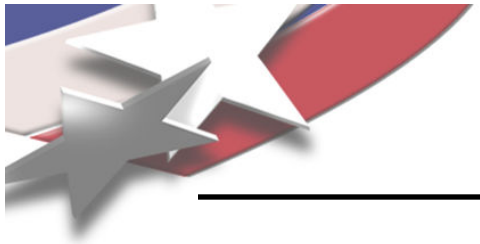


SAND2007-2787C

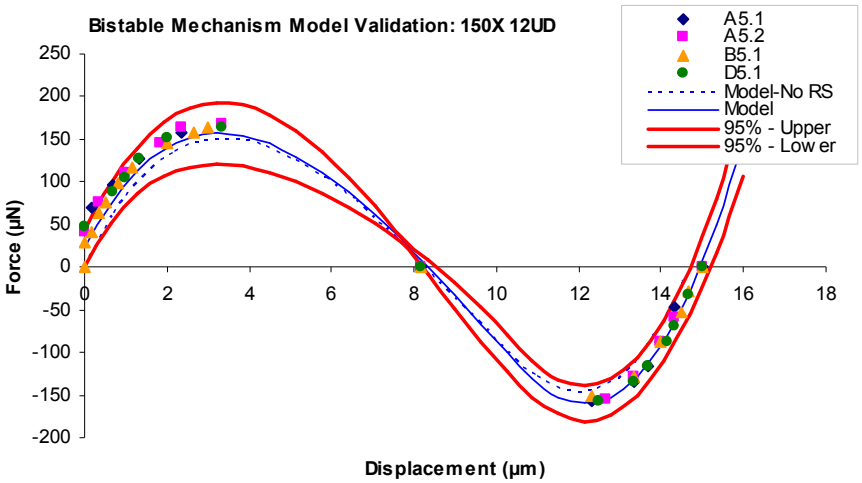
MEMS Latching Relay

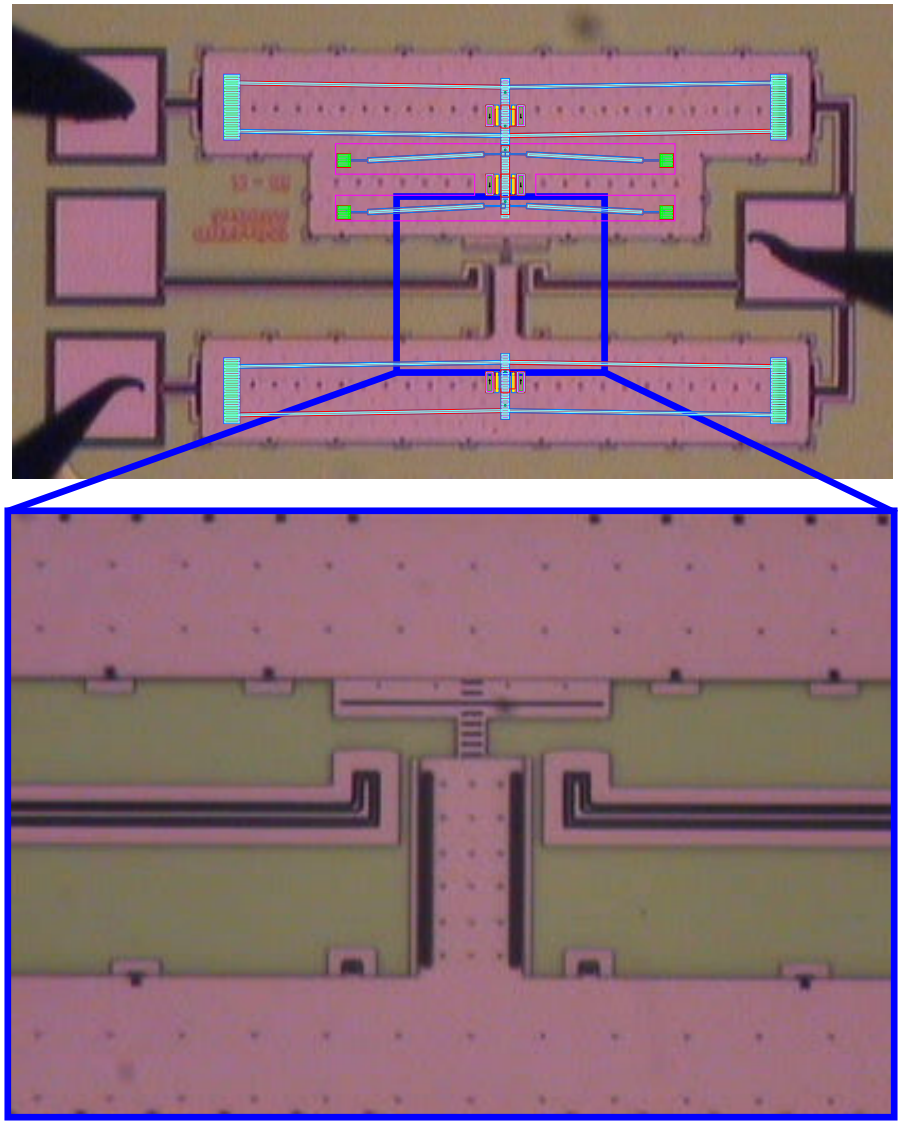
Michael Baker, 1749-2
David Czaplewski, 1749-2
Kenneth Pohl, 1749-2

Sandia National Laboratories

MEMS Latching DC Relay

- **Purpose: Develop a low power, shock/rad hardened, latching DC relay**
- **Technical Challenges**
  - **Performance of metal contacts with cycle count, both hot and cold switched.**





Current Project Status

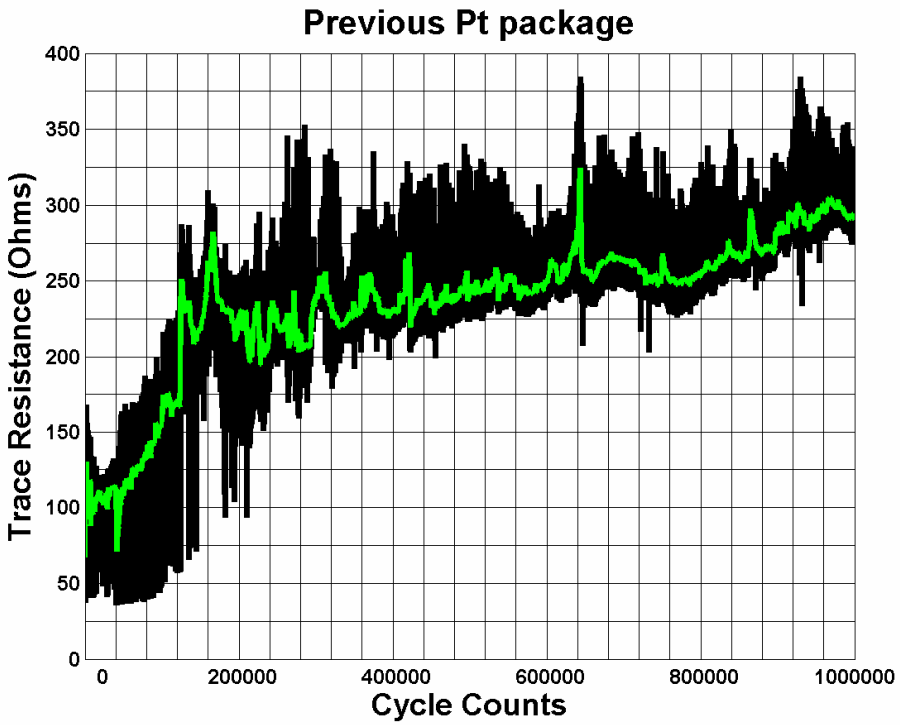
- Currently at TRL4 + "Key elements demonstrated in a laboratory environment."
  - Have done some testing beyond the "laboratory environment."

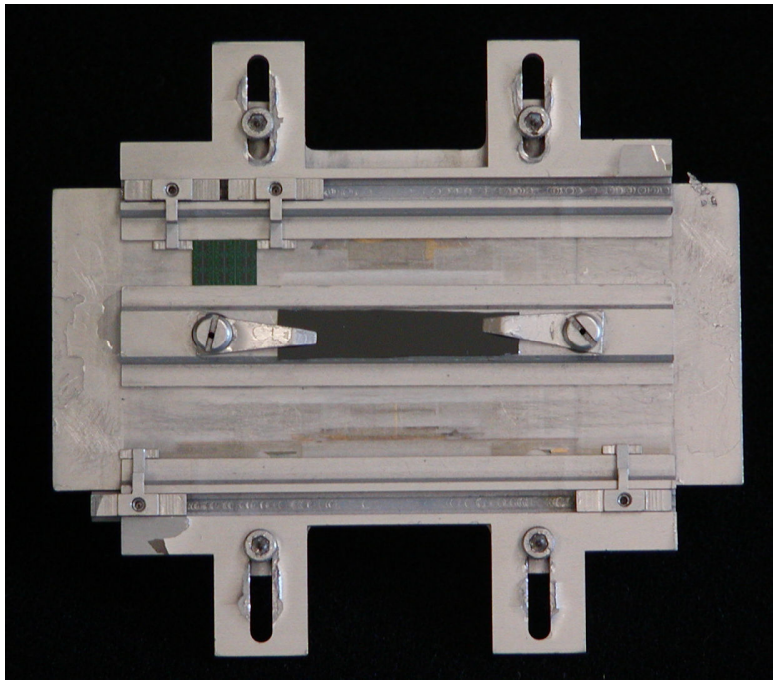
- Pro's of MEMS relay
  - Lower power (<200 mW switch power)
  - Smaller total volume
  - G and radiation hard
  - Reliability (at least it's under our control)
- Con's
  - Resistance/power handling of metal contact (we're working on improving this)

Sandia National Laboratories

Platinum Contact Metallization

- Platinum selected as initial contact metal.
- Contact is reliable but resistance is high and increases dramatically with cycle count.



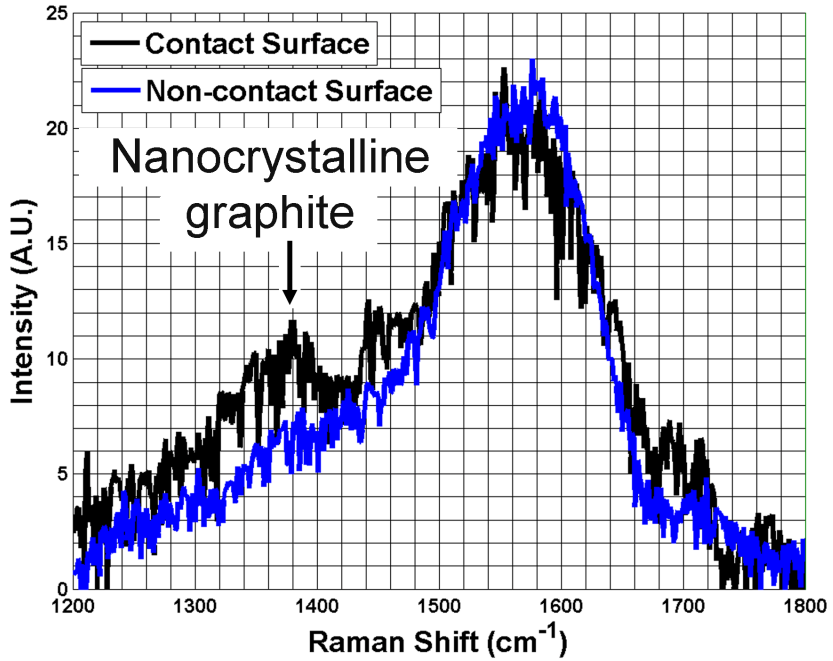


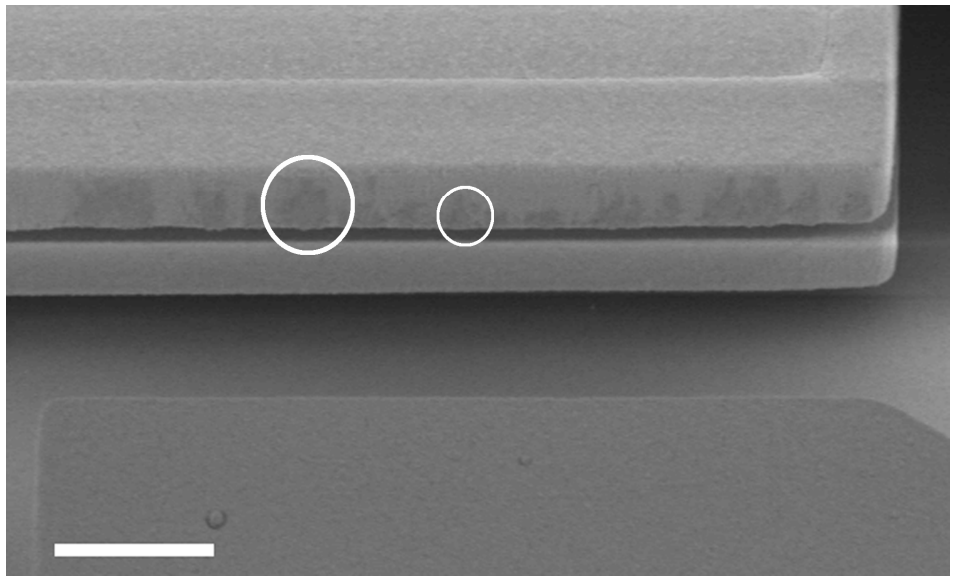
Pt Contact, O2 Plasma cleaned,
Hermetic package in N2 atmosphere

Sandia National Laboratories

Platinum Contact Contamination

- Raman spectroscopy shows adventitious carbon on all surfaces (graphene rings mixed with sp3-bonded carbon and residual hydrogen), and nano-crystalline graphite at contact point.
- This build-up is present under mechanical cycling only and is not due to hot or cold switching.

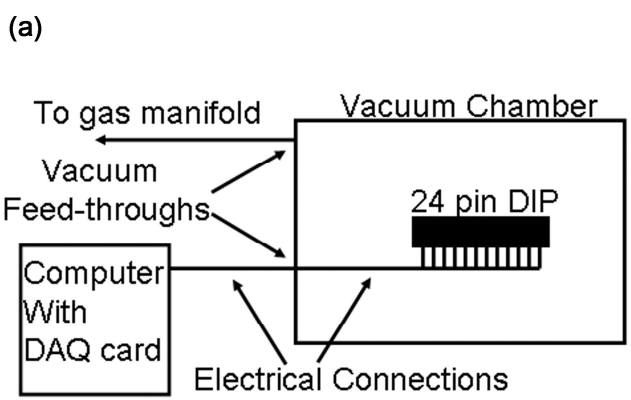


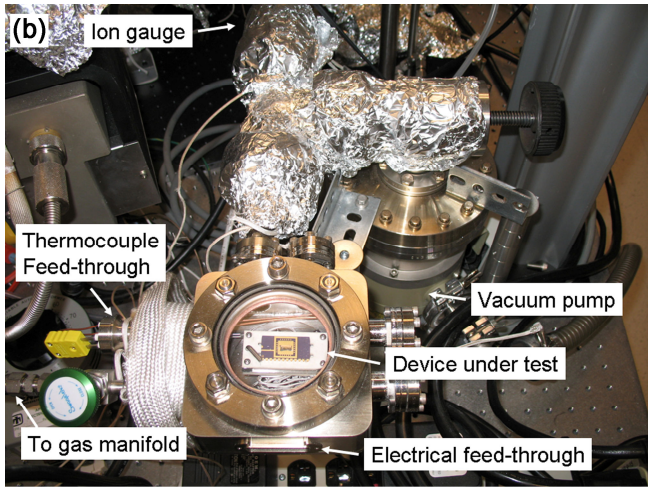


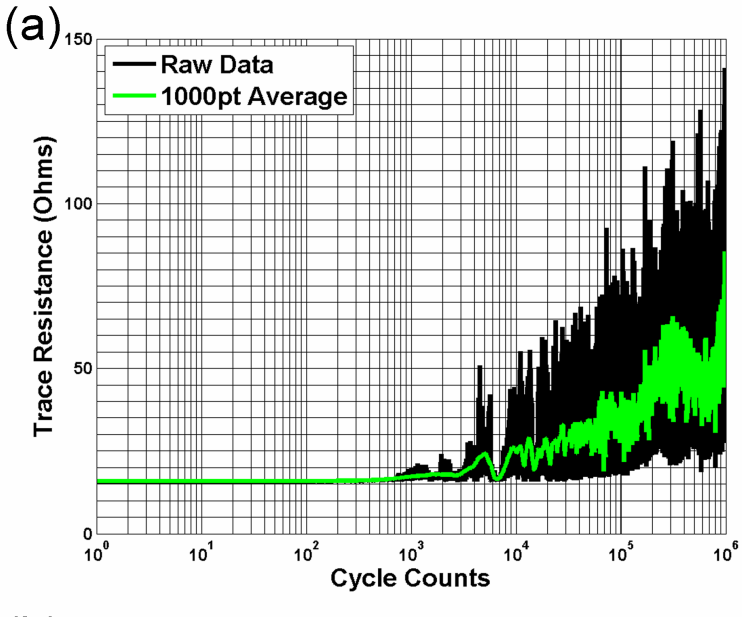
Sandia National Laboratories

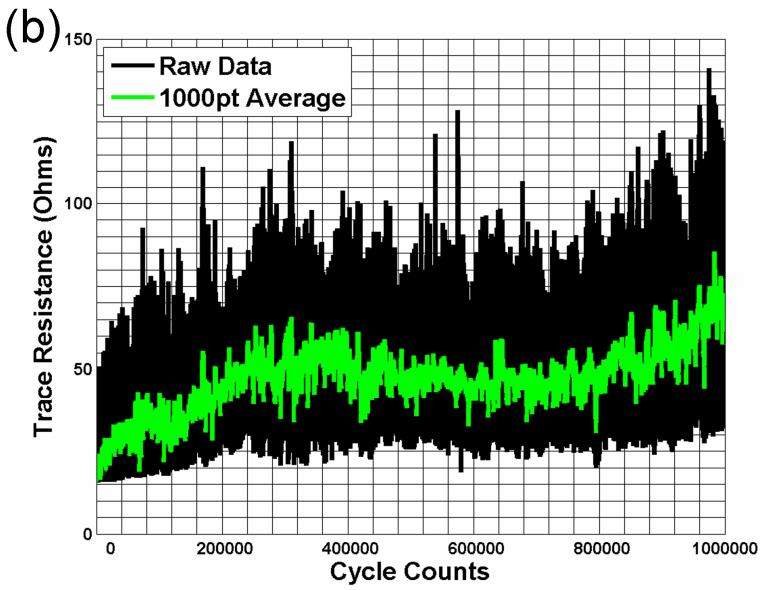
Testing Platinum in Clean Environment

- **Pt tested in UHV chamber after 12 hr. vacuum bake-out then UHP N_2 backfill.**





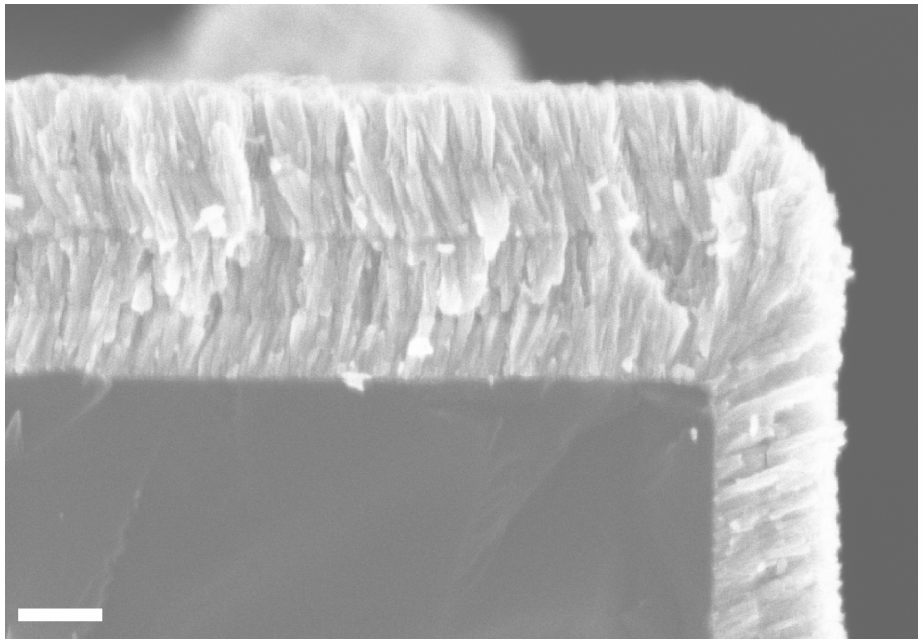


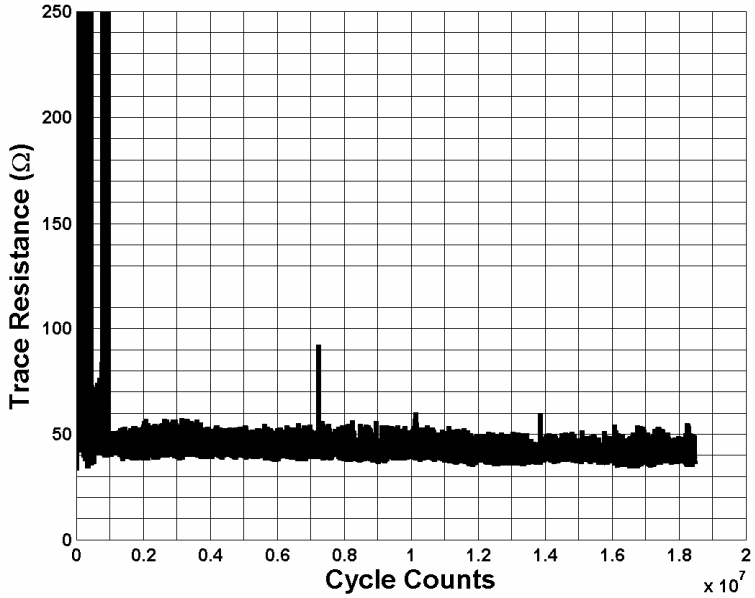


Sandia National Laboratories

Ruthenium Oxide Metallization

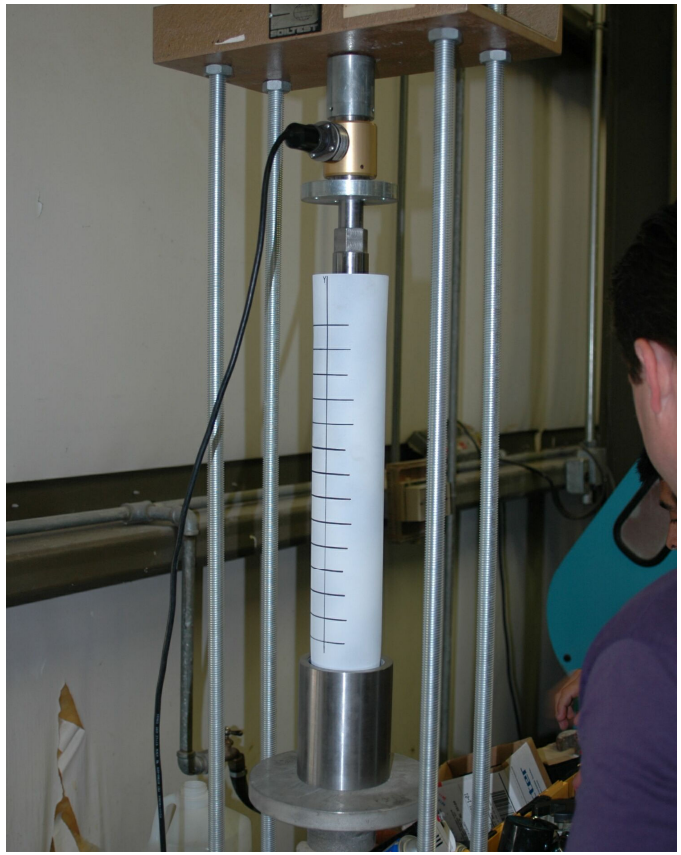
- Literature suggests that transition metal oxides prevent accumulation of friction polymer (Rh_2O_3, RuO_2, IrO_2, ReO_3)
- Proven in commercial reed relays (low force, high cycle count macro-scale relays)
- Ruthenium Oxide selected as candidate metal.





Sandia National Laboratories

Penetrator Test Setup



- Penetrator
  - 22” long, 3” diameter
  - 13.7 lbs.

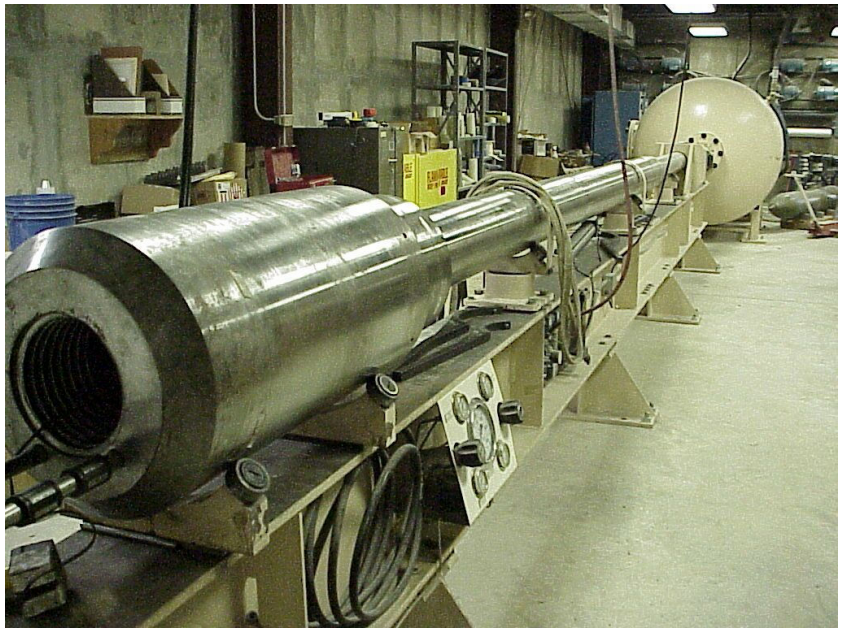
- Housing mates to MDES and assembles in penetrator
- MDES unit:
  - Power
  - Ground
  - Analog/digital inputs
  - Records analog/digital outputs

Tony Mittas – Org. 2621, 2005

Sandia National Laboratories

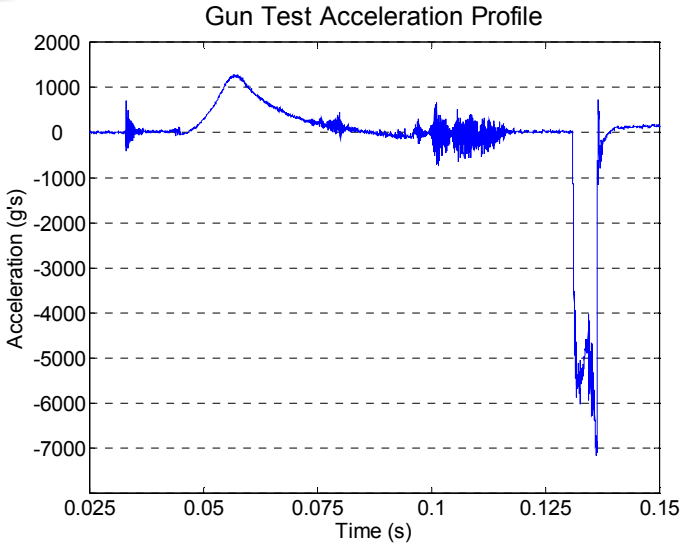
Penetrator Gun and Target

- Performed at the Waterways Experiment Station in Vicksburg MS (Army Corps of Engineers)

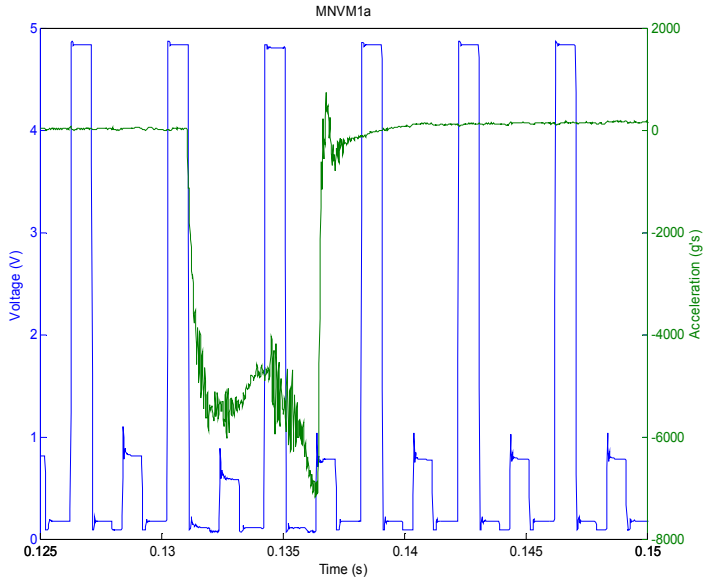


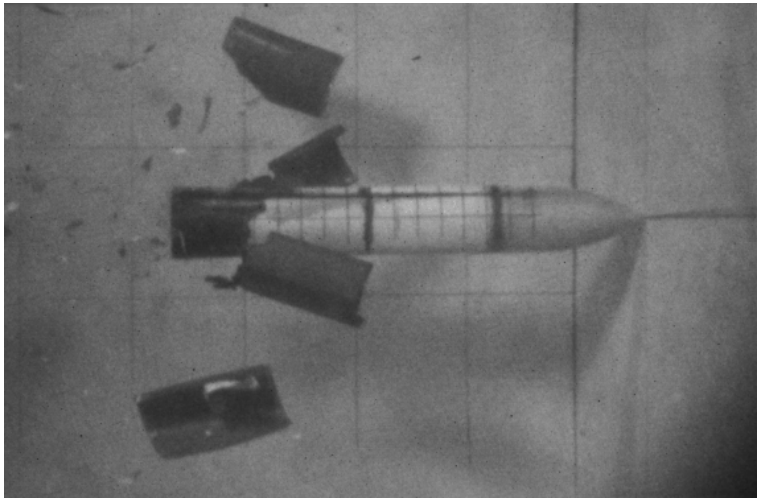
Sandia National Laboratories

Penetrator Test Results



Impact at 7200 g's over 5.5 milliseconds

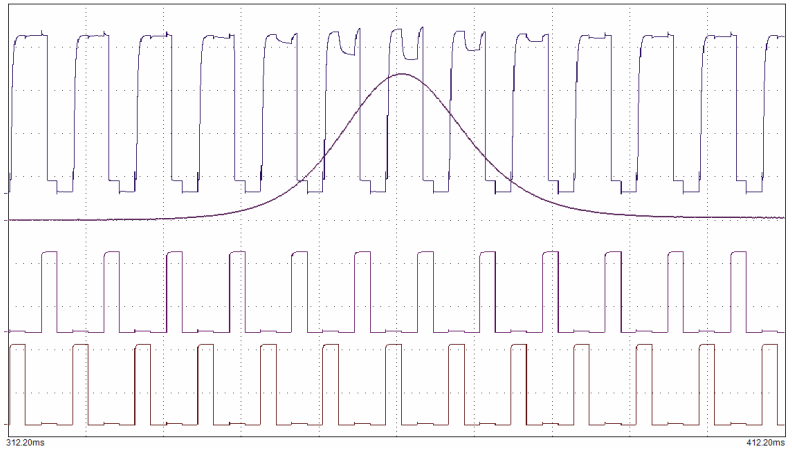


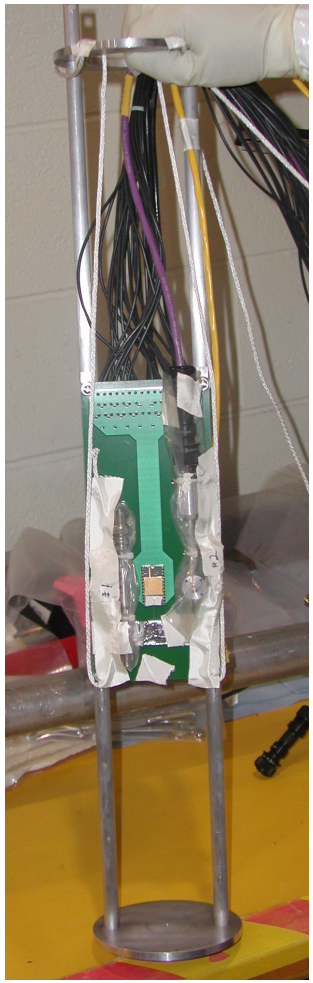


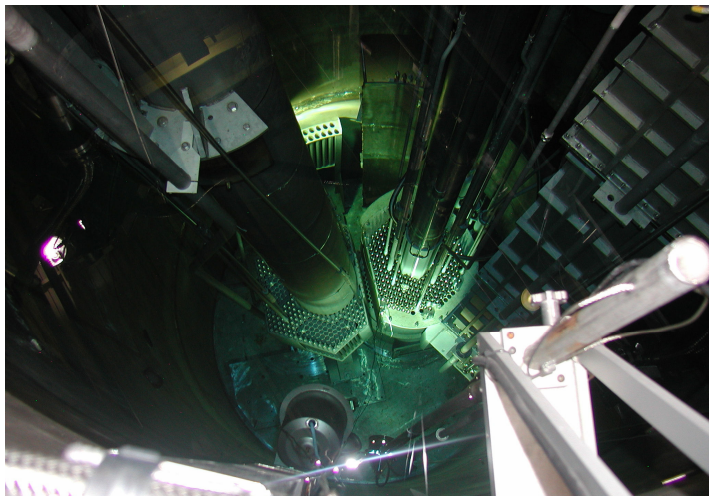
Sandia National Laboratories

ACRR Radiation Testing

- **Operated through both a max-pulse and a steady-state run free-field.**
  - **16.5 Mrad(Si) total dose at steady-state**
  - **100 Mrad(Si)/s peak dose rate from pulse**
  - **$1x10^{16}$ n/cm^2 max fluence**





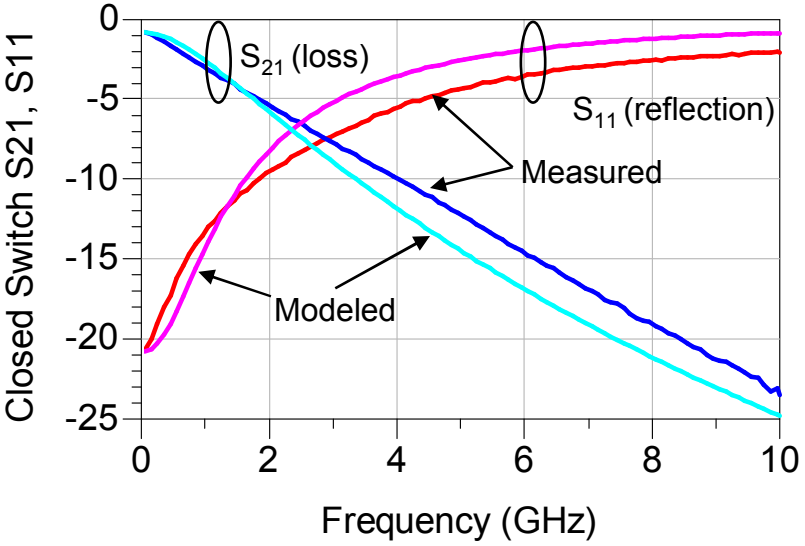


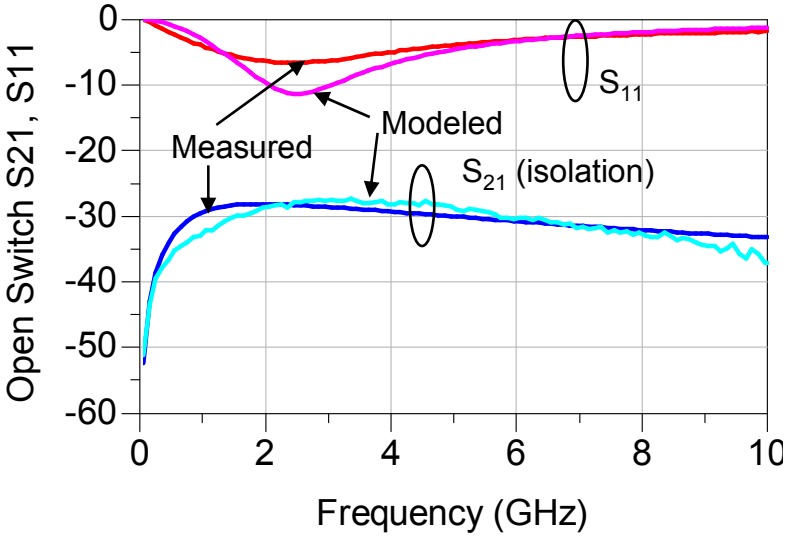
Mike Luker – Org. 1384, 2007

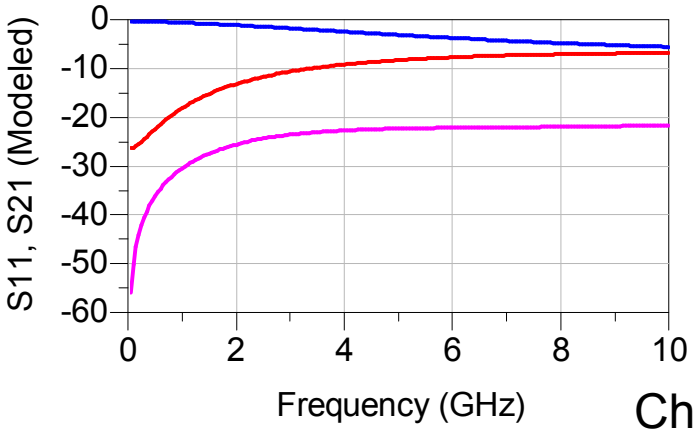
Sandia National Laboratories

RF Measurements

- **Gold-contact SPST tested using RF probes**
  - **–No change to baseline design**
  - **–Wirebonds ~2 mm long (~2 nH)**
- **SPST switch has 3 dB insertion loss and 32 dB isolation at 1 GHz**
  - **–Substrate capacitance is major contributor to insertion loss and off-state resonance**
  - **–Simple redesign of trace would greatly improved performance**

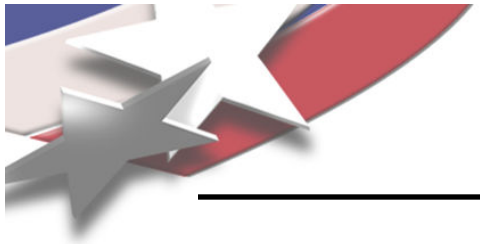






Modeled performance
L_{wire} = 0
C_{feed} = 0.45 pF
$R_{contact}$ = 3 Ω
Loss ~ 0.6 dB

Chris Nordquist, Garth Kraus - 1742, 2007



Questions?

Sandia National Laboratories