Paper ID: 77255
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IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Future Space Transportation Systems (4)

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DEVELOPMENT OF TRAJECTORY OPTIMIZATION TOOLS FOR QUICK PERFORMANCE EVALUATION OF REUSABLE LAUNCH VEHICLE CONFIGURATIONS

Abstract

Reusability is nowadays the most prominent development field in the Space transportation sector as demonstrated by the great increase in companies who try to enter this field and acquire such capability. The design of reusable launch vehicles represents a significant challenge for companies which aim at developing this technology. In the first phases of the design, a fast evaluation of candidate launch vehicle configurations is extremely important. This paper is intended to present a method for designing and optimizing the ascent and re-entry trajectory for a two stage to orbit launch vehicle, considering the recovery of the first stage. The aim is to develop a tool for a quick assessment of the vehicle performances over a wide set of missions: SSO, Mid inclination, equatorial and GTO. Regarding the recovery of the first stage, the tool will optimize ascent and re-entry trajectory considering any re-entry strategy, which can be summarized into a continuous domain composed of two families of trajectories depending on the position of the landing platform with respect to the natural impact point of the stage (NIP): (i) below the NIP, (ii) above the NIP. A degenerate solution divides the two families, corresponding with a platform positioned at the NIP. From separation, the first stage performs a controlled re-entry trajectory involving a maximum of three ignitions performed with an optimized number of the available liquid rocket throttleable engines: (a) BOOSTBACK burn (for the below the NIP family) or TARGETING burn (for the above the NIP family), aimed at injecting the vehicle into a trajectory with a ballistic impact point corresponding to the location of the landing platform/drone-ship , (b) Entry burn, needed to reduce dynamic pressure and adjust the downrange, (c) LANDING burn, where throttling is employed in order to ensure a touch down with the required velocity and position accuracy. The NIP strategy does not need any burn right after separation, only the entry and landing boosts are used for this strategy. The optimization is managed in two steps: the ascent trajectory is optimized estimating the propellant mass consumption needed for the re-entry with a simplified model. Once the ascent trajectory has been optimized, the re-entry phase is studied, designing the three boosts. Iterations of this process are then performed to refine the solution. The simplified boost strategy for reentry is also compared and validated with a more refined one based on convex optimization (SOCP).