SpaceX Dragon Re-Entry Vehicle: Aerodynamics and Aerothermodynamics with Application to Base Heat-Shield Design

Loretta Trevino
Space Exploration Technologies Corporation

The purpose of SpaceX is to improve the reliability and cost efficiency of access to space. The NASA COTS procurement provides the mechanism to accelerate the timing of human orbital transportation development. SpaceX's orbital transportation system is tailored to the requirements of NASA for both cargo and crew transport to the International Space Station (ISS), while allowing for its future applicability to other markets. This development is known as COTS and consists of the Dragon crew/cargo spacecraft, the Falcon 9 booster, and the Ground Segment. The goal of COTS is to provide continuing crew/cargo transport to the ISS once the Shuttle is retired.

The Dragon spacecraft design is structurally identical for both cargo and crewconfigurations. With a nominal internal or ex ternal cargo mass of 2550 kg of cargo, Dragon has a gross liftoff weight of 8750 kg. The design is based on a traditional re-entry capsule: A body of revolution with 0.78 height-to-diameter ratio. With a radially offsetcenter-of-mass, Dragon is designed for a canonical lifting re-entry at a "low" 12? trim angle of attack with a 0.18 L/D. The 12? sidewall angle represents a compromise between internal volume, TPS mass and L/D ratio and minimizes sidewall heating.

First, we built an Aerodynamic database of forces and moments coefficients used by the GN&C team to create nominal and abort entry trajectories. The 0.18 L/D allows a very narrow re-entry corridor and keeps deceleration-loading on the crew below approximately 5 g. Based on these trajectories we establish the associated Knudsen number and corresponding flow environment (free molecule, 11 species, 5 species, perfect gas, etc). The first flight regime point was computed in collaboration with NASA Ames using the DPLR software at Mach 21 for a full 3D configuration. However, for the purpose of designing the main base heat-shield we restrict the computational domain to the base heat shield and shoulders and do not account for the leeward flow. We built a set of clean OML solutions at altitudes of 41 km and 61 km for Mach 2 to 21 for laminar and turbulent flows. The current design of the base heat-shield is based on aerothermal environment computed with the NASA Ames CBAero software anchored to the 3D Mach 21 DPLR solution computed at Ames. Several comparisons were run with the new set of DPLR data computed at SpaceX and have, so far, been in very good agreement with the CBAero solutions. More detailed analyses will include protuberancs and penetration heating such as those associated with window, hatch, RCS, compression pads, etc.

6th International Planetary Probe Workshop Conference Proceedings
June 21-27, 2008
Atlanta, Georgia, USA