DEVELOPMENT STATUS OF DESTINY⁺ ONBOARD CAMERAS FOR FLYBY IMAGING OF (3200) PHAETHON

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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 [1]. The flyby target of the 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 [2-4]. The spacecraft will flyby (3200) Phaethon with a distance of 500±50 km at the closest approach and relative speeds of ~36 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.

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 1 shows the scientific imaging sequence of TCAP and MCAP during the flyby; 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.

Onboard Cameras: The design of the engineering models of both cameras has been completed.

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.

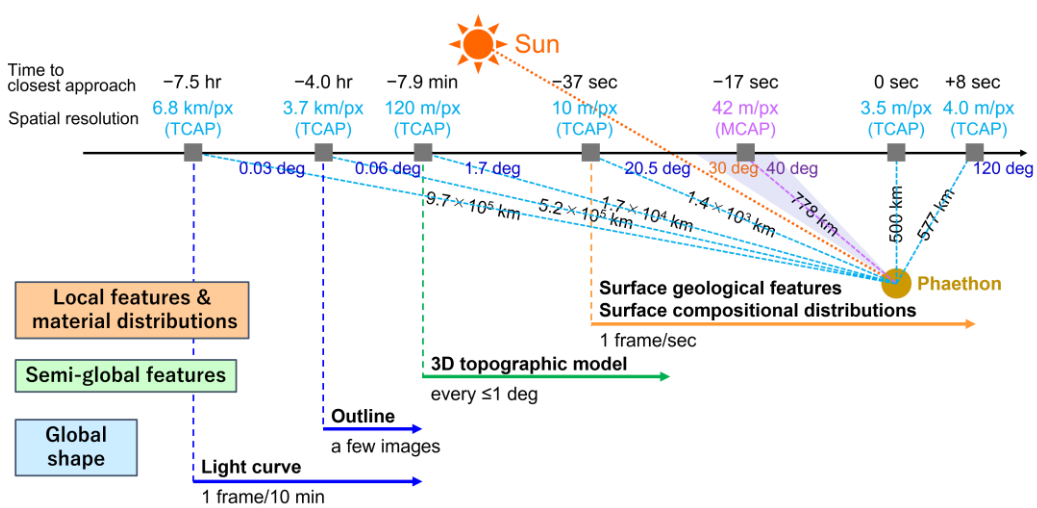

Figure 1: Science flyby imaging sequence of TCAP and MCAP with a relative velocity of 36 km/s.

TCAP is composed of TCAP-OH (an optical head unit containing an imaging sensor, a telescope, and a tracking mirror) and TCAP-E (an electric control unit) (Figure 2). The main specifications of TCAP 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.

Since the angular velocity at the closest approach is $4.1^{+0.5}_{-0.3}$ deg/s, which is too high to track by spacecraft attitude control only, a 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. The pointing accuracy requirements for TCAP are ≤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 $\leq 4\times10^{-4}$ deg/0.3 msec (1σ), which corresponds to 1 pixel. The development of the tracking mirror for TCAP in detail is described by Hong et al. [6].

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 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. MCAP has branching optical systems, which separate incident light into two imaging sensors using a dichroic prism. Thus, four bands can be covered with two branching optical systems (Figure 3). The transmittance of MCAP is shown in Figure 4. 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 (Figure 1), where the amount of the reflected light is enough to achieve high signal-to-noise ratios.

References: [1] Arai, T. et al. (2021) *LPS LII*, Abstract #1896. [2] Green, S. F. et al. (1985) *MNRAS 214*, 29-36. [3] Whipple, F. L. (1983) *IAU Circ.*, 3881. [4] Williams, I. P. and Wu, Z. (1993) *MNRAS 262*, 231-248. [5] Ansdell M. et al. (2014) ApJL 793, 50. [6] Hong, P. et al. (2022) *LPS LIII*, Abstract #1720.

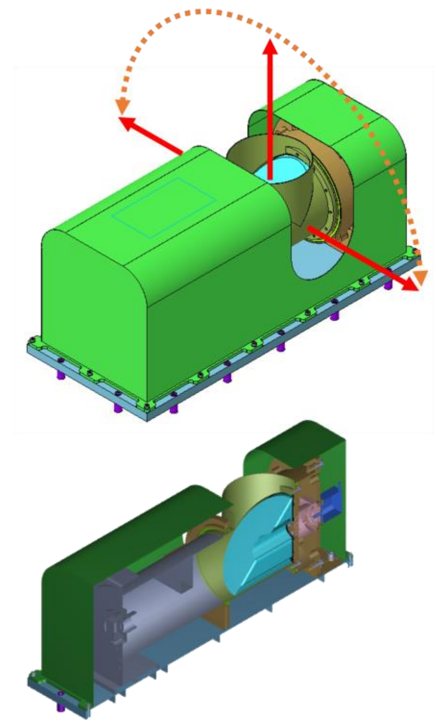

Figure 2: Appearance and intersection of TCAP-OH.

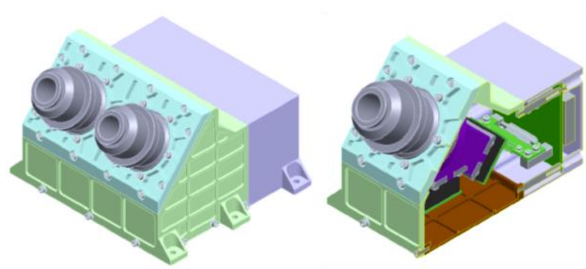

Figure 3: Appearance and intersection of MCAP.

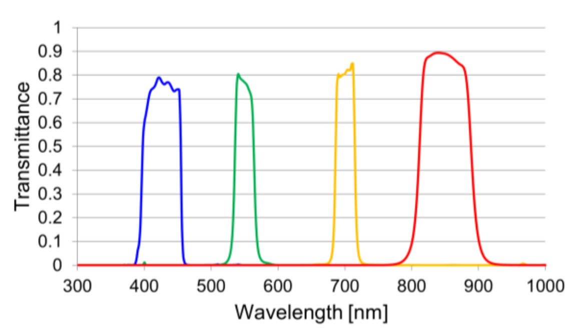

Figure 4: Transmittance of MCAP.