Paper ID: 78636
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (2) (4)

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MITIGATING FUEL SLOSHING DISTURBANCE IN ON-ORBIT SATELLITE REFUELING: AN EXPERIMENTAL STUDY

Abstract

In this study, a control strategy for on-orbit satellite refueling is proposed and experimentally evaluated, with a particular focus on mitigating the fuel sloshing disturbance during the docking phase. The ability to refuel satellites in orbit is a crucial aspect of satellite operations, as it can extend their lifespan and improve their overall performance. The proposed strategy combines model predictive control and linear quadratic gaussian control techniques to address the fuel sloshing disturbance, modeled using a spherical pendulum. Specifically, a stationary target satellite is to be refueled by a tanker satellite in the scenario. The fuel sloshing disturbance is induced by two 3DOF floating platforms, one of which carries a large fuel tank and acts as the tanker, while the other platform carries a small tank and serves as the target satellite. Experimental evaluations of the proposed control strategy were conducted in the Zero-G Lab facilities of the University of Luxembourg. The experiments involved the control of the tanker satellite to approach and dock with the target satellite while simultaneously compensating for the fuel sloshing disturbance. The performance of the proposed control strategy was evaluated in terms of the accuracy and safety of the docking process, as well as the fuel efficiency of the refueling mission. The results of the experimental evaluations demonstrate the effectiveness and feasibility of the proposed control strategy for mitigating the fuel sloshing disturbance during the docking phase of an on-orbit satellite refueling mission. Specifically, the proposed strategy achieved a safe and fuel-efficient docking trajectory in the presence of the fuel-sloshing disturbance induced by the floating platforms. These findings validate the simulation-based results and contribute to advancing on-orbit satellite refueling technology. Moreover, the proposed strategy has the potential to pave the way for more extended and more efficient on-orbit satellite missions.