







# MEMS Retard & Impact Sensors

Principal: Walter Maurer, NAWCWD China Lake

Contributors:

Dr. Daniel Jean, NSWC Indian Head
Ryan Knight, ARDEC

# Objective

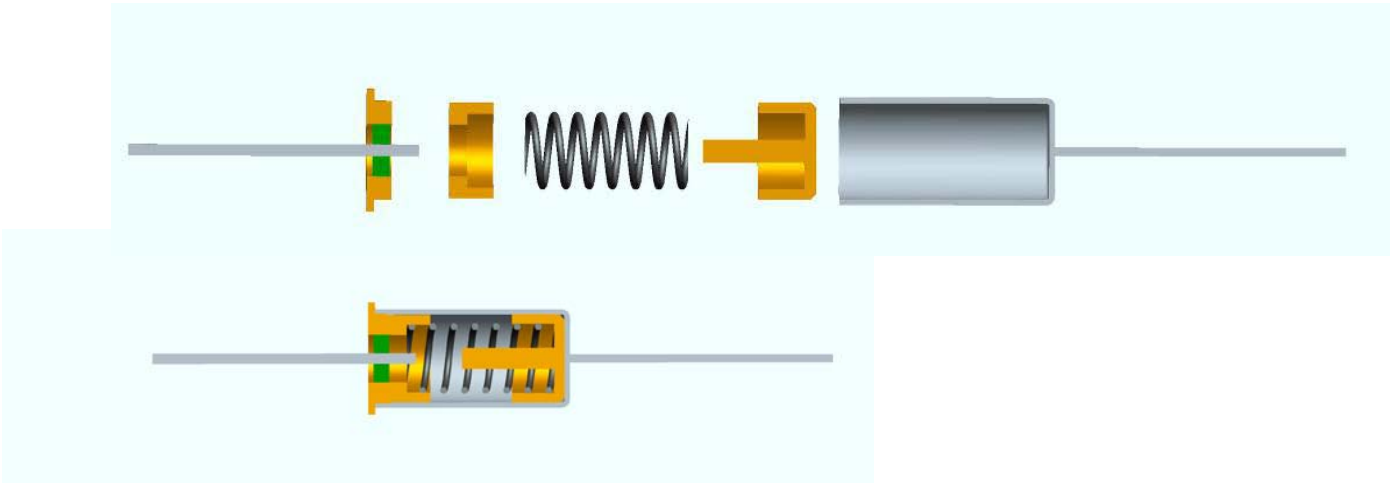
- ***Exploit existing MEMS microfabrication and packaging technologies to realize DoD retard and impact sensors with <u>improved performance</u>:***
  - ***precision***
  - ***reliability***
  - ***producibility***
  - ***cost effectiveness***

# Potential Payoff

- ***Improved G-sensor performance for existing & future fuzes including:***
  - ***FMU-139 (impact sensor; retard sensor)***
  - ***FMU-143 (impact sensor)***
  - ***High Reliability Fuze (impact sensor)***
  - ***Hardened freefall weapon fuzing applications***

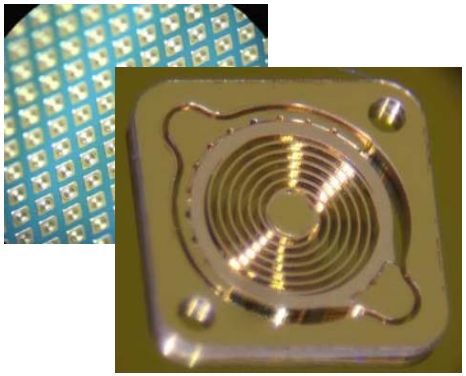
# Background

- ***Traditional coilspring-mass technology:***
  - ***Wider variability in performance than MEMS***
    - *wire & coil dimensional tolerances*
    - *coil winding stresses & annealing*
  - ***Difficult to <u>precisely</u> sense low G's with "macro world" springs***

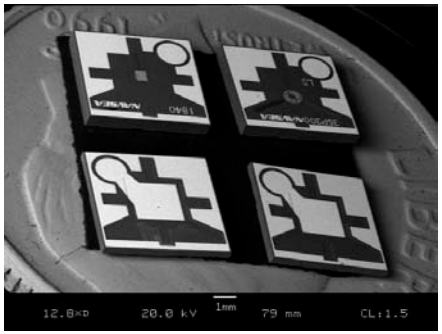


# Background (cont.)

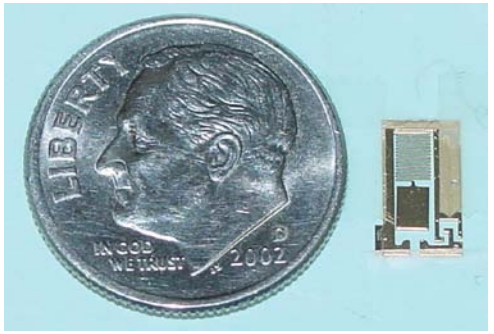
- ***Newer MEMS-technology appears well-suited for making improved low-G sensors per DoD exploratory work to date:***
  - ***ARDEC: metal G-sensors and packaging***
  - ***NSWCIH: silicon G-sensors and packaging***
  - ***NAWCWD: precision-electroplated G-sensors***



*Courtesy of ARDEC*



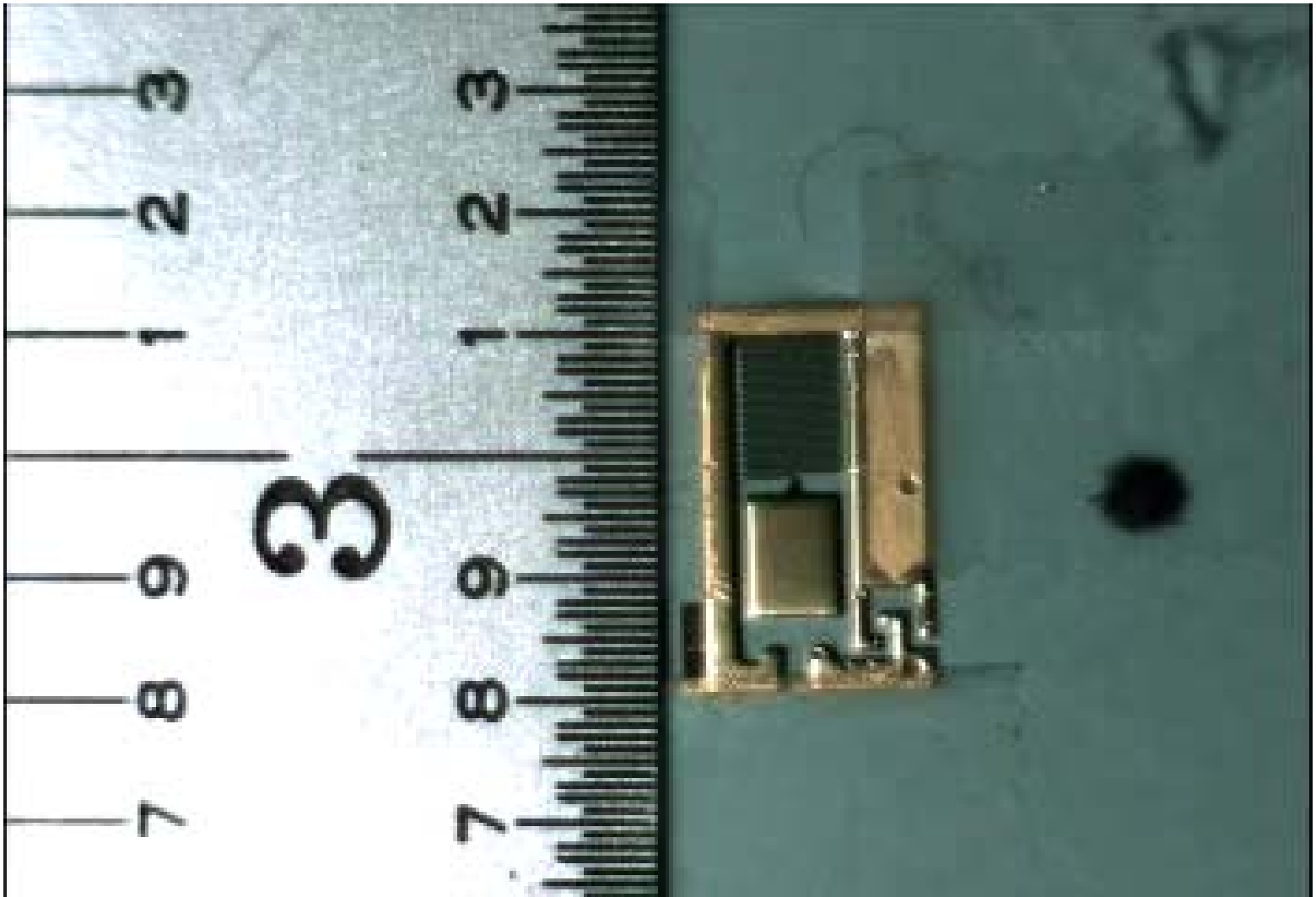
*Courtesy of NSWCIH*



*NAWCWD 5G Sensor (2005)*

# Background (cont.)

## Centrifuge Test of Low-G Sensor in 1G Increments



# Technical Approach

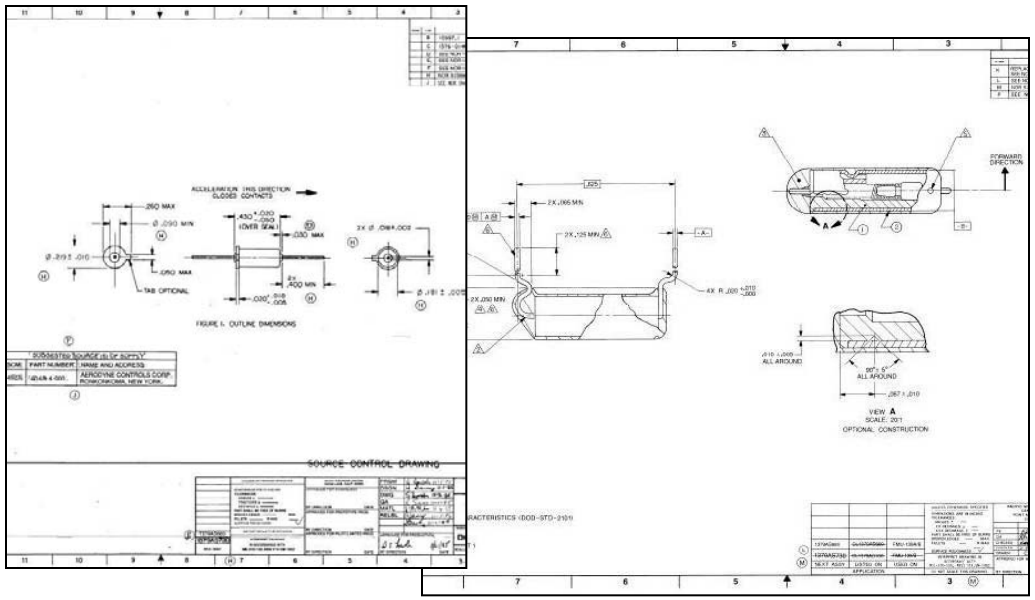
- ***Modify existing NSWC and ARDEC sensor designs to duplicate performance of currently-fielded non-MEMS sensors***
  - ***low-G impact sensors (<100G)***
  - ***very low-G retard sensors (<5G)***
- ***Fabrication***
  - ***ARL (NSWC sensors); HT-Micro (ARDEC sensors)***
- ***In-House Packaging & Testing***

# 1st-Year Progress



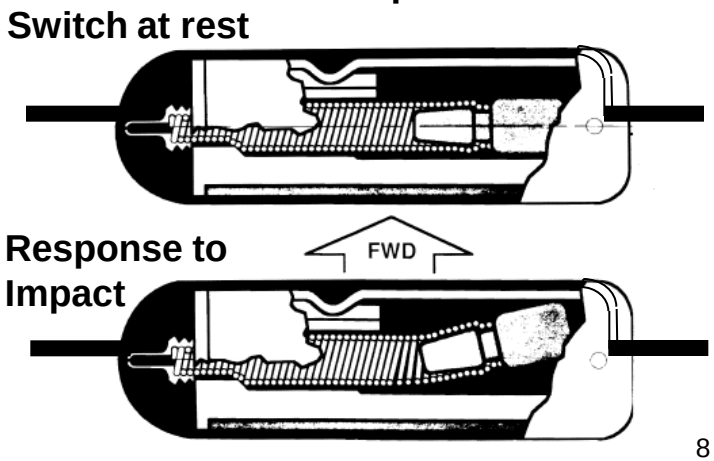
## ➢ *Requirements obtained for bomb fuze sensors*

- Retard sensor: 1.9G no-go, 2.3 all-go
- Impact sensor: 40G no-go, 80G all-go. Velocity change of 2 fps will cause closure.



Production Drawings of Retard Sensor (left) & Impact Switch

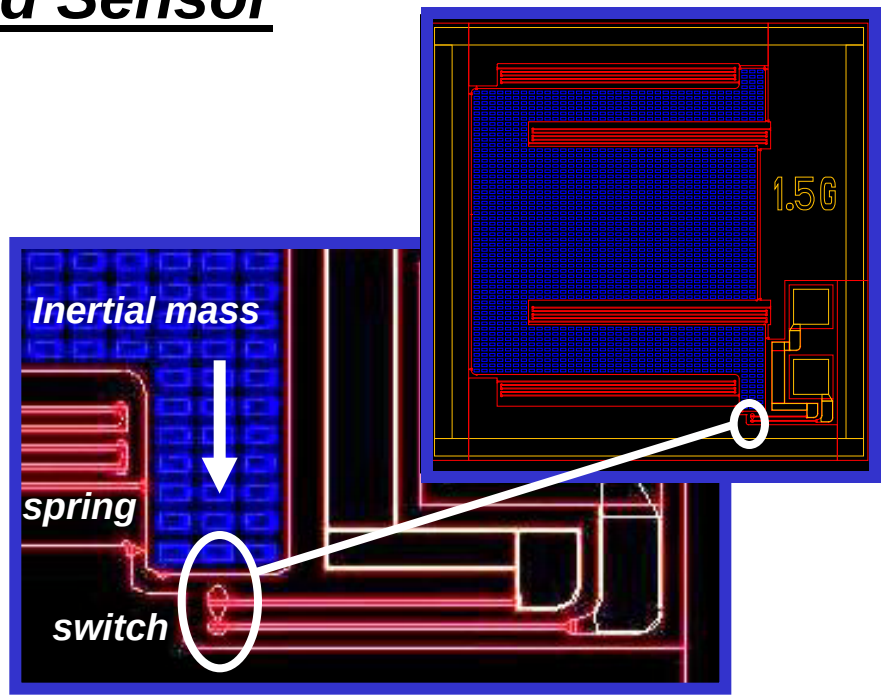
Impact Switch



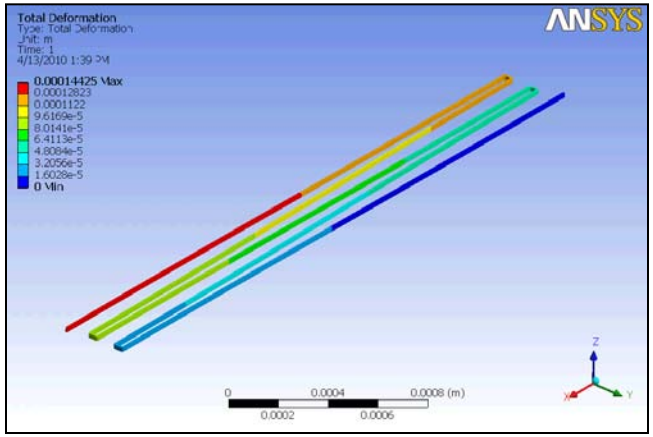
# 1st-Year Progress (cont.)

## NSWCIH Retard Sensor

- **Design layout completed**
  - Deep Reactive Ion Etching (DRIE)
  - Design variations: 1.5, 2.1, 3.0, 4.0, and 5.0 G
  - Unidirectional
  - In-plane contact switch
  - Chip size 5 x 5 mm



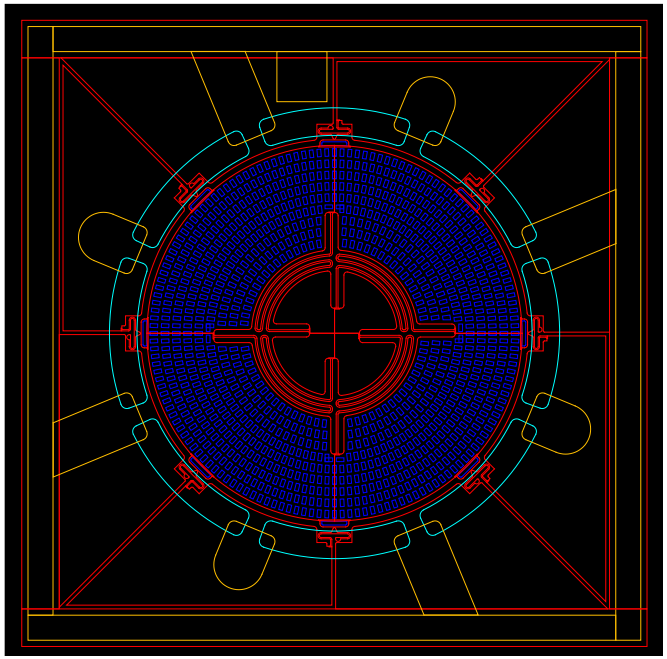

- **Simulation completed**
  - Spring deflection under a static load (k = 0.139 N/m)



# 1st-Year Progress (cont.)

## NSWCIH Impact Sensor

- ***Design layout completed***
  - Deep Reactive Ion Etching (DRIE)
  - Various closure levels to bracket target performance
  - Hemispherical contacts
    - 8 in-plane, 1 out-of-plane
  - Chip size 5 x 5 mm

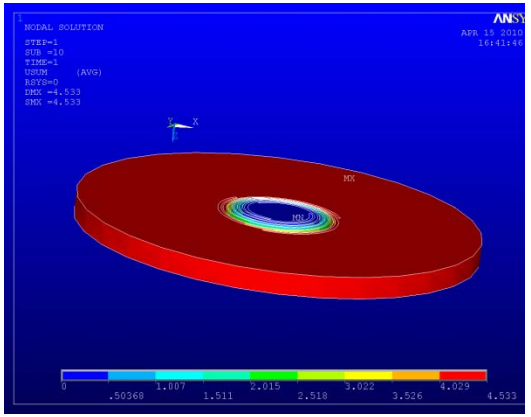


- ***Simulation nearly completed***
  - MATLAB-based dynamic modeling

# 1st-Year Progress (cont.)

## ARDEC Retard Sensor

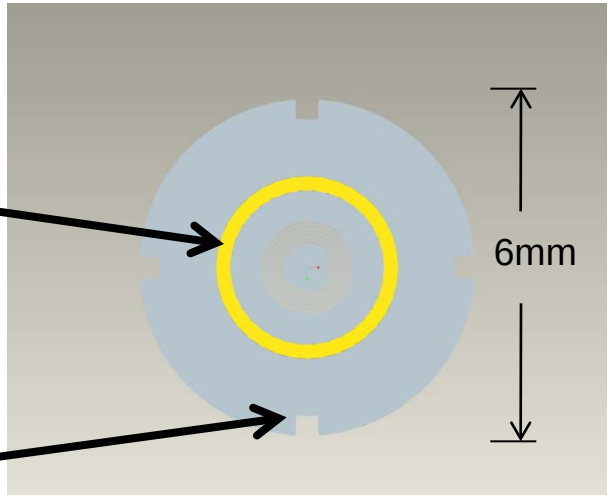
- ***Preliminary modeling completed***
  - Metal MEMS design to be made by htmicro
  - 2.1 G
  - Size ~ 6 x 6 x 1 mm




Preliminary FEA

Interior gold contact which only detects z-direction movements (will not detect rocking motion)

Anti-rotational features. Locks to keep proofmass from rotating

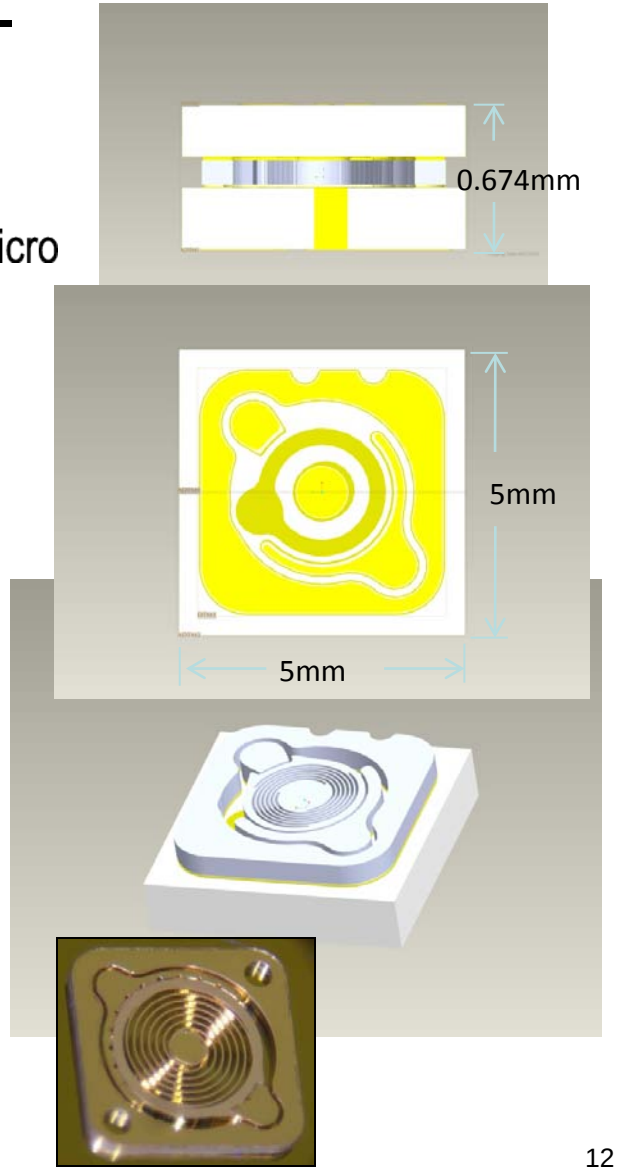



Preliminary ProE layout of MEMS 2.1G Retard Sensor

# 1st-Year Progress (cont.)

## ARDEC Impact Sensor

- ***Preliminary modeling completed***
  - Metal MEMS design to be made by htmicro
  - Size ~ 5 x 5 x 0.67 mm
  - Scaled version of successfully demonstrated 500G Impact Sensor
    - Over 100 data points collected with Mk19 40mm MEMS Integration fuze
    - Only two known failures
    - More data points to be collected in May 2010



# 1st-Year Progress (cont.)

## ARDEC Impact Sensor (cont.)

- ***Design Issues:***
  - Tends to make contact in a rocking/rolling mode (similar to contact that a spinning penny makes as its spinning dies down). Thus, squeeze-film air damping is not utilized very well.
  - This rocking motion will make contact under considerably lower inertial forces due to the moment created, thus affecting closure threshold.

# 1st-Year Progress (cont.)

## Other ARDEC Design Issues

- ***Sensitivity to short duration impulses***
  - increasing surface area will increase squeeze film and Couette damping, thus increasing sensor's g-seconds
  - Higher nitrogen pressure during packaging
- ***Contact sticking***
  - increase sputtered-gold contact's rhodium concentration
- ***Gap dimensions***
  - ensure that spring remains in linear bending regime
  - must be large enough to prevent lockup

# 1st-Year Summary

- *G-sensor basic requirements have been identified*
- *1st-iteration sensors have been designed & modeled*
- *Layouts are nearly ready for fabrication*
- *Fab contracts/delivery orders are in place*
- *Additional info to be obtained for existing sensors:*
  - *Resonance & response to orientation*
  - *Production/Acceptance test requirements, methods & data*