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APPLICATION OF NANOSATELLITES IN THE NEAR-EARTH SPACE INVESTIGATION

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Abstract: *We present based characteristics of the nanosatellites' equipment and we point to the advantages of their usage. The purpose of this paper is to survey the applications of nanosatellites as a new and advanced technology. It is reviewed the most employable of them in space science and technology. We present the conception of our new project that will investigate the polarimetry of the Zodiacal light on a Sun-synchronous low Earth orbit.*

ПРИЛОЖЕНИЕ НА НАНОСАТЕЛИТИ В ИЗСЛЕДВАНЕТО НА БЛИЗКИЯ КОСМОС

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Ключови думи: *Наносателити;Близък космос;Зодиакална светлина;*

Резюме: *Представени са основни характеристики на наносателитите и са посочени предимствата на използването им. Целта на тази статия е да се проучат приложенията на наносателитите като нова и напреднала технология. Разгледани са най-пригодни за заетост от тях в областта на космическите науки и технологии. Ние представяме концепцията на нашия нов проект, чиято цел е да изследва поляриметрията на Зодиакалната светлината на ниска околоземна орбита с помощта на наносателит.*

1. Introduction

Nanosatellites are a class of small satellites that have a mass between 1-10 kg. Within this class is the so-called CubeSat. CubeSat -1U class is a 10-cm cube with a mass of up to 1.33 kg. Typically, CubeSats are launched as secondary payloads into a circular sunsynchronous low-earth orbit at 500-600 km. The development time for a CubeSat is roughly one year with constant improvements in each generation. Distributed networks of CubeSats are also promising alternatives to conventional large single satellites.

Small satellite missions are supported by some contemporary trends, such as: Advances in electronic miniaturization, the progress in data manipulation, storage, imaging technology, autonomous intelligence and associated performance capability. The possibility of 'independence' in space is an important benefit, since small satellites can provide an affordable way for many countries to achieve Earth Observation and/or defense capability, without relying on inputs from the major space-faring nations.

Compared to conventional large satellites, nanosatellies or CubeSats are easily deployable and low-cost. Their fast delivery and small sizes makes them very appropriate for the educational purposes.

The idea and first design of CubeSat was proposed in 1999 by professors Jordi Puig-Suari of California Polytechnic State University and Bob Twiggs of Stanford University [2]. The purpose was to teach graduate students to be able to design, build, test and operate in space a spacecraft.

One of the earliest launches of CubeSats was 2003 from Plesetsk, Russia, with Eurockot Launch Services's. More than 80 CubeSats have been placed into orbit as of end of 2013.

In the next two sections we present a review of the nanosatellites' applications (Section 2) and the base description of the project BulCube (Section 3).

2. Applications

We list the names of nanosatellites and their scientific applications, which are most related to our aim of research, as separated in two category.

2.1. Earth and near-Earth Space investigations

Recently, the amount of the launched satellites has been increasing. The nanosatellites, such as CanX-7 (Canada, 2007); STARE CubeSat (US, 2012), are aimed to resolve the problems associated with orbital debris and space collision avoidance [9]. Tracking space debris and monitoring the entire sky for space junk are the main objectives of these missions.

The Nanosatellite for Earth Monitoring and Observation (NEMO) bus belongs to the Generic Nanosatelite Bus technology. The bus has primary structure with sizes: 20cm by 20 cm by 40cm. The spacecraft that is using this technology, the NEMO - AM (Aerosol Monitoring) is designed to perform multi-spectral observations in the visual band in two polarizations and from multiple angles. Its mission is to detect aerosol content in the atmosphere. The instrument also has optional observation capability in the short-wave infrared band. The satellite is developed by the collaboration of Canada and India [6].

The first Swiss satellite SwissCube mission should focus on the observation of the airglow phenomena. The primarily motivation is to educate students in space technologies and space system engineering. The other reason for these observations is to demonstrate the feasibility of using the airglow as basis for development of a low cost Earth Sensor (ES). A model of the airglow emissions as a function of intensity, latitude, longitude and time has been established and the objective the science mission is to collect data that will validate, or at least bring additional information to the model [7]. Technical parameters of the satellite: Swiss Cube (Switzerland, 2009); Size: 10x10x10 cm; Mass ~1kg.

An investigation of impulsive electromagnetic signals generated by electrical discharges in terrestrial thunderstorms (lightning), blizzards, volcanic eruptions, earthquakes and dust devils [3]. These are the main scientific objects of satellite: LiNSAT (Austria). The project is designed for the detection of electromagnetic signatures in VHF (very high frequency) range in low-earth orbit (LEO). The satellite is 20 cm cube and weights ~ 5 kg.

The nanosatellites are usable as well for the tracking maritime resources, and the integration of space-based AIS (Automatic Identification System) data into any national maritime tracking information system. As an example: AISSat-1, the Norway satellite, designed on the Generic Nanosatellite Bus (GNB) base. Size: 20x20x20cm; Mass: 6kg.

The NASA program FASTSAT has developed a NanoSail D (2008) and NanoSail D2 (2010) that are the first satellites to open a sail in low Earth orbit and was the first nanosatellites to be ejected from a microsatellite [1]. It also testing the cosmic sail made by polymer, much thinner than a human hair.

2.2. Astronomical investigations

A group of nanosatellites in space, called BRITE-Constellation (BRIght Target Explorer - Constellation), can capture the light shed by luminous stars and in turn shed light on their structures and histories [4].

The purpose of the mission is to photometrically measure low-level oscillations and temperature variations in stars brighter than visual magnitude 4.0, The other aim of these photometric observations of some of the brightest stars in the sky is to examine these stars for their variability. The observations will have a precision at least 10 times better than achievable using ground-based observations. It is included inside a CanX-class nanosatellite, the satellite: CanX-3 - BRITE Mission: The constellation is built by Austrian, Canadian and Polish space scientists. This is a group of 6 nanosatellites, each weights 7 kilo and in size a 20cm cube.

Draper Laboratory and MIT have developed a satellite with incredible small size that can discover transiting exoplanets around the nearest and brightest Sun-like stars . Analysis based on the blurring of the stars when in orbit to pass companion is a task of the The spacecraft prototype ExoPlanetSat, which is a 3U space telescope (USA, 2012). Each ExoplanetSat spacecraft can monitor one star at a time, instead of surveying thousands of stars simultaneously [5]. When properties of each target star are well known in advance, a fleet of nanosatellites to search enough stars to find a number of interesting exoplanets. Size: 10x10x30cm; mass: ~4 kg.

3. Project BulCube. Aims, mission and construction

One remarkable feature of the night sky in the tropics is the zodiacal light, which appears as a cone in the west after sunset and in the east before sunrise. It is caused by sunlight scattered or absorbed by particles in the interplanetary medium. It is important to investigate, because it is a source of information about the integrated physical properties of the whole ensemble of interplanetary dust. The brightness and polarization in different directions and at different colours can provide information on the optical properties and spatial distribution of the scattering particles.

From the Earth, the zodiacal light is best seen when the ecliptic plane is approximately perpendicular to the horizon. It is, however, a difficult task to do a high quality photometry of the zodiacal light from a ground-based observatory because of its faintness as well as the contamination of diffuse light sources such as the airglow. However the situation improves significantly when observing from space. For more precise polarimetry of Zodiacal light and to exclude the influence of the Earth's atmosphere different type of spacecrafts are involved.

According to the advantages described in the Introduction, the nanosatellites are more appropriate to resolve the task of the Zodiacal light. To checks out the possibility of examine the Zodiacal light by nanosatellites, it is developed the scientific project that to undertake with the problem.

The aim of our project is polarimetric measurements of the Zodiacal light by using a nanosatellite (such as CubeSat). It includes the following steps:

- Design and construction of the nanosatellite;
- Experimental measurements of the Stokes parameters by nanosatellite's cameras;
- Construction of a mobile-modular ground station;
- Software development for cubesat-to-ground communication;
- Day in the life, vibration and thermal-vacuum testing;
- Choice of a launcher, launch location and date;
- Polarimetry of the zodiacal light on sunsynchronous low-earth orbit.

In this section we will stress on the explanation of first two steps, which concern to the application.

Observation/measurement module is designed to implement few different functions.

- to measure Stokes parameters for every zone in the field of view.
- to take colour panorama pictures of the space.

A complete description of the zodiacal light polarization would require the knowledge of its Stokes parameters. This leads us to experimental measurements of the Stokes parameters by usage of two types nanosatellite's cameras.

The criteria for the choice of the sensor used for Stokes parameters measurement are defined by the fact, that observed object has relatively low illumination and big physical dimensions. Black/white camera is selected with high light sensitivity (4.8 V/lux.sec), dynamic range >110dB, relatively high resolution (752x480). It also has the property to average by hardware (as analog level) pixels in areas up to 4x4 in the whole frame, which additionally increase the signal to noise ratio. The exposure time can be extended to more the 2 seconds.

The panorama camera is selected to be colour with higher resolution (1.3MP) and integrated JPEG compression (Fig.1). This gives us very compact picture size, which easily can be transferred through the radio channel.

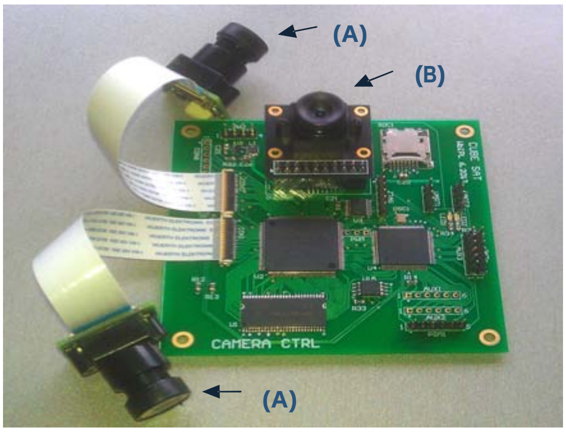

Fig. 1. Plate with 3 nanosatellite's cameras: black and white camera type (A);
panorama color camera (B)

To determine the polarization state of zodiacal light we need to modulate the intensity of light signal with optical elements. For Stokes parameters measurements we used a combination of quarter wave plate and linear polarizer. The two cameras from the chip were used as a detector.

To measure linear polarization, the light beam passed through a linear analyzer oriented at angle A = 0°, 90°, and ±45°, and measure the corresponding intensities. To measure circular polarization the light has to pass through a system of quarter wave plate and linear polarizer. By placing the quarter-wave retarder at C = 0° and analyzer oriented at A = ±45° we measure the intensities I_{RHC} and I_{LHC}. The pair of quarter-wave retarder and analyzer constitutes a circular analyzer (Fig.2).

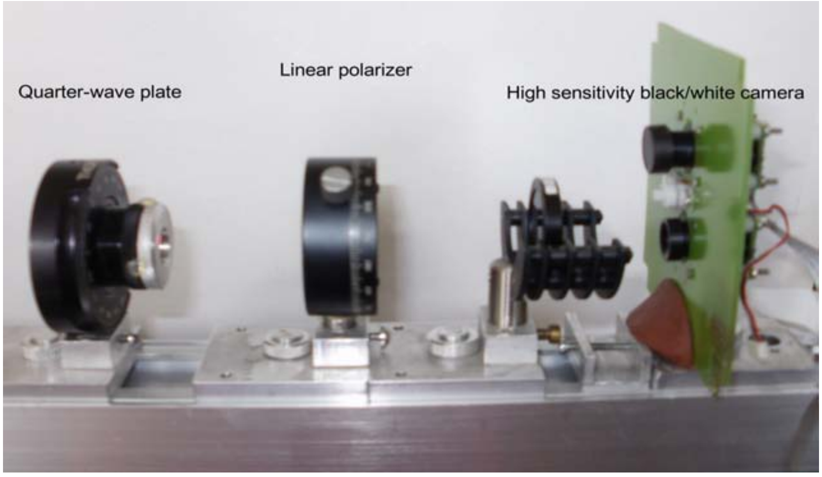

Fig. 2. Measurements of the Stokes parameters in experimental conditions

Conclusion

Nanosatellites and CubSats are able to perform a bit different type of missions. We presented the most relatively close to our investigations the nanosatellite's applications. We focused on the view of our project BulCube that aims to understand the nature of the Zodiacal light. The research goal of the project mainly includes an employment of the polarimetry methods and measurement the Stokes parameters. It requires the usage of two types of cameras. We showed the cameras in the observation/measurement module description. According to the project's stages, the next initial results are expected:

- Creation and deployment the nanosatellite to the Low Earth Orbit (LEO);
- Establishment the communication between nanosatellite and the ground station;
- To obtain and transfer the pictures and data;
- To define the Zodiacal light polarization from the receiving pictures;

In the future missions, we are planning to involve additional methods of polarimetry to investigate the Zodiacal light. Further, the model created could be applied in the study of small bodies in the near Earth space, diffuse matter and interplanetary space.

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