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Orbital Dynamics - Part 1 (3)

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SIMULATION OF ORBIT AND GUIDANCE DESIGN FOR TSLV

Abstract

This paper presents the simulation results for the orbit design and the potential guidance law design for the possible development of the Taiwan small launch vehicle (TSLV). As the first step, the TSLV is intended to bring a 100 kg class microsatellite to a 500 km altitude circular orbit. For the guidance design, the linear-tangent guidance law (LTGL) is proposed to be a candidate. TSLV is a three-stage launch vehicle (LV) to be launched from the Taiwan Island toward the east direction so that the Earth rotation can be sufficiently used. Since the latitude of Taiwan Island is between 22 and 24 deg north, the inclination angle for the orbit is designed to be 22.5 deg. Right after the vertical launch, a short duration of pre-programmed thrust kick is used to turn the LV to an east direction gravity turn. Then the LTGL is initiated to guide the LV for a precise orbit insertion. For a three-stage LV, there are a total of 8 parameters: initial thrust angle of stage 1, final thrust angle of stage 1, initial thrust angle of stage 2, final thrust angle of stage 2, initial thrust angle of stage 3, final thrust angle of stage 3, zero-thrust time duration between stages 1 and 2, and zero-thrust time duration between stages 2 and 3. The whole research work has been done in three phases. The first phase is to prove the effectiveness of the LTGL in the pitch plane and the yaw plane, respectively. In pitch (yaw) plane LTGL simulation, a normal force disturbance in the vertical (horizontal) plane is used to deviate the nominal trajectory. It is found that the disturbed trajectory has very large deviation in both cases. The LTGL is then imposed to guide the LV back to the nominal trajectory. Adjustments in only two parameters are required. The second phase is to combine the pitch and yaw channels to become three-dimensional LTGL. Both aerodynamic force and normal disturbance force are modeled in three-dimensional space. Simulation results show that the altitude error is within 3 km and the circular orbital speed error is within 3 m/s. Adjustments in four parameters are required: initial and final thrust angles of both stages 1 and 2. In the third phase, disturbance in the payload mass is added. One more parameter needs be adjusted: the zero-thrust time duration between stages 1 and 2.