Emission Spectroscopic Investigation of an Ionic Liquid Electrospray Thruster for Nanosatellite Propulsion

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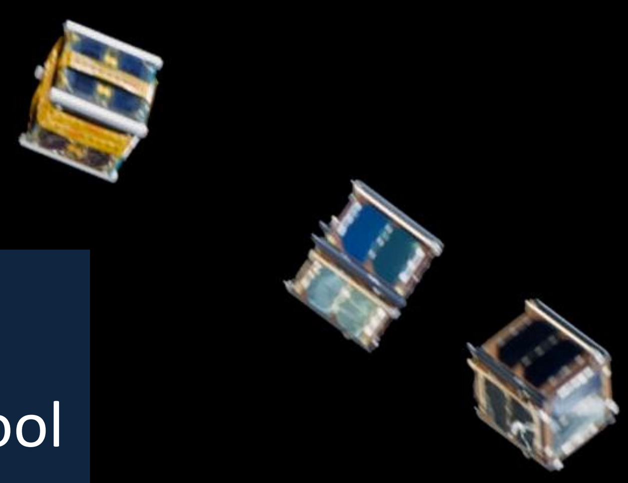


Paradigm shift in satellite design

In recent years, highly miniaturized 1dm³ Cubesats have evolved from a purely educational, low-cost tool into a promising candidate technology for missions with advanced scientific or commercial objectives. Fast development times, reduced launch costs and increasing capabilities due to leveraging commercial electric components have allowed this miniaturized satellites to break ground in space sectors traditionally dominated by large satellite platforms. The recent launch of a large fleet of commercially operated earth imaging Cubesats consolidates the success of Nanosatellites as alternative in satellite mission architecture, paving the way for future Cubesat based missions with even further advanced objectives.

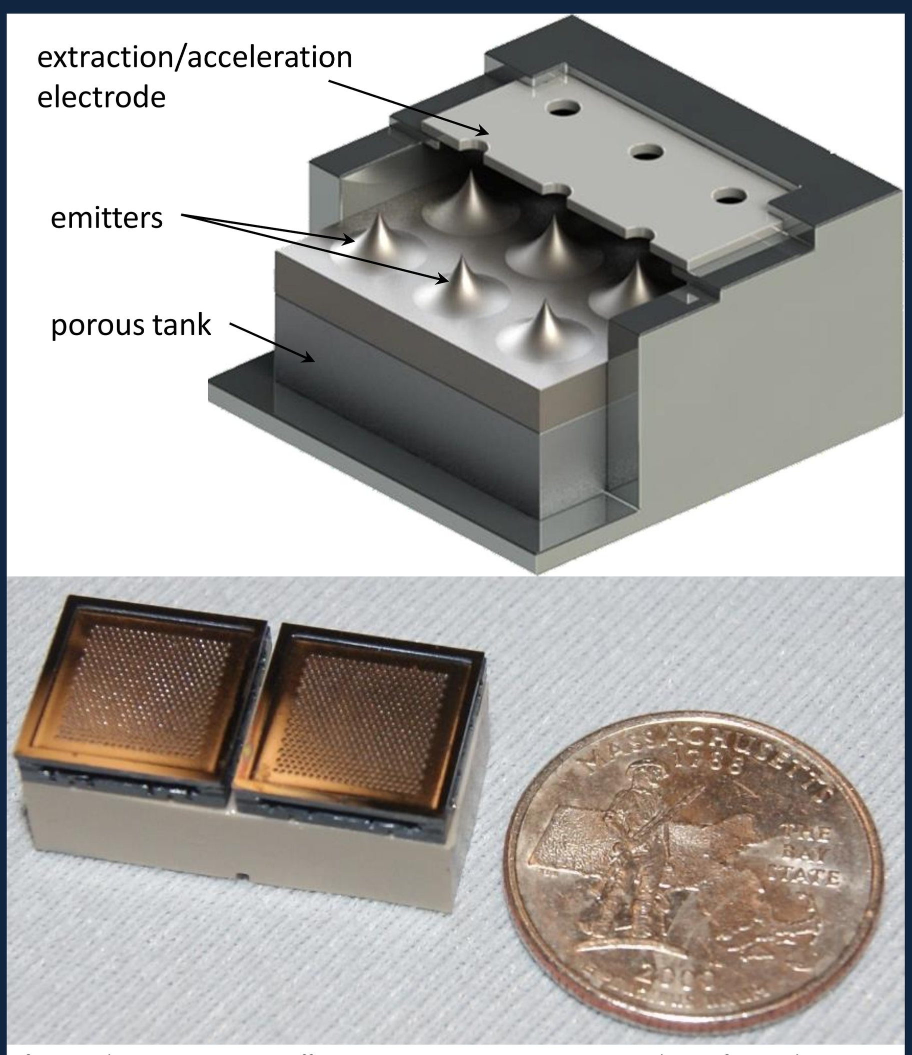
Electric propulsion: an enabling technology

Future Nanosatellite missions require propulsion capability for independent orbit control, active attitude control and de-orbit maneuvers at the end of lifetime to avoid space debris. Active orbit control is anticipated as an enabling technology for constellation based mission architectures, as well as missions advancing further into space.

MIT ionic liquid electrospray thruster

At the Space Propulsion Laboratory at MIT, a highly miniaturized electrostatic propulsion system is currently developed to cater to the constrained requirements of Nanosatellites, leveraging micro-electrochemical system (MEMS) manufacturing processes.

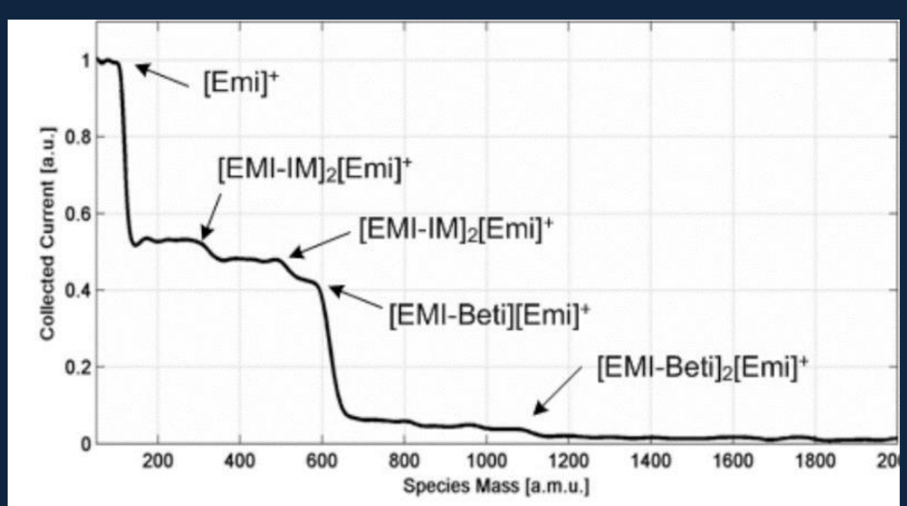
The key features of the thruster are:
-Electrostatic extraction and acceleration: ions are extracted from sharp emitter tips to reduce the necessary electric potential.
-Ionic liquids: non toxic, zero-vapor pressure ionic liquids are investigated as propellant.
-High performance: specific impulse Isp ~ 2500-5000s
-MEMS array: to increase thrust; ~20nN per emitter tip, up to 500 tips
-Bipolar operation: expulsion of both positive and negative charges to avoid potential build-up of the satellite and guarantee neutrality of the exhaust plume.



from: Hicks, F.M., Perna, L., Coffman, C.S., Arestie, S., Lozano, P.C.: High specific impulse ion electrospray propulsion for small nanosatellites, Interplanetary small satellite conference, Pasadena, CA, 2013.

Spectroscopy of plasma exhaust

Spectroscopic investigation of the exhaust plume leads to a better understanding on the composition of the ion exhaust produced by the thruster (mass and energy properties of exhaust, ion species and solvation and ultimately thruster efficiency) and will increase our knowledge on the occurrence of plasma processes , such as ion fragmentation or scattering occurring.



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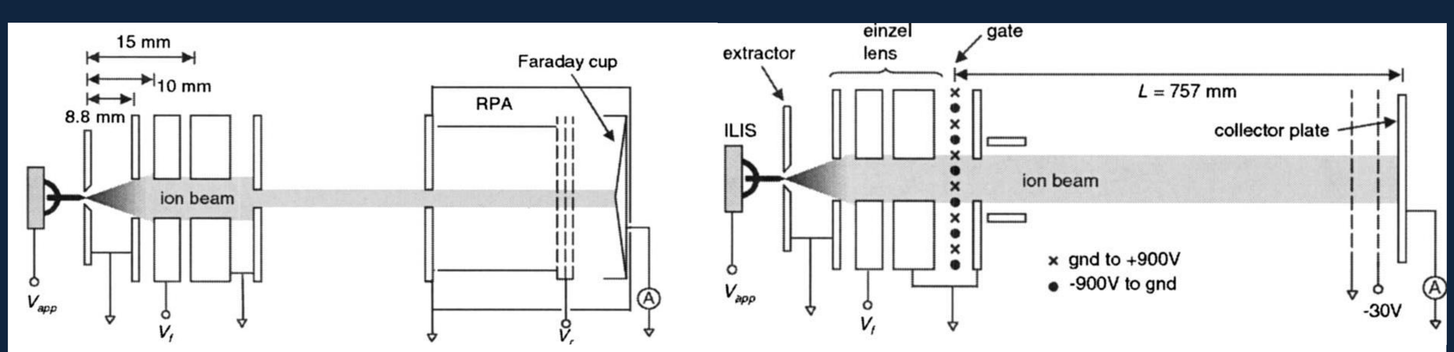
Experimental techniques

-Time of flight spectroscopy (image, right)
-Retarding potential spectroscopy (image, left)
-Optical spectroscopy



from: Fedkiw, T.P., Lozano, P.C.: Development and characterization of an iodine field emission ion source for focused ion beam applications, Journal of Vacuum Science and Technology B, Vol. 27, pp.2648, 2009.

Image credits: NASA visible earth (blue marbel) and ISS Expedition 32 crew/NASA (Cubesat deployment)