A comparison between conventional Earth Observation Satellites and Cubesats; Requirements, Capabilities and Data Quality

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From its early beginning as an educational tool in 1999, cubesats have evolved into a popular platform for technology demonstrations and scientific instruments. Ideas and innovations sparked from an enthusiastic community led to the development of new Earth Observation (EO) technology concepts based on large constellations of satellites with high-resolution optical imagers previously considered as infeasible. Probably the most significant constellation today is deployed by Planet who are currently operating a fleet larger than 120 3U Dove satellites, which provide an imaging service with up to 3m Ground Sample Distance (GSD). The number of low-cost EO Cubesat systems is constantly increasing. However, for a number of reasons there still seems to be a reluctance to use such data for many EO applications. A better understanding of the capabilities of the current generation of small Cubesats compared to the traditional well-established bigger operational missions of high and medium resolution EO satellites is required. What are the critical capabilities and quality indicators?

Due to the limited size and weight of Cubesats, critical system components, e.g. for navigation and communication, always compete with operational payloads such as optical camera/sensor systems. A functional EO system requires balanced payload, which provides adequate navigational capabilities, that match the requirements of the optical imagers (camera) deployed with the system.

Knowing the exact trajectory of the satellite is an essential requirement to task a successful image acquisition. The navigational data provides the position and orientation of the optical sensor at the time the image is captured. This so-called sensor orientation consists of a 3D position and three rotations, which are usually referenced to the World Geodetic System (WGS84). It is used to directly georeference the image to its exact location on the Earth surface. The current generation of very high-resolution (VHR) optical EO satellites are highly agile and are able to collect images from viewing angles of ±45° off-nadir with a pointing accuracy of less than 500m at the start and finish of the image collection. The image data collected is directly georeferenced with an absolute geolocation accuracy of less than 2.4m RMSE.

The quality of the acquired satellite images depends on the specifications and stability of the optical sensor and its calibration but also the orbital stability and atmospheric interferences. Key parameters are the geometric resolution called ground sample distance (GSD), spectral resolution and the radiometric resolution that is often described as the dynamic range. The spectral resolution specifies the number and width of bands recorded by the sensor within the electromagnetic spectrum. The radiometric resolution covers the 'bit depth' of an image channel. Dedicated optical EO imagers usually include panchromatic (greyscale), multispectral RGB and Infrared channels with a dynamic range of 11bit or higher. Hyperspectral imagers, which can record many 100 spectral channels with a separation of 10-20 nm, are less common but provide important data to many research communities, most often as airborne platforms. Sophisticated sensor models and elaborated calibration procedures ensure the quality of EO imagery from large satellites.

Small and inexpensive Cubesat systems may not match the capabilities and data quality achieved by dedicated EO missions but provide valuable data, which satisfy the requirements of many EO applications or service providers, but may fall short of the higher expectations by science or other sectors requiring very high-quality vetted image data. Continuous advances and innovative components continually push the envelope of Cubesat systems with better navigational control and more capable sensor systems. Planet's Dove constellation and GOMSpace's GomX4 demonstrators provide examples for operational optical EO systems based on Cubesats.

This study reviews the current performance and capabilities of Cubesats for optical EO and compares them to the capabilities of conventional, dedicated high and medium resolution EO systems. We summarise key performance parameters and quality indicators to evaluate the difference between the systems. An empirical study compares recent very high-resolution (VHR) imagery from big EO satellite missions with available images from Cubesats for the use case in disaster monitoring. Small and agile Nanosatellites or Cubesats already show remarkable performance. Although it is not expected that their performance and capability will match those of current bigger EO satellite missions, they are expected to provide a valuable tool for EO and remote sensing, in particular for downstream industry applications.

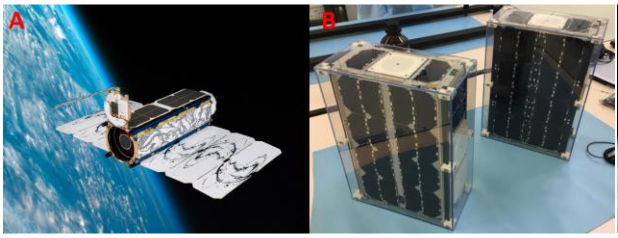

Figure 1: Planet Dove (A) GOMSpace GOMX4 (B)

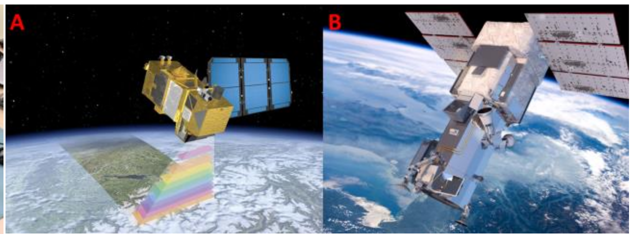

Figure 2: Sentinel 2A (A), WorldView 3 (B)

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