Plasma Plume Behavior in the Presence of Biased Spacecraft

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Introduction

There is interest in emitting a high-power electron beam from a spacecraft in the magnetosphere to better understand the space environment and the Earth's magnetic field behavior all the way to near the Earth's surface. However, such emission will charge the spacecraft positively, degrading or preventing the beam from reaching Earth [3]. However, Particle-in-Cell (PIC) simulations suggest that the spacecraft can be adequately electrically neutralized by producing a dense, ion emitting plasma before and during the electron gun operations [1,2]. To validate the simulations and study the effects of a charged spacecraft on the emitted plasma plumes a series of first-round experiments were performed at Michigan's Plasmadynamics and Electric Propulsion Laboratory's (PEPL's) 6x9m Large Vacuum Test Facility (LVTF). The plasma was emitted from a hollow cathode that was electrically isolated from chamber ground. Several diagnostics were used to study the plasma during steady state and transient conditions.

Materials and Methods

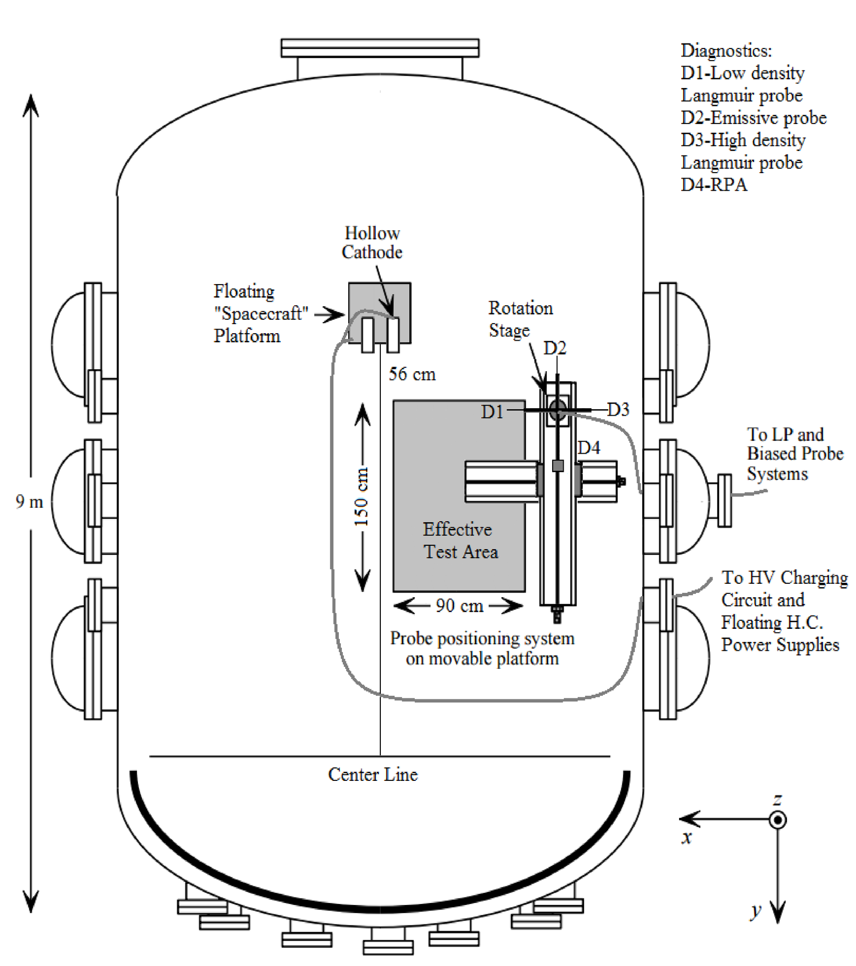


Figure 1: Experimental setup within PEPL's LVTF.

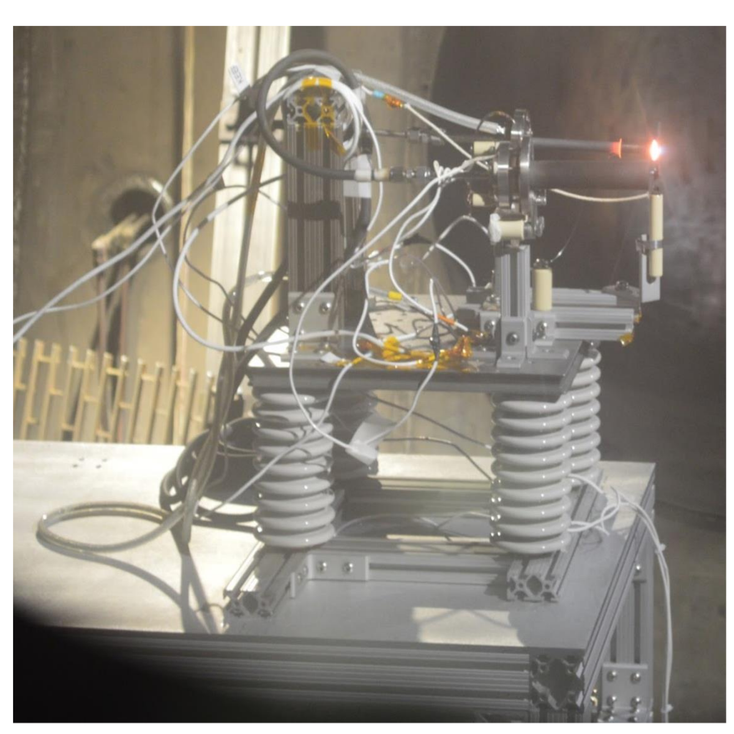


Figure 2: Electrically isolated conducting platform and hollow cathode.

Results and Discussion

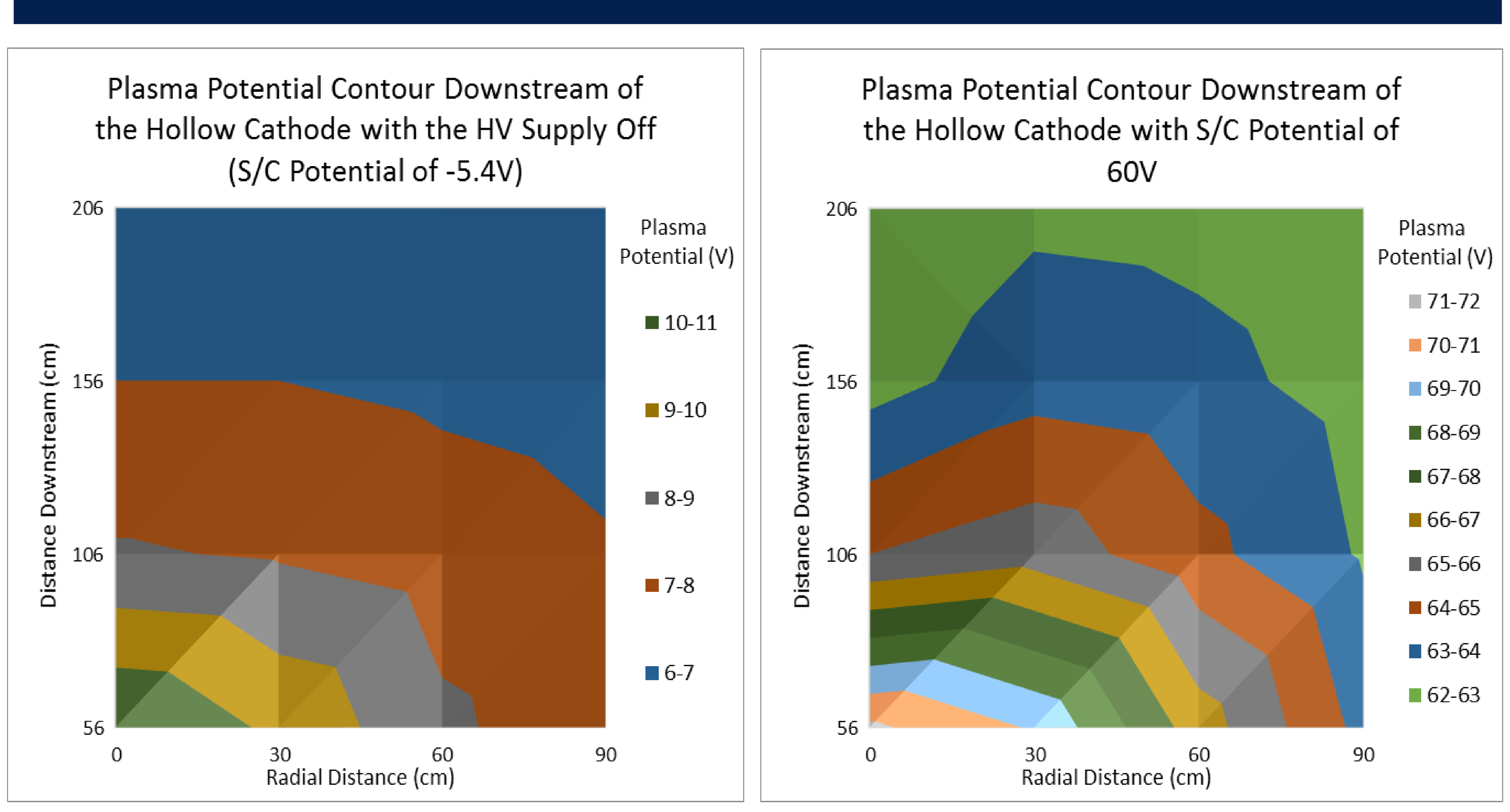


Figure 3: Plasma potential contour maps for spacecraft biases of 0 and 60 V for a discharge current of 5A. The potential drop across the plasma increases with S/C bias.

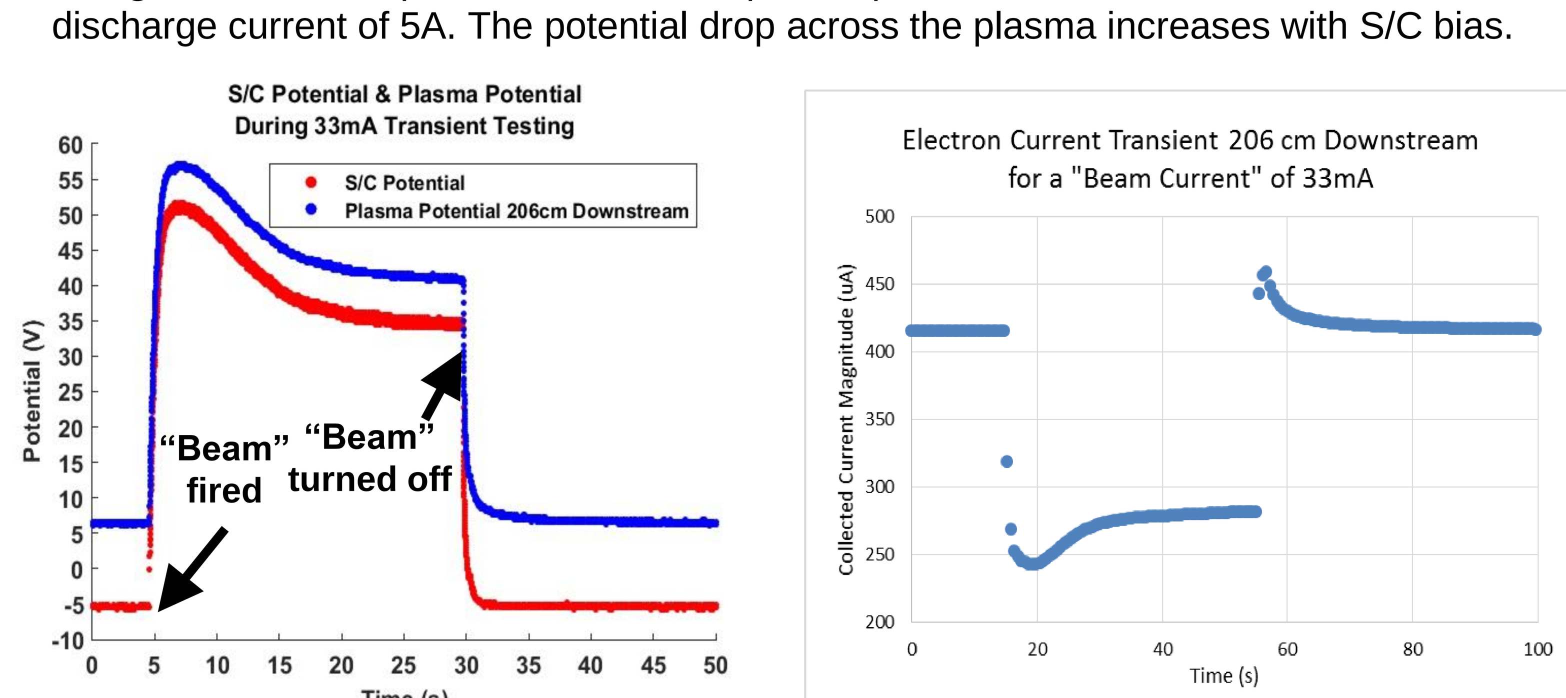
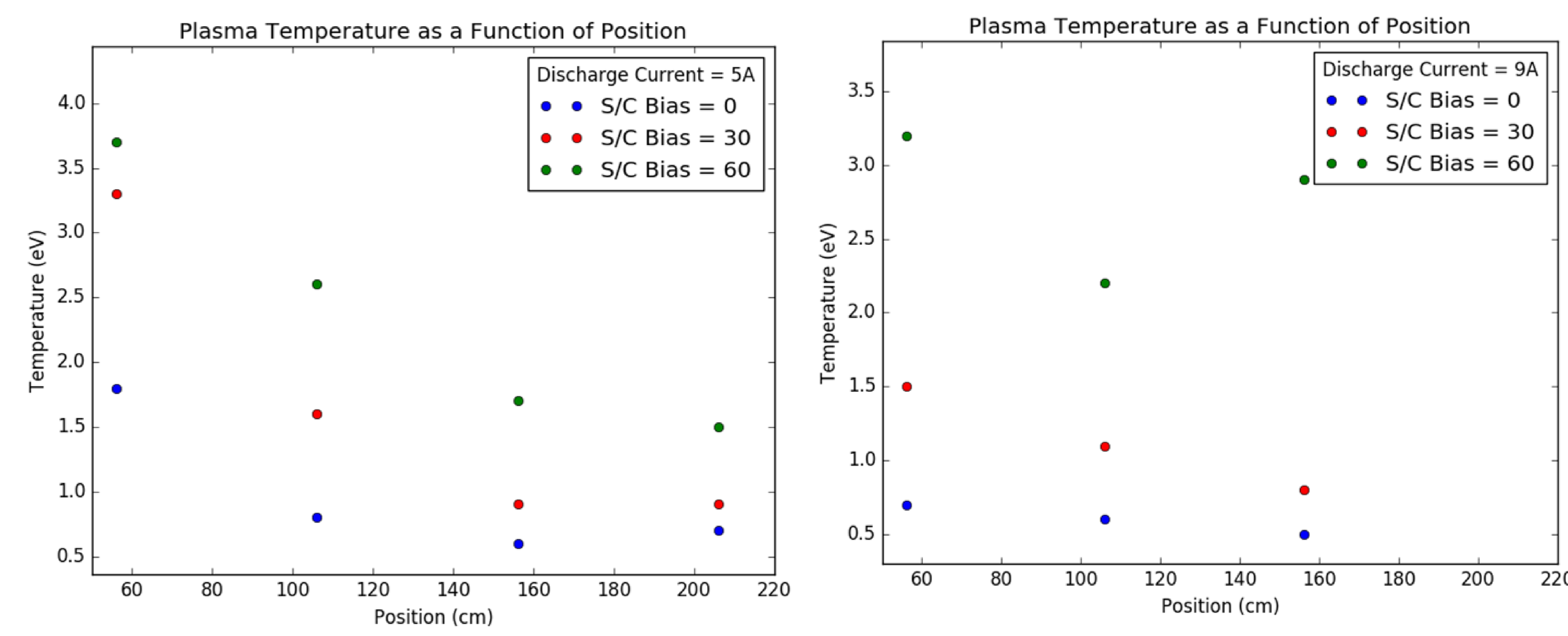
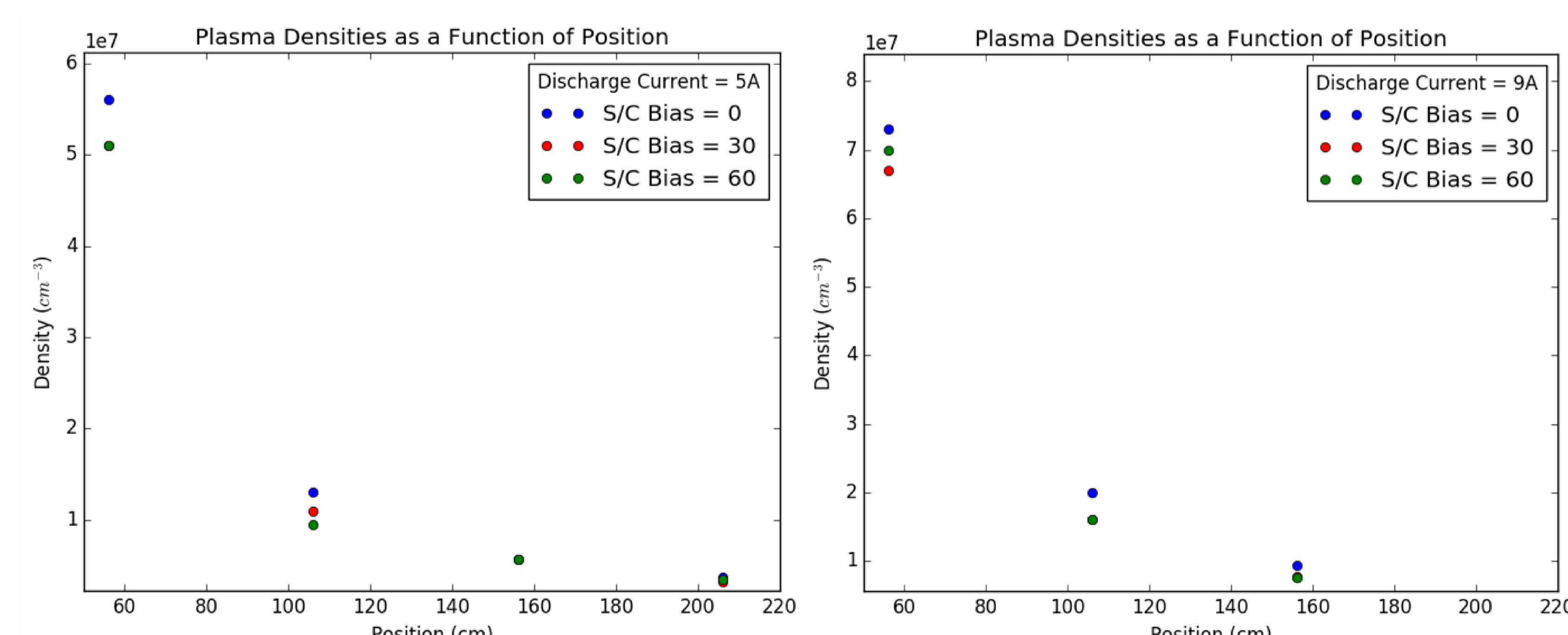


Figure 4: Plasma potential, spacecraft bias, and electron current for a current of 33 mA and 5A discharge current. The electron flux and plasma potential trace the S/C potential.



(a) (b)

Figure 5: Electron temperature as a function of distance downstream for of (a) 5 and (b) 9A. The electron temperature increases with spacecraft bias and decreases with increasing distance relative to the hollow cathode.



(a) (b)

Figure 6: Plasma density as a function of distance downstream for discharge currents of (a) 5 and (b) 9A. The density does not seem dependant on spacecraft bias as the values are roughly constant as the spacecraft bias changes. However, it decreases with increasing distance relative to the hollow cathode.

Conclusions

- Particle kinetic energy is dependant on spacecraft bias as seen in transient charged particle current measurements.
- Ion acceleration occurs at higher "spacecraft" potentials
- The plasma potential is dependant to the spacecraft bias.
- The electron temperature dependance on spacecraft bias implies an increase in their average kinetic energy with increasing spacecraft bias.
- Long charging transients, on the order of tens of seconds, were observed. These transients are orders of magnitude greater than the plasma's response time.

Acknowledgements

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References

[1] G.L. Delzanno, J.E. Borovsky, M.F. Thomsen, J.D. Moulton, E.A. MacDonald, *Future beam experiments in the magnetosphere with plasma contactors: how do we get the charge off the spacecraft?*, Journal of Geophysical Research (2015)
[2] G.L. Delzanno, J.E. Borovsky, M.F. Thomsen, J.D. Moulton, *Future beam experiments in the magnetosphere with plasma contactors: the electron collection and ion emission routes*, Journal of Geophysical Research (2015)
[3] Gussenhoven, M. S., Cohen, H. A., Hardy, D. A., Burke, W. J., & Chesley, A. Analysis of ambient and beam particle characteristics during the ejection of an electron beam from a satellite in near-geosynchronous orbit on March 30, 1979. (1980)