Moon Mission Lifetime Analysis of a 2U CubeSat Equipped with Pulsed Plasma Thrusters; The Aoba-VELOX IV Mission Case

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The capability enhancement of CubeSats shows that the proposal of deep space missions is becoming feasible. Moreover, recent advances in low-power propulsion systems potentiate CubeSats orbit control capabilities for the extension of their mission lifetime and increase of orbit manoeuvre range, in order to reach an optimal operational orbit [1]. Particularly in lunar orbit, the avoidance of unstable orbits is an issue to be overcome for the accomplishment of a long-term mission [2,3]. However, being a piggyback limit the choice of an optimal operational orbit and the implementation of this kind of propulsion systems become attractive for their implementation into CubeSats. In this paper, we focus on the analysis of mission lifetime extension capacity of a two-unit CubeSat whose propulsion system is based on pulsed plasma thrusters (PPT). Our analysis is based on the features of Aoba VELOX-IV (AV4), which is a two-unit CubeSat developed by Nanyang Technological University and Kyushu Institute of Technology. AV4 will serve as a platform for technology validation towards a future lunar mission for the observation of lunar horizon glow [4]. AV4 will be launched to LEO by Japan Aerospace Exploration Agency in 2018. One mission of AV4 is the demonstration of PPT technology to be used for the attitude and orbit control system (AOCS) in the future lunar mission. Because we needed to derive the success criteria of the PPT future lunar mission, such as ΔV, thrust, etc., a satellite flight simulator was developed, which includes the LP165p gravitational field model. Considering the PPT initial propellant budget that produce 60m/s ΔV, as well the lunar 2U CubeSat power system features and its orbit manoeuvre strategies, we conclude that 57.5 m/s ΔV should be designated for orbit maintenance and 2.5 m/s ΔV for the desaturation of the reaction wheels (about 125,000 pulses), to accomplish a one-year term lunar mission for the observation of the lunar horizon glow and orbit maintenance task in 100km altitude circular lunar orbit. Regarding orbit control capabilities and mission lifetime extension, our analysis shows that a one-year term lunar mission can be achieved by deploying this 2U CubeSat into an initial orbit whose inclination is above 70° or placed into frozen orbit, and performing orbit control manoeuvres by using 57.5m/s ΔV thrust budget. The deployment of the satellite into different orbits will not be suitable for a one-year term mission. For example, in the worst-case scenario (15° inclination), the mission lifetime will be increased from 40 days to more than 2 months, depending on the PPT ΔV capability and impulse bit, but at the expense of an increase in eccentricity (more than 0.08). Other orbit manoeuvre strategies such as eccentricity and inclination control demands higher ΔV capability and impulse bit requirements. Based on these results, mission lifetime extension capability for a 2U CubeSat in lunar orbit is possible but limited to certain orbit manoeuvres and orbit inclination to achieve a one-year term mission. Additionally, we demonstrate the feasibility of AV4 orbit control capabilities by its PPT unit, as well as the desaturation of the reaction wheels for the proper operation of the AOCS, to meet its mission requirements and further application into lunar orbit.

References

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