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SPACECRAFT AERODYNAMICS AND HEAT SHIELD CHARACTERISTICS IMPACT ON OPTIMAL AEROASSISTED COPLANAR ORBITAL TRANSFER

Abstract

A spacecraft designed to operate in a planetary atmosphere must have an adequate heat shield to withstand the high heat fluxes and heat loads that are generated by aerodynamic heating. Very often, the mass of the Thermal Protection System (TPS) can represent a significant fraction of the total mass of the vehicle. On the contrary, the use of the atmosphere, in order to carry out manoeuvres that would be very costly in terms of propellant consumption if they were performed completely outside of the atmosphere in a classic way, is a very attractive prospective technique. A basic question is assessing the advantages and disadvantages in terms of total mass spared. For the entirely extra-atmospheric case, one must take into account only the mass of the propellant against the sum of the masses of the TPS and the propellant for the aeroassisted case. The problem therefore involves optimisation in order to maximise the mass of the vehicle at the end of the manoeuvre. Actually, this fact corresponds to the minimisation of the masses of the propellant and the heat shield to be used in order to accommodate a larger payload in the vehicles. The mission investigated in this work involves an aeroassisted transfer between two coplanar circular orbits around the Earth, in particular from a High Earth Orbit (HEO) to a Low Earth Orbit (LEO). The approach uses a combination of three propulsive impulses in space to deorbit, boost to the final apogee, and re-circularise, together with an aerodynamic manoeuvre in the atmosphere. The heat shield adopted is fully ablative, given the expected high values of the entering heat flux. The convenience of the aeroassisted manoeuvre and the influence of the parameters involved are evaluated compared to a conventional Hohmann transfer, which is a fully propulsive extra-atmospheric manoeuvre. In particular, a parametric analysis is performed by varying the following characteristics of the vehicle: aerodynamic efficiency, mass-to-surface ratio, maximum coefficient of lift, deorbit impulse, and initial altitude of the orbit. The influence of the TPS is examined by assessing the impact of the type of ablative material employed, the thermal safety factor, and the allowable temperature for the bond-line, i.e. the adhesive layer on the substructure. The analysis is conducted through a highly representative thermal model for the ablative material by coupling the dynamic and thermal analyses and using a genetic optimiser. The optimisation methodology and the thermal model are completely original.