Suborbital Testing of a Micropropulsion System for Small Satellites

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Abstract

Small sattelite propulsion options include a number of chemical and micropropulsion systems each with unique advantages and disadvantages. The Film Evaporation MEMS Tunable Array (FEMTA) thruster has advantages over many chemical and micropropulsion options due to its low mass, low volume (<2 in^3), and low power requirements (0.5 W) while maintaining suitable thrust characteristics for small satellite operation. The FEMTA generates ~150 μN of thrust and a ~70 s specific impulse by inducing film-boiling of ultra-pure deionized water in a micron-scale water capillary. A suborbital flight on a Blue Origin New Shepard booster in the second quarter of 2021 has been secured for the first space flight test, in vacuum, of the FEMTA thruster. A team of Purdue University students has developed two unique experiments to be conducted on the same platform. The first will test a novel propellant management system and the second will test the FEMTA thruster itself.

FEMTA Microgravity Propellant Management System Experiment

The first experiment is a proof-of-concept demonstration of a propellant management system design. This design generates a back pressure of 7-10 kPa, by utilizing a hydrofluoroether (HFE), Novec 7100, to expand two flexible diaphragms in a rigid tank to induce propellant flow through tubing into a collection chamber. Upon reaching its vapor pressure, the HFE expands uniformly creating a constant pressure in its surrounding volume. This quality of HFE leads to a low volume design with self-regulating pressure that requires no power after initialization. Validation of these components has been demonstrated in Purdue's Aerospace Sciences Laboratory but has yet to be verified under space-flight conditions. Figure 1 illustrates the cross-section of the HFE chamber and its interface with the propellant chamber. Fabrication of the rigid tank and collection chamber is complete and the collection chamber has been modeled in SE-FIT. A modified Linux Kernel is used to control valve actuations, interface with electronics, and record sensor data. Tank and flow statuses are measured by multiple pressure and temperature sensors as well as IR flow sensors and flow meters.

FEMTA Thruster Experiment

A second experiment will quantify the thrust generated by the FEMTA Thruster. The experiment will consist of firing a FEMTA thruster in a containment chamber while logging pressure and temperature for the duration of the microgravity phase of the suborbital flight. A governing equation has been developed that predicts a mass flowrate of the thruster given changes in pressure and temperature. Expected results include a measured thrust from the thruster and no physical damage after use for the full duration of the flight.

Conclusions

These experiments are designed to verify FEMTA thruster integrity, thrust generation, the operation of the propellant management system at back pressure of 7-10 kPa, and flow with no air or vapor bubbles under space-flight conditions.

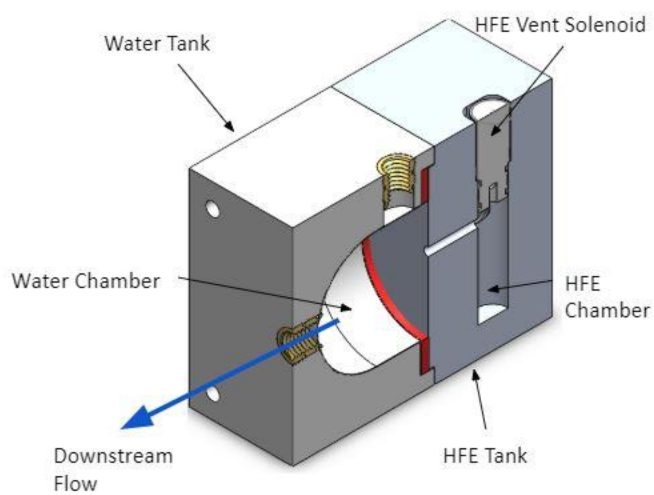

Fig 1. Cross Section of HFE Chamber and Propellant Tank

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