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ESTCube-2 integrated platform for interplanetary missions

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Abstract

This paper presents mission analysis, mission requirements and system architecture of a 3-unit CubeSat satellite ESTCube-2. Satellite subsystems are integrated in one compact satellite bus to allocate maximal volume for payloads in the satellite. The bus of ESTCube-2 is developed as technology demonstration unit for ESTCube-3 mission.

Plasma brake is a propellantless propulsion device concept based on coulomb drag interaction between ionospheric plasma and a negatively charged thin tether.

Upon succession of ESTCube-2 mission, ESTCube-3 will be launched to Moon orbit in order to test electric solar wind sail (E-sail) in interplanetary environment

1. Introduction

One of the main technical drivers to influence mission launch cost, design lifetime and mission objectives is spacecraft propulsion. By using conventional space propulsion systems, like rockets, tanks with propellant can take up large volume of satellite. One way of achieving thrust without gas propellant is to use propellantless propulsion systems. One of the most popular is solar sail, which rely on photon pressure.

Another way of tapping solar wind momentum is by using an electric solar wind sail (E-sail) [1]. E-sail uses coulomb drag force to propel spacecraft by positively charging E-sail tether [2]. Exploiting same E-sail tether, plasma brake concept can be tested in Low Earth Orbit (LEO). Plasma brake is a propellantless propulsion device concept based on coulomb drag interaction between ionospheric plasma and a negatively charged thin tether [3]

To validate tether system and deployment of it in Low Earth Orbit (LEO), ESTCube-1 satellite hosted E-sail module with 10 m tether. On ESTCube-1 main mission objectives were to demonstrate the deployment of E-sail tether and to measure the electrostatic force, however deployment test was unsuccessful [4]. This experience lead to a complete redesign of system architecture for ESTCube-2 satellite.

2. ESTCube-2 nanosatellite

Successor to ESTCube-1 satellite [5], ESTCube-2 is a 3-unit CubeSat satellite developed as technology demonstration unit for ESTCube-3 mission in Moon orbit. The bus of the satellite is developed as an integrated system, consisting of electrical power, communications, onboard computer and star-tracker systems, sensors, reaction wheels and prismatic type batteries (Figure 1).

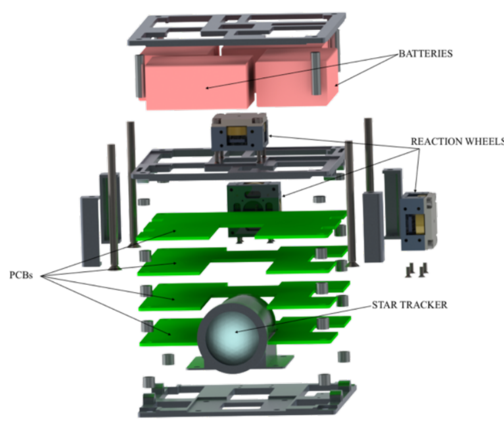

Figure 1: Exploded view of ESTCube-2 integrated bus. Credit: I. Iakubivskyi

In-orbit demonstration of the plasma brake device contains three experiments. 1. 300 m long tether deployment, will be done by centrifugal force spinning up satellite to 360 deg s^{-1}, achieved with ESTCube-1 [6]. 2. The change of angular velocity will be measured when deploying satellite or charging the tether. 3. Satellite deorbiting experiment will be carried out using plasma braking force which will reduce orbital speed in order to decrease orbital altitude.

In addition to plasma brake payload, ESTCube-2 will host two Earth observation cameras for red (650-680 nm) and NIR (855-875 nm) imaging, C-band spectrally efficient communications payload, which is compatible with

Deep Space Network standards [7] and cold gas propulsion system for angular velocity spin-up in order to deploy tether and unload reaction wheels (Figure 2).

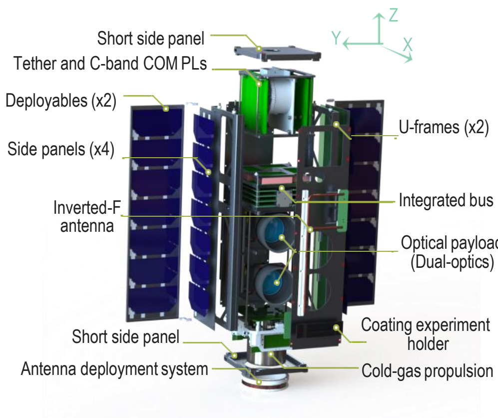

Figure 2: Exploded view of ESTCube-2 model. Credit: I. Iakubivskyi

3. Interplanetary mission platform

Geological and geophysical properties, including spectral information, are only known for a handful of large Main Belt asteroids such as (1) Ceres, (4) Vesta, (21) Lutetia, and (253) Mathilde, and a similar number of relatively small Near Earth Objects (NEO) such as (433) Eros and (25143) Itokawa. In addition to targeting asteroids belonging to different size regimes in the Main Belt and the near-Earth population, close-range studies by space missions have shown that all asteroids visited so far are virtually unique.

To attain more information about Main belt and NEO objects, self-propelled missions with E-sail (Figure 3) is very well suited to visit multiple asteroids in one mission. By launching fleet of satellites average cost per visited asteroid could be as low as 200 kEUR [8].

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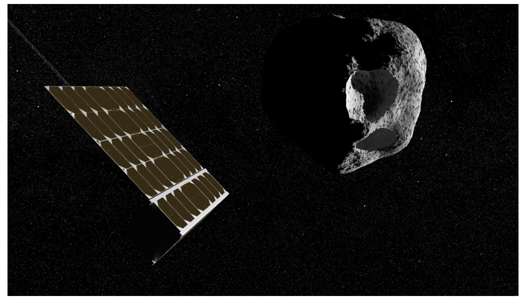

Figure 3: Artist's concept of asteroid touring nanosatellite. Credit: M. Pajusalu

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