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ON THE INCREASE OF CAPABILITIES OFFERED BY AN INDEPENDENT RESTARTABLE UPPER STAGE ON BOARD A STANDARD LAUNCHER

Abstract

The concept of an extra, independent kick stage on top of the standard configuration of a launcher to increase the performances for some specific range of missions is not new: the Payload Assist Module (PAM), used with the Space Shuttle, the Delta and the Titan launchers; and more recently, the Fregat upper stage, on board of Soyuz launcher; and the Breeze M module on board of Proton, are only some of the most prominent examples.

The main objective of such upper stage is to increase the capability of the launcher by adding an extra Δv for missions requiring it. This is the case, for instance, of satellites to be transferred from a Geosynchronous Transfer Orbit (GTO) to a Geostationary Earth Orbit (GEO); or satellites to be injected into an Earth Escape Trajectory (EET). Additionally to the extra impulse in absolute terms, the multi-burn option dramatically increases both the flexibility of the launcher and the range of missions that could benefit from it.

The purpose of this paper is to quantify the capabilities of one such independent, restartable upper stage on board the Ariane 62 launcher for interplanetary missions. This is done by analyzing, end-to-end (that is, from launch pad to injection in the final intended orbit), the trajectories of the several stages of the launcher, for a given range of hyperbolic excess velocities, or its square, C3, as it is usually considered in the context of interplanetary missions.

As optimization engine, a Multiple Sub Arc Sequential Gradient Restoration algorithm is used, for the optimisation of the duration, position and orientation of the exo-atmospheric burns. Further, the atmospheric arc is propagated from the parameters that fully determine the flight in the low layers of the atmosphere: mass at lift-off, azimuth angle and pitchover manoeuvre. The model is first validated against the Ariane 62 user manual, and only after is increased with the option of including an extra upper stage for the end-to-end analysis.

Performance maps, in terms of final mass at the target orbit for several C3 values, as a function of the upper stage design parameters (structural index, propellant mass and thrust level, as a minimum) are offered and discussed.