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AN OPTIMAL AERODYNAMIC-DRIVEN ROCKET LANDING STRATEGY

Abstract

In recent years, reusability has become a dominant feature in the design of novel small launch vehicles. In particular, the ambition of re-using one or more rocket stages is driven by the interest in reducing the cost associated to accessing space. The most effective solution implemented to date requires the capacity of landing one, or more, stages of the launcher maintaining its integrity and allowing rapid recovery, check and refurbishment. If it is true that the cost of these operations is a limited fraction of the total, landing a rocket requires guidance and control systems which are significantly more complex and expansive than the ones used on traditional expendable rockets. In this work, we propose a rocket landing strategy which can be implemented using the same control devices required for the ascent phase. The landing phase starts after the burnout of the rocket engine and evolves into (i) a coasting arc dominated by aerodynamic drag followed by (ii) a powered landing arc. An optimal control law, aimed at maximizing the energy dissipated by the aerodynamic drag, is developed for the coasting arc (i), based on the analysis of energy balances during the ballistic flight of the rocket stage. This control law defines the angle of attack of the rocket, therefore the required deflection of fin-tips devices, requiring only information on the velocity magnitude, pitch angle and drag coefficient of the rocket stage. The actuation of the fin tips can be derived explicitly from the control law and can be easily implemented for real-time operations. A second optimization problem is solved to identify the optimal time, or switching point, from arc (i) to arc (ii), when the rocket stage is rotated, to set the nozzle axis parallel to the local vertical direction, and the main thruster is ignited for a time sufficient to ensure a soft landing. The proposed strategy does not require knowledge on the inertia properties of the rocket stage, which vary during the powered ascent phase and landing arc (ii), and whose accurate determination is not trivial for real-time operations. The effectiveness and performance of the landing strategy are evaluated by means of numerical analysis, performed using aerodynamic and inertia data of the Algol first stage of SCOUT launchers.