Design and Analysis of a CubeSat Lunar far-side Positioning Mission

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Future lunar missions will intentionally explore the far side of the Moon. The far side of the Moon has very different terrains as well as resources from the near side. It is also an ideal platform for radio astronomy since the Moon can shield noises from the Earth. China will land the explorer Chang'E-4 on the far side in 2018[1]. However, special challenges of navigation and communication arise, for the far side is invisible to the Earth. Moreover, the tough terrain on the far side imposes strict requirement on the landing accuracy. For the above reasons, we propose a project named PHOEBE (Positioning using earth-moon Halo Orbit Experimental BEacons). PHOEBE consists of four 6U CubeSats deployed along an Earth-Moon L_2 (EML2) halo orbit for providing the required positioning service. The reason is twofold: 1) EML2 halo orbits can always be seen from the Earth and the far side of the Moon, which is favorable for constant communication as well as tracking; 2) CubeSats are of low cost and small size, and thus can be easily carried by a mother spacecraft along with a lander going to the Moon.
On the other hand, trajectory design and operations of CubeSats are restrained by their limited size. This paper presents the optimal transfer trajectories to deploy the four CubeSats evenly along a halo orbit and maneuver plan for the station keeping of the halo orbit. It is obtained in the study that the Δv budget of a CubeSat should cover a deployment cost up to 100 m/s and a station-keeping cost of 20 m/s per year. Figure 1 shows the transfer trajectories for distributing the CubeSats along a halo orbit. The positioning performance is best with such a most distributed configuration. Supposing that the desired accuracy of positioning is 1 km, the temporal and spatial coverages of the far side of lunar surface are analyzed. A continuous-thrust optimization is also computed for various magnitudes of thrust, based on which proper propulsion systems for the CubeSats can be selected. In addition, the paper presents the preliminary design of communication, attitude determination and control and power systems. The power availability for Earth-communicating, Moon-communication and thrusting phases is also given (see Figure 2).

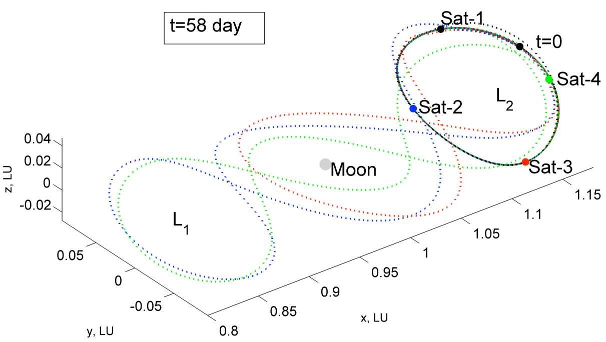

Fig. 1. Transfer trajectories to deploy the four CubeSats along a halo orbit.

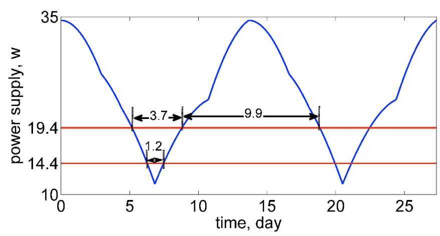

Fig. 2. Power availability for Earth- (14.4 w) and Moon-communication (19.4 w).

References

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