Paper ID: 41423
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ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations (IP)

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THE COMBINED LAMBERT-TISSERAND RESOLUTION APPLIED TO THE SINGLE FLYBY PROBLEM

Abstract

The design of an interplanetary trajectory of a spacecraft in its journey to a target planet has always been threaten as more or less complex version of a boundary-value problem constrained to departure, arrival and encountered planets. Its complexity depends on the type of approach used to identify the interplanetary legs and on the gravitational model at which the motion of the s/c is subjected to. Depending on the considered dynamics, two different methods can be distinguished:

- the phase resolution approach, solution of the well-known Lambert problem, which iteratively determines the conic arc connecting the two bodies in a given flight time;
- the Tisserand Criterion which, in a purely energetic manner, assesses the maximum distance that a s/c can possibly reach based on its orbit and identifies reachable bodies and encounter conditions.

Both methods represent an essential tool to achieve an optimal design: the usual procedure foresees an iterative approach, in which the approximate solutions of an extremely simplified model are refined in a more complex environment. However a comprehensive solution has not been formulated yet.

This paper combines a phase-energy resolution approach applied to a single fly-by design problem. In the circular restricted three body problem, the departure and arrival conditions are assigned to parking orbit about the respective planets whose ephemerides are represented in the synodical frame of the planet where the fly-by takes place. Such configuration enables the resolution of the Lambert problem in the circular restricted circular three-body problem.

An alternative formulation of the Tisserand parameter is presented: the elimination of the assumptions on the mass of the primaries and on the position of the s/c guarantees a free use in the three-body space. Although, attention must be paid in the determination of the orbital elements associated, which in such configuration must be determined in the barycentric frame. The pursuit of the possible trajectories in the infinite solution space is performed through a gradient-based approach and by means of the enhanced constancy of the modified Tisserand parameter which allow to satisfy the peri-apsis and flight time requirements. In the end, the selection of the optimal solution is demanded a conventional delta-v minimisation method.

This novel algorithm proved high capabilities when applied to a single flyby. Its verification was performed on the manned Mars mission which constitutes a key cornerstone of NASA Earth Independent Program.