Development Status of DESTINY+ Onboard Cameras for Flyby Imaging of (3200) Phaethon

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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. 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 is 5-6 km. 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.

The images of (3200) Phaethon for scientific objectives will be taken around the closest approach during the flyby. In this phase, automatic asteroid tracking using the TCAP images will be conducted by controlling the tracking mirror of TCAP and the spacecraft's rolling motion.

TCAP is a panchromatic camera that observes the global shape, 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. The main specifications of TCAP are as follows: The focal length, aperture, field of view, and IFOV (FOV per pixel) are 787.7 mm, ϕ114 mm, 0.81 deg ×0.81 deg, and 7 μrad/pixel, respectively. TCAP also plays the role of the optical navigation camera for the flyby observation. The specifications above are required for both scientific imaging and automatic asteroid tracking. Since the angular velocity at the closest approach is ~4.1 deg/s, which is too high to track by spacecraft attitude control only, a tracking mirror is required. In addition, 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 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 ≦4×10^{-4} deg/0.3 msec (1σ), corresponding to 1 pixel.

MCAP is a multiband camera with 425, 550, 700, and 850 nm wavelengths. The focal length, aperture, field of view, and IFOV are 99 mm, ϕ20.8 mm, 6.5 deg ×6.5 deg, and 54 μrad/pixel, respectively, for all the bands. MCAP has multiple optical systems and sensors to take all band images simultaneously; 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. 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 10-15 deg, where the amount of the reflected light is enough to achieve high signal-to-noise ratios.

The design of engineering models (EMs) of TCAP and MCAP has been completed, and both cameras passed the preliminary design review (PDR) last year. At the time of this writing, the EMs are being manufactured. In parallel with the manufacturing of the TCAP EM, a prototype of the tracking mirror equipped with TCAP (BBM3) was manufactured, and its driving performance was evaluated. BBM3 has the same structure as the tracking mirror of TCAP EM, but the motor, reducer, and bearings are not for space use (i.e., grease is not vacuum compatible). We used BBM3 to investigate the driving characteristics of the driving mirror in detail, especially its backlash-like behavior. The results are taken into account and fed back into the study of the control algorithm for the tracking mirror. We also conducted a vibration test with BBM3 to evaluate the vibration resistance of the tracking mirror prior to the evaluation with EM. After the manufacturing of EMs is completed, various evaluation tests will be conducted on EMs, and the results will be reflected in the design of the flight models (FMs) of TCAP and MCAP.

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