MEDLI:
From Instrumentation Concept to Flight Hardware

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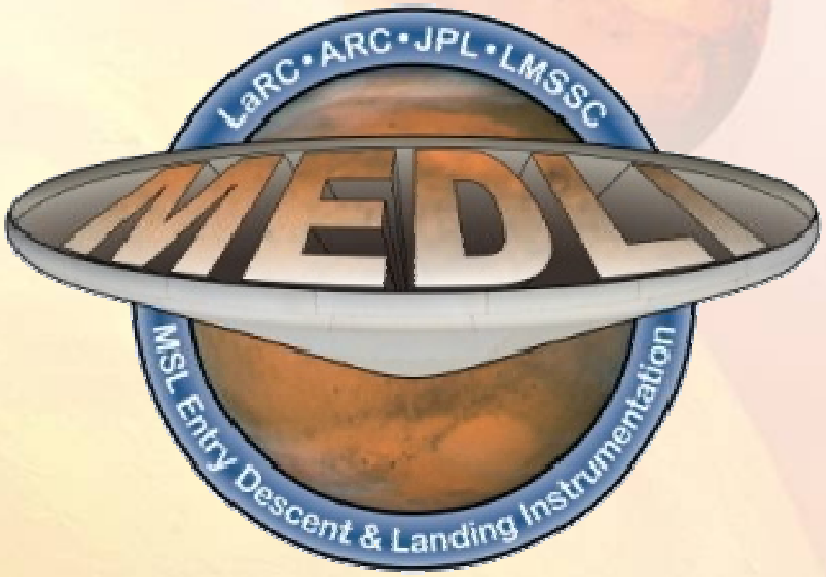

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Introduction

- MEDLI instrumentation suite will measure temperature, pressure, and recession of MSL entry vehicle's heatshield
- MEDLI will collect an order of magnitude more EDL data than all previous Mars missions combined, providing the community with a unique opportunity to validate models and improve predictions for missions to come
- MEADS is proving that a pressure measurement system can operate in an ablative environment
- Taking even a simple measurement system from paper to flight has extreme challenges
- There have been and will continue to be lots of lessons learned for the next implementation

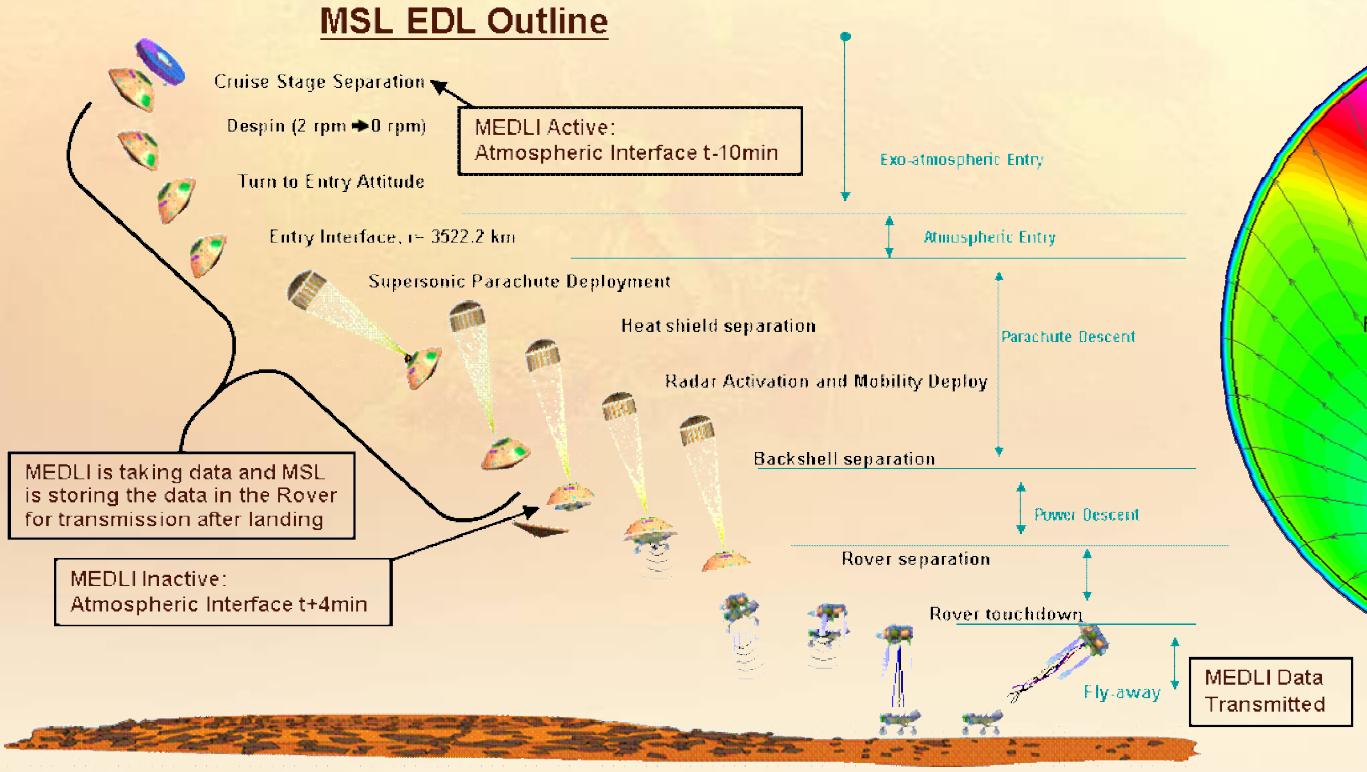
MEDLI System Objectives

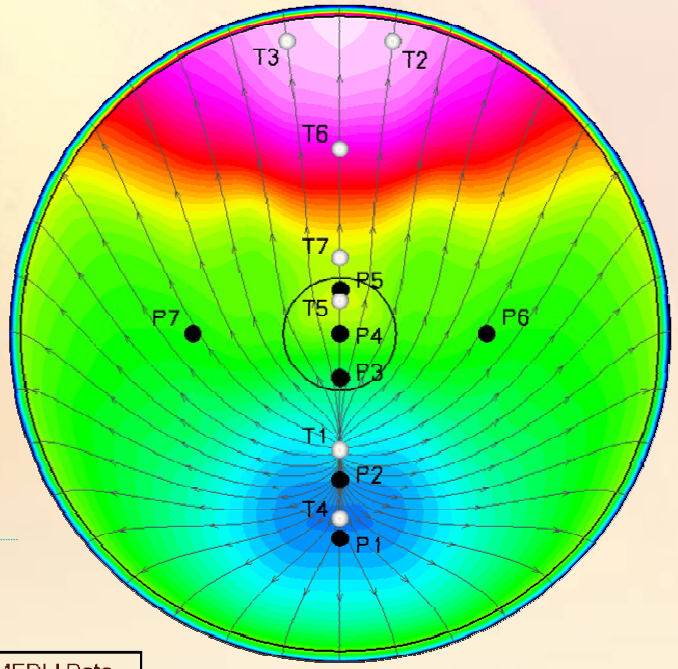
Aerodynamics & Atmospheric

- Determine density profile over large horizontal distance
- Determine wind component
- Separate aero from atmosphere
- Confirm aero at high angles of attack

Aerothermal & TPS

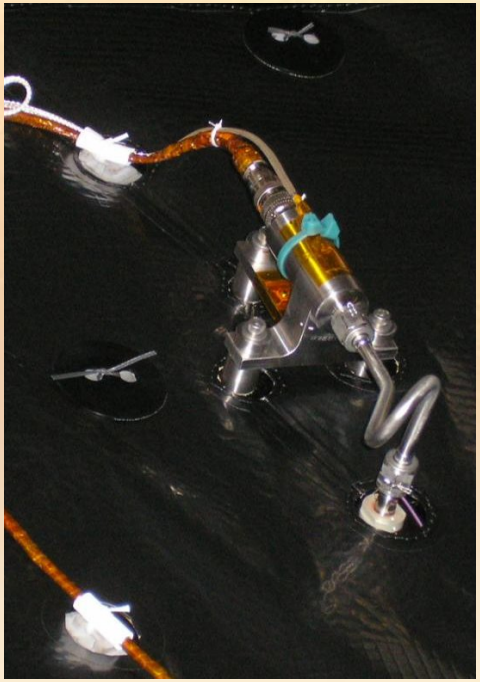
- Verify transition to turbulence
- Determine turbulent heating levels
- Determine recession rates and subsurface material response of ablative heatshield at Mars conditions



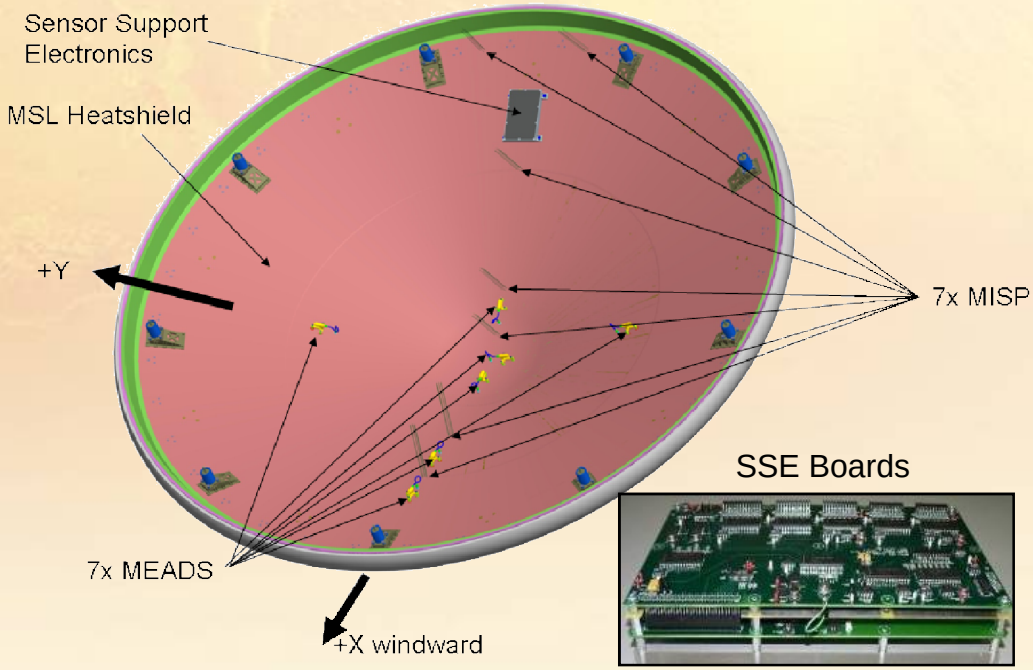


MEDLI System Description

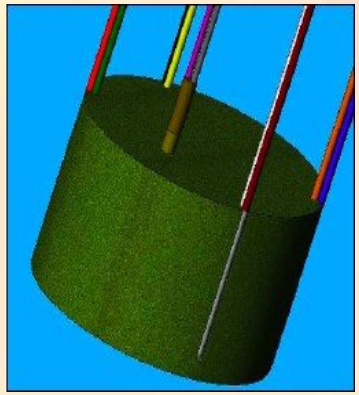
- MEDLI Instrumentation consists of:
  - **7 pressure ports** through heatshield -- Mars Entry Atmospheric Data System (MEADS)
  - **7 plugs:** 1-4 thermocouples + recession sensor -- Mars Integrated Sensor Plug (MISP)
  - **Sensor Support Electronics:** provides power to sensors, conditions/digitizes sensor signals
- Digitized data stream is sent via MSL's Descent Stage to Rover for storage until the data is telemetered back to Earth after landing



MEADS Assembly



SSE Boards

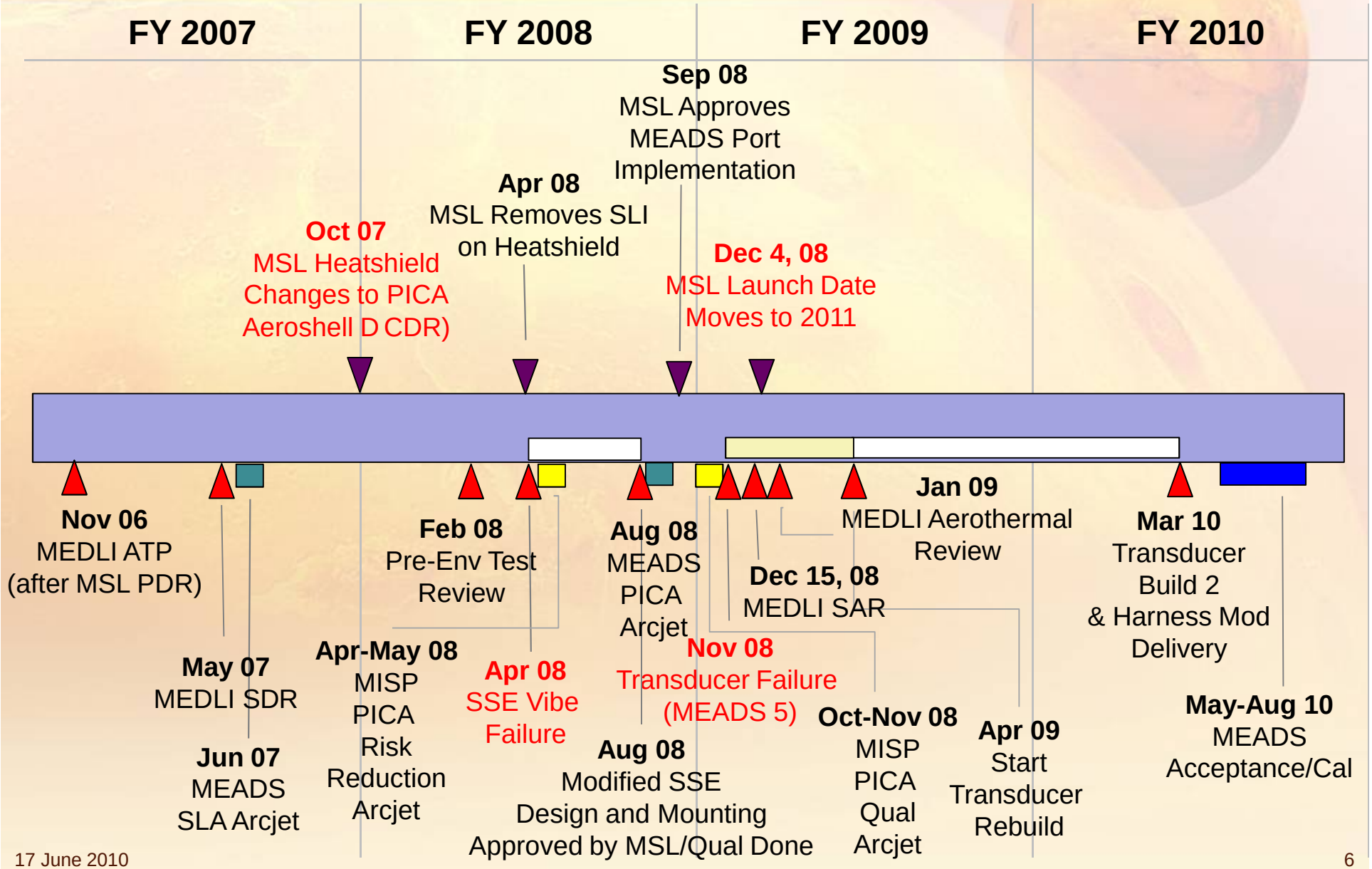


MISP Plug

The Plan

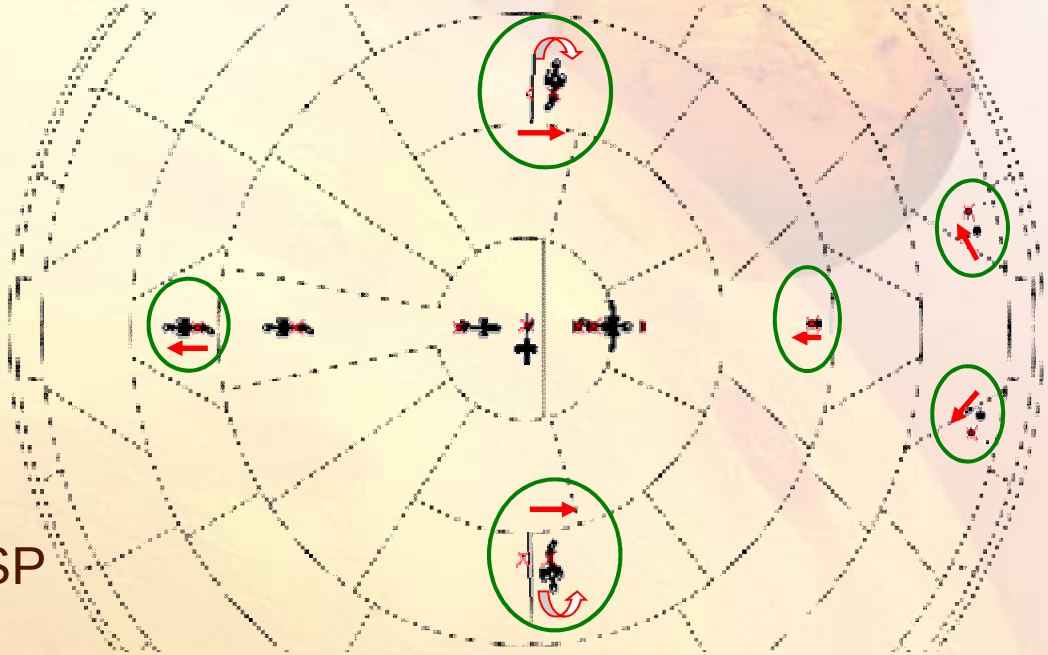
- **MISP plug**
  - HEAT sensor developed by ISPT
  - Thermocouple stack like used in arc jet
- **MEADS**
  - Transducers demonstrated on Shuttle (and developed for AFE)
  - Determine adequate port size through TPS
  - Could they handle the thermal environment?
- **SSE**
  - Digital conversion of MEADS analog data in DPAM
  - Desire by MEDLI to have that conversion performed by SSE

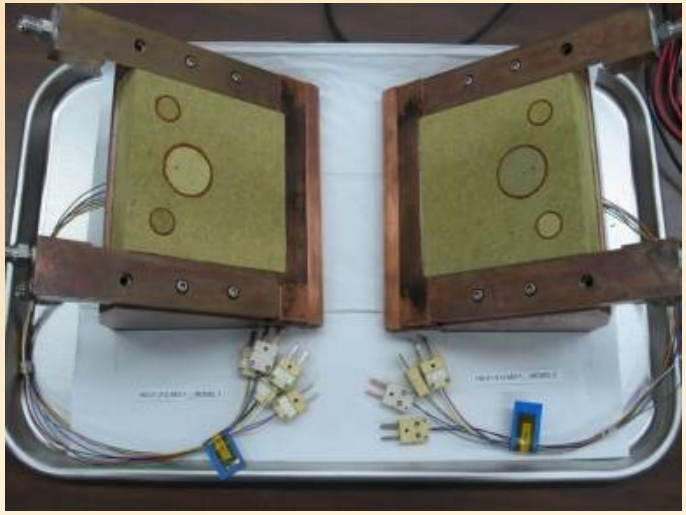
MEDLI Project Timeline



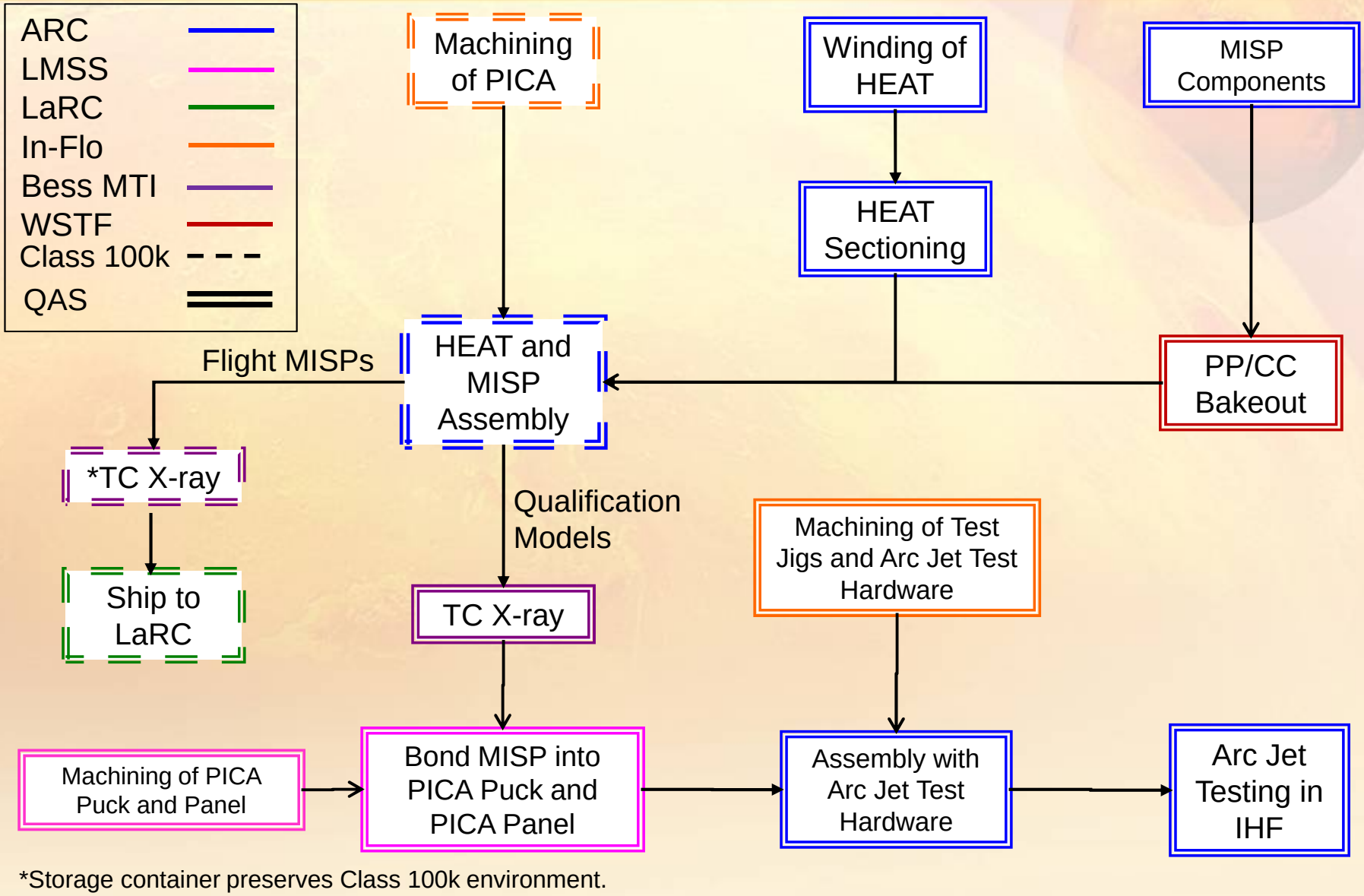
MSL TPS switch: Impacts to MEDLI

- Design changes
  - MEADS port locations
  - MISP locations
  - HEAT core changes from SLA to PICA
- Introduces new risks for both MISP and MEADS designs
  - Additional design and analysis
  - Additional developmental testing to retire risk
- Revised TPS qualification plan
  - Adds shear testing





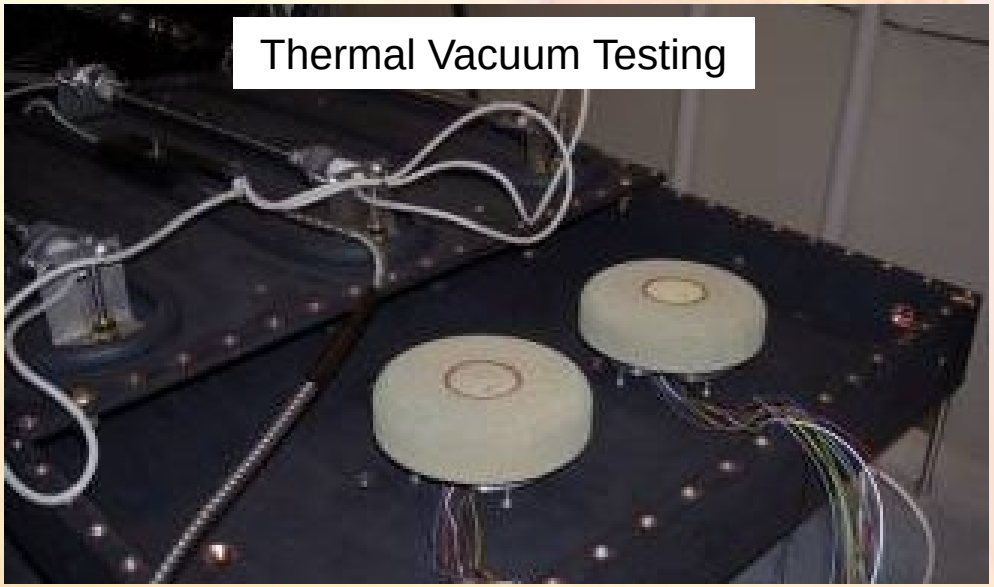
MISP Manufacturing Process



*Storage container preserves Class 100k environment.

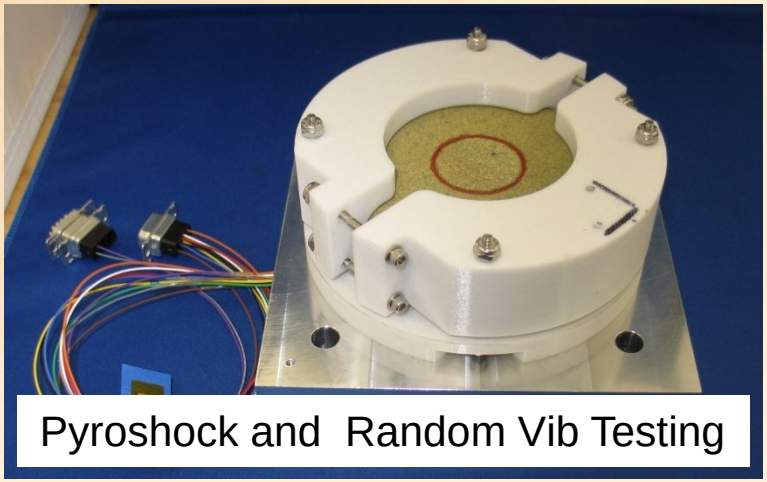
MISP Arcjet and Environmental Testing

Arcjet: Stagnation Tests



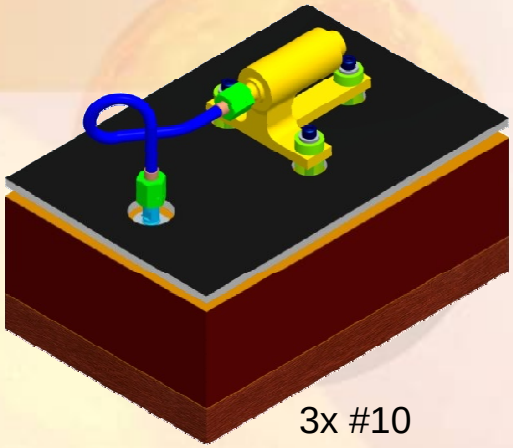
Thermal Vacuum Testing

Arcjet: Shear Tests



Pyroshock and Random Vib Testing

MEADS Configuration



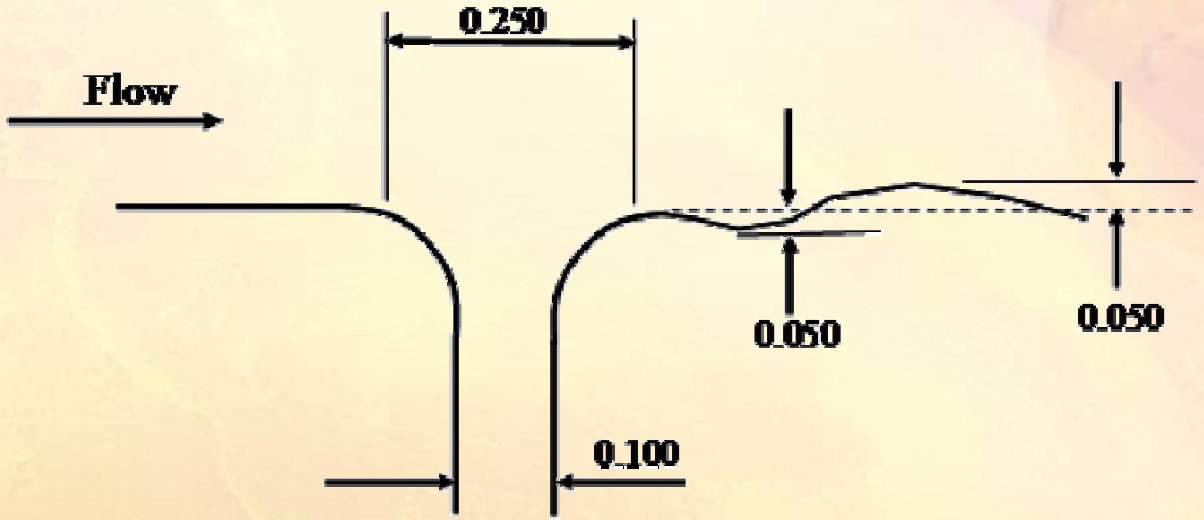
MEADS Port Evaluation

Must do adequate testing to prove that port hole will not cause TPS failure, and that we can get a good pressure measurement…

- All primary objectives were met with SLA-561V arc-jet testing (June 2007)
  - At surface, no discernable degradation of port shape at SLA interface
  - The bondline temperature for any model never exceeded the maximum allowable
  - Pyrolysis did not show an effect on the measurements at tested conditions; no sleeve needed
  - Demonstrated ability to measure pressure in SLA-561V

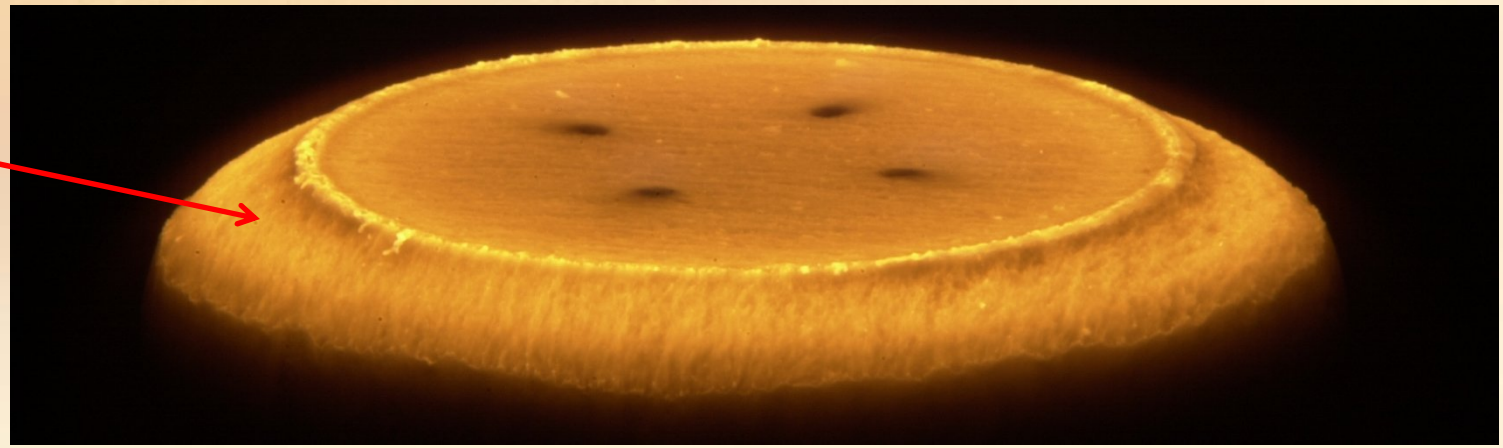
- MSL switch from SLA-561V to PICA in October of 2007
  - Repeated stagnation testing
  - Shear testing
  - Qualification testing (stagnation and shear)
  - With MSL, defined acceptable hole shape change (bondline temperature still met)

MEADS Port Qualification



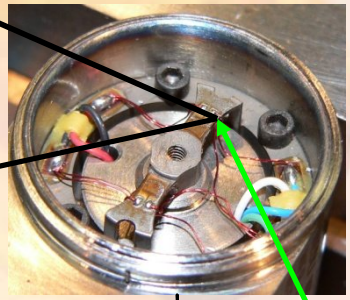
Pressure port and surrounding PICA dimensional requirements by the end-of-flight as specified in the MSL MEDLI ICD (Dimensions in Inches).

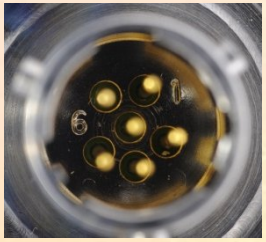
PICA collar bonded with RTV

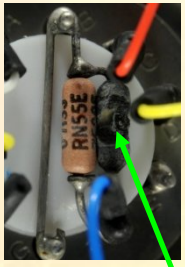


MEADS Transducer Failure Summary of Findings

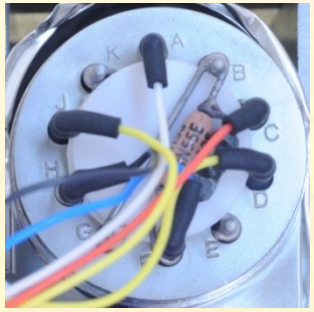
Compromised Insulation







Thermal Compensation Resistor (Burned During Testing)



Location of Low Impedance Path to Chassis

Electrical Connector

5
4
3
1
6
2

Blue From Connector
Yellow From Connector
White From Connector

R5 20-40

R7 800

RT1 °F

R6 800

Red From Connector
Black From Connector
Yellow From Connector

A B C D E F G H J K

Sealed Header

RTD

Span Resistors

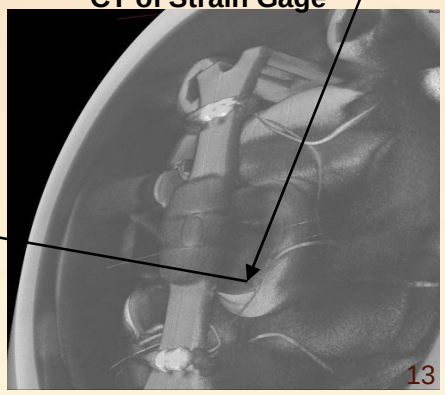
White To Gauge
Red To Gauge
Blue To Gauge
Green To Gauge
Black To Gauge

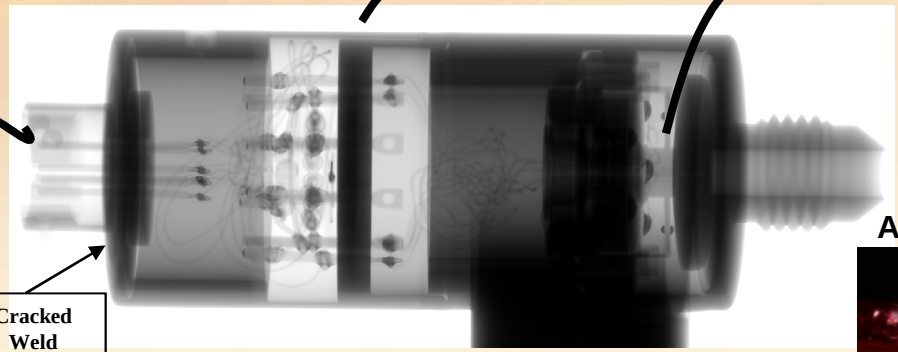
R1 5k Compression
R3 5k Tension
R2 5k Tension
R4 5k Compression

Strain Gauge

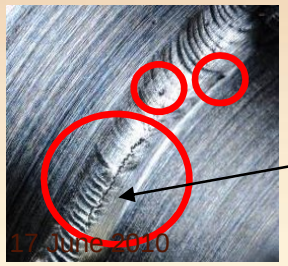
Short to Chassis (Abraded Wire)

CT of Strain Gage



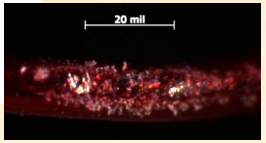


X-Ray of Transducer



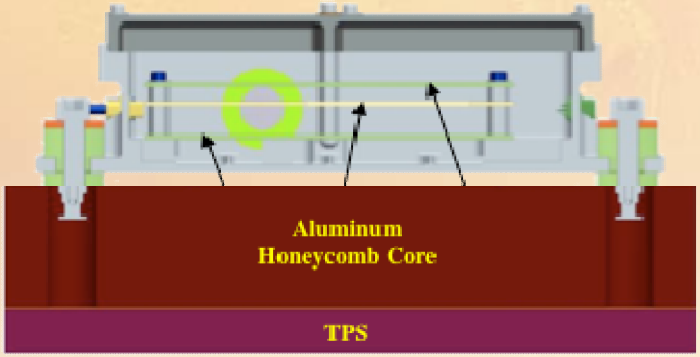
Cracked Weld

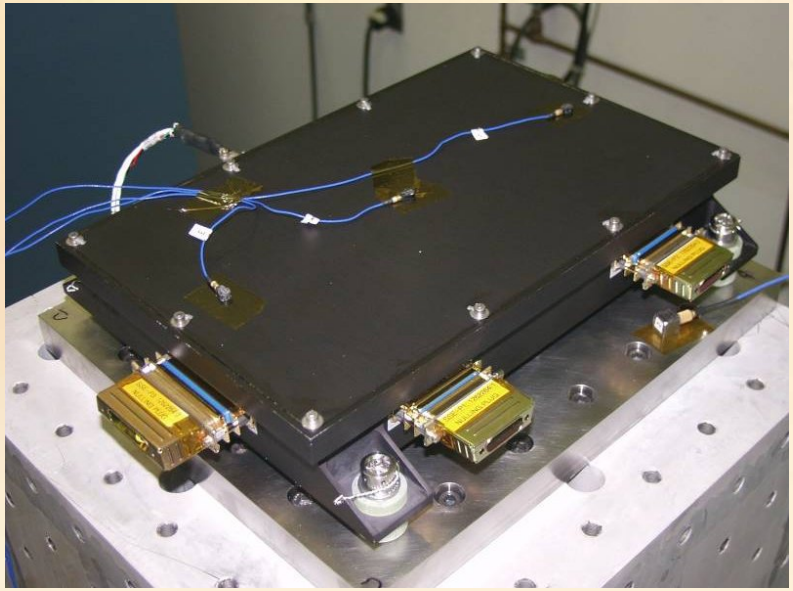
Abraided Wire



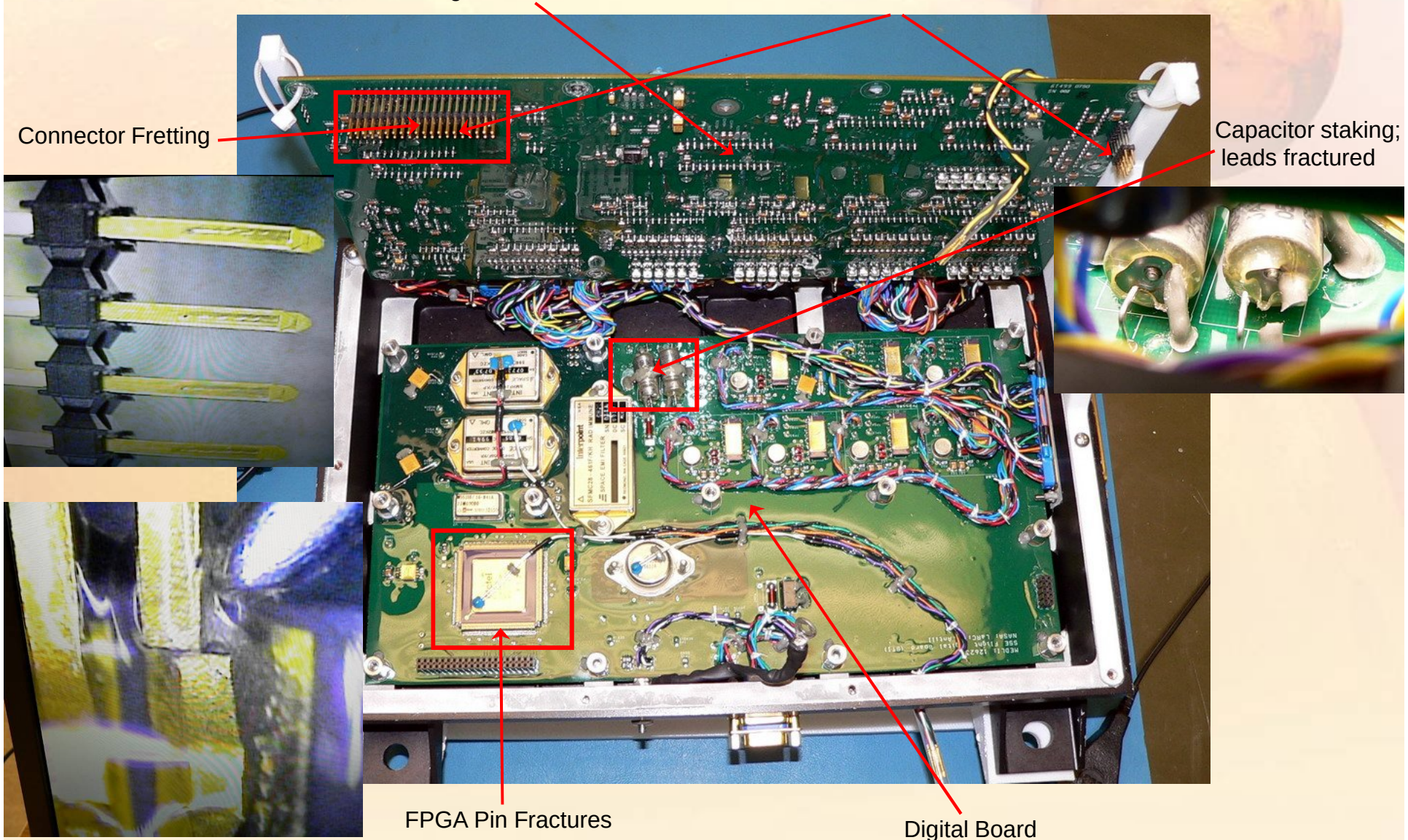
MEDLI SSE Vibe Failure

- Anomalous data was noticed during vibration testing of SSE in the first test axis (y-axis)
  - Initial indications were that anomaly was EMI related or thought to be workmanship
  - Further investigation showed that the Anomalous data from SSE was being caused by mechanical stresses
- Vibration testing was halted and Tiger Team was convened

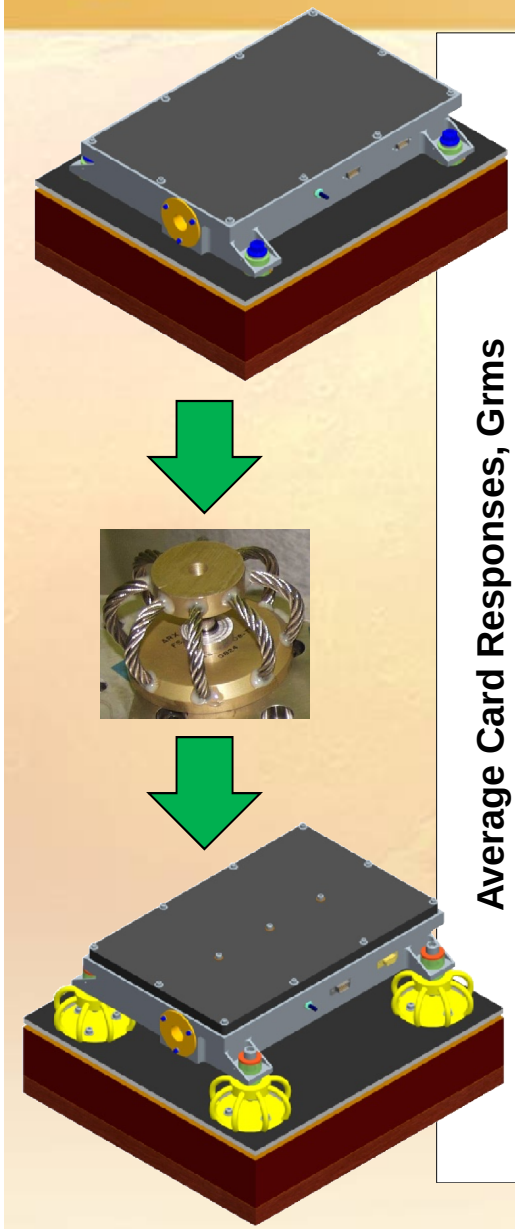


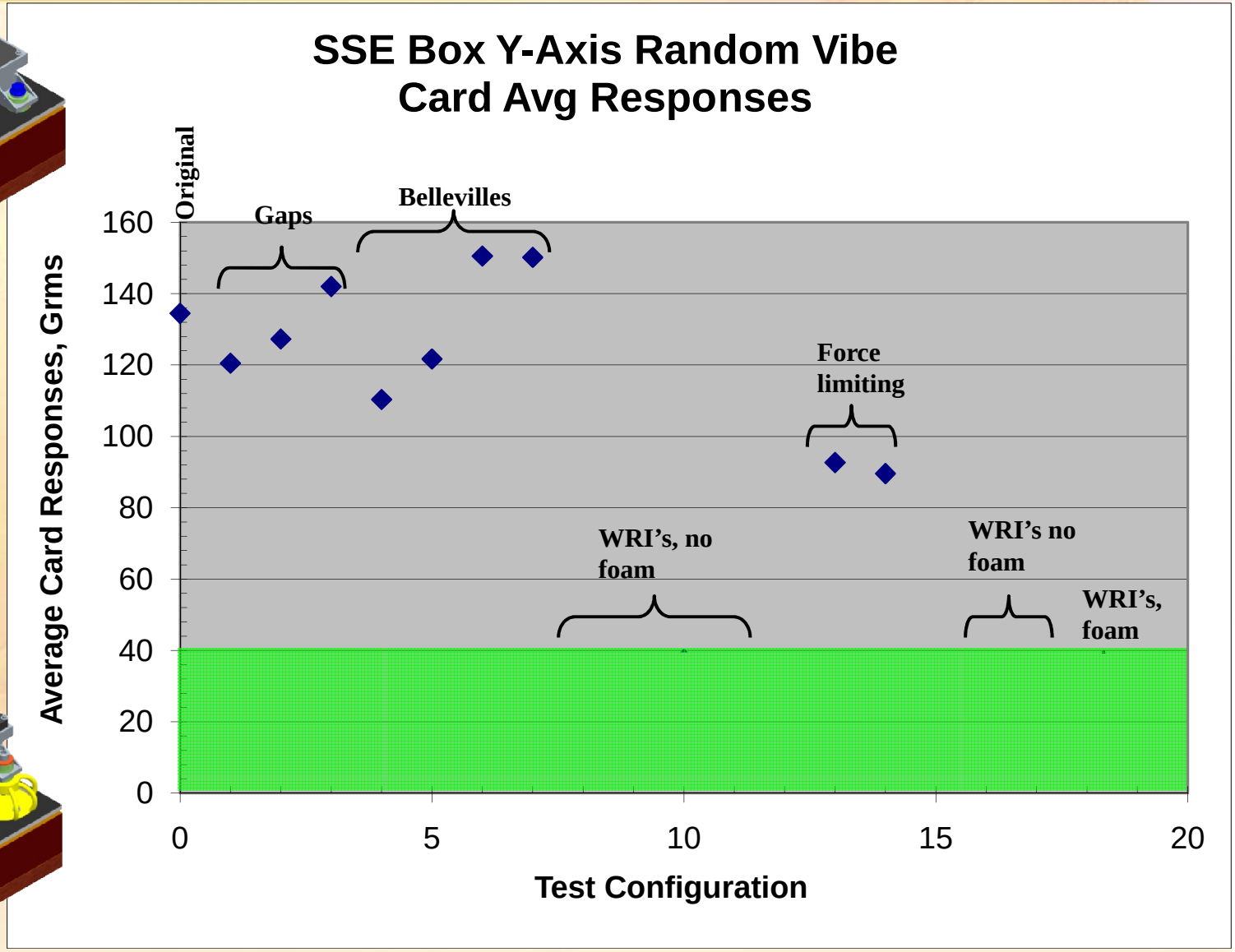


SSE #4 – Visual inspection (What We Found)

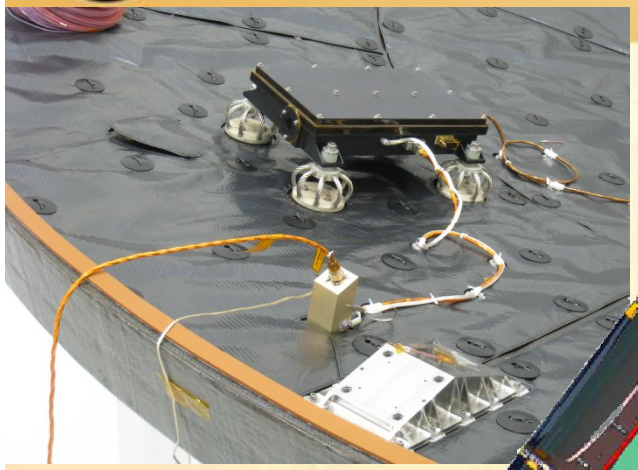


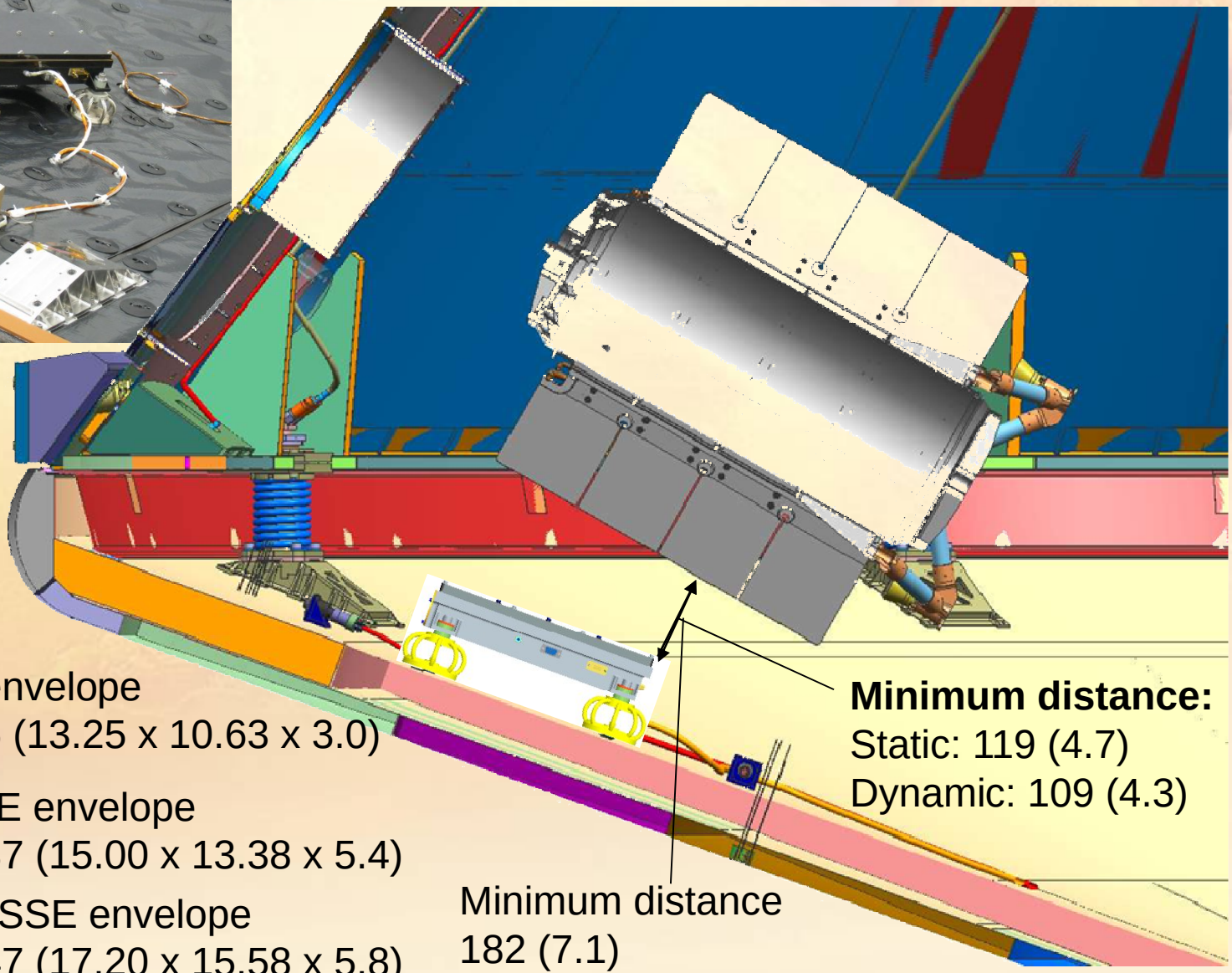
Design Space Test Summary with Isolators





Primary Configuration Envelope Changes





Original SSE envelope
337 x 270 x 76 (13.25 x 10.63 x 3.0)

New Static SSE envelope
381 x 340 x 137 (15.00 x 13.38 x 5.4)

New Dynamic SSE envelope
437 x 396 x 147 (17.20 x 15.58 x 5.8)

Minimum distance:
Static: 119 (4.7)
Dynamic: 109 (4.3)

Minimum distance
182 (7.1)

mm (in)

Current Status of MEDLI Project

- MEADS transducers undergoing flight acceptance testing/calibration (May-Sep)
- Flight SSE and MEADS transducers will be delivered to Lockheed in Dec 2010 for flight aeroshell integration
  - SAR and IRR in that timeframe
  - Will participate in system tests in 2011
- Flight data analysis/reconstruction efforts are underway (funded by ARMD)


MEADS Ports Drilled
Feb 2009


MISP plugs installed Dec 2008

Summary

- MEDLI development has resulted in a flight heatshield instrumentation system that can be implemented on other entry vehicles
- Using even existing technology has been challenging—technology investments in instrumentation are needed
- MEDLI data return will hopefully set a precedent for instrumenting all entry vehicles