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MAVEN OPTIMAL AEROBRAKE MANEUVER ESTIMATION

Abstract

The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission was designed to determine the role that loss of volatiles from the Mars atmosphere to space has played through time, giving insight into the history of Mars' atmosphere and climate, liquid water, and planetary habitability. The spacecraft has been orbiting Mars for four years in a highly-inclined and highly-elliptic orbit. As part of a proposed extended relay mission, an apogee decrease is required which will be achieved through a combination of small impulsive maneuvers and aerobraking. However, due to the diminishing quantity of propellant remaining in the spacecraft, the maneuvers need to be as efficient as possible. Aerobrake maneuver schemes are challenging for many reasons, perhaps the most important from a flight dynamics perspective is the need to accurately account for orbital perturbations. Particularly for MAVEN, higher-order gravitational perturbations, perturbing gravitating third bodies as well as atmospheric drag must all be accounted for in order to accurately predict the evolution of the spacecraft's orbit. Accounting for drag effects requires consideration of the spacecraft's attitude and the dynamics of the Martian atmosphere. This study presents a method to calculate an optimal aerobrake maneuver scheme that minimizes the propellant consumption. The proposed method uses the spacecraft's state transition matrix, propagated with several perturbation models, to evaluate the stability of the spacecraft's final position with respect to the velocity throughout the trajectory. The most unstable points define the most efficient maneuver timings. Once the number and time of the impulses are defined, a linear optimal control policy is derived using the state transition matrix. This strategy defines the optimal direction and magnitude that each impulse needs to be given in order to target the desired orbital parameters. The method is shown to reasonably predict the optimal aerobrake maneuvers (time, direction and magnitude) when compared to an indirect optimization method with all the perturbations. Finally, its software implementation permits an orders of magnitude quicker calculation allowing it to be used in large searches, such as grid and Monte Carlo.