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NOVEL NUMERICAL OPTIMISATION OF THE HOHMANN SPIRAL TRANSFER

Abstract

As commercial satellites have an ever-increasing role in our everyday lives, there is great demand for more satellite platforms to accommodate the services offered such as telecommunications, Global Positioning System (GPS) and Earth-monitoring. As the revenue of such platforms is generated by its payload, of which the capacity is maximised when fuel-mass is minimised, there is great interest in ensuring the fuel required for the trajectory to deliver the satellite to its working orbit is minimum. This paper presents an optimisation study of a novel orbit transfer, recently introduced by the authors through an analytical analysis, known as the Hohmann Spiral Transfer (HST). The transfer is analogous to the bi-elliptic transfer but incorporating high and low-thrust propulsion. The high-thrust system is used to propel the spacecraft beyond the target orbit to an intermediate orbit where the low-thrust system is activated and used to direct the spacecraft on a spiral trajectory in-toward the target orbit. Previous research conducted by the authors has shown that the HST can outperform conventional transfer methods for different mission configurations, when the inclination change is performed by either the high or low-thrust system separately. For this analytical analysis, certain constraints are necessary; the intermediate orbit has to remain circular to ensure that no eccentricity control is required and, in the case where the low-thrust system performs the inclination change, the inclination manoeuvre is performed at the intermediate orbit before the low-thrust system is used to send the spacecraft on a spiral trajectory in-toward the target. Although this approach highlights the benefits of the transfer and has been validated numerically, it is not considered optimal due to the aforementioned constraints. By now implementing the novel optimisation method, adopting locally optimal control laws coupled with optimised weighting constants, these constraints are removed and the method is allowed to deliver a time and mass-minimum transfer. The application of optimised weighted constants reduces the simulation complexity and hence computational effort. Both scenarios, where the inclination change is performed by either propulsion system, are considered in separate case studies and for the low-thrust case, the inclination change and spiral-in phases are combined. These results are compared to the analytical cases to quantify the differences and it is found although the analytical methodology offers rapid approximation of the transfer, removing the constraints and applying the optimisation method offers a greater fuel-mass benefit. The full thrust-steering profiles are also determined.