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LOW-THRUST TRAJECTORY DESIGN AND OPERATIONS OF PROCYON, THE FIRST DEEP-SPACE MICRO-SPACECRAFT

Abstract

PROCYON is a micro-spacecraft developed by The University of Tokyo and JAXA [1], which was launched on Dec. 3 2014 as secondary payload of H-IIA (primary payload was Hayabusa2 [2]). PROCYON is the first deep-space micro-spacecraft; it was developed mainly by students, with a very short development time of about one year, and at low-cost. Depending on the launch date, PROCYON trajectory involves one or two Earth flyby, and a low-altitude flyby of a near-Earth asteroid [3].

PROCYON has several mission objectives, including: demonstration of a micro-spacecraft bus for deep-space exploration; in-flight validation of telecommunication and propulsion system components; precise VLBI navigation; very-low-thrust flight path control; imaging of the geocorona; and asteroid close flyby observation and optical navigation.

This paper discusses PROCYON's low-thrust trajectory design and operations, from before launch to the current status. We formulate the optimization problem in a high fidelity model, with constraints coming from the spacecraft design and from ground operation considerations. The optimization is performed with jTOP, a novel in-house software, which is first presented in this paper.

Using pre-launch spacecraft parameters, the launch window analysis is examined first in the linked-conics model, and then in the high-fidelity model used also for spacecraft navigation. Surprisingly, while

the results in the simplified model reflect those of the preliminary design [4], the results in the high-fidelity model are significantly different. In some cases, new low-dv, low time-of-flight solutions are found in the high-fidelity model, which were deemed unfeasible in the simplified model. One important example is the post-launch baseline trajectory, which is also first presented here.

As the start of continuous low-thrust operations was delayed, new baselines were computed and implemented. We discuss the effect of the delayed operations and present backup scenarios to target the Earth sphere of influence or a secondary target asteroid. An analysis is performed using first and second order expansions of the nominal trajectory (provided by jTOP) and low-thrust targeting on the B-Plane.

[1] Funase et al., 50kg-class Deep Space Exploration Technology Demonstration Micro-spacecraft PROCYON, SSC 2014 [2] Tsuda et al, System Design of Hayabusa2 - Asteroid Sample Return Mission to 1999JU3, IAC 2012 [3] Ozaki et al. , Preliminary Mission Design of PROCYON: A Micro Spacecraft to Asteroid, ISSFD 2014 [4] Yam, Launch Window and Sensitivity Analysis of an Asteroid Flyby Mission with Miniature Ion Propulsion System: PROCYON, IAC 2014