Studying Miniature Electrodynamic Tethers and Interaction with the Low Earth Orbit Plasma

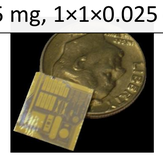
Iverson Bell, III and Brian Gilchrist

The University of Michigan

Picosatellites and Femtosatellites

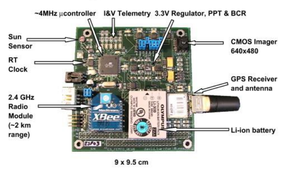
Picosats (1 kg –100 g) and femtosats (<100 g) are the next frontier in satellite miniaturization. Fleets can enable multipoint, simultaneous sensing.

Sprite ChipSat
7.5 mg, 1×1×0.025 cm

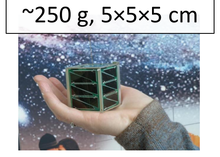


Picosat 1 and 2
250 g, few cm length

PCBSat
~300 g, 9×9.5×2.5 cm

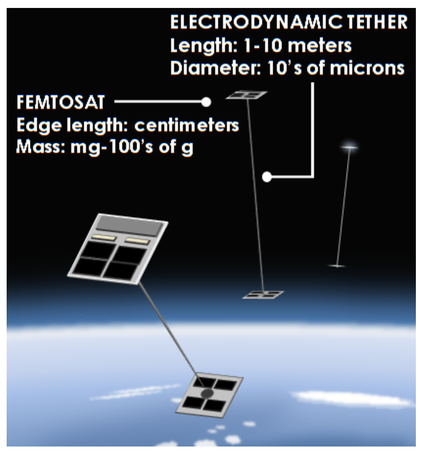


PocketQub
~250 g, 5×5×5 cm



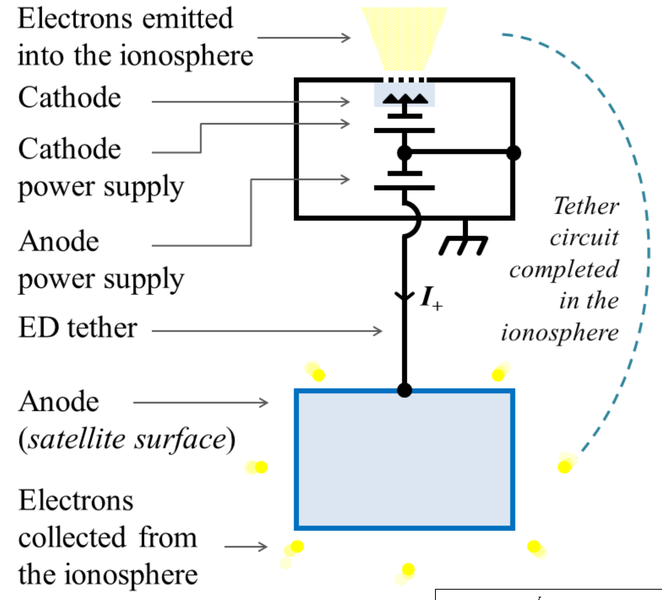
Electrodynamic Tethers for Propulsion

Short electrodynamic tethers (1–10 m) have potential to provide pico- and femtosats with propulsion



Concept of EDTs with pairs of femtosats as a maneuverable and coordinated fleet.

System Concept Illustration

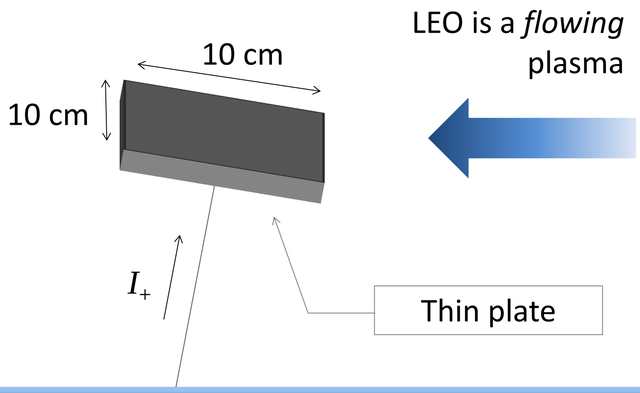


Note: each satellite is a 100-g femtosat

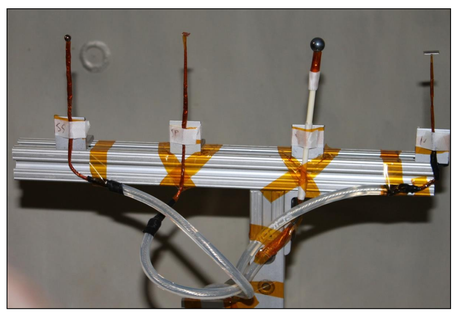
$$\mathbf{F}_{\text{Tether}} = \int_0^L (I_{\text{tether}}\, d\mathbf{L}) \times \mathbf{B}$$

Estimating Tether Current

Our goal is to simulate characteristics of the low Earth orbit (LEO) environment to refine our current estimates



Probes



The I–V curves of 2 femtosat-shaped probes were compared to the wide sweeping Langmuir probe (WLP) model, which was derived for a 10-cm diameter spherical probe in LEO

$$I_{\text{WLP}} = \frac{I_{\text{thermal}}}{2}\left(1 + \frac{q\left(V_{\text{anode}} - \Phi_p\right)}{kT_e}\right)^{0.85}$$

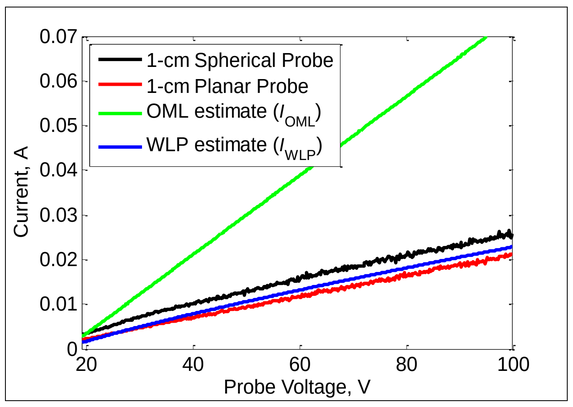
Experiment

A hollow cathode generated a flowing plasma to simulate LEO

Approx. plasma parameters

- $T_e \approx 3$ eV
- $n_e \approx 1\times10^8$ cm^{-3}
- $\lambda_D \approx 1$ mm

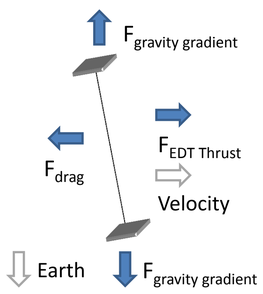
Results

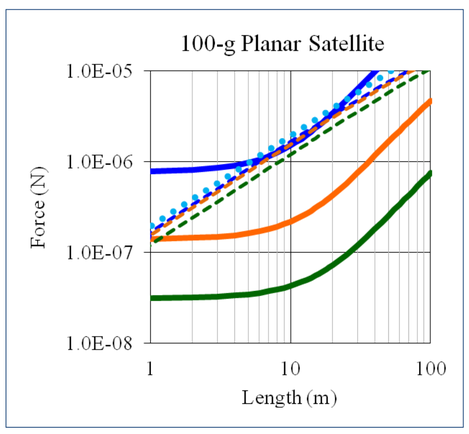


We can roughly estimate current collection by using WLP model

Force Estimates

We estimated atmospheric drag (solid line) and thrust (dashed line) at 400 km (**blue**), 500 km (**orange**), and 600 km (**green**) and the gravity gradient force (**dotted, light blue**).



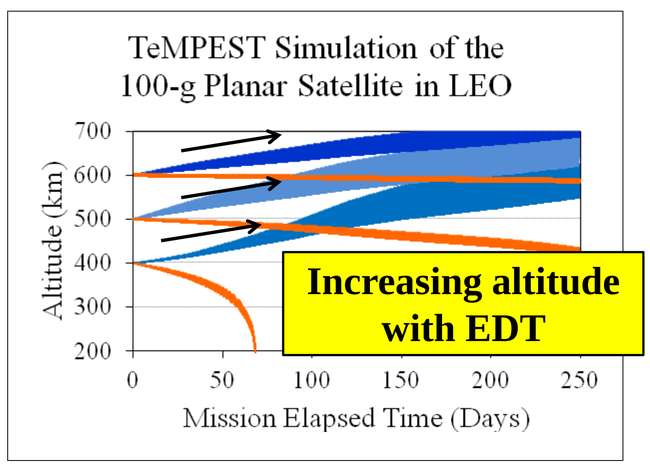


A 10 m EDT can generate thrust that exceeds drag

Simulation of Performance

We simulated:

- a satellite starting at 400 km, 500 km, and 600 km (**orange**) and
- dual satellites with an ED tether (**blue**).



Miniature Tether Electrodynamics Experiment (MiTEE)

MiTEE is a space mission being planned at U of M that will use CubeSat capabilities :

- to deploy a picosat and short tether
- study dynamics
- study anode and cathode I–V curves
- measure thrust