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TRAJECTORY OPTIMIZATION FOR MULTI-STAGE SYSTEMS: A COMBINED AIRBREATHING AND ROCKET APPROACH

Abstract

This paper presents a trajectory analysis methodology for multi-stage launch systems that combines airbreathing propulsion with classical rockets, developed by FAST, a group of students from Politecnico di Milano. The proposed algorithm is used as a tool to predict the system performance and to give a broad set of values to perform a phase A comparison between potential architecture proposals. The considered mission is a combination of a first stage and a second stage: the former is thrusted by a turbofan, a ramjet, while the latter by a rocket. The goal is to optimize the trajectory of this system to achieve the most efficient and effective orbit placement of satellites. The selected cost function is the total mass of the system while economical, management, and operational constraints were imposed so that a functional and feasible system is obtained. The multi-stage rocket system presents unique challenges, particularly in terms of trajectory planning and control. The trajectory analysis will consider various factors, including the rocket's propulsion capabilities, atmospheric standard conditions, and desired orbital placement. The paper will discuss the methodology for optimizing the trajectory, including the use of numerical simulations and optimization algorithms. The results of the trajectory analysis will be presented, including the trajectory path and time-to-orbit for various scenarios. The paper will also consider potential limitations and challenges of the trajectory analysis, including uncertainties in atmospheric conditions and system parameters. Nevertheless, the presented tool can perform a sensibility analysis of various sets of open parameters. From this analysis it is possible to obtain a broad range of values spanning from the thrust of the engines to the expected wing surface and change them to a desired number. This is then an optimal tool to perform a phase A analysis of potential combined airbreathing and rocket systems. Ultimately, the proposed multi-stage rocket system has the potential to significantly enhance the efficiency and effectiveness of satellite placement in space, and the trajectory analysis presented in this paper provides a foundation for future research and development in this area.