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HYBRID TRAJECTORIES OPTIMIZATION FOR INTERPLANETARY MISSIONS – THE MSR-ERO CASE

Abstract

Thanks to its high propellant consumption efficiency, the use of electric propulsion in space missions has been constantly increasing during the last years and has been recently successfully employed also for interplanetary probes (i.e. Bepi Colombo). Nevertheless, the low-thrust capability of these propulsion systems increases considerably the transfers' duration with respect to classical chemical engines, posing serious difficulties to the realization of missions with tight timeline constraints. Shall then a mission designer mandatorily renounce either to engine efficiency or to short mission durations? The answer is no, as recently demonstrated by the Mars Sample Return (MSR) mission analysis study: for the European Return Orbiter (ERO) a hybrid solution, combining both chemical and electrical propulsion has been proposed, with the goal of optimizing the advantages of both systems. The overall trajectories optimization becomes in this case extremely complicated, because it combines the complexity of low-thrust trajectory optimization (such as the multi-leg interplanetary transfer or the multi-revolution spirals around Mars) with the optimal use of the chemical burns to fulfil complex timeline constraints. In this paper the work performed by DEIMOS team, as responsible of the MSR-ERO mission analysis, to optimize the hybrid ERO trajectory will be presented, with a special focus on the techniques implemented to achieve global optimum results within the real mission constraints, both at system and timeline level. All the details of a real mission design have been considered, taking into account also operational constraints such as the gravity losses for the chemical burns or the power limitation, the maximum operability time, the engine duty cycle for communication and the solar panels degradation for the electrically thrusted legs. The obtained trajectories and the distribution between chemical and electrical burns resulted to be very dependent on the specific selected propulsion systems and on the mission timeline constraints, making then the present analysis a very interesting study of both pure trajectories optimization techniques and system level mission design.