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OPTICAL SYSTEM DESIGN FOR A MULTI-CUBESATS DEBRIS SURVEILLANCE MISSION

Abstract

The detection and observation of space debris in Low Earth Orbit is generally carried out through the use of ground based radars and telescopes. These instruments allow for a precise reconstruction of the space debris trajectories, and therefore represent a key asset for planning avoidance maneuvers when threats of collisions are predicted.

The recent deployment of mega-constellations, with the consequent increase of the number of satellites, imposes new challenges in terms of simultaneous tracking capability and readiness of the current space situational awareness systems. This adds to current need to track small and dull objects to further mitigate the probability of triggering cascade collisions. However, ground based observations are limited due to their intrinsic sensibility to atmospheric refraction, their diurnal inoperability and their dependence meteorological hazards.

This paper proposes to study the feasibility and the benefits of a potential deployment of a constellation of CubeSats in Low Earth Orbit, to acquire optical observations of space debris with enhanced accuracy, as part of the ORCA mission: Orbit Refinement for Collision Avoidance. Here, the focus is on the optical design of the payload instrument to be integrated onboard of the orbiting platforms.

The study trades-off the current state-of-art of optical detection technologies, by assessing their performance against a set of specific requirements: (a) the minimization of the uncertainty associated to the image resolution; (b) a field of view that maximizes the extent of the monitored area; (c) an optimal exposure time to avoid under or overexposure of the image; (d) minimization of the effects of light diffraction and above all, (e) the maximization of the signal to noise ratio to detect the smallest and dullest objects possible. Real observations of space debris are conducted to validate the models.

Several configurations of optical systems are then chosen as suitable for the ORCA constellation, also considering the system design implications on its integration into a CubeSat such as size requirements. Commercial Off-The-Shelf hardware are explored and performances of the optical system are evaluated through numerical simulations in order to estimate the detectable sizes of space debris while taking into account their potential distances from the sensor. This paper concludes with estimates of the impact of the ORCA mission on space situational awareness for decades to come.