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DEVELOPMENT OF A LOW-THRUST MULTI-OBJECTIVE TRAJECTORY OPTIMIZATION TOOL FOR CLEANSPACE ONE

Abstract

CleanSpace One (CSO) is an innovative mission which aims to test technology related to orbital debris removal by de-orbiting SwissCube, a decommissioned CubeSat formerly operated by the École Polytechnique Fédérale de Lausanne (EPFL). The mission presents many challenges including the ability to transfer to SwissCube's orbit using a low-thrust propulsion system. This paper presents a low-thrust multi-objective trajectory optimization tool designed for first-order mission analysis and applied to study the trajectories of the CSO mission. The direct optimization method implemented in the tool uses orbital averaging and control parameterization to set-up the optimization problem and Differential Evolution to minimize the cost function. Analytical expressions for the average perturbing gravity potential due to Earth's irregular gravity field and third-body effects were used to model these effects, while models for atmospheric drag and charged particle radiation experienced in the Van Allen belts were adapted to fit an orbital averaging scheme. Two transfers were then studied for the CSO mission using MicroThrust, an innovative electric propulsion system for small spacecraft. The results showed that the J_2-effect was beneficial when performing large changes in the right ascension of the ascending node (RAAN) for the minimum time-of-flight optimization case. For a worst-case transfer including a 90^o change in RAAN, the time-of-flight and propellant mass were reduced by 48% and 61%, respectively, when including this effect in the dynamical system. In addition, a multi-objective optimization function was minimized considering the radiation fluence (defined in protons/cm^2) experienced during the transfer and the time-of-flight. The resulting two-dimensional Pareto frontier showed that the former parameter could be reduced by 98.8% by only increasing the latter by 5.2% compared to the minimum time-of-flight case. The final trajectory was selected considering these two parameters, the propellant mass consumed during transfer and additional mission requirements.