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TRAJECTORY CO-SIMULATION OF LAUNCH VEHICLE POWERED BY BEAMED ENERGY PROPULSION AND ITS RELAY SATELLITES DESIGNED FOR MICRO-PAYLOAD AT LEO

Abstract

Micro-payloads at low earth orbit (LEO) (e.g. Starlink communications and meteorological monitoring satellite) have been increasing in recent years. In view of this, the corresponding transportation systems with the abilities of quick response, low cost, environment friendly, and safety are needed. Vehicles powered by laser energy are considered as a meaningful solution because of the separation of vehicle and its power. The current plan is developed with three typical modes, including the pulsejet, the ramjet, and the rocket. The trajectory under an ideal atmosphere is studied, and ablation propulsion with pulsed laser has been considered in LEO transferring in both single-phase flight and three-phase flight. A few studies prove that laser propulsion system shows obvious advantages on cost, carrying capacity, and improving orbital lifetime of re-orbiting nanosatellites. However, a real force environment should be considered not to avoid velocity loss caused by air drag, and to provide an energy-saving scheme for LEO regarding vehicle as a mass point. Moreover, an LEO relay satellite should be investigated to lengthen the illuminated range of ground-based laser device, and to reduce the distance that beam travels inside the atmosphere. This study proposes an overall design of the vehicle powered by earth-based laser and relay satellites for LEO micro-payload. And the co-simulation of the trajectory, including the transport vehicle and its relay satellites, is depicted. Four disciplines are preliminarily considered in this overall design, including the propulsion, the structure, the aerodynamics, and the trajectory. A laser propulsion system with air-breathing mode inside the atmosphere and rocket mode at vacuum flight is chosen, which is both supported by beamed energy from an earth-based super laser station. A typical Myrabo vehicle is selected for air-breathing mode, while water is selected as medium for erosion at rocket phase. The U.S. 76's standard atmosphere model is adopted, and drag coefficients are provided by simulation. Relay satellites are used to support the vacuum flight phase through laser power from the earth. A 3-degree-of-freedom trajectory is simulated by 4-order-Runge-Kutta method with an ellipsoid rotating earth. Scheme trajectory is designed by different phases. To save maximum energy, an optimization is developed and multi-island genetic algorithm is chosen for its good global searching ability. The results show that the overall payload ratio (more than 0.1) is obviously better than traditional rocket launch vehicles. This study also reveals that the proposed method is useful for search the most energy saving laser trajectory, and relay satellites can solve the problem caused by long distance from laser source to vehicle.