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FREQUENT DEEP-SPACE ACCESS STRATEGY FOR VENUS AERONOMIC EXPLORATION MISSION USING EARTH-SYNCHRONOUS ORBITS

Abstract

Deep space missions are always expensive and less frequent due to several challenges during operations, such as selecting launch windows for the missions and desired orbital insertion. Recently, there has been an increase in the number of ultra-small spacecraft or CubeSats launches aided with a primary mission on the same launch vehicle as piggyback payloads or also referred to as rideshare missions [1]. Such missions include JAXA's Earth-Moon Liberation point orbiter, EQUULEUS, and the world's smallest lunar lander OMOTENASHI as piggyback spacecraft alongside Artemis 1 Orion spacecraft to the Moon [2].

Geostationary Transfer Orbits (GTO) are good launching points for deep space missions. However, in the case of rideshare missions, the primary mission typically determines launch conditions. This paper presents the design and development of an ultra-small spacecraft system with frequent deep-space access capabilities to explore the Venusian upper atmosphere. In this paper, we have applied our novel transfer strategy [3] that coordinates the CubeSat's time of departure from the GTO of Earth to Venus via an Earth Synchronous Orbit (ESO). This transfer strategy also enables the spacecraft to change its velocity direction by introducing multiple Earth gravity assists, thus allowing for a broader launch opportunity for CubeSat to reach Venus. This type of mission usually involves several major challenges: a) change of positional relationship between Earth and the target body, b) limitation of the GTO plane's orientation (inclination i, argument of perigee ω, longitude of ascending node Ω), c) attitude deviation due to spin of satellite, d) solar radiation exposure to the onboard systems, e) ΔV execution errors. In this paper, we developed a robust orbit transfer strategy that compensated for all CubeSat's mission constraints and technical challenges. We also developed systems design with scientific payloads and subsystems that utilize a hybrid rocket motor for this tech demo mission. Preliminary results suggest that the transfer method proposed in this study reduced the required total ΔV of 3.7km/s for transfer compared to the direct transfer method, even when the GTO's orientation elements and the positional relationship with Venus diversely changed.

References

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[2] Campagnola et al., IEEE Aerospace and Electronic Systems Magazine, 34, 4, 38-44.
[3] Ito et al., Journal of Spacecraft and Rockets, 60,1, 79-94.