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REFEX NAVIGATION DESIGN: IMPROVEMENTS TO THE NAVIGATION FILTER

Abstract

In the context of the ReFEx mission (Reusability Flight Experiment), the German Aerospace Center (DLR) aims to demonstrate Guidance, Navigation, and Control capabilities for an aerodynamically controlled Reusable Launch Vehicle (RLV) stage. This paper focuses on the Navigation system. In particular, it presents the last improvements in the Navigation algorithms, and the changes in the design that stem from them. As the vehicle is controlled via aerodynamic forces, ensuring precise knowledge of the attitude is essential to guarantee the success of the mission. This work revises two different scenarios in which the navigation solution deteriorates. First, the IMU errors together with the high rotational rates reached during ascent lead to considerable accumulated error in the estimated attitude. After ascent, the attitude is only partially observable through Sun sensor measurements. Once the aerodynamic forces are measurable again, the coupling of acceleration and position measurements provide full attitude observability. However, reaching that point with an excessive attitude error leaves Guidance and Control with limited reaction time. Second, due to the high speed with which the ReFEx vehicle penetrates the atmosphere, a bending in the structure due to thermal loads is expected. The Flush Air Data Sensing system (FADS) is located in the nose of the vehicle, and is used to estimate the Angle of Attack (AoA). The location of the FADS sensor together with the thermal bending induce a biased estimation of the AoA. This paper also proposes a solution for each of the mentioned problems. In order to reduce the error accumulated during ascent, an additional sensor (magnetometer) capable of observing a direction different from the Sun direction is included. The measurement model used in an Extended Kalman Filter (EKF) is described. Analysis of simulation results shows that having the magnetometer reduces the attitude error, leading to a reduction in the number of unstable trajectories during atmosphere re-entry. On the other hand, the bending angle is estimated in an additional EKF. This is accomplished through the combination of acceleration measurements with an aerodynamic database that relates attitude with respect to wind with forces experienced by the vehicle. Simulation results show how the additional knowledge of the bending angle reduces the error in AoA. Both improvements increase the probability of mission success.