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Editorial

Special Issue on Small Satellites Missions and Applications

Simone Battistini [1,*], Filippo Graziani [2] and Mauro Pontani [3]

1 MBDA Italia S.p.A., 00131 Roma, Italy
2 GAUSS Srl, 00138 Roma, Italy; filippo.graziani@gaussteam.com
3 Dipartimento di Ingegneria Astronautica, Elettrica ed Energetica (DIAEE), Sapienza Università di Roma, 00184 Roma, Italy; mauro.pontani@uniroma1.it
* Correspondence: simone.battistini@mbda.it

1. Introduction

Over the past few decades, space missions have been significantly revolutionized by the advent of small satellites. Ranging from tiny devices that fit in the palm of one's hand to larger craft weighing less than 1 ton, these platforms have proven to be very versatile and successful. Thanks to their compact size, reduced cost, and the use of standards, small satellites have given access to space to new subjects, such as universities and private companies. Many countries with little or no heritage at all in space missions have recently gained access to space through a small satellite mission. In some cases, the chosen satellite platform was a CubeSat, a nanosat in the form of a cube with s 10 cm side and a weight of less than 1 kg. CubeSat started as an educational project for university students at the end of the 1990s, and in less than 30 years it has established itself as the reference standard for commercial space applications [1].

Small satellites are nowadays used to integrate or even replace larger platforms in many tasks that were not considered possible for them previously. Their capabilities continue to evolve and adapt to new scenarios and demands. This Special Issue seeks to provide an overview of recent trends in the world of small satellite missions and applications. Great value is added by papers that report examples of solutions and lessons learned from real space missions.

The contributed articles belong to two broad groups—small satellite missions and spacecraft subsystems.

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2. Small Satellite Missions

The continuous development of technologies and the reduction in launch costs have allowed small satellites to be employed in a wide range of missions. Scientific exploration [1], disaster monitoring [2], data collection systems [3], telecommunications [4], and Earth observation [5] are some of the applications that have benefitted from the introduction of small satellites, which can be deployed in large flocks of inexpensive craft, thus guaranteeing short revisit times and global coverage.

An example of a real small satellite mission is reported in [3], which describes the capability and coverage of a satellite-based IoT network for providing remote data collection services to several developing countries. The system is based on a single CubeSat unit on board the KITSUNE satellite, a 6U CubeSat, and on a network of ground-based terminals. The performance of the system, evaluated using simulations, ground test results, and on-orbit observations of the KITSUNE satellite, show that it is capable of providing valuable information from remote locations.

Along with remote data collection, another essential service for developing countries is communication with remote areas. Small satellites provide this capability at a very low cost with respect to a ground-based infrastructure. Ref. [4] describes the development and early results of the AlfaCrux CubeSat mission at the University of Brasília (UnB, Brazil), whose main payload is a software-defined radio module. AlfaCrux is also an example of an educational project that trained university students on all the stages of the mission development [5], i.e., design, integration, and operation of satellite systems, all. Most of the small satellites for communications are placed in low Earth orbit (LEO). Their link performance and channel characterization are directly related to the elevation angle. Ref. [6] presents an innovative method to calculate the statistics of the random variable that characterizes the elevation angle distribution, overcoming the difficulties related to its direct analytical expression.

Earth observation is the third field of application for small satellites investigated in this Special Issue. Once again, what is lost in terms of available resources on board a small satellite (power, weight, etc.) is made up for by the greater number of spacecraft dedicated to the task. Small satellites offer the potential for high-frequency imagery of the Earth, with near real-time global Earth observation reconnaissance of all sunlit cloud-free locations. One of the issues faced by this application are the aerosol effects that degrade image interpretability. Ref. [7] describes an algorithm for atmospheric correction that was specifically developed for small satellites application.

The great number of spacecraft needed to perform all of these missions means that the launch and reentry phases are a critical aspect for the small satellites ecosystem. As a matter of fact, new companies have been created to target this sector of the market, and innovative launcher concepts have been proposed to allow launching on specific orbits at a low cost. The study of an analytic method to define multistage launcher trajectories is introduced in [8]. This method allows one to predict the payload mass that can be inserted into different orbits. The investigation of the attitude motion of the TNS-0 #2 nanosatellite during reentry [9] gives some insight into the magnetic and aerodynamic stabilization using real telemetry data from the spacecraft.

3. Small Satellite Subsystems

Due to the constraints they have to deal with, the design of small satellite subsystems often presents state-of-the-art solutions. It is therefore important to examine the contributions on small satellite subsystems in this Special Issue.

One of the most investigated fields is that of guidance, navigation, and control (GNC). Modern small satellite missions heavily rely on autonomy to achieve their objectives. One of the new frontiers in this sense is the autonomous execution of close-proximity operations, which would open the way to a new market based on in-orbit services. Ref. [10] describes the design of the guidance and navigation algorithms necessary to perform a rendezvous between two small satellites. The guidance is based on an iterative algorithm so that the errors of the navigation are corrected at every firing step. Innovative algorithms rely on novel sensors, including image sensors. An artificial intelligence-based algorithm for brightest object segmentation in night sky images' field of view is presented in [11]. This algorithm has a dual use for both attitude determination and control operations and space surveillance and tracking. Other algorithms are dedicated to sensor calibration, as in the case of [12]. This paper focuses on the calibration of a magnetometer through genetic algorithms using data observed by BIRDS-3 CubeSats. The design of the electrical interface bus for the same nanosatellites is presented in [13]. This design allows for accommodating multiple missions and different payload requirements. An interface like this allows one to maximize the productivity of the system from a manufacturing point of view. Ref. [14] expands this concept to the structural design, introducing flexible 3U and 1U CubeSat platforms based on the slot concept, instead of the conventional stacking design method.

Some sensors place stringent requirements on the spacecraft to guarantee their functioning. The temperature operational range is a classic example of the challenges involved in sensors' design and integration. The design of isostatic bipod mounts for the LIDAR primary mirror of the HERA mission is presented in [15]. Passive thermal control methods for imagers on micro and nanosatellites are investigated in [16]. The advantage of passive methods like the ones proposed in [15] and [16] is that they meet the specific design requirements of the spacecraft and save energy on board, which is limited by the reduced dimensions of small satellites. The production of power through solar energy is an essential task and the power system needs to be reliable and robust to failures. Ref. [17] proposes using machine learning methods to evaluate faults on the solar panels.

4. Conclusions

This Special Issue of *Applied Sciences* offers a practical and varied overview of some of the main challenges and developments relating to small satellites. The ongoing research addressing these topics holds great promise for the future, where small satellites will continue to play an ever more important role in scientific exploration, empowering global connectivity, and offering commercial services.

Conflicts of Interest: The authors declare no conflict of interest.

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