FLYBY OBSERVATION OF ASTEROID (3200) PHAETHON TO BE CONDUCTED BY CAMERAS ONBOARD THE DESTINY+ SPACECRAFT.

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Introduction: DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLy-by and dUst Science) is a mission proposed for JAXA/ISAS Epsilon class small program, currently in the pre-project phase (Phase-A). 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 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 km at closest approach and a relative speed of 30 to 40 km/s. In this mission, spatially resolved images of Phaethon will be taken by two onboard cameras, the Telescopic CAmera for Phaethon (TCAP) and the Multiband CAmera for Phaethon (MCAP), in order to understand the nature of a meteor shower's parent body, which is 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 conceptual studies of the camera observation to consider the flyby observation sequence and the camera designs.

Objectives of the (3200) Phaethon Flyby Observation: 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 Phaethon, (2) obtaining the semi-global features of Phaethon such as large impact craters and an evidence of surface disruption, (3) observing the local features of Phaethon such as topography related to dust ejection, and (4) observing the material distribution on Phaethon. The observations (1) to (3) will be conducted by TCAP, and (4) by MCAP.

Flyby Observation Sequence: TCAP is expected to detect (3200) Phaethon at least two weeks before the encounter. The imaging observation during the flyby allows only a small orbit error of the spacecraft less than approximately ±50 km (3σ) at closest approach. Thus, an optical navigation using the images taken by TCAP to reduce the orbit error is planned. This optical navigation will be conducted 5 to 2 days before the encounter. Different from rendezvous missions, such as Hayabusa 2, an high-speed flyby mission DESTINY$^+$ requires an onboard automatic optical navigation since there is not enough time before the

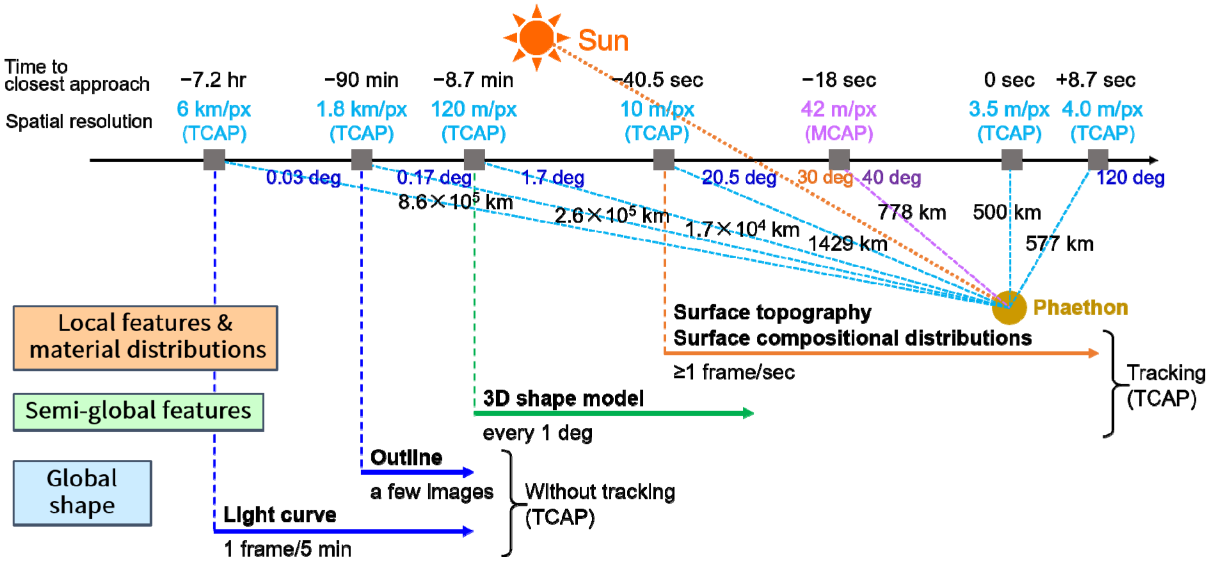

Figure 1: Flyby imaging sequence of TCAP and MCAP.

encounter to downlink the images needed for the optical navigation.

An automatic asteroid tracking during the flyby observation is also required to keep the asteroid in the field of view of TCAP. This will be conducted with both a motion of the rotational mirror equipped on TCAP and a rolling motion of the spacecraft. Several tracking algorithms including a combination of feed-forward and feedback control have been studied.

Figure 1 shows the (3200) Phaethon flyby observation sequence of the DESTINY$^+$ spacecraft. It will conduct several types of observation depending on the distance from the asteroid to achieve the objectives described in the previous section. TCAP will start taking images for making a global shape model of the asteroid by the light curve taken for approximately two rotation periods. Different from ground-based light curve observations, TCAP can also observe the outline of the asteroid simultaneously, which must provide a higher quality 3D shape model. Approximately 9 minutes before the closest approach TCAP will start taking images for a precise local 3D shape model of sunlit portion of the asteroid. Then, TCAP will take images of high resolution local topography less than 10 m/pixel for ~50 seconds around the closest approach with solar phase angles of 0 to 90 deg. In this final phase TCAP will take mages of the asteroid with a frame rate of 1 fps. Since MCAP does not have a tracking function due to the weight limitation, and the boresight of MCAP is fixed to the spacecraft with 40 deg off the relative velocity vector of the spacecraft. Thus, MCAP will observe (3200) Phaethon just while the asteroid is in the field of view of MCAP for ~10 seconds around a solar phase angle of 10 deg.

Onboard Cameras: We have carried out conceptual studies of two onboard cameras, and conceptual designs of them 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, as explained in the previous section. To achieve those observations TCAP has a rotational mirror that can change the boresight of TCAP and can track (3200) Phaethon all the time during the flyby (Figure 2). The specifications of TCAP obtained through the conceptual study so far 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.

Multiband CAmera for Phaethon (MCAP). MCAP is a multiband camera, the wavelengths of which are 425, 480, 550, 700, 850, and 950 nm (700 and 950 nm are optional bands). 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 in order 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. Now we are considering a branching optical system for MCAP, which separates incident light into two imaging sensors using a dichroic prism. Thus, for bands can be covered with two branching optical systems (Figure 3). 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.

References: [1] Arai, T. et al. (2018) *LPS XLIX*, Abstract #2570. [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.

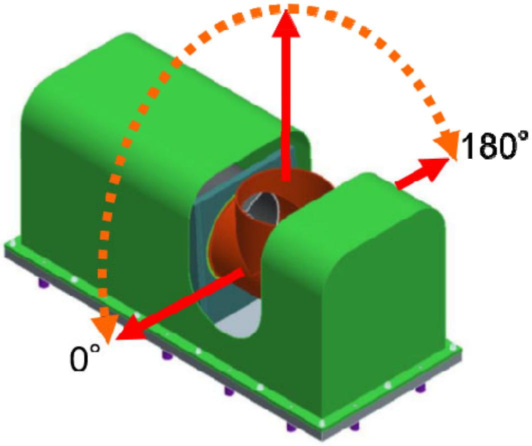

Figure 2. TCAP.

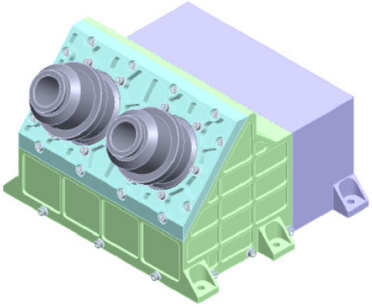

Figure 3. MCAP (nominal 4 bands with two branching optical systems).