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INTEGRATION OF RADAR AND OPTICAL SYSTEMS ON CUBESATS FOR ENHANCED SPACE DEBRIS DETECTION IN LEO

Abstract

The frequency of satellite launches has surged significantly in the past 2 decades, owing mainly to its short development time and lower costs. Small satellites have become essential tools for testing technology and educational initiatives. However, this surge in the number of space objects also brings its own challenge; space debris. Detecting and tracking these smaller than 10 cm fragments in low Earth orbit (LEO) or 50 cm in geostationary orbit (GEO) from the ground has proven to be a difficult task. This study focuses on enhancing space debris monitoring by integrating radar and optical observation methods, aiming to improve both detection and tracking precision. The proposed framework is composed of a computational model that simulates CubeSat constellation orbital mechanics to evaluate the performance of active and passive sensors during the CubeSat lifetime, while simultaneously taking into account characteristics such as the CubeSat power, size and operational complexity. To improve precision, NASA GMAT will be used to model orbital dynamics and analyze tracking performance under different operational scenarios. Complementary tools such as Orekit will be integrated for more accurate propagation models. The study employs computational optimization algorithms to identify the most effective combinations of detection technologies and mission concept of operations (ConOps) strategies.The combination of radar and optical systems enhances measurement capabilities, as radars deliver precise range data while optical sensors refine angular accuracy. The contribution of this study aims to maximize debris detection efficiency while adhering to the inherent limitations of CubeSat platforms. In order to enhance debris tracking, machine learning algorithms will be analysed. Random forest and gradient boosting will be used to classify debris from the received data. LSTM on the other hand will be used for collision risk assessment and trajectory forecasting.

By effectively mapping space debris smaller than 10 cm using software simulations, this study will help advance space sustainability efforts. It will also enhance debris tracking capabilities and help mitigate collision risks for operational satellites. Ultimately, this study aligns with the ongoing initiatives by the world's space ecosystem aimed at improving space sustainability and promoting the responsible use of space technologies.