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Introduction: DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) is an upcoming flyby mission to Asteroid (3200) Phaethon [1,2]. Phaethon is the parent body of Geminid meteor shower [3,4] and an active asteroid with recurrent emission of sodium [5] and dust during its perihelion passage [e.g. 6, 7]. DESTINY+ is a joint mission of science observation and technology demonstration. For the science observation, high-speed (36 km/s) flyby imaging of Phaethon at the closest distance of 500 ± 50 km is performed with a tracking telescopic camera (TCAP) and a VIS-NIR multiband camera (MCAP) with four bands (425, 550, 700, 850 nm) [8]. TCAP and MCAP are developed by a team led by PERC, Chiba Institute of Technology [8,9]. Also, direct measurement of dynamical and chemical properties of each dust particle is conducted for interplanetary dust, interstellar dust entering the solar system, dust trails and dust nearby Phaethon, with a dust analyzer (DDA). DDA is an impact-ionization dust detector and time-of-flight mass spectrometer, equipped with a two-axis gimbal [10,11]. DDA is developed with a heritage of Cosmic Dust Analyzer (CDA) onboard Cassini and provided by a team led by Stuttgart University [10,11]. Preliminary measurement of dust impact ionization TOF mass spectra with the DDA EM and the electrostatic accelerator installed at University of Stuttgart has been successfully performed.

Updates and changes: DESTINY+ was originally planned to be launched by a solid-fuel Epsilon S rocket [1] in FY2025 and fly by Phaethon in January 2028 [12]. Due to recent multiple failures in the static fire testing of Epsilon S rockets, the launch rocket has been changed to H3 rocket or equivalent. Accordingly, the DESTINY+ launch is now planned to be in FY2028 and the Phaethon flyby in November 2030. The above changes affect both engineering and scientific aspects.

Trajectory. DESTINY+ originally planned to perform spiral apogee-raising and multiple lunar gravity assists to escape the Earth efficiently after Epsilon S rocket would insert the spacecraft into a near-geostationary transfer orbit. With the change of rocket, the Earth spiral orbit raising and the Moon flyby is no more needed. Baseline trajectory is currently being studied and revised.

Dust analyses. Without the Earth spiral orbit phase, there will be no opportunity for direct measurement of cosmic dust and microdebris around the Earth. Also, there will be no chance of in-situ direct analyses of dust around the Moon without the lunar flyby. The delayed launch will have a positive effect on interstellar dust observation. A simulation study of the flow of interstellar dust through the Solar System, using the interstellar dust module of the Interplanetary Meteoroid environment for EXploration model (IMEX) [13, 14] shows that the impact rate of interstellar dust tends to increase by a factor of four up to ten toward 2030 because the interplanetary magnetic field changes to a focusing configuration for small ($\lesssim$ 0.1 μm) interstellar dust particles from late 2020s to early 2030s [15, 16].

Target asteroids. Before reaching Phaethon, a flyby observation of at least one asteroid is planned as a rehearsal for the flyby observation. Asteroid (99942) Apophis is a candidate target. To reach Phaethon in November 2030, a flyby of Apophis should be conducted prior to its Earth closest approach on April 13, 2029. If that is a case, data on Apophis's physical shape, surface topography, and geology obtained through DESTINY+'s flyby imaging holds significance not only for planetary science and defense, but also serves as reconnaissance by gathering preliminary information for following rendezvous missions, such as OSIRIS-APEx [17] and RAMSES [18]. Further, chemical compositions of Apophis's surface material possibly obtained by DDA analyses of dust around Apophis would be of notable scientific significance. As long as the spacecraft remains in good condition, we plan to conduct flyby observations of multiple asteroids, employing low-thrust and Earth gravity-assist maneuvers.

Flyby observation of Phaethon. Flyby geometry for 2028 flyby and 2030 flyby of Phaethon will not be much different, and thus the current operational planning upon the closest flyby of Phaethon remains valid [12]. Thanks to the currently available rotation period (3.603957±0.000001 (hr)) [19,20], pole orientation [19, 20] and the updated 3D shape model (Fig. 1) of Phaethon [21], we can adjust the flyby timing to observe the targeted area on Phaethon during the closest approach. The current observation target is the feature "d" (about 2 km in size) located in the lower latitude region on the northern hemisphere (Fig.1), which is the largest among km-scale concavities identified by the Arecibo radar observation [22].

Ground-based observation of Phaethon: Imaging of Phaethon will be conducted autonomously during the high-speed flyby. Detailed understanding of its size, shape, albedo, and rotation state prior to the flyby is crucial for successful imaging by TCAP with a range of solar phase angle [8]. Continuing efforts of ground-based observation of Phaethon have been made [e.g. 23-25]. Stellar occultation observation was conducted in Japan and China on November 16, 2024. Eighteen stations with total 63 observers were deployed across the predicted path in the western part of the main island of Japan, and four stations in China. The observation was not successful due to cloudy weather. Short visible-wavelengths observation with the Faint Object Camera and Spectrograph (FOCAS) of the Subaru Telescope was planned on November 11, 2024, but was cancelled due to a higher-priority observation.

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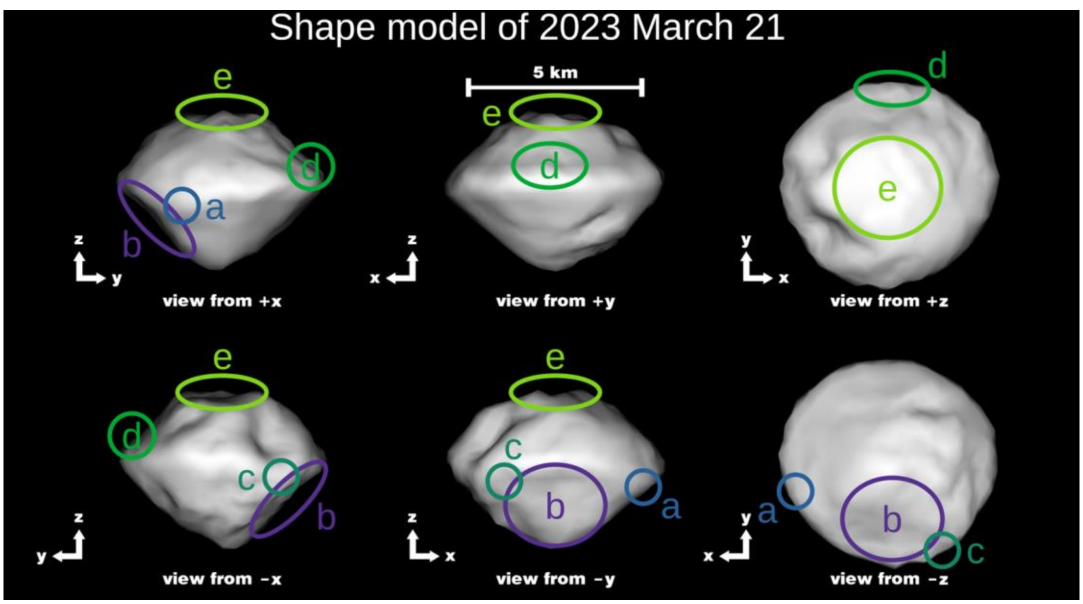

Fig.1. The latest 3D shape model of Phaethon [21] with markings for the five depression features of [22].