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IMPROVED INTERPLANETARY TRANSFERS WITH LUNAR-EARTH GRAVITY ASSISTS

Abstract

ESA is preparing the JUICE (JUpiter ICy moons Explorer) mission to Jupiter and its Galilean moons Europa. Baseline is multi-swing-by, chemical transfer to Jupiter, followed by a tour in the Jupiter system which contains 34 swing-by's with the Jovian moons., Specific phases include fly-by's at Europa, a high inclination (w.r.t. Jupiter's equator) phase and in-orbit phase around Ganymede (first elliptic, then circular at low altitude).

The baseline interplanetary transfer to Jupiter uses a near-ballistic Earth-Venus-Earth-Earth (EVEE) swing-by sequence with launch early June 2022 and arrival in January 2030. Several alternative options exist (EVEEM, EEVEE, EMEE, EVVEE, EEVEEM, EEVEEEM. VEEEM) in the period 2022-2026, allowing each year a back-up transfer within 9 years and with a mass margin equal or better than the baseline.

In the frame of the on-going industrial study, Lunar-Earth gravity assists (LEGA) have been introduced to improve the mass margin. For the sequences involving a return to Earth roughly one year after departure (Earth DeltaV-GA), the trajectory is adapted such that a close moon encounter occurs on approach to or at departure from the Earth. This allows an increase of infinite velocity w.r.t. the Earth of up to 400 m/s depending on the geometry, resulting in a lower launch escape velocity from Earth and hence larger mass on arrival at Jupiter. No correction manoeuvre is foreseen between the 2 swing-by's of a LEGA, as the time between them is of the order of 1 to 2 days. This keeps the operations similar to a single Earth swing-by. However this approach can be penalizing in terms of navigation DeltaV cost.

The use of the LEGA in an Earth DeltaV-GA is a new avenue. A further mass margin improvement can be obtained from an already described method by preceding the LEGA('s) with launch in a High Eccentric Orbit of apogee near 600.000 km, followed by a Lunar Gravity Assist (HEO-LGA) on the return path which injects the S/C to interplanetary space with an infinite velocity around 1.5 km/s. This, however, involves more complex early orbit operations and poses an issue of launcher dispersion. An additional lunar gravity assist on the ascending leg of the HEO, although it would further boost the mass margin, is not recommended as it introduces complex and risky early orbit operations.

The paper will address the following aspects of the LEGA's: 1.Theoretical analysis on benefit for planar case 2.Aspects limiting the efficient application 3.Consequences on launch window and deterministic Delta-V budget 4.Application to JUICE transfers between 2022 and 2026 involving an Earth DeltaV-GA 5.Preliminary navigation analysis 6.Application of HEO-LGA prior to LEGA for selected JUICE transfers 7.Launcher correction of HEO-LGA