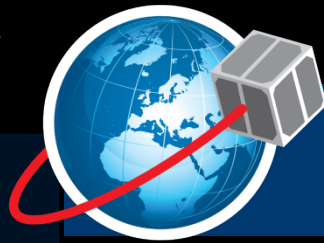


TARTU OBSERVATORY  
space research centre



**ESTCUBE**<sup>+</sup>

per solem ad astra

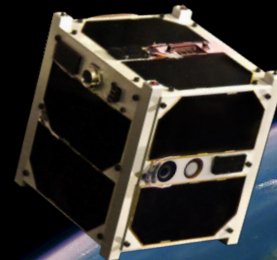


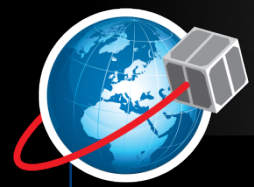
# ESTCube-1 from the beginning to the end

**Paul Liias**

**12th Annual CubeSat Developers' Workshop**

**April 22, 2015**

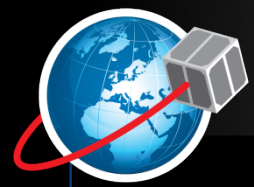




# ESTCube-1 the beginning

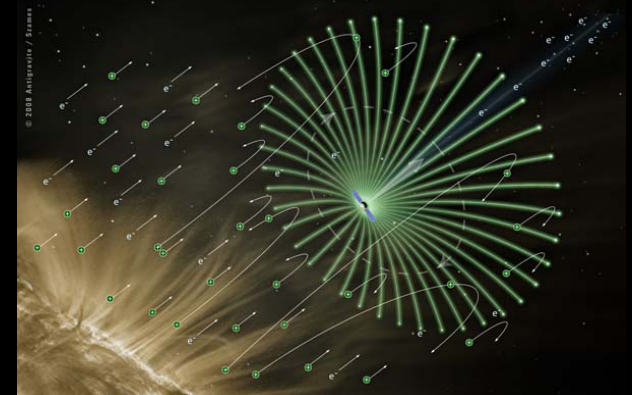
- **ESTCube-1 is the first satellite of Estonia**
- **Started in the summer of 2008**
- **Initiated by University of Tartu and Tartu Observatory**
- **Project objectives**
  - Support Estonia with new generation of successful engineers and scientists
  - Help mankind to explore space
- **Mission to demonstrate electric solar wind sail (Esail) was found in October 2008**

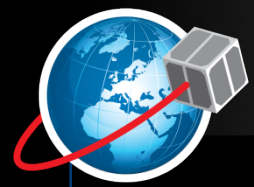




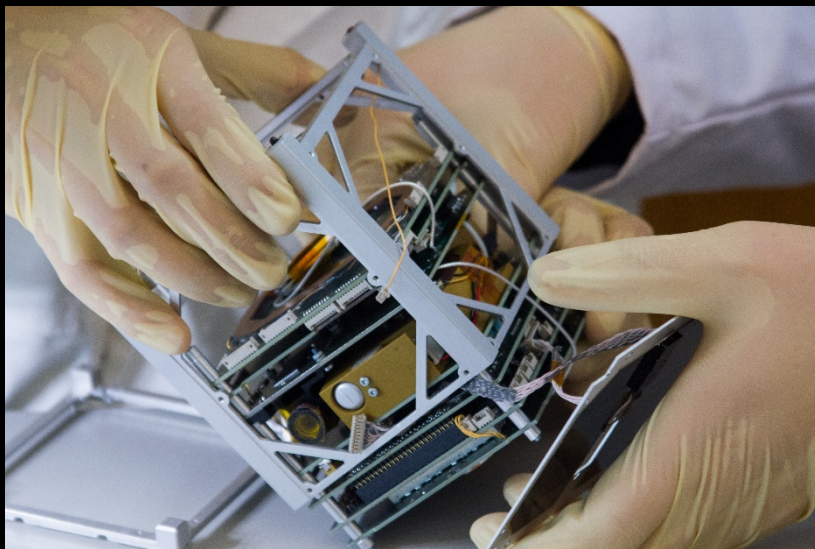
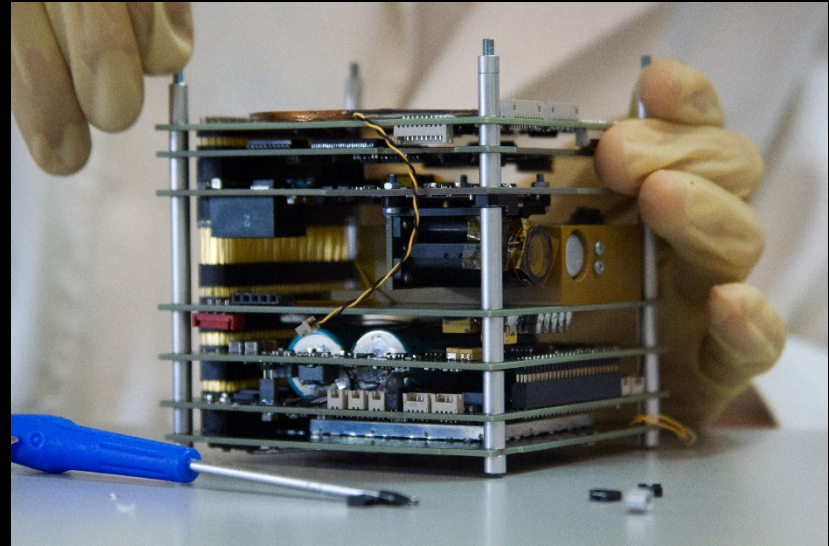
# ESTCube-1 scientific objectives

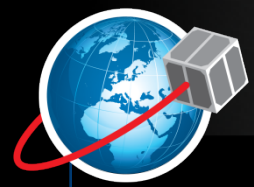
1. Develop satellite...
2. ...which would work in space
3. Study technical solutions
  1. Spin up the satellite
  2. Develop suitable subsystems
4. Mission to test components and solutions for Esail
  1. Esail tether deployment system
  2. Electron gun
5. If deployment succeeds, measure the interaction between charged tether and atmospheric plasma
6. Secondary: image Estonia





# ESTCube-1 assembly images

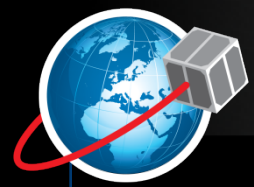




# ESTCube-1 selfie



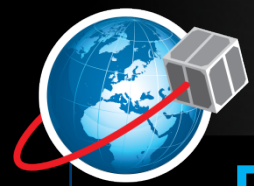
A photo of the satellite in the mirror, made by the camera onboard the satellite at the Guiana Space Centre in Kourou. The satellite is connected to the access port device, which is used to communicate with the satellite before launch.



# ESTCube-1 launch

- May 7th, 2013 on Vega from Kourou

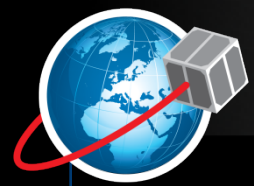




# ESTCube-1: two years in numbers

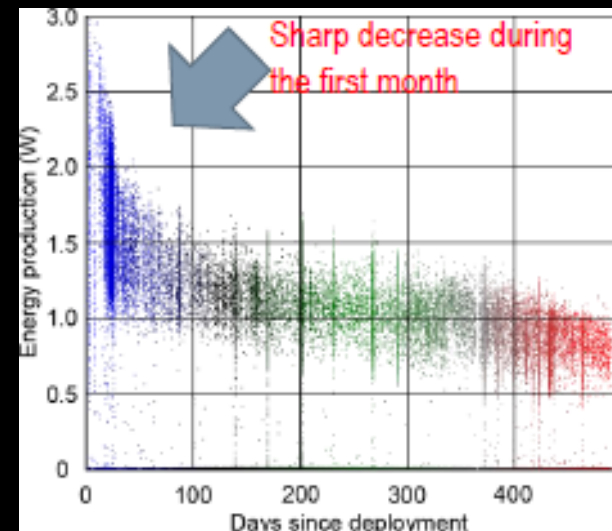
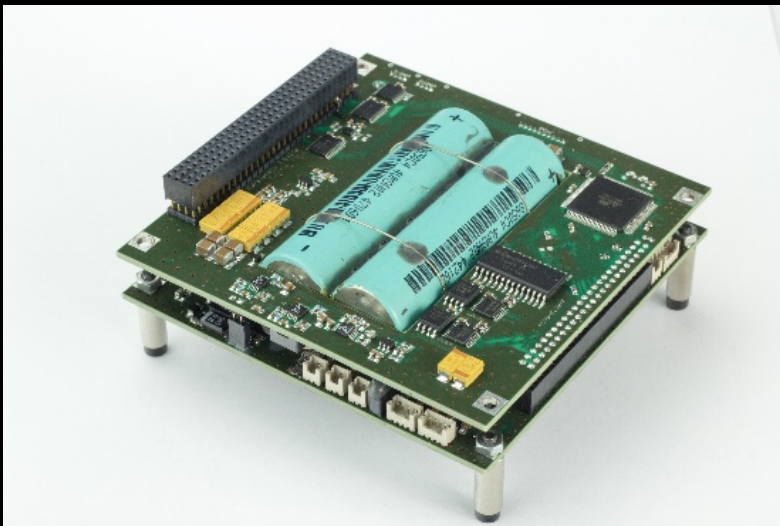
- 5100+ two-way communication sessions
- 300+ MB data downloaded
- 10500+ orbits around Earth
- 32 software updates
  - 11 EPS, 2 CAM, 19 CDHS
- 300 full images (375 KB each)





# Electrical power system (EPS)

- **Still alive and subsystems operational, but power production has decreased significantly due to the lack of cover glass**
  - Only EPS enabled. Everything else turned off. COM also disabled except for ~20 minutes per day during couple of passes
  - This way battery keeps its voltage level but power production is expected to decrease even further



*Design and pre-flight testing of the electrical power system for the ESTCube-1 nanosatellite, M. Pajusalu, 2014*

*Electrical Power System for ESTCube-1 nanosatellite lessons learned from in-orbit operations, M. Pajusalu, 2014*

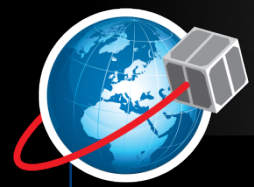




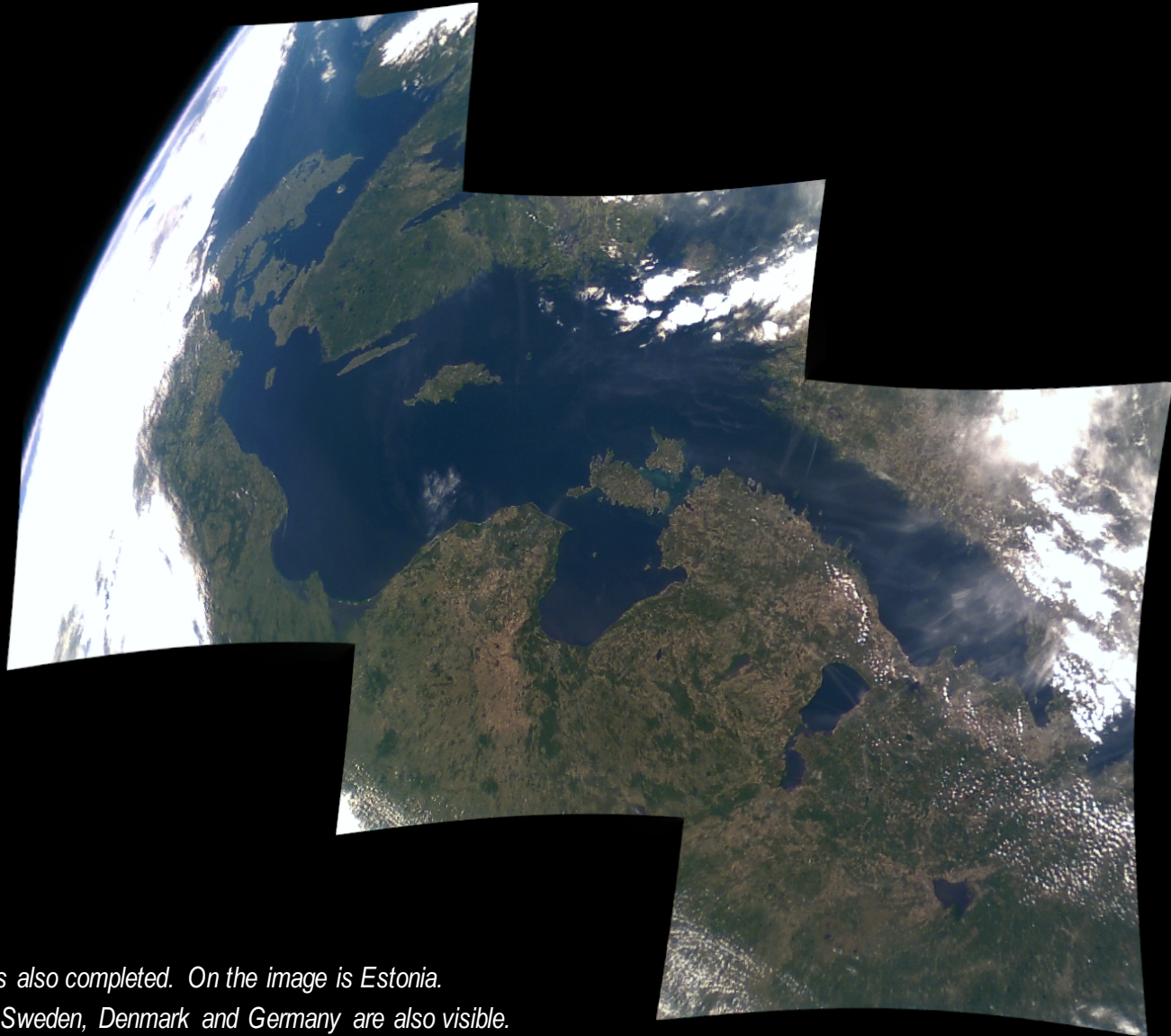
# 300th and the last image of California



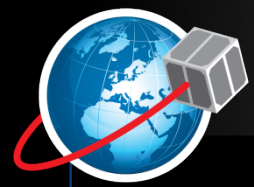
*The last and 300th full image downloaded by ESTCube-1. Image is not yet color corrected. On the left is Los Angeles and on the right is San Jose. San Luis Obispo is in the middle of the image.*



# Estonia and the Baltic Sea

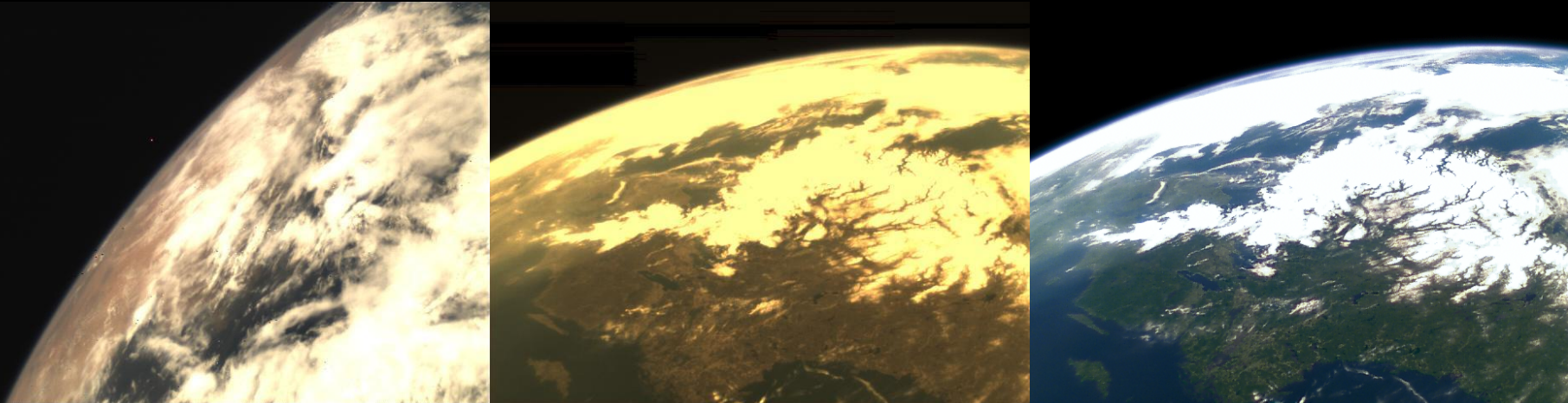


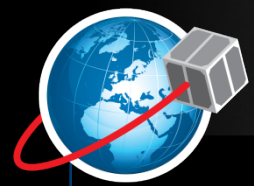
*Secondary objective was also completed. On the image is Estonia.  
Latvia, Russia, Finland, Sweden, Denmark and Germany are also visible.*



# Extreme conditions for CAM

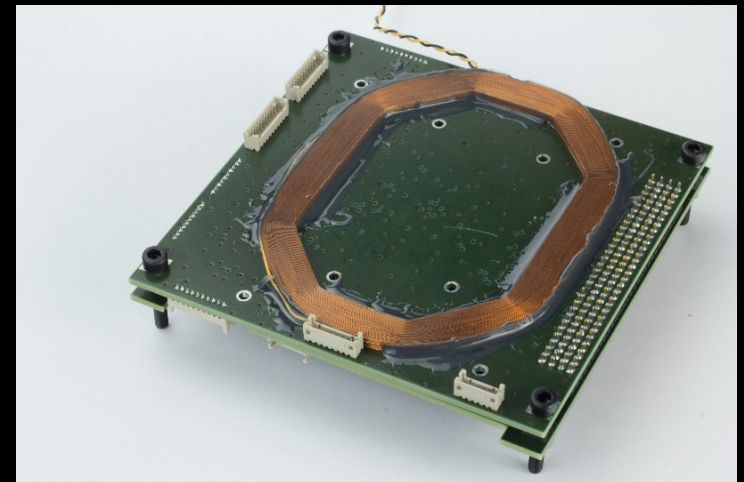
- **Images are becoming more yellow**
  - First raw ESTCube-1 image on the left. Image after a year in orbit in the middle.
- **Probably due to the changing properties of camera filters**
- **Fixed by adjusting sensor Red and Blue gains to get neutral image.**
- **Process slow enough for CAM to be well usable for ~4 years**

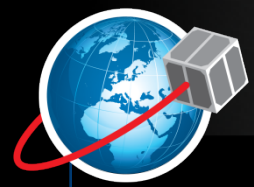




# Attitude determination and control

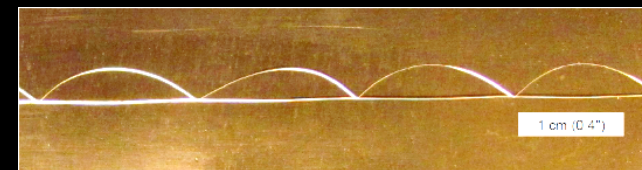
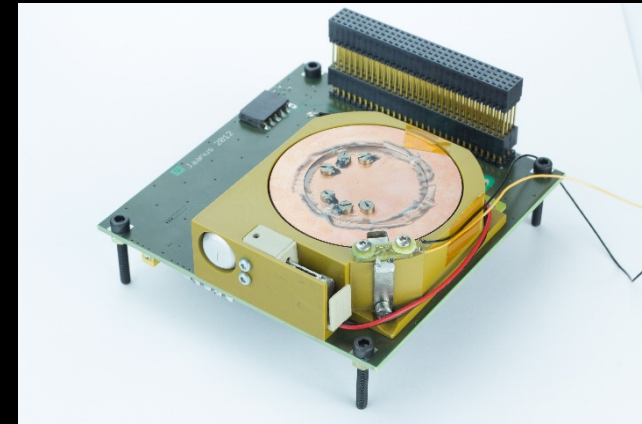
- **Attitude determination uncertainty  $< 2$  degrees**
- **Large internal magnetic disturbance (residual moment)**
  - Probably due to ferromagnetic battery casings and stack connectors
  - Stronger than the magnetic moment of magnetic torquers
  - Made pointing and inertial alignment very difficult
  - Detumbling and spin-up were still possible
- **Achieved controlled spin-up to 841 deg/s with magnetic torquers**
  - Small effect on power production and communications

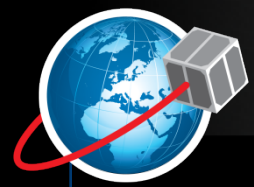




# Experiment mission log

- Satellite was spinning 250 deg/s (optimal to deploy 3 m of tether)
- Burned tether reel lock and endmass lock
- Reeled 5 cm of tether
- No endmass visible on images and no change in angular velocity
- Tried several times and spun-up satellite to 841 deg/s and tried again, still no result
- Later determined that motor was not physically rotating
- Probably due to mechanical damage to tether reeling system during launch





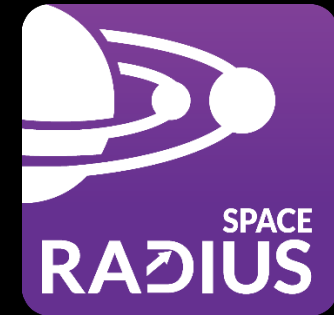
## Scientific results in numbers

- 19 MSc
- 29 BSc
- 2-5 PhD in progress
- 5 spin-offs
- 12 scientific publications (5 being finished)
- 54 scientific presentations



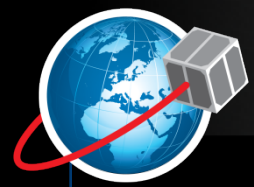
## Spin-offs

- **Radius Space** [www.radiuspace.com](http://www.radiuspace.com)
  - Structures and deployable systems, manufacturing service
- **Cubehub** [www.cubehub.io](http://www.cubehub.io)
  - Global ground station network service
- **Crystalspace** [www.crystalspace.eu](http://www.crystalspace.eu)
  - CubeSat EPS, sun sensors, COM etc
- **Taevanael**
- **Krakel**

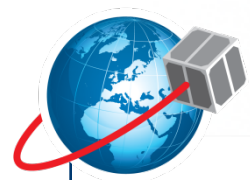


cubehub

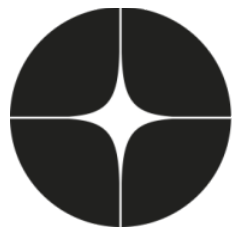
Crystal  
SPACE







**Paul Liias**  
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TALLINN UNIVERSITY OF TECHNOLOGY



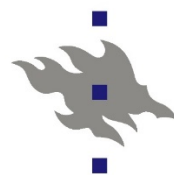
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FINNISH METEOROLOGICAL  
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UNIVERSITY OF HELSINKI



UNIVERSITY OF  
EASTERN FINLAND

