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ANALYSIS OF ATMOSPHERIC AND NON-SPHERICAL GRAVITATIONAL PERTURBATIONS ON HYPERBOLIC ORBITS ABOVE VENUS, EARTH, AND MARS.

Abstract

The hyperbolic orbits have been used widely in multiple interplanetary missions since the beginning of the space exploration era. In interplanetary flights, the hyperbole is created on the planetocentric reference frame inside the sphere of influence of the planet, to calculated maneuvers like the swing-by of fly-by. A valid mathematical model and the first approach to quantify the effects of this maneuver is to implement the two-body problem, with the planet's spherical gravity and far from the influence of another perturbation. In that way, it is possible to quantify the changes in the velocity vector before and after the close approach to the planet. Furthermore, this model could derive into analytical solutions. Nevertheless, this approach is not valid when the pericenter of the maneuver is lower than the upper limit of the atmosphere of the planet. In this case, forces like drag could affect the trajectory, which is possible to observe from the flight data of missions like Galileo and BepiColombo. In fact, a recent paper describes the need to increase the altitude of the passage of the mission Lucy (16/10/22) in order to reduce the perturbation on its trajectory. Then, perturbations such as drag and non-spherical gravity could perturb this kind of trajectory. The scientific literature only reports a few papers that analyze those perturbations in hyperboles, showing a lack of information. When compared to the other conics, the hyperbole presents the largest velocities and the lowest time of the influence of the perturbations, which means a short-term perturbation. Due to that, this paper presents the results of multiple numerical simulations of hyperbolic orbits above Venus, Earth, and Mars, quantifying the effects of the two additional perturbations as a function of the altitude and velocity of the pericenter. These results are compared and approached to analytical solutions, looking for a reduction in the computational cost. Hence, this research quantifies the boundary region where the mathematical models are valid, proposes alternative analytical solutions, and presents the effects on the resulting orbits. It is expected that the results presented in this paper could contribute to the analysis and design of future interplanetary missions.