ANALYSIS OF THE MSL/MEDLI ENTRY DATA WITH COUPLED CFD AND MATERIAL RESPONSE.

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Brief Presenter Biography:
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Abstract:
The Mars Science Laboratory (MSL) was protected during its atmospheric entry by an instrumented heatshield using NASA's Phenolic Impregnated Carbon Ablator (PICA) material [1]. PICA is a lightweight carbon fiber/polymeric resin material that offers outstanding performances for protecting probes during planetary entry. The Mars Entry Descent and Landing Instrument (MEDLI) suite on MSL offers unique in-flight validation data for models of material response and atmospheric entry. MEDLI recorded, among other things, time-resolved in-depth temperature data of PICA using thermocouple sensors assembled in the MEDLI Integrated Sensor Plugs (MISP) [2].

The objective of this work is to showcase and analyze the coupling between the material response and the aerothermal environment. As shown in Figure 1, the workflow is divided into the following steps. First, the aerothermal properties are computed in the Data Parallel Line Relaxation (DPLR) code [3] and used with the Nonequilibrium air radiation (NEQAIR) program [8] to compute radiative heating. Second, the thermal response inside the material is computed in the Porous material Analysis Toolbox based on OpenFOAM (PATO) [4,5,6] using a fixed blowing correction parameter. Third, the pyrolysis gases computed in PATO are used as inputs to a blowing boundary condition within DPLR. Fourth, the new environment properties from DPLR are used in NEQAIR to provide an updated solution, then both the updated aerothermal environment and radiative heating are used in PATO without blowing correction. The third and fourth steps are then repeated until convergence in surface temperature is obtained. Convergence in the radiative heating is generally achieved before surface temperature, at which point the radiative heating is no longer updated. Char mass loss rates are forced to zero to produce a non-receding surface condition.

For early time points in the trajectory, where flow around the MSL aeroshell is rarefied, the Direct Simulation Monte Carlo (DSMC) code, SPARTA [7], is used to compute the aerothermal environment. Iteration between PATO and SPARTA is not performed due to the computational cost of DSMC simulations.

Preliminary results of the coupling between PATO and DPLR for the MSL heatshield atmospheric entry model are presented in Figures 2-4 at 65 seconds after entry interface. Figure 2 shows the surface temperature results from an uncoupled simulation in PATO with the blowing correction parameter applied (left) along with the coupled surface temperature after iteration (right). Figure 3 shows the surface temperature along the centerline from windward to leeward for easier comparison. Figure 4 shows the coupled and uncoupled pyrolysis gas blowing rate.

Mars 2020 used a similar heatshield consisting of PICA for thermal protection during entry, descent, and landing. In preparation for Mars 2020 post-flight analysis, the predictive material response capability is benchmarked against flight data from MEDLI. This work represents an important milestone toward the development of validated predictive capabilities for designing thermal protection systems for planetary probes.

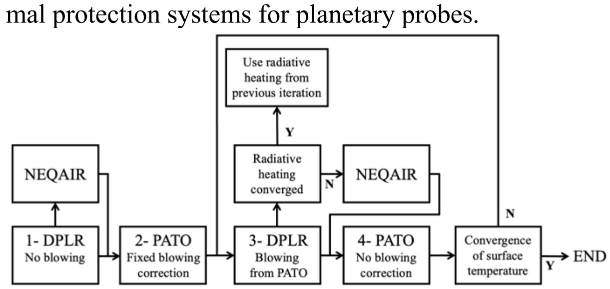

Fig. 1 Diagram of coupling process between CFD and material response.

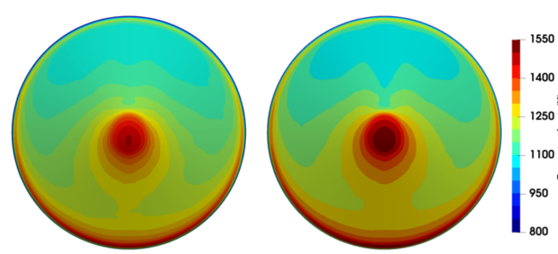

Fig. 2 Uncoupled (left) and coupled (right) surface temperatures at 65s.

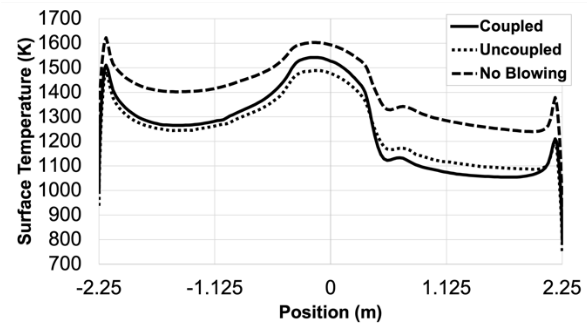

Fig. 3 Surface temperature along heatshield center at 65s.

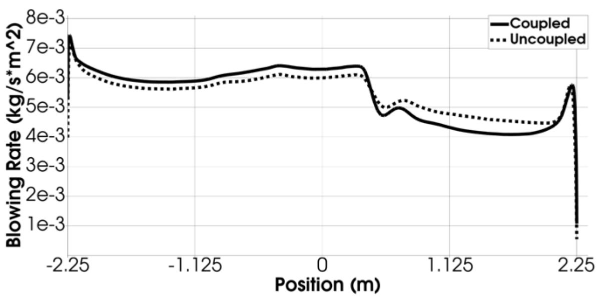

Fig. 4 Pyrolysis gas blowing rate along heatshield center at 65s.

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