On-orbit Performance of a Miniature Propulsion System on a 70 kg Space Probe to Explore Near-Earth Asteroids

What is the micro-space probe, PROCYON?
University of Tokyo, in 2003, developed and launched the world's first cubalet, XI-IV, into the L2. In 2014, we challenged the world's first microsatellite, PROCYON, to develop micro-deep-space exploration.

The PROCYON & I-COUPS, Developed & Launched?

The first interplanetary micro-spacecraft, In-Flight Operation
Initial checkout of the propulsion system started on Dec. 5th, 2014, two days after the launch. In one month, the project team finally finished the checkout of the COTS-based high-pressure system, cold-gas thrusters, and the ion thruster. Torque by the cold-gas thrusters was confirmed by the angular momentum change of the space probe and thrust of the ion thruster was confirmed and measured by Doppler shift of the communication wave.

Requirements to Propulsion
Multiple thrusters for RCS (reaction control system) High ΔV for orbit transfer of gravity assist High thrust for TCM (trajectory correction maneuver)

What is the unified-micropropulsion, I-COUPS?
I-COUPS (Ikejiri, I) [Ionthruster and Cold-gas thruster Unified Propulsion System] is a micro propulsion system equipped with ion thruster and multiple cold-gas thrusters to develop ion thruster and cold-gas thrusters share the same gas system, xenon gas. For downsized propulsion system, reduction of gasfeeding system becomes dominant rather than propellant. Hence, reducing dry mass of gas system is a key of micro propulsion system.

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The ion thruster accumulated the total operation time up to 225 hours after solving problems #01-04. The averaged ion beam current was 5.62 mA corresponding to the Ion Beam Power of 44.6 mW. The thrust coefficient γ_F was updated to 0.964 according to the thrust estimated from the Doppler data. The beam current showed a trend of gradual decrease by 1.7% over 200 hours.

Problems exposed in the flight operation of the ion thruster 1. Leakage at the ion thruster valve. 2. Error control of the pressure regulation valve 3. Occasional freeze of the controllers 4. Gradual increase of the neutralizer voltage 5. High-voltage anomaly of the ion thruster

#01-04 were found in the initial checkout and solved by changing the operating conditions/methods. #05 appeared after the 225th operation. Recovery operation for the problem #05 has continued to clear the expected cause, grid-short.

Achievement up to today
The miniature propulsion system has operated for more than 6 months, as the first interplanetary micropropulsion, 
- COTS-based micro-EP subsystems, including high-pressure gas system, have been in good health. 
- The cold-gas thrusters are successfully working over 103 operations. 
- The ion thruster operated in 225 hours

PROCYON has no gimbal system and cold-gas thruster unloading is necessary, typically once a two days. Gas ejection from the cold-gas thrusters had potential to increase the gas pressure surrounding the space probe and to disturb the operation of the ion thruster. The unloading maneuver was conducted with continuous operation of the ion thruster and it showed no interference with its operation.

The University of Tokyo & JAXA2

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