Reliability Analysis of Ballistic Landing in Binary Asteroid 65803 (1996GT) Didymos under Uncertainty and GNC Error Considerations

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In last two decades, the interest on missions to near-Earth asteroids (NEAs) has been increased. NEAs are crucial to understand the formation of our solar system, furthermore they have been identified as resources for valuable raw materials and a threat to earthly life in the event of an impact. As remote sensing techniques capture the finest details of a target body, in-situ investigations may provide the "ground-truth" and enhance the scientific return. Nevertheless, due to the strongly perturbed dynamical environment around asteroids, spacecraft around them are generally preferred to be operated at a distance where potential risks are deemed as minimum. Unpowered "science packages" have already been used in asteroid missions and are considered for future missions. A good example of their potential use can be seen in ESA's current mission study Asteroid Impact Mission (AIM). AIM is considering to carry along two CubeSats to be deployed in binary asteroid Didymos; one of which, ROB-led AGEX study is proposed to land ballistically on the smaller companion (Didymoon). Celik & Sanchez [1] previously demonstrated ballistic soft landing opportunities in binary asteroids within the framework of Circular Restricted Three-Body Problem (CR3BP). The study utilised a backwards propagation from a variety of latitude-longitude coordinates on surfaces of a spherical asteroid pair. It mapped the energy of natural trajectories, touchdown speeds and coefficient of restitution values, also performed a stability analysis of trajectories. The energy map is depicted in Fig. 1. This follow-up research considers Didymoon as the target body to land on, and addresses the impact of uncertainties on the landing trajectory. Main uncertainties considered include mothership GNC errors, deployment system uncertainties, and the density uncertainties of Didymoon. The ideal trajectories within 12h time frame for each point are obtained by the previously developed model, and after randomly selected uncertainties added, these have been run forward in a Monte Carlo (MC) simulation. The success criteria for the simulation is *touchdown*. Deployment altitude is observed to be the key factor affecting the success rate, i.e. increasing altitude decreases the success significantly. For the same altitude, the velocity-based uncertainties are dominant compared to their position-based counterparts. Limiting velocity uncertainties by only 10% in deployment system could provide a sharp increase in the success rate. Longer-duration simulations show that majority of trajectories remain in the vicinity of the binary system, some even touchdown later on either body. The success rate over 99.7% is achieved, though it may put extra requirements in mothership development.

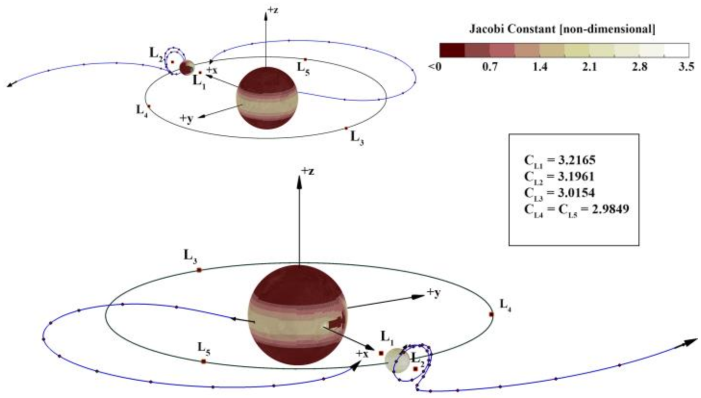

Fig. 1 The energy map with two example trajectories [1]

References

[1] Celik, O. & Sanchéz, J. P., Opportunities for Ballistic Soft Landing in Binary Asteroids, *Journal of Guidance, Control and Dynamics*, 2016, in review.