DEVELOPMENT OF CAMERAS ONBOARD DESTINY^{+} SPACECRAFT FOR FLYBY OBSERVATION OF (3200) PHAETHON. K. Ishibashi[1], P. Hong[1], T. Okamoto[2], T. Ishimaru[2], N. Ozaki[2], T. Hosonuma[3], S. Sato[2], T. Arai[1], F. Yoshida[4,1], O. Okudaira[1], M. Kagitani[5], S. Kameda[6], T. Miyabara[2], M. Ohta[2], and T. Takashima[2], [1]Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino-shi, Chiba 275-0016, Japan, [2]Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan, [3]The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan. [4]University of Occupational and Environmental Health, 1-1, Iseigaoka, Yahatanishi-ku Kitakyushu-shi, Fukuoka, 807-8555, Japan. [5]Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, Miyagi 980-8577, Japan, [6]Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima-ku, Tokyo 171-8501, Japan.

Introduction: DESTINY^{+} (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLy-by and dUst Science) is a mission proposed for JAXA/ISAS Epsilon class small program, scheduled to be launched in 2024. DESTINY^{+} is a joint mission of technology demonstration and scientific observation [1]. The flyby target of DESTINY^{+} mission is the near-Earth asteroid (3200) Phaethon, which is known as an active asteroid and a parent body of the Geminid meteor shower. The size of (3200) Phaethon is 5 to 6 km in diameter [2-4]. The spacecraft will flyby (3200) Phaethon with a distance of 500 ± 50 km at the closest approach and relative speeds of ~35 km/s. In this mission, spatially resolved images of (3200) Phaethon will be taken by two onboard cameras, the Telescopic CAmera for Phaethon (TCAP) and the Multiband CAmera for Phaethon (MCAP). These observations would help understand the nature of a meteor shower's parent body, one of the sources of interplanetary dust particles that are thought to be an important transport medium of organic matter to the Earth. We have carried out the camera observation's conceptual studies to consider the flyby observation sequence and the camera designs.

Objectives of the (3200) Phaethon Flyby Observation: (3200) Phaethon will be observed to understand the nature of a meteor shower's parent body and, in particular, to constrain the dust ejection mechanisms from it. The specific objectives of the camera observation are (1) Obtaining the global shape of (3200) Phaethon, (2) Obtaining the semi-global features of (3200) Phaethon, such as large impact craters and evidence of surface disruption, (3) Observing the local features of (3200) Phaethon, such as topography related to dust ejection, and (4) Observing the material distribution on (3200) Phaethon. The observations (1) to (3) will be conducted by TCAP, and (4) by MCAP.

Onboard Cameras: We have carried out conceptual studies of two onboard cameras, and their conceptual designs have been obtained.

Telescopic CAmera for Phaethon (TCAP). TCAP is a panchromatic camera that observes the global shape, the semi-global features, and local surface features of (3200) Phaethon. To achieve those observations TCAP has a tracking mirror that can change the boresight of TCAP and can keep (3200) Phaethon in the field of view of TCAP all the time during the flyby (Figure 1). The specifications of TCAP obtained through the conceptual study are as follows: The focal length, aperture, field of view, and IFOV (FOV per pixel) are 790 mm, φ114 mm, 0.82 deg × 0.82 deg, and 7.0 μrad/pixel, respectively. TCAP also plays the role of the optical navigation camera for the flyby observation. The specifications above are required for both the scientific imaging and for achieving the flyby imaging sequence described in the next section.

Multiband CAmera for Phaethon (MCAP). MCAP is a multiband camera, the wavelengths of which are 425, 550, 700, 850 nm. The focal length, aperture, field

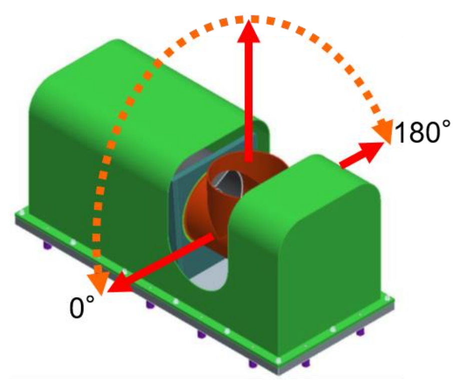

Figure 1. TCAP.

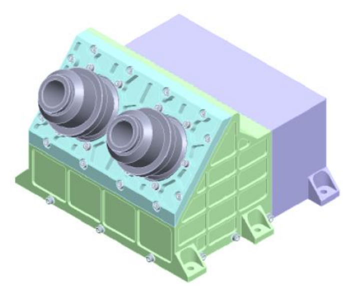

Figure 2. MCAP

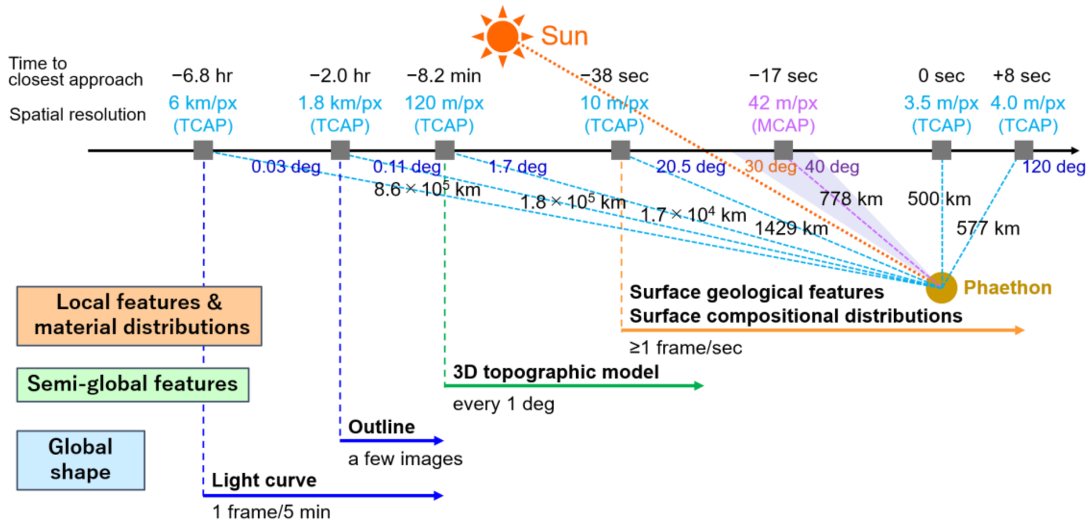

Figure 3: Flyby imaging sequence of TCAP and MCAP with a relative velocity of 35 km/s.

of view, and IFOV are 100 mm, φ21 mm, 6.5 deg × 6.5 deg, and 55 μrad/pixel, respectively, for all the bands. MCAP has multiple optical systems and sensors to take all band images simultaneously. This is because there is not enough time to take each band image in turn with changing bandpass filters in this high-speed flyby mission. We are considering a branching optical system for MCAP, which separates incident light into two imaging sensors using a dichroic prism. Thus, four bands can be covered with two branching optical systems (Figure 2). Using these optical systems reduces the size and mass of MCAP. Although the spatial resolution of MCAP is worse than that of TCAP, the correlation between surface materials and topography can be understood by comparing the images taken by MCAP and the high spatial resolution images by TCAP. MCAP does not have a tracking mirror because of a strict weight limitation and will take images at the solar phase angles of around 10 deg, where the amount of the reflected light is enough to achieve high signal-to-noise ratios.

Flyby Imaging: The observation for searching (3200) Phaethon will start 30 days before the encounter. We estimated the time of detection of (3200) Phaethon using the phase curve of (3200) Phaethon obtained by ground observation [5], and (3200) Phaethon will be detected by TCAP at least ten days before or earlier the encounter. The optical navigation using TCAP images to estimate relative trajectory will be conducted 5 to 2.5 days before the encounter.

Then, the images of (3200) Phaethon will be taken around the closest approach for scientific objectives. Figure 3 shows the flyby imaging sequence of TCAP and MCAP; observations for several objectives will be conducted depending on the distance between the spacecraft and the asteroid. In this phase, the automatic asteroid tracking using the TCAP images will be conducted by controlling the tracking mirror of TCAP and the spacecraft's rolling motion. Since the angular velocity at the closest approach is $4.0^{+0.5}_{-0.4}$ deg/s, which is too high to track by spacecraft attitude control only, the tracking mirror is required.

High pointing accuracy and pointing stability are required to keep the asteroid in the field of view of TCAP and image the asteroid without motion blur. The apparent diameter of (3200) Phaethon is $0.69^{+0.08}_{-0.06}$ deg at the closest approach if the diameter of (3200) Phaethon is 6 km, whereas the field of view of TCAP is 0.82 deg × 0.82 deg. We set the pointing accuracy requirement to ≤0.05 deg (1σ) and ≤0.067 deg (1σ) for the horizontal and vertical directions, respectively. The pointing stability requirement during 0.3 msec, the nominal exposure time of TCAP, is set to ≤4×10-4 deg/0.3 msec (1σ), which corresponds to 1 pixel. Since these requirements have to be satisfied under the pointing accuracy and stability of the spacecraft, the requirements for TCAP are higher than those. The main error sources in TCAP include the tracking mirror motion [6] and the alignment among the telescope's boresight, the rotational axis of the tracking mirror, and the direction of the mirror. We have been evaluating those errors, and the preliminary results show that the requirements are satisfied.

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