UV-VISIBLE OBSERVATION OF METEORS BY CUBESAT: S-CUBE PROJECT.

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Introduction: Meteors are a luminous phenomenon caused by the entry of meteoroids into the Earth's atmosphere at hypervelocity. Most meteoroids originate from comets and asteroids. So, the meteor gives us valuable opportunities of an indirect exploration of the primordial objects, such as comets and asteroids, in our Solar System. Although meteors have been observed mainly from the ground so far, the ground-based observations have weak points: narrow observational range and weather dependent. In contrast to ground-based observations, a space-based observation by an earth-orbiting satellite enables a continuous global observation of meteors. It has an advantage in estimating the flux of meteoroids colliding with the Earth. Furthermore, a satellite can access ultra-violet light from meteors, because the light is not hindered by the ozone layer. The meteor's UV light contains emission lines, which have not been observed previously by ground-based observations. As a result, it would offer new information about the composition of comets or asteroids. Carbary et al. [1] observed UV spectra from a meteor for the first time by using five spectrographic imagers onboard the Midcourse Space Experiment satellite during the Leonid meteor shower on 18 November 1999. Unfortunately, however, no observation from space has been applied since 1999. Therefore, the intensity and emission mechanism of meteor's UV light remain largely unknown.

Thus, the Planetary Exploration Research Center of the Chiba Institute of Technology (PERC/Chitech) has launched a CubeSat project to observe meteors from space [2]. The standard ~10×10×10 cm cubic satellite is often called a "1U" CubeSat meaning one unit, and has a mass of ~1 kilogram. A CubeSat project can be carried out with a reasonable cost, suitable technology, and effective manpower. Therefore, CubeSat has been a familiar tool for engineers to test new technologies in space and often used for Earth remote-sensing. With its successful missions to date, CubeSat is primed and ready to proceed with science missions, although use of CubeSat for astronomical and planetary sciences has been rare.

Our satellite, a "3U" CubeSat, is called S-CUBE (Fig. 1). S-CUBE stands for Shootingstar Sensing Satellite (S^3). The S-CUBE is being developed by a partnership between PERC/Chitech and Tohoku University. We develop the 3Unit CubeSat S-CUBE based on the design of 2U CubeSat RAIKO that was developed and launched by the Tohoku University in 2012 [3].

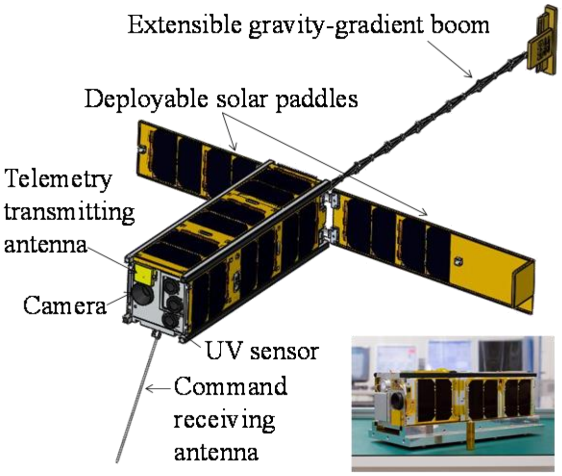

Fig.1. Appareance of S-CUBE

Scientific instruments: The scientific instruments of the S-CUBE consists of one visual camera and 3 UV sensors (Fig. 1). The camera has been proven in the flight of the CubeSat RAIKO [3]. The camera has a field of view of 37.5 × 27.7 degrees. The camera takes visible images to estimate the meteoroid size from the brightness of meteors. According to our sensitivity estimate, the camera can image meteoroids larger than ~1cm. From the camera observation,we aim to estimate the size distribution of meteors.

The UV sensors can observe UV emissions from meteors. The sensors are attached with UV band-pass filters so as to extract emission lines in the meteor's light. The first UV sensor is designed to observe meteors at bloadband wavelength (200-300 nm), which enables photometric measurement of UV emissions from meteors.

The second sensor is designed to detect a singly ionized magnesium (Mg^+) line (~280 nm). Magnesium is one of the most typical metal elements in meteoroids. The line was detected as the strongest line by Carbary et al. (2003) [1]. From this data we aim to estimate not only the magnesium abundance but also the ionization degree.

The third sensor is designed to detect a neutral line of sulfur (~180 nm). Although sulfur in meteors has not been observed yet, an inclusion of the line is suggested because the line has been identified by the laserinduced breakdown spectroscopy in the ultraviolet region [4]. Because sulfur is a volatile element, the abundance of sulfur in meteors would give a indicator of the thermal alteration of meteoroids and thermal history of their parent body. Sulfur is also one of the most important chemical elements which make up biomolecules and, therefore, the detection of sulfur in meteors would be important in terms of Astrobiology.

Signals of UV sensors is also used as a trigger of the camera. Because the ozone layer blocks UV lights from the Earth, detecting UV lights in the low earth orbit can be regareded as the occurrence of a meteor. The trigger makes it possible to capture only images of meteors, lowering the downlink data amount.

Satellite bus system: The S-CUBE is equipped with two solar paddles which are deployed after release in orbit. Attitude control subsystem of the S-CUBE consists of magnetic torquers, deployable gravity-gradient boom, and 3-axis reaction wheels. The boom can maintain an Earth-facing orientation, which make it possible for sensors (camera and UV sensors) to point nadir direction during the meteor observation. On the other hand, the reaction wheels are not to be used during meteor observation. The wheels are to be tested for future missions, such as space telescope missions. The communication system consists of an UHF receiver for command data uplink and an S-band transmitter for sending observation data.

Ground station: Communication with the S-CUBE can be conducted by a ground station at Chiba Institute of Technology: U-band uplink (400 MHz approx.) and S-band downlink (2 GHz approx.) with 2m diameter antenna.

Orbital requirements: Most of meteors occur on the leading edge of the Earth [5] where the Earth collides with dusts producing meteors at hypervelocity. In addition, to take images of meteors, the observation of the night side of the Earth is required. Therefore, we wish to observe the leading edge of the shadow area. A possible solution to meet our requirements is low inclination orbits such as those of CubeSats deployed from the International Space Station.

References: [1] Carbary J. F. et al. (2003) *Icarus*, 161, 223–234. [2] Ishimaru R. et al. (2013) *LPS XXXXIV*, Abstract #1944. [3] Sakamoto Y. et al. (2013) *ISTS*, f-13, 1-6. [4] Radziemski L. et al. (2005) *Spectrochimica Acta Part B*, 60, 237-248. [5] Campbell-Brown (2008) *Icarus*, 196, 144-163.

System specifications

Size	W100 × D100 × H327 mm (structure) W113 × D113 × H340.5 mm (envelop)
Weight	< 3.99kg
Orbit	Low earth orbit
Attitude control	3-axis magnetic torquers, gravity-gradient boom, 3-axis reaction wheels
Communication	Uplink: UHF-band, 401.25MHz, 50 W, 1200 bps Downlink: S-band, 2.285GHz, 0.1 W 9600 bps to 100 kbps S-band beacon, 2.285GHz, 2 mW 32 bps Ground station: Chitech
Power	Solar cells: ZTJ 2series×18parallels Batteries: 6-cell NiMH (7.2V) Power generation: 5.3 W (avg. in sunshine w/o paddle) 7.4 W (avg. in sunshine with paddle) Power comsuption: 1.0 W (stanby mode) 3.1 W (observation mode)
Instruments	Camera×1, UV sensor×3