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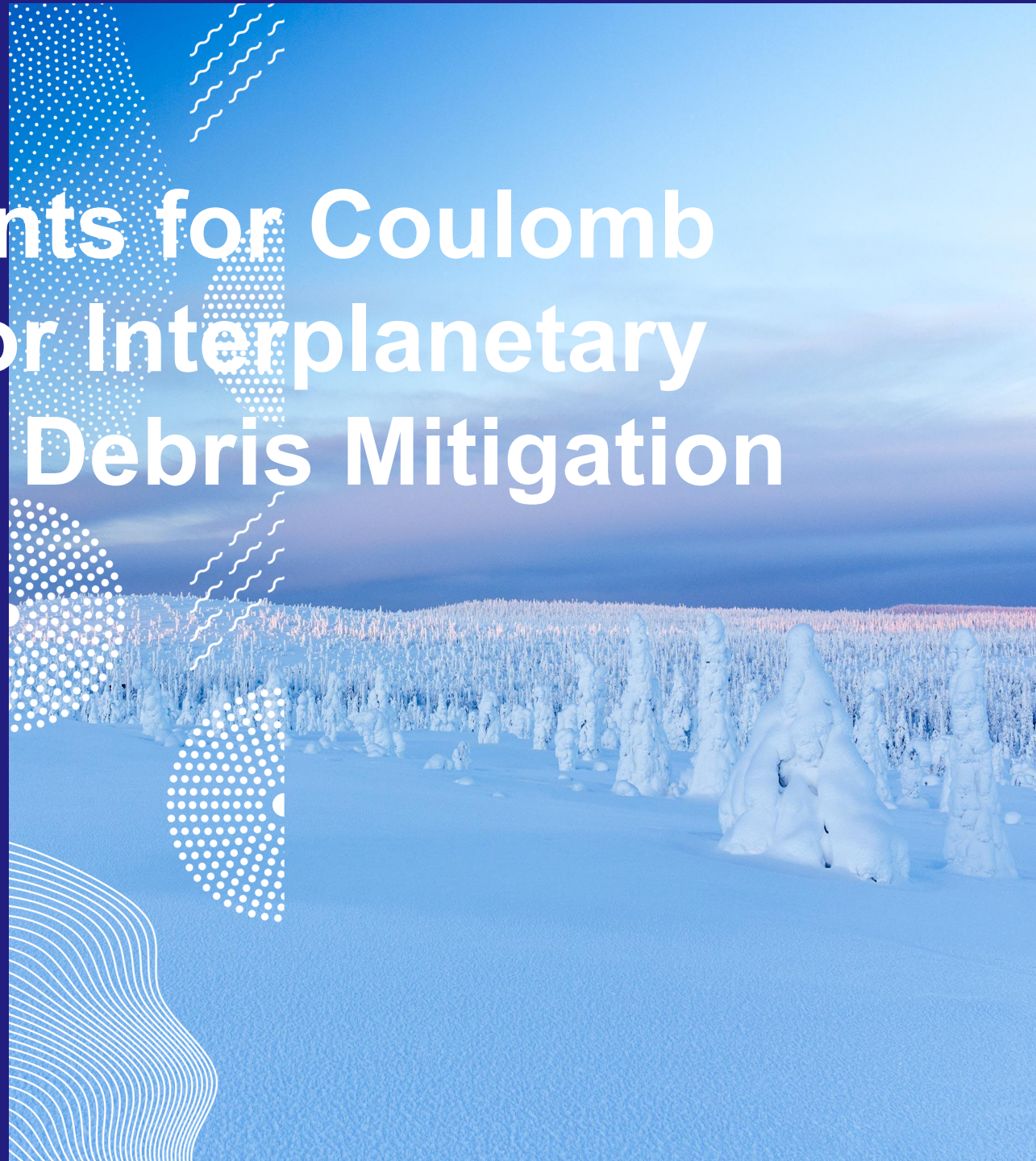
Cubesat Experiments for Coulomb Drag Propulsion for Interplanetary Missions and Space Debris Mitigation

Petri Toivanen[1], Pekka Janhunen[1], Jarmo Kivekäs[1], Sean Haslam[1], Jouni Polkko[1], Iaroslav Iakubivskyi[2,3], and Maria Genzer[1]

[1]Finnish Meterological Institute
[2]Tartu Observatory
[3]Massachusetts Institute of Technology



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Introduction

- Coulomb drag in space plasmas, analogy of air drag
  - In LEO, RAM pressure and orbital braking
  - Solar wind, dynamic pressure and sailing
- Plasma brake and space debris mitigation
- Fleet of cubesat telescopes to main asteroid belt
- Ongoing cubesat experiments in LEO
  - FORESAIL-1, launched May, 2022
  - EstCube-2, launch February, 2023
- Integration of EstCube-2 Coulomb drag payload
- Conclusions

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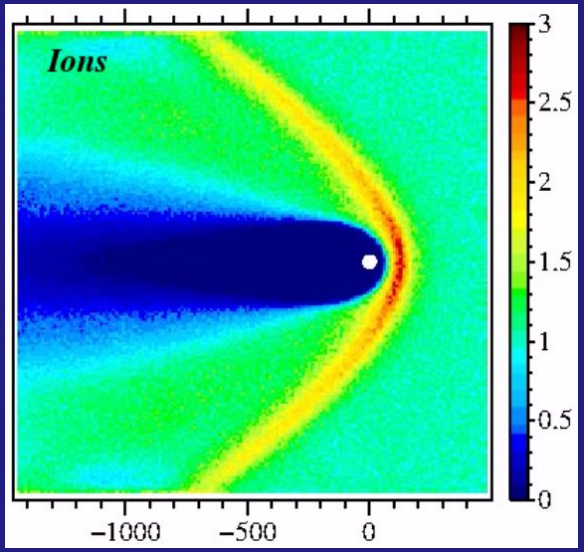
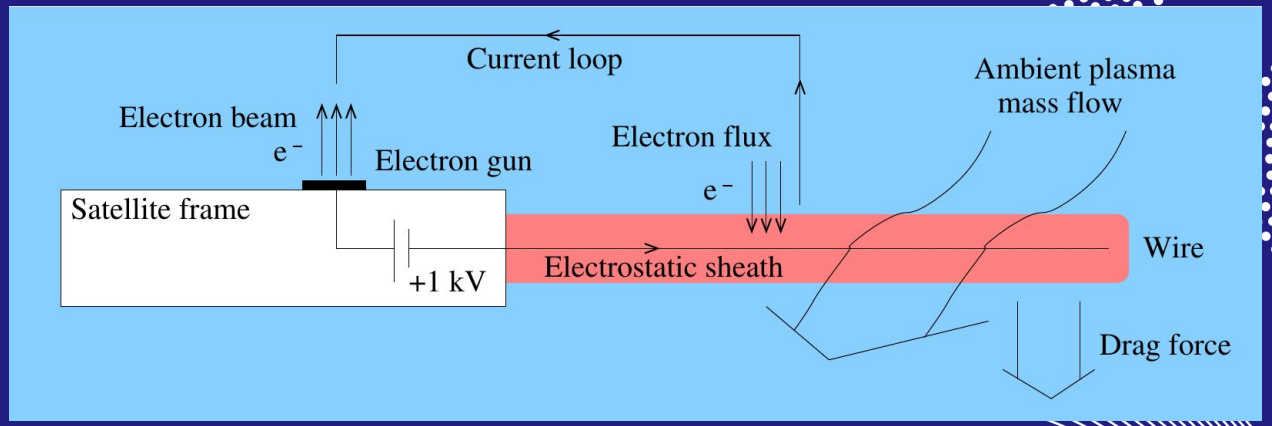
From Coulomb Drag ...



1. High voltage conducting wire
2. Electrostatic sheath (PIC simulation)
3. Plasma mass flow distorted
4. Drag force

to Propulsion:

1. Electrons neutralise the wire
2. Maintain the high voltage with an electron gun
3. Moderate amount of electric power to run the current loop



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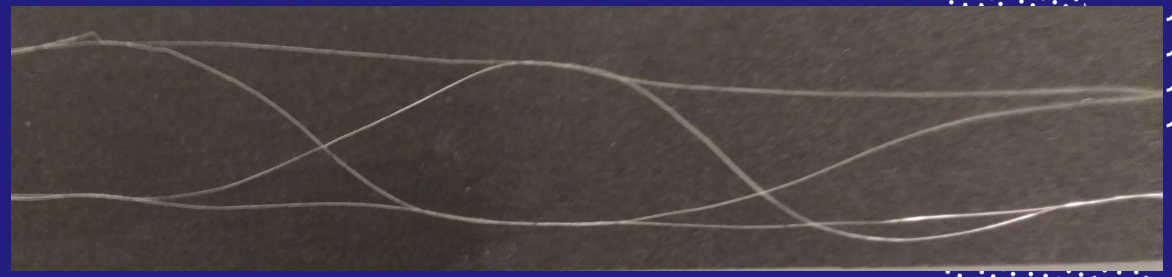
Plasma Brake



- Negative tether and electron collecting surface
- ESA CleanSat Building Block 15 (BB15), 2017
  - Tether harmless (MASTER-2009 model by ESA)
  - Reduces AreaxLifetime ∝ collision probability
  - Device, 2 kg in 2-unit cubesat spatial scale

Sat. mass	Init. alt.	One device	Two devices
200 kg	850 km	2.9 a	1.5 a
400 kg	850 km	5.5 a	2.9 a
600 kg	850 km	7.9 a	4.2 a
800 kg	850 km	10.1 a	5.5 a
200 kg	1000 km	5.3 a	2.7 a
200 kg	1100 km	7.8 a	4.0 a
200 kg	1200 km	11.0 a	5.6 a

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Multi-Asteroid Touring

- ESA Call for new science ideas 2016
- +50 identical 3-unit cubesats
  - Optical & near infrared imager
  - Coulomb drag propulsion, $a_c = 1 mm/s^2$, year of acceleration ⇒ $\Delta v = 31.5$ km/s
- Autonomous flybys and rendezvous
- Data down during an Earth flyby
- Freedom of selecting targets
  - Main belt object flyby (3.2 a)
  - Inner belt rendezvous (5.0 a)
  - Trojan (8.3 a)

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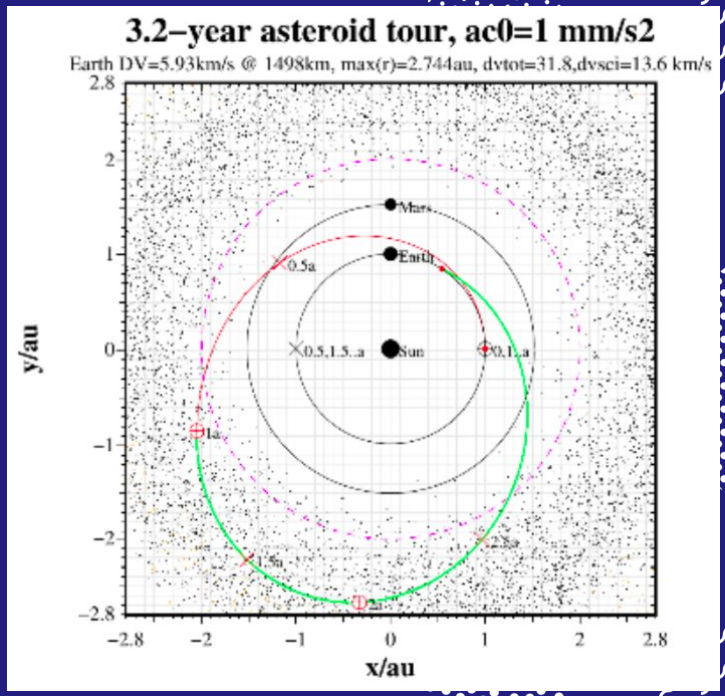

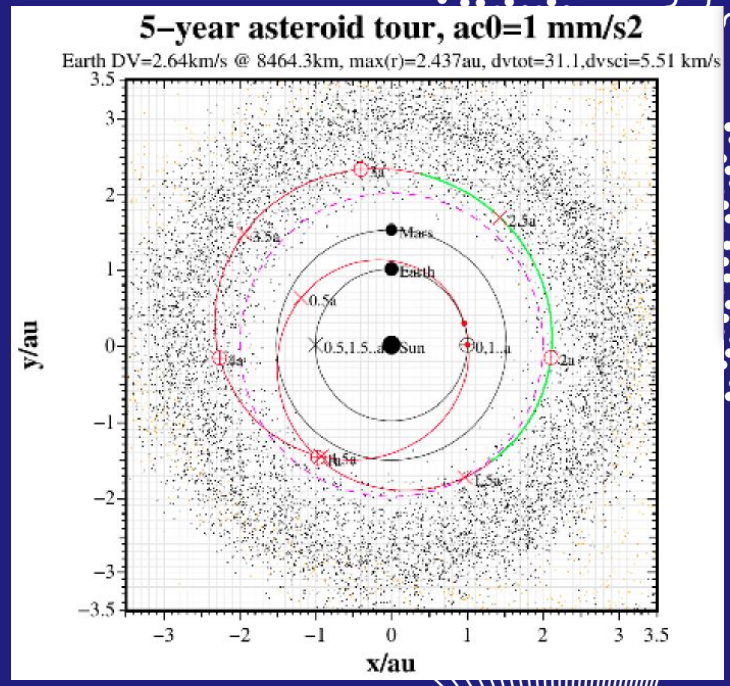

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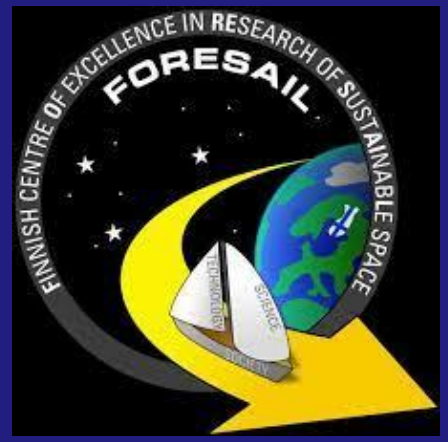
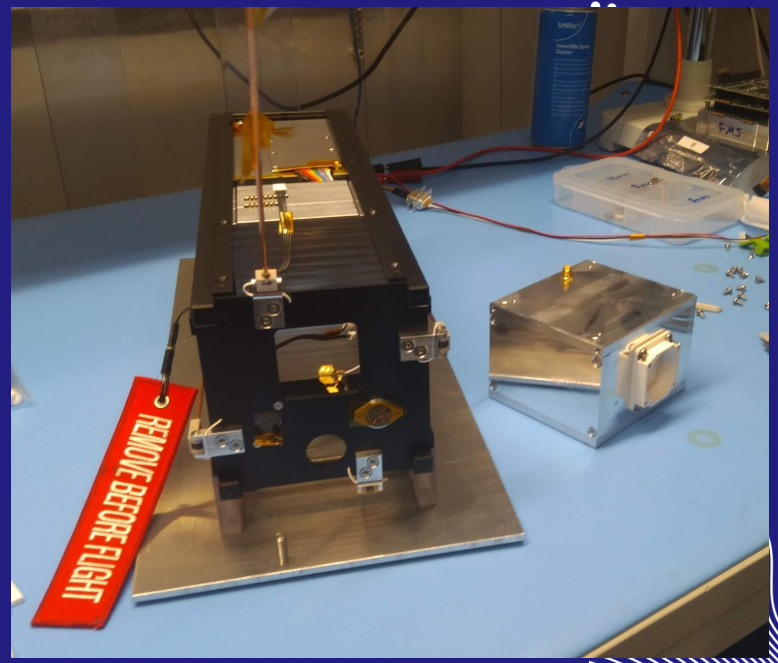
FORESAIL-1



- 3-unit cubesat (Aalto University)
- Successful launch and commission May, 2022
- Centre of Excellence, Academy of Finland
- Payloads
  - Plasma Brake (FMI)
  - Particle Telescope (Univ. of Turku)
- Plasma Brake
  - - 1 kV
  - 50-m tether
- Presently, communication problems



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EstCube-2

- 3-unit cubesat (University of Tartu)
- Launch in Feb, 2023.
- Student satellite, EstCube Foundation
- Payloads
  - Plasma Brake (FMI)
  - Camera (Tartu Observatory)
  - Cold gas thruster (GOMspace, Sweden)
- Plasma Brake
  - Positive and negative HV
  - Electron guns (Univ. of Dresden)

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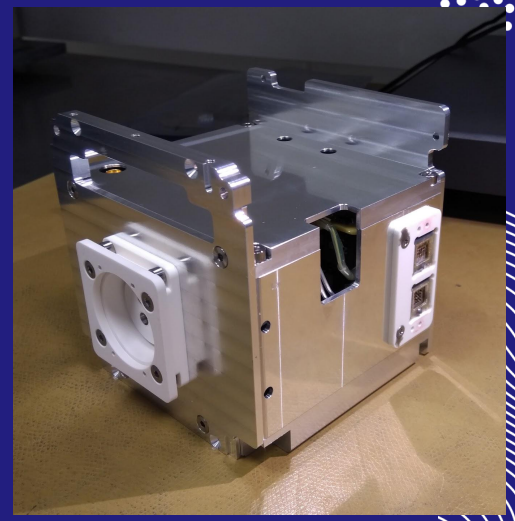
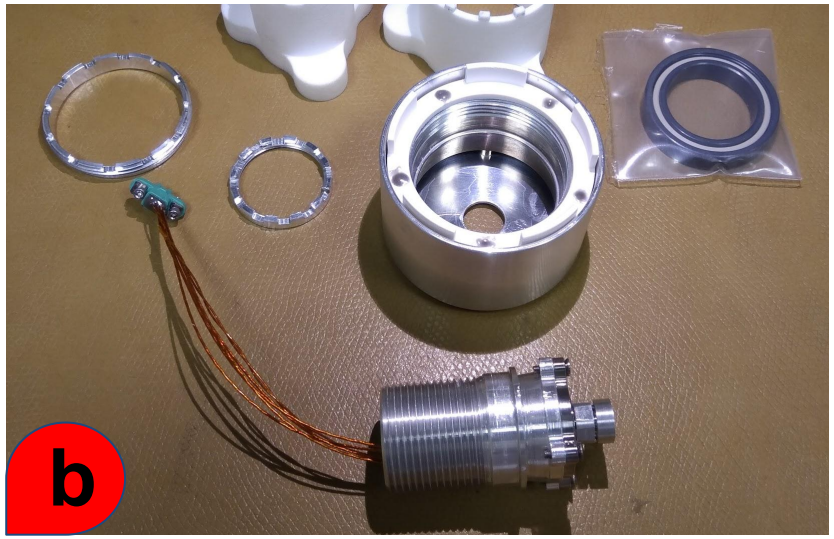
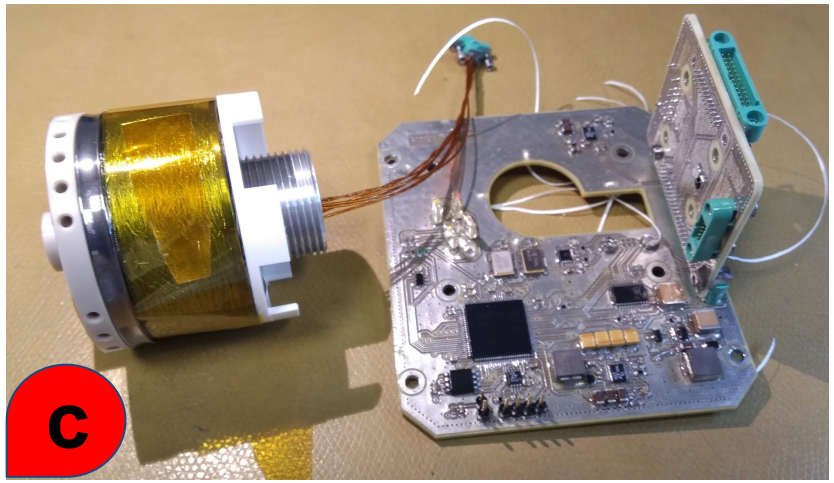


Integration of EstCube-2 Coulomb Drag Payload





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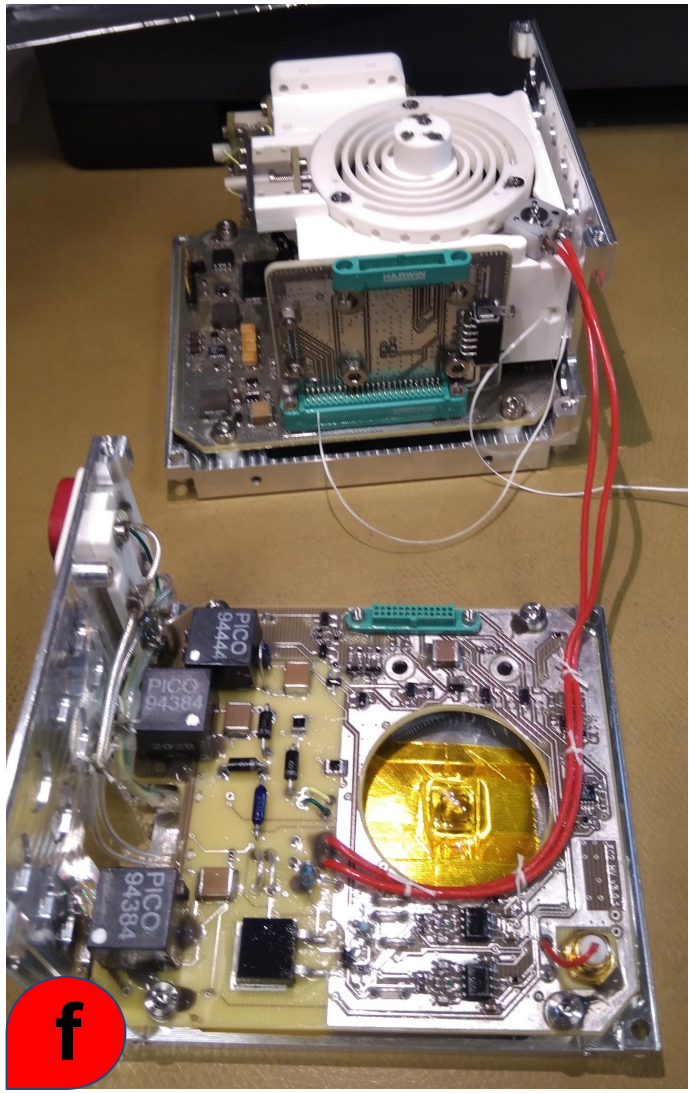

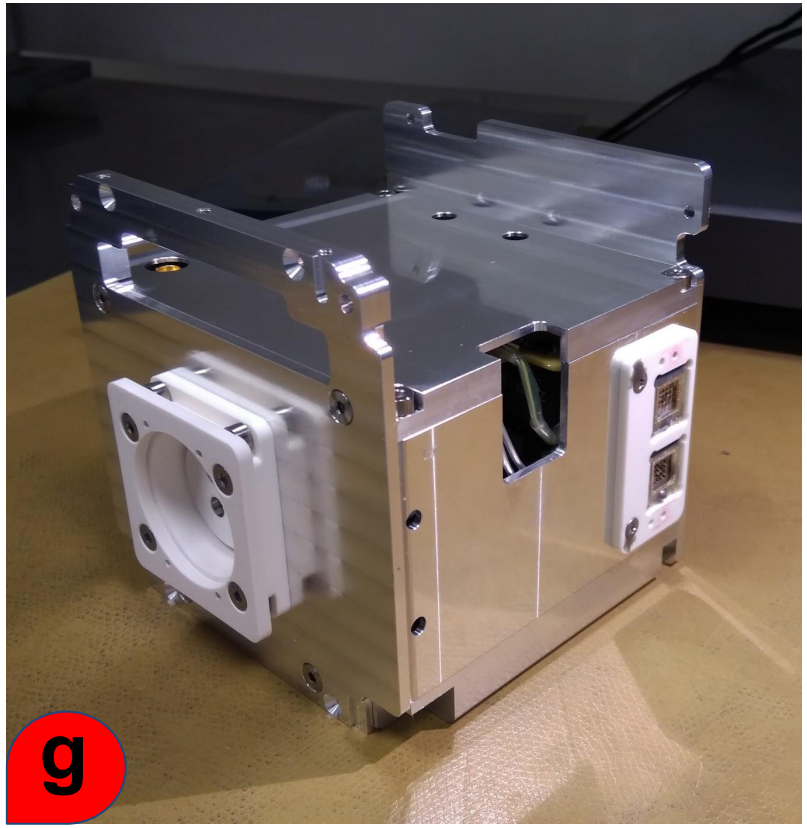

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Conclusions

- Continuous Coulomb drag low-thrust propulsion system ready for experiments and evaluation in cubesat scale in LEO
- μ-meteoroid resistant tether, woven from 4 wires (Al, ⌀50 μm)
- Applications in
  - Space debris mitigation
  - Interplanetary exploration
  - Space weather and planetary defence
  - Please, see https://www.electric-sailing.fi/ for further details
- Expecting results from FORESAIL-1 and EstCube-2

Thank you and have a nice dinner!