Propulsion System Testing for the Iodine Satellite (iSAT) Demonstration Mission

Kurt A. Polzin *
NASA-Marshall Space Flight Center, Huntsville, AL 35812

Hani Kamhawi†
NASA-Glenn Research Center, Cleveland, OH 44135

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 cm^3 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 I_2 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 cryopanels.

An iodine-based system is not without its challenges. The primary challenge is that the entire feed system must be maintained at an elevated temperature to prevent the iodine from depositing (transitioning from the gas phase directly back into the solid phase), which will block the propellant feed lines. Furthermore, deposition will occur unless the temperature in the lines is not greater than the temperature of the propellant reservoir. The flow rate can be controlled by adjusting the heating applied to the reservoir, but as with any thermal control there is a relatively slow response to changes in the heating rate.

In the present paper, we describe the propulsion and propellant feed system for the iodine satellite (iSAT) flight demonstration mission.[3] The system is based around the Busek BHT-200 Hall thruster, which has been modified for chemical compatibility with iodine vapor. While the gross propellant flow rate is maintained by the heated propellant reservoir, the flow to the anode and cathode are adjusted using two heated Vacco proportional flow control valves (PFCV), which provide very fast response on the flow rate adjustment. The flight mission design layout will be presented, showing how the system will be packaged into the overall 12-U spacecraft and the techniques being employed to protect the remaining spacecraft hardware from the propulsion system (e.g., plasma impingement, iodine deposition, thermal loads).

*Propulsion Research Engineer, Propulsion Research and Technology Applications Branch, Propulsion Systems Department.
†Aerospace Engineer, Propulsion and Propellants Branch.

In addition to the flight system design, results of testing the thruster and cathode with both operating on iodine propellant are presented. The tests are conducted on a thrust stand (see Fig. 1) in a large vacuum chamber containing a beam dump chilled to below -100 °C to 'cryopump' the propellant. The thruster performance during these tests is presented, with these data used to evaluate the feed system and guide further refinements. Results of relatively long duration testing are presented to demonstrate the capability to operate for the length of the iSAT mission and to perform a number of re-starts as will be required by the mission concept of operations.

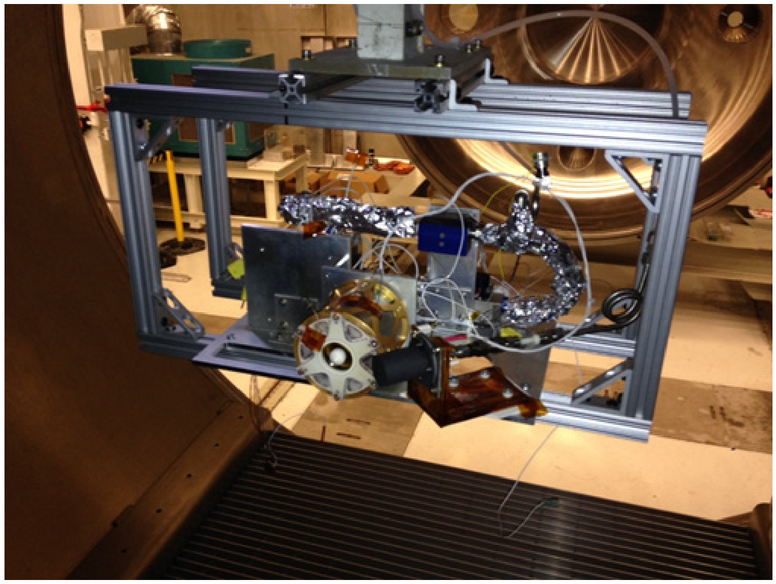

Figure 1. The BHT-200 iodine-fed Hall thruster and feed system mounted to a thrust stand.

References

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

[2] J. 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).

[3] J.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.

[4] K.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.