Mission plans of the Coulomb Sailing Group

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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)

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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.

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PIC simulation of E-sail

- Typical thrust per length 0.5 mN/km at 20 kV tether voltage
- Typical tether mass per length 10 grams/km
- Tether only: \( a = \frac{F}{m} = 50 \text{ mm/s}^2 = 130 \text{ km/s/month} \)
- E-sail system: \( a = \frac{F}{m} \sim 5 \text{ mm/s}^2 = 13 \text{ km/s/month} \)

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Nominal solar wind parameters at 1 au
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.


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PIC simulation of plasma brake

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

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Goal 1: plasma brake module

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

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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.

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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.)

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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 $\sim m^{5/3}$.

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

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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.

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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:
  ● Asteroid mining. Enabled by E-sail.

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