Microfluidic Electric Propulsion - A Future Alternative to Sails?

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Benefits & Challenges of MEP

- MEP, compared to sails, could eliminate
  - Sail & Deployment mechanisms
  - Reaction Wheels
  - Cold Gas System
  - cg shift mechanism or solar arrays off-loading schemes
- MEP is not yet available off-the-shelf
  - Under laboratory development
  - About 1-2 yrs and $2-4M from TRL 6
  - Not for near-term use – but a technology offering significant future system benefits (above).

What is MEP?

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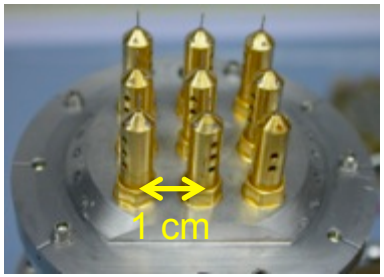
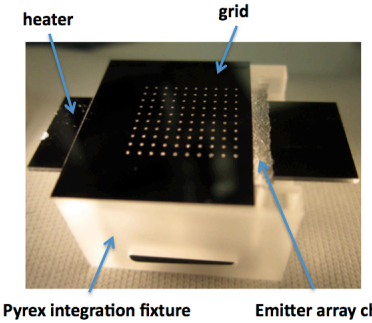
Electrospray thrusters have been flight qualified by NASA for the LISA Pathfinder Mission

Thruster Head

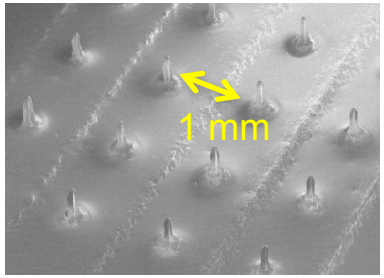


Conventional Emitter Array

MEP thruster is based on same electrospray physics with highly scalable microfabricated components



Thruster Head, feed system and reservoir



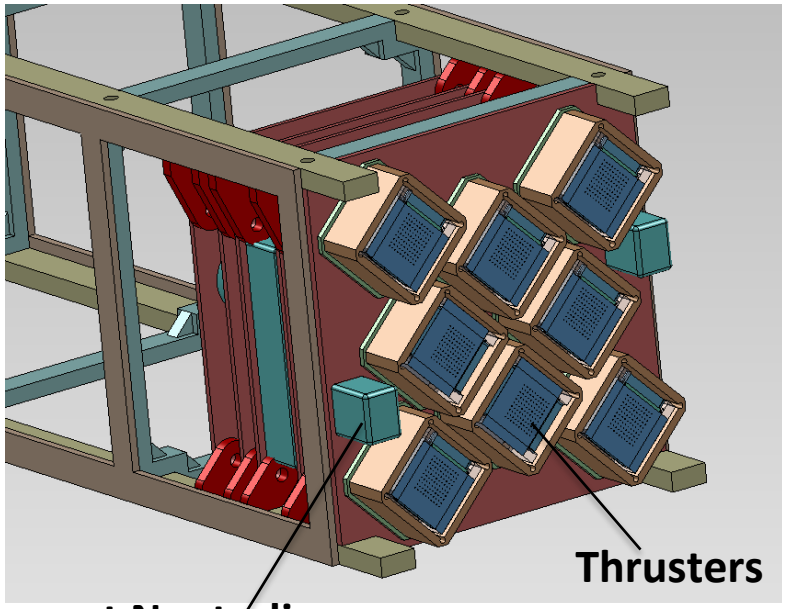
Microfabricated Emitter Array

Busek Electrospray Thruster
Size: ~25 x 25 x 38 cm
Number of emitters: 9
Thrust: 4-30 uN
Mass: > 2 kg (head, reservoir, valve, PPU)
- with pressurized reservoir and valve

Integrated MEP thruster/feed system module:
Size: 1.9 x 1.9 x 1.2 cm (4.3 cm^3)
Number of emitters: >100
Thrust: 10-100 uN
Mass: < 100 g (head, reservoir, PPU)
- no pressurized reservoir or valve required
Cost: ~ much lower with batch microfabrication

Microfabricated components, microfluidic flow control and microelectronics enable >10X improvement in thrust range, mass, volume and cost over SOA.

MEP CubeSat Integration



- Thrusters are modular – including dedicated propellant reservoir.
- No valves, no propellant lines.
- Indium propellant – solid at room temperature, capillary-fed, no pressurized vessels
- PPU approx ½ U
- Multiple redundant sets of thrusters to reduce risk and lifetime concerns.
- Tailor thrust/trip time using multiple thrusters.
- Canted thrusters will allow for dual use – delta-v (at some losses) & attitude control

MEP System for Heliophysics Application - Mass -

- Assume 6U CubeSat, ~ 8 kg, 1.5 km/s delta-v for L5 insertion
- Isp 5000 sec
- Propellant Requirement: 240 grams
- Assume 8 primary thrusters: 30 gram per unit
- Add 5 grams per unit for ACS (estimate).
- Dry Mass: 10 grams per unit
- 8 x (35 + 10)gram = 360 gram for primary thrusters.
- Add additional fully redundant set of 8 thrusters to reduce lifetime requirements: **720 grams**
- Two sets of canted thrusters at opposite ends of CubeSat allows for 3-axis attitude control.
- PPU Mass (0.5 U): est. **500 grams**
- **Total Mass: 1220 grams**
- No reaction wheels needed, no cold gas

MEP System for Heliophysics Application - Power -

- 7 W / thruster unit, including neutralizer and heater to melt Indium propellant
- Assume 4 thrusters firing at a time to keep trip time to 1 year.
- 4 x 7 W = 28 W thruster power.
- PPU efficiency losses: 0.8 (?) => **35W**

MEP System for Heliophysics Application - Thrust, Trip Time & Life -

- Thrust/unit: 100 uN (projected)
- Assume 4 thrusters firing at a time:
  - 6 U CubeSat reaches 1.5 km/s in **~ 1 year**
  - 4 thrusters allows for differential thrust and ACS during firing
- Lifetime Requirements:
  - 16 thrusters (8 primary and 8 redundant)
  - **3 month per unit** plus ACS at L5

Summary

- Sail, reaction wheels, cold gas is a good near term option.
- MEP is a potential future technology advance, pending further development and associated risk, simplifying system architecture - one system replacing three.