Variable Specific Impulse Electrospray Thrusters for SmallSat Propulsion

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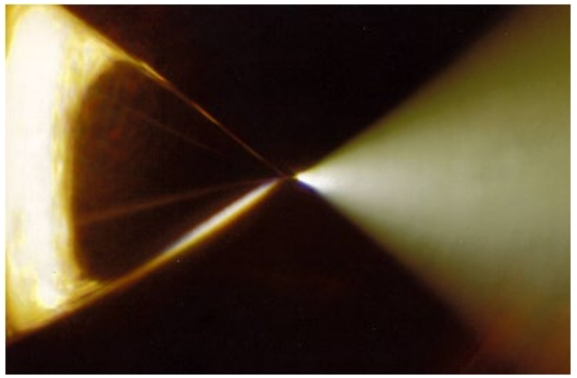
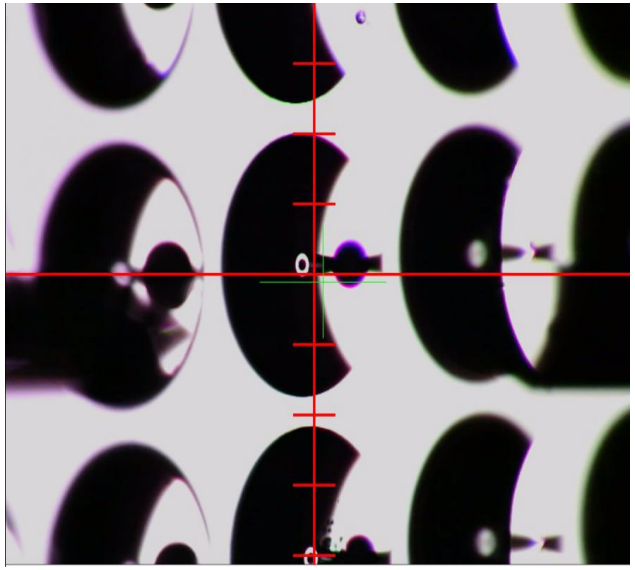




Cooperative Agreement (CA) #: 80NSSC20M0084
NASA Support: Jet Propulsion Laboratory

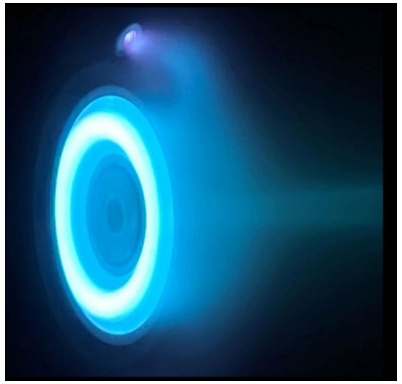
Propulsion is an enabling technology for many SmallSat missions

Propulsion system is essential for:

- Orbit insertion (beyond initial deployment orbit)
- Orbit maneuvering and maintenance
- SmallSat constellations (insertion, maneuvering, maintenance, redeployement)
- Deorbit

Propulsion system must be:

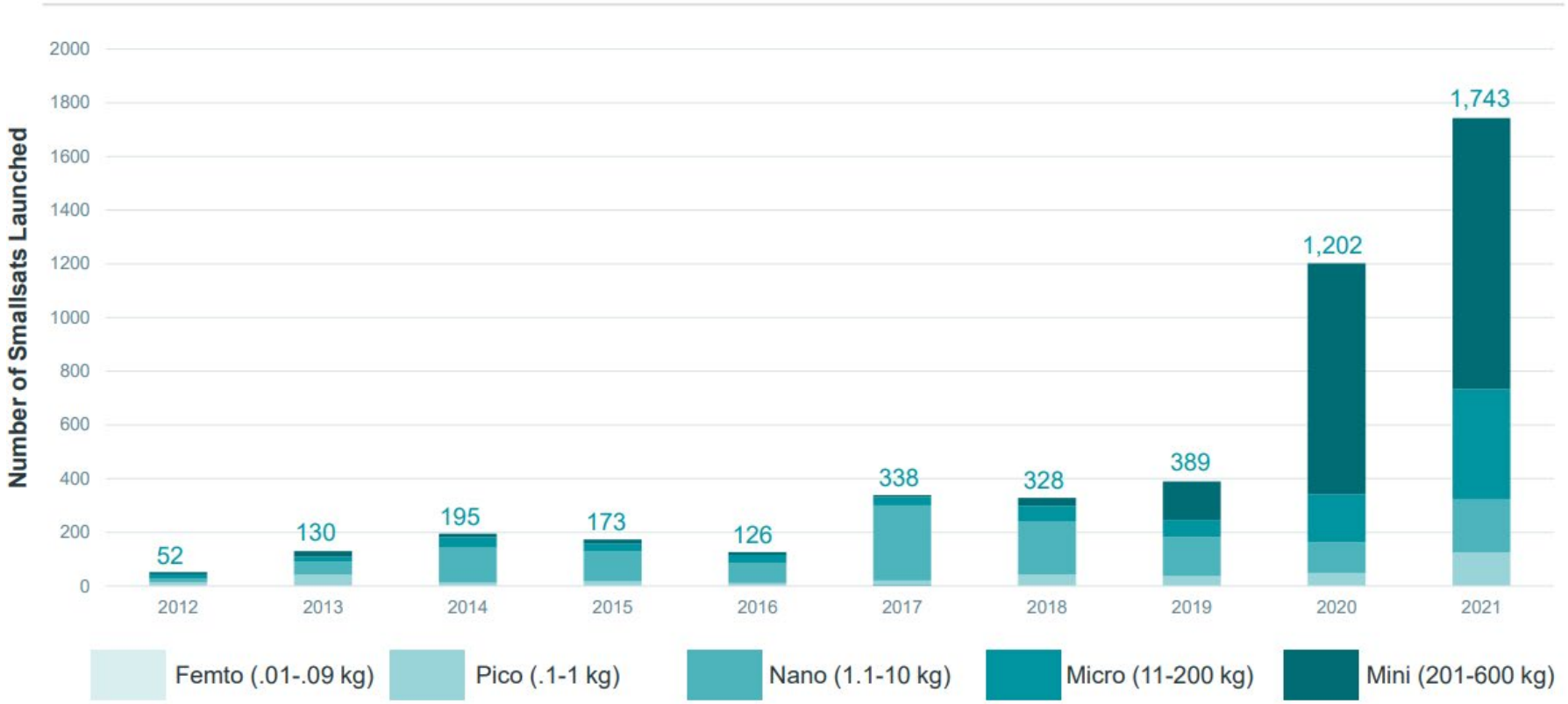
- compatible with SmallSats' reduced mass and volume budget
- Efficient at low available power
- Scalable to operate throughout SmallSats power range and thrusting needs (primary propulsion and attitude control)



Plasma discharge thrusters cannot be scaled down to the power levels typical of SmallSats

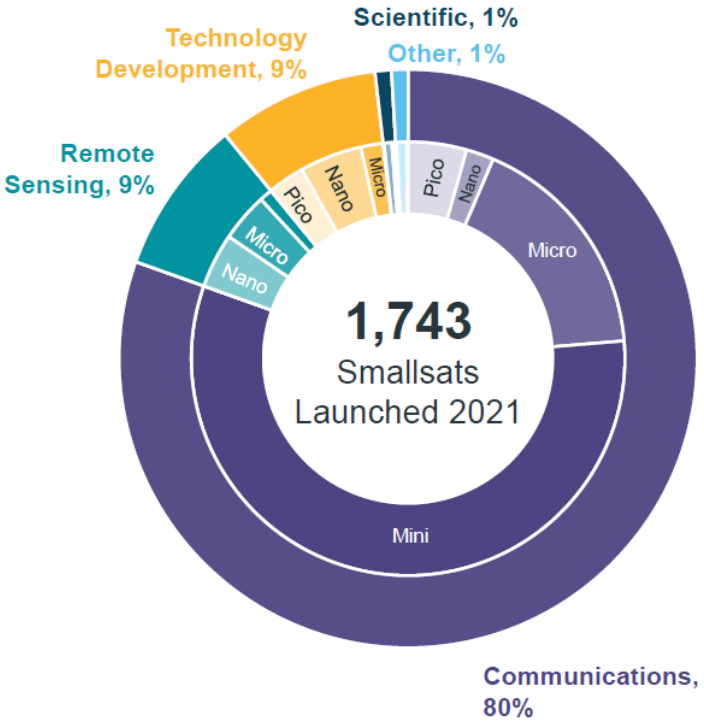
SmallSats and Electrospray Propulsion

Evolution of annual number of launched SmallSats



Source: Smallsats by the Numbers 2022. Bryce Tech

SmallSats launched in 2021



94% of spacecraft launched in 2021 = smallsats

43% of total 2021 spacecraft upmass = smallsats

37% of all smallsats in last 10 years launched in 2021 (69% 2020+2021)

80 launches in 2021 carried smallsats

6% of smallsats launched on small/micro launch vehicles in 2021

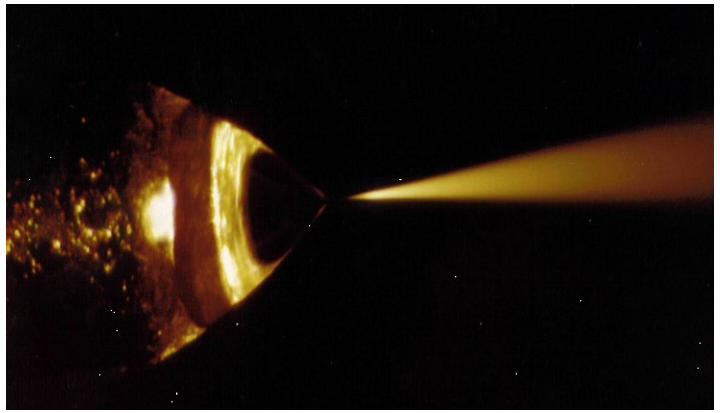
Source: Smallsats by the Numbers 2022. Bryce Tech

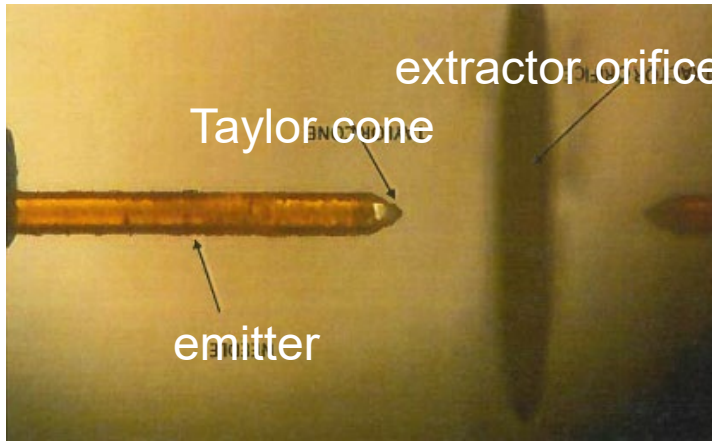
Electrospray propulsion is an ideal technology for SmallSats

A single emitter atomizes a liquid propellant into charged droplets/ions, which are accelerated by an electrostatic field. Typical propulsive parameters per emitter:

- Thrust $\cong 0.5\ \mu N$
- Power $\cong 1\ mW$
- Efficiency $\cong 68\%$

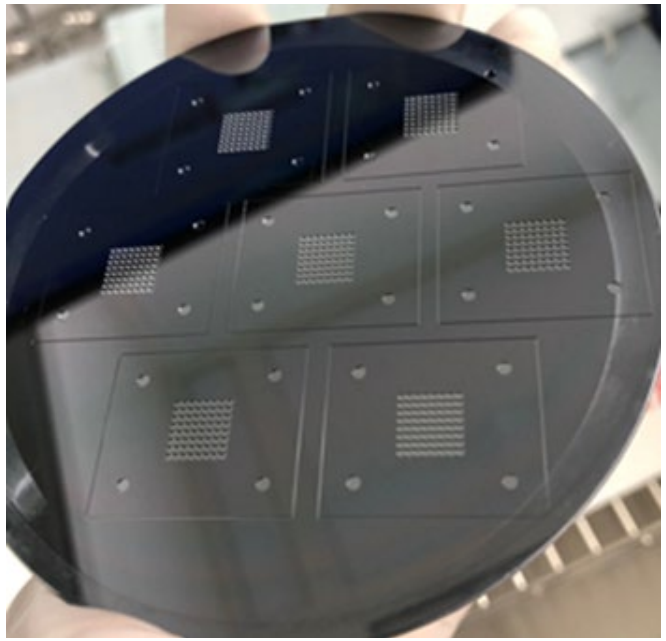
Gamero and Hruby, 2001

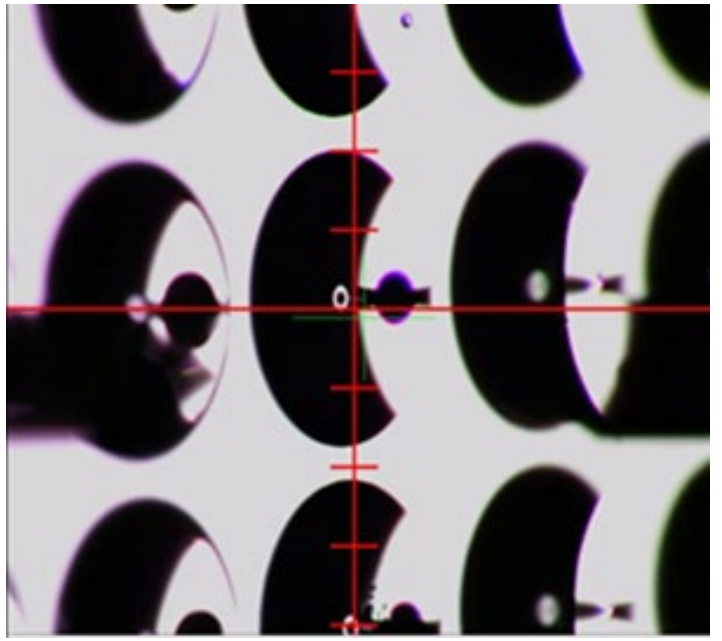




Thruster is scalable with the help of micromachining (micromachined emitter arrays):

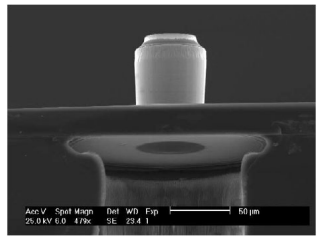
- Very high emitter density
- Variable emitter array size can deliver all power/thrusting levels of SmallSats (scalability)

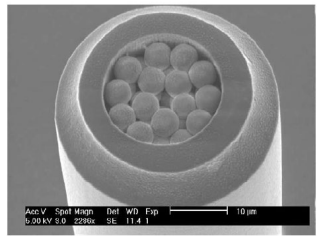




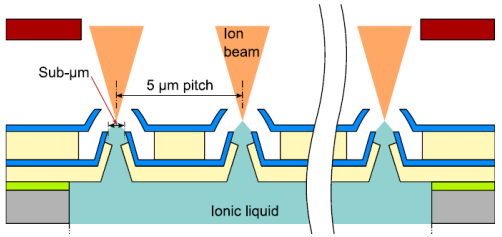
Electrospray Propulsion SoA

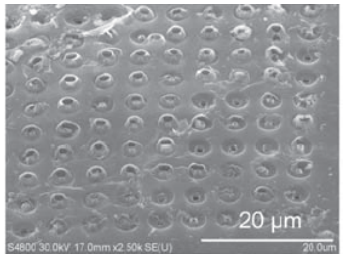
Internally wetted emitters



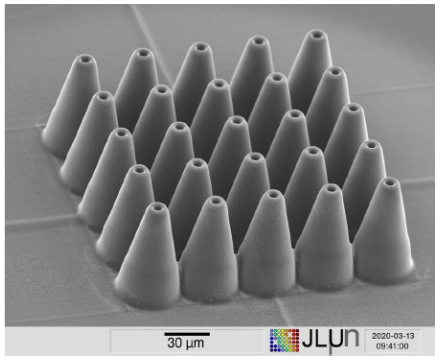


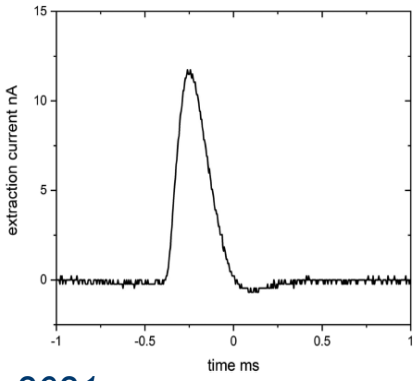
R Krpoun et al., 2009





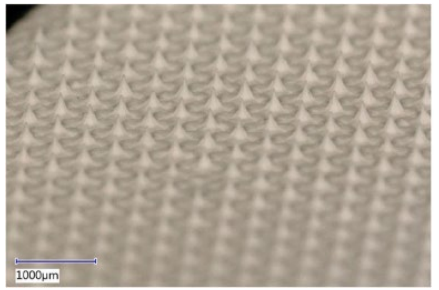
Inoue et al., 2019

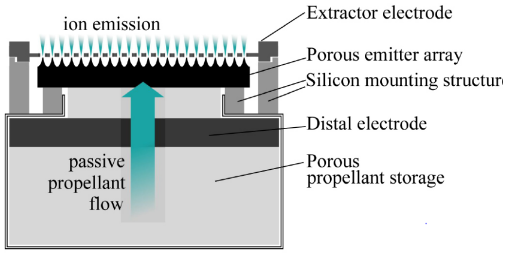


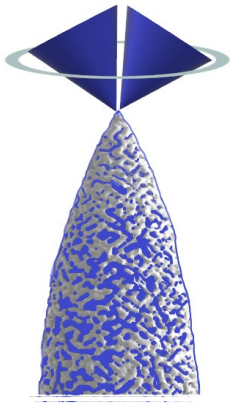


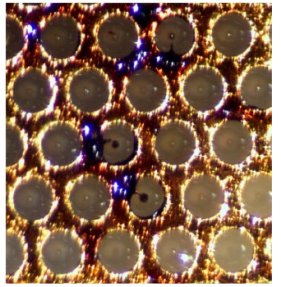
Kunze et al., 2021

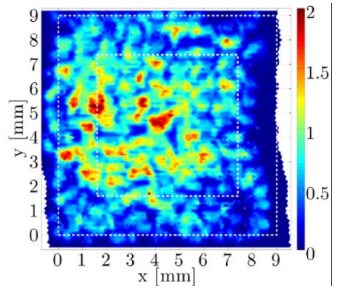
Externally wetted emitters





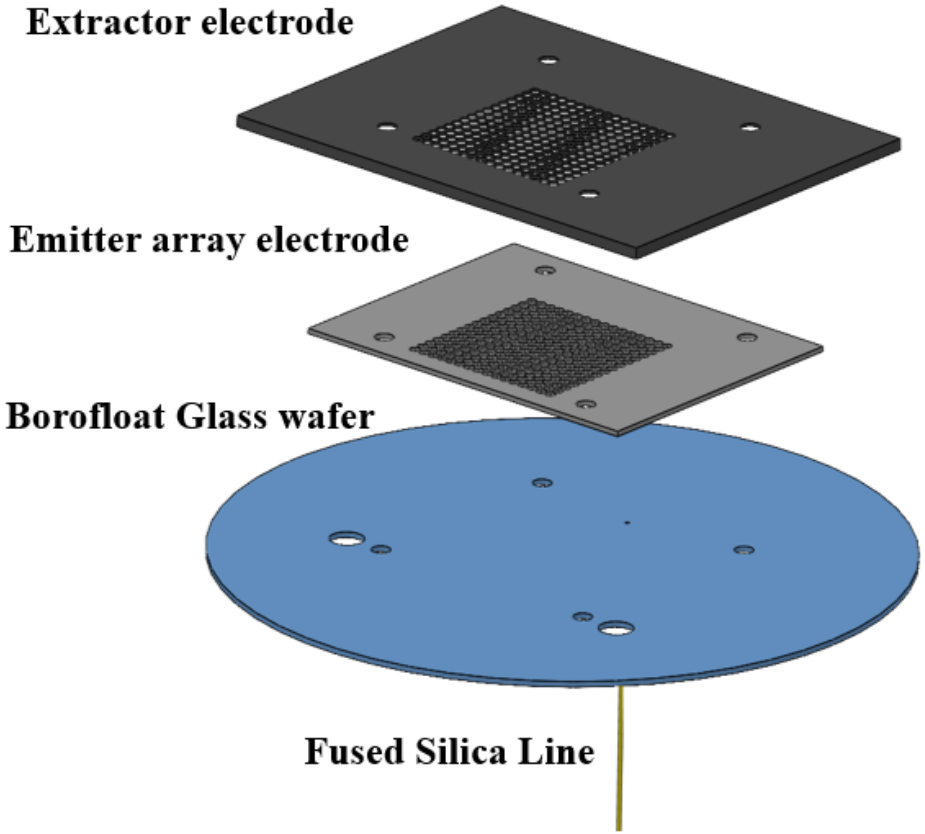


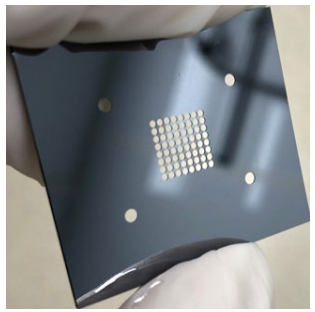


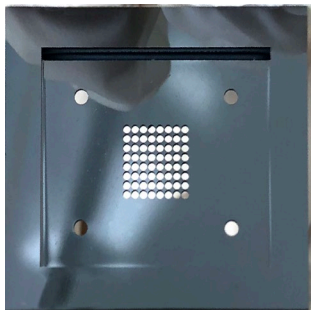


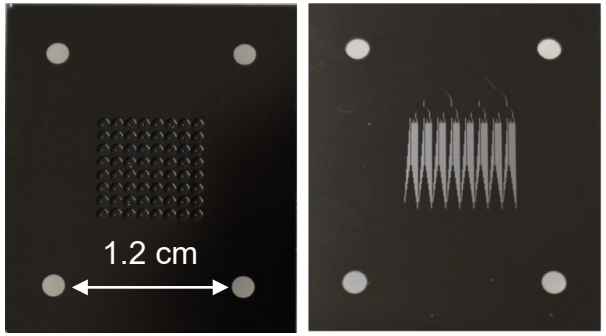
Krejci et al., 2017

Microfabrication on Si and glass wafers

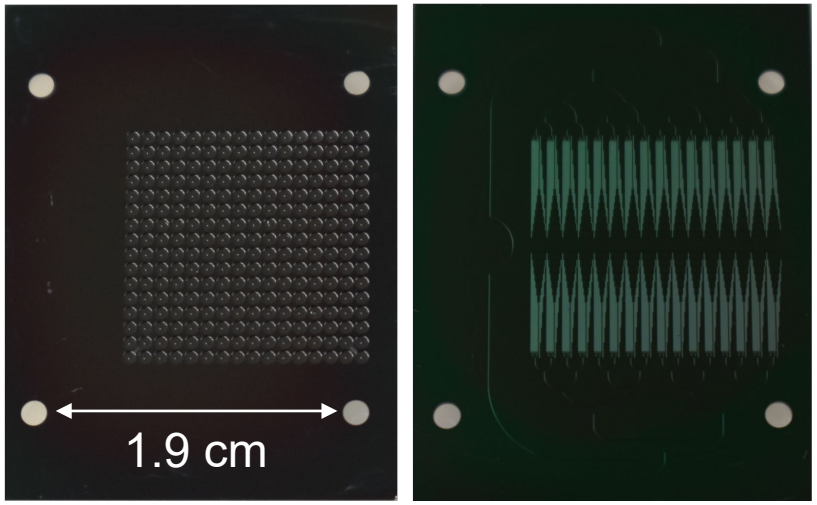


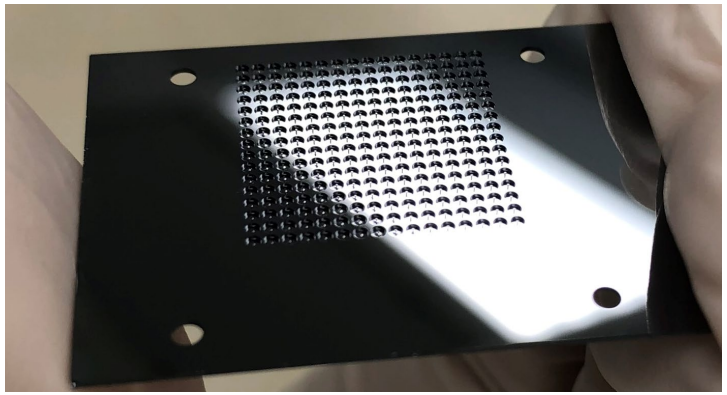


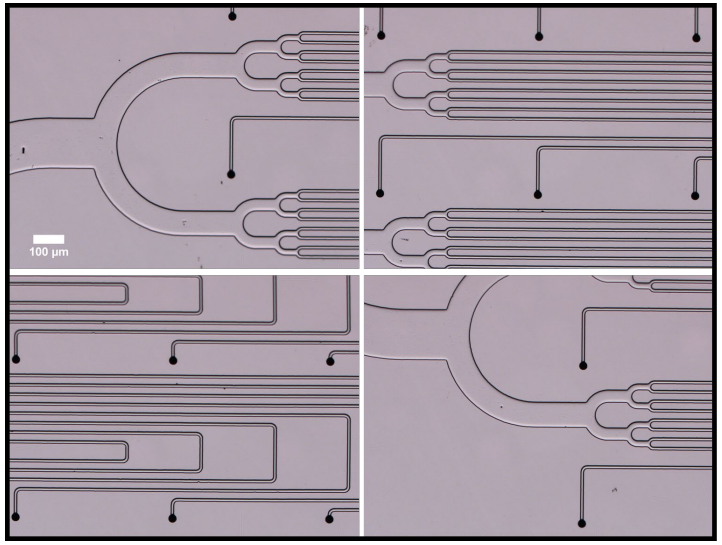


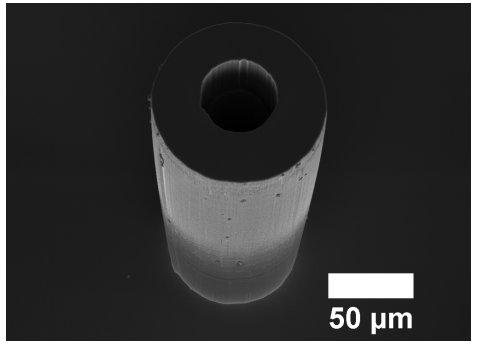


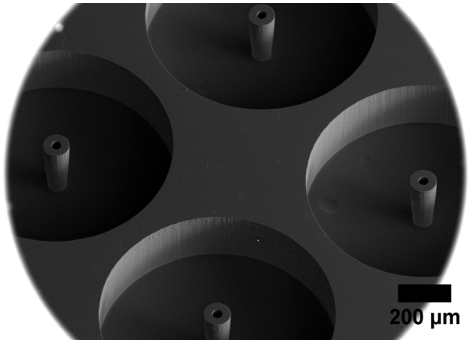
Internally wetted emitter arrays with network of microfluidic channels matching emitters (excellent flow regulation)



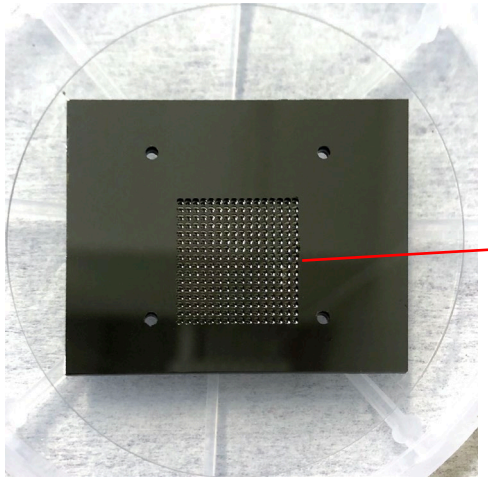


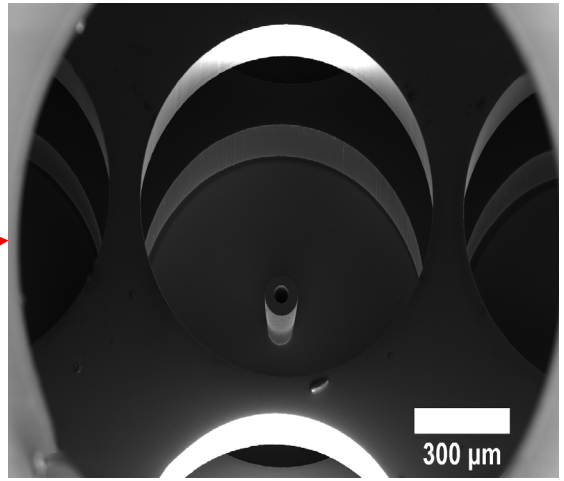


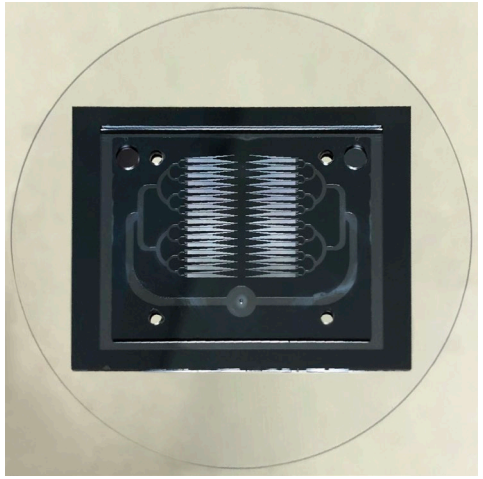


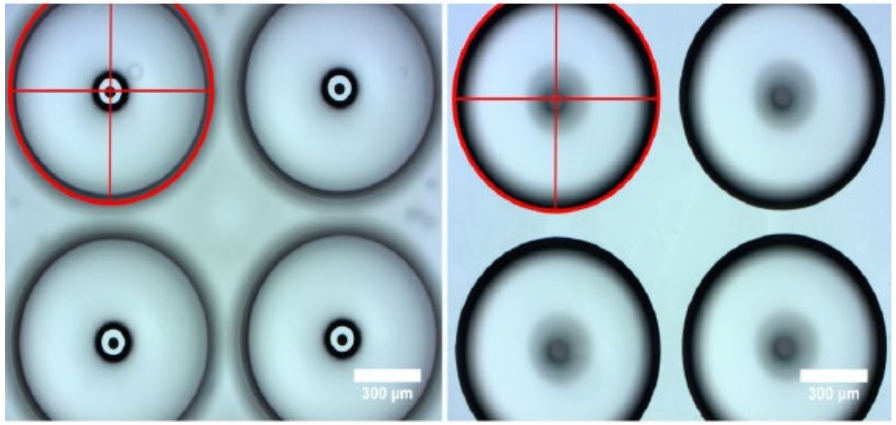


Bonding of all wafers to produce a single, integrated thruster head with excellent emitter-extractor alignment

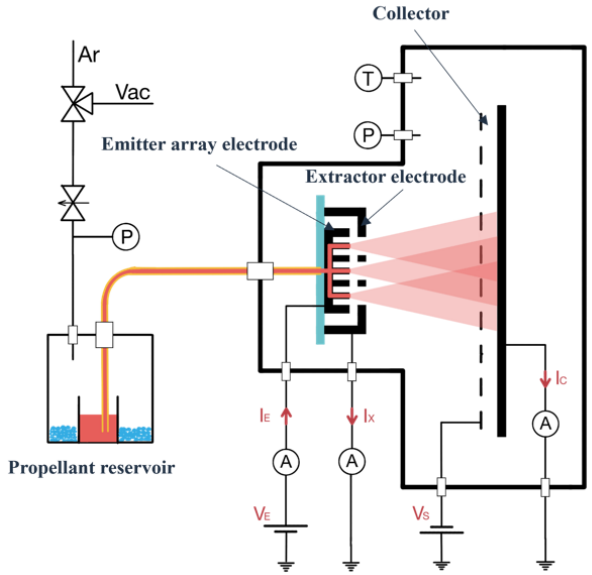


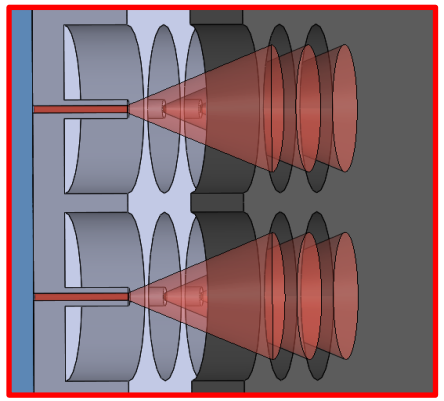


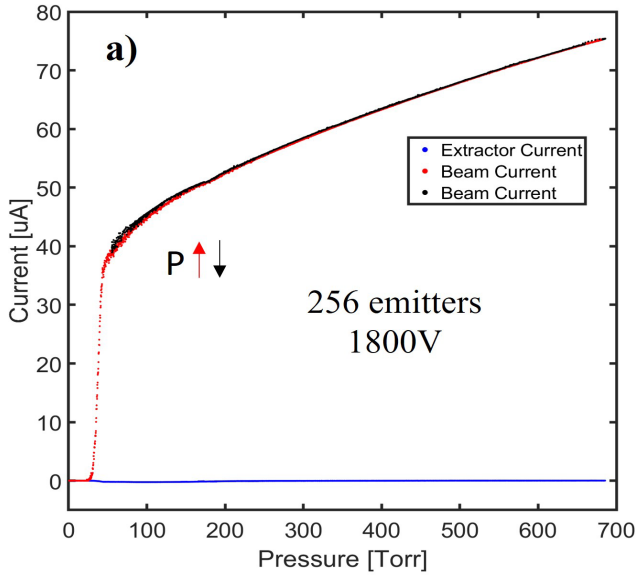


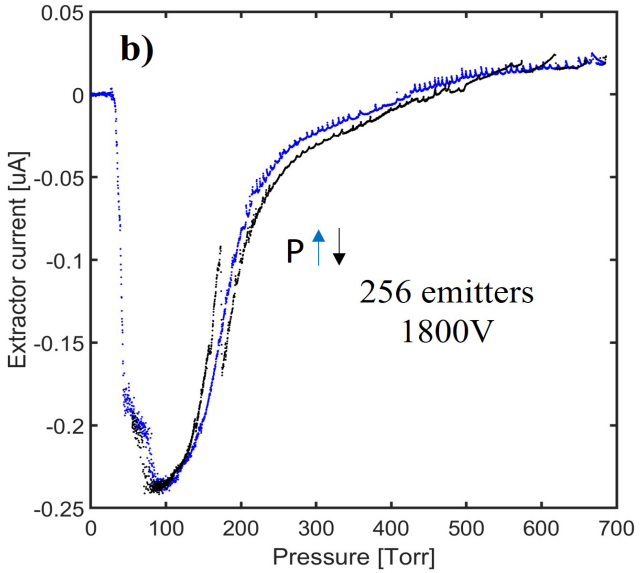


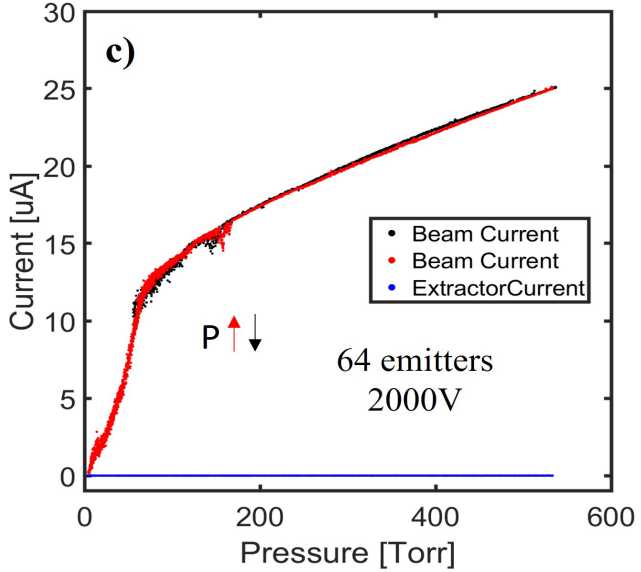
TRL 5, Demonstration in Relevant Environment (I)

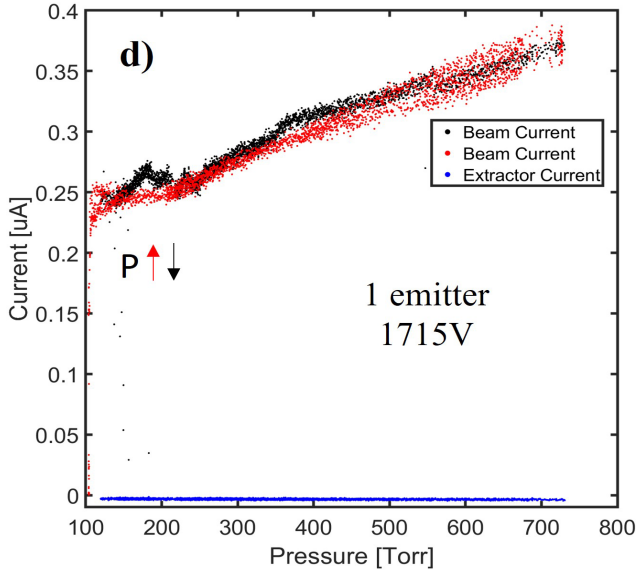




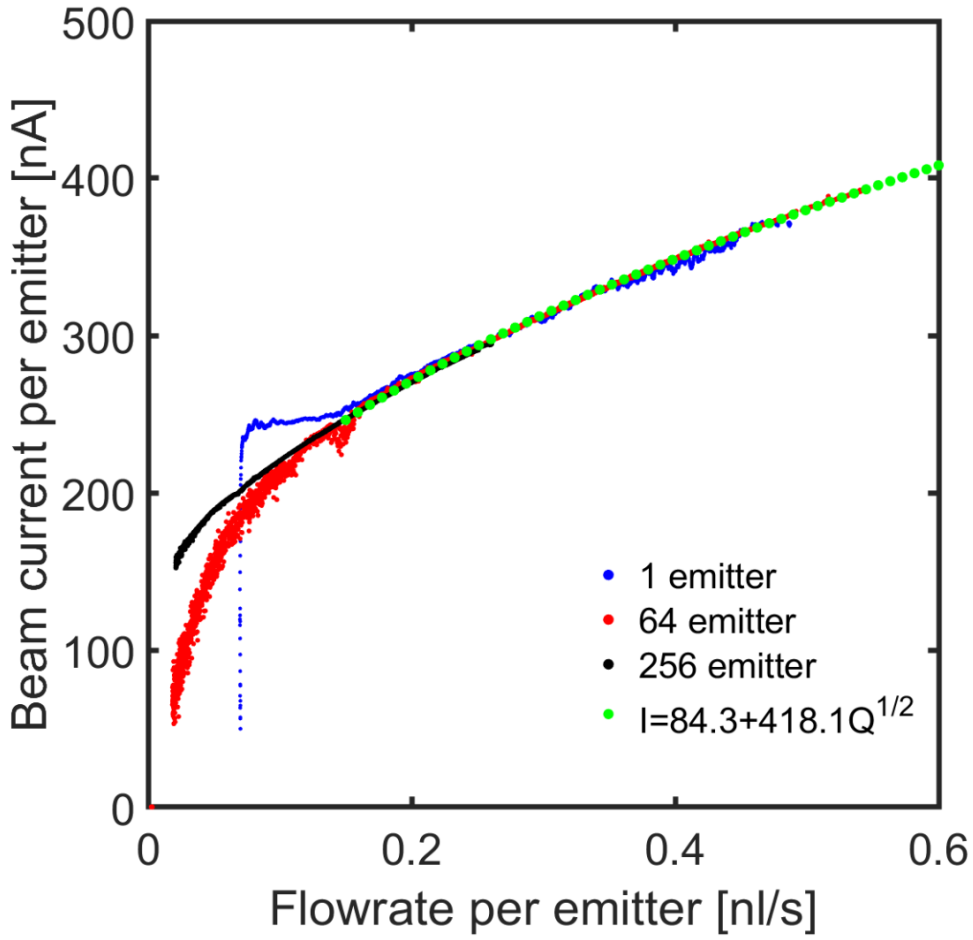






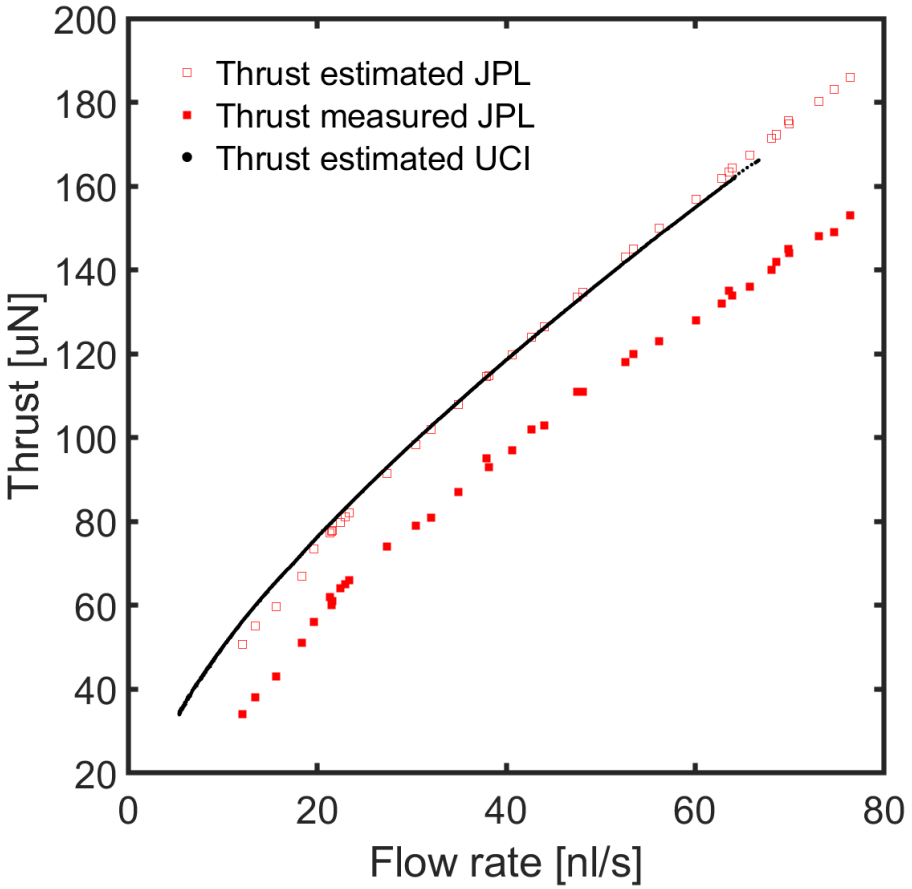


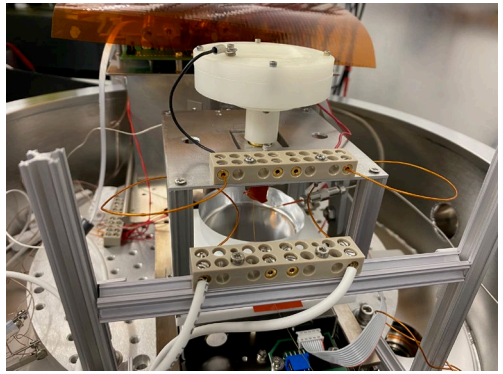
TRL 5, Demonstration in Relevant Environment (II)



every emitter is in the same operational state regardless of array size

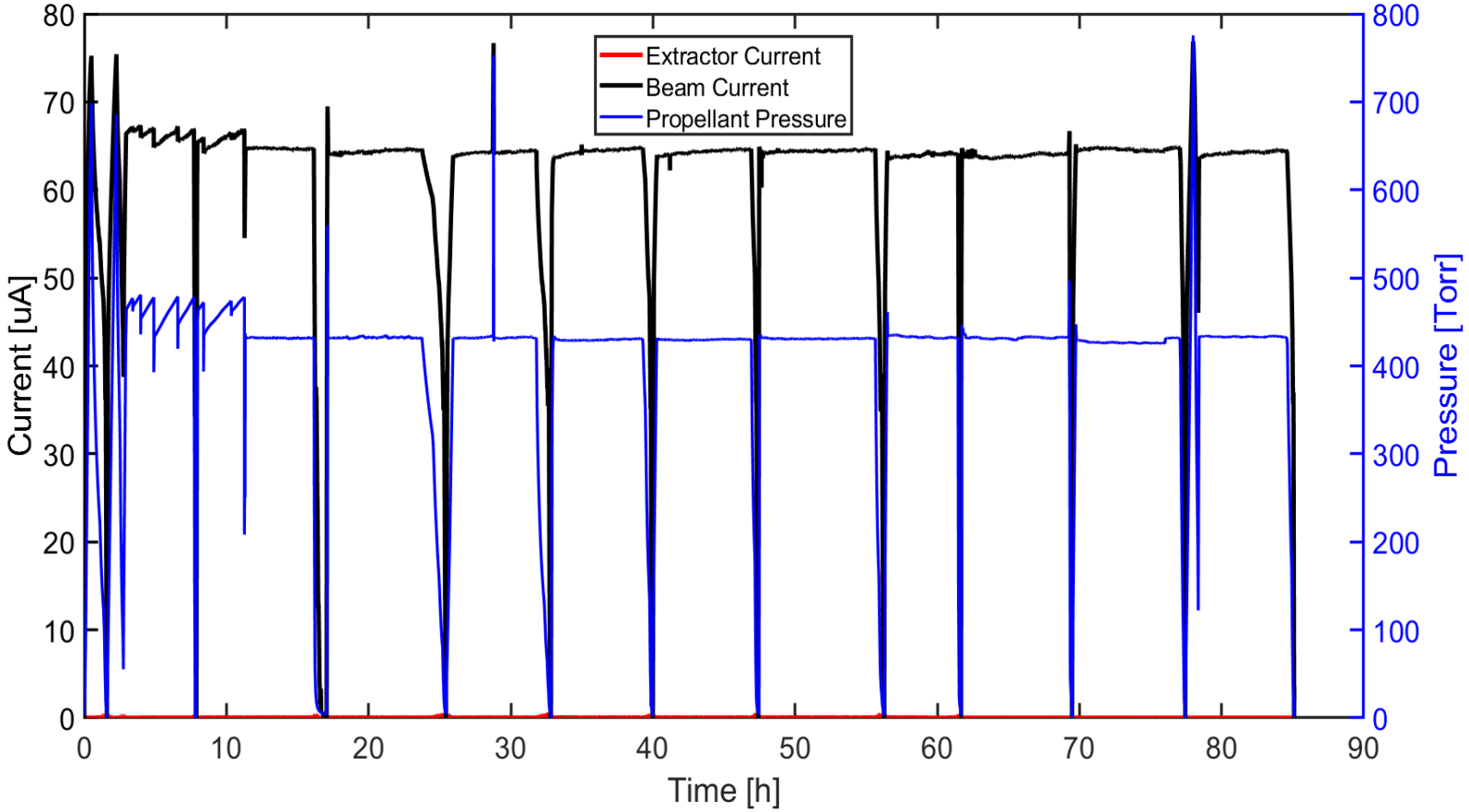
TRL 5, Demonstration in Relevant Environment (III)

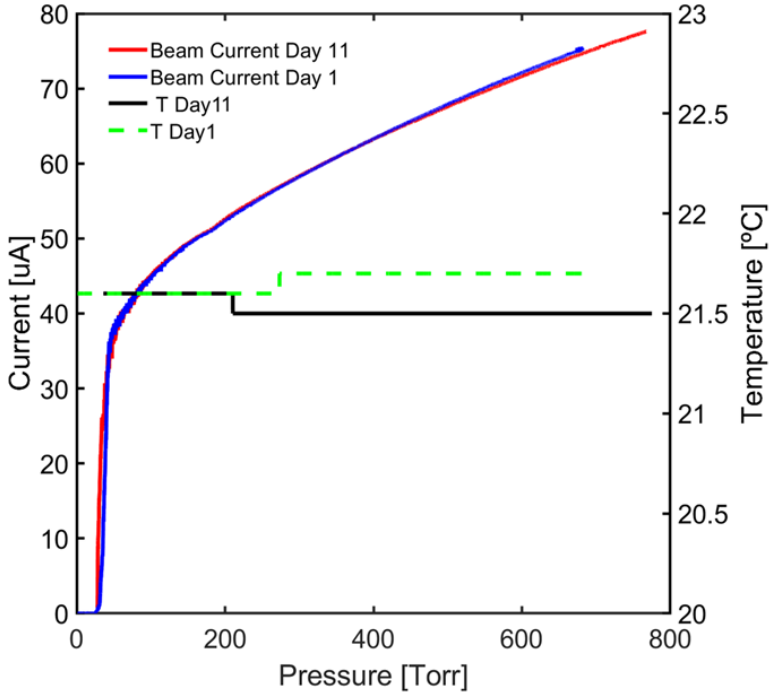




direct thrust measurements (Dr. Colleen Marresse, JPL) compared to estimated thrust (based on beam voltage, current and mass flow rate)

TRL 5, Demonstration in Relevant Environment (IV)

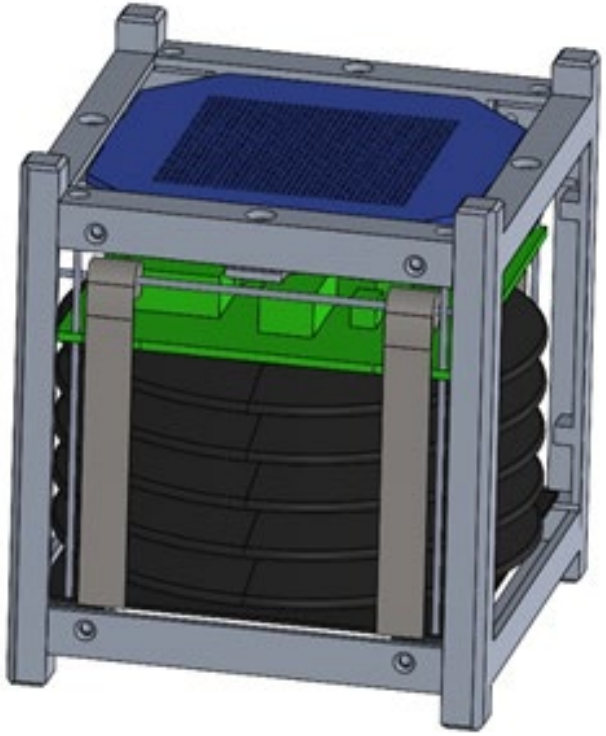


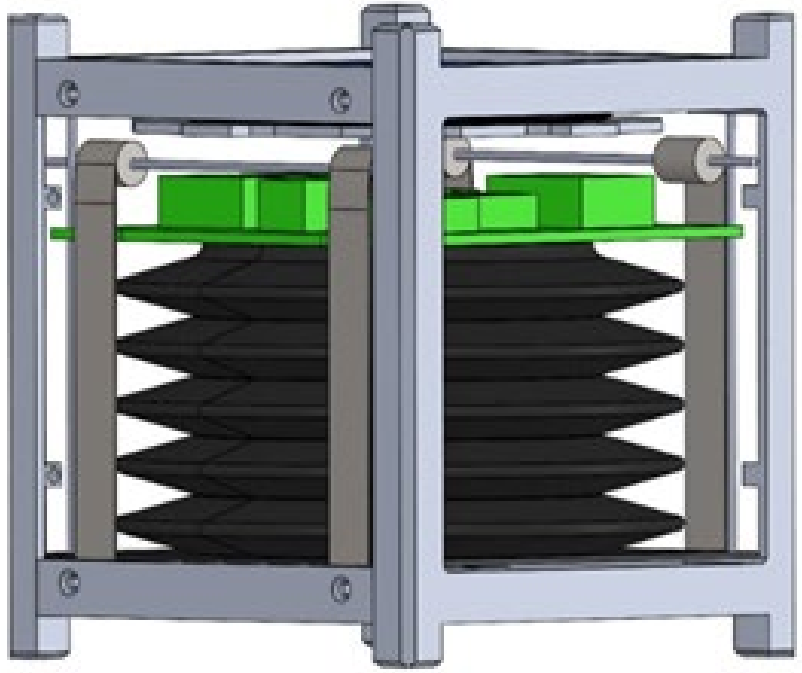


86 hours of operation without change in performance. JPL is setting up a longer 1000-hour life test

Next Step: TRL 6 Demonstration

Demonstration of high-fidelity propulsion system (emitter array, propellant delivery system and PPU) in relevant environment





- 1U CubeSat propulsion system
- Bellows tank
- On-off microvalve
- Off-the-shelve components PPU
- Inclusion of accelerating electrode to increase Isp

Thank You!

Prof. M. Gamero-Castaño

Dr. A. Cisquella-Serra

M. Galobardes-Esteban

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Electric Propulsion Lab at UCI