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ORBIT MANOEUVRE STRATEGIES FOR VERY LOW EARTH ORBIT (VLEO) SATELLITES

Abstract

Background
The VLEO region at altitudes below 450 km provides a viable option for reducing the congestion in Low Earth Orbit (LEO). Being closer to the Earth, satellites operating in VLEO benefit from higher image resolution and reduced communication latency. However, they also experience a significantly larger atmospheric drag compared to higher orbits, leading to rapid orbital decay under passive fall due to much denser atmosphere present in VLEO. Another challenge associated with operating in VLEO is the modelling error of atmospheric density. This paper focuses on predicting the orbit of a future VLEO satellite and subsequently proposing orbit maintenance strategies between altitudes 250 km and 500 km. It is hoped that the results will provide insightful guidance for mission designers with an enhanced understanding of VLEO as an operational region for satellites.

Methodology
A satellite operating in VLEO with a dual-thruster electric propulsion system is considered. The impact of solar activity on atmospheric drag is investigated by modelling the F10.7 solar index based on observation data of the past 4 solar cycles. Using MATLAB, the satellite's non-Keplerian orbit subject to atmospheric drag is propagated. After predicting the satellite's orbit under passive fall, a trade-off study is conducted to analyse different orbit maintenance strategies by varying the key parameters including altitude, thrusting frequency, thrusting duration, ΔV and thrust magnitude.

Results
The upcoming solar activity cycle, depending on the sources, is expected to be similar or much stronger than the previous one, with a peak of 220 sfu occurring in December 2024. Without any orbit-raising manoeuvre, a 100 kg satellite to be launched in January 2025 at 500km is predicted to re-enter the atmosphere after 1190 days. By fixing the thrusting duration, contours of ΔV required in a graph of altitude increments against the targeting altitude are plotted. By fixing the altitude increment, contours of thrusting force in a graph of thrusting duration against the targeting altitude are plotted. An optimal combination of fuel consumption and thrusting frequency can be extracted from the graphs that will fulfil both the mission requirements and propulsion system constraints. Finally, comparison between electric propulsion and traditional chemical propulsion is drawn by computing their ΔV ratio.

Conclusion
This paper demonstrates the potential and feasibility of operating satellites in VLEO using electric propulsion. The results serve as a steppingstone towards enabling more VLEO satellite missions to be advanced in the future.