InSight Aerothermal Environment Assessment

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The InSight spacecraft was proposed to be a build-to-print copy of the Phoenix vehicle due to the knowledge that the lander payload would be similar and the trajectory would be similar. However, the InSight aerothermal analysts, based on tests performed in CO2 during the Mars Science Laboratory mission (MSL) and completion of Russian databases, considered radiative heat flux to the aftbody from the wake for the first time for a US Mars mission. The combined convective and radiative heat flux was used to determine if the as-flown Phoenix thermal protection system (TPS) design would be sufficient for InSight. All analyses showed that the design would be adequate. Once the InSight lander was successfully delivered to Mars on November 26, 2018, work began to reconstruct the atmosphere and trajectory in order to evaluate the aerothermal environments that were actually encountered by the spacecraft and to compare them to the design environments.

The best estimated trajectory (BET) reconstructed for the InSight atmospheric entry fell between the two trajectories considered for the design, when looking at the velocity versus altitude values. The maximum heat rate design trajectory (MHR) flew at a higher velocity and the maximum heat load design trajectory (MHL) flew at a lower velocity than the BET. For TPS sizing, the MHL trajectory drove the design. Reconstruction has shown that the BET flew for a shorter time than either of the design environments, hence total heat load on the vehicle should have been less than used in design.

Utilizing the BET, both DPLR and LAURA were first run to analyze the convective heating on the vehicle with no angle of attack. Both codes were run with axisymmetric, laminar flow in radiative equilibrium and vibrational non-equilibrium with a surface emissivity of 0.8. Eight species Mitcheltree chemistry was assumed with CO_2, CO, N_2, O_2, NO, C, N, and O. Both codes agreed within 1% on the forebody and had the expected differences on the aftbody. The NEQAIR and HARA codes were used to analyze the radiative heating on the vehicle using full spherical ray-tracing. The codes agreed within 5% on most aftbody points of interest.

The LAURA code was then used to evaluate the conditions at angle of attack at the peak heating and peak pressure times. Boundary layer properties were investigated to confirm that the flow over the forebody was laminar for the flight.

Comparisons of the aerothermal heating determined for the reconstructed trajectory to the design trajectories showed that the as-flown conditions were less severe than design