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The Experience of Preparing to Launch the TUMnanoSAT nanosatellite

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***Abstract*—In this paper, a brief overview of TUMnanoSAT's educational and scientific missions, the impact on system design and educational opportunities are presented. The main basic test procedures for the launch of this nanosatellite are described, including the structure, power supply and attitude control. The main mission of TUMnanoSAT is to provide practical experience to students not only in designing, building, but also testing the nanosatellite with various missions.**

Keywords—nansatellite; TUMnanoSAT; testing procedures.

I. INTRODUCTION

CubeSats are experiencing unprecedented growth, for instance, in 2020 the world registered 1260 new satellites and other space objects with the United Nations Office for Outer Space (UNOOSA) [2]. The National Center for Space Technologies (NCST) of Technical University of Moldova (TUM), like many universities focusing on the international CubeSat standard, has decided to develop a series of satellites with specific and efficient missions. The first general mission is TUMnanoSAT, the main objective of which is to verify in real conditions the functionality of the various satellite modules and subsystems for future missions. The concrete missions of TUMnanSAT are:

- space testing of sensors on nanostructures, developed by partners from the TUM Nanotechnology Center;
- establish an effective "satellite-to-ground station" communications subsystem with the possibility to modify the range of communication speeds and ensure high reliability, including verifying the communication protocol with different levels of access;
- searching for the optimal ways of distributing the accumulated energy and testing the power supply system;
- in order to optimize the attitude of the process control satellite, testing the sensor subsystem to determine the attitude of the satellite (magnetometers, micro-gyroscopes, solar sensors);
- testing the operation of COTS electronic components under radiation conditions, including the on-board computer, digital memories.

It is known, that each spacecraft system involve always ground segment which basically consist of ground station and a monitor and control center. In this context in order to assure a successful mission, it is mention NCST was set up a whole infrastructure with two ground stations and a mission control center with the possibility of processing, command and control, including nanosatellite testing [5].

The paper deal with the experience of the NCST team obtained in the process of testing some satellite subsystems in preparation for its launch from the International Space Station (ISS).

Figure 1. TUMnanoSAT the first TUM 1U CubeSat

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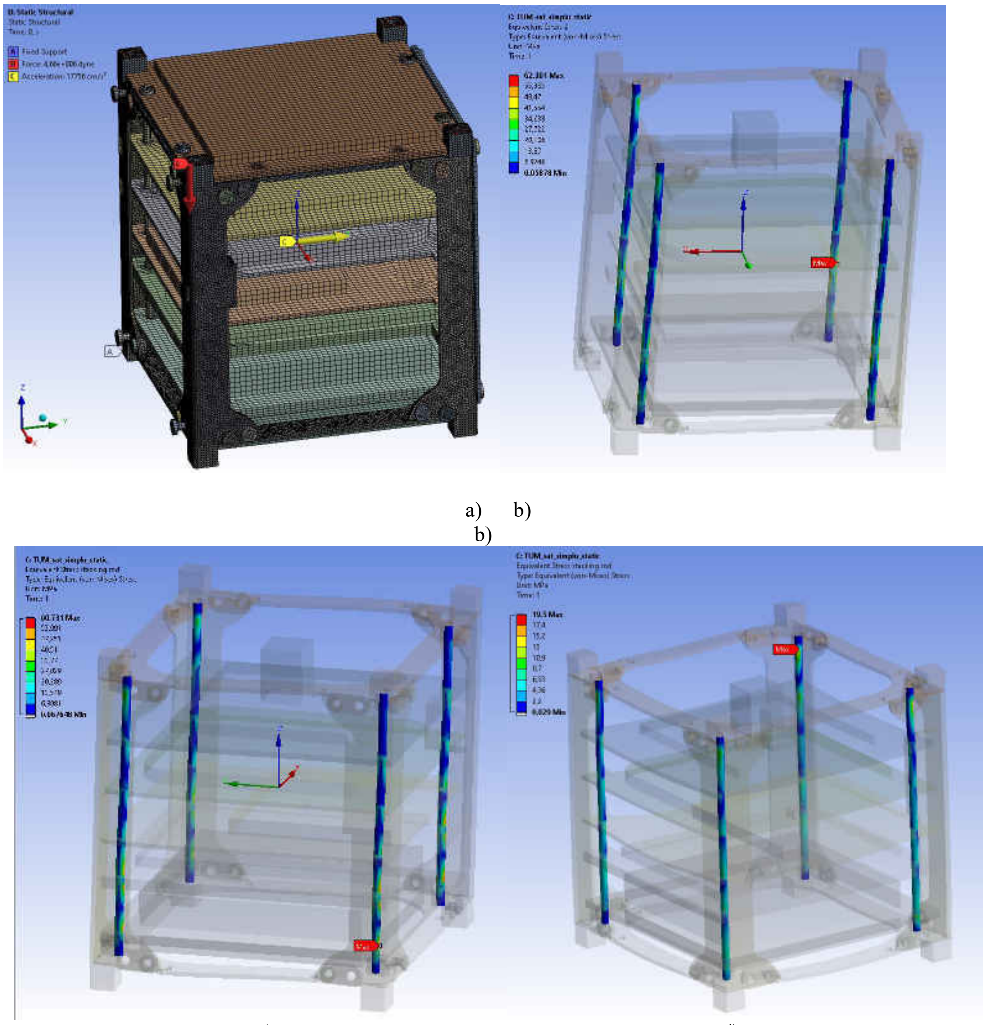
II. STRUCTURE OF TUMNANOSAT

For each nanosatellite the main purpose of the structural subsystem is to provide a rigid and reliable structure that can withstand all harsh launch conditions. At the same time, in the design of structural subsystems is the maximization of usable interior space while minimizing the complexity of the subsystem. When designing the TUMnanoSAT structure, the constraints imposed were taken into account by the CubeSat Design Specifications and the Control Document of the implementation interface of small satellites for JEM payload accommodation.

In order to reduce the manufacturing costs and the mass of the structure, we opted for a structure consisting of several parts, despite the fact that the monolithic structure is much more rigid, and the material used in manufacturing in the structure TUMnanoSAT was proposed aluminum alloy 6061. On on the other hand, due to the fact that TUMnanoSAT is designed to be launched from the International Space Station, three deployment switches have been added on the rails of the structure, that must physically interrupt all power lines in the satellite, so when the satellite is installed in the deployment device, early antenna deployment must not be activated.



a) b)
b)

c) d)

Figure 2. TUMnanoSAT finite element model (a) and analysis results with :
b) X direction acceleration; c) Y direction acceleration; d) Z direction acceleration

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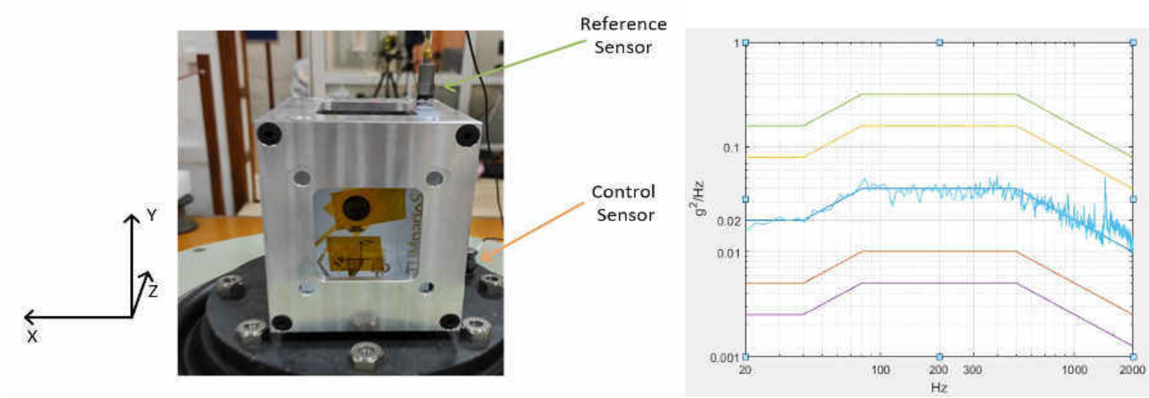

a) b)

Figure 3. Overview of TUMnanoSAT:
a) Acceleration measurement point (Z-axis) b) Z-axis Vibration at Control Sensor with Satellite

Initially the finite element model of the structure was created by using ANSYS Mechanical. The mass properties were used to construct a model with approximately equal mass as the components. The natural frequency and static load simulations by ANSYS Workbench Modal analysis results that it has revealed that minimum fundamental frequency is 366.57[Hz] which is higher than 60[Hz] and the maximum stress on the satellite was 94.5 MPa, 100.8 MPa and 19.5 MPa in the necessary limits of loads. Stress levels on various parts of the satellite are displayed in Figure 2 show the FEM with input load, acceleration and constraint condition for each analysis cases. The margin of safety for the various components was computed using a factor of safety of 1.5 for yield strength (Fty) and 2.0 for ultimate strength (Ftu).Real following vibration tests were performed along X, Y and Z axes, with low level sinusoidal sweep and random vibration. The verification points are: no breakage in main structure; main structure needs to satisfy specified natural frequency; natural frequency before and after tests need to remain unchanged; no improper antenna deployment, and no malfunction to cubesat; no breakage in grass material such as solar battery cover; no loosening in all fasteners. Low level sinusoidal sweep is adequate for model verification of simple structures with relatively rigid components, whose flexibility is confined to mounting jig or frequency isolation hardware. It is performed on each axis with the frequency 20~2000 [Hz] and amplitude 0,5 [G].

The random vibration test level It is performed with the frequency 20~2000 [Hz] and amplitude 02-04 **[**G^2/Hz**]**. This level is the envelope of the environments for HTV, Space X Dragon and NG Cygnus (reference: JX-ESPC-101132). This test level was defined by Structure Fracture Control Evaluation Form. Some results are presented in the figure 3.

III. POWER SUBSYSTEM of TUMnanoSAT

TUMnanoSAT subsystems require a nominal voltage stabilized by 3.3V or 5V for normal operation. The voltage on the battery can vary in the 3.5V - 4.2V range, so for 3.3V voltage the DC-DC converter with the Buck (Step-Down) topology will be used, and for 5V - DC-DC converter with the Boost

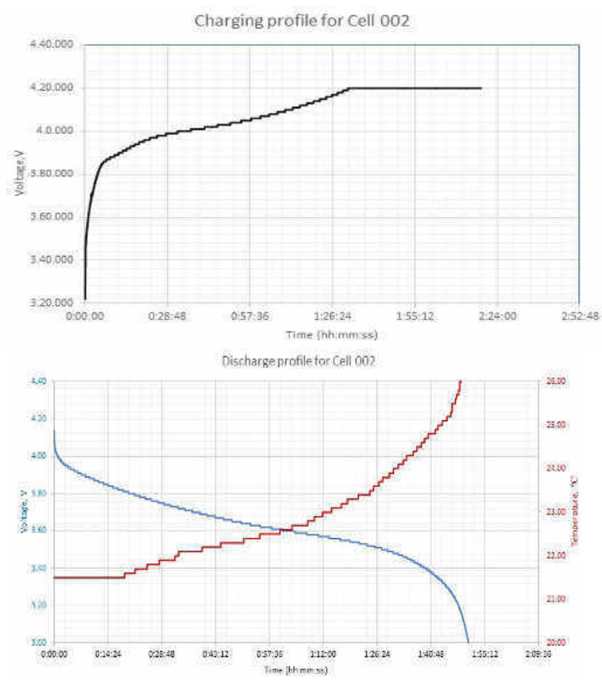

Figure 4. Batteries characteristics
(Top : Charge, Bottom: Discharge)

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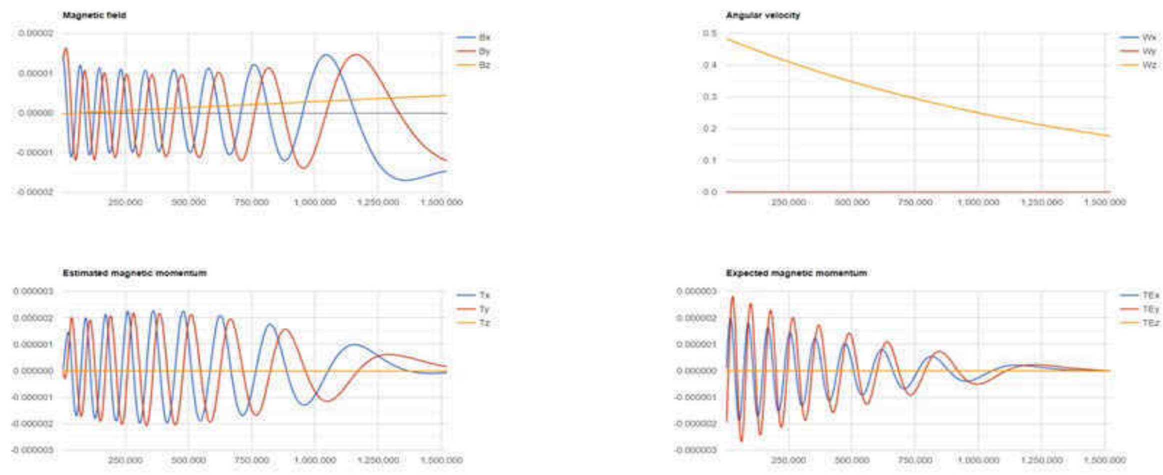

Figure 5. TUMnanoSAT attitude control: detumbling algorithm simulation results.

(Step-Up topology). Therefore, The power subsystem of TUMnanoSAT has one integrated Li-Po battery pack that contains two Varta Li-Po cells with a total capacity of 10 Wh. Also in EPS (Electrical Power Subsystem) are five solar panels. Each Solar Panel Channel has a DC-DC step-up converter with Maximum Power Point Tracking (MPPT). The output energy for each solar panel is monitored. The Solar Panel Channels can handle input voltages up to 5.5V and the current maximum threshold for overcurrent protection is set to 1.8A. The EPS subsystem was subjected to real tests, priority was given to the characteristics of the batteries, being COTS components. Therefore, charge and discharge characteristics tests are performed for each battery cells before and after the environmental tests. From these tests, it is confirmed that charge and discharge characteristics do not change due to the environmental and are within the nominal range (figure 4) It is important prior to handover after the environment tests for TUMnanoSAT Charge/Discharge Characteristic tests of battery inside nanosatellite is measured to see that there is no damage. To be mentioned that the Charge/Discharge Characteristics test was measured the range between maximum voltage and minimum voltage.

IV. ATTITUDE AND ORBIT CONTROL SUBSYSTEM

The TUMnanoSAT attitude control is a low-performance Attitude Determination and Control System (ADCS), that required to orient the nanosatellite to the Nadir direction, because the camera is low resolution and has a large aperture angle (56 degree), on the other hand the antenna also has a transmit/receive diagram with an angle of 120 degrees. Based on these, there are a network of sensors and a magnetorquers on the solar panel PCB and they can be interfaced to an ADCS. The network can be all or a combination of the following: temperature sensor, Sun sensor, magnetorquer, and gyroscope. The temperature sensor and Sun sensor (photodiode) are positioned on the top surface of the solar panel whereas the magnetorquer and gyroscope are positioned within the solar panel and not visible. The magnetorquer is a series of large electrical coils positioned over several layers of a multi-layer PCB. Furthermore, the PCB is equipped with a connector for an external magnetorquer. To calibrate sensors and to test magnetorquers and attitude control algorithms was build a facility to simulate geomagnetic conditions for the satellite.

The verification of the attitude control algorithms was performed with the terrestrial magnetic field simulation stand that ensures in a computerized way the creation of the magnetic field as intensity and direction in any point of the orbit of the nanosatellite. The results obtained confirm the correctness and quality of the satellite orientation, which are partially shown in figure 5.

V. CONCLUSIONS

In this paper was presented the test experience of the first TUMnanoSAT nanosatellite within 4th round of the KiboCube program. The TUMnanoSAT missions are mainly with educational objectives, in the realization of which the students are involved and other objectives are with elements of research and technological verifications. The experimental tests in terrestrial conditions give us confidence in their efficient operation in space conditions.

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