From Cold-Gas to ArcJet MicroPropulsion for Nanosatellites

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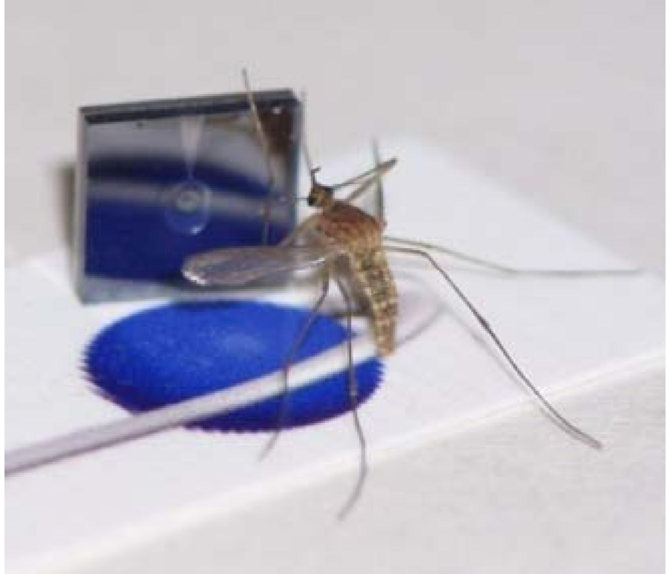
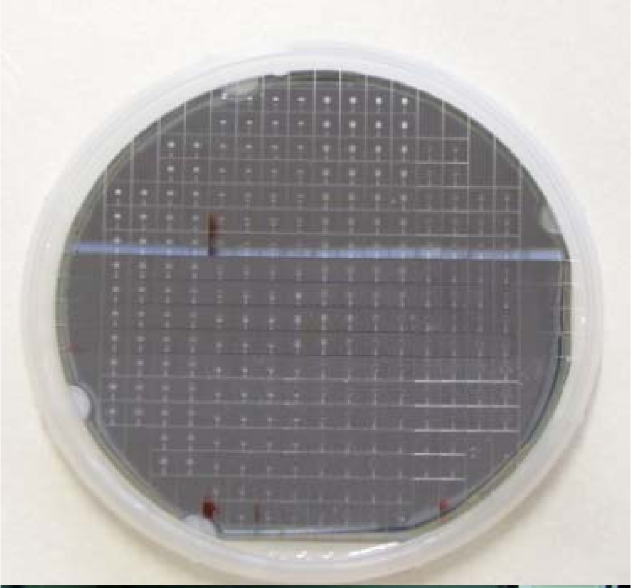
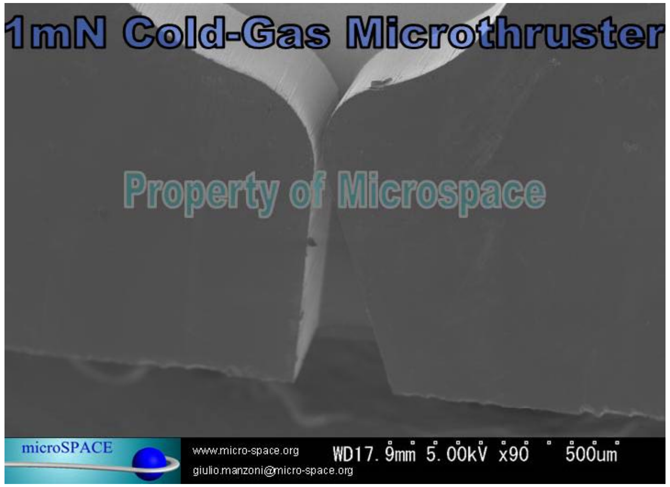
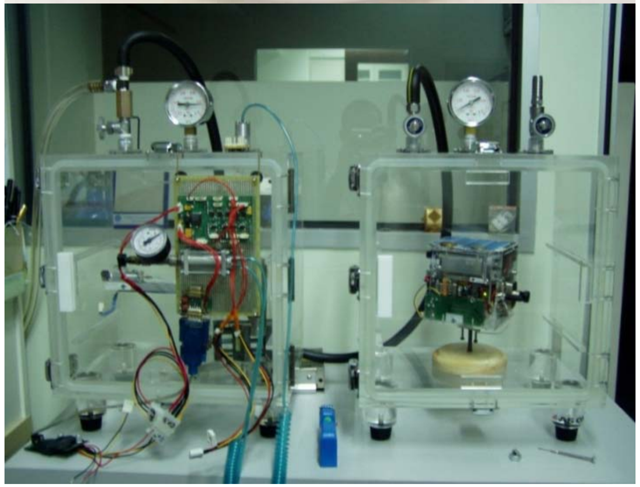
Supersonic Micronozzle

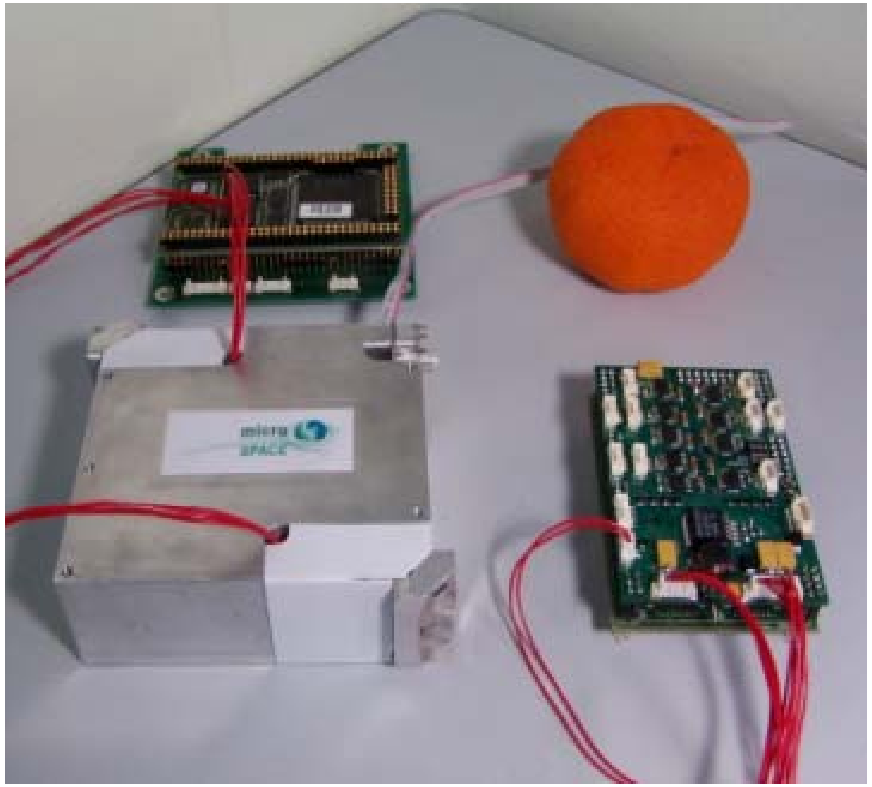


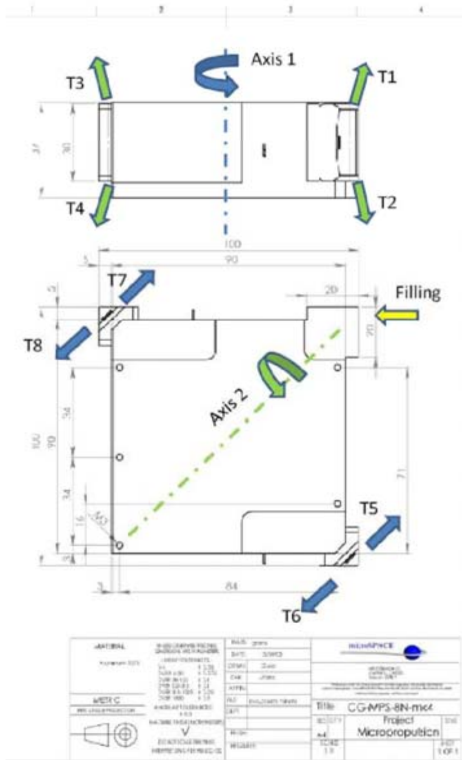






2nd gen. Cubesat micropropulsion

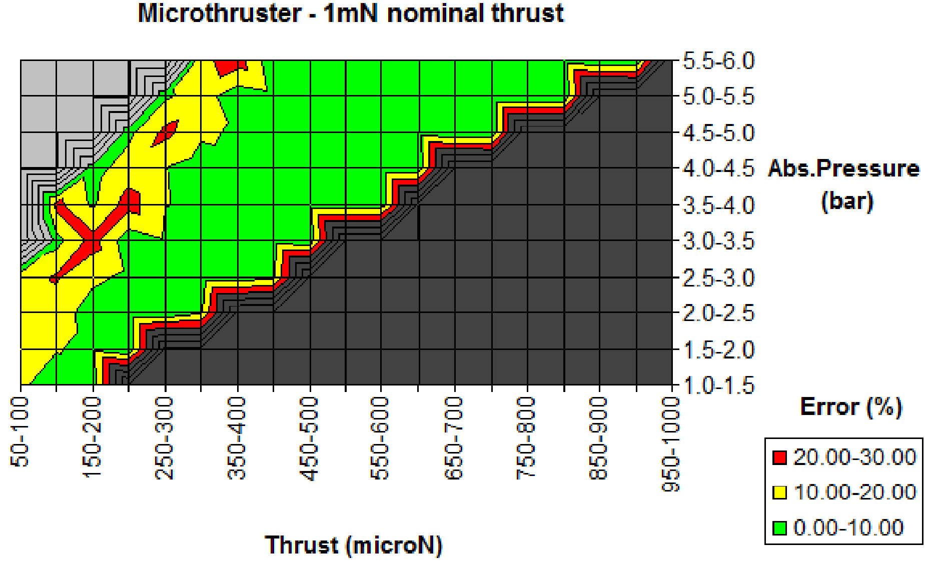


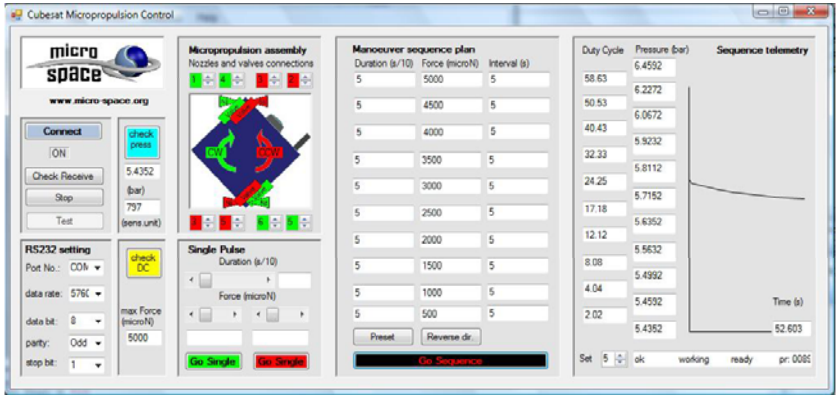


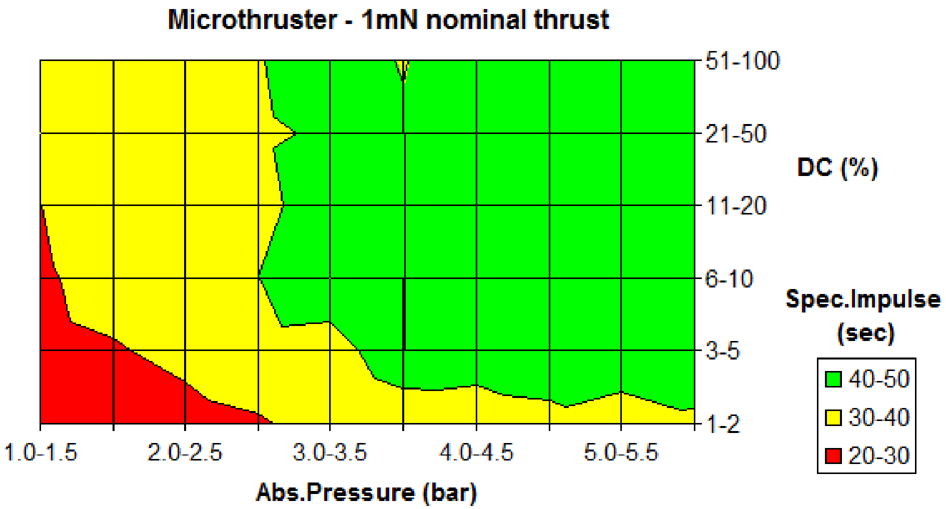
Nominal Thrust	100 µN to 10 mN
Thrust Control	1 to 100%, 1% resolution
Impulse Duration	2ms to unlimited
Specific Impulse	50s – 100s (warm gas option)
Pointing Resolution	0.1 arcsec
Minimum Total System Mass	300g
Max Power	2W
Supply Voltage	12V

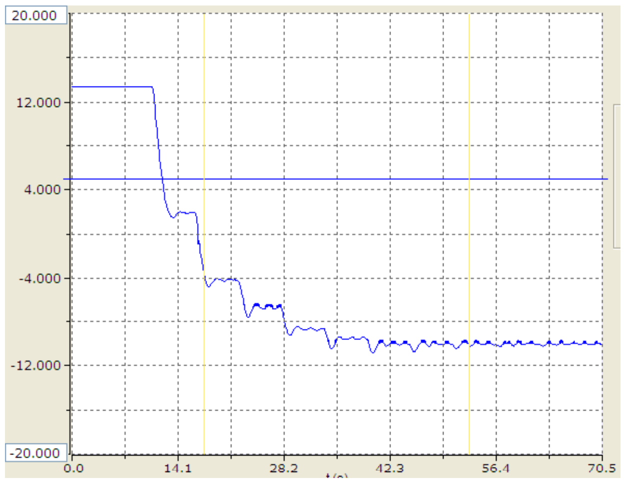
- *3-axis stabilization*
- *Suitable for 1kg~100kg satellites & spacecrafts*
- *Based on proven, reliable MEMS technology*
- *Rigorously lab-tested under vacuum conditions*
- *Space environment certified*
- *Modular and customizable, cubesat compatible*
- *Already integrated on cubesats ready for launch*

2nd gen. Cubesat micropropulsion









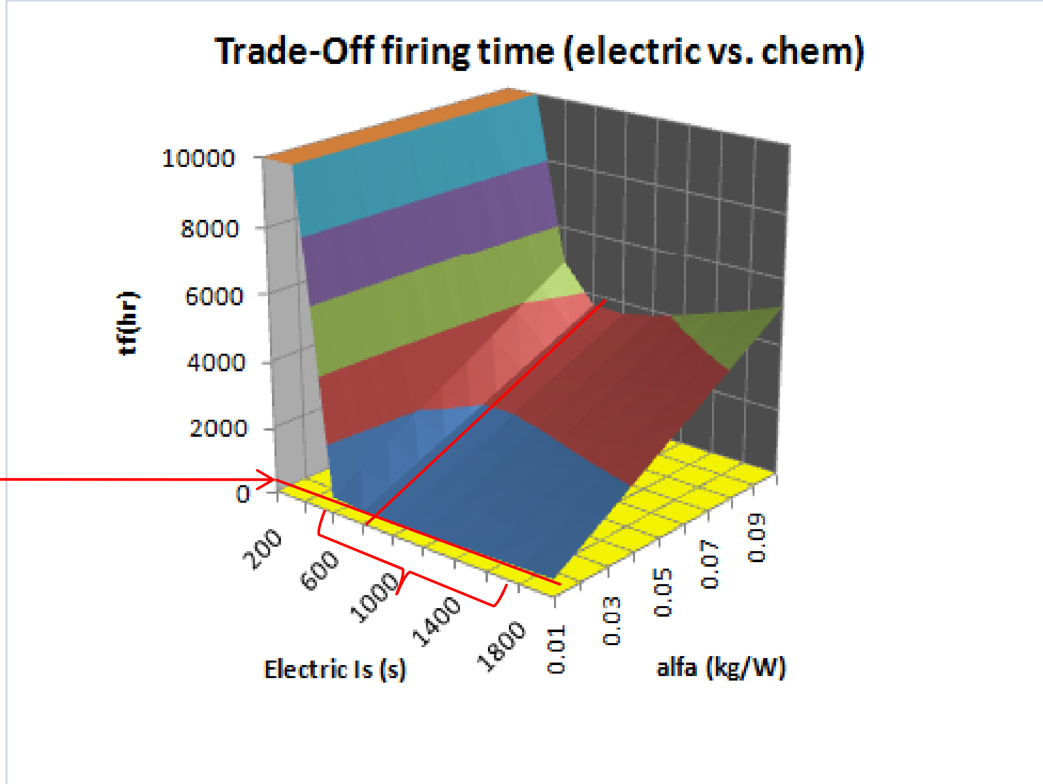
Trade-Off Parameters
(Power supply mass and efficency)

$$\gamma = \frac{m_{elec} + m_{pe}}{m_{chem}} = \frac{v_{chem}}{v_{elec}} + \frac{1}{2}\frac{\alpha}{t_f \eta} v_{elec} v_{chem}$$

$$(I_{s-elec})_{opt} = g\,(v_{elec})_{opt} = g\sqrt{\frac{2 t_f \eta}{\alpha}}$$

$$t_f = v_{elec} v_{chem} \frac{\alpha}{2\eta} \frac{1}{\gamma - \frac{v_{chem}}{v_{elec}}}$$

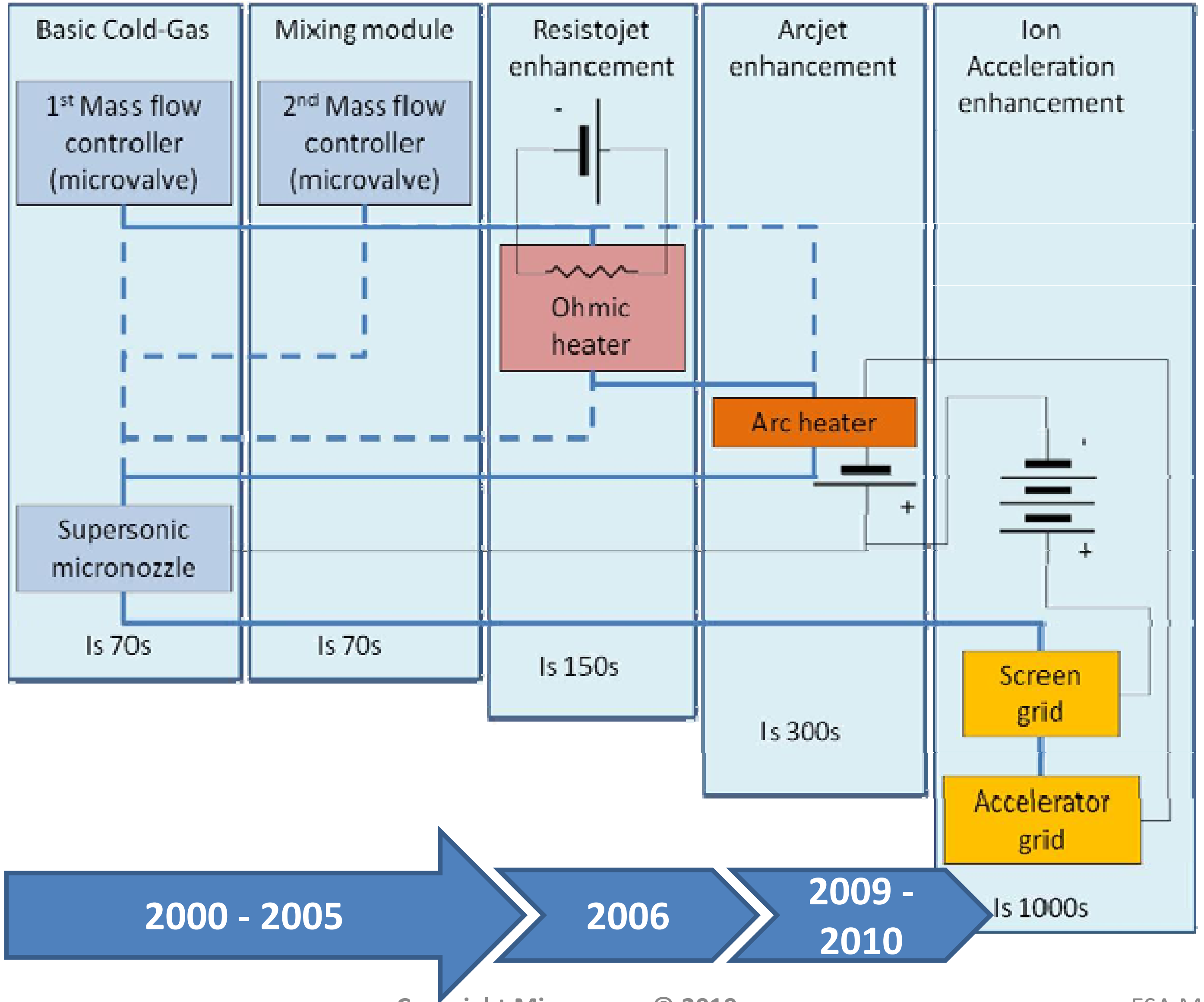
Tf = m Δv / F
= 3kg * 300m/s /1E-3N
= 250hr



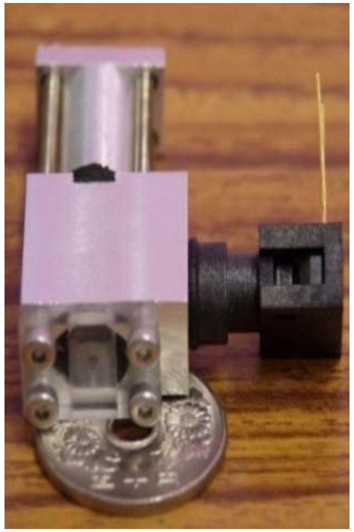
Electric Propulsion Advantage Trade-Off	gamma tradeoff		1
Chemical Propulsion Specific Impulse	Is(ch)	s	450
exit velocity	vc	m/s	4415
Electric Propulsion Efficiency	eta		0.3

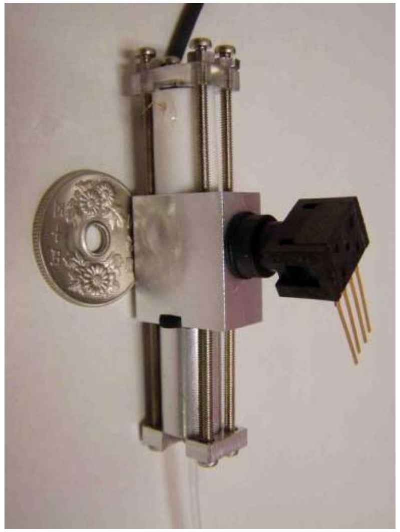
From NANOSAT-CDF study performed at ESA in 2009
- Thrust between 500µN and 500mN
- Minimum ΔV 10m/s (only AOCS[1])
- Average ΔV 100m/s (includes orbit injection correction, acquisition and maintenance),
- up to 200m/s if including deorbiting
- Maximum ΔV 2000 m/s (including Moon, GEO[2] transfers or orbit changes)
- Dry mass budget 1kg (possibly 400g)
- Propellant mass budget 3kg
- Tank size max 200mm diameter
- Power budget , max 10W, average 2~3W
- 1 DoF[3] for high ΔV, 3DoF for low ΔV, 6DoF for moderate ΔV, µN for attitude control

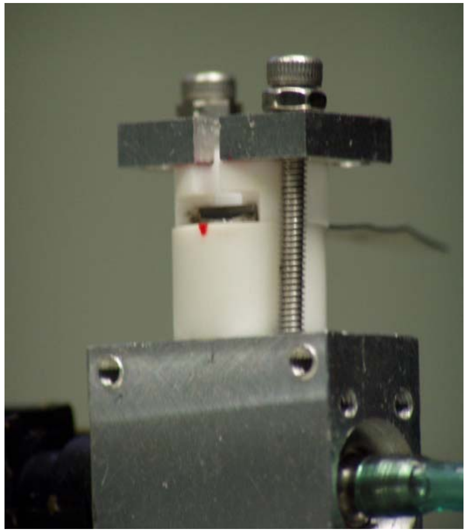
Technology Concept Evolution

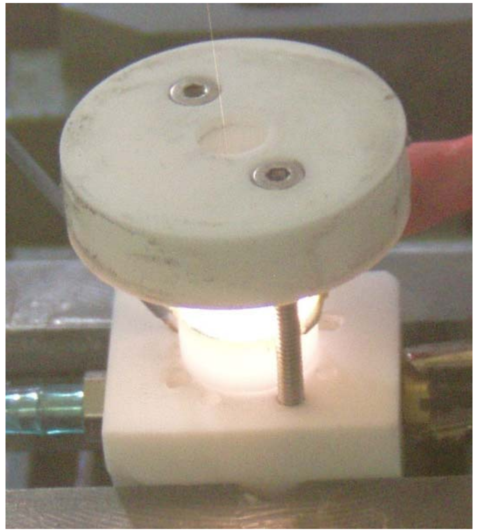


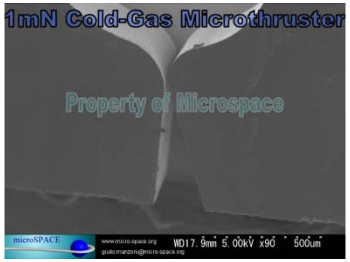
Technology Concept Evolution

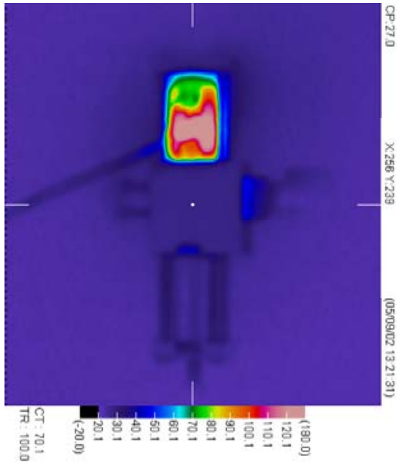


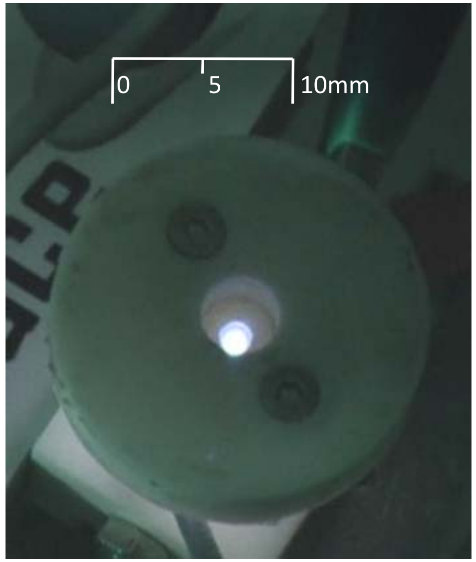










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space
Plasma ArcJet MicroNozzle
for Nanosatellites
3mN – 10W (200kW/cm³)
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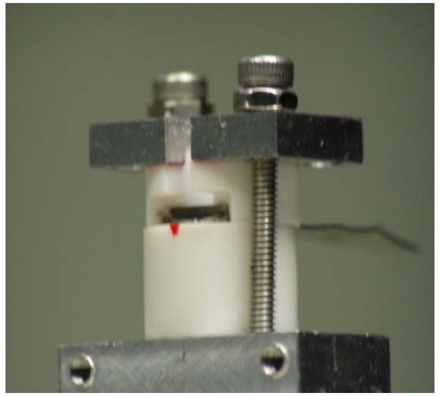
Prototypes and Tests (micronozzle)



Plasma – ArcJet MicroNozzle (PAJMiN©)– Throat 100 μm ≈1000V

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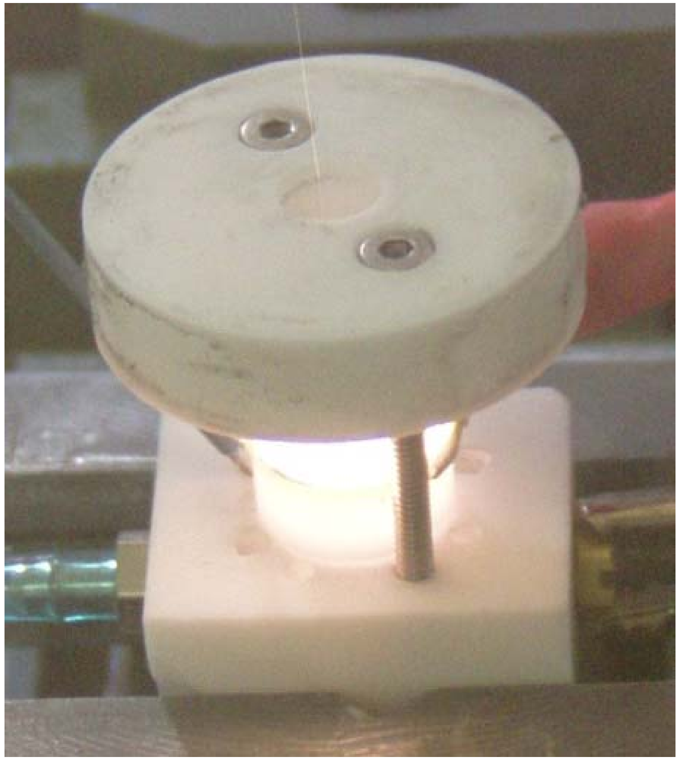
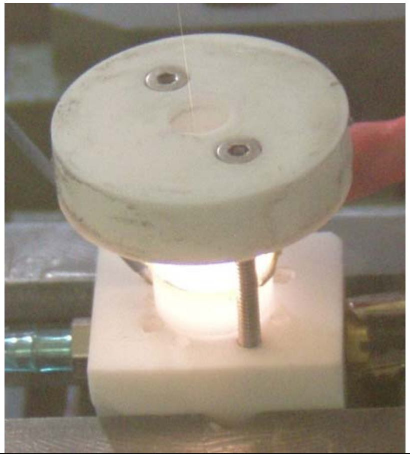
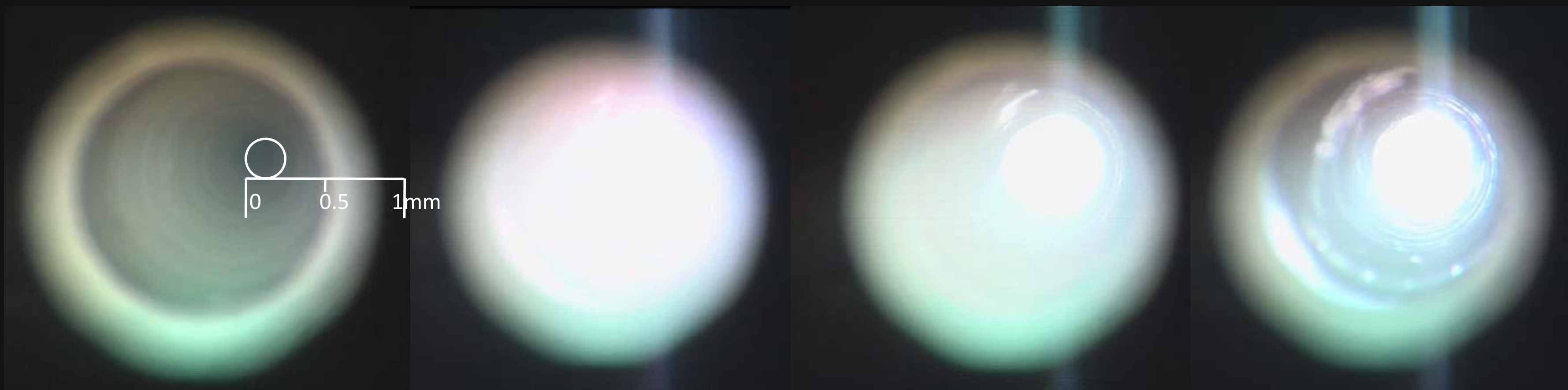
Prototypes and Tests (microrocket)



Prototypes and Tests (microrocket)



Plasma – ArcJet MicroRocket (PAJMiR©)– Throat 0.2mm ≈1000V



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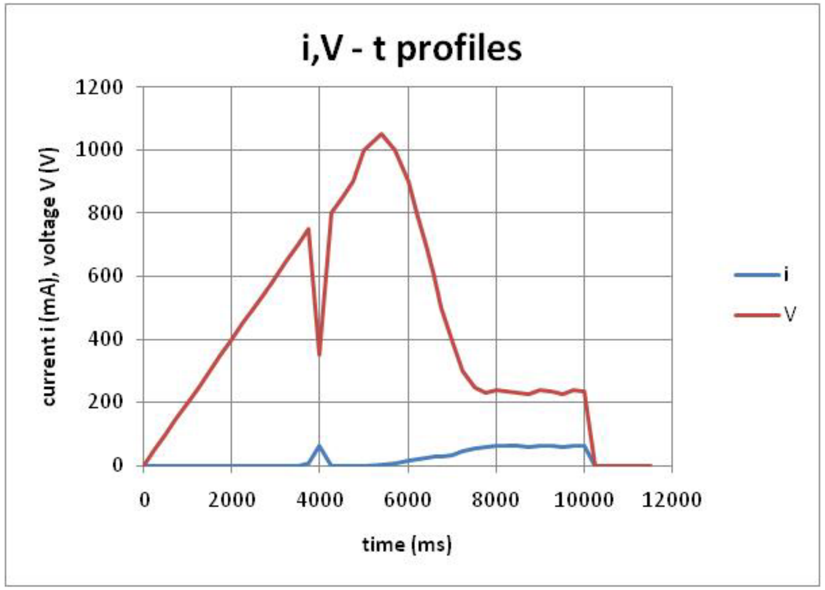
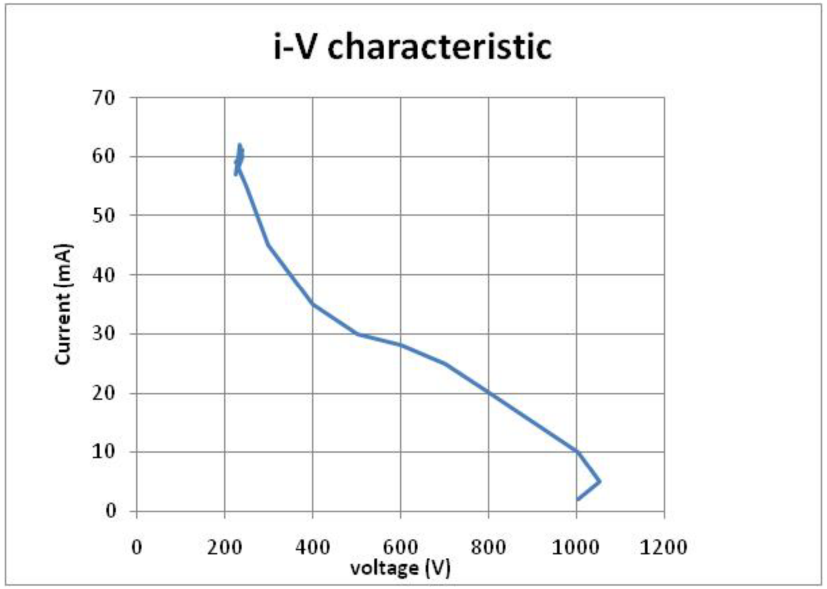
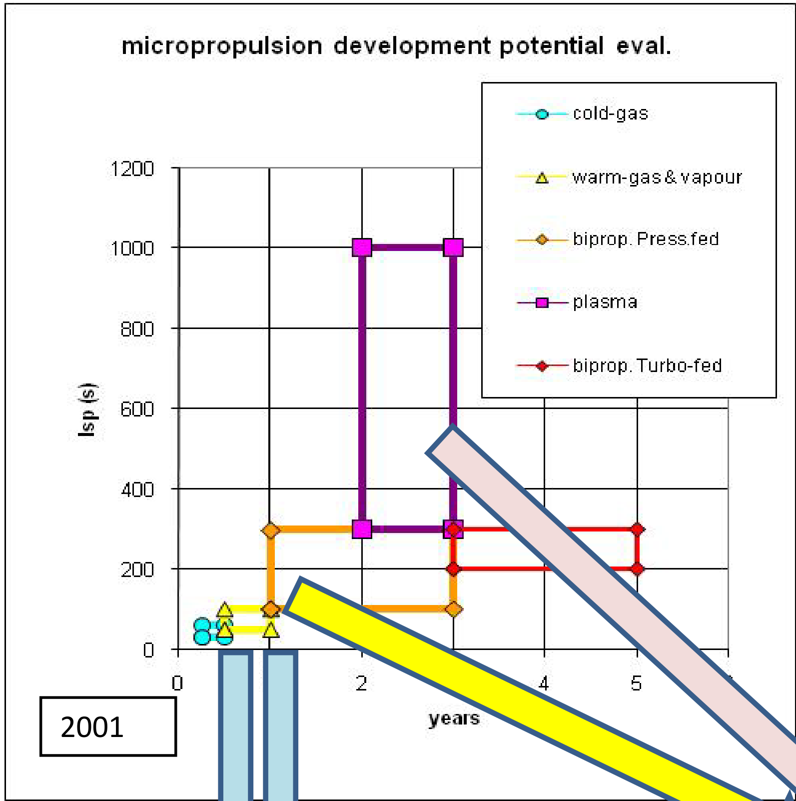
Prototypes and Tests (Discharge characteristic)





Conclusion (roadmap)

Technology R&D



Commercial applications

2002, 2004/06	Single axis Cold-Gas System
2006	Tri-axis Cold-Gas System
2010/12	Tri-axis Cold-Gas Cubesat

Common parts

Next Generations Hi-Isp Systems and Nanosatellites

2012 and beyond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