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HYBRID PROPULSION SYSTEMS FOR RECONFIGURABLE SMALL SATELLITE CONSTELLATIONS

Abstract

Earth observation (EO) satellite constellations offer new applications enabled by innovative technologies extending their use cases. Additionally, the design of small satellites limits cost and development time, but imposes tight size, weight, and power (SWAP) constraints. Long revisit times make traditional EO satellites unsuited to observe rapidly evolving phenomena such as wildfires or cyclones. Reconfigurable constellations provide responsive solutions using satellites moving between a Global-Observation Mode (GOM), which offers complete coverage of the Earth, and a Regional-Observation Mode (ROM) where areas of interest benefit from a higher revisit frequency. To answer urgent observation needs, the satellites are able to transfer from a GOM orbit to a ROM orbit in little time. However, less time-critical maneuvers, such as the return to GOM, can focus on saving propellant to increase the total number of reconfigurations over the satellite lifetime. Therefore, satellites in reconfigurable EO constellations require both high thrust and high specific impulse, which are incompatible in most current propulsion systems. This research focuses on the optimal combination of two independent propulsion models into a hybrid propulsion system that satisfies performance requirements. By covering two complementary perspectives, a comprehensive analysis of current and future possibilities in hybrid propulsion systems for CubeSats between 3U and 27U is performed. The first approach is bottom-up and focuses on commercially available propulsion systems. Using a database of components as well as combinatorial optimization algorithms, optimal designs considering SWAP constraints are quickly identified to offer practical solutions to small satellite engineers hoping to take advantage of hybrid propulsion starting from a catalogue of components. However, the selected designs might not be optimal, since the propulsion systems were developed independently. Therefore, the second approach focuses on concurrent design optimization of both systems to produce optimal performance, subject to the same SWAP constraints, in a top-down methodology. Starting from the governing equations defining several types of propulsion systems, the space of possible hybrid designs is thus populated and then explored by a multi-objective optimization algorithm. Considering different levels of assumptions, this analysis shows how the design space for small satellite hybrid propulsion systems is bounded by theoretical limits. Additionally, a comparison with the bottom-up approach allows to quantify an optimality gap and helps inform how manufacturers could change their propulsion products to make them more efficient in combination with others. This research will be demonstrated on a 2U propulsion package for the Reconfigurable on-Orbit Adaptive Maneuverable Satellites (ROAMS) mission.