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INTERPLANETARY TRAJECTORY OPTIMIZATION FOR A SEP MISSION TO SATURN

Abstract

The increasing interest in outer solar system exploration, recently confirmed by the proposed NASA and ESA flagship missions to Saturn and Jupiter, poses difficult tasks to mission designers. Because chemical propulsion scenarios are not capable of transferring heavy spacecraft on a direct trajectory into the outer solar system, gravity assists are required, which lead to prolonged mission durations and inflexible mission profiles. For the joint NASA/ESA Titan Saturn System Mission (TSSM), the developed mission scenario baselines solar electric propulsion (SEP) to improve mission flexibility, transfer time, and payload factor. SEP trajectory optimization, however, is very challenging, especially for realistic (i.e., complex) spacecraft models, because for every time instant the optimal thrust vector has to be found. For the calculation of near-globally optimal low-thrust trajectories, we have used a method called Evolutionary Neurocontrol (ENC), which is implemented in the low-thrust trajectory optimization software InTrance, developed by DLR. For the work presented in this paper, the software was extended with a realistic solar electric power generator model and an ion thruster model with variable specific impulse. The investigated SEP scenario covers the interplanetary Earth-Saturn transfer including the optimization of the launcher-provided hyperbolic excess energy. To find the optimal mission design, numerous variations of the relevant mission design parameters have to be performed and the optimal interplanetary trajectory has to be found for each setting. Those design parameters are the number of engines (maximum thrust level), the specific impulse (beam voltage) of the engines, and the size (power level) of the solar power generator. Because the optimality of the interplanetary transfer trajectory is a multi-objective optimization problem w.r.t. transfer time and launch mass, the overall mission design and optimization process yields a Pareto-optimal front of solutions. To find the best mission design, first the basic mission design parameter variations are performed for zero hyperbolic excess energy and later optimized by taking the maximum payload capacity of the launcher into account. The most promising solutions on the Pareto-optimal front have then been recalculated with a complex solar generator model and a variable specific impulse ion engine model, yielding a thorough final solution. Our method yields good optimization results, which are valid for a realistic spacecraft model, with, as compared to Cassini/Huygens, a faster transfer time, a higher payload ratio, and additionally higher mission flexibility.