Abstract

In 2012, NASA's mission of landing the Mars Science Laboratory (MSL) on Mars was successful. MSL was protected by an ablative heatshield of tiled low density material known as PICA (phenolic impregnated carbon ablator). The heatshield was instrumented with MEDLI (MSL Entry Descent Landing Instrument) a suite of sensors & thermocouples at discrete locations in order to monitor the in-depth ablator temperature response and surface pressure. MEDLI was designed and developed by NASA Langley, in partnership with NASA Ames Research Center for the purposes of probing Mars and evaluating the performance of the spacecraft upon entry into the Martian atmosphere. The flight data reduces the uncertainty in engineer models for predicting the response of a spacecraft towards the extreme heating environment of an entry into the Martian atmosphere. MEDLI2 is a part of the Mars 2020 mission and is the next-generation sensor suite for entry, descent, and landing. This data will again help engineers validate their flight models. Additionally, the atmospheric data, can help us understand atmospheric density and winds. This is a critical study for reducing risks to both robotic and future human missions to Mars. Engineered models for Mars 2020 are dependent upon parameters related to the materials response to heating and radiation. In this work, the thermal properties and other measurements of various ablative materials are analyzed to achieve greater utility of the 2012 MEDLI flight data and more accurately determine the parameters being used in Mars 2020. The purpose of this study was to measure specific heat, thermal conductivity, char yield, reflectance as a function of wavelength, and other thermal parameters and optical properties of various ablative materials. $CO_2(g)$ at extreme temperatures emits radiation impacting MEDLI2 flight predictions. Emissivity & absorptivity as a function of temperature were calculated from FTIR and UV-Vis data as a means of investigating whether these materials might absorb CO_2 radiation upon entry into the Mars atmosphere.

CHARACTARIZATION OF THERMAL PROTECTION SYSTEMS

National Aeronautics and Space Administration

Brian Cole[1], Jay Feldman[2], Matthew Gasch[2]

[1]Clemson University, [2]NASA Ames Research Center

BACKGROUND

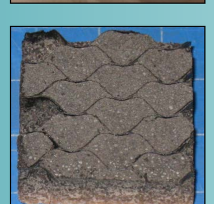
- In 2012, NASA successfully landed the Mars Science Laboratory (MSL). MSL was protected by an ablative heatshield of tiled low density material known as PICA (Phenolic Impregnated Carbon Ablator).
- HEEET (Heatshield for Extreme Entry Environment Technology), a 3D woven material, can be used on multiple missions reducing cost and design time.
- In 2020, NASA is sending a new rover to mars, Mars 2020. The aeroshell for this vehicle will be instrumented with a suite of sensors & thermocouples at discrete locations in the heatshield. The instrumented suite MEDLI2 (Mars Entry Descent Landing Instrument) will allow monitoring in-depth ablator temperature response and surface pressure. The backshell Thermal Protection System (TPS) is made of SLA-561V, a super lightweight ablative manufactured by Lockheed Martin. The SLA also features MEDLI2 Instrumentation.
- Flight data provides information relating to material response towards heating and radiation. This helps (1) Define entry aerothermal environment, (2) Reduce entry vehicle TPS mass, and (3) Improve Aerocapture and EDL performance

OBJECTIVES

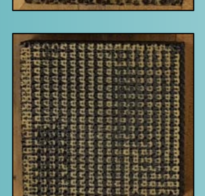
- The purpose of this study was to measure specific heat, thermal conductivity, and other thermal parameters and optical properties of ablatives.
- CO_2(g) at extreme temperatures emits radiation impacting MEDLI2 flight predictions. Emissivity was calculated to investigate whether CO_2 radiation will transmit through these materials.
- White paint is added to PICA and HEEET materials to aid in on orbit thermal control. Emissivity was again calculated to observe the effect of white paint.

MATERIALS & INSTRUMENTS


SLA Virgin


SLA CHAR


HEEET Insulating Layer

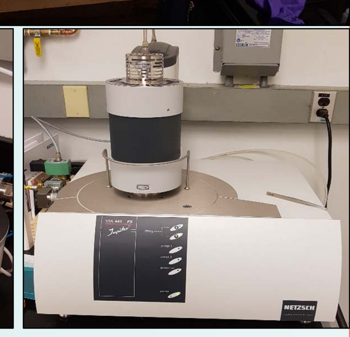

HEEET Recession Layer


PICA-D


AZ93 Coating


AZ2100 Coating


AZW Coating



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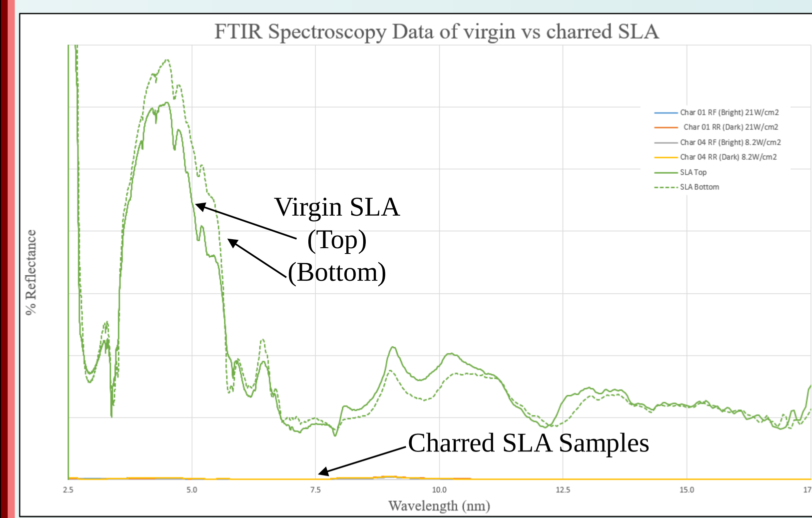
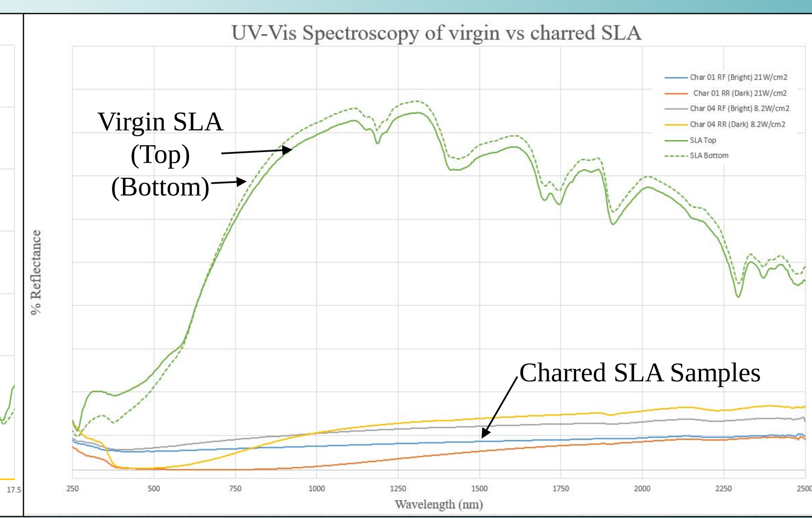
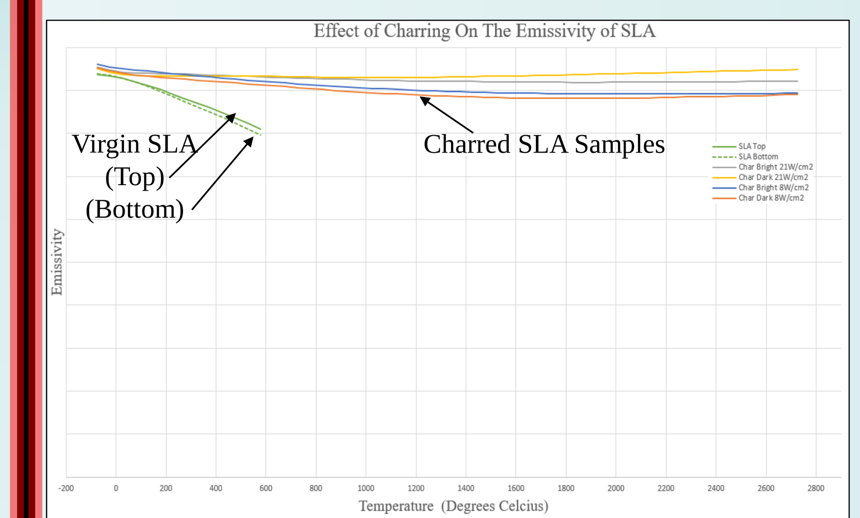
SLA OPTICAL PROPERTIES







INFRARED REGION

- Evidence of O-H & C-O Chemistry

UV & VISIBLE REGIONS

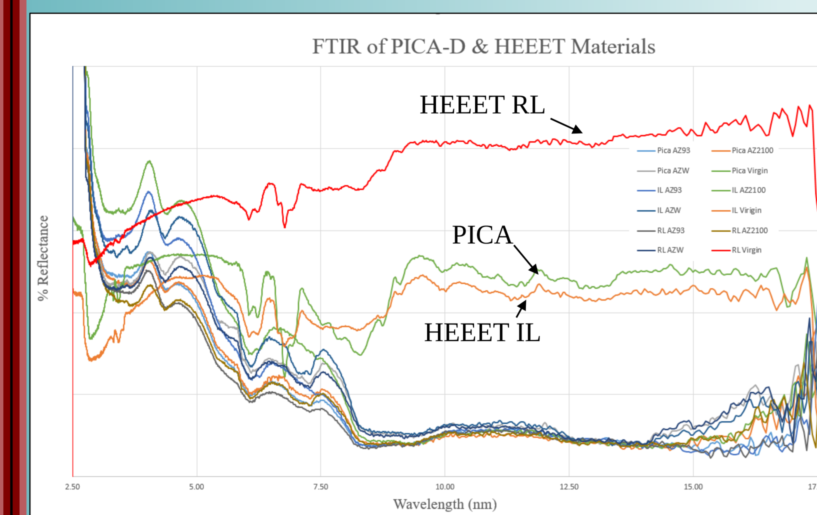
- Black char data is consistent with expectations (Absorbs Visible Light)

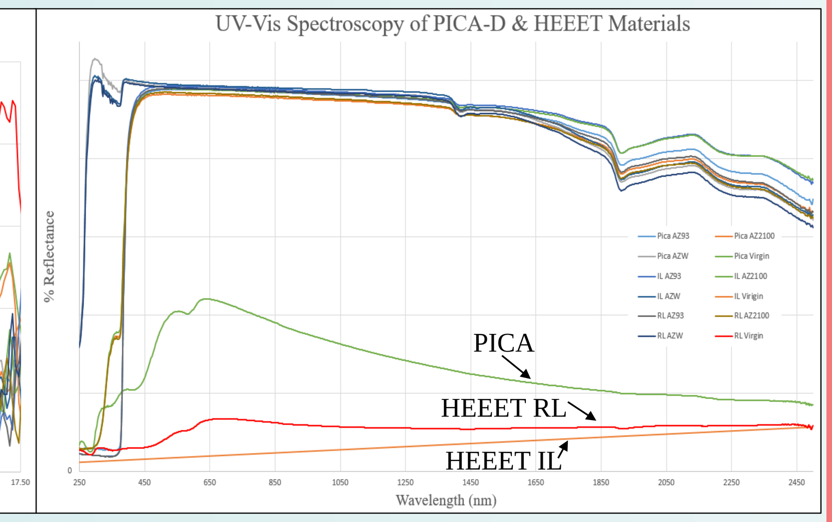
EMISSIVITY (-73ºC -> 2700ºC)

NOTE: SLA Fully Chars at 600ºC

- All Chars Emit Strongly

PICA & HEEET OPTICAL DATA





INFRARED REGION

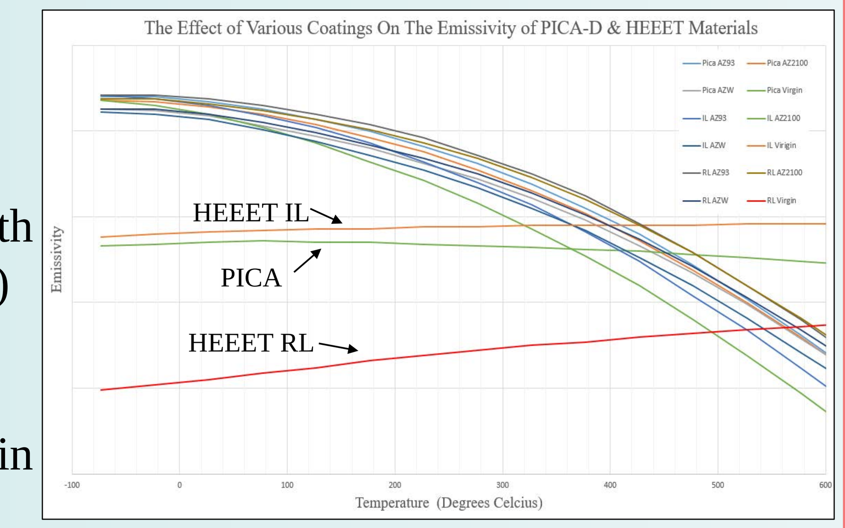
- Influence of Coatings > Materials

UV & VISIBLE REGIONS

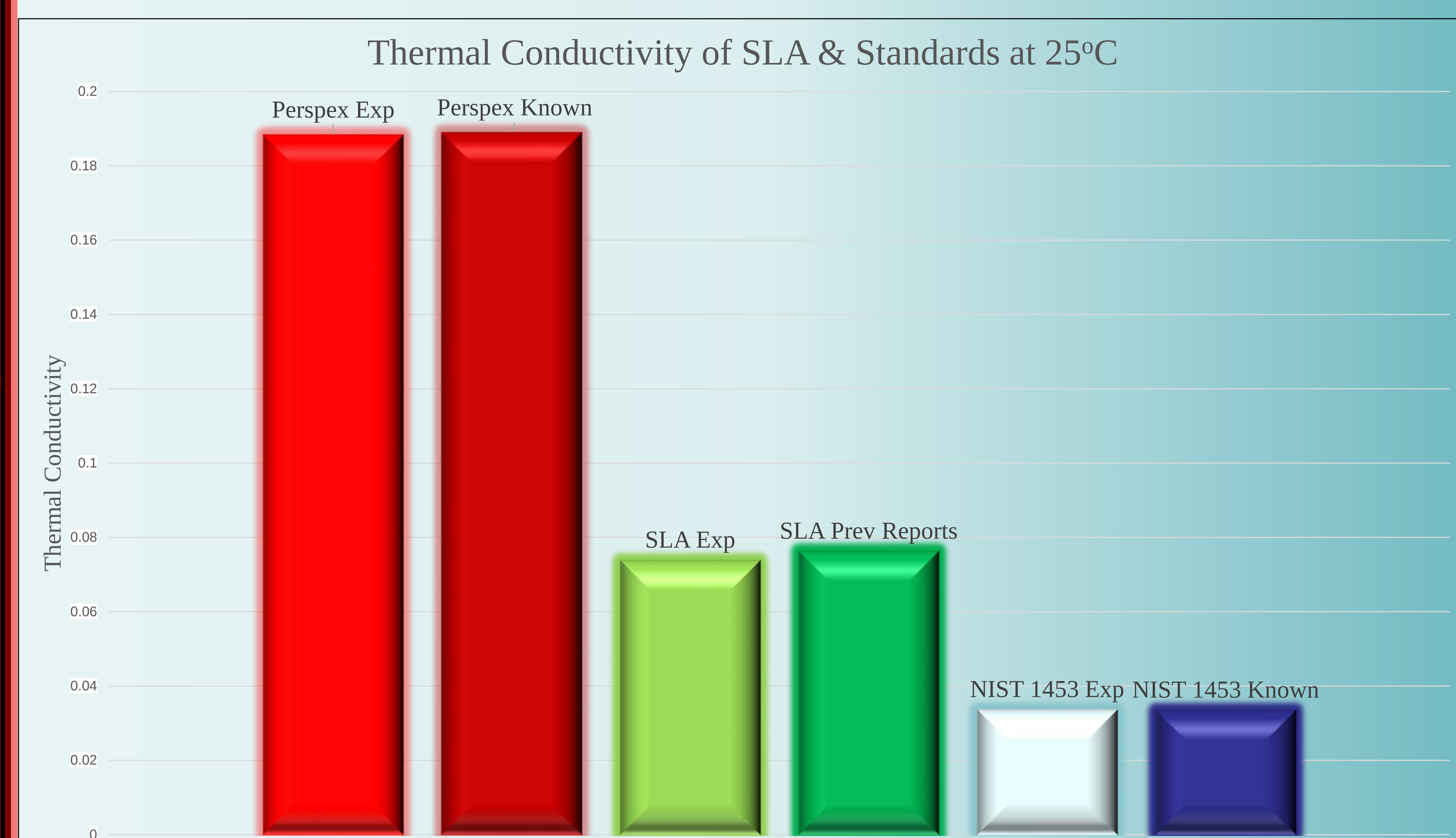
- White coating data is consistent with expectations (Reflects Visible Light)

EMISSIVITY (-73ºC -> 600ºC)

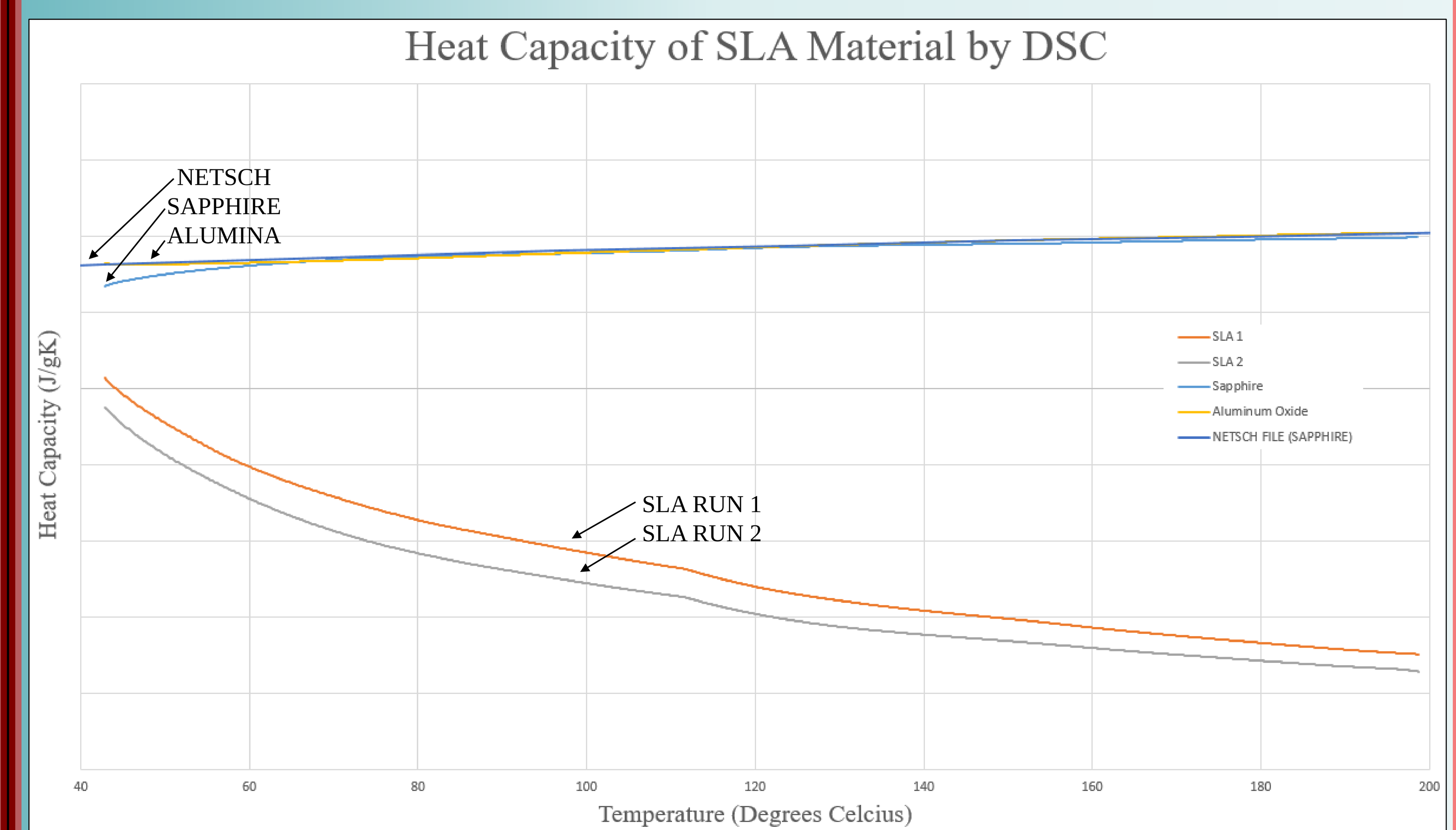
- White coatings offer an increase in emissivity at low temperatures.



THERMAL CONDUCTIVITY



SLA HEAT CAPACITY



THE DISCUSSION OF RESULTS & THE FINAL CONCLUSIONS

The optical property data (FTIR & UV-Vis) confirms that charring SLA results in a significant decrease in emissivity and reflectance, while the application of a white coating to TPS results in an increase in emissivity prior to burning off exposing the ablative. This is significant because radiative emission is a primary cooling phenomenon for TPS and significantly impacts the efficiency of the TPS. Specific heat capacity measurements so far have shown a decrease in heat capacity with increased temperature and is currently still under investigation. Additional thermal property characterization will include thermal gravimetric analysis (TGA), differential scanning calorimetry (DSC), and a solid state thermal conductivity heat flow meter. (Fox 50). This work contributes to the MEDLI2 thermal response model used for deriving flight environments from the Mars 2020 entry data sent by the spacecraft's instrument suite. This will increase our understanding of the Martian entry environment and TPS response and will be beneficial for more efficient heatshield design of future missions.