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ENHANCING SMALL EARTH OBSERVATION SATELLITES WITH SPACE GRADE COMMERCIAL-OFF-THE-SHELF (SCOTS) TELESCOPE PAYLOADS

Abstract

Aim: Small satellites are transforming Earth observation by providing cost-effective, agile platforms for environmental monitoring. The HYPSO (HYPer-spectral Smallsat for ocean Observation) series—comprising HYPSO 1 and HYPSO 2—has demonstrated that open-source hyperspectral imaging (HSI) optics with commercial off-the-shelf (COTS) components can effectively monitor coastal water quality along the Norwegian coast. Building on this success, the upcoming HYPSO mission aims to achieve a better than 10-meter ground sampling rate (GSD) to capture detailed inland water quality data. Preliminary prototyping using a 900mm Tokina front lens on the HSI V6 platform indicates that achieving the desired resolution is hard without having a bad signal-to-noise ratio (SNR) with high spectral resolution. While the performance of the Tokina lens underscores the impressive capabilities of COTS lenses, it may also represent the upper-performance limit of current COTS lenses. Moreover, traditional COTS telescope systems have been dismissed for space applications due to issues with focusing mechanisms and mechanical rigidity. Although specialized telescope optics have been successfully deployed in space, no COTS hyperspectral imaging telescope has yet been deployed. This study investigates how traditional COTS telescope designs can be modified into space-grade COTS (SCOTS) optical payloads that meet the demanding performance criteria of small Earth observation satellites.

Method: This study modifies a Celestron Schmidt-Cassegrain (C6) COTS telescope by integrating a robust delta mechanism that enables post-launch focal adjustment. Traditionally, these telescopes rely on adjusting the primary mirror to focus, a method prone to focus inaccuracies, drift, and mechanical instability under the stresses of launch and orbital operations. In contrast, this research redesigns the secondary mirror, similar to the Tokina lenses, to enhance focusing precision and overall structural robustness. The modified design is evaluated against the established 900mm Tokina configuration. Rigorous laboratory tests—including vibration and thermal vacuum tests- simulate space's harsh conditions, while optical performance is quantitatively assessed through point spread function (PSF) analysis.

Results: Initial vibration testing indicates that the re-engineered telescope has the same mechanical robustness as a Tokina 900mm lens. Optical evaluations demonstrate improved image resolution and SNR, with the SCOTS configurations successfully meeting the high GSD target.

Conclusion: This research establishes a viable pathway for transforming conventional COTS telescope designs into SCOTS optical payloads, effectively bridging the gap between cost efficiency and high-performance requirements. The findings underscore the potential of SCOTS payloads to enhance the capabilities of small satellites.