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INTERPLANETARY TRANSFERS BY THE AUTOMATIC SEARCH OF EARTH AND EARTH/MOON RESONANT ARCS

Abstract

Interplanetary trajectories to inner or outer planets -except Venus and Mars- often require multiple gravity assists. Most of the time, the first arc after launch sends the spacecraft either towards Venus or Mars. The required equatorial declination of the escape infinite velocity can be far from the Earth equator.
For the European launcher Ariane 5 ECA, the performance sharply drops when the declination is not close to the equator. Considering an earlier departure, followed by one or more Earth-resonant arcs, often represents a useful trick, as it can allow to de-couple the "true" interplanetary transfer from the launch conditions, at the cost of an increased time of flight: starting from an optimal launch in the equator, the last gravity assist targets the required declination.
Independently from Ariane 5 ECA, an advantage of multiple initial Earth gravity assists is to allow V_∞ leveraging, which increase the final payload mass. These V_∞ leveraging allow themselves a reduction of the launch window ΔV cost, which is another asset.
Moreover, meeting the Earth multiple times also opens the door for another opportunity: a Lunar-Earth Gravity Assist (LEGA). Developed for the first time for ESA's JUICE mission, this type of encounter exploits the Moon's relative motion around the Earth to increase the spacecraft's Earth-infinite velocity at virtually no deterministic ΔV expense. The increase in the stochastic ΔV leads to a global trade-off.
The focus of this work is on the development of an approach to automatically identify promising Earth and LEGA resonant sequences (full/pseudo resonance, pi-transfer), that connect the launch to the first "true" interplanetary leg. In the proposed approach, both ballistic and v_∞ leveraging transfers are considered. The combinatorial nature of resonance problems is exploited, and the search space is reduced from combinatorial-continuous to fully discrete, allowing to investigate all the feasible alternatives. A preliminary design technique to formulate a first guess for an efficient LEGA is also outlined and incorporated into the search algorithm. Initial guesses are then refined in the flight dynamics software Godot, to generate fully optimised transfers. The computed possibilities for resonant sequences will provide the mission analyst with a bird's eye view on the feasible alternatives, substituting lengthy and possibly sub-optimal manual searches. To validate the results, the tool is tested using the JUICE mission as a case study, demonstrating high fidelity in finding baseline and backup trajectories developed by ESOC, both with and without LEGA.