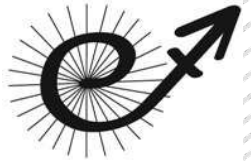
FINNISH METEOROLOGICAL INSTITUTE

Mission plans of the Coulomb Sailing Group

***Pekka Janhunen*, Petri Toivanen, Jouni Envall,**
Finnish Meteorological Institute, Helsinki, Finland

Finnish Satellite Workshop 2018
Aalto University, Jan 17-18, 2018

Coulomb drag propulsion

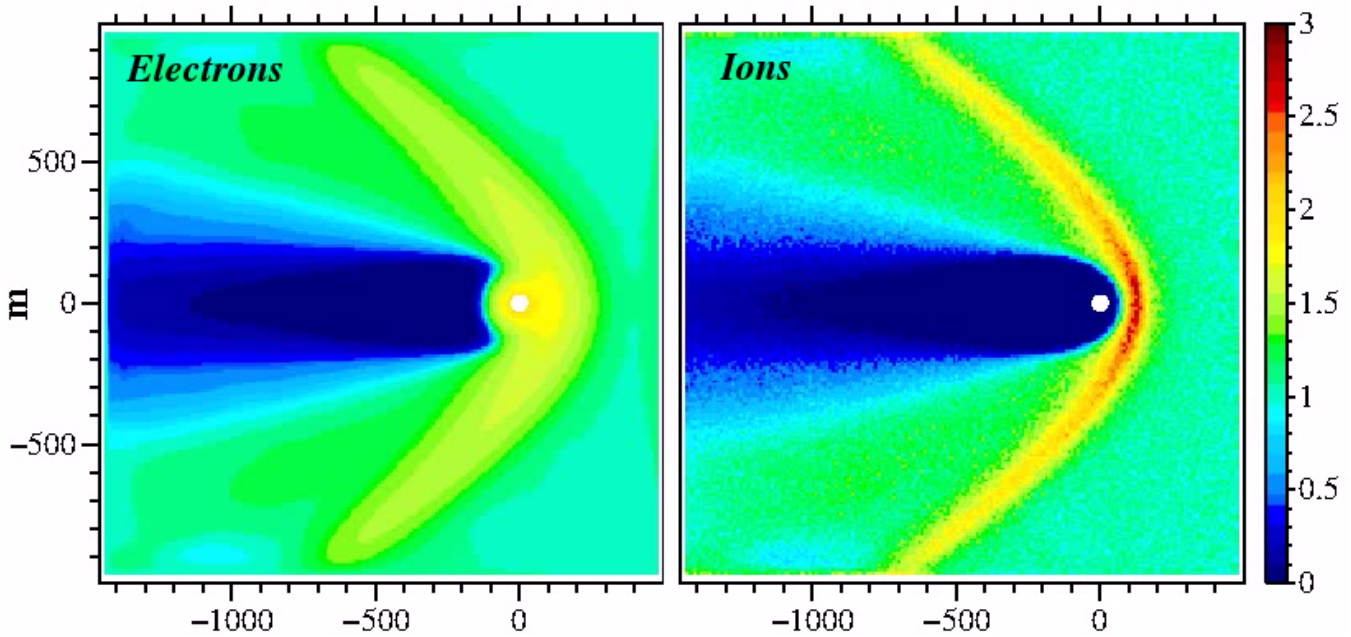


- Way to harness natural space plasma flow for propulsion
  - Charged thin tether taps momentum by deflecting ion flow.
  - One or more tethers: for cubesat, one suffices.
- Two application domains:
  - Solar wind → E-sail, interplanetary propulsion
  - LEO → plasma brake, satellite deorbiting
- At least order of magnitude more efficient than existing methods (efficiency = impulse per propulsion system mass)

Coulomb Sailing Group (CoSaG)

- A loose international team developing and promoting Coulomb Drag Propulsion.
- Mainly in Finland and Estonia at the moment.
- The intention is to commercialise the technologies.

PIC simulation of E-sail

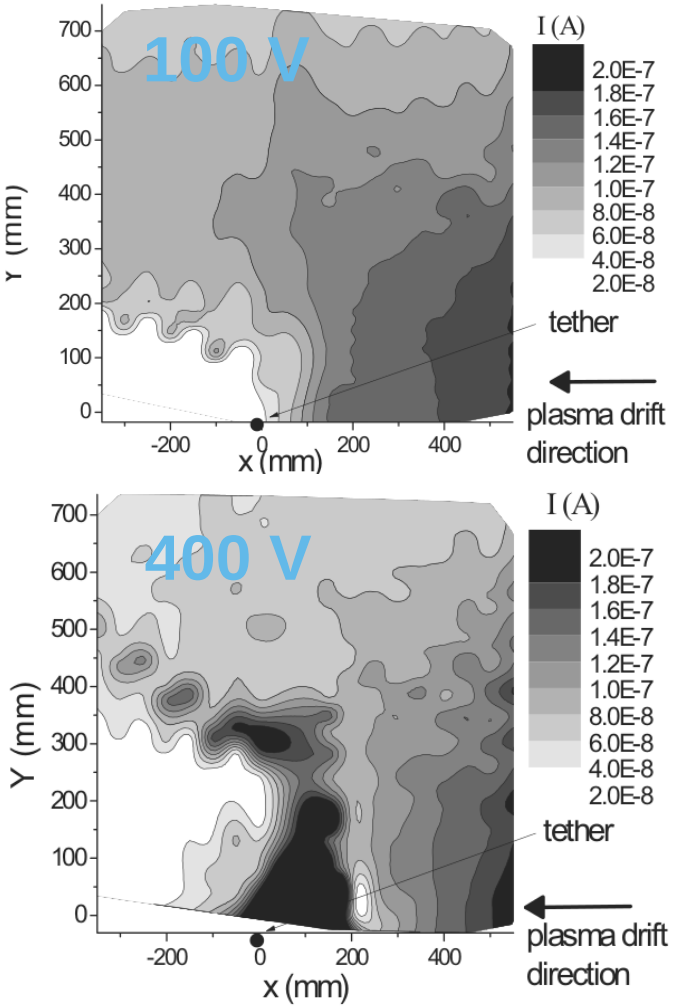


- Nominal solar wind parameters at 1 au

- Typical thrust per length 0.5 mN/km at 20 kV tether voltage
- Typical tether mass per length 10 grams/km
- Tether only: $a=F/m$ = 50 mm/s² = 130 km/s/month
- E-sail system: $a=F/m$ ~ 5 mm/s² = 13 km/s/month

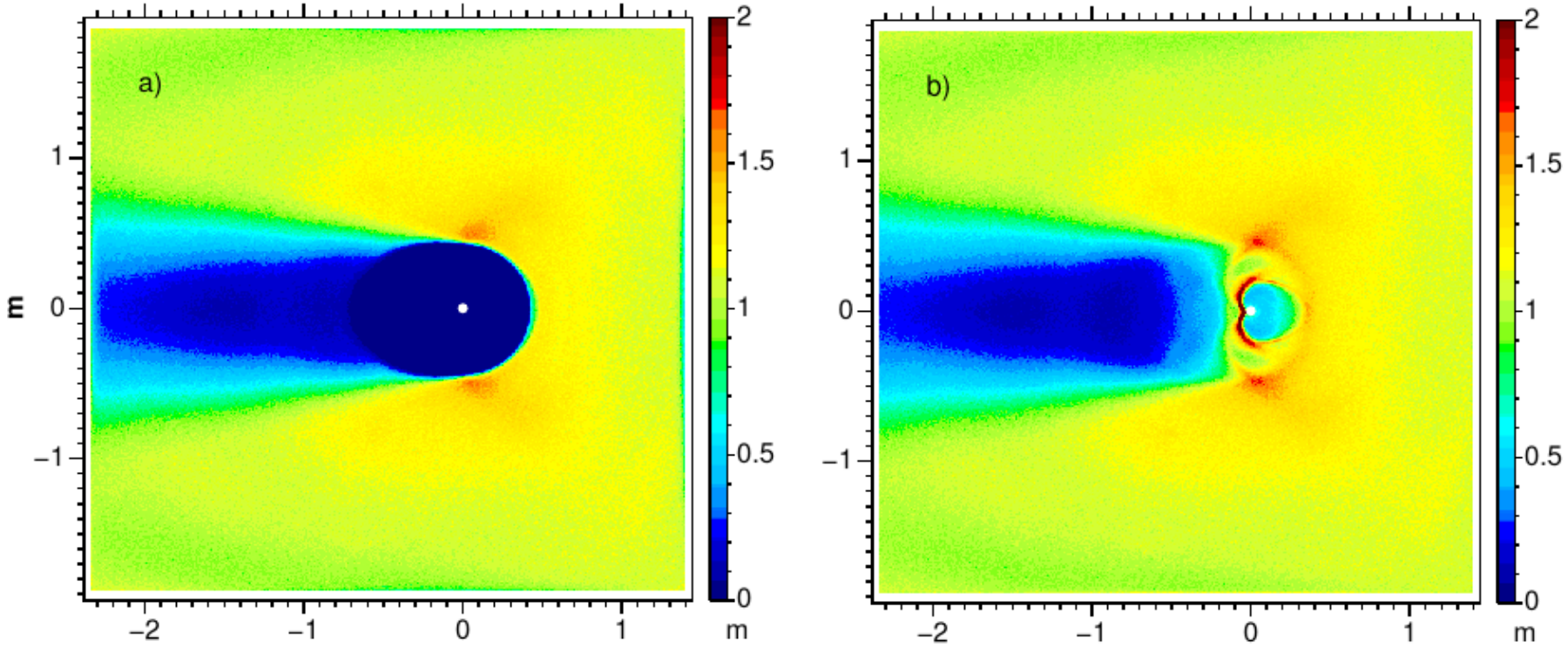
Laboratory experiments

- Sheath width as function of tether voltage (Siguier et al., 2013*).
- LEO-like plasma, tether voltage 100 V and 400 V.
- Good agreement with simulation.
- New experiment in 2017 by NASA MSFC: thrust seems larger than expected by factor ~2. Analysis going on, results not published yet.



(*)Siguier, J.-M., P. Sarrailh, J.-F. Roussel, V. Inguimbert, G. Murat and J. SanMartin, Drifting plasma collection by a positive biased tether wire in LEO-like plasma conditions: current measurement and plasma diagnostics, IEEE Trans. Plasma Sci., 41, 3380-3386, 2013

PIC simulation of plasma brake

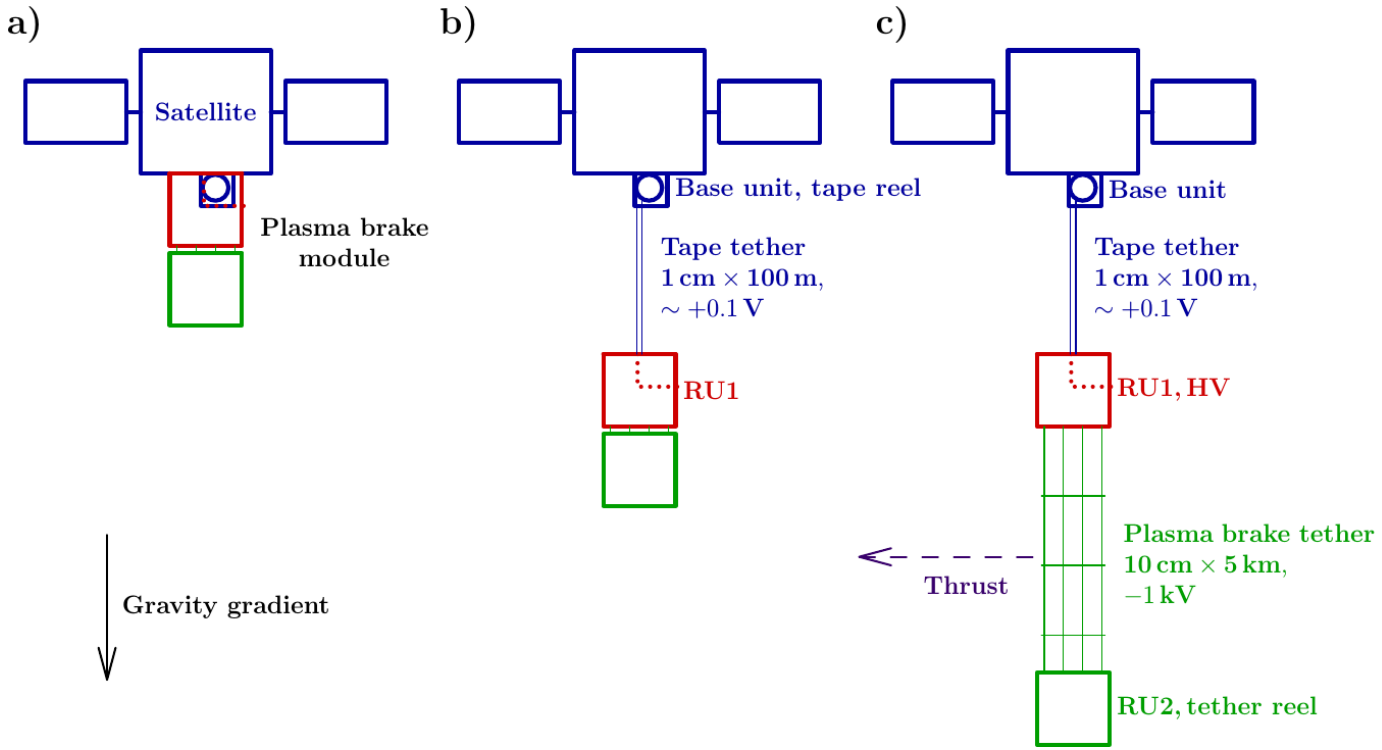


- LEO parameters, -0.34 kV tether polarity
- Electrons left, ions right

http://www.electric-sailing.fi

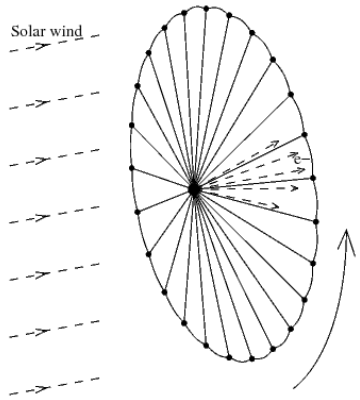
Goal 1: plasma brake module

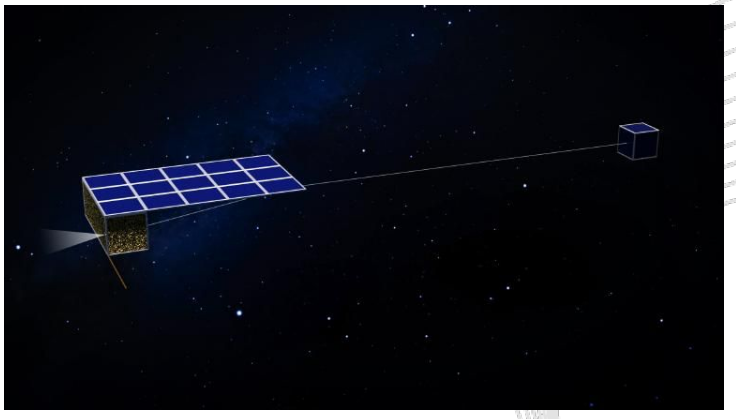
- Good for 800 kg/850 km and 200 kg/1200 km.
- Are LEO megaconstellations feasible without plasma brake?



http://www.electric-sailing.fi

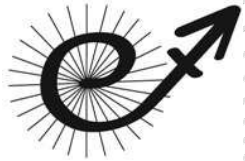
Goal 2: E-sail





- Propulsion for small to medium-sized interplanetary spacecraft.
- First single-tether version for nanospacecraft, later also multi-tether version for medium-sized spacecraft.
- Asteroid mining needs E-sail in order to be economical.
- Asteroid mining can be a future super-application.
- Other applications such as:
  - Space weather prediction with longer warning time.
  - Solar system science missions.

Goal 3: Access to solar wind (Collaborator seek)



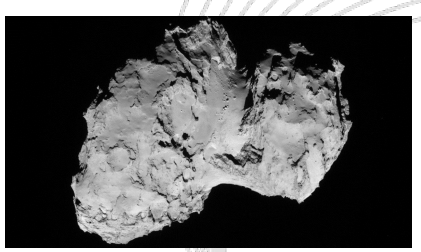
- Any E-sail mission needs to get into solar wind first.
  - From GTO, one needs only 500-700 m/s of delta-v (impulsive).
- Satellites also need propulsion: orbit customisation, orbit maintenance. (E-sail does not work inside magnetosphere; plasma brake does, but can only lower the orbit.)
- Need small propulsion which is qualifiable as a piggyback:
  - Hybrid motor ?
  - Green monopropellant LMP-103S ?
  - Water electrolysis propulsion ?
  - Electric propulsion ? (Low thrust, long time in radiation belt.)

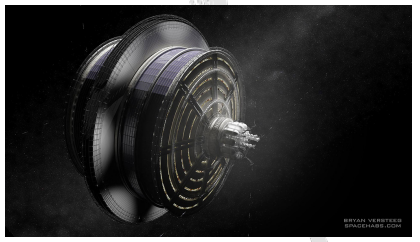
Goal 4: Deep-space telemetry (Collaborator seek)

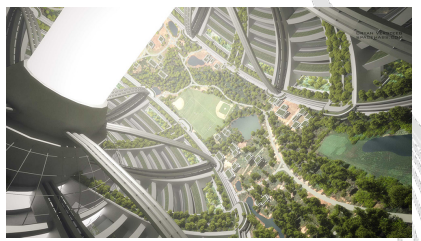
- E-sail needs it(*).
- E-sail prefers phased array, because platform cannot be pointed (except the single-tether version).
- A particular challenge for nanospacecraft: bitrate ~ $m^{5/3}$.

- (*)In the “Multi-asteroid touring” (MAT) proposal, we get around the problem by making an Earth flyby at the end.

Goal 5: Asteroid mining (Collaborator seek)

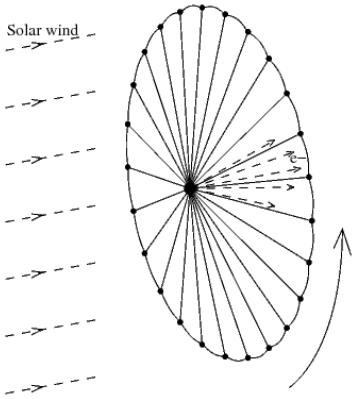






- Asteroid mining is enabler of large space activity:
  - Orbital constructions of unlimited size.
  - Orbital cities where people live in 1g artificial gravity and earthlike radiation protection.
  - Scientific instruments of unprecedented size, e.g. telescopes and particle accelerators.
- Expecting a long period of exponential growth !
- The E-sail solves the last remaining problem i.e. logistics.
- Some startups exist, but we need more.

Conclusions



- Plans of the Coulomb Sailing Group:
  - Commercialise the Plasma Brake Module:
    - To make LEO megaconstellations feasible.
    - Can be applied for up to 800kg satellites.
  - Commercialise E-sail for small and medium interplanetary spacecraft.
    - Single-tether E-sail.
    - Multi-tether E-sail.
- Seeking collaborators for:
  - Access to solar wind for small platforms. Needed by E-sail.
  - Deep-space telemetry. Needed by E-sail (for some missions).
  - Asteroid mining. Enabled by E-sail.