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FEASIBILITY STUDY OF SUN OCCULTATION MISSIONS USING NATURAL BODIES

Abstract

Understanding the solar corona and its composition can provide new insights regarding the temperature and the magnetic field of the Sun. The light coming from the corona is more than a million of times weaker than the direct light from the Sun. Observing the corona is only possible when obscuring the Sun in order to see the most external region. From ground, total solar eclipses offer a good opportunity to observe the corona; however, these events only occur every 18 months on average, lasting typically only for few minutes. Another option for observing the corona is to use coronagraphs. These special telescopes allow astronomers to observe only the external region of the Sun by adding an occulting disc. This technique allows almost unlimited number of observations, although it is affected by the turbulence of Earth's atmosphere and atmospheric scattering. To avoid these disturbances, it is necessary to perform the observation from space. Some space missions to study the corona have already been proposed. Those missions usually involve two satellites, flying in formation. One satellite is the observer while the second one, when placed between the Sun and the first satellite, behaves as an occultation disc. Natural bodies, such as Earth or the Moon, can be used as occulting bodies. The goal of this paper is to perform a feasibility analysis of a Sun occultation mission using Earth as an occulting body. However, the occultation zone created by the Earth does not follow a Keplerian trajectory. So, the satellite will slowly drift apart from this zone without re-entering it for a long time. The focus is to design trajectories that allow the spacecraft to revisit the occultation zone as many times as possible while using the least amount of fuel. In addition to these first requirements, the analysis considers constraints at systems level such as limited mass and power budgets. Due to power limitation, the satellite is not allowed to control while performing the scientific mission (if using electric propulsion). In addition, the satellite has to go out from the umbra region in order to recharge the batteries before the following revisit. The trajectory design is developed in Sun-Earth-Spacecraft circular restricted three body problem. Optimal control theory is applied to compute either energy-optimal and fuel-optimal spacecraft trajectories. Preliminary results using a linear quadratic regulator have shown that it is possible to obtain up to 4 revisits per year with 1.5941 km/s.