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Plastic Cubesat: An innovative and low-cost way to perform applied space research and hands-on education ☆

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ABSTRACT

This paper describes the design and the manufacturing of a Cubesat platform based on a plastic structure.

The Cubesat structure has been realized in plastic material (ABS) using a "rapid prototyping" technique. The "rapid prototyping" technique has several advantages including fast implementation, accuracy in manufacturing small parts and low cost. Moreover, concerning the construction of a small satellite, this technique is very useful thanks to the accuracy achievable in details, which are sometimes difficult and expensive to realize with the use of tools machine. The structure must be able to withstand the launch loads. For this reason, several simulations using an FEM simulation and an intensive vibration test campaign have been performed in the system development and test phase. To demonstrate that this structure is suitable for hosting a complete satellite system, offering innovative integrated solutions, other subsystems have been developed and assembled.

Despite its small size, this single unit (1U) Cubesat has a system for active attitude control, a redundant telecommunication system, a payload camera and a photovoltaic system based on high efficiency solar cells.

The developed communication subsystem has small dimensions, low power consumption and low cost. An example of the innovations introduced is the antenna system, which has been manufactured inside the ABS structure. The communication protocol which has been implemented, the AX.25 protocol, is mainly used by radio amateurs. The communication system has the capability to transmit both telemetry and data from the payload, in this case a microcamera.

The attitude control subsystem is based on an active magnetic system with magnetorquers for detumbling and momentum dumping and three reaction wheels for fine control. It has a total dimension of about $50 \times 50 \times 50$ mm. A microcontroller implements the detumbling control law autonomously taking data from integrated magnetometers and executes pointing maneuvers on the basis of commands received in real time from ground.

The subsystems developed for this Cubesat have also been designed to be scaled up for larger satellites such as 2U or 3U Cubesats. The additional volume can be used for more complex payloads. Thus the satellite can be used as a low cost platform for companies, institutions or universities to test components in space.

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1. Introduction

This paper describes the design and the manufacturing of a Cubesat platform realized within the activities of the Space Robotics Laboratory and V-Lab of the II Faculty of Engineering of Bologna University in collaboration with the AeroSpace System Laboratory of the University of Rome "La Sapienza".

It is a satellite of cubic shape (10 cm per side), weighing approximately 1 kg, based on the creation of a central body made entirely of plastic material using the Rapid Prototyping Techniques [1–7].

The aim of the work is to realize a multipurpose low-cost cubesat platform, easy to adapt to different possible nanopayloads, suitable for potential aerospace research applications, such as microcameras, electronic components to be tested and space weather monitoring sensors. The requirements for the Cubesat have been set considering a standard Low Earth Orbit environment with a half orbit eclipse period and a lifetime of 1 year. The typical launcher environmental conditions have been chosen considering a possible low cost solution for this kind of satellite, represented by the Indian PSLV launch vehicle.

Particular attention has been given to the structural analysis since the material used for rapid prototyping has never been tested in space, and an intensive ground test campaign has been carried out. The results of these tests are highlighted in the paper.

The power system is based on triple junction small solar cells. The telecommunication system uses components usually employed for terrestrial uses and adapted to the space environment.

In the final part of the paper an extensive overview of the miniaturized attitude control system, specifically designed for this kind of nanosatellite, will be given.

2. Satellite overview

The Cubesat under development will permit us to test the effectiveness of using structures manufactured with the rapid prototyping techniques in orbit and the performance of the new miniaturized attitude control system, evaluating its reliability and endurance.

The Cubesat will host a camera as the main payload, already used on board stratospheric balloons, in the framework of the AURORA experiment [9,10], flown from Kiruna thanks to the ESA REXUS/BEXUS project [11], which passed the thermovacuum test at ESA ESTEC facilities. This is a COTS camera usually employed in terrestrial industrial applications. Using different COTS optics it is possible to change the field of view and resolution of the system adapting it to the specific mission. The camera can take color pictures with a resolution of 640×480 pixels and can provide them directly in the JPEG compressed format, saving on-board computation efforts and memory. The characteristics that have determined the choice of this microcamera are its small dimensions, about $20 \times 28 \times 11$, and the weight, about 30 g.

3. Satellite structure

To respect the specifications of the 1U Cubesat, many restrictions are present, especially on the external dimensions [9].

The structure is designed as a cube with 100 mm side, with square columns (8.5 mm side and 113.5 mm height), placed at four parallel corners. The structure has a front access point and an opening in the top side, to allow the assembly and accessibility of internal parts (Fig. 1).

The structure is realized by exploiting a rapid prototyping technique. This choice allows us to optimize the design and the construction of a Cubesat.

Usually rapid prototyping techniques are used to build the prototype of a product; the aim of this paper is to investigate the suitability of using this technique for the final product manufacturing. The advantages of this manufacturing technique are the possibility to produce very complex shapes, which would be expensive or impossible to achieve using traditional production methods, short manufacturing time and low costs.

Moreover, this material has a density lower than aluminum (ABS$=$1.05 g/cm^3; aluminum$=$2.7 g/cm^3), this allows for potential mass savings. This technique changes the usual idea of primary and secondary structure because the whole part is produced at the same time, thus reducing the number of parts and the need for screwing and gluing, also increasing the reliability of the structure. This simplifies also the assembling phase. Traditional manufacturing techniques usually remove

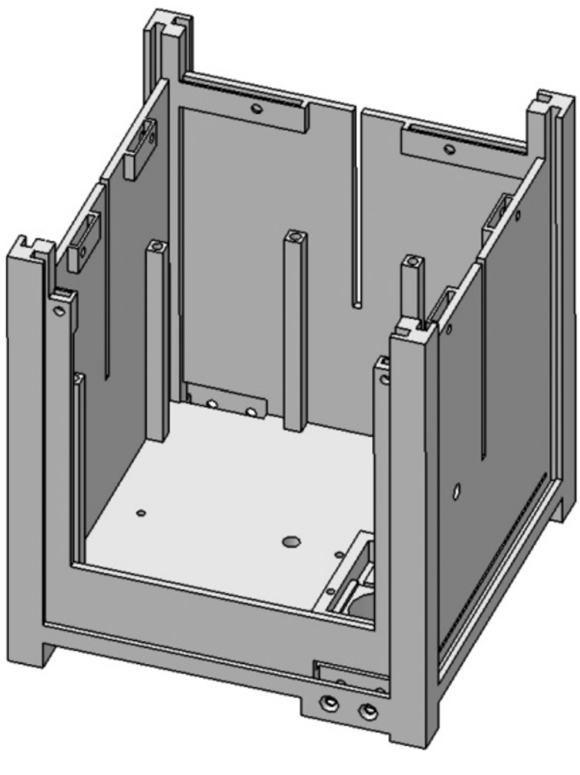

Fig. 1. Complete structure.

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