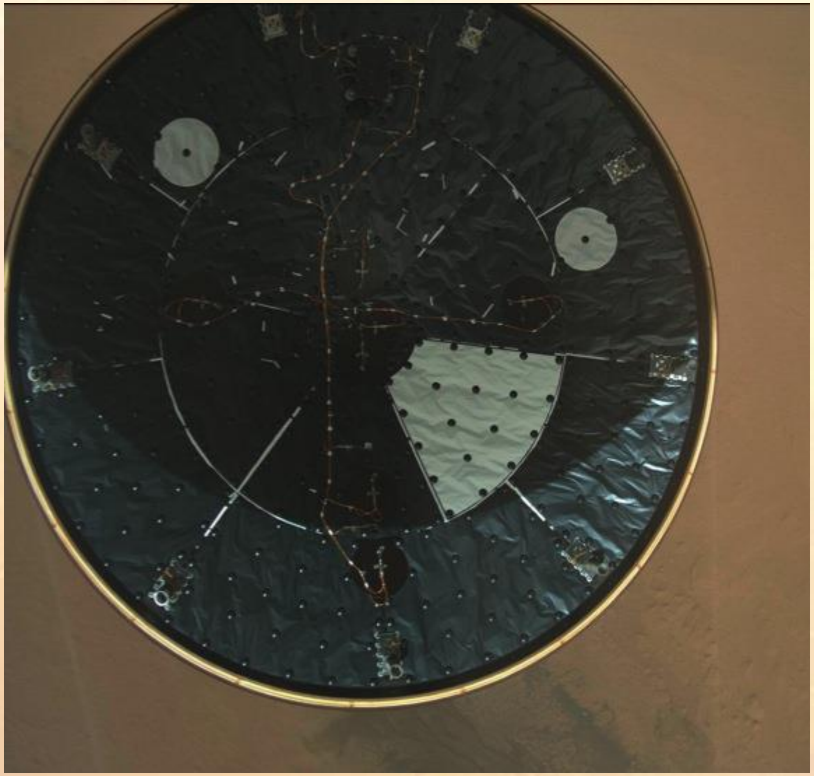


Mars2020 Entry, Descent, and Landing Instrumentation 2 (MEDLI2) Do No Harm Test Series

IPPW 14
June 12 - 16th, 2017

Greg Swanson – AMA Incorporated @ NASA ARC

Jose Santos – Sierra Lobo @ NASA ARC

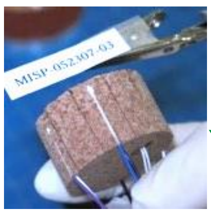
Todd White – NASA ARC

Walt Bruce, Chris Kuhl, Henry Wright – NASA LaRC

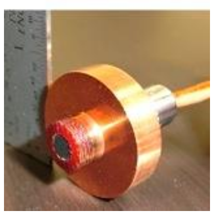
MEDLI2 Instrumentation Summary

MEDLI2 complements and extends the measurements of MEDLI on the Mars Science Laboratory (MSL) with additional heatshield observation locations, inclusion of supersonic aerodynamics, and backshell aerothermal and pressure observations.

6 MEDLI2 Instrumented Sensor Plug (**MISP**)
- 5 Plugs: 1 TC
- 1 Plug: 2 TCs

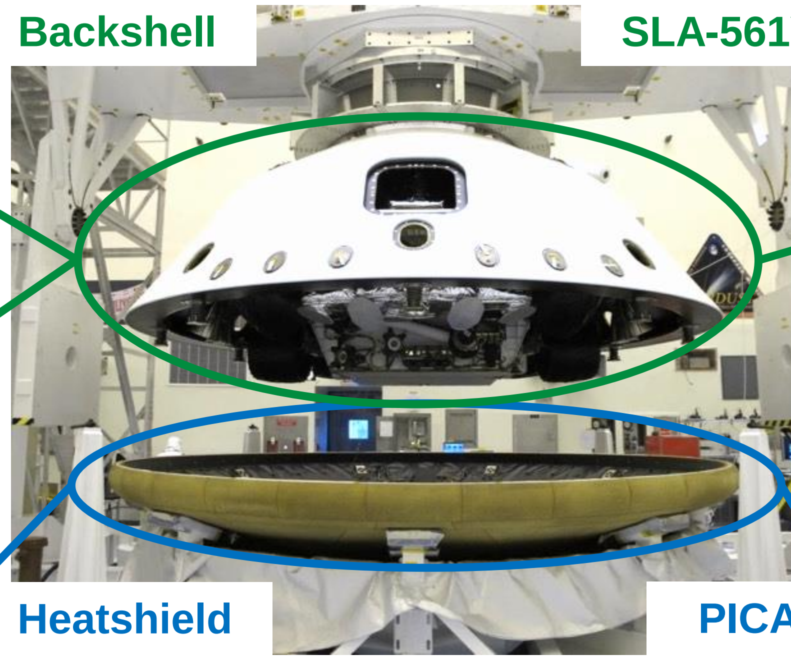


3 Heat Flux Sensors
- 2 Total
- 1 Radiative



11 MISP
- 3 Plugs: 3 TCs
- 8 Plugs: 1 TC

Backshell **SLA-561V**



Heatshield **PICA**

Mars2020 is a MSL Build-to-Print Aeroshell

Mars Entry Atmospheric Data System (**MEADS**)
- One Base Pressure Transducer (PT)

MEADS
- 1 PT for Hypersonic
- 6 PTs for Supersonic

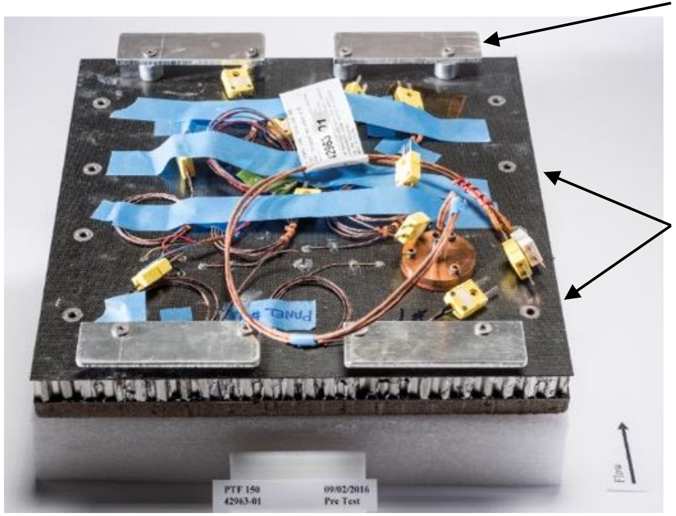
Scope of Do No Harm (DNH) Testing

Accommodation of MEDLI2 sensors requires modifications to the Mars 2020 TPS

- **DNH testing ensured:**
  - TPS Performance degradation due to the sensor integration is minimized (or prevented)
  - TPS Performance changes (if any) are characterized
  - TPS failures are prevented
- **MEDLI2 DNH Testing included:**
  - Environmental testing (vibe, shock, t/vac) of the DNH panels
  - Bounding aerothermal (arc jet) testing of the DNH panels
  - Associated pre- and post-test inspections & associated analysis
- **MEDLI2 DNH Testing covered *only new backshell instrumentation (SLA-561V)***
  - MEDLI2 relied on earlier MEDLI/MSL testing as the basis of heatshield (PICA) DNH efforts
  - MEDLI2 will perform arc jet and environmental testing for the heatshield components later in the project life cycle as part of the normal flight lot TPS accommodation certification
  - MEDLI2 DNH Testing does not include the environmental testing of the backshell mounted pressure transducer –this will be performed separately

DNH Test Panel Design

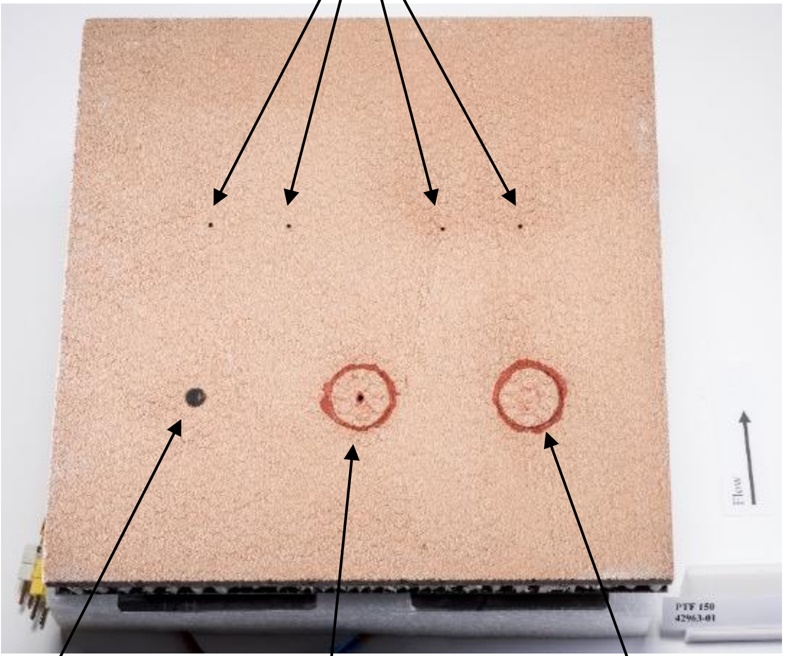
- Four 12” x 12” SLA-561V Panel with Substructure
- Installed additional Thermocouples (TCs) at the bondline and backface after environmental testing for arc jet testing
- The four pressure port holes were located in specific proximities to the SLA-561V flexcore to examine the effect of the flexcore on the port hole (if any)
- The MEADS port plug was a mitigation concept if any issues were seen with port hole proximity to the flexcore



Tabs For Arc Jet Mounting

Threaded Inserts for Mounting During Testing

Four Pressure Port Holes



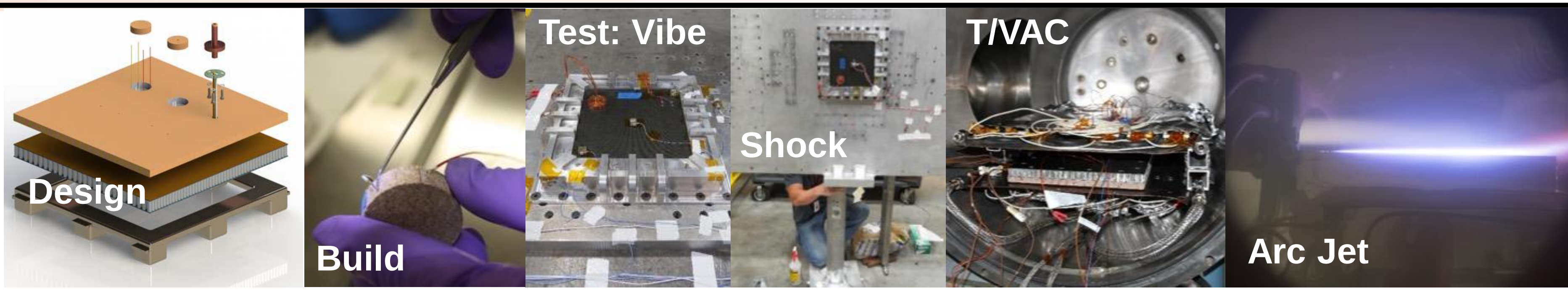
One Heat Flux Sensor

One MEADS port plug

One MISP (2 TCs)

*All pressure ports are blind holes in the TPS, no active pressure measurements are present

Do No Harm Test Series Sequence



➢ MEDLI2's Overall DNH Approach

- Build / procure flight-like backshell instrumentation
- Have Lockheed Martin develop and demonstrate backshell sensor integration on four flight-like TPS/substructure panels
- Expose the integrated panels to Mars 2020 qualification level environments (loads and durations)
- Expose the environmentally tested panels to worst-case simulated aeroheating in an arc jet
- Inspect and document the panels between each of the above tests
- One of four panels used as a control for the environmental testing

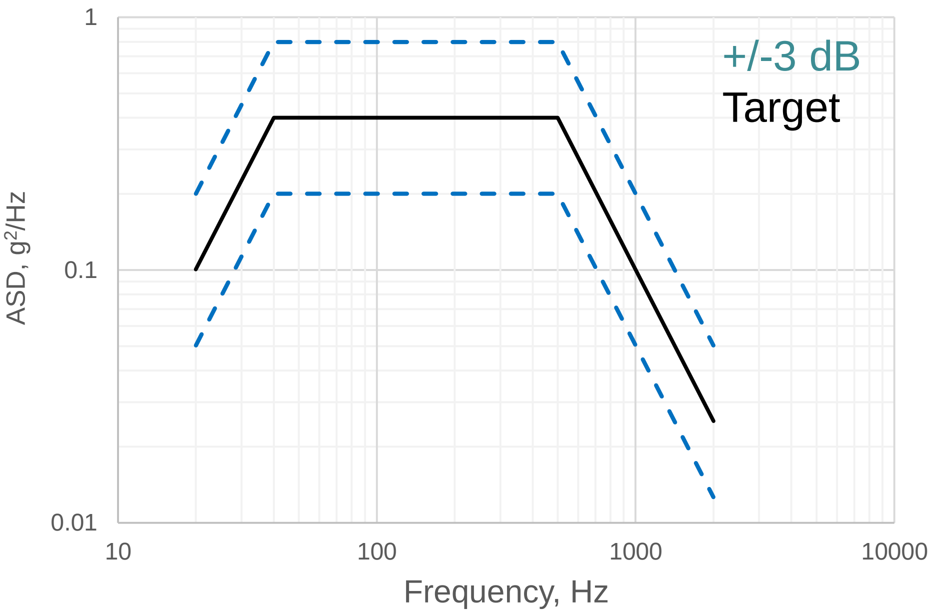
Random Vibration Test Specifications

The acceleration spectral density (ASD) test levels for random vibration testing are taken from the Mars2020 Environmental Requirements Document and are detailed in "Qualification/Protoflight level" column below.

Vibrational Loads are derived from the expected Atlas V launch environment

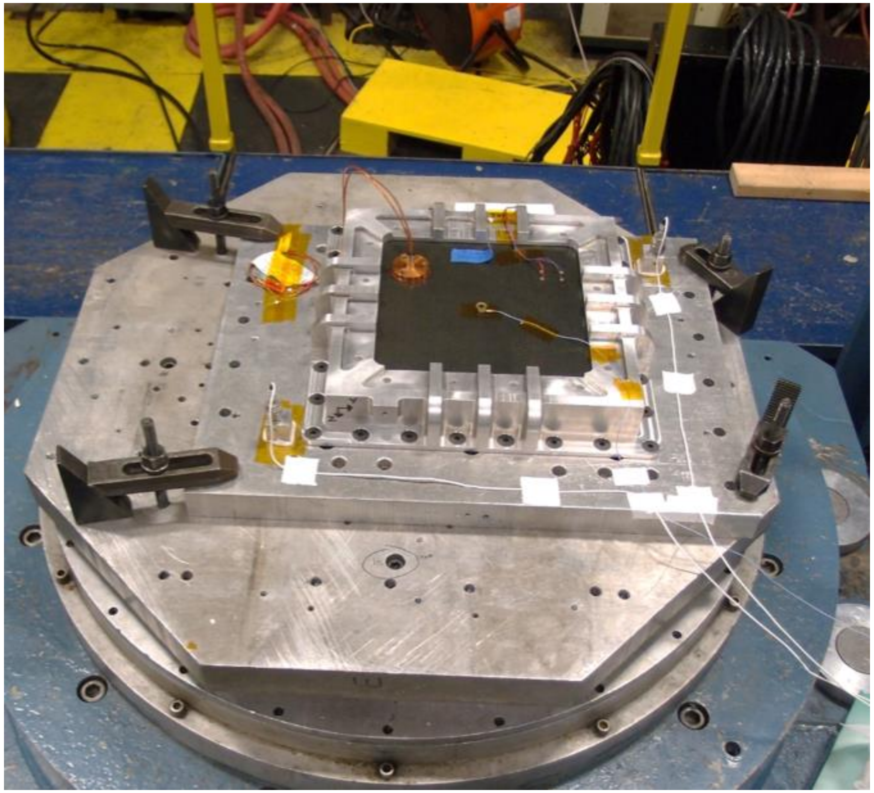
Launch Random Vibration Profile		
Frequency (Hz)	Flight Acceptance Level	Qualification/ Protoflight Level
20-40	+ 6 dB/oct	+ 6 dB/oct
40-500	0.2 g2/Hz	0.4 g2/Hz
500-2000	- 6 dB/oct	- 6 dB/oct
Overall	13.0 grms	18.4 grms

<u>Overall Limits</u>	
Target:	18.4 grms
+1dB:	*23 grms*
-1dB:	*14.65 grms*



- Test in all 3-axes, two minutes per axis
- The ASD shall be within ±3 dB over the 20-2000 Hz
- Overall spectrum level shall be within ±1 dB of the specified rms level

Random Vibration Test Setup



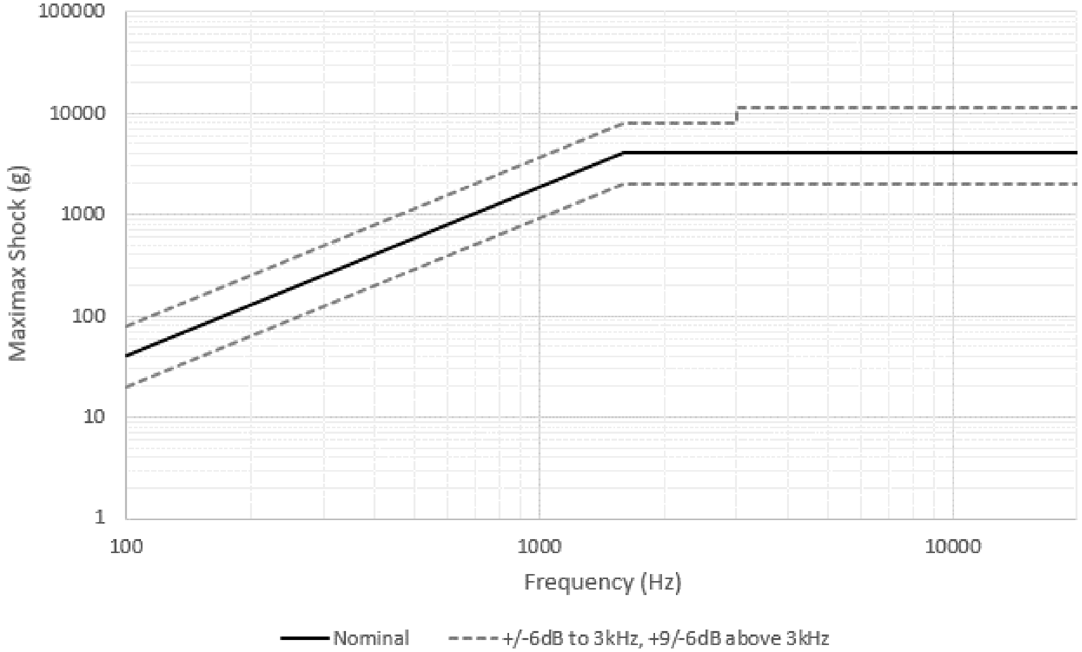
Z-Axis Setup

X-, Y-Axis Setup

Shock Test Specifications

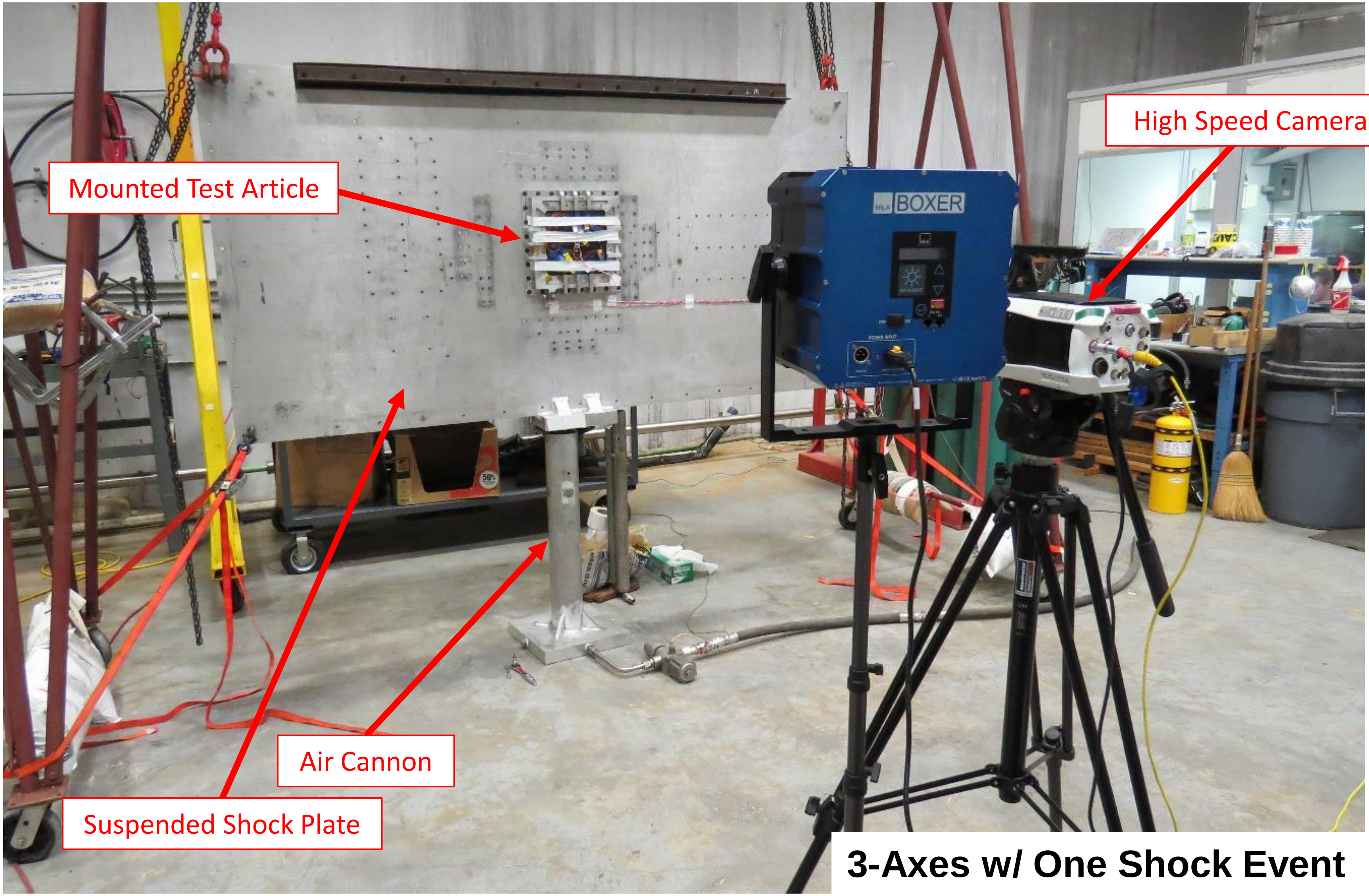
Shock loads are derived from the expected load of the ballast mass jettison event since many of the sensors are in close proximity

Frequency (Hz)	Level
100	40 g
100 - 1600	+10 dB/oct
1600 – 10000	4000 g



- Tolerance bands of +/- 6 dB to 3000 Hz, and +9/-6 dB above 3000 Hz
- At least 50% of the maximum spectrum values shall exceed the nominal
- Shock pulse should decay to less than 10% of its peak value within 20ms
- All 3-axes (x, y, and z) must be shocked, two shock per axis

Shock Test Setup



3-Axes w/ One Shock Event

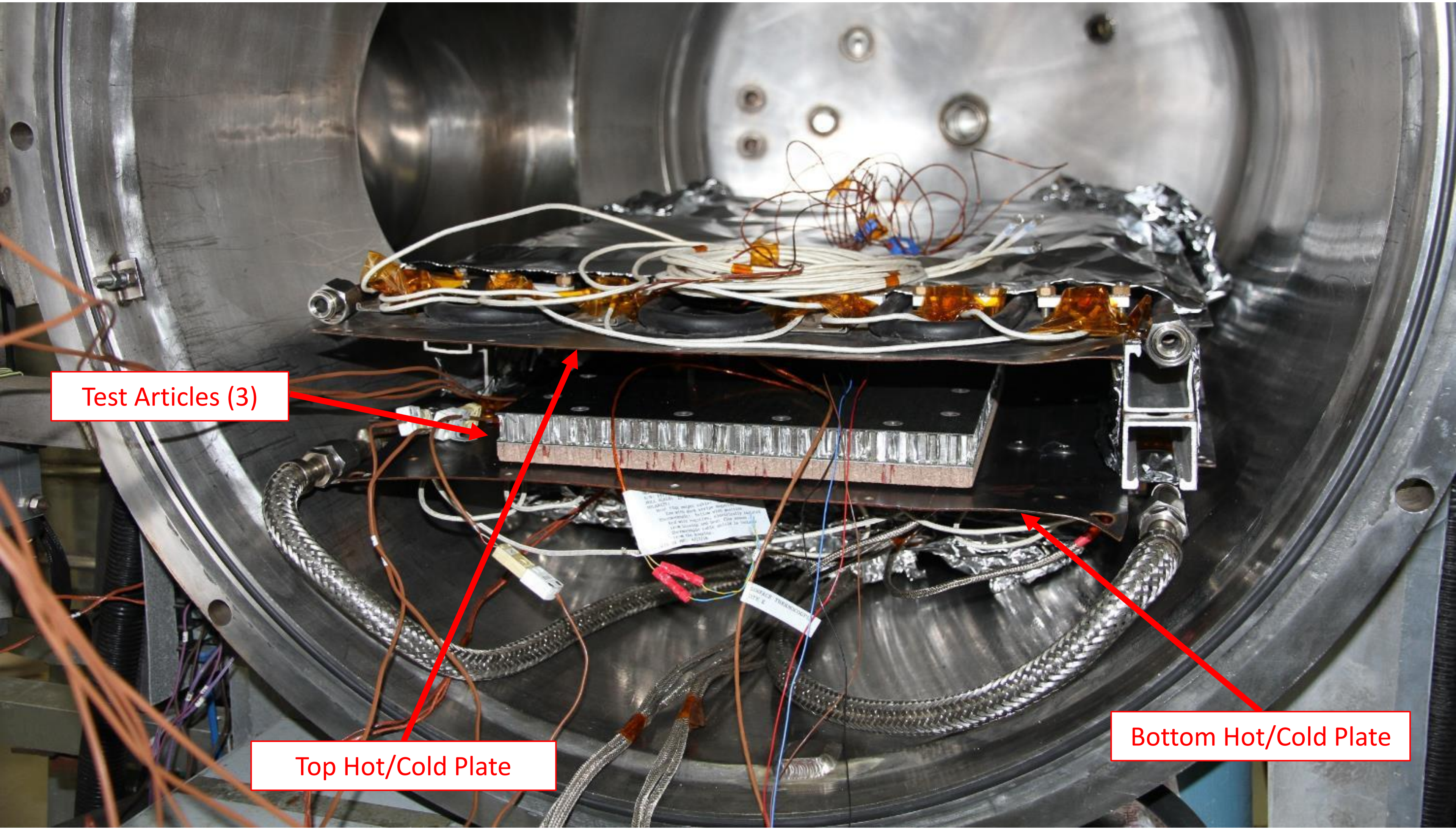
Thermal Vacuum Test Specifications

Thermal loads are derived from the expected backshell worst case environments during the cruise phase

Condition No.	Phase	Target Temperature (°C)	Pressure (torr)	Dwell Time (minutes)
1	Check up	T_{room} +5 °C /- 0 °C	Ambient	60
2	Worst hot	+77 +/- 2 °C	<10^{-5} Torr	180
3	Worst cold	-140 +/- 2 °C	<10^{-5} Torr	180
4	Worst hot	+77 +/- 2 °C	<10^{-5} Torr	180
5	Worst cold	-140 +/- 2 °C	<10^{-5} Torr	180
6	Worst hot	+77 +/- 2 °C	<10^{-5} Torr	180
7	Worst cold	-140 +/- 2 °C	<10^{-5} Torr	180
8	Check up	T_{room} +5 °C /- 0 °C	<10^{-5} Torr	60
9	Back fill	T_{room} +5 °C /- 0 °C	Ambient	-

- Test to be performed as specified in the table above
- Temperature ramp rate must be less than or equal to 5°C per minute when transitioning between test conditions
- Dwell time does not begin until all conditions are correct

Thermal Vacuum Test Setup



PTF 150 Arc Jet Test

- **DNH PTF arc jet test was performed Sept 2016 after completion of all the environmental testing**
- **Arc Jet Test Objectives:**
  1. Demonstrate that the presence of the pressure ports through the TPS do not result in unacceptable degradation of the surrounding TPS.
  2. Demonstrate that the presence of the pressure ports through the TPS do not results in TPS to backshell structure bond line exceeding maximum allowable temperatures
  3. Demonstrate that the presence of the MISPs in the TPS do not result in unacceptable degradation of the surrounding TPS.
  4. Demonstrate that the presence of the MISPs in the TPS do not result in the TPS to backshell structure bondline exceeding their specified maximum allowable temperatures
  5. Demonstrate that the presence of the heat flux sensors in the backshell TPS do not result in unacceptable degradation of the surrounding TPS.
  6. Demonstrate that the presence of the heat flux sensors in the backshell TPS do not result in the TPS to backshell structure bondline exceeding their specified maximum allowable temperatures

Arc Jet Test Matrix

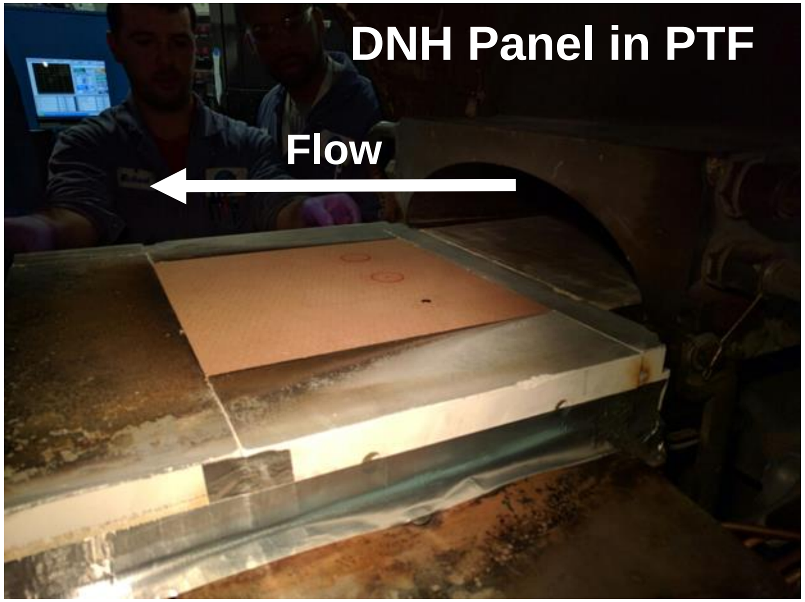
Run, Panel	Environmental Test			Target Arc Jet Conditions			
	Shock	Vibe	TVac	LN_2 Cold Soak	Heat Flux (W/cm^2)	Exposure (sec)	Pressure (kPa)
Run 1 Panel 2	Y	Y	Y	N	8.2	110	*Best Effort*
Run 2 Panel 3	Y	Y	Y	Y	21.0	43	0.86
Run 3 Panel 1	Y	Y	Y	Y	21.0	43	0.86
Run 4 Panel 4	N	N	N	N	8.2	110	*Best Effort*

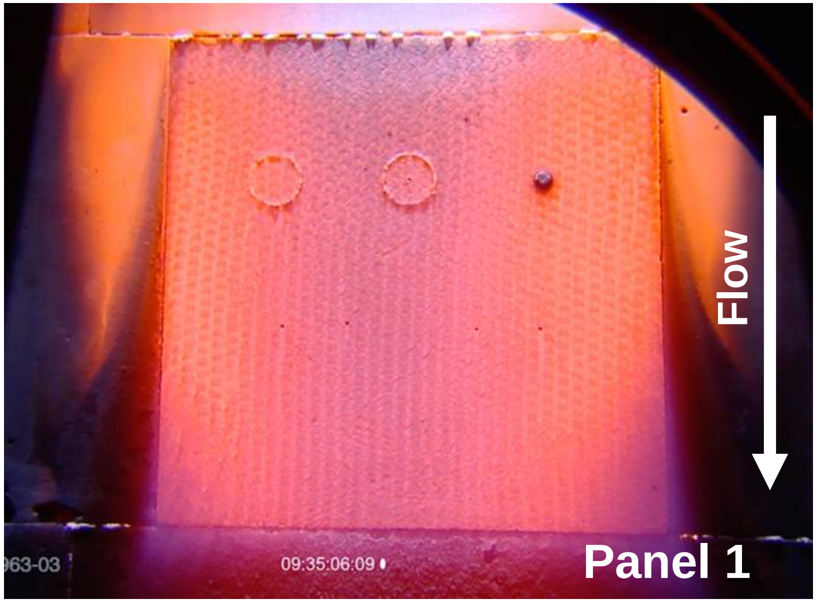
- **Two calibration runs (180 & 181) on August 30-31.**
- **Model runs were performed on September 6-8.**

Cold Soak Performed Immediately Prior to Arc Jet Test providing Thermal Shock

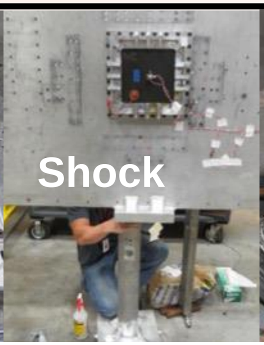
Do No Harm Arc Jet Summary

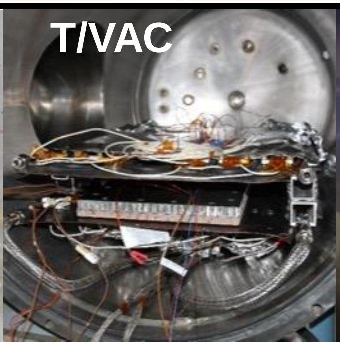
- MEDLI2 met targeted aerothermal test conditions (heatflux, heatload, pressure & shear) in the Ames Panel Test Facility (PTF)
- Inspection and analysis of test articles confirmed that MISP, pressure ports, and Heat Flux sensors did not cause degradation of the surrounding TPS
  - Laser scans show surface features at the sensor locations are all much less than 0.050”
  - All IML and bondline temperatures stayed below 150°C
- No observable difference between panels (Panels 1-3) and the control (Panel 4)



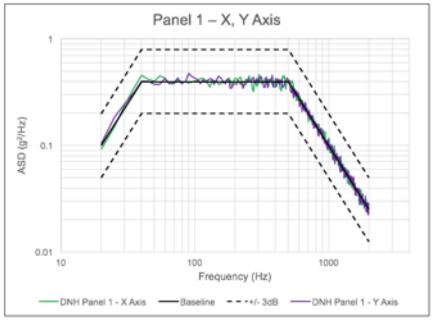


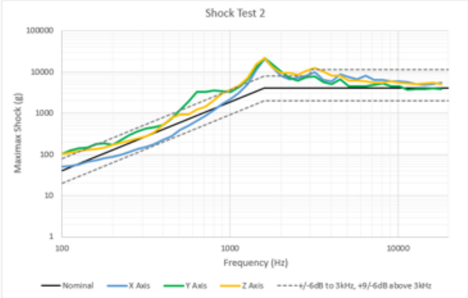
Do No Harm Test Data Products



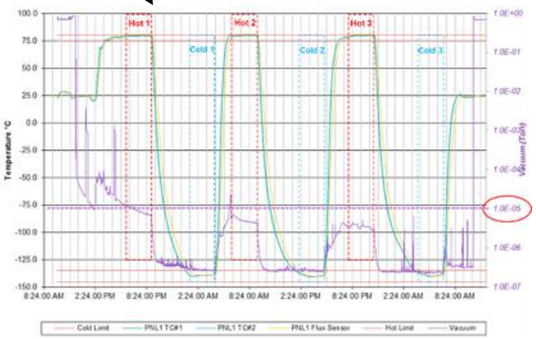


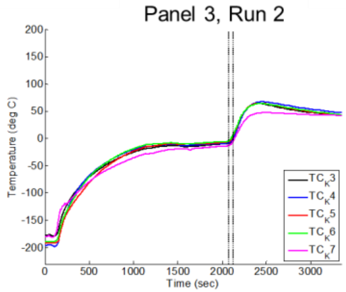
	Overall 18.4 grms +/-1 dB	ASD Profile +/- 3dB	Duration 2 mins per Axis
Panel 1, Z-axis	85.5 grms (overtest)	Overtest at 1k &1.6kHz	2 mins
Panel 2, Z-axis	19.0 grms	Overtest at 1k &1.6kHz	2 mins
Panel 3, Z-axis	18.9 grms	Overtest at 1k &1.6kHz	2 mins
Panel 1, X-axis	18.4 grms	Within Limits	2 mins
Panel 1, Y-axis	18.3 grms	Within Limits	2 mins
Panel 2, X-axis	18.4 grms	Within Limits	2 mins
Panel 2, Y-axis	18.4 grms	Within Limits	2 mins
Panel 3, X-axis	18.5 grms	Within Limits	2 mins
Panel 3, Y-axis	18.5 grms	Within Limits	2 mins

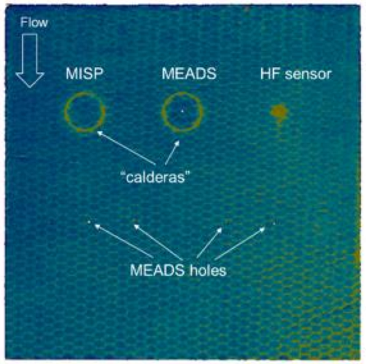


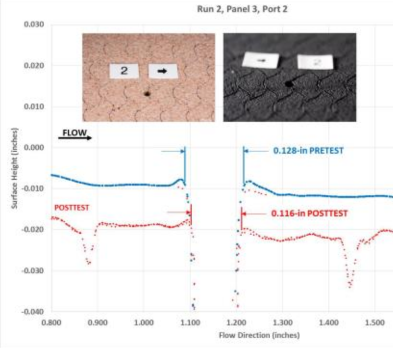


	Shock Above Min			% Over Nominal			10% Decay Time		
	X-Axis	Y-Axis	Z-Axis	X-Axis	Y-Axis	Z-Axis	X-Axis	Y-Axis	Z-Axis
Panel 1, Shock 1	Yes	No	No	100%	17%	63%	21ms	15ms	15ms
Panel 1, Shock 2	Yes	Yes	Yes	63%	89%	100%	17ms	18ms	18ms
Panel 1, Shock 3	Yes	Yes	Yes	63%	100%	98%	15ms	17ms	18ms
Panel 2, Shock 4	Yes	Yes	Yes	61%	87%	76%	19ms	18ms	17ms
Panel 2, Shock 5	Yes	Yes	Yes	72%	85%	74%	19ms	24ms	19ms
Panel 3, Shock 6	Yes	Yes	Yes	61%	89%	91%	18ms	20ms	19ms
Panel 3, Shock 7	Yes	Yes	Yes	63%	96%	89%	17ms	17ms	16ms









DNH Test Summary and Lessons Learned

Test Series Summary

- MEDLI2 project built and procured flight-like instrumentation
  - Ames built MISP, and Heat Flux sensors were procured from outside vendor
- Lockheed Martin developed and exercised integration procedures on four test panels
- MEDLI2 successfully tested 3 of 4 panels in environmental tests (vibe, shock, t/vac)
  - New mechanical shock test approach was used to efficiently test all 3-axes with one shock event
- All 4 models successfully underwent arc jet testing
  - Two panels were thermally shock using a LN_2 bath prior to arc jet testing
- Overall panel and instrument Do No Harm performance was excellent
  - Pressure transducer port holes appear to be unaffected by proximity to SLA-561V cell walls
  - Laser scans show surface features at the sensor locations are all much less than 0.050"
  - All IML and bondline temperatures stayed below 150°C
- In addition to Do No Harm, science data was collected from sensors allowing investigation past Do No Harm requirements

BACKUP

MEDLI vs. MEDLI2 Science Payload

MEDLI on MSL (2012)

Heatshield

7 Pressure Transducers
- Hypersonic

7 Instrumented Plugs
- 4 TCs
- 1 Isotherm Sensor

Sensor Support Electronics Box

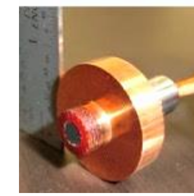
MEDLI2 on Mars2020

Backshell

1 Pressure Transducer
- Base Pressure

6 Instrumented Plugs
- 1 Plugs has 2 TCs
- 5 Plugs have 1 TC

3 Heat Flux Sensors
- 2 Total & 1 Radiative



Heatshield

7 Pressure Transducers
- 6 Supersonic
- 1 Hypersonic

11 Instrumented Plugs
- 3 Plugs have 3 TCs
- 8 Plugs have 1 TC

Sensor Support Electronics Box