On-orbit verification of luminance based target tracking and faint body extractions by a small telescope on the world’s first micro-interplanetary space probe

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World’s first interplanetary micro space probe

Flight model of PROCYON [1]

Proximate Object Close fLyby with Optical Navigation (PROCION) was the world’s first interplanetary micro-spacecraft that had the full ability to achieve actual scientific survey such as observation of geocorona with the Lyman Alpha Imaging Camera. Other than the main technology demonstration mission, PROCYON had bonus goals to fly adjacent to an asteroid and to capture high-resolution images of its surface. See also: [1] SSC16-III-05.

Visual feedback tracking experiment

Bottom direction

Distance: 4.9 × 10⁶ km

Earth

Bottom direction

Distance: 4.9 × 10⁶ km

Earth

PROCYON

Experimental configuration of the target tracking

Flight model of PROCYON [1]

Line-of-sight movement

Line-of-sight change during a close distance flyby

Earth pictures taken by the telescope

Field of view at 1

Field of view at 2

Field of view at 3

Field of view at 4

Time [HH:MM:SS]

Angle [deg]

Field of view at 1

Field of view at 2

Field of view at 3

Field of view at 4

Time [HH:MM:SS]

Angle [deg]

Field of view at 1

Field of view at 2

Field of view at 3

Field of view at 4

Time [HH:MM:SS]

Angle [deg]

Field of view at 1

Field of view at 2

Field of view at 3

Field of view at 4

The on-board image feedback tracking technology was partly verified using Earth as a virtual target body. The apparent diameter of Earth at the time of the experiment was about 0.15 deg = 70 pixels. By looking at the field of view direction plots (①〜④), there are some angular separations between central points (red □, desired direction of Earth) and the Earth directions (blue ○). It was simply explained the delay of the image processing.

Telescope for two purposes

Optical telescope of PROCYON

Specifications of the telescope

Pupil diameter 40mm

F-number 3.75

Focal length 150mm

Angle of view (Half the vertex angle) 2.6deg

Number of pixels 1088 × 2048

Size of a pixel 5.9μm

PROCYON is equipped with a telescope to achieve two objectives;

① Detect the target asteroid as early as possible

There is relative position uncertainty between the asteroid and PROCYON. The target should be detected 5 days before closest approach to perform trajectory correction maneuvers.

② Take pictures of the asteroid leading up to closest approach

In the vicinity phase of the close distance flyby, PROCYON had a plan to capture high-resolution images, while the line-of-sight direction of the telescope was autonomously controlled using asteroid image processing on-board.

The small telescope should achieve the objectives with the same 4cm caliber barrel.

Dark-star detection experiment

Small spot noises are removed by the composite

12.16 mag

12.08 mag

12.06 mag

12.17 mag

12.16 mag

12.08 mag

12.06 mag

12.17 mag

a) Star position from Simbad Data Base

b) 50% overlay image of right and left images
c) Composed image

d) Original images taken by PROCYON (10 second exposure time)

PROCION should detect 12.7 magnitude stars in order to find the target asteroid 5 days before arrival. A dark star detection experiment was performed to verify the detection capability. PROCYON was limited to a 4 cm aperture telescope for optical navigation, and the single-shot S/N ratio is not applicable for such dark star detection. Actually, many small spot noises can be observed in the original images taken by the small telescope (Fig. d). These spot noises cause miss detections of the dark stars. In order to remove these noises, two original images are composited based on some positions of dark spots, and Fig. c was generated. The composed image was compared with the star database, and several stars darker than 12th magnitude were detected.