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TRAJECTORY OPTIMIZATION OF AIR-LAUNCHED ROCKETS VIA DIRECT COLLOCATION METHOD

Abstract

Recently, satellites of reduced size and mass have attracted the interest of the scientific community. This is due to the fact that more and more frequently specific mission objectives can be achieved with small, cheap satellites. A convenient option for launch and orbit injection of these systems is represented by air-launch. The use of an air-dropped rocket for delivering a small payload into the desired orbit has several advantages. First of all, payload release is much more flexible, because the delivery conditions are directly related to the dynamics of the aircraft and can be viewed as independent of ground facilities. Secondly, reduced costs are associated with the higher efficiency of an aircraft in the lower layers of the atmosphere with respect to traditional ground-launched rockets. Lastly, air-dropped rockets are the most promising option to perform launch-on-demand missions. Usually, air-launched rockets separate from the aircraft in a horizontal flight condition. This study considers the trajectory of an air-launched three-stage rocket vertically released from an aircraft. Realistic rocket characteristics are assumed, with regard to mass distribution, aerodynamic properties, propulsion, and size (in connection with the carrier aircraft). The rocket trajectory after release is composed of five phases: (i) vertical drop, with a parachute; (ii) first stage propulsion; (iii) second stage propulsion; (iv) coasting arc; (v) third stage propulsion. The overall trajectory is controlled through the thrust direction and the selection of the optimal time intervals associated with each flight phase. The trajectory optimization is aimed at maximizing the final mass in orbit and is pursued through the use of the direct collocation with nonlinear programming algorithm. The method at hand is based on the conversion of the dynamic equations into nonlinear constraints through collocation. This transcription process employs high order quadrature rules, which make it particularly accurate. Guess generation for this method is required and is relatively challenging. This study proposes a simple and intuitive approach to generating suitable trajectories, which can be utilized as a guess by the direct collocation with nonlinear programming algorithm. This work definitely demonstrates that the method at hand is actually capable of optimizing a variety of ascending trajectories of air-dropped rockets, with respect to distinct operational orbits