InSight's Reconstructed Aerothermal Environments

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Introduction: The InSight Mars Lander successfully landed on the surface on November 26, 2018. This poster will describe the methodologies and margins used in developing the aerothermal environments for design of the thermal protection systems (TPS), as well as a prediction of as-flown environments based on the best estimated trajectory. The InSight mission spacecraft design approach included the effects of radiant heat flux to the aft body from the wake for the first time on a US Mars Mission, due to overwhelming evidence in ground testing for the European ExoMars mission (2009/2010) [1] and 2010 tests in the Electric Arc Shock Tube (EAST) facility [2]. The radiant energy on an aftbody was also recently confirmed via measurement on the Schiaparelli mission [3]. In addition, the InSight mission expected to enter the Mars atmosphere during the dust storm season, so the heatshield TPS was designed to accommodate the extra recession due to the potential dust impact. This poster will compare the predicted aerothermal environments using the reconstructed best estimated trajectory to the design environments.

Design Approach: The InSight spacecraft was planned to be a near-design-to-print copy of the Phoenix spacecraft. The determination of the heatshield TPS requirements was approached as if it was a new design due to the new requirement of flying through a dust storm. The baseline for aftbody was build-to-print, and all analyses focused on ensuring adequate margin**.** This proved to be a challenge because the Phoenix aftbody was designed to withstand only convective heating and the InSight aftbody was evaluated for both convective and radiative heating. Aerothermal environments were predicted using the Langley Aerothermodynamic Upwind Relaxation Algorithm (LAURA) and the Data Parallel Line Relaxation (DPLR) CFD codes, and the Nonequilibrium Radiative Transport and Spectra Program (NEQAIR) utilizing bounding design trajectories derived from Monte Carlo analyses from the Program to Optimize Simulated Trajectories II (POST2). In all cases, super-catalytic flowfields were assigned to ensure the most conservative heating results. Two trajectories were evaluated: 1) the trajectory with the maximum heat flux was utilized to determine the flowfield characteristics and the viability of the selection of TPS materials; and 2) the trajectory with the maximum heat load was used to determine the required thicknesses of the TPS materials. Evaluation of the MEDLI data [4], along with ground test data [5] led to the determination of whether or not the flow would transition from laminar to turbulent on the heatshield, which also determined the TPS sizing location for the heatshield. Aerothermal margins were added for the convective heating and developed for the radiative heating. TPS material sizing was determined with the Reaction Kinetic Ablation Program (REKAP) and the Fully Implicit Ablation and Thermal Analysis program (FIAT) using a three-branched approach to account for aerothermal, material response, and material properties uncertainties. In addition, the heatshield recession was augmented by an analysis of the effect of entry through a potential dusty atmosphere using a methodology developed in References [6] and [7]. These analyses resulted in an increase to the Phoenix heatshield TPS thickness.

Reconstruction Efforts: Once the best estimated trajectory is reconstructed by the team, the LAURA/HARA (High-Temperature Aerothermo-dynamic Radiation model) and DPLR/NEQAIR code pairs will be used to predict the as-flown aerothermal conditions. In these runs, fully-catalytic flowfields will be assigned because it is a more physically accurate description of the chemistry in the flow. Once again, determination of the onset of turbulence on the heatshield will be evaluated. The as-flown aerothermal environments will then be compared to the design environments.

References:

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