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IN-FLIGHT PERFORMANCE OF WATER RESISITOJET THRUSTER AQUARIUS; FROM LONG-TERM TREND TO SPACE ENVIRONMENTAL EFFECT

Abstract

EQUULEUS, developed by the Japan Aerospace Exploration Agency (JAXA) and the University of Tokyo, is one of the 6U CubeSats launched alongside NASA's Orion spacecraft by SLS in November 2022. Since its launch, EQUULEUS has achieved notable milestones, including the world's first controlled lunar flyby by a small satellite. AQUARIUS, a key technology supporting EQUULEUS' mission, is a 2.5U-sized resistojet propulsion system utilizing water as a propellant due to its CubeSat-friendly features such as safety, low cost, low-pressure storage, and potential for future ISRU. Conventional water resistojet thrusters face challenges such as high-power consumption and unreliable vapor-liquid separation. To address these issues, a vaporization chamber, a designated room for water vaporization positioned between a tank and thruster heads, was introduced. Water droplets are intermittently supplied to the chamber and start to vaporize by receiving heat from the chamber wall, heated by both heaters and the waste heat of X-band transponders. This vaporization takes place at low pressure and room temperature, enabling the utilization of exhaust heat from the spacecraft bus system, leading to a low-power operation of less than 20 W. The vapor flow to the thruster heads, while remaining liquid droplets are trapped by a labyrinth structure in the chamber. The thruster heads consist of two delta-V thrusters (DVT) and four reaction control thrusters (RCT). DVTs have a high-aperture-ratio nozzle for delta-V maneuver, and RCTs employ a tilted small nozzle to generate unloading torque around the three axes. During the ground test, a thrust of 4.5 mN and a specific impulse of 75 s for DVTs were measured, predicting a total delta-V of 70 m/s. EQUULEUS has successfully completed three delta-V maneuvers, eleven trajectory correction maneuvers and multiple controlled lunar flybys. During the first six months of the flight, telemetry data for AQUARIUS, including more than 400 injections under varying system temperatures and remaining propellant conditions, were collected. Moreover, generated delta-V of every single shot was measured from the Doppler shift of the communication waves. From these data, we found that the specific impulse of DVTs increased 1.3 times compared to the ground test, possibly due to extremely low back pressure. Furthermore, an analysis of on-orbit performance, including temperature and tank-pressure dependency, along with a discussion on the microgravity effect on vaporization behavior, will be shared in this presentation.