Thruster Parameters Estimation for a Micro Deep Space Explorer: PROCYON

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Abstract: *This paper presents the results of parameters estimation of a micro deep spade explorer. PROCYON (Proximate Object Close flyby with Optical Navigation) is a 50kg-class micro-spacecraft for deep space exploration, which was launched on December 3, 2014 as a secondary payload by an H-IIA launch vehicle along with the Hayabusa-2 spacecraft. The objectives of PROCYON are to demonstrate the technology of micro spacecraft deep space exploration and proximity flyby to asteroids performing optical measurements. The propulsion system can be one of PROCYON's features, which is called I-COUPS (Ion Thruster and Cold-gas Thruster Unified Propulsion System) [1]. The I-COUPS is a combined propulsion system of ion thruster and cold-gas thrusters by sharing the same xenon gas system. This enables both systems to reduce its sizes and to use these 2 thrusters with different characteristics for efficient low-thrust maneuver and high thrust by the cold-gas system. This system is indispensable for the orbit control and unloading the angular momentum of Reaction Wheels. The performance of the I-COUPS is well known by ground tests before the launch. However there is a possibility that the properties change because of the impact at the launch. To perform expected and precise maneuvers, knowledge about the actual thrust performance is absolutely imperative. This paper presents how to estimate the thrust magnitude of ion thruster and cold-gas thrusters by using the flight data and its validations. Our latest results found that the thrust magnitude of cold-gas thruster is up to about 15% deviated from the reference values measured by ground tests.*

Keywords: *Micro-Spacecraft, PROCYON, Parameter Estimation, Thruster, In-orbit experiment.*

1. Introduction

PROCYON (Proximate Object Close flyby with Optical Navigation) is the first deep-space micro spacecraft, which is mainly developed by Intelligent Space Systems Laboratory (ISSL) in the University of Tokyo and the Japan Aerospace Exploration Agency (JAXA). The mission objective of PROCYON is to demonstrate micro-spacecraft bus technology for deep space exploration and a proximity flyby to an asteroid performing optical measurements. The nominal trajectory of PROCYON includes one Earth flyby and a propinquity flyby to a near-Earth asteroid. For the trajectory plan and the mission objective, accurate and expected maneuvers are essential. However there are uncertainties like an impact of launch. Therefore the performance of propulsion system can differ. From this point of view, accurate calibration of the thrusters is meaningful.

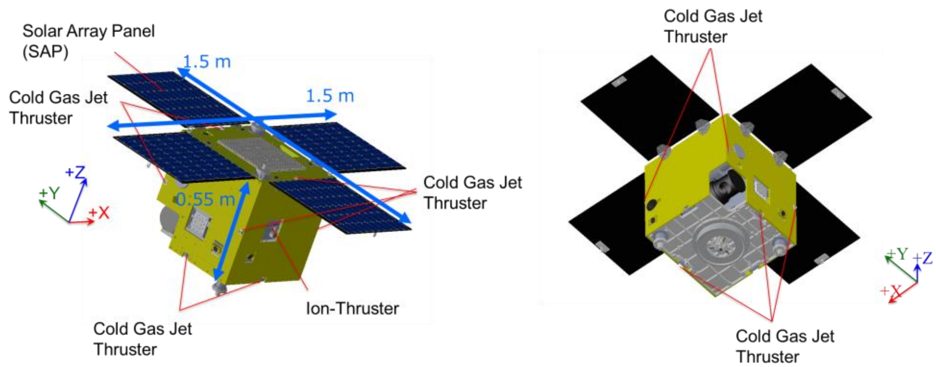

Fig.1 Schematic of PROCYON

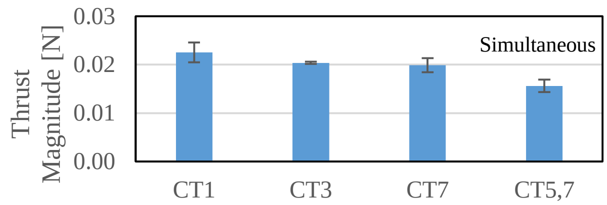

Fig.2 Thruster estimation results of each cold-gas thruster

2. Method and Results of Parameter Estimation

2.1 Cold-gas thrusters

As shown in Fig.1, PROCYON has eight cold-gas thrusters, which are used for unloading angular momentum of reaction wheels and the orbit control at asteroid flyby. The former doesn't need the highly precise knowledge of thrust magnitude. However for the latter, the performance of thrusters is significant because PROCYON must approach the target asteroid accurately and rapidly within a restricted time frame.

To estimate the actual thrust magnitude of cold-gas thrusters, Euler's dynamical equation is used on the assumption that the spacecraft and reaction wheels inertia tensor is constant. The flight data, mainly unloading data: the spin rate of reaction wheels and spacecraft, is used for this estimation.

2.2 Ion thruster

The ion thruster performance affects the trajectory plan significantly, as it is the only propulsion system for translational maneuver. Taking into account the orbit determination (OD) results and actual thrust and attitude history, the thrust magnitude and specific impulse can be estimated by minimizing the position difference between the OD results and the trajectory propagation with estimated parameters.

2.3 Preliminary Results

A part of estimation results of cold-gas thrusters is shown in Fig.2, based on data from January to March, 2015. The gas of CT (Cold-gas Thruster) 5 and 7 hit Solar Array Panels and estimated thrust magnitude is lower than results of ground tests. In the presentation, the results and their accuracy are evaluated and validated by various error factors like thrust time error, which is considered as the dominant factor, and by statistical methods. Furthermore the results and their accuracy of ion thruster are validated by another estimation methods using Doppler measurements and various error factors like the installation error.

3. References

[1] KOIZUMI, Hiroyuki, et al. "Unified Propulsion System to Explore Near-Earth Asteroids by a 50 kg Spacecraft." 2014.