LABORATORY-BASED THERMAL SHOCK INVESTIGATION OF HEAT FLUX SENSORS FOR THE MARS 2020 BACKSHELL.

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Brief Presenter Biography: Ruth Miller earned a PhD in Aeronautics and Astronautics from Stanford University. She is currently working as a Systems Engineer for AMA Inc. at NASA Ames Research Center in the Entry Systems and Vehicle Development Branch.

Abstract: In 2012 during the entry, descent, and landing of the Mars Science Laboratory (MSL), the MSL Entry, Descent, and Landing Instrumentation (MEDLI) sensor suite was collecting in-flight heatshield pressure and temperature data. The data collected by the MEDLI instruments has since been used for reconstruction of vehicle aerodynamics, atmospheric conditions, aerothermal heating, and Thermal Protection System (TPS) performance as well as material response model validation and refinement. The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) sensor suite for the Mars 2020 heatshield and backshell is being designed to expand on the measurements and knowledge gained from MEDLI. Similar to MEDLI, MEDLI2 will measure the pressure and temperature of the heatshield. MEDLI2 will additionally measure the temperature, pressure, total heat flux, and radiative heat flux on the backshell.

Since the backshell instrumentation is new to MEDLI2, Do No Harm (DNH) testing was conducted on instrumented backshell TPS (SLA-561V) panels [1]. The panels consisted of four pressure port holes, one Mars Entry Atmospheric Data System (MEADS) pressure port plug, one MEDLI2 Integrated Sensor Plug (MISP) thermal plug, and one heat flux sensor. DNH testing was conducted to ensure the performance of the TPS was not degraded due to sensor integration and to characterize any TPS performance changes. The testing consisted of environmental testing— vibration, shock, thermal vacuum (TVAC) cycling— and bounding aerothermal (arc jet) testing.

During arc jet testing, the heat flux sensors embedded in the SLA-561V panels exhibited an unexpected temporary reduction in the heat flux sensor temperature and response. After review of the test results, it was determined that this unexpected response was confined to the two heat flux sensors that experienced the greatest thermal shock condition. This condition consisted of a liquid nitrogen (LN_2) bath that induced temperatures of approximately -190°C, and then a transition (thermal shock) to an arc jet test at a heat rate of approximately 21 W/cm^2. Both heat flux sensors that were exposed to this thermal shock experienced a blister in the thermal coating (see Figure 1) during the arc jet test.

Two heat flux sensor thermal shock test series were performed to investigate the cause of the blistering and subsequent energy release. In these tests, the heat flux sensor was first cold soaked in either a dry ice or LN_2 bath to induce temperatures of approximately -78°C or -190°C, respectively. Then the sensors were thermally shocked using two propane torches with a heat rate of either approximately 8 W/cm^2 or 21 W/cm^2. The key findings indicated that there is a correlation between thermal shock and the blistering observed in the DNH test series, and that the cause appeared to be rooted in the heat flux sensor epoxy that encapsulates the sensor thermopile. Blistering was experienced after cold soaks of -78°C and -190°C and a heat rate of approximately 21 W/cm^2. However, blistering was not observed after cold soaks of -78°C and -190°C and exposure to heating at approximately 8 W/cm^2.

Since the heat flux sensors are required to measure heat fluxes up to 15 W/cm^2 during the Mars 2020 entry, a third test series was designed to determine if blistering is an issue at this maximum expected flight heat flux. The third test series used a linear actuator table to simulate a flight-like time-varying heat pulse as opposed to the square heat pulse used in the two previous test series. A schematic of the test setup is shown in Figure 2.

Results from all three thermal shock test series and a discussion about whether or not blistering of the heat flux sensor thermal coating could be an issue for the Mars 2020 mission will be presented.

References: [1] Swanson, G. T. et al., (2017) 14th IPPW, The Hague, Netherlands, June 12-16.

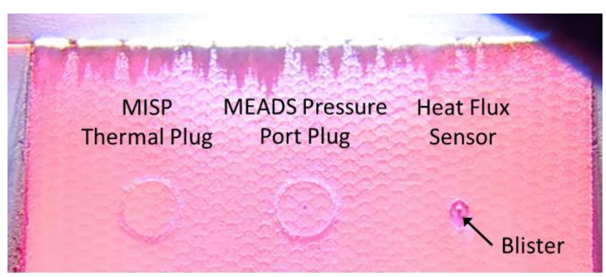

Figure 1. DNH backshell panel during arc jet testing.

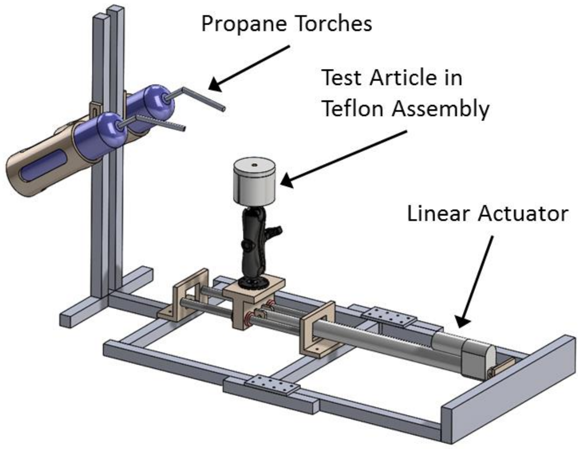

Figure 2. Test setup to expose a heat flux sensor to a time-varying thermal shock.