ABSTRACT

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Endgame Strategies for Planetary Moon Orbiters

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Delivering an orbiter to a planetary moon such as Titan or Europa requires an exorbitant amount of fuel if the trajectory is not carefully and cleverly planned. V-infinity leveraging maneuvers are an effective means to reduce total Delta-V requirements to achieve orbit about a planetary satellite. This work seeks to characterize optimal trajectories making use of flybys, leveraging maneuvers, and capture orbits in order to minimize fuel requirements. With the aid of customized tools to construct, map, and analyze sequences of resonances and maneuvers, we derive heuristics of global optima and formulate a theoretical minimum. The theoretical minimum, which is found using an infinite series of flybys and leveraging maneuvers, results in a Delta-V savings of over 70% when compared to a direct insertion during flyby. We then generate numerical results, which show that the optimal location for performing V-infinity reduction maneuvers is not necessarily at apoapsis, due to targeting constraints. By plotting total Delta-V vs. time-of-flight for tens of thousands of generated sequences, a Pareto front is created of the most efficient sequences for each given flight time. This Pareto front shows that while infinite missions are not possible, it is feasible to reduce the total Delta-V by 50% with only a modest increase in flight time. Increasing the mission duration further does not result in significant reductions.

It is shown that periodic orbits exist in the restricted three-body problem whose Jacobi constants correspond to a positive V-infinity in the two-body problem. This indicates that these orbits are classically hyperbolic and yet are gravitationally bound to the vicinity of the target body. This dissertation explores the limits and usefulness of these hyperbolic periodic orbits and their application to the endgame problem. Families of orbits are generated using a single shooting method and integrated into the final phase of V-infinity leveraging sequences. Using a hyperbolic periodic orbit to capture to the vicinity of a target moon following an optimized sequence of leveraging maneuvers and flybys yields significant fuel savings (60-70%) over direct trajectories.