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FUEL-OPTIMAL FORMATIONS FOR TELESCOPE-STARSHADE OBSERVATORIES IN LUNAR SPACE

Abstract

Starshades are one starlight suppression system that can achieve a sufficient exoplanet-to-star flux ratio for direct light spectroscopy measurements of exoplanets. This external occulter flying in formation with the telescope along the telescope's line of sight to the target star blocks on-axis starlight while still allowing off-axis light from the exoplanet to reach the telescope. However, starshades have yet to be flown in a mission. Additionally, mission planning has primarily been focused on telescope-starshade systems in a halo orbit about the Sun-Earth L2 (SEL2) point. These orbits are favorable for the telescope but have not been proven to be optimal for starshades. Thus, we perform a survey of lunar orbit families to identify optimal orbits for telescope-starshade observatories in order to capitalize on the current lunar interest and further develop the field of exoplanet mission design beyond SEL2 halo orbits. The orbit families were built using differential corrections algorithms and shooting and continuation methods. Subsequently, observatory models were designed using the generated orbits for the telescope and the starshade flying relative to the telescope. State-of-the-art mission simulation software was used to examine the stationkeeping and slewing phases. We present starshade stationkeeping metrics for observation scheduling, including delta-v and the portion of the simulation time spent firing thrusters to correct for starshade drift, for a grid of stars uniformly distributed in ecliptic latitude and longitude. Cases with and without a starshade axial drift control law are included to demonstrate controller impact. From the end-to-end mission simulations, we show metrics like starshade slew fuel usage and unique exoplanet detection and characterization counts as averages over 300 simulations. We discuss the benefits and drawbacks of each lunar orbit family to make recommendations for future mission concept development. Finally, we contextualize the lunar orbit results through a comparison to SEL2 halo orbits and a discussion on economics, mission type, and technology readiness levels. This work aims to provide a more detailed investigation of starshade operations by searching for its optimal environment. Orbit evaluation and observatory model development, which is made available as open-source code, will aid future mission concept development in selecting the best candidate for exoplanet research using direct imaging techniques. Moreover, this work can be adapted to a formation-flying trajectory analysis of the lunar orbital environment for a gamut of astrophysics research requiring distributed space systems.