Entry and Powered Descent Guidance for Mars Robotic Precursors

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Future crewed missions to Mars require improvements in landed mass capability beyond that which is possible using state-of-the-art Mars Entry, Descent, and Landing (EDL) systems. Current systems are capable of an estimated maximum of 1-1.5 metric tons (MT), while human Mars studies require 20-40 MT. A set of technologies were investigated by the EDL Systems Analysis (SA) project to assess the performance of candidate EDL architectures. A single architecture was selected for the design of a robotic precursor mission whose objective is to demonstrate these technologies. In particular, inflatable aerodynamic decelerators (IADs) and supersonic retro-propulsion (SRP) have been shown to have the greatest mass benefit and extensibility to future exploration missions. In order to evaluate these technologies and develop the mission, candidate guidance algorithms have been coded into the simulation for the purposes of studying system performance. These guidance algorithms include entry and powered descent (in addition to aerocapture, which is the subject of another paper). The performance of the algorithms for each of these phases in the presence of dispersions has been assessed using a Monte Carlo technique.

The aerocapture maneuver is used to slow the vehicle from a hyperbolic orbital energy to an elliptical energy by utilizing the atmospheric drag. The mission design assumes that a period of time is spent in orbit for checkout prior to entry. A de-orbit burn is then performed to initiate the entry sequence and drive the vehicle toward the atmosphere. Once the atmospheric drag forces increase above a threshold, bank modulation is accomplished according to calculations provided by the entry guidance. Two entry guidance methods have been incorporated: a numerical predictor corrector, and the Apollo Entry Guidance. The numerical predictor corrector integrates a simplified set of the equations of motion, and iterates on a specified control parameter (e.g. bank angle command) to determine the optimum. The Apollo Entry Guidance is an analytical terminal point control method which calculates control parameter gains based on driving the final state to a pre-determined value. A description of each guidance and performance results will be presented.

Following the entry phase and jettison of the heat shield, a supersonic retro-propulsion (SRP) phase is initiated. During the SRP phase, the remaining vehicle velocity is reduced using a propulsive method with thrust magnitude and thrust direction calculations provided by the guidance. The guidance can dynamically retarget the landing site real-time to avoid hazards. The SRP phase culminates with safe touchdown on the Martian surface. A description of the guidance, powered descent performance, divert performance, and some further considerations for safe landing will be included.