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ON-ORBIT PERFORMANCE OF AQUARIUS: WORLD'S FIRST SUCCESSFUL WATER PROPULSION SYSTEM IN DEEP SPACE

Abstract

This paper presents the latest on-orbit performance of AQUARIUS (AQUA ResIstojet propUlsion System). AQUARIUS is installed on 6U CubeSat EQUULEUS (EQUilibriUm Lunar-Earth point 6U Spacecraft), one of the ten CubeSats launched by NASA Space Launch System in November 2022. AQUARIUS has currently been playing an important role in the spacecraft to reach the EML2 (Earth-Moon L2 Point). It has completed several delta-V maneuvers and trajectory corrections including the world's first orbit transfer by any water propulsion system in deep space. AQUARIUS is a 2.5 U resistojet propulsion system using water as a propellant. Water is highly suitable for CubeSats as it is safe, low-cost, condensable, and capable of future in-situ resource utilization. AQUARIUS consists of three main components: a tank for liquid water storage, a vaporization chamber for water evaporation, and six thruster heads for thrust generation. The vaporization chamber separates vapor from liquid water, and it uses the waste heat from the high-temperature devices to compensate for the large latent heat of the water. AQUARIUS has two delta-V thruster heads (DVTs) for major delta-V generations, and four reaction control thruster heads

(RCTs) mainly for three-axis momentum unloading. Ground tests of AQUARIUS indicated that its DVT thrust is 4.1 mN, and the specific impulse is 73.1 s under the total power consumption of 20 W. The operations of AQUARIUS are categorized into two types: delta-V maneuvers and trajectory correction maneuvers. The major orbit transfer in the limited time is realized in delta-V maneuvers using DVTs, and the minor orbit correction is realized in trajectory correction maneuvers using not only DVTs but also RCTs for more precise delta-V generation. The thrusters' on-orbit performance is determined by observing the doppler shift of the spacecraft and the attitude determination system. After the separation of EQUULEUS from the launch vehicle, the spacecraft completed its initial checkouts and delta-V maneuvers within 72 hours. The EQUULEUS operation team has trained and prepared using a hardware simulator for an intense limited time of the initial operation. EQUULEUS is now ready for reaching EML2 after multiple delta-V operations and trajectory corrections. This paper reports and discusses the operational results of AQUARIUS from its initial operation to the present and compares them with that of ground tests. Learned lessons from the operation are also introduced.