Paper ID: 69859
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IP)

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A PRELIMINARY INVESTIGATION OF AEROGRAVITY ASSIST MISSIONS TO CERES AND OTHER ASTEROIDS USING VARIOUS TRAJECTORY PATHS

Abstract

Aerogravity assists (AGAs) offer a significant improvement to traditional gravity assists since they allow for greater turning angles and thereby larger ΔV's. This results in reduced times of flight, launch energy requirements, and most importantly, mission costs. This paper primarily considers Ceres as there is very little known about the dwarf planet. It could benefit from future missions due to the potential presence of liquid and solid water. Trajectory options for missions to ten major asteroids including Pallas, Vesta, Hygiea, Eunomia, Europa, Cybele, Sylvia, Davida and Interamnia are also considered. This investigation explores several aerogravity assist trajectory paths using combinations of the inner planets, Lift-to-Drag (L/D) ratio vehicles ranging from 1 to 7 and a range of launch velocities from 3 km/s to 5 km/s. Desirable trajectories are identified based on lower times of flight, launch characteristic energy (C3) and arrival velocities. Graphical methods such as vector diagrams and Tisserand plots are used to represent the design space and potential trajectories as well as the encounter with the asteroid and arrival or departure conditions. Potential entry flight path angles, and the aerogravity assist turning angle are determined using specific candidate trajectories identified for their desirability using the criteria described above. Bounds of the theoretical entry corridor width at the AGA planets are determined through numerical integration of equations of motion for atmospheric flight for full lift-up and full lift-down trajectories. This analysis does not include constraints from aerothermodynamic heating and Thermal Protection Systems (TPS). Mission design considerations include investigating combinations of trajectory paths, viable L/D ratios, launch energies, times of flight and arrival velocities. The design space is used to produce desirable candidate trajectories which are compared to the NASA mission Dawn which launched in 2007, arrived at Vesta in 2011 and then began orbiting Ceres in 2015, in order to illustrate the benefits of using an aerogravity assist maneuver. If speed is the main objective, using an aerogravity assists allows spacecraft to arrive at Ceres as quickly as 385 days which is a significant improvement over the roughly 8 years it took Dawn. If cost minimization is the objective, using an AGA at one or more inner planets can reduce the launch C3 for a Ceres mission to 9 km^2/s^2, or the Ceres arrival velocity to as low as 2.8 km/s which may not require additional maneuvers to bleed off excess energy for orbit insertion.