Sensitivity analysis of GNC strategies to propulsion system parameters for multi-orbits deliveries

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With the emergence of always more demanding space services, a whole new market dynamics has been set into motion. To answer these needs, the efficiency of orbital stage systems is not to be proven anymore, especially when looking at their active development worldwide. The introduction of these new types of spacecrafts in the sector is the perfect opportunity to strategically implement novel technologies, more efficient in terms of deliverable mass and time. In this perspective, trajectories need to be designed to optimize payloads delivery sequences, analyzing both the visitation arrangement and the transfers between orbits. The optimization process must, however, evolve very closely with the system it applies to, in order to avoid pushing the optimization too far without considering its real feasibility with existent and proven technologies.

The present study analyses how sensitive the mission strategy is to propulsive system constraints, using a broadly applicable algorithm on a case study. The mission scenario used for the analysis is the delivery of 6U CubeSats to eight Low Earth Orbits (LEO). The optimization strategy used in the study investigates the delivery sequence as a whole unit, without entering each transfer separately, and requires many input parameters. It is a bi-objective algorithm which optimizes both the mission time and either the propellant mass consumption or transfer time. The sensitivity analysis presented here assesses the effects of propulsion system-related parameters to the global mission strategy, in order to identify the design margins of the system. This study includes two-levels: first, the system level is investigated, especially the allocated mass of the propulsion system, the propellants choice, the engine cycle, the required specific impulse and the attitude control strategy. This loop offers a range of feasible key characteristics under which a generic mission could operate and identifies the constraints to the propulsion system operations. Once these operational characteristics are set, they are given as input to the second-level analysis which studies the effective performance and feasibility of such requirements. This means that the various system-level choices are analyzed at sub-system and component-levels. Finally, to close the loop, the impact of component-level choices to the overall mission strategy is analyzed by checking the sensitivity of the chosen mission plan to these parameters and hence validating its robustness to operational changes that could occur also after the beginning of the mission.

All in one, this paper assesses how mission logistics strategies and propulsion system architectures must work hand-in-hands from the very start in order to reach optimal results. The sensitivity of GNC strategy to various system and sub-system parameters is reported, together with possible mitigation choices. Among the range of possible values, the motivation to set certain input values are highlighted together with the presentation of the resulting output delivery sequence.