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Review

A survey and assessment of the capabilities of Cubesats for Earth observation

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ABSTRACT

In less than a decade, Cubesats have evolved from purely educational tools to a standard platform for technology demonstration and scientific instrumentation. The use of COTS (Commercial-Off-The-Shelf) components and the ongoing miniaturization of several technologies have already led to scattered instances of missions with promising scientific value. Furthermore, advantages in terms of development cost and development time with respect to larger satellites, as well as the possibility of launching several dozens of Cubesats with a single rocket launch, have brought forth the potential for radically new mission architectures consisting of very large constellations or clusters of Cubesats. These architectures promise to combine the temporal resolution of GEO missions with the spatial resolution of LEO missions, thus breaking a traditional trade-off in Earth observation mission design. This paper assesses the current capabilities of Cubesats with respect to potential employment in Earth observation missions. A thorough review of Cubesat bus technology capabilities is performed, identifying potential limitations and their implications on 17 different Earth observation payload technologies. These results are matched to an exhaustive review of scientific requirements in the field of Earth observation, assessing the possibilities of Cubesats to cope with the requirements set for each one of 21 measurement categories. Based on this review, several Earth observation measurements are identified that can potentially be compatible with the current state-of-the-art of Cubesat technology although some of them have actually never been addressed by any Cubesat mission. Simultaneously, other measurements are identified which are unlikely to be performed by Cubesats in the next few years due to insuperable constraints. Ultimately, this paper is intended to supply a box of ideas for universities to design future Cubesat missions with high scientific payoff.

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1. Introduction

TIROS-1, a US meteorological satellite launched in 1960, was the first satellite to be launched for the purpose of observing the Earth [1]. Since then, hundreds of Earth observation satellites have been launched that provide useful measurements to all the disciplines of the Earth sciences: hydrology, climatology, meteorology, aeronomy, atmospheric chemistry, oceanography, geology, biology, and so on [2].

The power of space-based measurements compared to ground-based or airborne measurements lies on their global or regional coverage and their relatively high temporal resolution. These two characteristics have made satellite measurements a key asset for a variety of societal applications including amongst others weather forecasting, disaster monitoring, water management, pollution, and agriculture.

Trends in Earth observing mission architectures have certainly changed over the years. The mass of past and present Earth observing satellites ranges from only a few kgs to 8 mt. The peak of mass was achieved in the 1990s and early 2000s with the launch for example of ESA's Envisat (2002, 7.9 mt), NASA's UARS (1991, 5.9 mt), and NASA's TERRA (1999, 5.2 mt) for example.

Large satellites such as Envisat were advertised to be great in terms of science as one could easily cross-register a variety of highly synergistic measurements taken at the same time from the same platform. Also, a reduction in cost per kg of payload was expected, as several instruments shared a single bus and a single launch. In reality, these cost reductions did not fully materialize due to the emergence of a plethora of engineering and programmatic problems during development: electromagnetic incompatibility between RF instruments; scanning instruments inducing vibrations on the platform that affect sensitive instruments; technologically ready instruments having to wait for less mature instruments to be ready for launch, and so forth.

Perhaps as a reaction to the problems found in these multi-billion programs, the increase in mass has stopped in the last decade, and both NASA and ESA have created programs based on smaller satellites around 1 mt, such as ESA's Earth Explorers or NASA's Earth System Science Pathfinders. Smaller programs based on single instrument satellites are more desirable from the engineering standpoint, as all the aforementioned issues related to several instruments sharing a platform are avoided. Furthermore, programs based on smaller satellites have desirable programmatic properties, for example in terms of robustness