The Mars Science Laboratory (MSL) Entry, Descent and Landing Instrumentation (MEDLI) Hardware

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Agenda

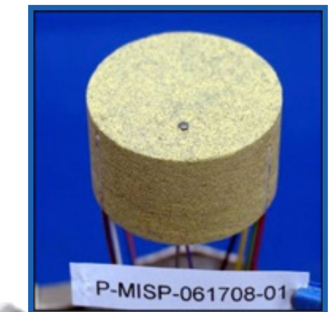
- MEDLI Objectives and Overview
- MEADS: Mars Entry Atmospheric Data System
  - Description
  - Unique Challenges/Testing
- MISP: MEDLI Integrated Sensor Plug
  - Description
  - Unique Challenges/Testing
- SSE: Sensor Support Electronics
- Conclusions

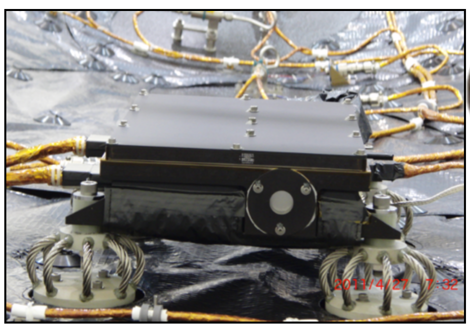
MEDLI: MSL Entry, Descent and Landing Instrumentation (2006-2012)

- MEDLI consists of 7 pressure ports, 7 integrated sensor plugs, and support electronics
- Gathered engineering data during entry and descent for future Mars missions
- Partnership between NASA Mission Directorates to build, fly, and analyze data

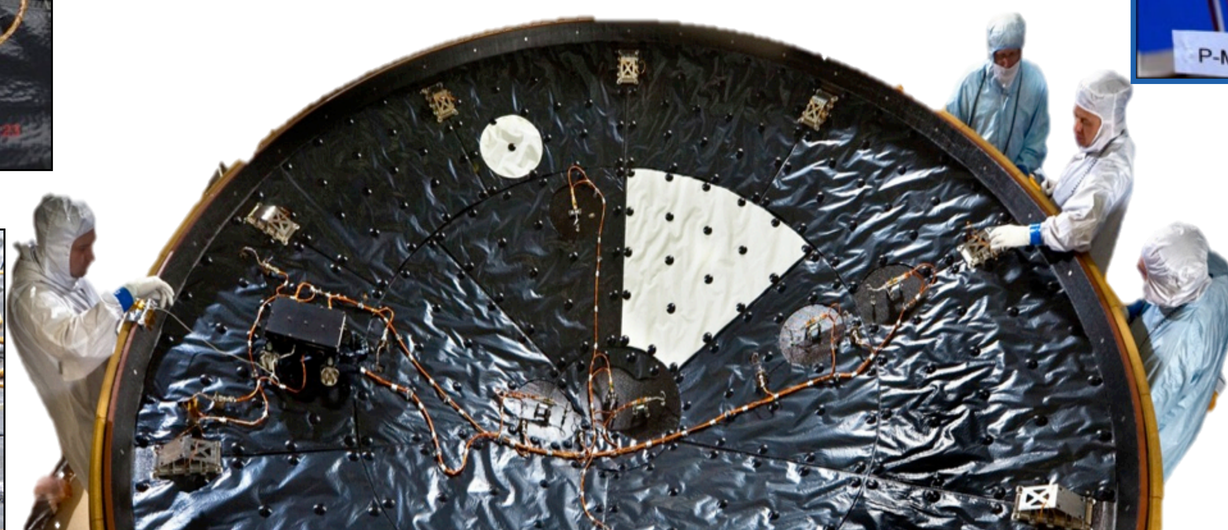
Mars Entry Atmospheric Data System (MEADS)

MEDLI Integrated Sensor Plug (MISP)





Sensor Support Electronics (SSE)



The MEDLI instrumentation makes MSL the first extensively instrumented heatshield ever sent to Mars

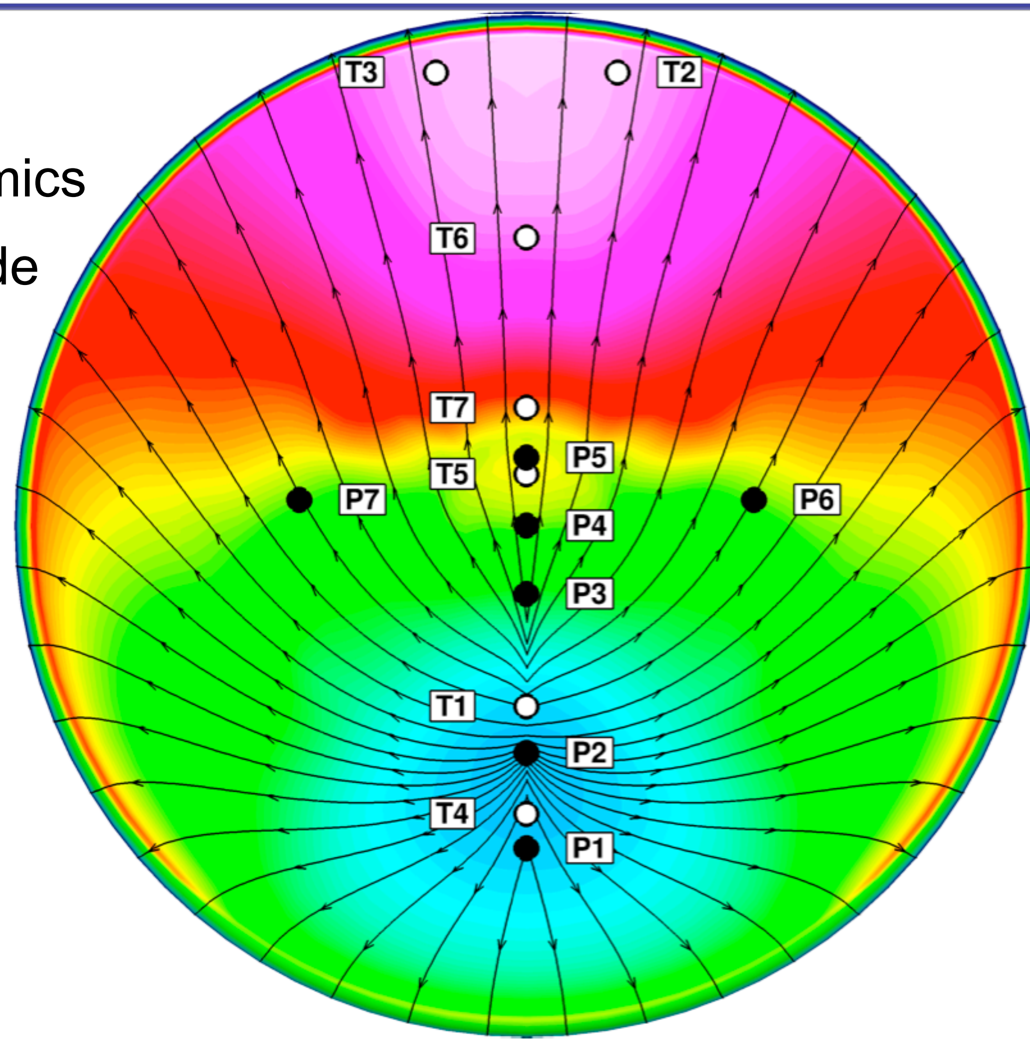
MEDLI Objectives

Measure Pressure

- Confirm spacecraft aerodynamics
- Independently measure attitude
- Determine density profile
- Determine wind component

Measure Temperature

- Verify heating levels on spacecraft surface
- Determine recession amount and rate
- Validate material response at Mars conditions



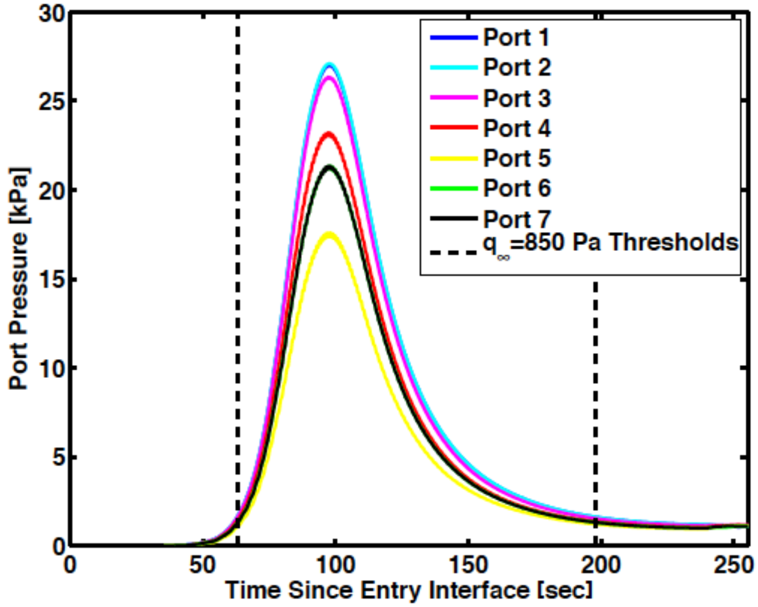
The better we understand the Mars entry environment, the better we can design the next spacecraft

MEADS: Requirements

Fundamental objectives:

(1) Do no harm to MSL

(2) Obtain good measurements



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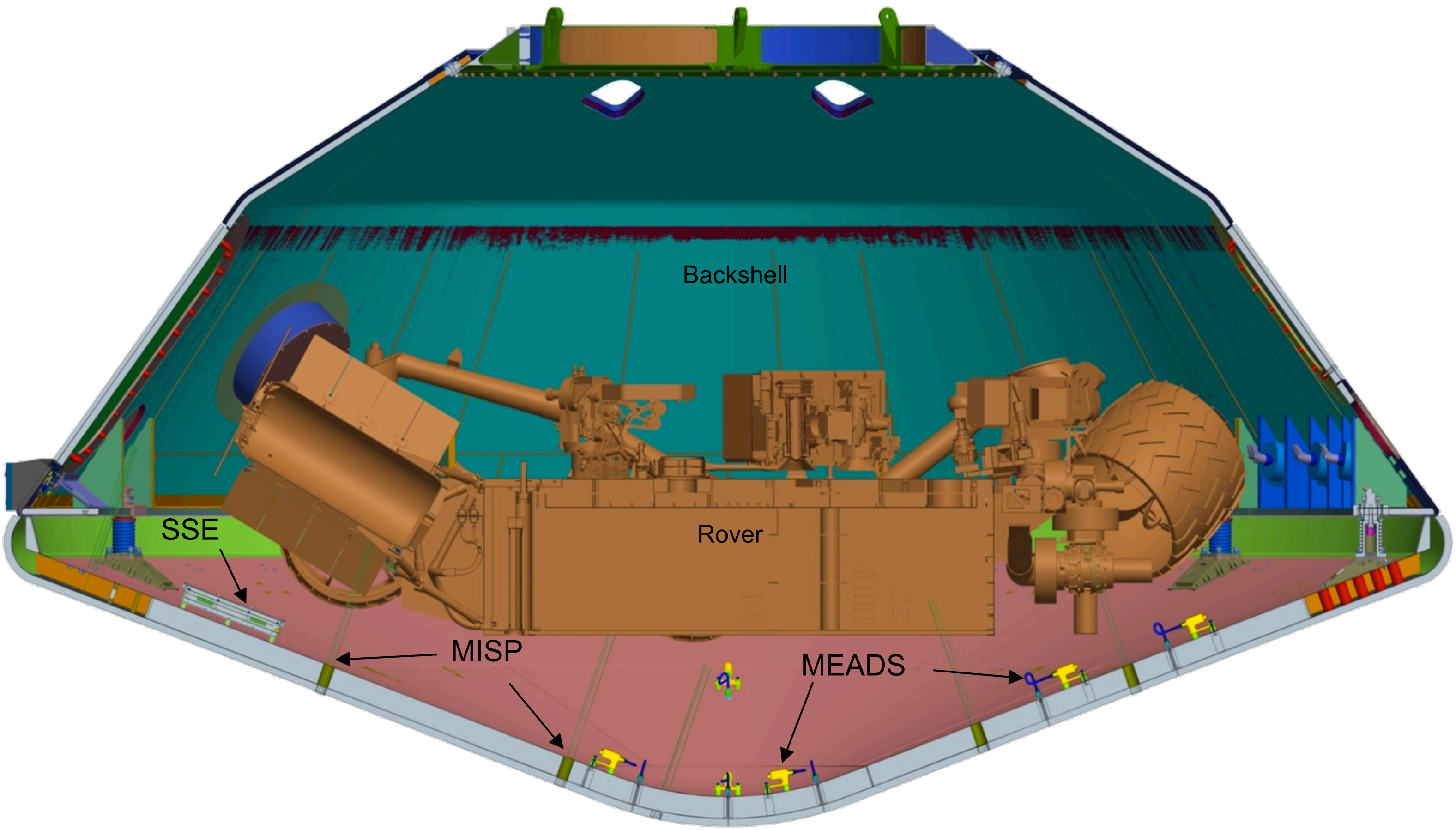
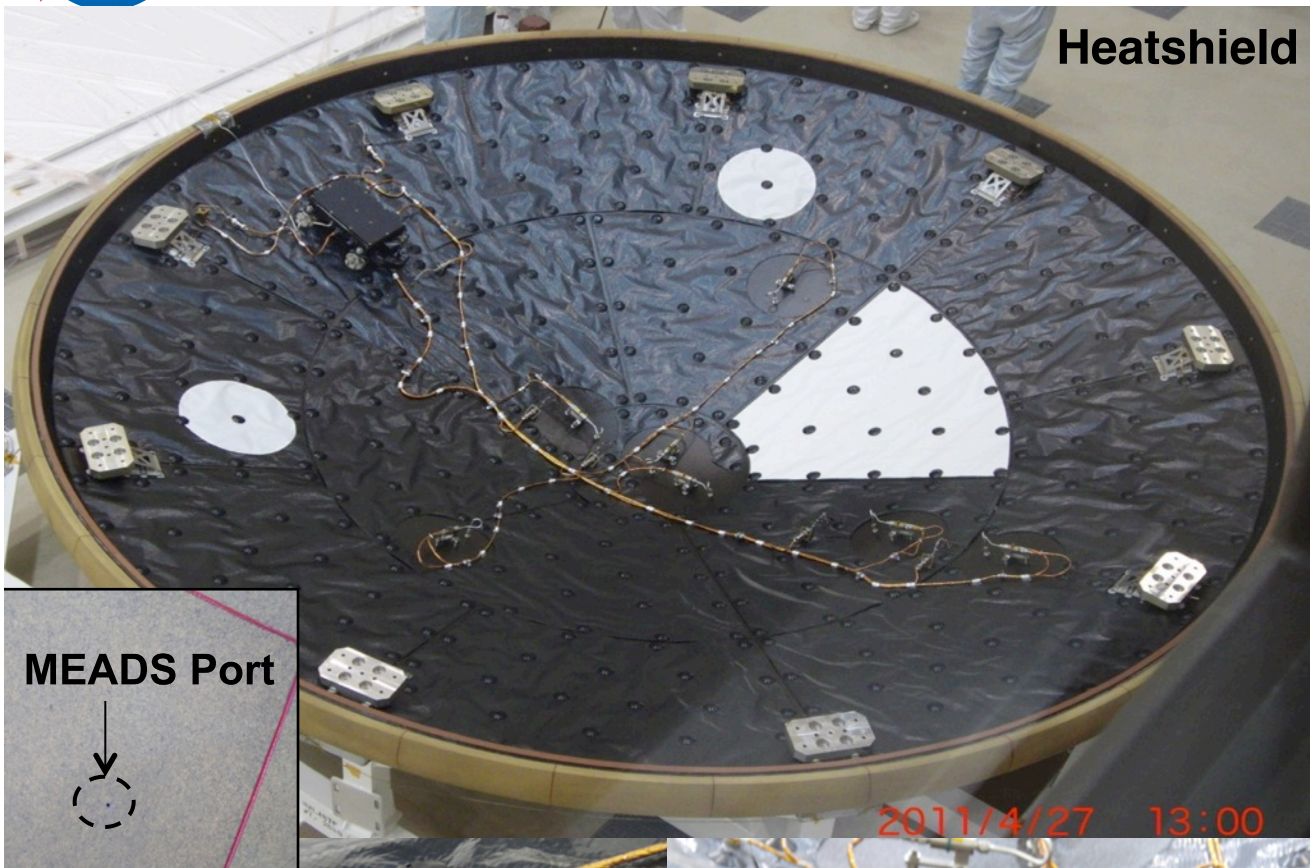
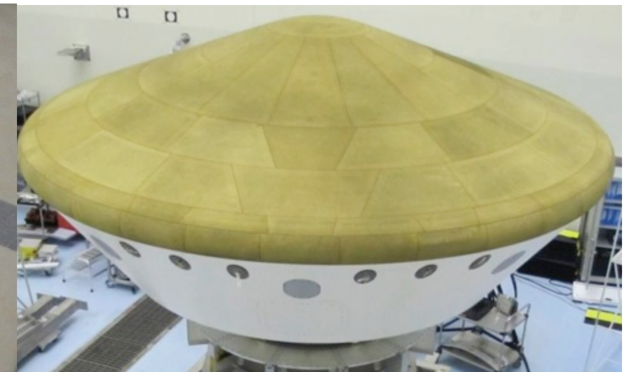
Determine time of boundary layer transition onset	2 seconds
Determine presence, if any, of stagnation point heating augmentation	± 30 W/cm^2
Measure subsurface material temperature response	± 12%
Determine total TPS recession	± 0.635 cm (0.25”)
Measure depth of isotherm in TPS	720^oC ± 80^oC and ± 0.8mm

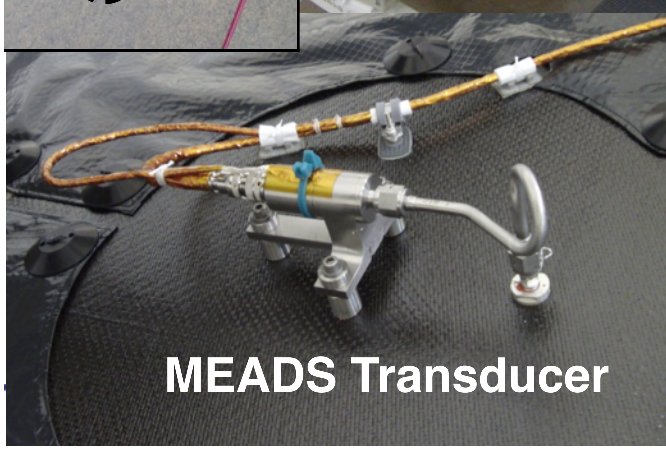
MEDLI Locations in MSL Vehicle

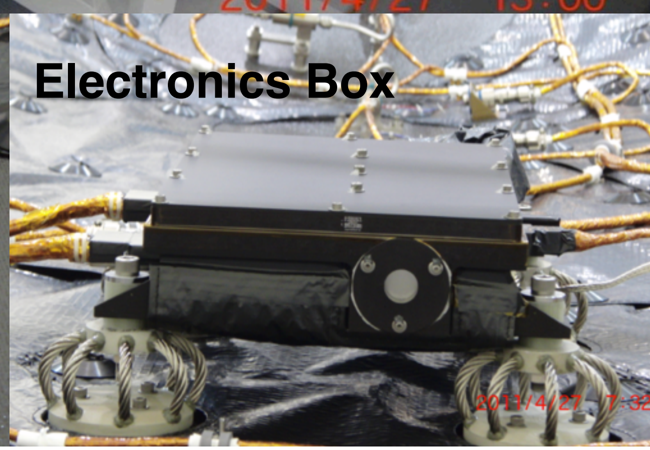


MEDLI — The Path to Mars!









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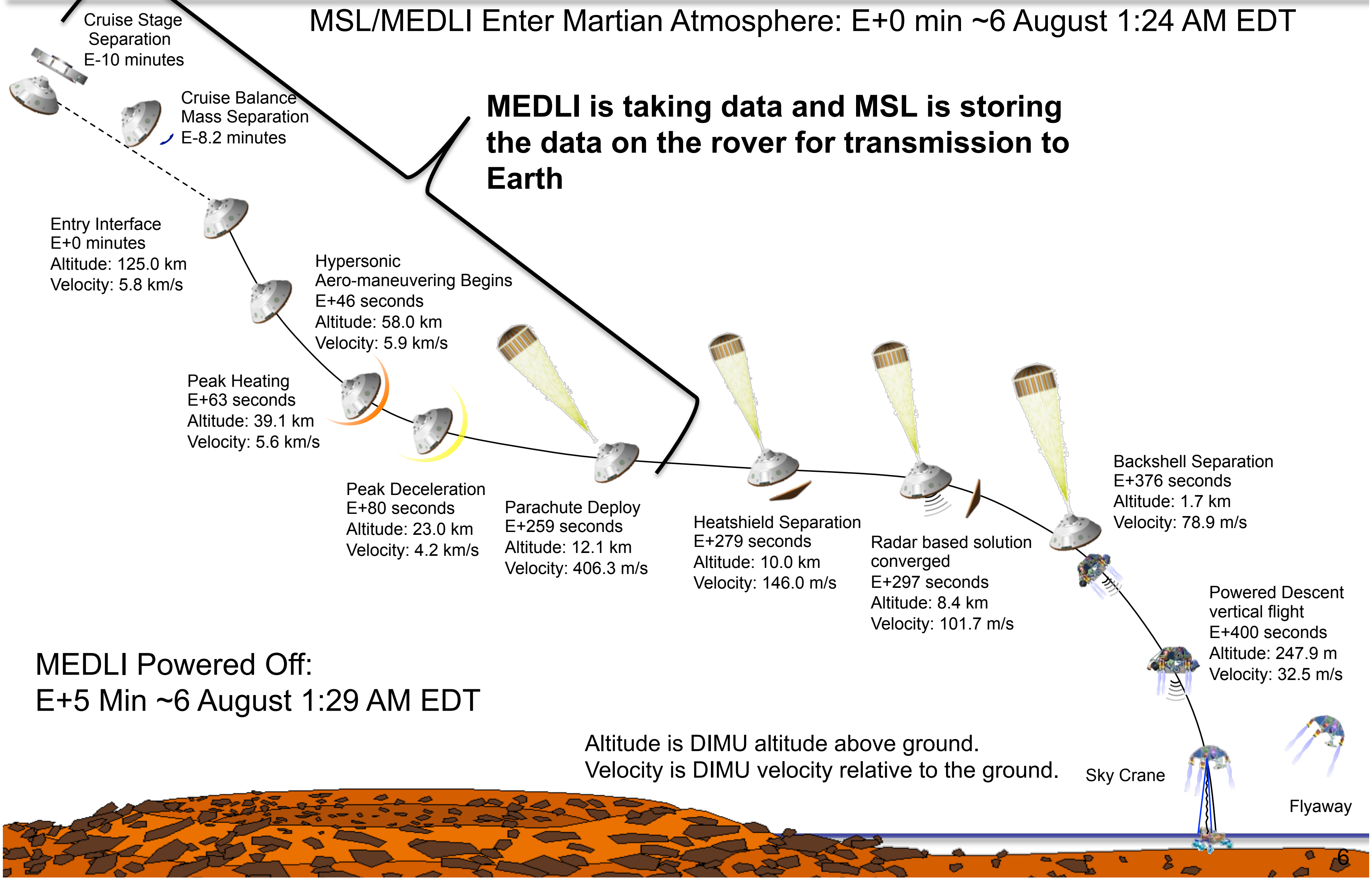
MSL Entry, Descent and Landing (EDL) Sequence

MSL/MEDLI Enter Martian Atmosphere: E+0 min ~6 August 1:24 AM EDT

MEDLI is taking data and MSL is storing the data on the rover for transmission to Earth

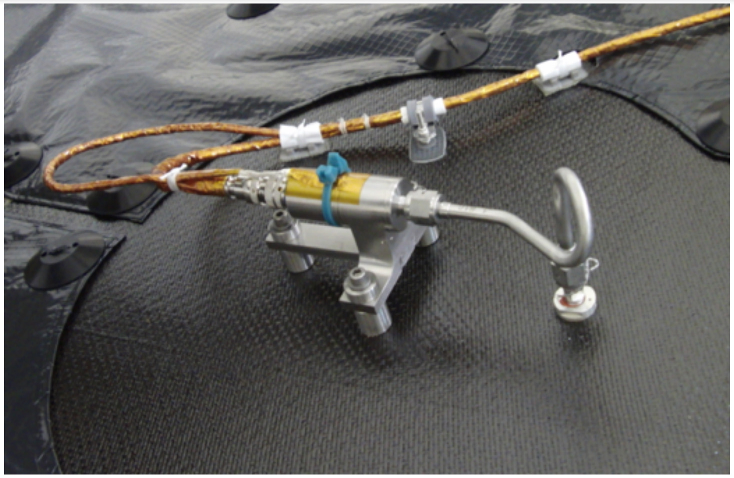


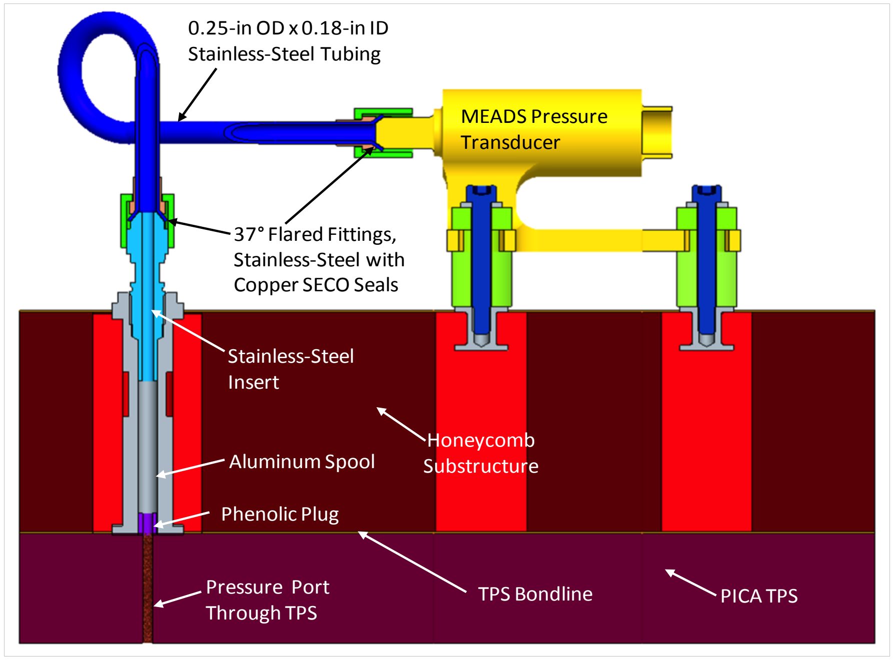
MEDLI Powered Off:
E+5 Min ~6 August 1:29 AM EDT

Altitude is DIMU altitude above ground.
Velocity is DIMU velocity relative to the ground.

Mars Entry Atmospheric Data System (MEADS)

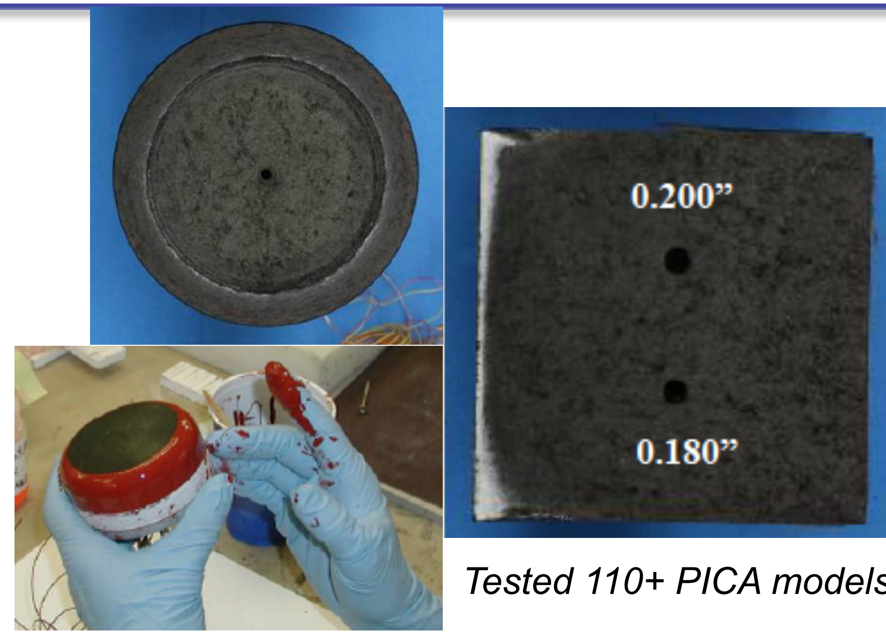
- Modified off-the-shelf transducers from Stellar Technologies, Inc. (STI)
- Diaphragm-type transducers with 0.5% full scale repeatability
- ~305 grams, 0-10 mV output, 0-5 psia
- Data is sampled at 8 Hz from entry interface to heatshield separation
- Transducer heads are located near pressure taps to minimize lag
- Electronics located within dedicated Sensor Support Electronics (SSE) box due to low temperatures during cruise



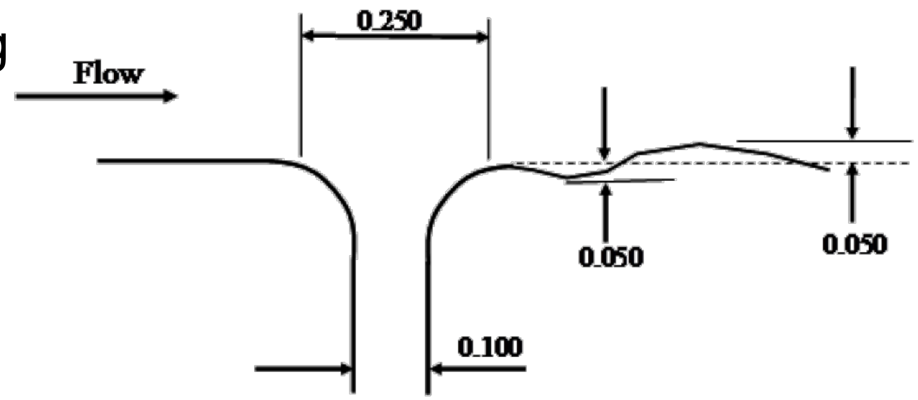


MEADS: Arcjet Testing

- Unknown at outset whether a port could survive in ablating TPS
- Developmental arcjet testing in SLA, then PICA, at Boeing Large Core Arc Tunnel (LCAT)
- Investigated port sizes from 0.05” to 0.2”, with sleeve/liner and without
- Active pressure measurements during arcjet test to show data quality
- Established shear post-test port and surface shape as qualification criteria
- Qualification included stagnation and shear

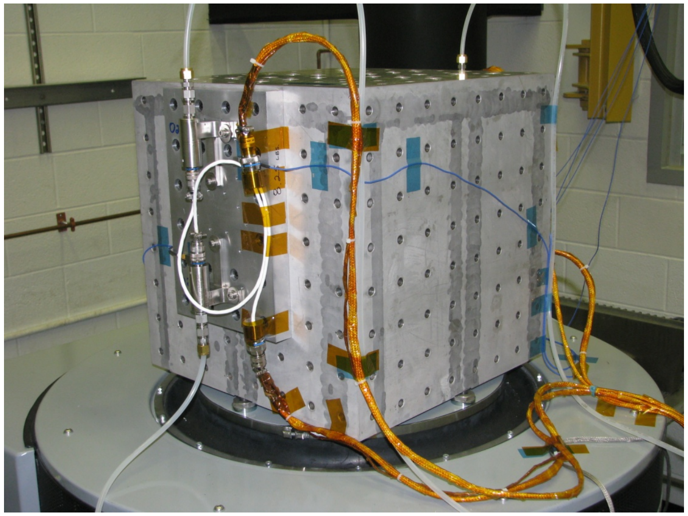


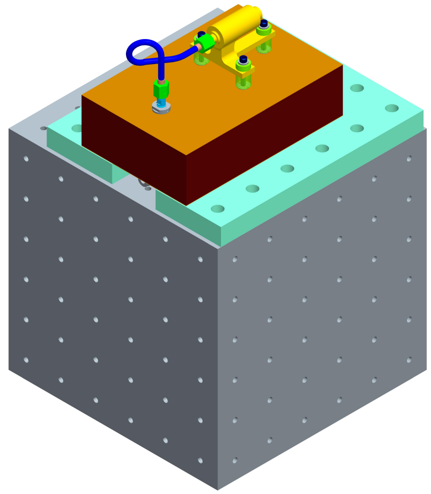
Tested 110+ PICA models

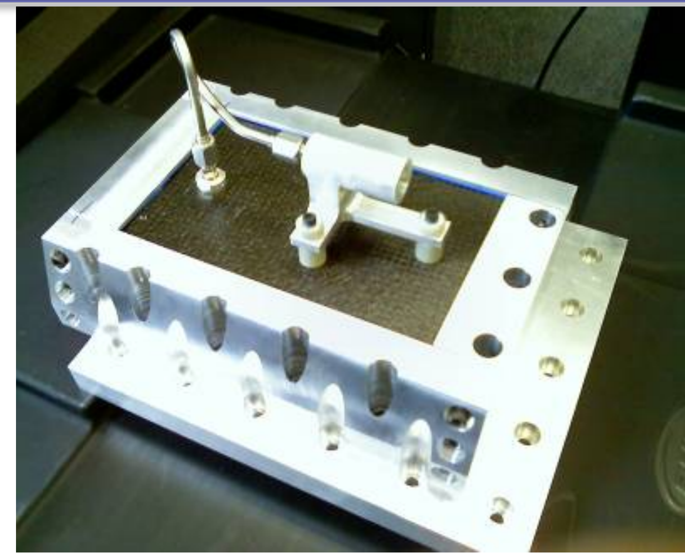


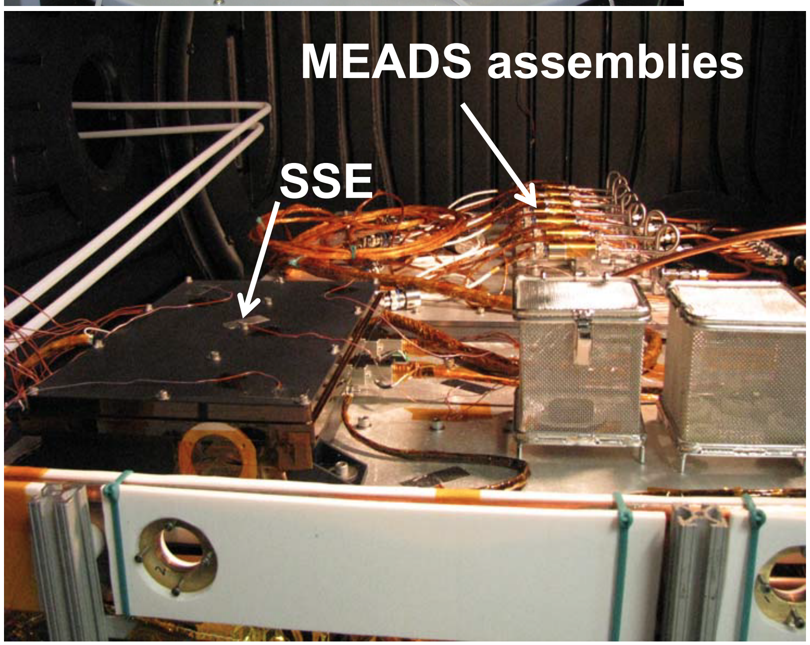
Shear port shape criteria, dimensions in inches

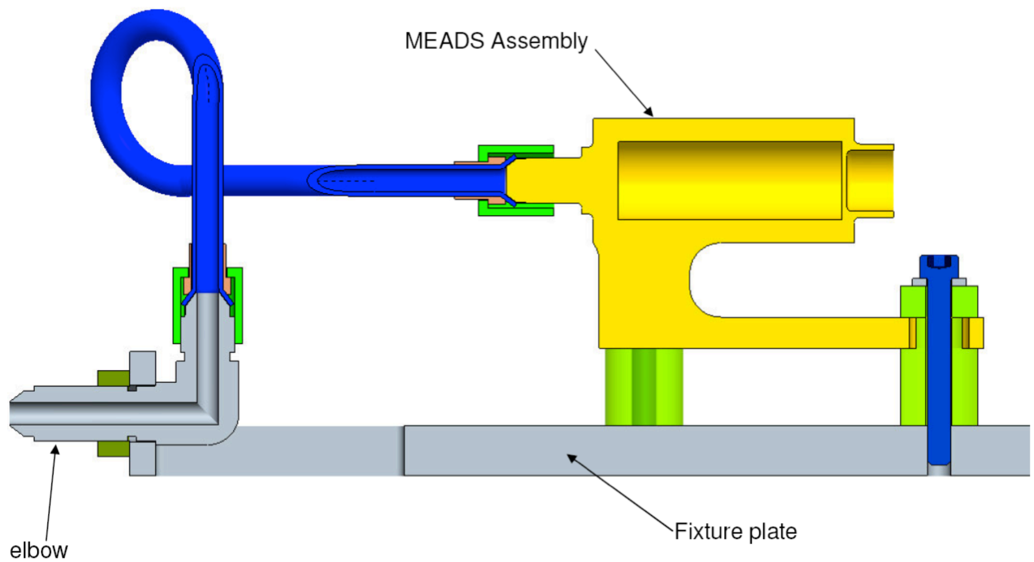
MEADS: Unique Hardware Testing



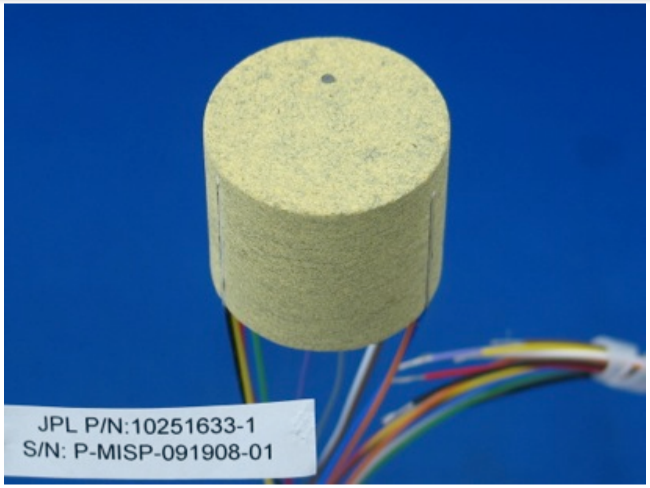




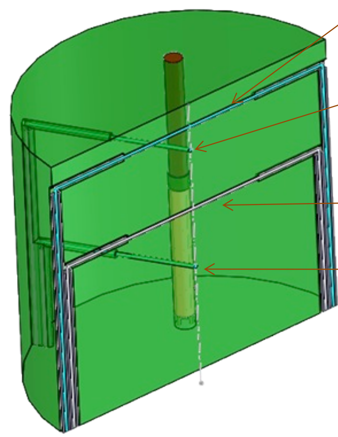




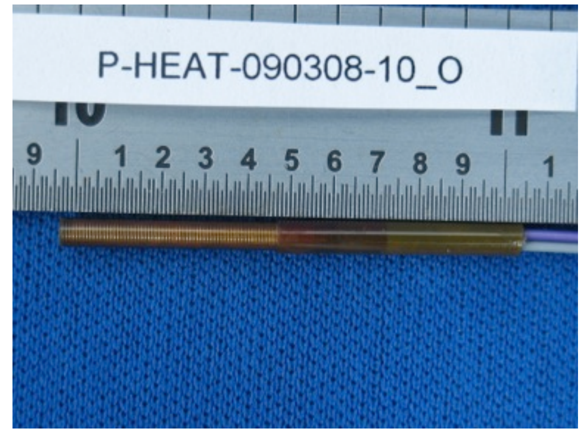
MEDLI Integrated Sensor Plug (MISP)



MISP PICA Plug



MISP Plug Cross Section

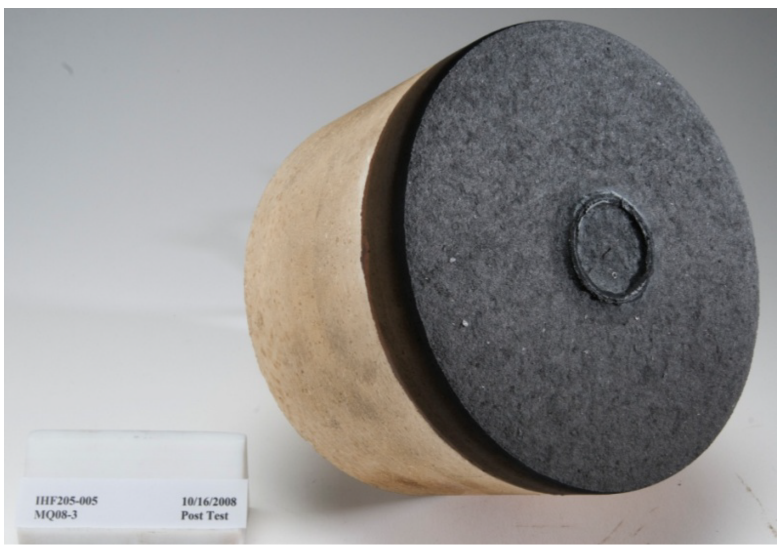


HEAT Sensor

- Each plug is 1.3" diameter by 1.14" long PICA cylinder
- Each plug contains
  - 4 Type-K thermocouples (TCs)
  - One Hollow aErothermal Ablation Temperature (HEAT) sensor designed to track ablation process through the thickness
- The four thermocouples nominally installed at depths of 0.1", 0.2", 0.45", and 0.7" from the top surface

MISP: Arcjet Testing

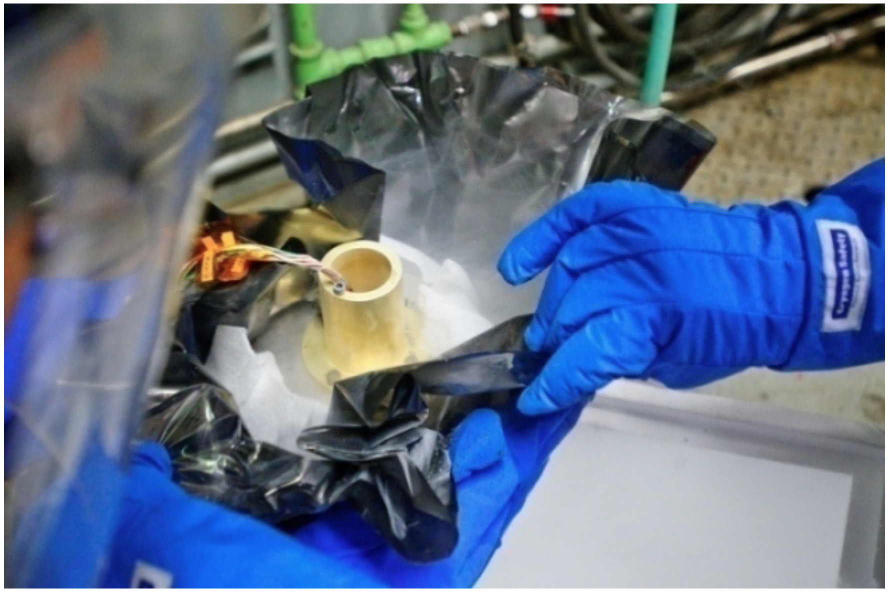
- Conducted stagnation and shear
- Qualification: 6" models with aeroshell structure included
- Constructed and integrated with flight materials and processes

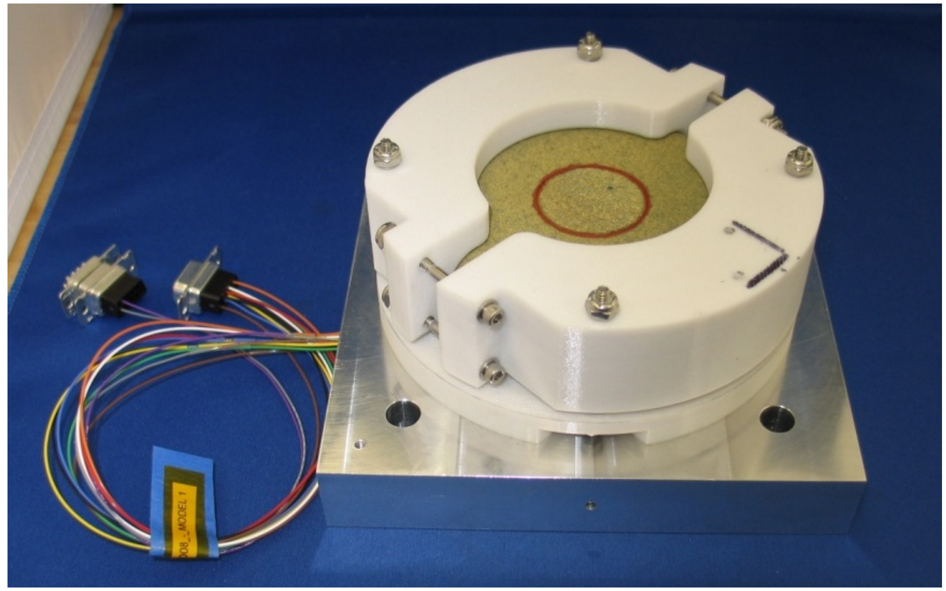


82 W/cm^2, 0.33 Pa

270 W/cm^2, 0.27 Pa

MISP: Environmental Testing

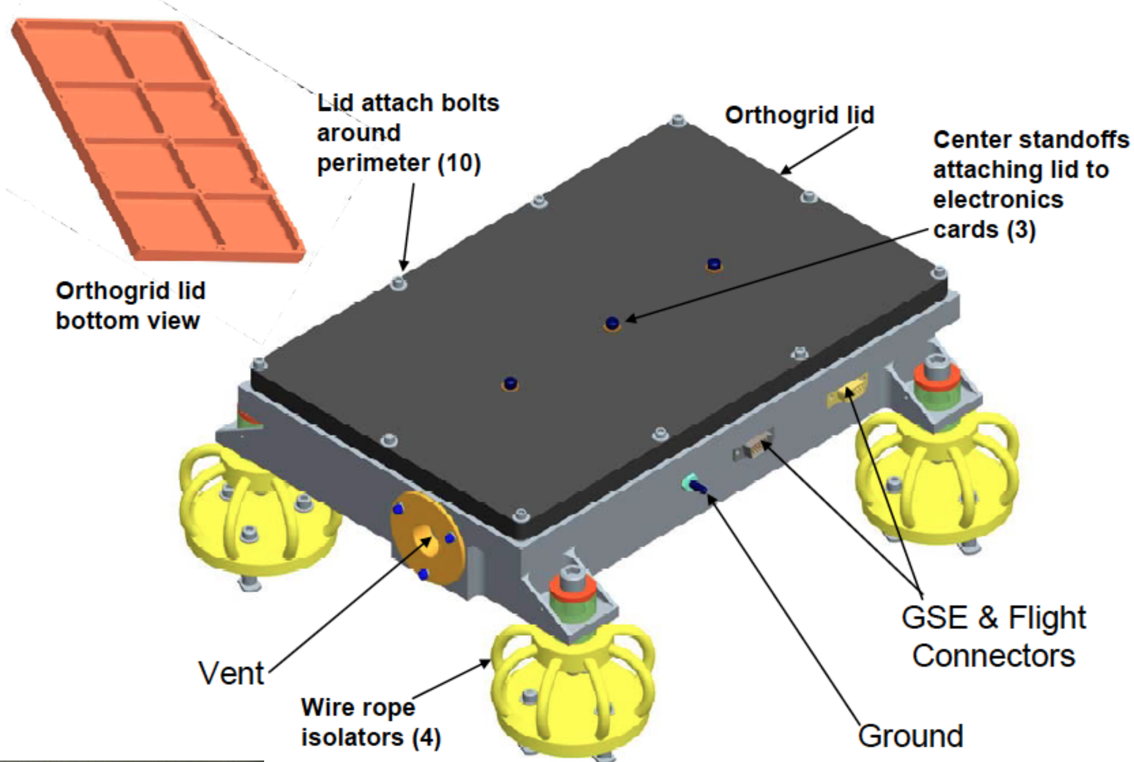


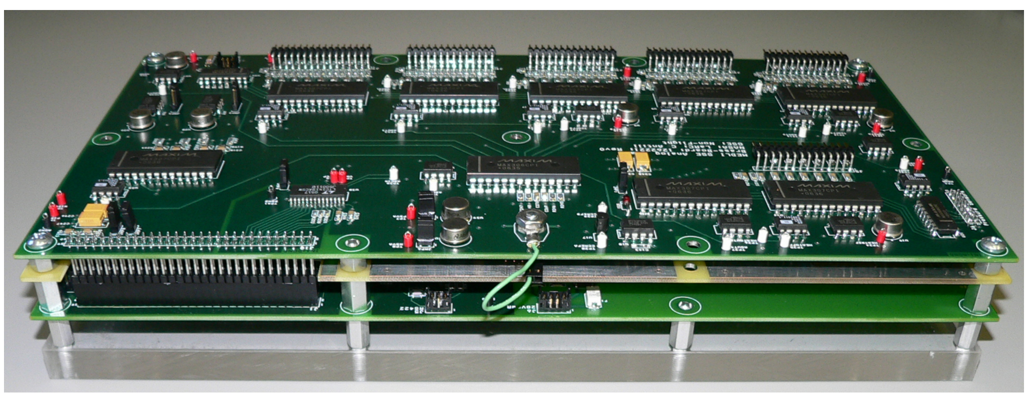


- Arcjet samples cold-soaked in liquid nitrogen to simulate cruise
- Pyroshock and vibration testing required unique fixture to simulate flight boundary conditions

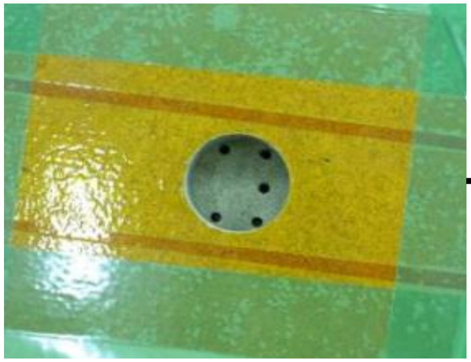
SSE: Sensor Support Electronics

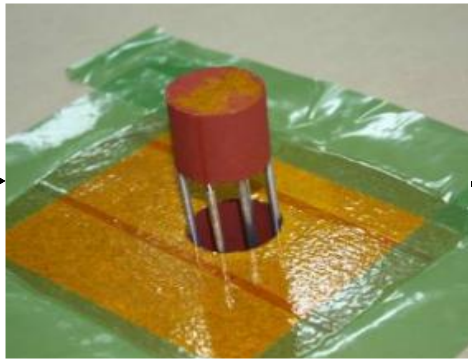
- Contains analog, digital, and shield boards
- Placed under MMRTG to stay warm during cruise
- Mounted on wire rope isolators to attenuate launch vibration loads
- Powers MISP and MEADS, sends MEDLI data to rover compute element (RCE)

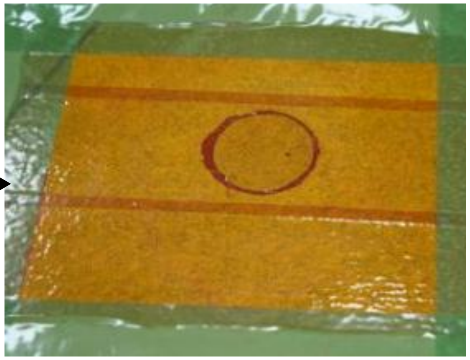


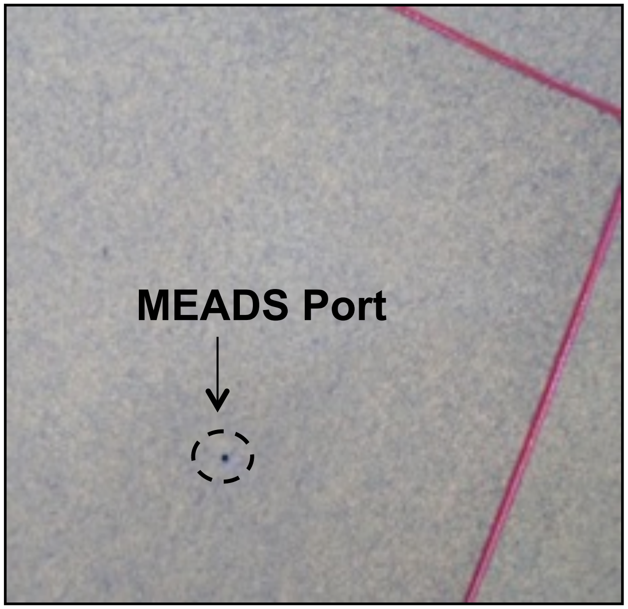


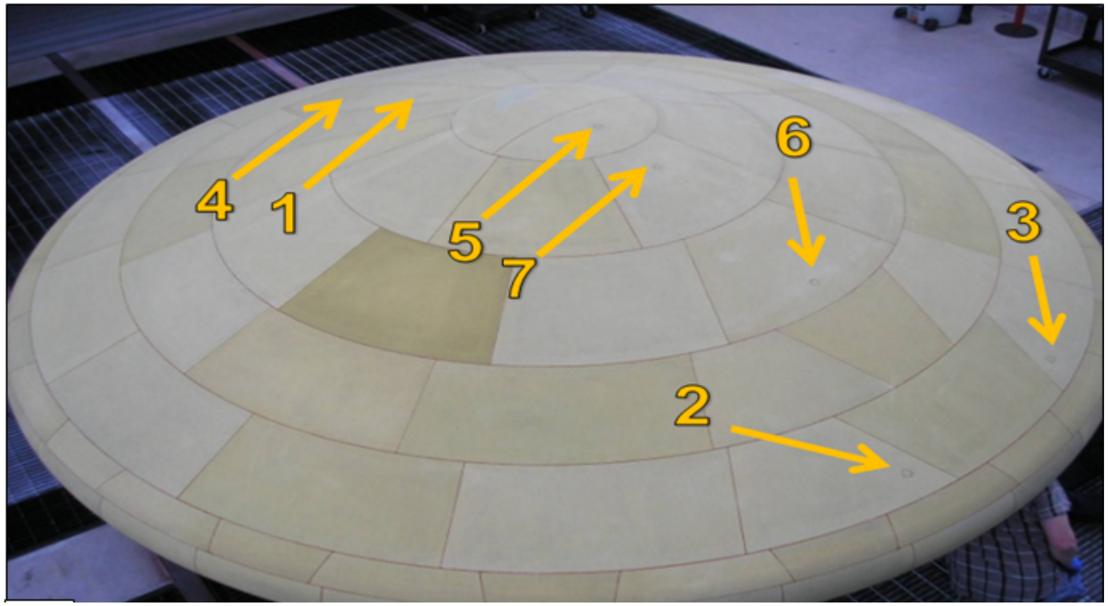
MEDLI: Integration





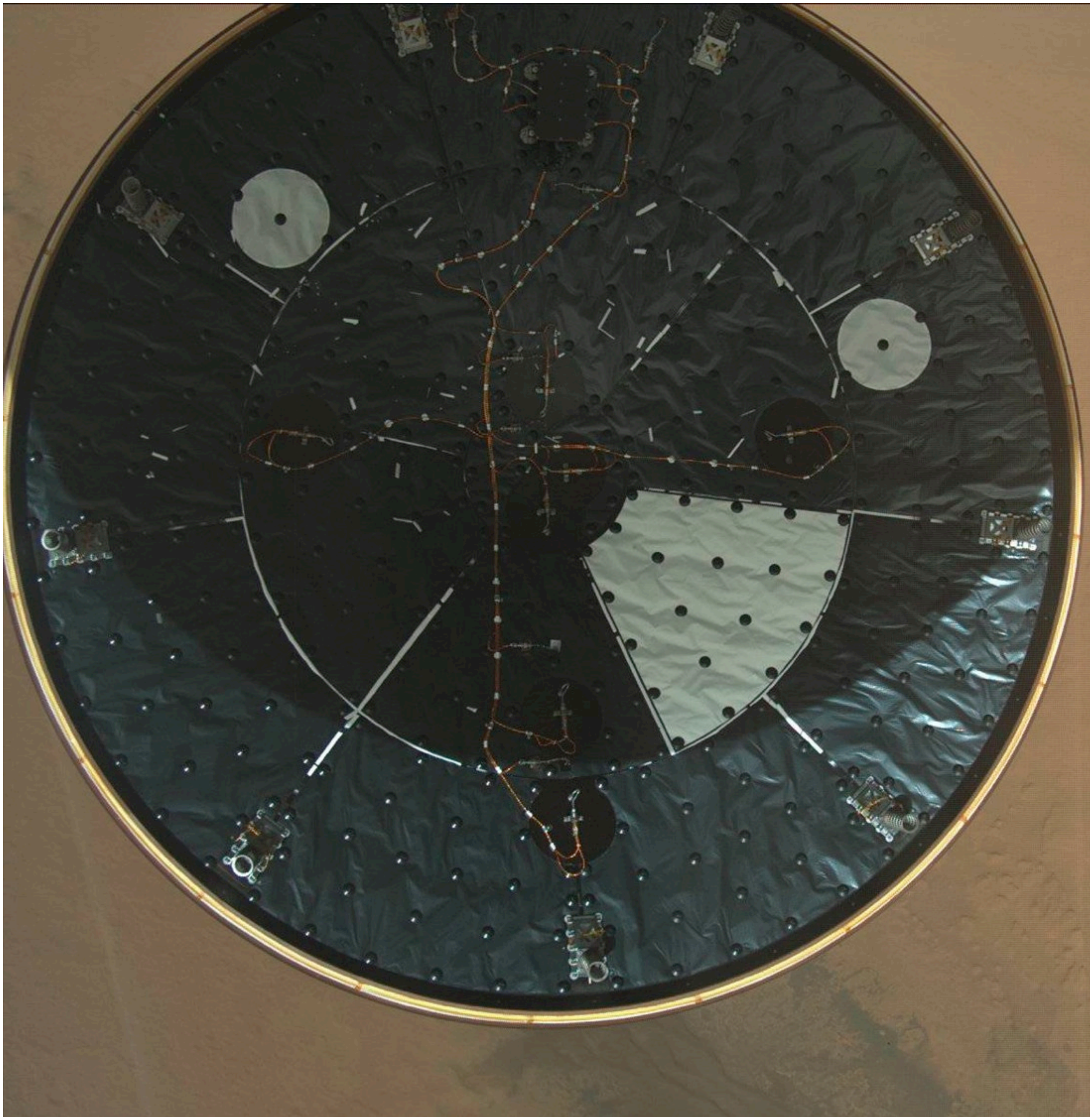






Summary

- The MEDLI instrumentation made MSL the first extensively instrumented heatshield ever sent to Mars
- The MEDLI hardware development was challenging due to the environments it had to withstand
  - Heavy launch vibration
  - Extreme cold during cruise
  - Entry heating environment
- A unique collaboration between NASA mission directorates, NASA centers, and industry partners made MEDLI an unqualified success
- Ultimately, the MEDLI hardware was designed, built and tested to achieve the two fundamental objectives:
  1) Do no harm to MSL
  2) Return high-quality data



Thanks to the entire MEDLI team!

Backup

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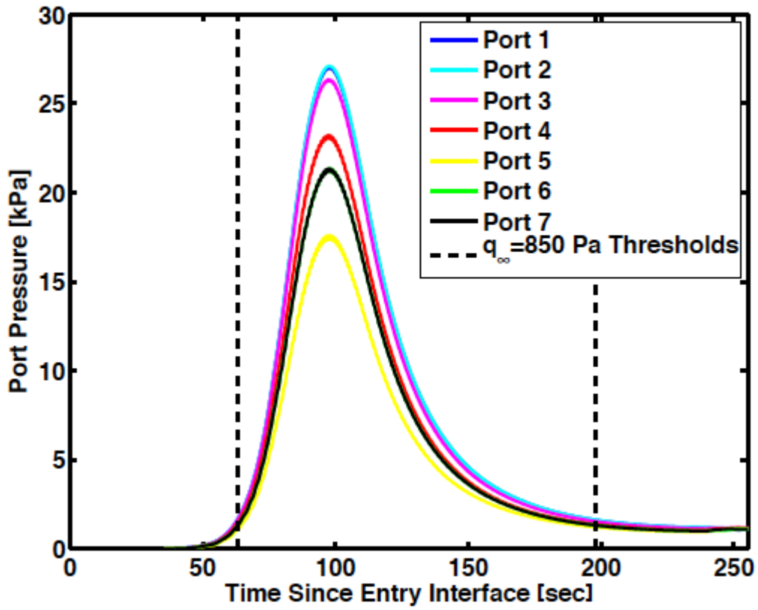

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