

TARTU OBSERVATORY
space research centre



ESTCUBE⁺

per solem ad astra

ESTCube-1 student satellite in-orbit experience and lessons learned

*10th IAA Symposium on Small Satellites for Earth
Observation*

Berlin, Germany

Andris Slavinskis et al.

23.04.2015



FMI



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DoRa

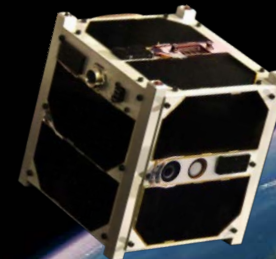


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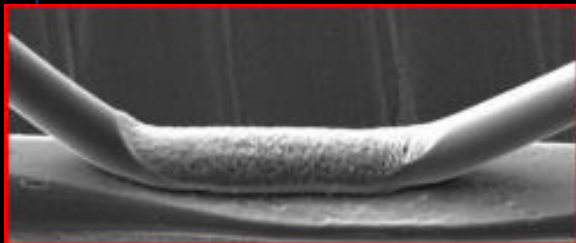
ARCHIMEDES

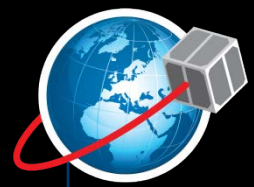




Electric solar wind sail (E-sail)

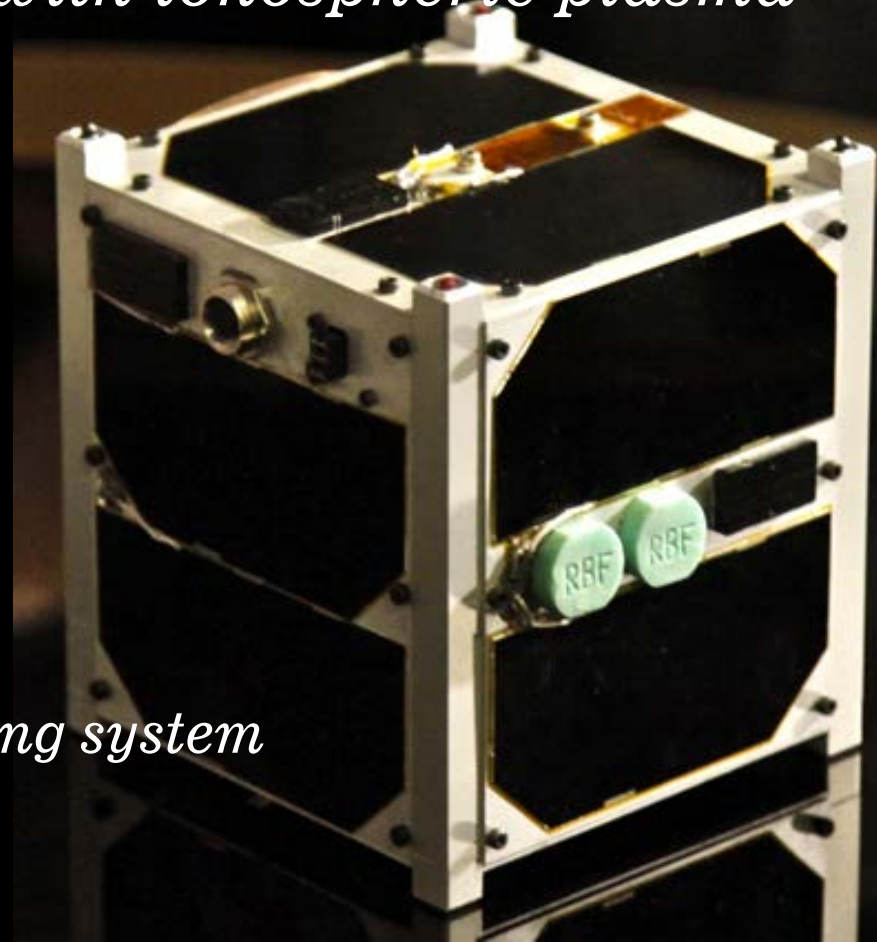
- *Propellantless propulsion system*
- *Charged long thin tethers*
- *Charged particles in the solar wind*
- *Invented by Pekka Janhunen (FMI)*
- *Record fast transportation in Solar System*
- *Enables new missions*
- *Spin-off: plasma brake for deorbiting*
- *Has to be tested!*

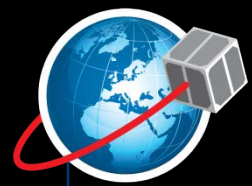




ESTCube-1 overview

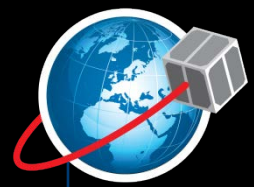
- *Project started in 2008*
- *First E-sail in-orbit experiment*
- *10-metre tether interacts with ionospheric plasma*
- *Subsystems*
 - *Attitude control to spin up satellite*
 - *Payload to deploy tether*
 - *Camera to image tether end-mass*
 - *Attitude determination to measure E-sail force*
 - *Electrical power system*
 - *Command and data handling system*
 - *Communication system*
 - *Structure*





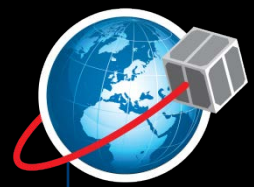
In-orbit experience

- *In August 2012 schedule was accelerated by moving delivery date from May to January, 2013*
- *Launched on May 7, 2013 on board Vega*
- *Successful early operations*
- *Software updates*
 - *Power saving methods and modes (EPS, CDHS, CAM)*
 - *Timed beacon function (EPS)*
 - *Data logging functions (EPS, CDHS, ADCS)*
 - *Stability updates/bug fixes (EPS, CDHS, ADCS)*
 - *ADCS software (runs on CDHS)*
 - *Histogram analysis (CAM)*
 - *Experiment-related functions (EPS, CDHS, ADCS)*
- *First image on May 15*
- *In total more than 270 images*



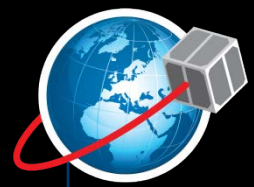
First image





Histogram analysis: before





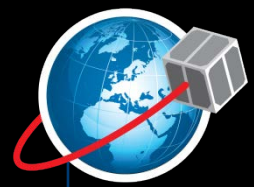
Histogram analysis: after





Many other images





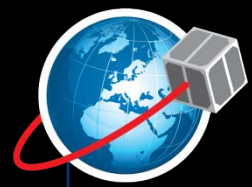
In-orbit experience

■ *Purposes of images*

- *Characterise camera: white balance, degradation of optics, hot pixels*
- *Provide independent source of attitude to validate ADCS: accuracy better than 2°*
- *Public outreach: media, facebook, presentations*

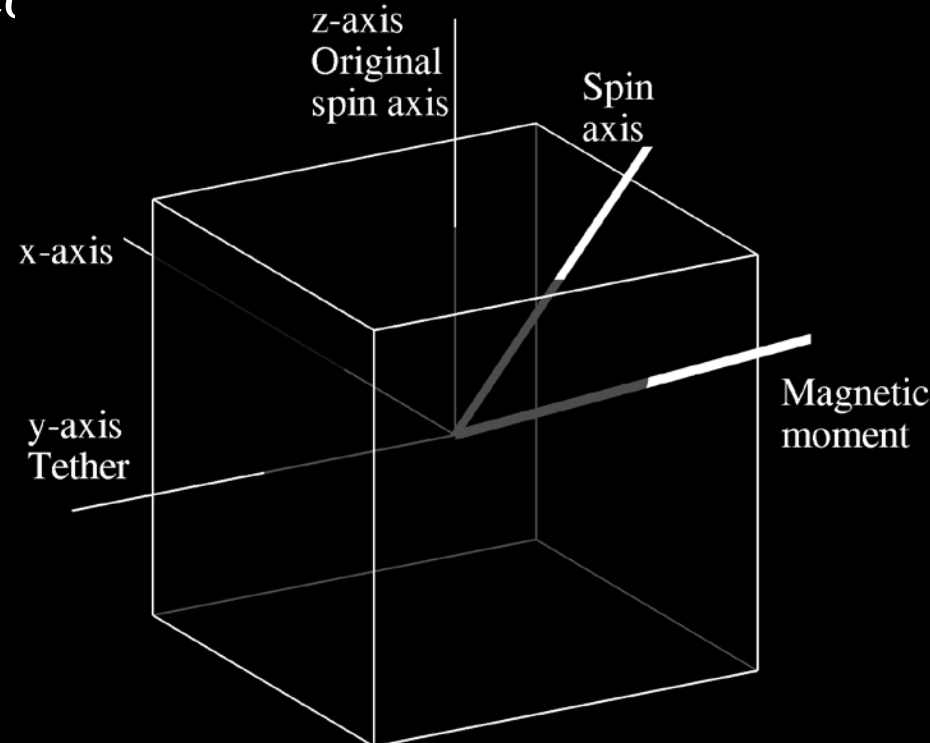
■ *In-orbit calibration of ADCS*

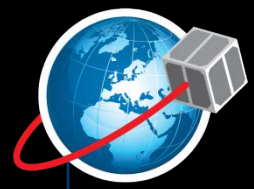
- *In-orbit results differ from laboratory calibration*
- *Statistical methods*
- *On-board images*
- *Kalman Filter output*



In-orbit experience

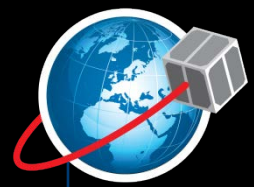
- *Problems with unwanted internal magnetic field*
 - *Ferromagnetic bolts and battery casings*
 - *Magnetic moment larger than coils can produce*
 - *Satellite follows geomagnetic field and spins*
 - *Tests with the engine magnetic field vector model and Helmholtz coils*
 - *Characterisation of internal magnetic field and coil correction matrix*
 - *Detumbling: successful*
 - *Pointing: (mostly) impossible*
 - *Spin up: partly successful and suitable*





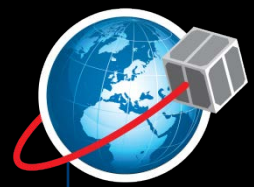
Secondary mission objective



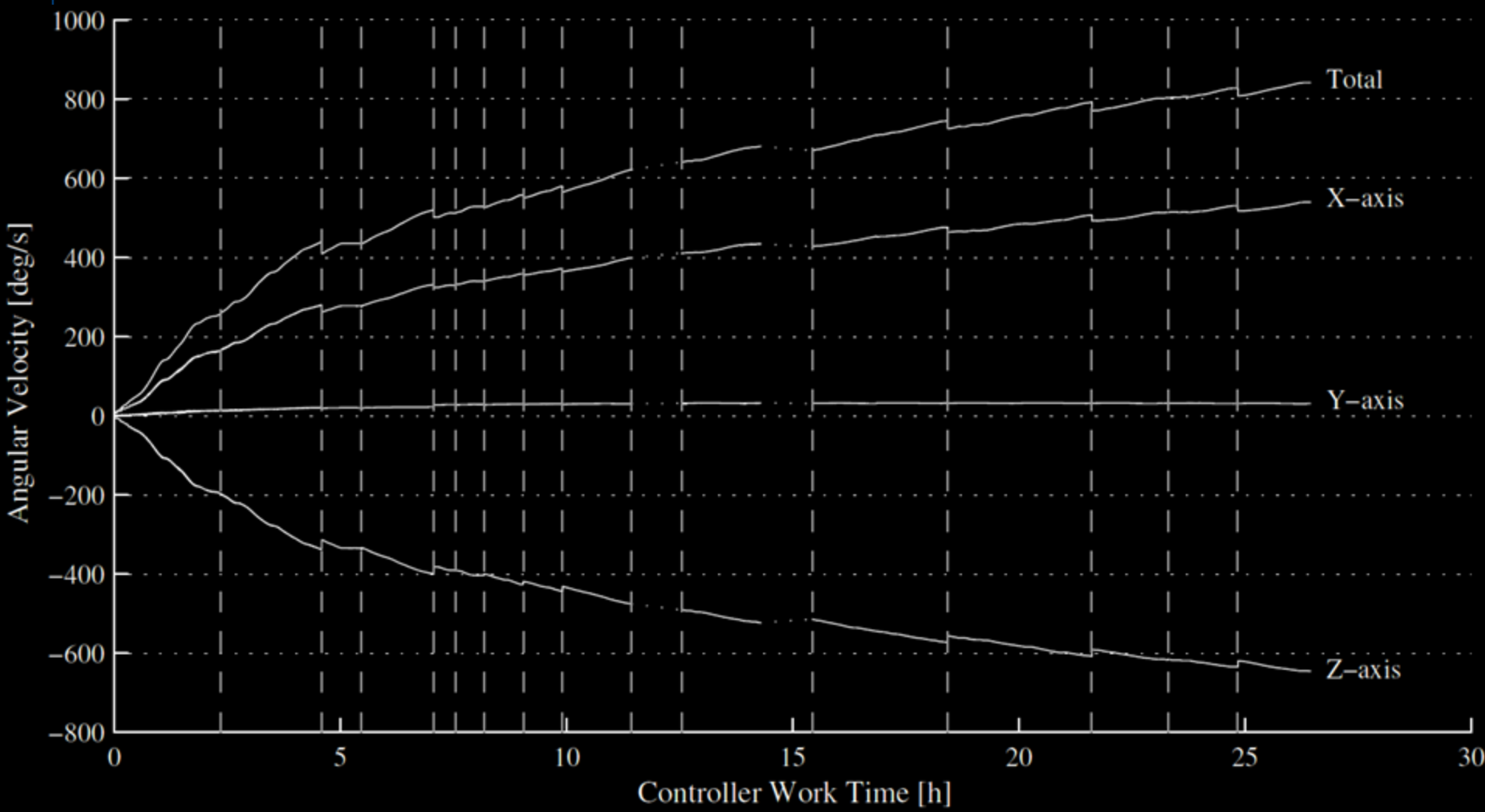


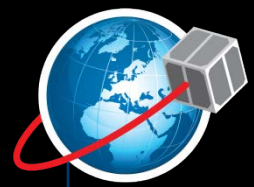
Experiment

- *In September 2014 attempts were made to deploy tether*
- *Tether deployment has not been confirmed by camera nor angular velocity measurements*
- *Attempts to measure reel (not) turning*
- *Probably tether reel is not turning*
- *Failed reel lock deployment or*
- *Motor is jammed*
- *Attempts to provide different centrifugal forces with attitude control*
- *Spin rate of 840 degrees per second*



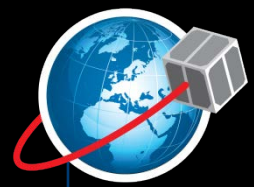
Spin control





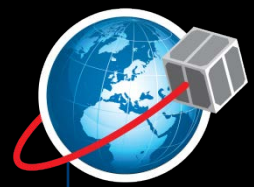
Lessons learned ☹️

- *Cover glass*
 - *Faster than expected power production deterioration*
- *Attitude sensor laboratory calibration*
 - *Need to recalibrate attitude determination sensors in orbit*
- *Unwanted magnetic field*
 - *Ferromagnetic materials used on-board aligning the satellite with the geomagnetic field*
- *Payload testing and diagnostics*
 - *Inability to deploy the tether made it impossible to measure the E-sail force*
- *Schedule*
- *System engineering*



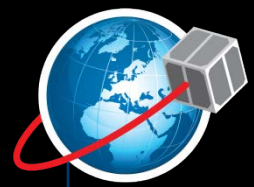
Lessons learned 😊

- *Rest of the satellite*
 - *Worked as expected and required little in-orbit improvements*
- *Redundancy*
 - *Failed gyroscopic sensor and internal flash memory device had redundant counterparts*
- *Engineering research journal articles*
 - *Pre-launch tests and simulations of all subsystems (8 articles)*
 - *Post-launch ADCS, EPS, CAM and lessons learned (5)*
- *Leader*
- *Technical advisors*
- *Start-ups*
- *Educational impact*



Conclusions

- *Fly early & fly often*
- *Be honest*
- *COTS: cost-efficiency and redundancy*
- *System engineering*
- *Technical advisory*
- *Magnetic cleanliness*
- *Calibration*
- *Plasma brake*
 - *Small, scalable and efficient deorbiting technology*



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