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Space Debris Detection, Tracking and Characterization - SST (1)

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A CUBESAT-BASED SPACE SYSTEM TO MONITOR SPACE DEBRIS POPULATION IN LEO

Abstract

We present a feasibility study of a tentative mission for spaced-based space debris observation in low Earth orbit (LEO). The goal of the mission is to characterize the space debris population in a chosen region of interest in LEO, provide statistical information for small (not large enough to be catalogued and tracked via ground-based monitoring systems) space debris objects, and perform on-demand orbit determination for specific debris objects.

The proposed space system architecture implies using clusters of CubeSats (each comprising two or three spacecraft). The study starts with the spacecraft sizing provided the commercially available optical sensors. One of the objectives of the study is to derive system's requirements (such as number of clusters, intersatellite distances within clusters, number of spacecraft and their characteristics, and optical sensors' parameters) from the high-level requirements (such as size distribution of the debris objects to be observed and accuracy of orbit determination from short-arc multipoint observations).

An important part of the study is the optimized orbital configuration for the mission, which takes into account the visibility conditions, imposed by using the optical sensors, the assumed distribution of debris objects in the region of interest (corresponding to ESA's MASTER models), and exploits J2-effect to collect enough observations in the region of interest to verify the existing statistical models describing the small space debris objects populations. We optimize the orbital configuration for time and analyze the number of clusters needed to collect enough samples depending on the time requirements.

Another important outcome of the study is the multipoint measurements processing algorithm that determines a space debris object's orbit from short-arc observations performed by the spacecraft in the same cluster. We derive an Extended Kalman Filter to process the measurement data and relate its accuracy to the number of spacecraft in the cluster, required intersatellite distances, and optical sensors' parameters. The proposed algorithms are tested by extensive simulations.

The proposed study lays the groundwork for CubeSat-based space segment architectures enabling smaller space debris objects identification and tracking, verification of statistical models used to uphold space situational awareness, and paves the way for a technical demonstration mission to be designed by Skoltech University.