ESTCube-1

Estonia's first student satellite

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The mission and payload

ESTCube-1 scientific mission is to test the electric solar wind sail[1] (E-sail) technology. Using the solar winds dynamic pressure, E-sail could enable fast and affordable interplanetary and deep space missions. The sail consists of long, thin, and conductive tethers that are charged to high positive potential. For example, 100 tether, 40 kV potential, 20 km radius E-sail at 1 AU would accelerate a 1 ton satellite with 1 mm/s². The sail system would only weigh about 100 kg.

Mission parameters
- 1 unit CubeSat
- Mass ~1.3 kg
- 2 W average power generation
- 2 m and 70 cm amateur radio bands
- 600 to 800 km Sun synchronous orbit
- Orbit inclination 98 degrees

Mission phases
- Detumbling
- Nadir pointing and Earth imaging
- Spin-up in single axis to 1 rev/s
- Deployment of the tether
- Measuring the E-sail effect
- Slow deorbiting using the tether

The satellite will deploy a single 10 m long tether using centrifugal force. After deployment, the tether is charged to 450 V potential. Charged tether will interact with the ionospheric plasma, causing a breaking force. In result it will slow down the spin rate and lower the orbit. The change in angular velocity can be measured onboard.

- 10 m long, 50 µm four-fold Heytether
- 5 g white matte tether endmass
- Cold cathode electron gun
- ±450 V tether potentials

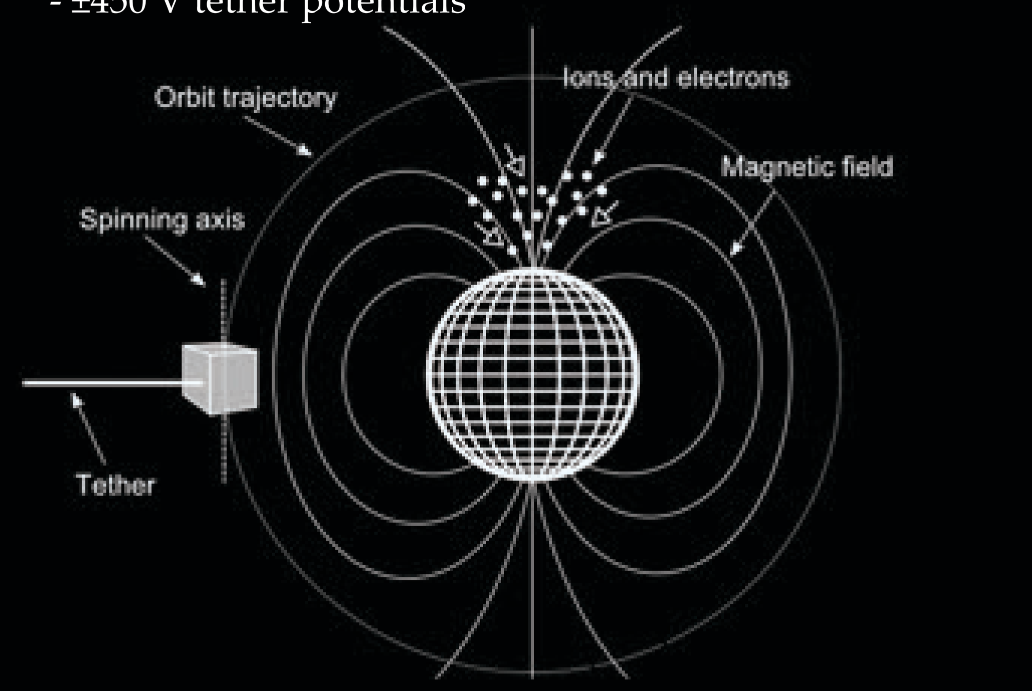


Fig 1. Tether deployment and E-sail effect experiment layout

ADCS

Attitude Determination and Control System

Detumbling, nadir pointing and giving the satellite a rotational speed of 1 revolution per second in a single axis for the experiment will be done by using only electromagnetic actuators. During a successful experiment the angular velocity will change and the ADCS is also responsible for measuring it. We determine the attitude, position and the angular velocity of the satellite by combining data from the sun sensors, gyroscope and magnetometer. The last two are duplicated for redundancy.

- 3 electromagnetic coils
- 6 dual axis sunsensors
- 2 three axis gyroscopes
- 2 magnetometers

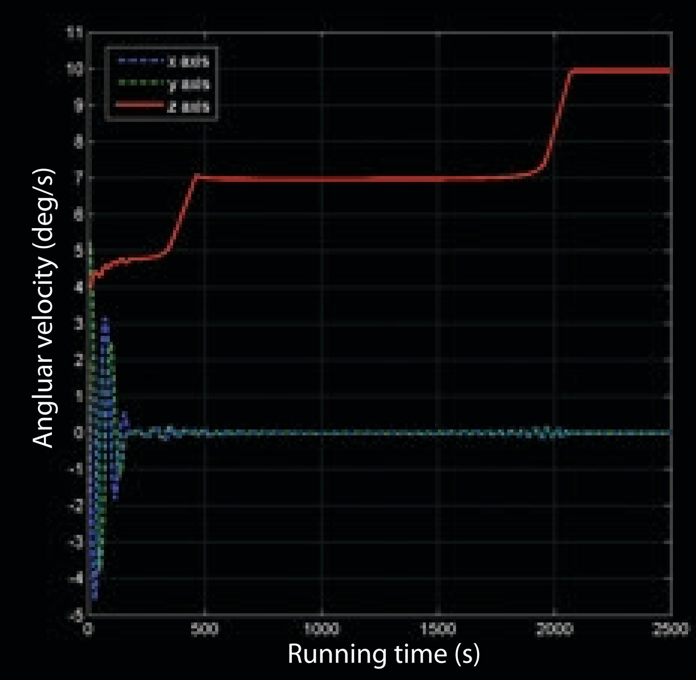


Fig 5. Single-axis spin up algorithm simulation

EPS

Electrical Power System

EPS collects, stores and distributes power in the satellite. In order to free up critical processor time, improve the efficiency and robustness of the system, special Maximum Power Point Tracking chips are used. This feature allows for the power harvesting to continue even if the processor goes offline. The system's flexibility is further improved with duplicate power regulators and dedicated latchup protection for each subsystem.

- 12 triple-junction solar cells (efficiency ~ 30 %)
- Average power produced ~2 W
- 2 cylindrical Li-Ion cells 1840 mAh
- 3 regulated voltages onboard 3.3 V, 5 V, 12 V
- Ferroelectric memory (FRAM)

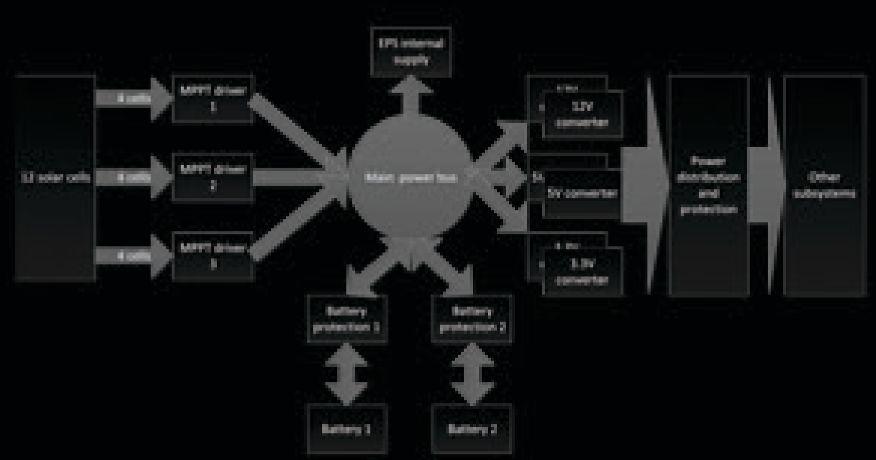


Fig 2. Redundant electrical power harvesting, storage and distribution

CAM

Camera

Custom built module based on commercially available components gives us more control over the mechanical construction, interfacing methods and the overall quality. This approach ensures that our specific needs are met. The module will be used for imaging Earth and confirming the tether deployment. Using a dedicated processor allows for computationally intensive image processing and size reduction.

- 4.4 mm lens, F/# 1.85
- 46×35 degrees field of view
- Capable of taking multiple 10-bit VGA RAW images
- Dedicated ARM processor for image processing
- 16 Mbit of memory to store three 10-bit full resolution and one 16-bit HDR image
- Low power 200 mW

Fig 4. Camera for tether and Earth imaging

CDHS

Command and Data Handling System

A real time operating system (based on FreeRTOS) enables fault-tolerant variable operations for distributing commands and data, monitoring satellite state and performing time critical ADCS calculations. Sufficient power enables us to use three-fold voting system to determine the correct results of the onboard calculations.

- 2 ARM Cortex-M3 microcontrollers
- Real time operating system
- Microcontrollers in cold-redundancy
- Ferroelectric memory (FRAM)
- 3 flash memory modules
- Memory in hot-redundant mode

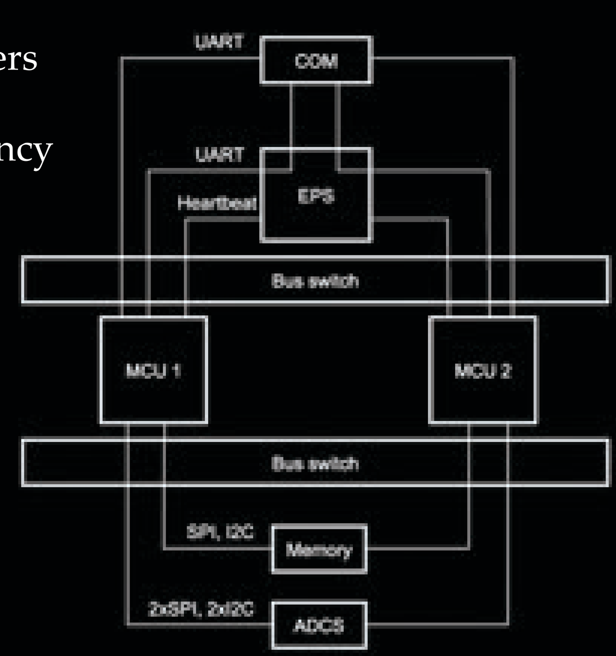


Fig 6. Fault tolerant system design of ESTCube-1

STR

Structure

The satellite's frame has been milled out from a single piece of aluminium to provide strength and durability. Two solar cells can be mounted on all sides including the antenna deployment side, 4 antenna configuration is supported, but two anetennas are used. The PCB stack consists of 7 boards and shares a single 120 pin bus.

- Frame mass 97 g
- STR total mass 295 g
- PCB dimensions 92×94 mm

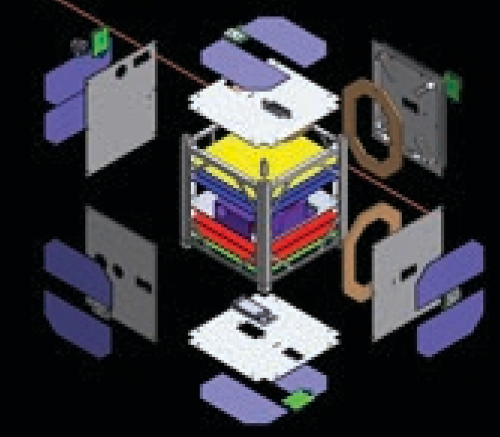


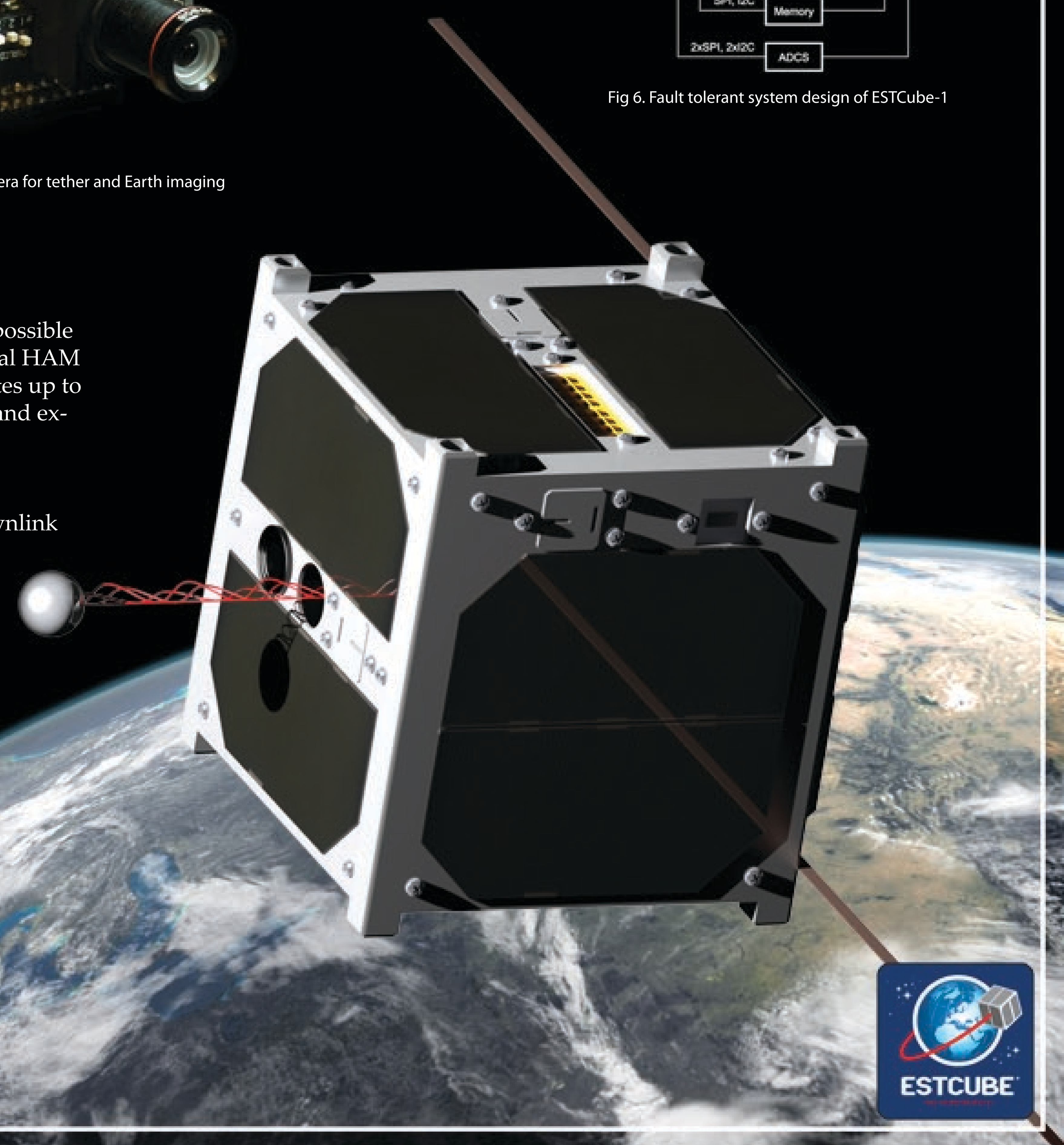
Fig 3. Monoframe assembly

COM

Communications

The use of 2 m and 70 cm bands make it possible for the GENSO operators and international HAM community to reach our satellite. Data rates up to 9600 bps are used for regular operations and experimental speeds go up to 19200 bps.

- 2 quarter wave monopole antennas
- 437.505 MHz UHF for beacon and downlink
- 145 MHz VHF for uplink
- Callsign ES5E/S
- 0.5 W FSK/MSK downlink
- 0.1 W CW beacon 17 WPM



[1] Janhunen, P., et al., Electric solar wind sail: Towards test missions (Invited article), Rev. Sci. Instrum., 81, 111301, 2010