

**SHOOTINGSTAR SENSING SATELLITE (S<sup>3</sup>: S-CUBE): CUBESAT PROJECT FOR OBSERVATION OF METEORS FROM LOW EARTH ORBIT.** R Ishimaru<sup>1</sup>, Y. Sakamoto<sup>2,1</sup>, M. Kobayashi<sup>1</sup>, N. Namiki<sup>1</sup>, H. Senshu<sup>1</sup>, K. Wada<sup>1</sup>, S. Ohno<sup>1</sup>, K. Ishibashi<sup>1</sup>, M., Yamada<sup>1</sup>, T. Arai<sup>1</sup>, T. Matsui<sup>1</sup>, S. Hosokawa<sup>3</sup>, Y. Tanabe<sup>2</sup>, H. Yagisawa<sup>2</sup>, S. Abe<sup>4</sup>, K. Kurosawa<sup>5</sup>, S. Nakasuka<sup>6</sup>, H. Akiyama<sup>7</sup>, K. Yoshida<sup>2</sup>, M. Sato<sup>8</sup>, and Y. Takahashi<sup>8</sup>, <sup>1</sup>Planetary Exploration Research Center (PERC), Chiba Institute of Technology (Chitech) (2-17-1 Tsudanuma, Narashino, Chiba 275-0016, Japan; ishimaru.ryo@it-chiba.ac.jp), <sup>2</sup>Tohoku University (6-6-11, Aza-Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8579, Japan), <sup>3</sup>General Research Institute, Chiba Institute of Technology (Chitech) (2-17-1 Tsudanuma, Narashino, Chiba 275-0016, Japan), <sup>4</sup>Institute of Astronomy, National Central University (300 Jhongda Road, Jhongli, Taoyuan 32001, Taiwan), <sup>5</sup>ISAS/JAXA (3-1-1, Chuo-ku, Yoshinodai, Kanagawa 252-0222, Japan), <sup>6</sup>Department of Aeronautics and Astronautics, The University of Tokyo (Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8656, Japan), <sup>7</sup>Institute for Education on Space, Wakayama University, <sup>8</sup>Hokkaido University.

**Introduction:** A CubeSat is a type of miniaturized satellite for space research. The standard 10×10×10 cm basic CubeSat is often called a "1U" CubeSat meaning one unit, and has a mass of no more than 1.33 kilograms. CubeSat has been a popular tool for engineers to test new technologies in space and often used for Earth remote-sensing, too. On the other hand, use of CubeSat for astronomical and planetary sciences has been rare because of severe constraints on payload. We propose in this work to use a CubeSat for the first time in planetary sciences, specifically to observe meteoritic entry into Earth's atmosphere. A development of new CubeSat brings about many difficulties, but our challenge can possibly open a new field of observational research in astronomy and planetary sciences.

An advantage to use a CubeSat in comparison with previous missions led by national space agency is that a CubeSat project can be carried out within a limit of cost, technology, and organization available in academy. For example, total cost of CubeSat project including rocket launch is less than 50 million yen (about 600,000 dollars) that can be ac-

quired from national scientific fund. Also, a CubeSat typically uses commercial off-the-shelf technologies allowing a development of the satellite in a few years.

**S-Cube Project:** Our new project is called "Shooting star Sensing Satellite (S<sup>3</sup>) Project." The S<sup>3</sup> Project was a project started by a partnership between Planetary Exploration Research Center of Chiba Institute of Technology (PERC/Chitech) in Narashino and Tohoku University in Sendai to develop a "3U" CubeSat (34.1×11.3×11.3 cm) (Fig. 1). Based on the design of RAIKO that was developed and launched by Tohoku University in October, 2012, the S<sup>3</sup> is equipped with a wide angle camera to take images of meteors from a low-Earth orbit. In order to keep Earth-pointing attitude, a mast with weight at the tip will be expanded after pod separation. The weight is no more than 4 kg.

The launch date is scheduled in the summer of 2014 while the launch vehicle has not been determined yet. A desirable orbit is a sun synchronous orbit of which altitude is between 600 and 800 km. For command uplink and data downlink, an UHF antenna and an S-band antenna of 2 m in diameter at

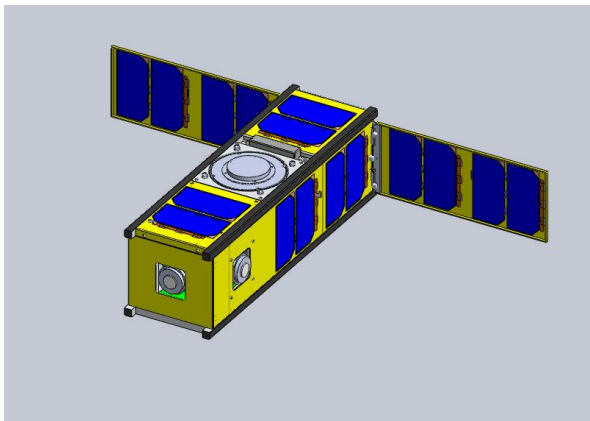


Fig. 1. Early engineering drawing of S<sup>3</sup>.



Fig. 2. A 2-m S-band antenna to be used for data downlink.

Chitech (Fig. 2) are used, and communication rates are 1200 bps and nominal 38,400 bps, respectively. These antennae are refurbished and were moved to a rooftop of 20-story building so as to avoid any interference from surrounding buildings.

**Scientific Objectives:** Luminous emission of meteors induced by hypervelocity entry of meteoroids into the Earth's atmosphere has been studied to reveal size distribution and elemental abundances of meteoroids. Because most meteoroids are originated from comets and asteroids, meteors serve as natural sampling of the primordial objects in the solar system.

Meteors have been observed mostly from the ground. Thus the observations, in particular those by camera, has been biased in the northern hemisphere. There has been a shortage of observations in the southern hemisphere or on the ocean. In contrast, a space-based observation is not influenced by weather nor biased by a distribution of observatories [1]. Further, a space observation is not hindered by ozone layer that absorbs emission in ultra-violet wavelength.

Carbary et al. [1] have observed meteor spectra from 110 to 860 nm by using five spectrographic imagers onboard the Midcourse Space Experiment satellite during the Leonid meteor shower on 18 November 1999. From their observations, strong emission of singly ionized iron and ionized magnesium is verified, and even an inclusion of some light elements such as carbon and sulfur is suggested. Unfortunately, however, no observation from space has been applied since 1999. Thus the S<sup>3</sup> project is of importance for new advancement in meteor research.

**Specifications of Wide Angle Camera and Photo-multiplier:** The S<sup>3</sup> is designed to be equipped with one wide angle camera and 2 (or possibly 4) photo-

Table 1. Specifications of CCD camera.

Item	Value
CCD Size	6 mm (diagonal)
Effective number of elements	659 (H) x 494 (V)
Cell size	7.4 $\mu\text{m}$ x 7.4 $\mu\text{m}$
Dynamic range	10 bit
Voltage	DC 5V
Consumption current	180 mA
Weight	34 g

multiplier. The wide angle camera points nadir direction to take images of meteors during flight over the night side of the Earth. We adopt Watec T065 CCD camera on the basis of heritage of RAIKO (Table 1). Exposure time and gain are variable and are between 1/4000 and 1/30 sec and between -6 and 42 dB, respectively. We have tested sensitivity of the CCD by taking an image of stars on December 27, 2012. While it was a full moon, Orion is visible from the image (Fig. 3).

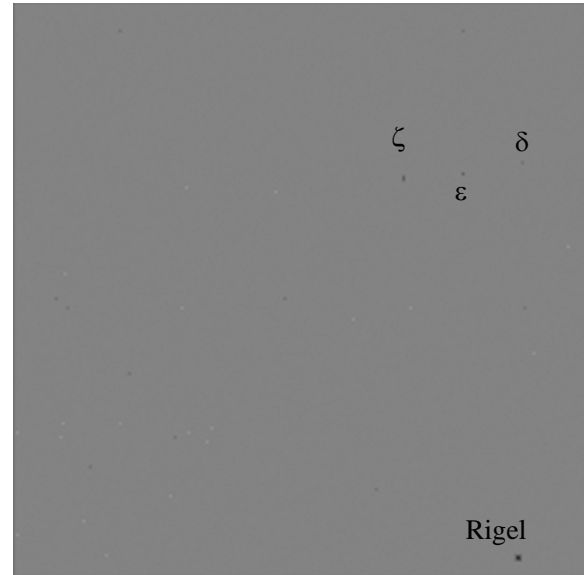


Fig. 3. Star image taken by T065.

We adopt photo-multiplier of Hamamatsu photonics, R9875P (Table 2) as a substitute of R7400 that was used in JEM-GLIMS on ISS but is not manufactured any more. The photo-multipliers are attached with band-pass filter of Materion so as to distinguish Mg emission in UV from lights from the Earth. Detection of Mg emission is used as a trigger of wide angle camera.

**References:** [1] Carbary J.F. *et al.*, *Icarus*, **161**, 223–234, 2003.

Table 2. Specifications of photo-multiplier.

Item	Value
Range of wavelength	160-320 nm
Effective diameter	8 mm
Temperature range for operation	-30 ~ +50°C
Max. voltage	1250 V
Average current	0.01 mA
Weight	6.5 g