MARS SCIENCE LABORATORY PARACHUTE DYNAMICS MODELING AND SIMULATION

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ABSTRACT

The historical perspective on the importance of the parachute opening loads to the Mars Science Laboratory (MSL) design is described. That these parachute forces were ultimately the driving requirement for a significant portion of the primary load-bearing structure provides impetus for a renewed and careful investigation into the parachute load cases realizable during the descent. These loads were determined through use of a coupled parachute opening model incorporated into an entry body dynamic simulation that properly captured the “weather vaning” effect of the parachute drag loads. In particular, this new model for the parachute opening loads was developed to include special features designed to capture the supersonic area oscillations (sharp reductions in drag) that have been measured and observed during high altitude terrestrial testing. These unloading and reloading events are known to be a feature of parachutes that function in supersonic flows at Mach numbers above 1.5. The target opening condition for MSL is Mach 2.2 which is the highest Mach number ever attempted in any spacecraft flight. This new supersonic model is based on a Pflanz opening profile for a scaled Viking disk-gap-band parachute but has several additional parameters; these new parameters were used to vary the intensity, frequency, amplitude, and the duration of the superimposed area oscillations in an effort to build a conservative estimate for the potential entry body attitude relative to the drag force vector at the design maximum inflation load.

The formulation of the final design loads case was done through a series of Monte Carlo simulations intended to stress the entry body. The parameters used in the area oscillation simulation were derived through empirical fitting and estimation based on available Viking era parachute data. The model allows for the variation of many of these controlling parameters, including the spacecraft initial attitude and nonlinear parachute bridle slacking and loading. The lateral motion of the parachute has also been modelled based on historical data and the affects of the parachute coning motion are included in the dynamics simulation. A suite of Monte Carlo simulations were performed in order to establish the design loads, with liens against the higher-order effects described above, for the MSL project; these margined loads reduced the shear loads in the structure by more than 40% thus eliminating the need to redesign significant portions of the vehicle.