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MULTIDISCIPLINARY OPTIMIZATION FOR NANO-SATELLITE LAUNCH VEHICLES

Abstract

Launch vehicles require highly optimized designs to maximize the mass fraction of the vehicle and reduce operation costs to maximize revenue. As a result, numerous studies and methodologies have been developed for the purposes of optimizing Launch Vehicles through a spectrum of disciplines. Although a number of methodologies exist, the scope is subjected to large traditional launch vehicles with multi-tonne payloads and therefore are invalid for small launch vehicles which typically operate with payloads in the range of 1-100kg. A major source of discrepancies when comparing nano satellite launch vehicles to tradition Launch Vehicles is regarding the weight estimation. Most weight models are empirical models based on traditional-sized datasets and do not accurately extend to small-scales. In particular for nano satellite launch vehicles, many structural components approach, or reach, minimum size limits, which means new models must be used. In addition, due to the reduced size, the structural mass becomes a much more significant portion of the launch vehicle weight, making the design optimization much more sensitive to the weight model used and so additional importance is placed on their accuracy. To address this need, a Multidisciplinary Optimization (MDO) technique specifically developed for nano satellite launch vehicles is described. The optimization model was built around three major sub-models, namely the structural model, the aerodynamics model, and the trajectory model. The structures model utilizes a Reduced Order Model (ROM) that is trained from Finite Element Analysis (FEA) results. The Aerodynamics model uses Missile DATCOM to asses aerodynamic performance, stability coefficients and pressure loading. Sensitivity Analysis is presented on each major sub-model that explores various approaches and their implications on the optimization results with comparison to traditional launch vehicles. A hybrid GA-SQP algorithm was used for the global optimization. For validation of the MDO model, two techniques of optimizing fuel volume and tanks lengths are presented. The first approach is by directly allowing the tank lengths as free input parameters and applying constraints on the optimizer to meet the required target orbit and payload, while the second approach is to set only the tank diameters and Delta-v loading ratios between stage, and iteratively solving the required tank lengths within an internal iteration loop.