



TARTU OBSERVATORY
space research centre



esa



UNIVERSITY OF TARTU

Overview of the ESTCube-1 nanosatellite project

Tartu Observatory, Space Technology Department
University of Tartu, Institute of Physics

Full list of contributors available at
www.estcube.eu

CCF/OHDXF/ERAU Winter Meeting 2014

What is the ESTCube Project?





Aim of the project/mission

Soft goals:

- Give our students unique hands-on engineering and project management experience
- Popularise science in Estonia, main target being current and future uni students
- Promote Estonia, its students and engineering companies in the space sector

Hard goals:

- Demonstrate the Electric Solar Sail technology
 - Test the system to deploy a long tether in space
 - Take images of the deployment of the tether
 - Measure the E-Sail force
- Take an image of Estonia if possible
- Create infrastructure for future space missions

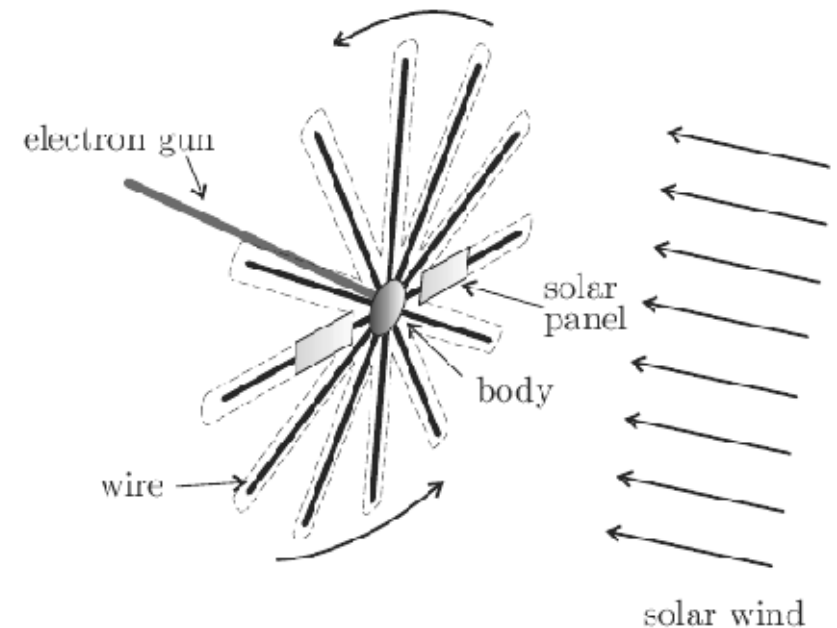
Electric Solar Sail (E-Sail)

Invented by Pekka Janhunen (FMI) in 2006

Consists of long multi-strand conductive tethers (25-50 μ m) and electron guns

Converts solar wind momentum into thrust

- Tethers are charged with high voltage
- Electron guns are used to dissipate the opposite charge
- Charged particles of the solar wind are deflected and momentum is transferred to the spacecraft



Electric Solar Sail (E-Sail)

Baseline full scale mission

100 tethers, each 20km long

1N thrust at 1AU (1 mm/s² acceleration for 1000kg spacecraft, 600 m/s in a week)

E-sail weight ~150kg

Thrust vector controllable

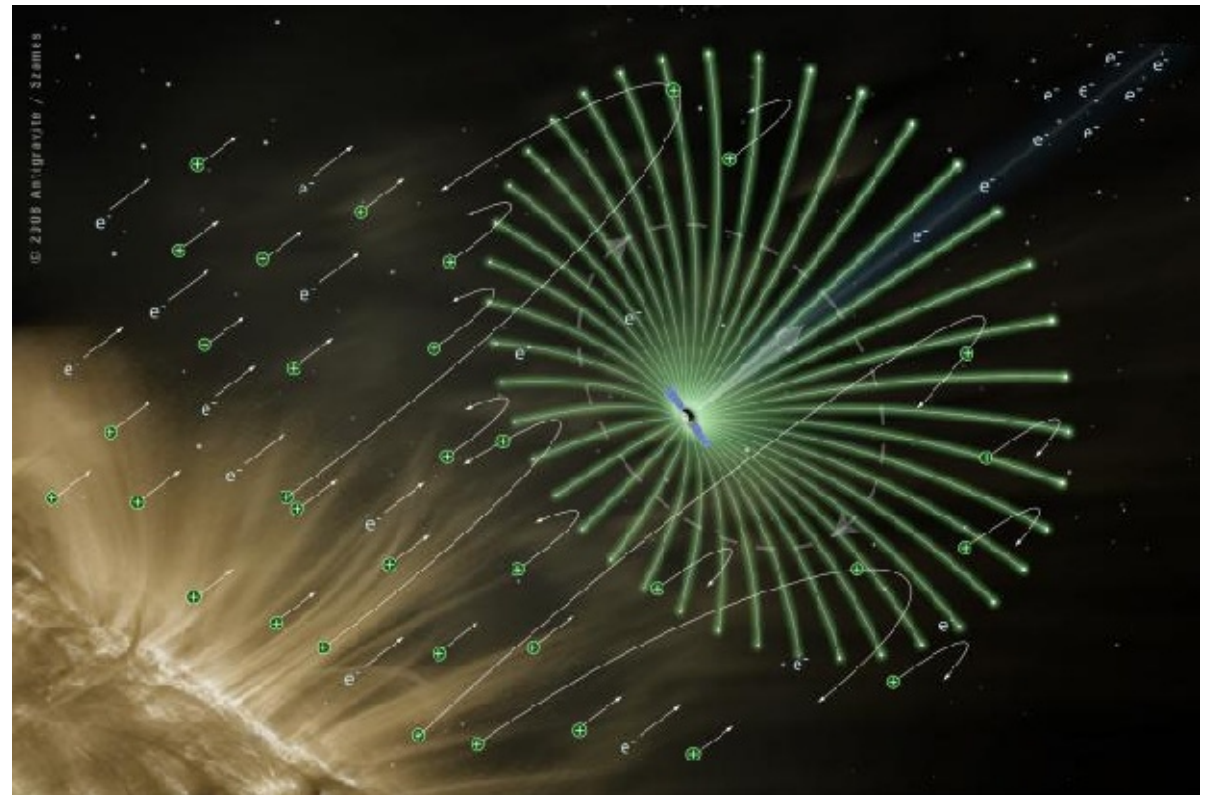
by tilting the sail plane

Applications

Multi-Asteroid touring

Mercury sample return

.....

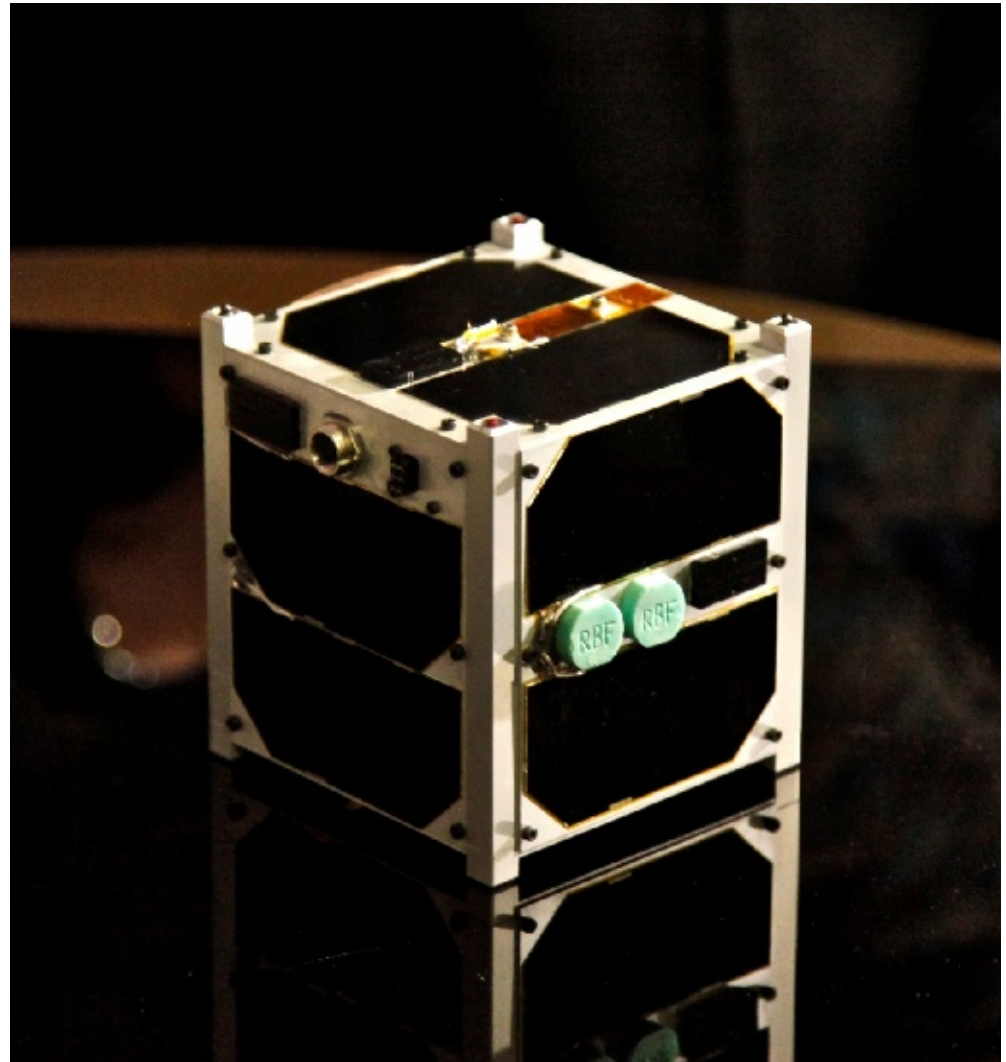
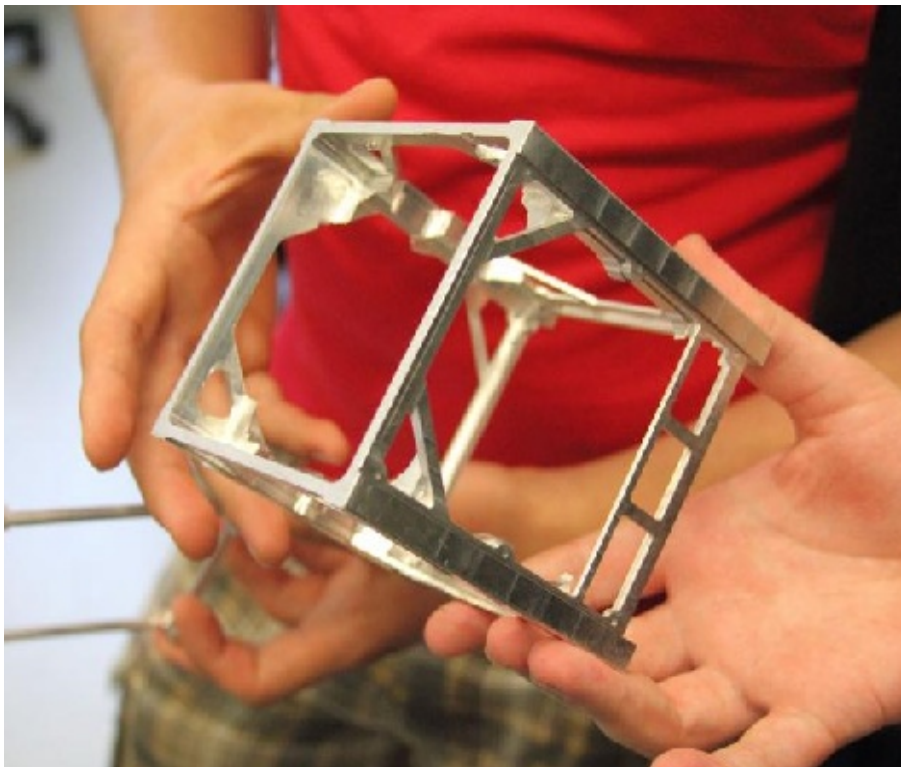


The Satellite

1U Cubesat

10x10x11 cm, 1.05 kg

Custom designed subsystems stacked inside
Sides covered with solar panels



The Satellite

Electrical Power System (EPS)

Command and Data Handling System (CDHS)

Attitude Determination and Control System (ADCS)

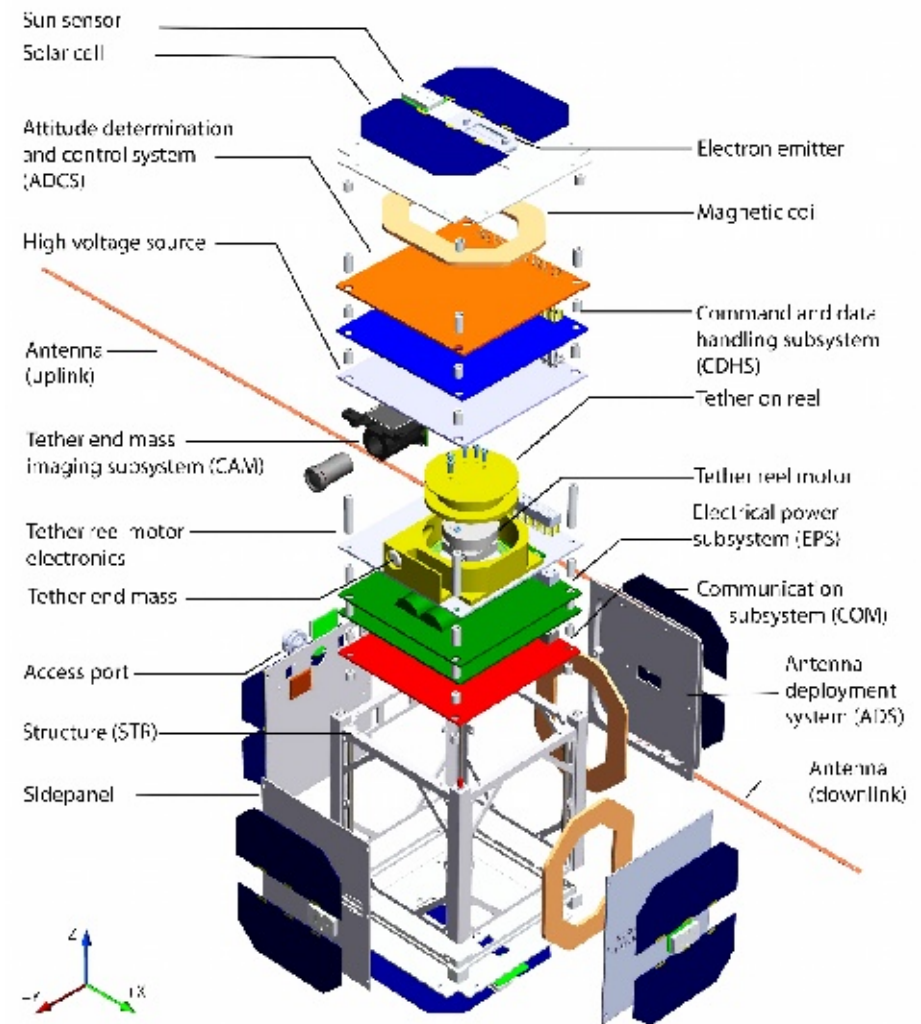
Communication System (COM)

Imaging System (CAM)

Structure (STR)

Payload

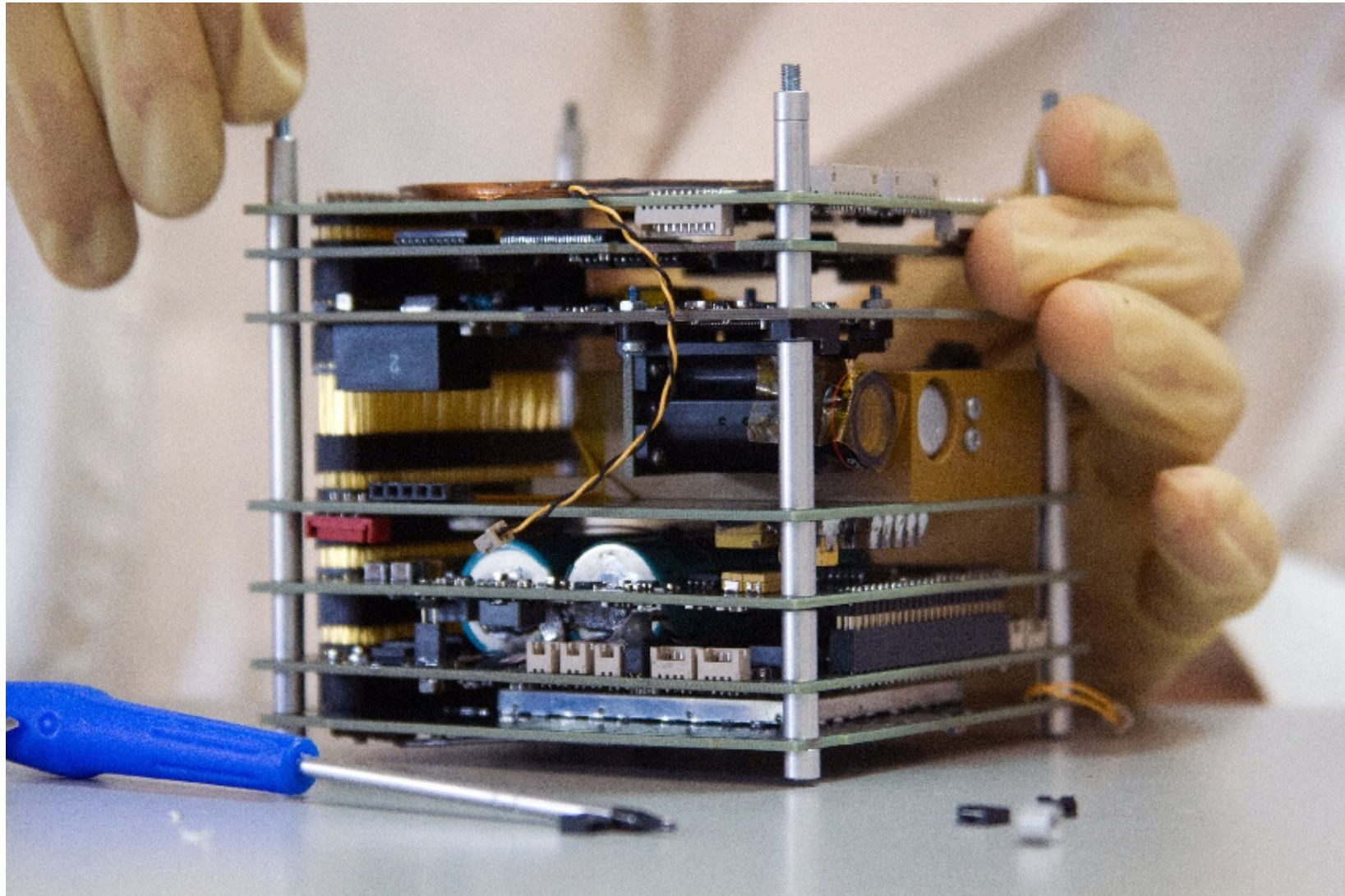
- Tether, reel and motor
- Electron gun with high voltage source



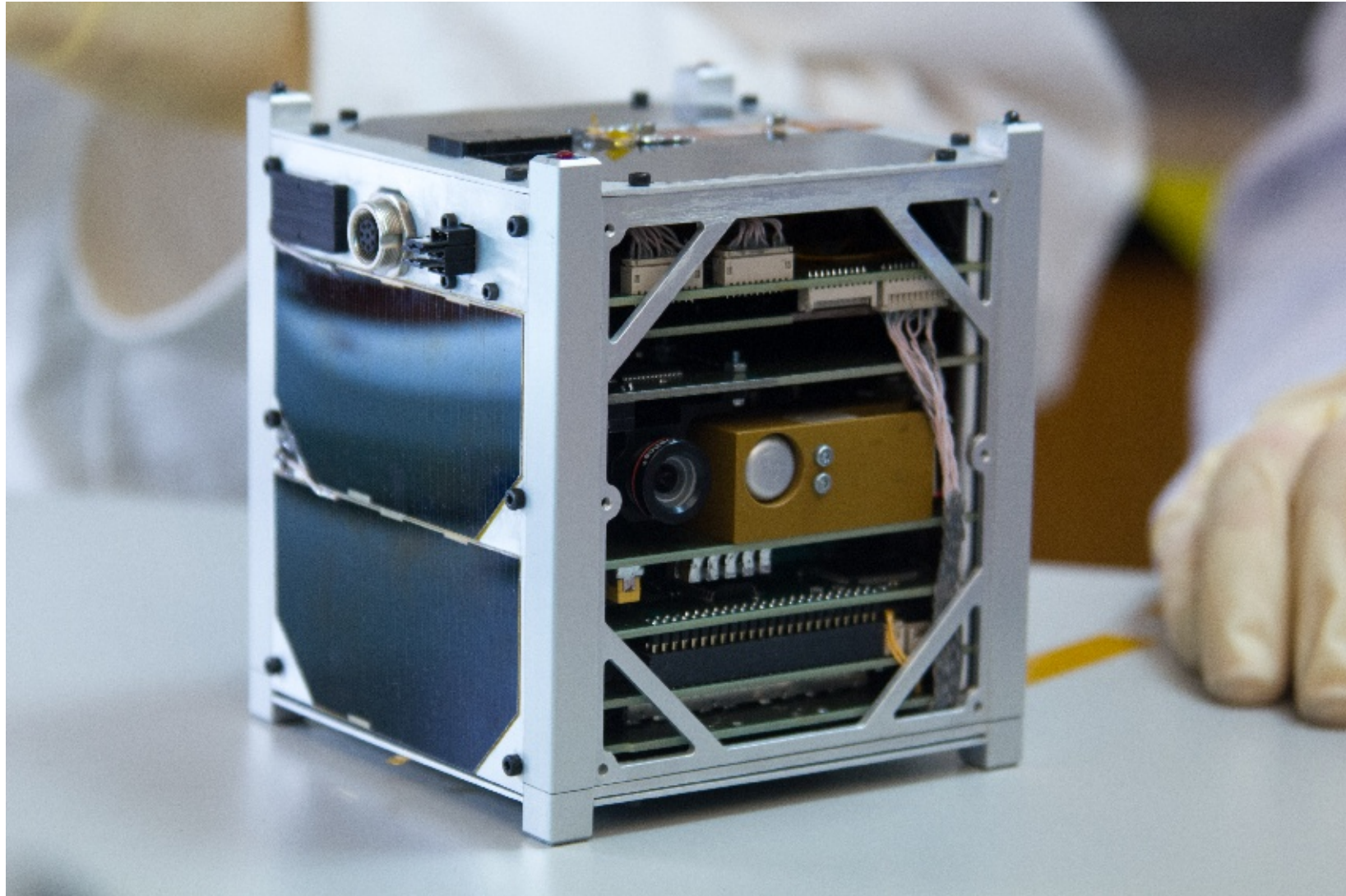
Subsystems



Satellite Integration



Satellite Integration



Autoportrait



Communication

(<http://www.estcube.eu/en/radio-details>)



Ground stations at Tähe 4, Tartu and Tartu Observatory, Tõravere

Packet Beacon

Freq 437.505

GMSK modulation

9600 bps G3RUH

500 mW

AX.25 UI frames

CW Beacon

Freq 437.250

9 bps / 18 wpm

Period 3-10 min

100 mW





Project Timeline

2008

In summer – the project is started and the „crazy idea“ broadcast in media
Active search for a scientific mission for ESTCube-1

2009

First version of principal design complete in spring 2009

2010 – 2011

Improvements of the overall design
Design and simulation of subsystems
First lines of software coded

Spring 2012

First pieces of hardware prototypes finished
Several student theses completed on different subsystems

E-Sail Experiment on ESTCube-1

Single 10m long tether, Single electron gun, 500V voltage source

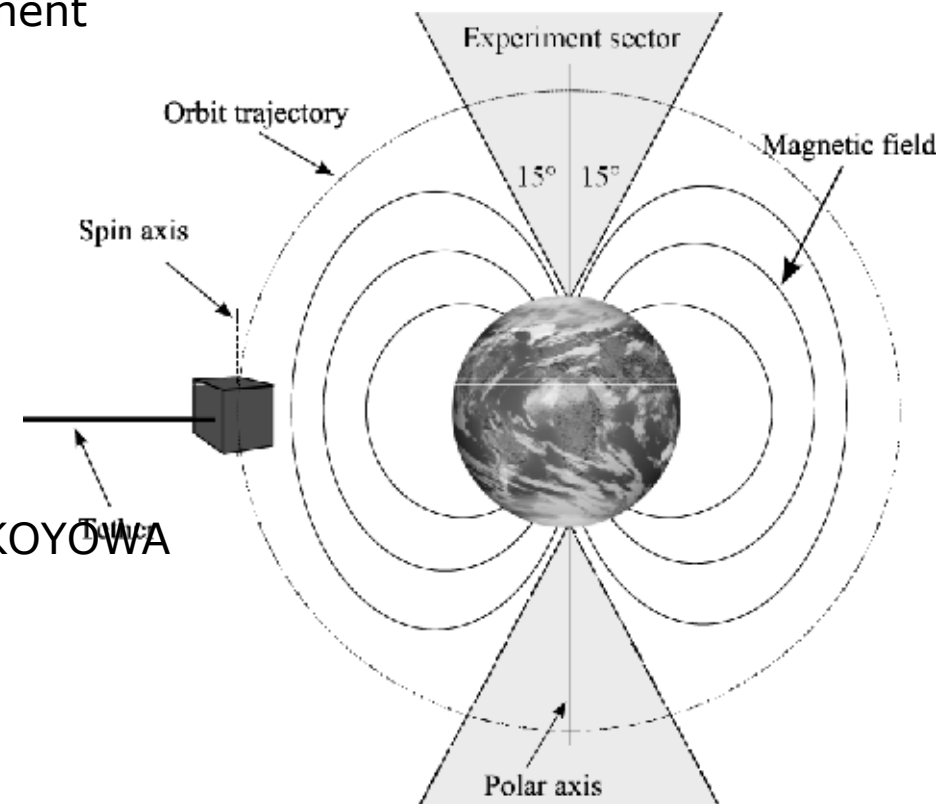
Deployment:

- Spin up satellite to 1 rps, align spin axis with Earth's polar axis
- Deploy tether in stages using centrifugal force and piezoelectric motor
- Take images of endmass to verify deployment

Experiment:

- Synchronise electron gun with sat spin
- Measure change in spin rate
- Estimated change 0.3 deg/s per pass
- Max E-Sail force is $\sim 1 \mu\text{N}$

<http://www.youtube.com/watch?v=WKnYPKOYOWA>





Project Timeline

October 2012

- Engineering Model manufactured and integrated
- First pieces of flight hardware manufactured

December 2012

- Most flight hardware components finished
- Active testing of flight hardware and software

January 2013

- Late evening 20.01 – Final reel of tether arrives at Tartu
- Early morning 21.01 – Final integration of flight hardware completed in Tartu
- Noon 21.01 – Final press conference in Tallinn presenting the finished satellite
- Evening 21.01 – The satellite is sent off to ISIS, Netherlands



Project Timeline

February – April 2013

Lots of programming and software testing

Two support missions to ISIS and one to Kourou

End of April – EC1 is mounted to the Vega payload capsule

May 2013

04.05 – First launch attempt, postponed due to weather

07.05 05:06 – Successful launch of EC1 on board ESA's VEGA launcher

07.05 07:07 – EC1 separates from the launcher into stable orbit

07.05 ~9am – Email from Dmitry Pashkov (UB4UAD) with details of first contact

07.05 10:31 – First CW beacon reception in Tartu

15.05 – First image of Earth taken by CAM

http://www.youtube.com/watch?feature=player_detailpage&v=FsFmKEVoBRc#t=188



Life in Orbit

3967 orbits completed, >175 600 000 km travelled (more than 1AU)

Sun sync orbit, average altitude 670 km

Activities:

- Subsystem testing and software upgrades

- Taking images of the Earth

- Radio ranging from Tähe 4, Tõravere and Darmstadt (CGI)

Data transfer:

- 121 complete images, ~50 MB total data downlinked

- 15 software updates uplinked

Issues:

- Solar panel degradation

- Space debris <http://www.youtube.com/watch?v=1mZe-KhgeNI>

- Software hickups, ADCS calibration



Future Plans

ESTCube-2

Stepping stone for ESTCube-3

3U Cubesat in Low Earth Orbit

Technologies to be tested for EC-3

- E-Sail with a longer tether (up to 1km)

- Small cold gas thrusters from Nanospace

- Star tracker

- 2.4 or 5.7 GHz downlink

ESTCube-3

3U Cubesat in Moon orbit or at a Lagrange point

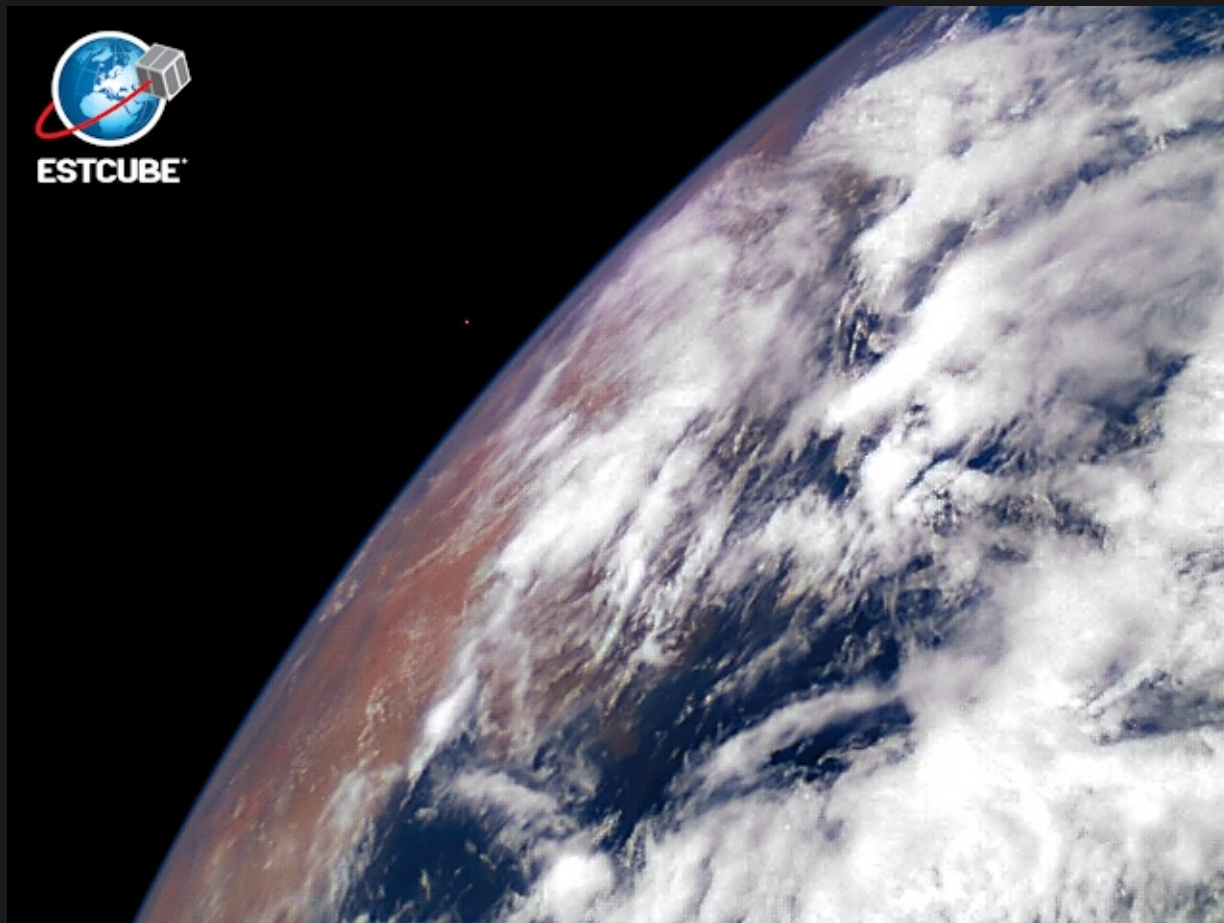
Test E-Sail in pure solar wind away from the Earth







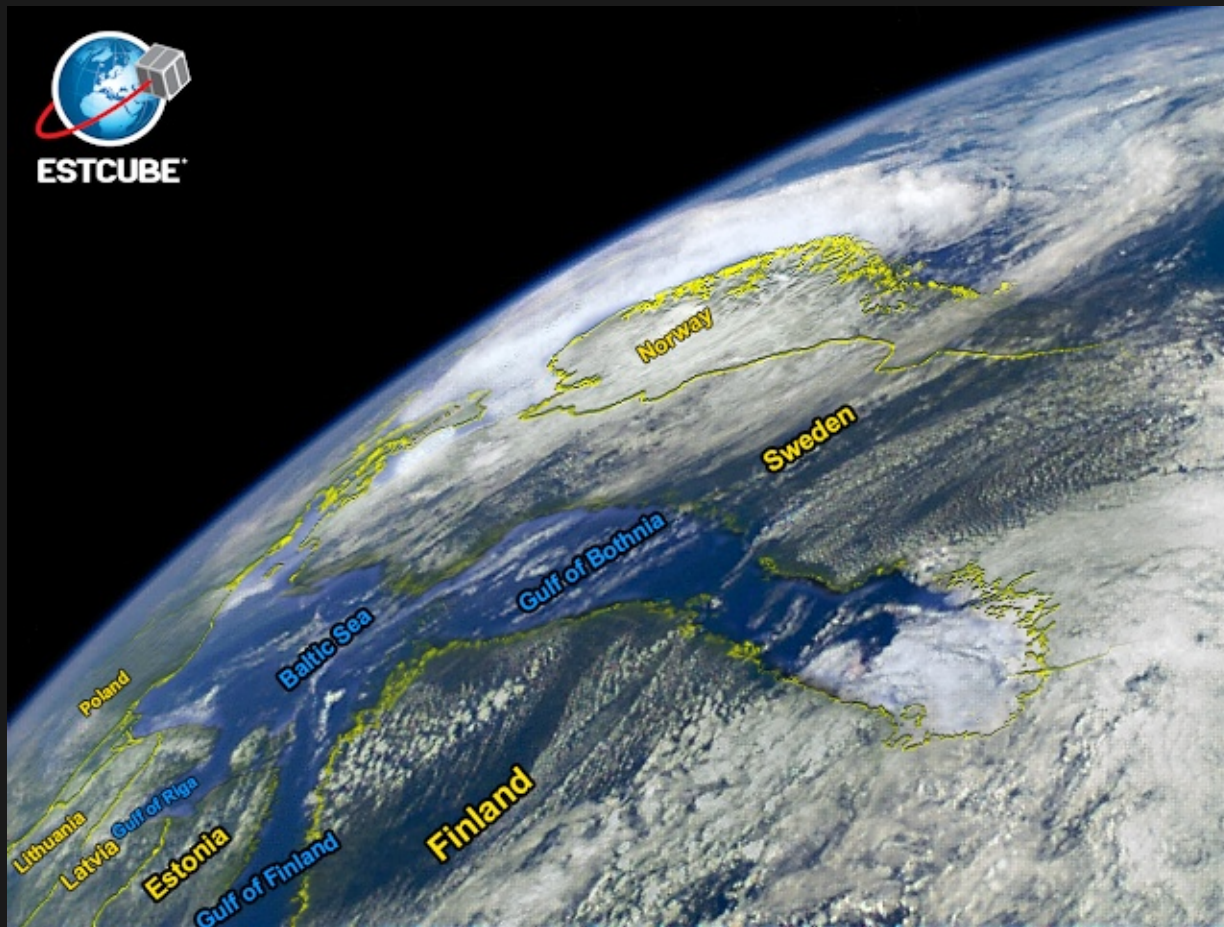




First Image by EC-1: Mediterranean and North-Africa, 15.05.2013



Scandinavia, 16.08.2013



Scandinavia, 16.08.2013



Corsica, Sardinia, Mallorca, Gibraltar, Libya, Tunisia, Algeria, Morocco



Brazil, French Guiana, Suriname, 04.10.2013



Australia, Northern Territory, Gulf of Carpentaria, Arafur Sea, Timor Sea, 05.10.2013



Chad, 15.10.2013



Gulf of Oman, Iran, Oman, United Arab Emirates, Saudi Arabia, 19.10.2013



Vietnam, Cambodia, 28.10.2013



The Himalayas, Tibet, Bhutan, Nepal, India, 03.11.2013



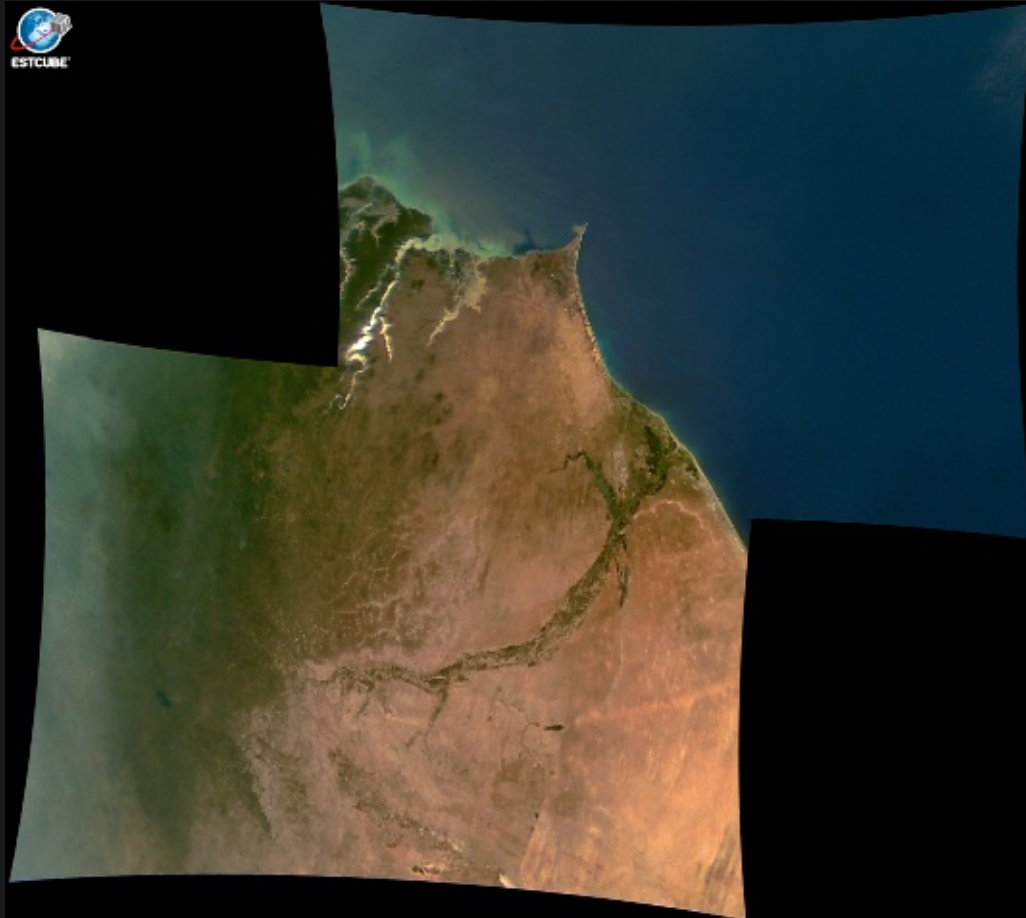
Yucatan Peninsula, 17.11.2013



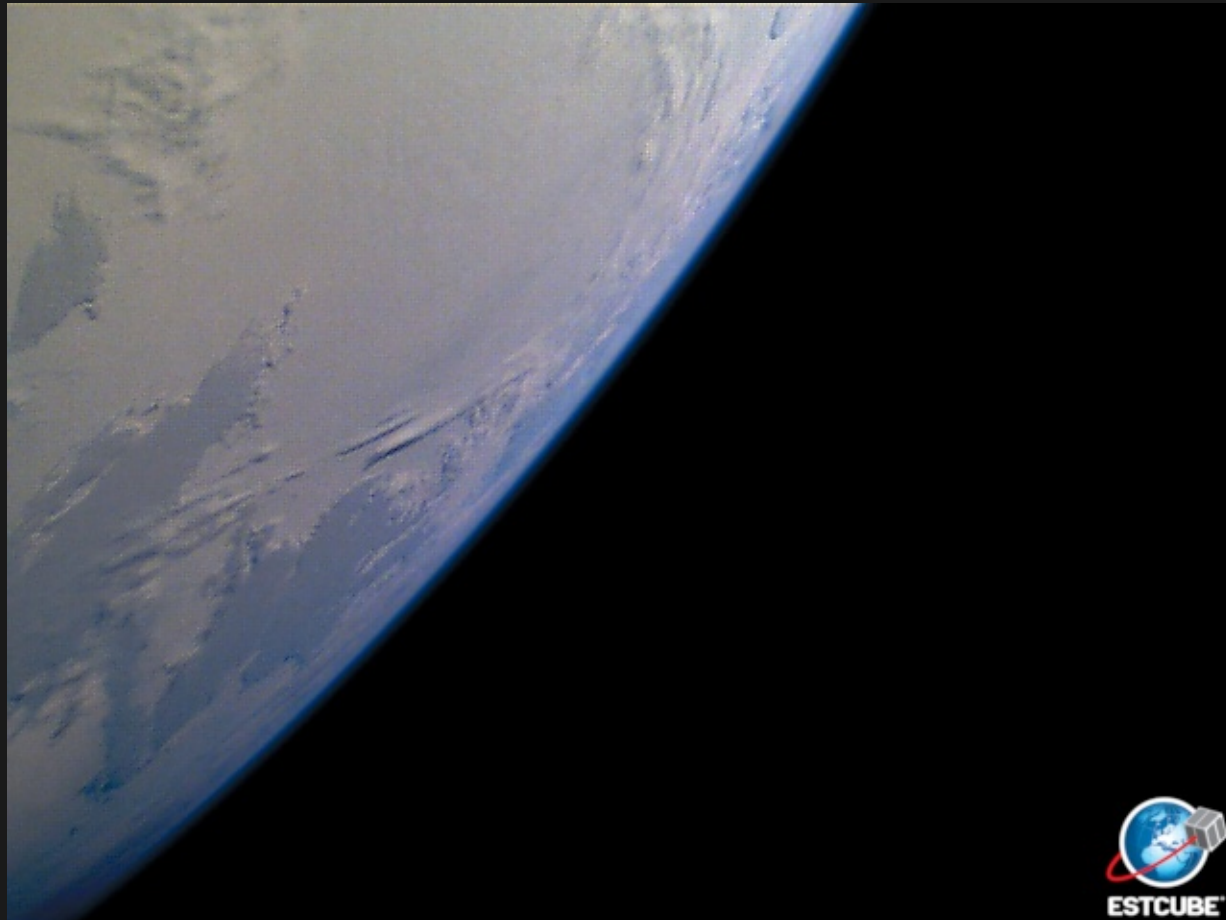
Algeria, Morocco, Mauritania, Mali, 27.11.2013



Yemen, Red Sea, Eritrea, ..., 08.12.2013



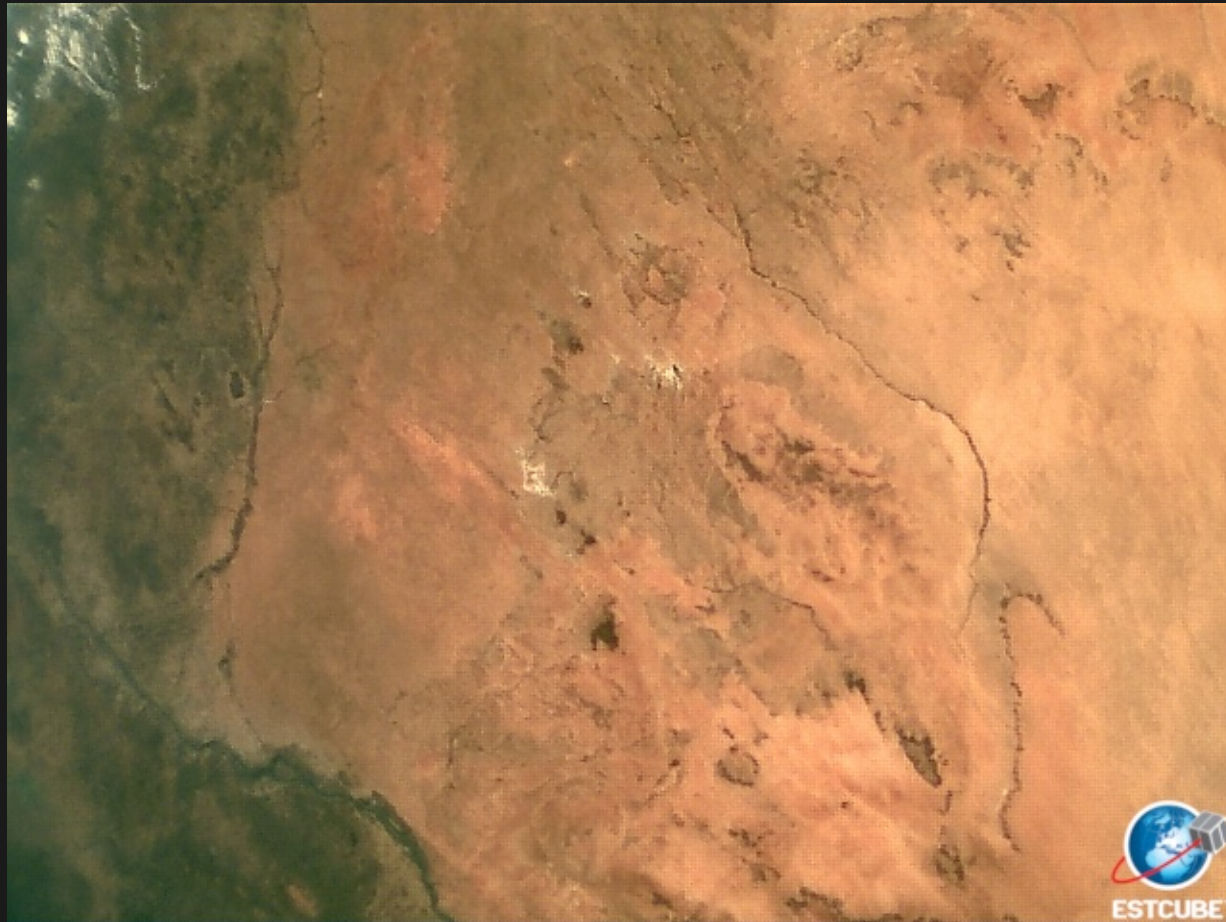
Gambia, Mauritania, Senegal, 28.12.2013



Antarctica, 06.01.2013



Gulf of Aden, Red Sea, Yemen, Djibouti, Eritrea, Saudi Arabia, 18.01.2014



Sudan, 23.01.2013, Last downloaded image



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