ESAIL: Electric SAIL propulsion technology


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ESAIL Partners and their roles

- Finnish Meteorological Institute, Finland: Coordinator & inventor group of E-sail
- University of Helsinki, Finland: Ultrasonically bonded E-sail tether
- University of Jyväskylä Accelerator Lab., Finland: Various vacuum tests of tether
- DLR-Bremen, Germany: Tether reel
- Ångström Space Technology Centre, Uppsala University, Sweden: Remote Unit
- Nanospace AB, Uppsala: Remote Unit cold gas thruster option
- Tartu Observatory, Tartu, Estonia: Some subsystems of Remote Unit
- University of Pisa, Italy: E-sail mission orbit calculations
- Alta S.p.A., Pisa, Italy: Remote Unit ionic liquid FEEP thruster option

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The E-sail effect

- PIC simulation with solar wind parameters

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E-sail construction

- Positive tethers (10-20 km length made of 25-50 um wire, +20-40 kV voltage)
- Up to 1 N thrust (scales as $1/r$) from 100-200 kg unit (30 km/s delta-v per year to 1000 kg spacecraft)
- Power consumption modest, scales as $1/r^2$
- Baseline approach uses non-conducting Auxiliary Tethers to stabilise flight without active control
- “Remote Units” at tips contain auxtether reels and spinup propulsion/spin control
ESAIL FP7 project results

- Produced 1 km tether
- Demonstrated unreeling after vibration test
- Tested in vacuum & under HV
- Prototyped and tested the Remote Unit
- E-sail “flight simulator”
E-sail tether factory

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Tether factory and its product

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E-sail “Remote Unit”

- Reels of auxiliary tethers and cold gas (or FEEP) thrusters to initiate and control spin

- Remote Unit $m=0.56 \text{ kg (CG version dry)}$, allowed solar distance range 0.9-4 au
ESTCube-1 E-sail test mission

- 1-U CubeSat built by Estonian students, 670 km orbit
- 10 m tether, ±500 V
- Launched May 7, 2013 (Vega/Kourou)
- Tether experiment scheduled for September 14, 2014 (!)

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Aalto-1 E-sail test mission

- 3-U CubeSat, work led by Aalto University, Finland
- 100 m tether, similar orbit as ESTCube-1
- Satellite carries also other payloads
- Planned launch 2015

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Planned E-sail missions

• **BCUBE: 3-U CubeSat in LEO with 1 km tether**
  - Demonstrate Plasma Brake deorbiting of the satellite
  - Flight-validate hardware for ECUBE

• **ECUBE: 3-U CubeSat in solar wind with 1 km tether**
  - Nearly identical with BCUBE, but different orbit
  - Measure E-sail effect in solar wind (for example, lunar mission piggyback)
  - Demonstrate simple E-sailing in solar wind

• **OLCUBE: 3-U CubeSat near Lagrange L1 point for off-Lagrange solar wind monitoring**
  - First scientific/commercial application of E-sail: space weather prediction with longer warning time

• “Production-scale” E-sail demonstration mission (NEO?)

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Conclusions

- ESAIL reached its goal: E-sail technology is at TRL 4-5
- 1 km piece of tether was successfully made
- Predicted E-sail performance level is revolutionary
  - Disruptive technology
- Outside ESAIL: ESTCube-1 is in orbit (10 m tether), Aalto-1 launched 2015 (100 m tether)
- Roadmap (still unfunded) of three CubeSat missions
  - The third one is scientific/commercial mission (off-Lagrange point solar wind monitor)

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