Low-cost and Fast-delivery Verification Strategy for the Aalto-1 Nano-satellite Attitude Determination and Control System

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The satellite: Aalto space crew and partners

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- Final- and in-orbit validation

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Aalto-1


Aalto-1
Design: 3U CubeSat
Mission: Technology Demonstration
Payload: Aalto Spectral Imager
Radiation Monitor
Electro-static Plasma Brake
Status: pre-CDR
Launch: 2014/2015

Aalto-1 Mission

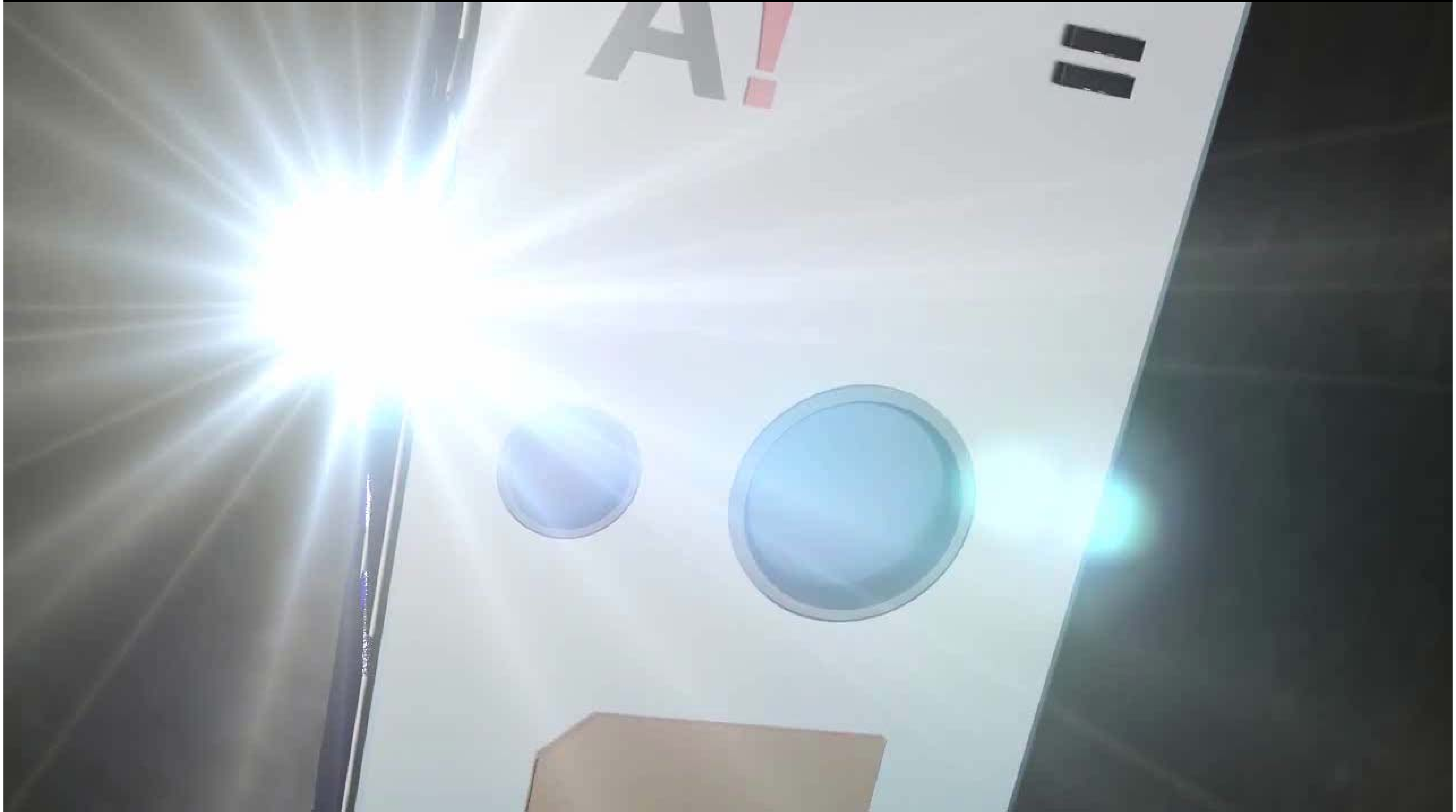
Technology demonstration:

Aalto Spectral Imager (AaSI)

Pointing requirements:

Nadir-pointing/target tracking **<<1 deg**

Piezo-actuated Fabry-Perot spectral filter
Sensor: 5 Mpx **CMOS Dimensions:** 5x10x10 cm **Mass:** ~400 g **Focal lenght:** 61mm
Spectral range: visible, infra-red **Spectral resolution:** 7-10 nm
FOV: 10 deg, **Ground resolution:** 250 m **3-channel simultaneous measurement**



Aalto Spectral Imager (AaSI)

Aalto-1 Mission

Technology demonstration:

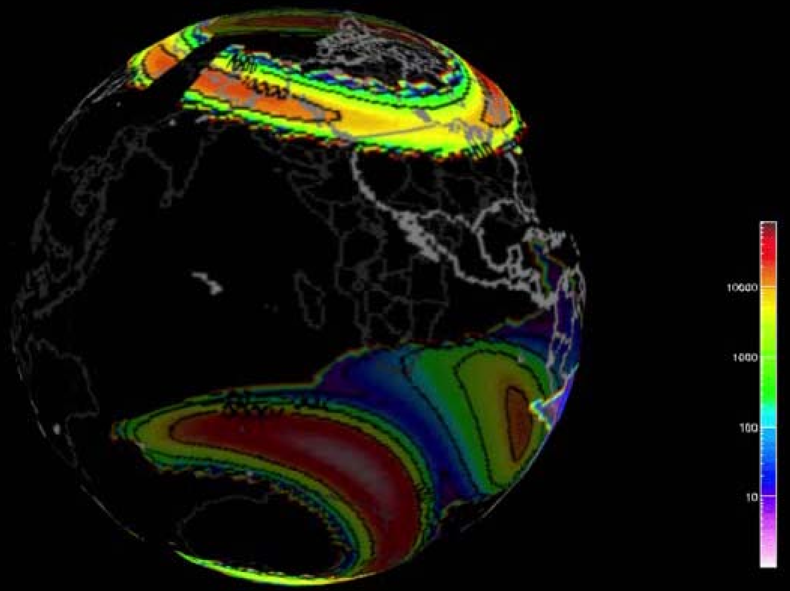
Aalto Spectral Imager (AaSI)

Radiation Monitor (RADMON)

Pointing requirements:

Nadir-pointing/target tracking	<<1 deg
Z-axis along latitudes	**<10 deg**

Dimensions: 10x10x4 cm **Mass:** 500 g, **Si detector and CsI(Tl) scintillator**
Electrons > 60 keV (5 energy channels), **Protons** > 1 MeV (7 energy channels)
Counting rate up to 1 MHz



Electron flux >1 MeV at 500 km altitude

Radiation Monitor (RADMON)

University of Helsinki

Turun yliopisto
University of Turku

ASRO

Aalto-1 Mission

Technology demonstration:

- Aalto Spectral Imager (AaSI)
- Radiation Monitor (RADMON)
- **Electro-static Plasma Brake (EPB)**

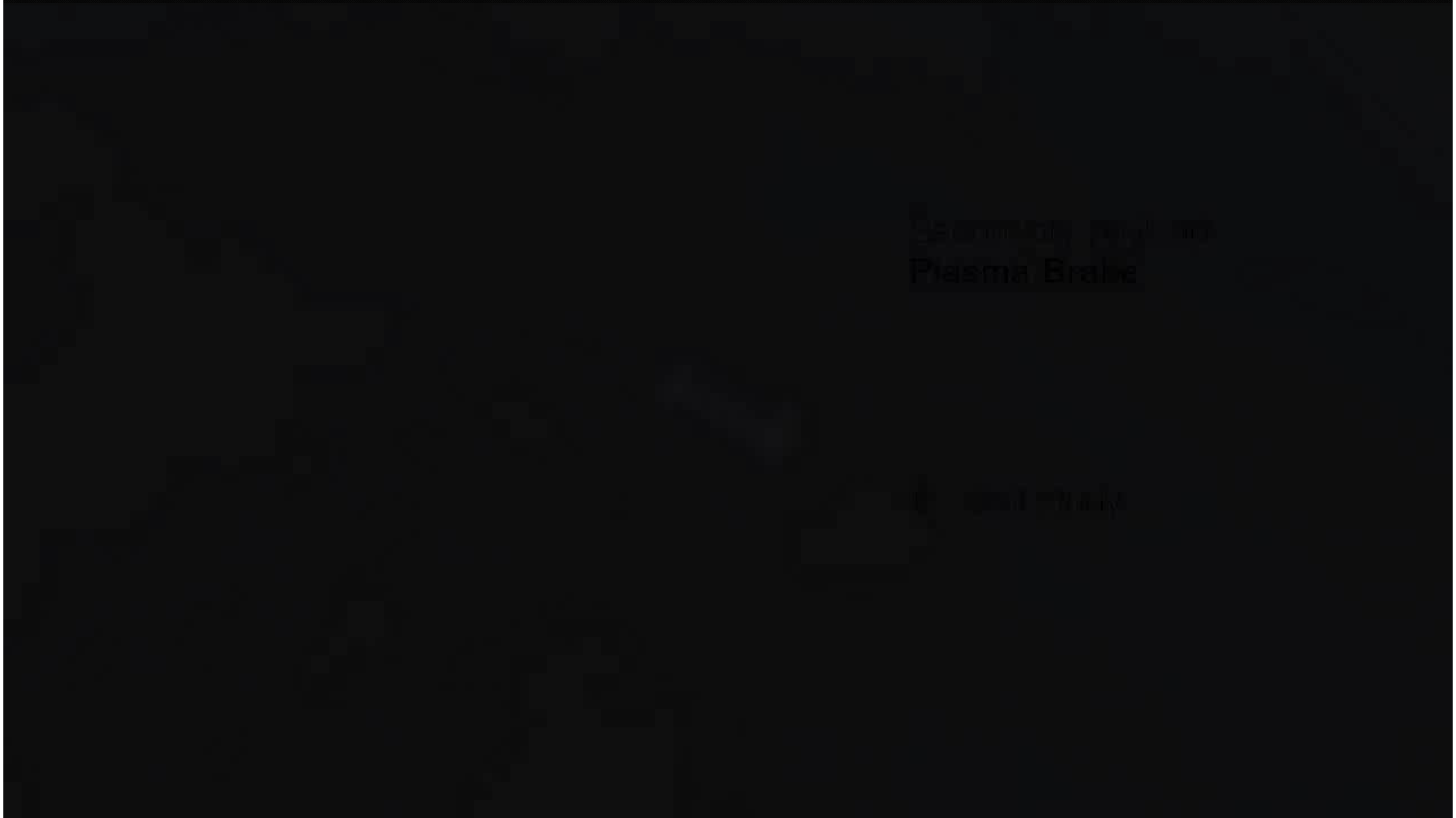
Pointing requirements:

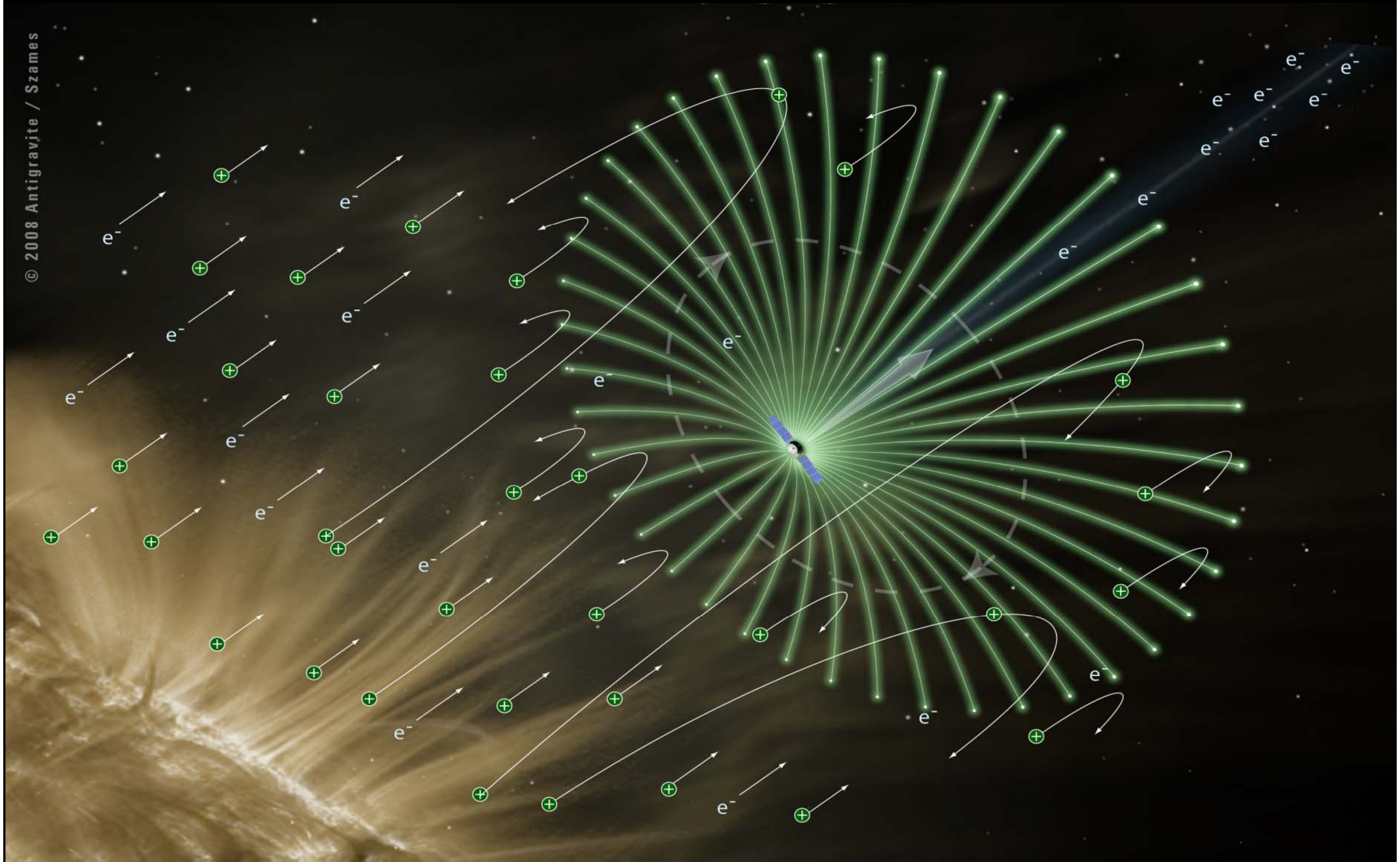
Nadir-pointing/target tracking	<<1 deg
Z-axis along latitudes	<10 deg
Spin about axis of MMoI	**>200 deg/s**
Spin axis aligned to Earth spin axis	**<10 deg**

Dimensions: 10x10x2,5 cm **Mass:** 300 g

Tether: 10-100 m **Tether material:** Aluminium **Tether dimeter:** 50 µm

Negative and positive tether charge up to 1 kV, Cold cathode electron guns

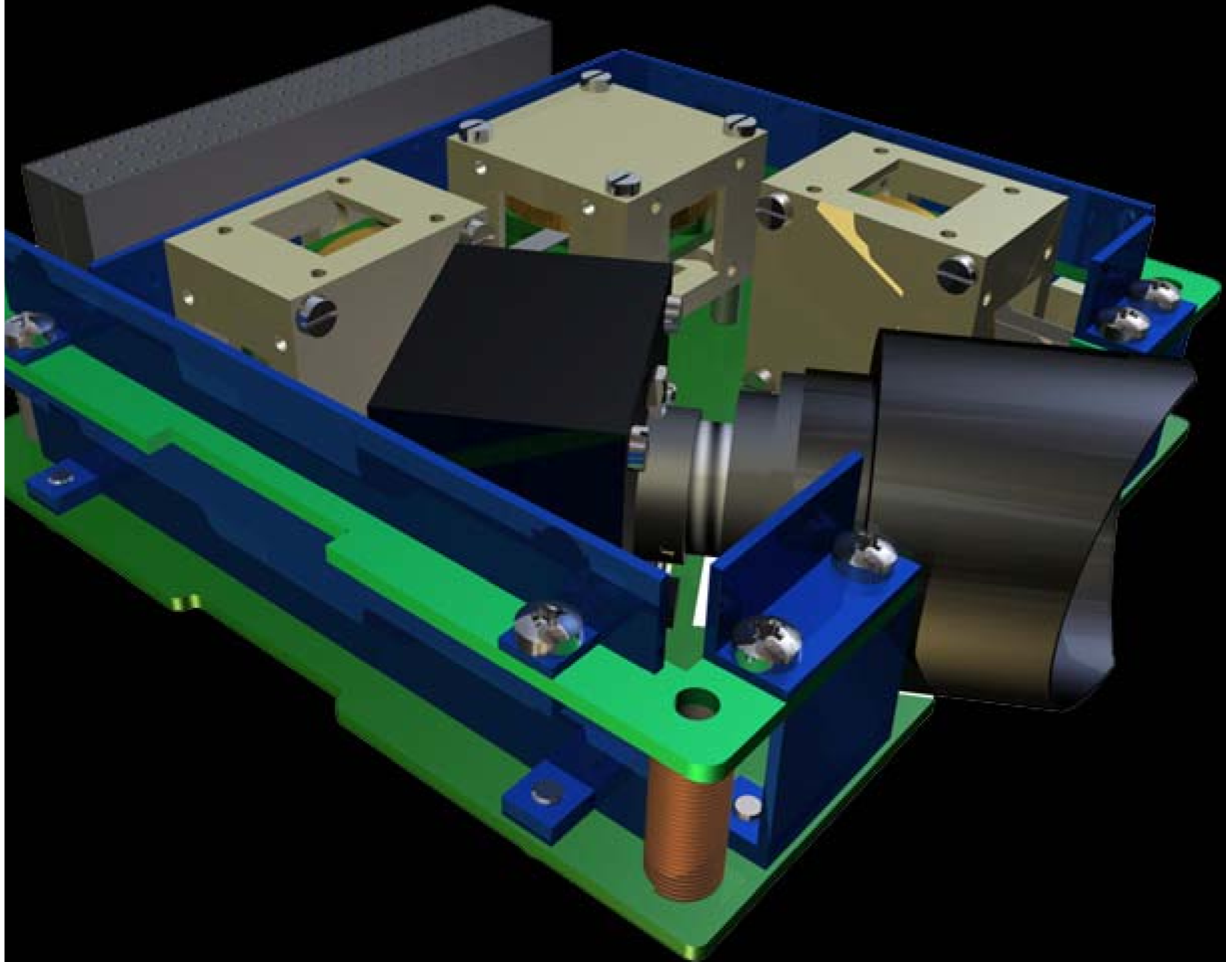




E-sail - traveling in interplanetary space without fuel

Aalto-1 ADCS

In cooperation with Berlin Space Technologies and Hyperion Technologies



Sensors:
Star tracker
3-axis magnetometer
3-axis gyroscope
3-axis accelerometer

Actuators:
3 magnetorquers
3 reaction wheels

Interfaces:
I2C
RS485
UART

Additional components:
6 Sun sensors
GPS receiver

ADCS Verification Strategy for Nano-satellites

Nanosatellite project characteristics:

- Low-cost
- Fast delivery
- Few employees
- Limited infrastructure
- Use of COTS components and third-party systems

ADCS Verification Strategy for Nano-satellites

Nanosatellite project characteristics:

- Low-cost
- Fast delivery
- Few employees
- Limited infrastructure
- Use of COTS components and third-party systems

Verification solutions:

- Limit the amount of testing where possible
- Test concurrently along the design process
- Limit the amount of tests needing specialized equipment
- Divide testing between the satellite developer and ADCS developer

ADCS Verification Strategy for Nano-satellites

Sensor and actuator testing → Simulation and HIL testing → Final- and in-orbit validation

Aalto-1

The Finnish Student Satellite

ADCS Verification Strategy for Nano-satellites

Sensor and actuator testing

- Start immediately after sensor and actuator selection
- Test functionality and performance (also at worst-case conditions)
- Performance parameters from COTS component datasheets may be used

- Testing much simpler at unit level
  - Sun sensors with rotation stage and light source
  - Gyros with Earth's rotation rate
  - Star tracker with real night sky
  - etc.

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ADCS Verification Strategy for Nano-satellites

Sensor and actuator testing → Simulation and HIL testing

- Create sensor/actuator simulation models from performance parameters.
- Include sensor/actuator simulation models and ADCS algorithms in an orbit and attitude dynamics simulator (including disturbance torques).
  - e.g. Aalborg Toolbox
- If ADCS developer does not share algorithms, they can be accessed by Hardware-In-Loop (HIL) testing
  - Allows investigating worst-case execution times on real hardware

ADCS Verification Strategy for Nano-satellites

HIL testing

Host computer:
e.g. Aalborg Toolbox
in Simulink

Target computer:
Run simulation in
real-time using e.g.
xPC Target

Aalto-1 ADCS

ADCS Verification Strategy for Nano-satellites

HIL testing

- Any mission scenario can be tested with relative ease
- Allows testing even the most complex mission operations
- Does not require an expensive ADCS test environment
- Most suspectible failure cases from FMECA can be investigated
- Serves also as an ADCS software test platform after launch

ADCS Verification Strategy for Nano-satellites

Sensor and actuator testing → Simulation and HIL testing → Final- and in-orbit validation

- Functional tests should be performed as soon as possible with the ADCS connected to OBC.
- Environmental tests can be performed according to Nanosatellite Environmental Test Standardization (NETS) guidelines.
  - Equipment may be rented or bought as a service
- ADCS performance in full satellite configuration may be tested with ADCS test equipment
  - Equipment may be rented or bought as a service
- Magnetic calibration
- Commissioning after launch

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Conclusions

- Nanosatellite ADCS testing requires unconventional methods.
- Early verification provides valuable feedback to ADCS development and mission design.
- Durability can be tested by following environmental test standards tailored especially for Nanosatellites.
- HIL testing method allows major cost savings compared to an ADCS test environment capable of testing complex mission operations.

Thank you! Questions?

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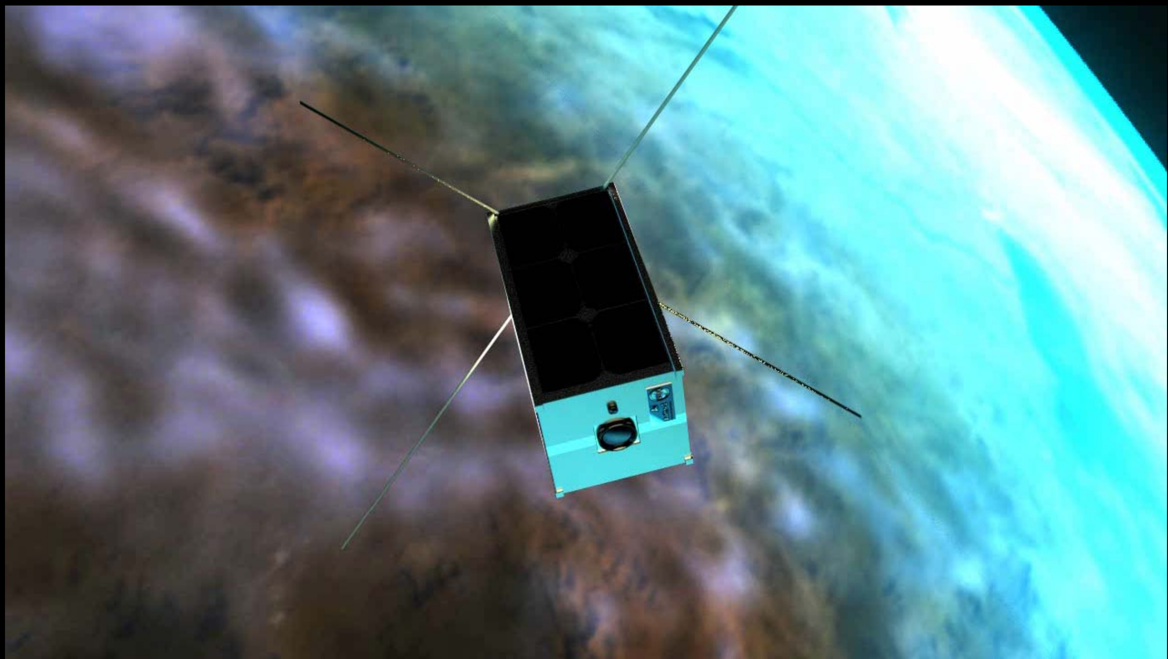
Aalto-2

Launch: 2015



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