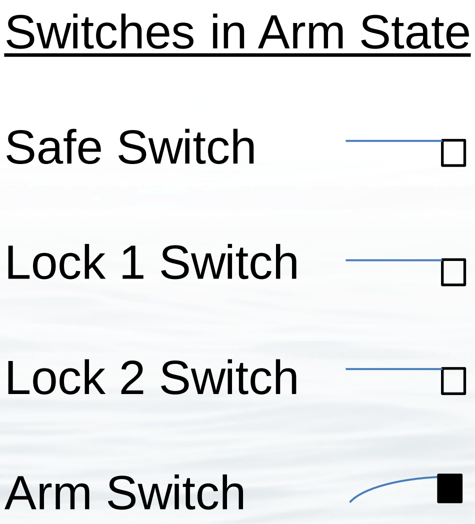


Resettable Fuze Schematic: Armed

- Low power draw
  - Single pulse actuators, few hundred millijoules for each pulse
    - Lock actuators 1A, 1B, 2A, 2B, and Arm Latch
  - Cycled actuators, less than half a joule for complete slider travel
    - Arming Actuators and Re-Safing Actuators



Once armed, no power is drawn



Resettable Fuze Status

- Chip design and fabrication complete; prototype MEMS chips functioning well in laboratory
- Over 500 safe/arm cycles and counting on a single demonstration chip (unlock, arm, re-safe, re-lock)
- Lock and safe switches tested to survive and function for more than 100 cycles
- Latest arm switch design currently in fabrication; expected to function over 100 cycles
- Future work: insertion into prototype fuzes and field testing

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Summary

- MEMS fuze design provides needed and new capability
  - Capability to reset as needed by mission/system requirements
  - Capable of numerous safe-arm cycles
  - Provides feedback of safe/arm status when queried
  - Low power draw
    - Little power needed to actuate locks
    - Little power needed to move slider
    - No power draw in armed state