

Engineering Model Propellant Feed System Development for an Iodine Hall Thruster Demonstration Mission

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I. Abstract

CUBESATS are relatively new spacecraft platforms that are typically deployed from a launch vehicle as a secondary payload,¹ providing low-cost access to space for a wide range of end-users. These satellites are comprised of building blocks having dimensions of 10x10x10 cm³ and a mass of 1.33 kg (a 1-U size). While providing low-cost access to space, a major operational limitation is the lack of a propulsion system that can fit within a CubeSat and is capable of executing high Δv maneuvers. This makes it difficult to use CubeSats on missions requiring certain types of maneuvers (i.e. formation flying, spacecraft rendezvous).

Recently, work has been performed investigating the use of iodine as a propellant for Hall-effect thrusters (HETs)² that could subsequently be used to provide a high specific impulse path to CubeSat propulsion.^{3,4} Iodine stores as a dense solid at very low pressures, making it acceptable as a propellant on a secondary payload. It has exceptionally high ρI_{sp} (density times specific impulse), making it an enabling technology for small satellite near-term applications and providing the potential for systems-level advantages over mid-term high power electric propulsion options. Iodine flow can also be thermally regulated, subliming at relatively low temperature (< 100 °C) to yield I₂ vapor at or below 50 torr. At low power, the measured performance of an iodine-fed HET is very similar to that of a state-of-the-art xenon-fed thruster. Just as importantly, the current-voltage discharge characteristics of low power iodine-fed and xenon-fed thrusters are remarkably similar, potentially reducing development and qualifications costs by making it possible to use an already-qualified xenon-HET PPU in an iodine-fed system. Finally, a cold surface can be installed in a vacuum test chamber on which expended iodine propellant can deposit. In addition, the temperature doesn't have to be extremely cold to maintain a low vapor pressure in the vacuum chamber (it is under 10^{-6} torr at -75 °C), making it possible to 'cryopump' the propellant with lower-cost recirculating refrigerant-based systems as opposed to using liquid nitrogen or low temperature gaseous helium cryopanel.

In the present paper, we describe the design and testing of the engineering model propellant feed system for iSAT (see Fig. 1). The feed system is based around an iodine propellant reservoir and two proportional control valves (PFCVs) that meter the iodine flow to the cathode and anode. The flow is split upstream of the PFCVs to both components can be fed from a common reservoir. Testing of the reservoir is reported to demonstrate that the design is capable of delivering the required propellant flow rates to operate the thruster.

The tubing and reservoir are fabricated from hastelloy to resist corrosion by the heated gaseous iodine propellant. The reservoir, tubing, and PFCVs are heated to ensure the sublimed propellant will not re-deposit within the feed system. Heating is accomplished through a number of individual zones to control the overall power expended on heating the system and insulation is employed to minimize the amount of power used to heat the system prior to thruster operation.

If available, testing of the feed system will be performed in conjunction with a thruster and cathode and multiple electronics components. One is an auxiliary board that provides power to the feed system and measures temperatures for feedback control. Another is a power board to supply power for the auxiliary board. Also, if the development flight computer and a lab-model power processing unit are available, they will be used as well.

References

¹ *CubeSat Design Specifications*, rev. 13, The CubeSat Program, California Polytechnic State University, San Luis Obispo, CA (2014).

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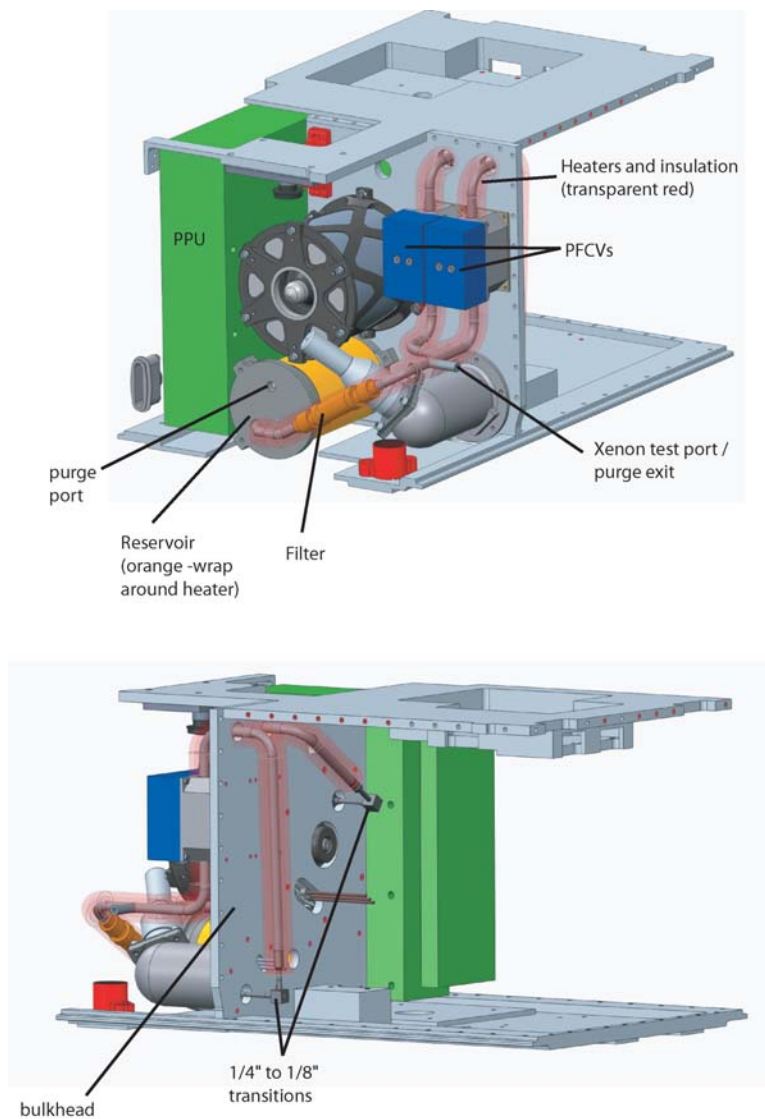


Figure 1. iSAT propulsion system rendering.

²J. Szabo, B. Pote, S. Paintal, M. Robin, A. Hillier, R.D. Branam, and R.E. Huffman, "Performance Evaluation of an Iodine-Vapor Hall Thruster," *J. Propuls. Power* Vol. 28, No. 4, pp. 848–857 (2012).

³J.W. Dankanich, K.A. Polzin, D. Calvert, and H. Kamhawi, "The iodine Satellite (iSAT) Hall Thruster Demonstration Mission Concept and Development," in *50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference*, Cleveland, OH (2014). AIAA Paper 2014-3910.

⁴K.A. Polzin and S. Peeples, "Iodine Hall thruster propellant feed system for a CubeSat," in *50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference*, Cleveland, OH (2014). AIAA Paper 2014-3915.