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LANDING IN BINARY ASTEROIDS: A GLOBAL MAP OF FEASIBLE DESCEND OPPORTUNITIES FOR UNPOWERED SPACECRAFT

Abstract

Near Earth asteroids (NEAs) are the easiest celestial objects to reach from Earth (excl. the Moon), and offer a unique window to the early stages of accretion and differentiation of the inner planets of our Solar System. As such, they have become appealing targets for science missions. For such missions, on-board remote sensing instrumentation is paramount, however, in-situ measurements provide the necessary "ground-truth" to enhance the science return. The chaoticity of the strongly irregular dynamical environment found at asteroids, however, entails some daring challenges for navigation, and thus, most missions spend long periods of times (∼months) stationed well beyond the asteroid's Hill radius, where the heliocentric dynamical environment is still predominant, and thus much more easily predicted. NanoSats and other shoebox-sized landers have already been identified as potential valuable assets for in-situ asteroid exploration, since, due to their low cost, they can be used much more daringly. However, due to constraints in mass and volume, these systems may only allow for extremely crude orbit and landing control. This paper thus explores the potential for passive landing opportunities that may be enabled by the asteroid's natural dynamics. Particularly, the paper focuses on binary asteroid systems, i.e. asteroids with a satellite, which are believed to account for about 15% of the NEA population. The dynamics near a binary asteroid are then modelled by means of the Circular Restricted Three Body Problem, which provides a reasonably representative model for a standard binary system. Natural landing trajectories are sought that allow for a deployment well outside the orbit of the asteroid's satellite, and a touchdown with minimum local-vertical velocity. The analysis of these landing opportunities allow us to define the required coefficient of restitution (i.e. energy damping) to ensure that the spacecraft does not bounce away from the system. Deployment velocities from a mothership stationed outside the orbit of the satellite are also computed. These results show that landing in the main asteroid entails more constraining structural requirements, as well as the capability to reduce the spacecraft's kinetic energy at touchdown. On the other hand, the natural dynamics of the binary system allow for passive landing opportunities at the secondary, that can be ensured with naturally occurring coefficients of restitution of >0.9, which have been seen in past missions such as Rosetta, Hayabusa and NEAR.