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ENABLING LIDAR INSTRUMENTS FOR SMALL SATELLITE EARTH OBSERVATION MISSIONS

Abstract

The past decade has seen tremendous progress in nanosatellite (less than 10 kg), or CubeSat, technologies. Enabled by the increasing availability of low-cost launch services and commercial off-the-shelf (COTS) components, these miniaturized satellite platforms offer affordable access to space for a variety of scientific payloads. As the capabilities of these small satellites have increased, interest in utilizing these platforms for advanced scientific instruments has grown considerably. Advances in sensor design and technology have similarly allowed sophisticated payload instruments to be miniaturized. However, there are still considerable challenges to deploying active remote sensing instruments such as lidars on these constrained platforms and maximizing their scientific returns.

Lidar (light detection and ranging) is a remote sensing technique that can provide observations with very high spatial, optical frequency, and timing (range) resolution. Based on the use of lasers as the active energy source, lidar instruments can achieve higher resolutions and precision than comparable radar technologies, often with relatively low power consumption and smaller instrument sizes. Lidar systems are highly relevant for space-based remote sensing, as they allow the study of fine-scale phenomena on planetary surfaces (such as measuring ice sheet heights, mapping terrain features, and determining wind speed from sea and land surface roughness) and in the atmosphere (such as monitoring emissions and measuring aerosol concentrations). Lidar was identified as a particular technology of interest by the National Research Council's "2018 Earth Science Decadal Survey for Earth Science and Applications from Space" as it can be used as a measurement approach for several of its targeted observables.

More recently, there has been significant research into technologies such as fiber lasers, integrated photonic circuitry, and single-photon detectors, facilitating the development of compact and efficient laser transmitters and highly sensitive detectors. These technologies have the potential to enable lidar instruments with reduced size, weight, and power (SWaP) constraints. This paper provides an overview of lidar techniques and technologies for nanosatellites and CubeSats and describes the key considerations and challenges of these miniaturized platforms. We analyze the performance requirements for specific observables and applications, including altimetry and atmospheric characterization. We present a model simulating the performance of a small satellite lidar instrument, based on which performance estimates for the various observables will be compared. With these results, we make recommendations for future instrument designs and mission profiles.