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OPTICAL AND LIDAR SYSTEM FOR ON-ORBIT SPACE DEBRIS DETECTION

Abstract

It is estimated that the amount of space debris will continue to grow in the future, however, current Earth-based observations can only track relatively large debris. With the increase in the number of space missions, it is important to perform Space Surveillance and Tracking (SST) on small debris which can still lead to catastrophic collisions. This work presents the preliminary design of a combined optical and laser system for Low Earth Orbit (LEO) centimeter-sized space debris detection from a small satellite. The laser is intended to complement the optical system, which is the main observation mechanism, by enhancing close proximity detection capabilities.

The project was developed in the context of PoliSpace students association in Politecnico di Milano. The team was composed of two team leaders and three members pertaining to their capabilities and interests. The team split into two groups, each with its own leader, working synergistically on the two different aspects of the proposed approach. As foreseen within the association's regulations, weekly update meetings involving the whole team, plus additional meetings involving only the sub-groups, took place.

Concerning the system design, an ND:Yag LiDAR system was selected for further study through radiometric model analysis. Then, a Three Mirror Anastigmat (TMA) architecture was developed, including a beam splitter, and an SNR model of the visible detector. Finally, to preliminary validate the performances, a detectability study was performed through ESAs PROOF software employing the characteristics of the optical system and focusing on the orbital region of interest.

Focusing on the 0.9 to 10 cm range of debris diameters, the LiDAR system, with 125 Watts dedicated power, can detect debris at distances up to 50km. The optical system has a 10 degree Field Of View (FOV) and operates close to the diffraction limit with no aberrations, while efficiently separating visible and IR light. Ultimately, it can detect large numbers of debris at ranges of 40km to 500km and SNRs higher than 5. Thus, 198 weekly detections are possible with the optical system alone while the LiDAR can supply a further 25, a significant improvement with respect to other systems in literature. The feasibility study shows an innovative system that theoretically delivers detection capabilities from an in-orbit small platform, as opposed to the current Earth-based systems. The combination of optical and laser observations differs from the commonly implemented ground-based radar and optical systems, offering a new technological approach for future missions.