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CHALLENGES IN SYSTEM DESIGN OF A HIGH-PERFORMANCE VNIR/SWIR HYPERSPECTRAL IMAGER FOR MINI-SATELLITES

Abstract

Small satellites for responsive space and spaceborne hyperspectral remote sensing are two contemporary emerging and enabling technologies. Small satellites suggest significant effectiveness in terms of mission life costs and efficiency due to reduced launch costs and improved performance enabled by low power consumption, increased maneuverability and on-board computing capabilities. Responsive space suits well the effectiveness of small satellites in Earth Observation (EO) for both commercial and defense purposes. The improved agility provides for improved ground coverage, image quality and imagery throughput. Spaceborne hyperspectral sensors acquire information across the optical spectrum, enabling image-based detection of materials through the identification of their unique spectral signatures in the scenery. An increasing range of hyperspectral applications require quick tasking and imaging opportunities and on-line data exploitation information generation for the end-user. In search rescue/recover operations, wild forest fires, oil spills, etc., responsive hyperspectral can be solicited to support real-time decision making. Also, affordability of hyperspectral information in more routine operations for environmental and human activity surveillance implies the use of advanced such imagers in small-satellites. Hyperspectral products which are both responsive and of commercial value, require high-quality imagery, minimizing effortful processing and manual intervention that results in exceeding costs and long delays in end-user product delivery. However, considerable challenges arise when trying to integrate such high-performance sensors in small satellites. This study presents system-level design trade-offs and analyses resulting in a radically different design optimization, providing a high-performance, VNIR/SWIR hyperspectral sensor compatible with mini-satellites. High-performance hyperspectral sensors require large apertures with high throughput and tight optical design for, among others, axial and lateral color, stray light, and telecentricity. The combination of a wide spectral range and the need to correct the secondary spectrum significantly limits the use of dioptric or catadioptric optics. However, large-aperture catoptric telescopes, such as TMA, fail to meet the compactness required by a mini-satellite exercise. The results suggest a different design approach, combining a compact catadioptric telescope with a novel light-weight, compact and high-efficiency imaging spectrometer and an advanced, low-noise, high responsivity detector. Addressing demanding commercial service class applications, this novel design can reach SNR ¿ 200 in spectral bands of 10nm, at a ground sampling distance of 7m from a sun-synchronous 600km orbit with an about 100kg sensor system, fully compatible with mini-satellites of less than 400kg.