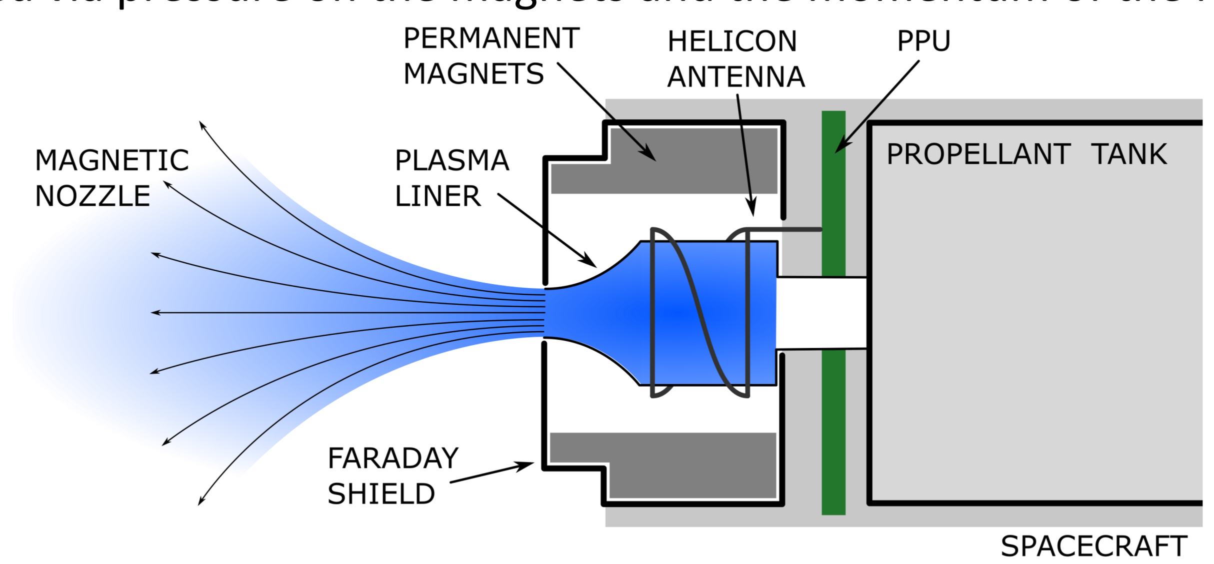
Initial Plume Characterization of the CubeSat Ambipolar Thruster

Timothy A. Collard[1] and J. P. Sheehan[1]
[1]*Aerospace Engineering, University of Michigan*

The CubeSat Ambipolar Thruster (CAT)

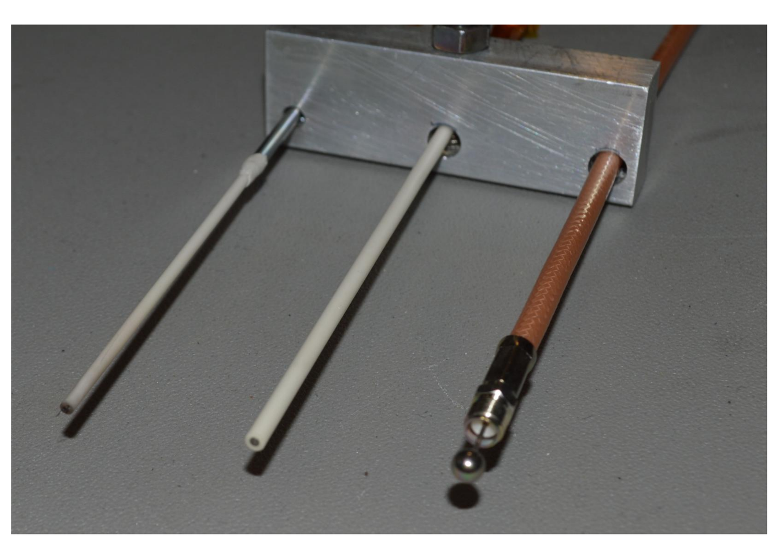
CAT is an electrodeless helicon thruster that generates thrust by expanding plasma through a magnetic nozzle. The propellant is injected into the plasma liner where radio frequency (RF) power is coupled via a helical half-twist antenna, resulting in ionization. The plasma then exits the ionization region through a converging-diverging magnetic nozzle generated by permanent magnets. The magnetic field is parallel to the plasma liner walls, limiting wear and plasma recombination at the wall. Downstream the plasma detaches from the magnetic nozzle and thrust is generated via pressure on the magnets and the momentum of the ions.

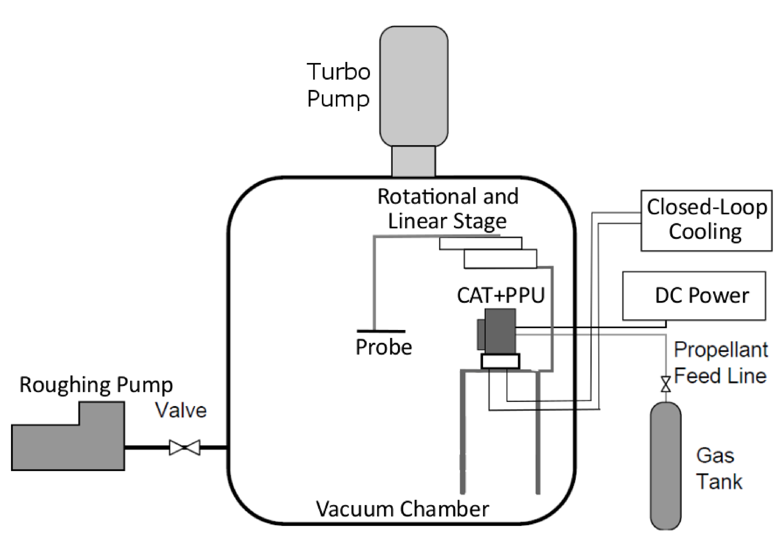


Motivation

CubeSats are attractive options to commercial and scientific groups interested in a wide range of missions, from imaging to satellite health monitoring to space weather [1],[2]. However, current propulsion technology provides ΔV capabilities of < 300 m/s, allowing for limited on-orbit maneuvering [3]. The CubeSat Ambipolar Thruster (CAT) is designed to overcome this technology gap and enable high ΔV (≥ 1000 m/s) missions. These missions include geostationary orbit insertion from geotransfer orbit, interplanetary exploration, and long-lived low altitude orbits.

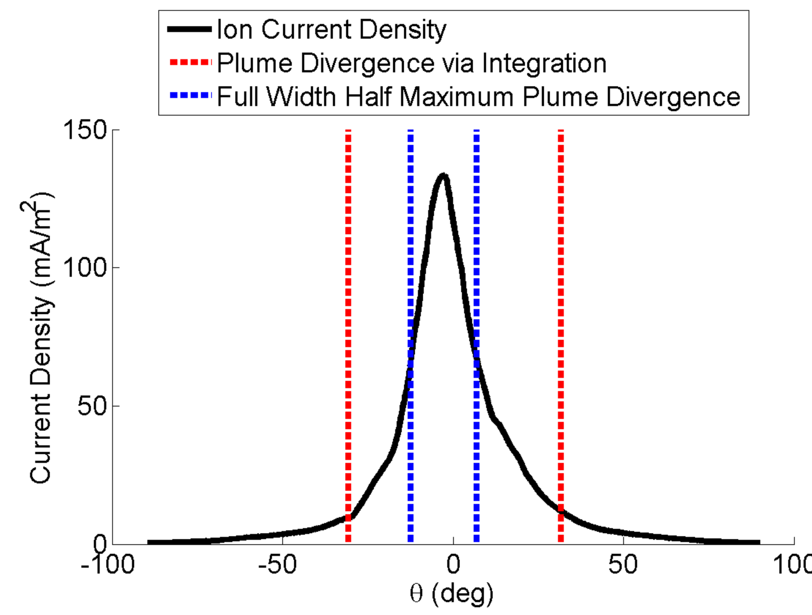
Experimental Setup



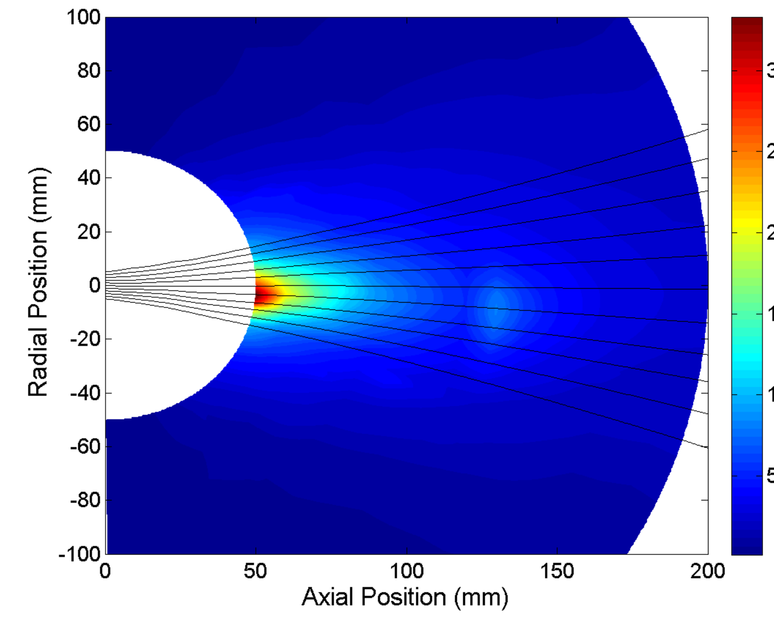


A diagnostic suite comprised (left) of an emissive, a Faraday, and a spherical resonance probe was used to interrogate the CAT plume. Using a combination of a rotational and a linear motion stage the probes could be positioned ±90˚ from thruster centerline and between 5 and 20 cm downstream of the thruster exit plane. All experiments were conducted in the Junior Test Facility at the Plasmadynamics and Electric Propulsion Laboratory.

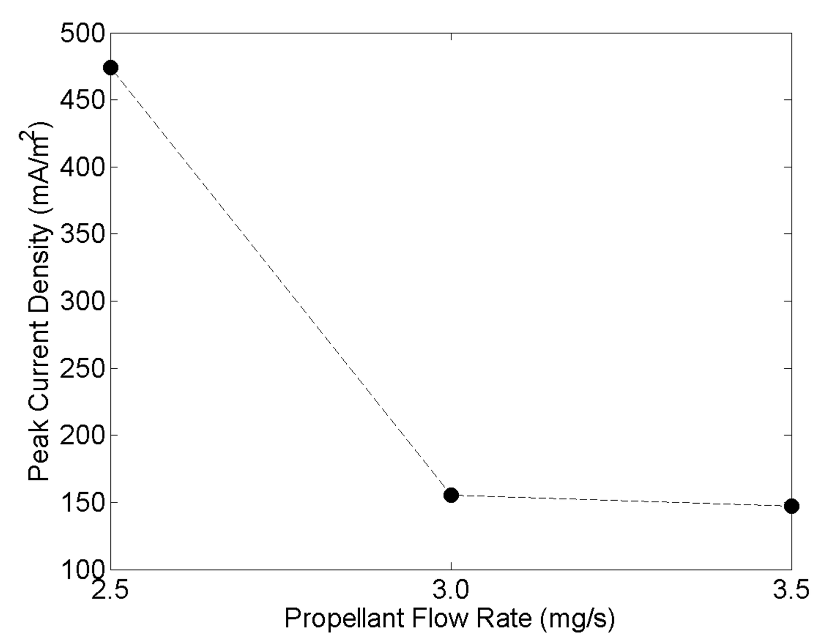
Faraday Probe Results

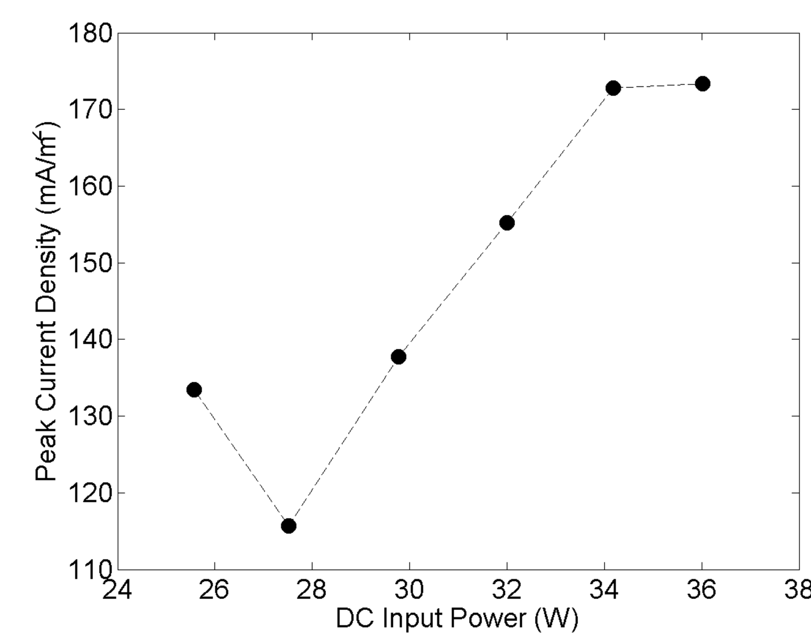


The current density traces made by sweeping the Faraday probe through an arc at a fixed distance from the thruster exit exhibited a peak profile consistent with an ion beam. The beam divergence half angle can be extracted from the current density trace, with the example bounds shown here. Unless otherwise stated the measurements shown were made at 5 cm downstream of the thruster exit plane.

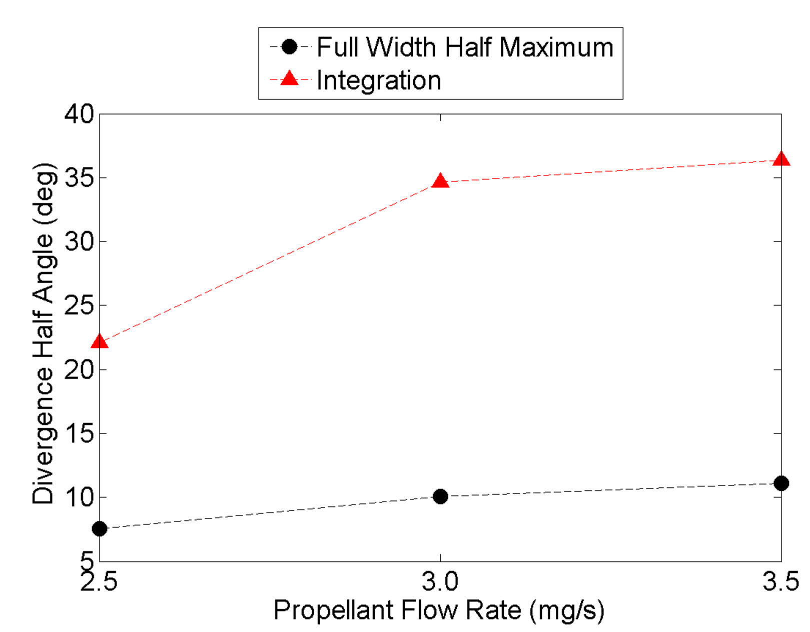


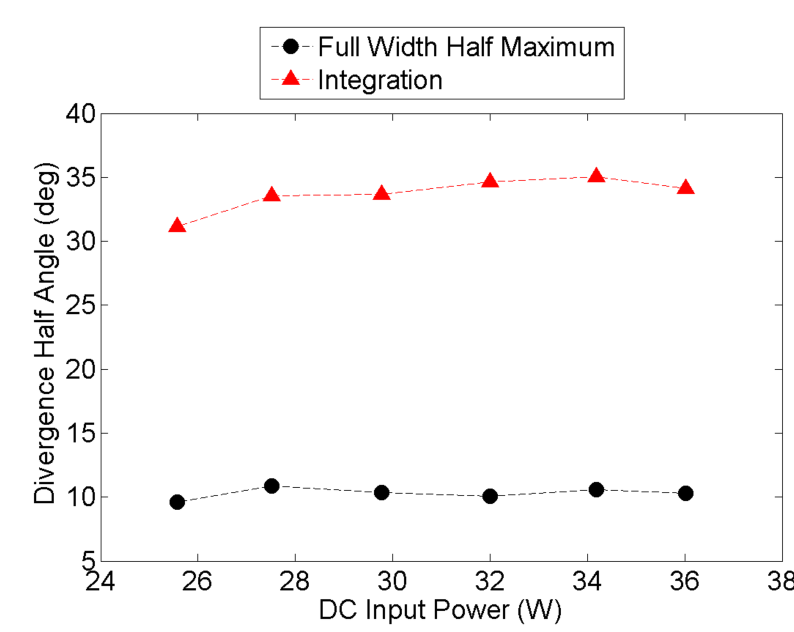
Weak confinement of the ions by the magnetic nozzle suggests the ions follow a ballistic trajectory, and the plume is detached.





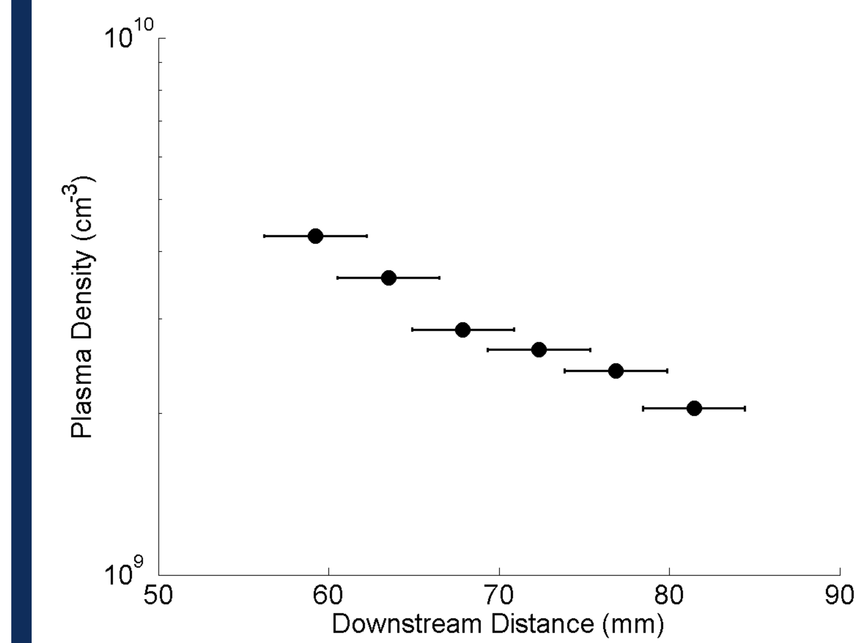
The Faraday probe peak current density results suggest performance scales significantly with decreasing propellant flow rate and moderately with increasing input power.





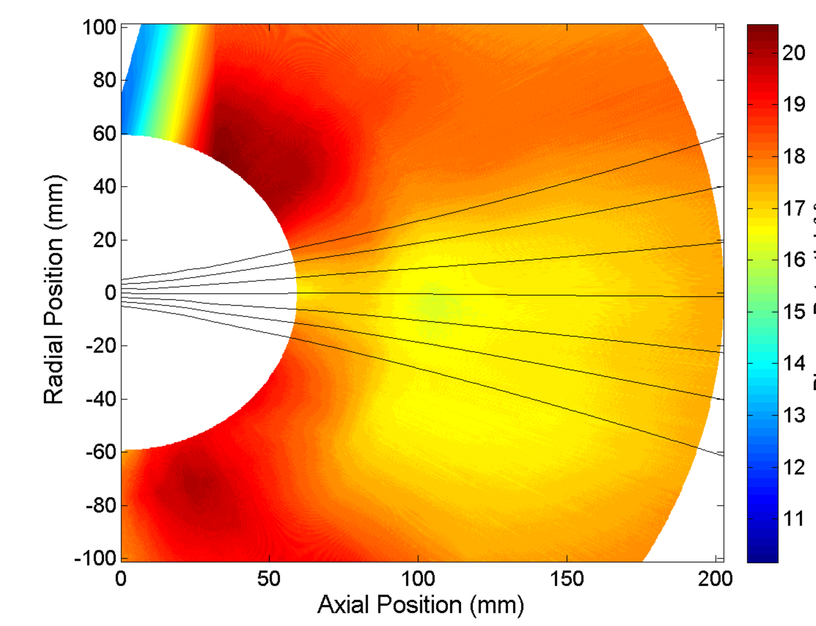
The beam divergence results suggests that the beam tightens, generally improving performance, with decreasing propellant flow rate and is unaffected by input power.

Resonance Probe Results



The centerline density results from the resonance probe exhibit a decrease in density consistent with the expansion of the cross sectional area of the magnetic nozzle further from the thruster exit plane.

Emissive Probe Results



The emissive probe results suggest an electric field pointing toward the thruster centerline develops, creating a self-tightening of the beam. This electric field diminishes farther from the thruster exit as the electrons become less tightly bound to the magnetic nozzle field lines.

Conclusions

Analyses of these initial plume results indicate that the optimal operating space has not yet been determined. The ion current density profiles suggest that a higher performance region exists at lower propellant flow rates than what could be stably operated with the existing power architecture. 2D plume maps also suggest interesting plasma phenomena occur within the plume, including possible detachment and beam self-tightening. Modifications to CAT are required to expand the operating space of the thruster and comprehensive plume measurements will determine the dominant physics driving CAT.

Acknowledgements

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