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BALLISTIC CAPTURES AND TRANSFER OPPORTUNITIES FOR A MISSION TO MARS

Abstract

Current transfer opportunities to Mars are based on patched conics approach. They are typically based on direct transfer trajectories from Earth to Mars which are easily calculated by means of Lambert solvers with or without intermediate deep space manoeuvres (DSM). The launch periods to Mars are therefore conditioned by the recurrent synodic motion of both Earth and Mars, which implies that efficient launches to the Red Planet are possible approximately every two years (every 25.6 months). Making use of advanced astrodynamics methods based on the restricted three-body problem and the fuzzy boundary concept, it has been demonstrated very recently (see Belbruno and Topputo, "Earth–Mars Transfers with Ballistic Capture", 2014) that launch to Mars can be performed anytime without needing to wait for a synodic opportunity. This concept adds flexibility to the launch opportunities, broadening the current launch windows. Additionally, it is reported to render significant ΔV reductions with the corresponding increase in the payload mass delivered at Mars. The work presented in this paper applies the concept of ballistic capture to realistic mission profiles targeting the Red Planet. Once a final orbit of scientific interest has been identified around Mars, the possible transfers employing a ballistic capture are first identified. The aim is to find mission profiles which enable a transfer time and ΔV compatible with typical Martian mission constraints. Then, the possibility of modifying the ballistic capture by applying intermediate manoeuvres to reduce the transfer duration is also considered. Special emphasis is dedicated to the analysis of mission profiles which allow launching outside of the standard Earth-Mars launch windows or which enable a significant ΔV saving. In order to find feasible transfer solutions, a Pareto front in terms of total transfer time and total ΔV is constructed by using a Multi-Objective Genetic Algorithm (MOGA) selected for the wide dimension of the solution space and the integer nature of some of the optimization variables. In fact, the latter have been searched within the space of optimization variables consisting of: launch, arrival, manoeuvres dates; manoeuvres magnitude and direction, and ballistic capture geometrical parameters. With respect to the formulation of Belbruno and Topputo, also out of plane transfers have been considered. Finally, the technique is applied to existing Earth-Mars transfer missions (i.e. ExoMars, Phobos Sample Return). Preliminary results show the feasibility of the proposed approach and the possibility to avoid the Earth-Mars conjunction with a limited increase in the transfer budget.