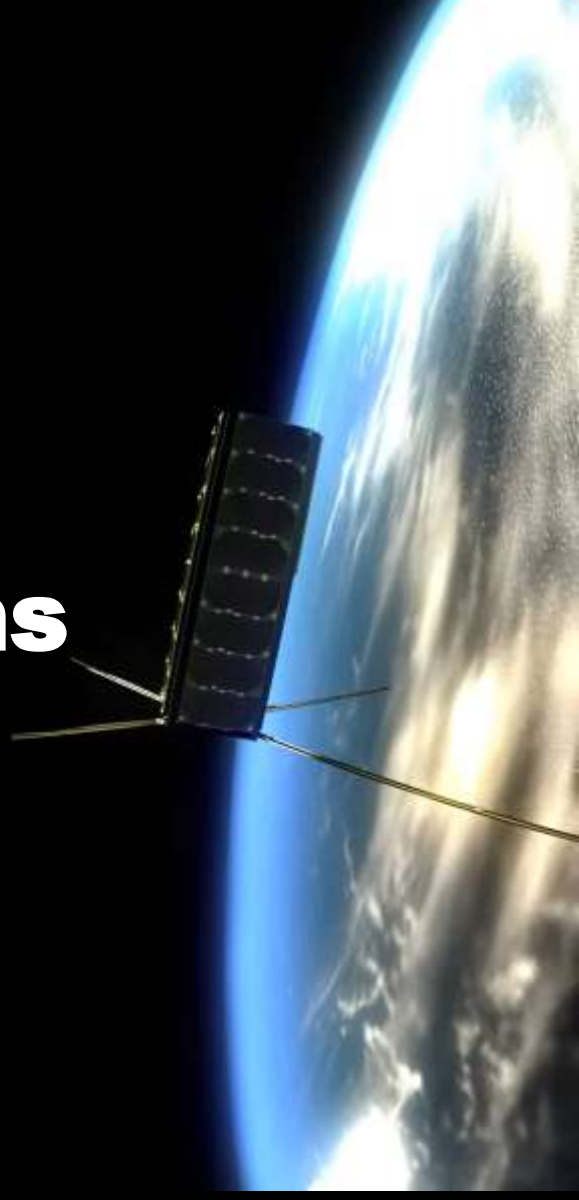
Aalto University
School of Electrical
Engineering

FORESAIL
FINNISH CENTRE OF EXCELLENCE IN RESEARCH OF SUSTAINABLE SPACE

Small Satellites for Finnish Science Missions



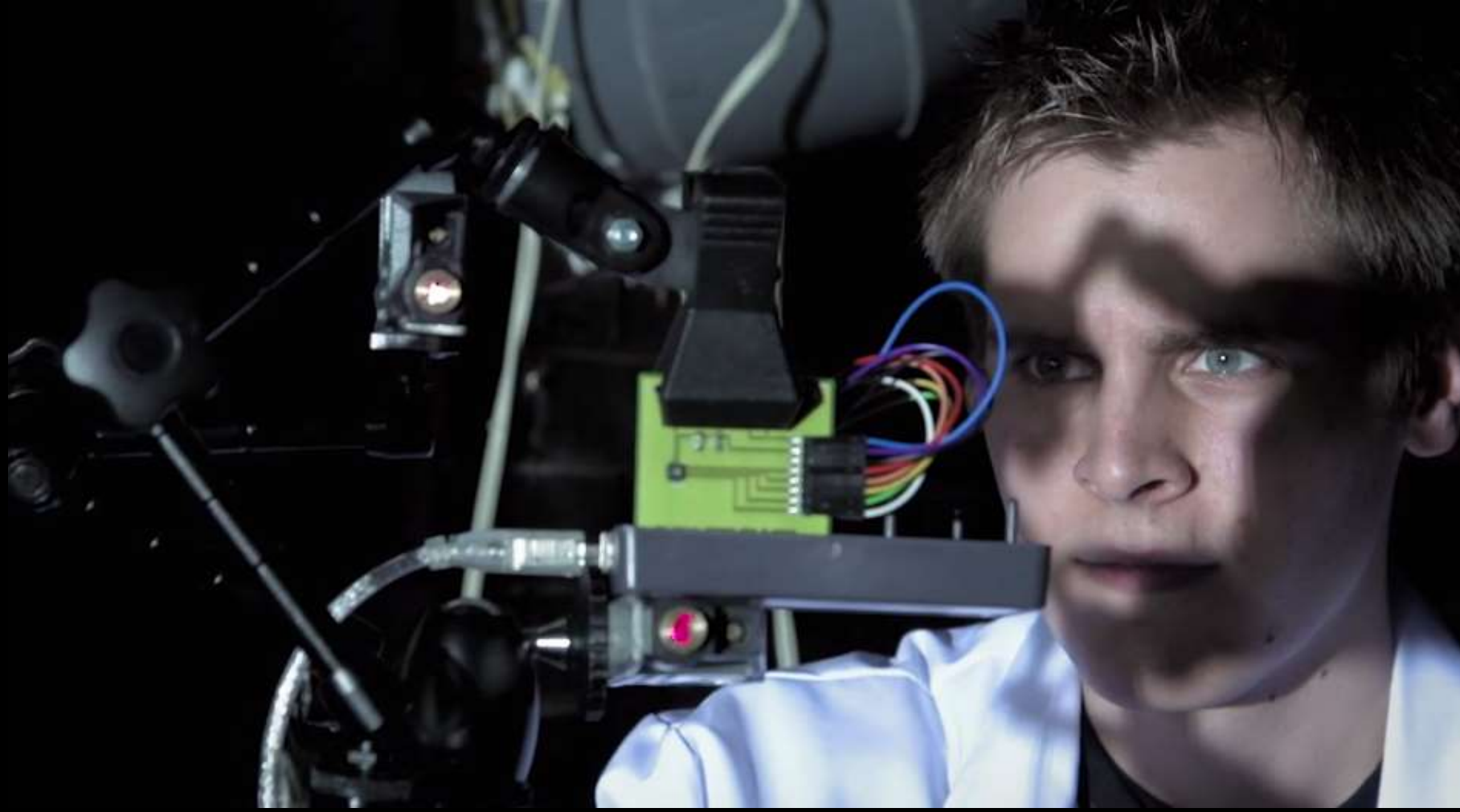
Jaan Praks, Foresail team

Aalto University, Department of Electronics and Nanoengineering
Finnish Centre of Excellence in Research of Sustainable Space

Aalto-yliopisto

Growing with CubeSat generation


DEPARTMENT
EST.
Aalto-1 2010



A!
Aalto University

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The Finnish Student Satellite

Picture: Harri Ha

Aalto Univer

Aalto University

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The Finnish Student Satellite

A!
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The Finnish Student Satellite

esa business incubation centre Finland

Reaktor Space Lab

AURORA PROPULSION TECHNOLOGIES

Kitsat

ICEYE

Aalto Space spin-off companies

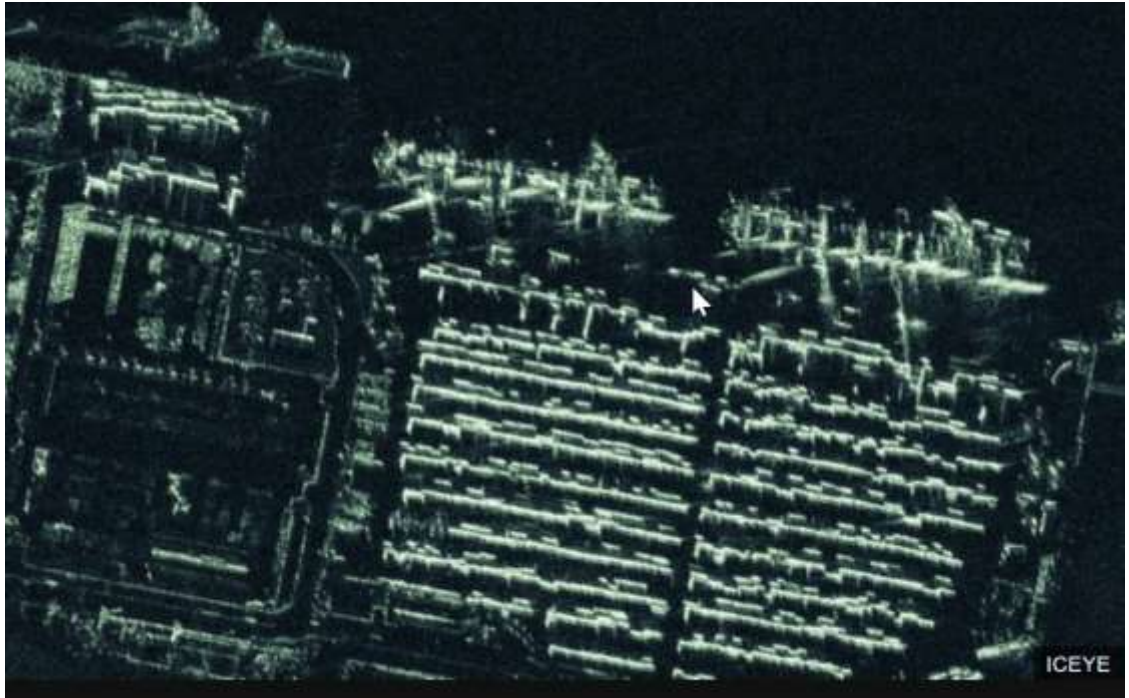
Aalto University

Now one of the biggest space companies in Finland


ICEYE

BBC NEWS
Science & Environment

Iceye satellites return super-sharp radar images



A container terminal near Port Harcourt, Nigeria: detail under a metre across is visible to the radar

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Established Education

Aalto Space Science and Technology

Major in Electronics and Nanoengineering

Student missions

Aalto satellite projects are integrated to Space Science and Technology curriculum.

Students get hands on design, integration, testing experience and operation.

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Aalto University
Student Satellite Program

Aalto-yliopisto

Mature Small-sat Technology

VTT Fabry-Perot Spectrometers

for CubeSat

AaSI VNIR spectral imager (400-900 nm)

(IOD Aalto-1 2017)

HW SWIR Specral imager (900-1400 nm)

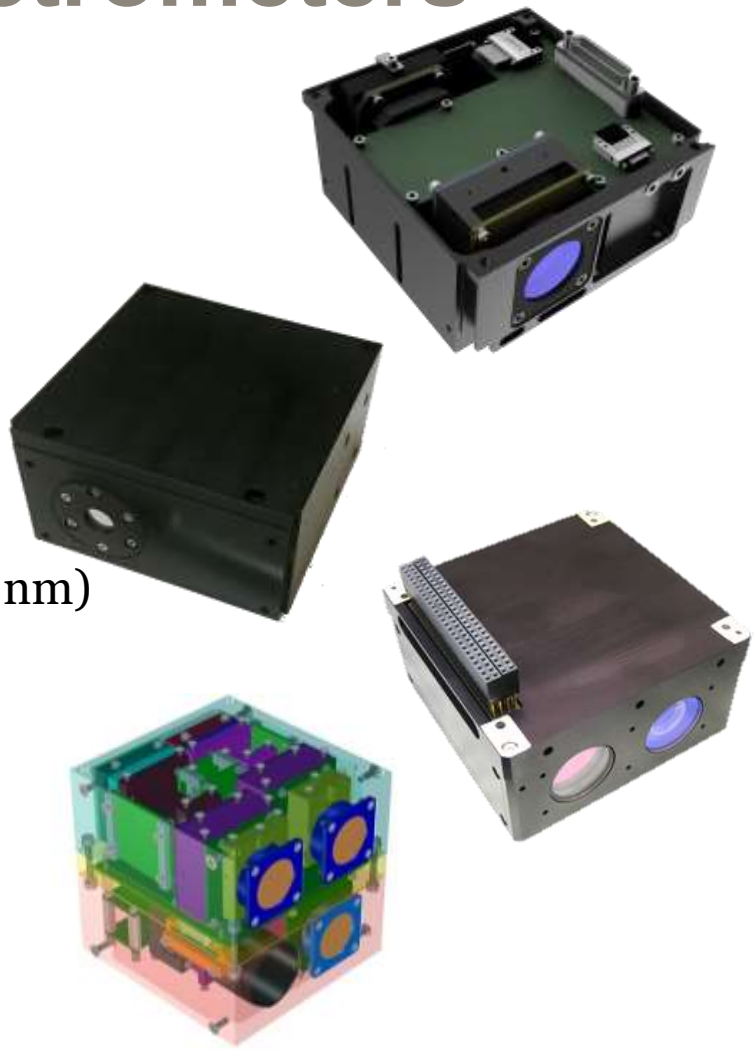
(IOD Hello World 2018)

VISION Solar Occultation Imager

(Launch 2019-2020)

Asteroid Spectral Imaged Concept (500-2500 nm)

(designed for APEX/HERA mission)

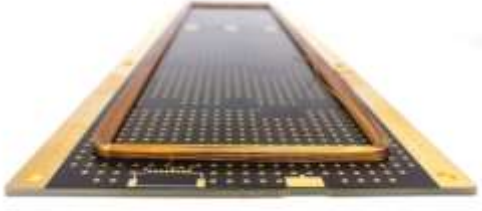


In-house developed complete Cubesat solutions

Aalto has developed two complete CubeSats and launched three.

Aalto has developed all avionics subsystems in-house.

Currently three more CubeSats ar under development.



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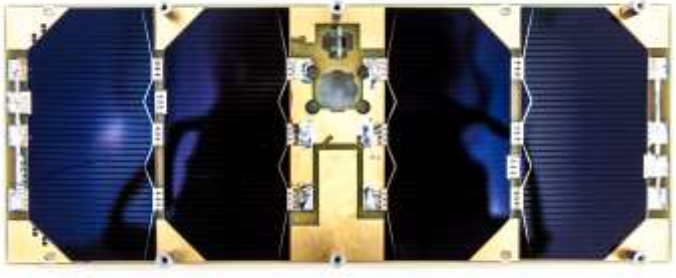
Flight-proven technologies

Reaktor Space Lab

TM / TC radios
TRL 9

Power supplies
TRL 9

Battery packs
TRL 9



Solar panels
TRL 9

Onboard computers
TRL 9

New science with smaller spacecraft

- Higher risk, more experimental missions
- Higher temporal and spatial characterization of phenomena
- Multi node systems
- Long baselines
- Better match with models

Aalto-yliopisto

Increasing mission opportunities with ESA

W-Cube (ESA)

Science / Telecom

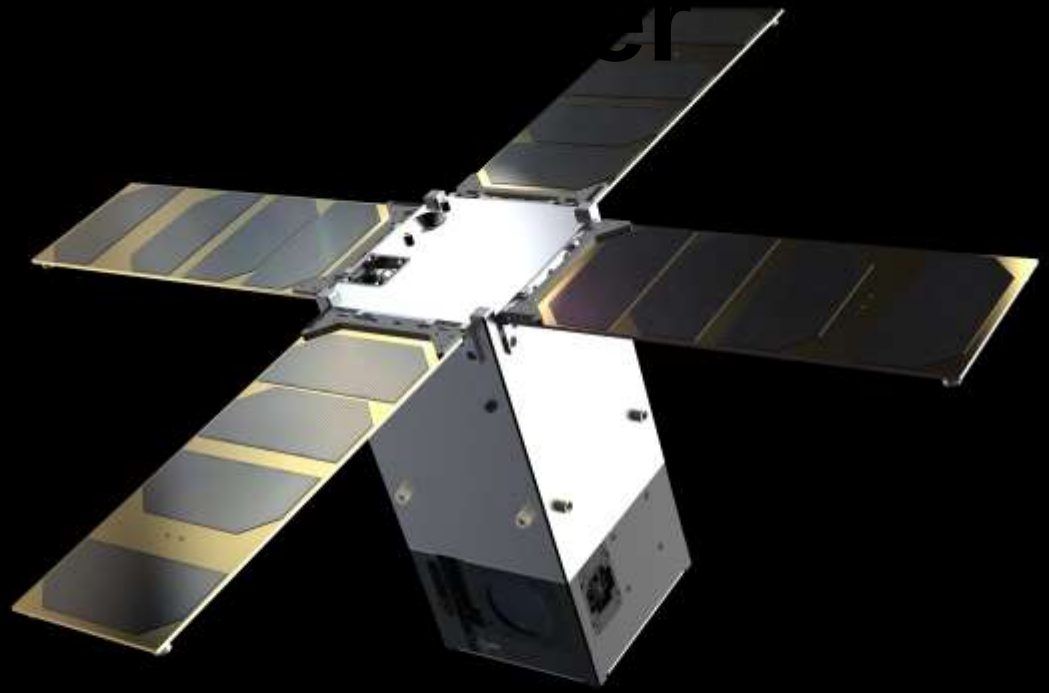
First ever W-band frequencies to be transmitted from space to Earth. Provides information for atmospheric and ionospheric propagation models. Higher frequencies will provide higher communication speeds for future telecom satellites.

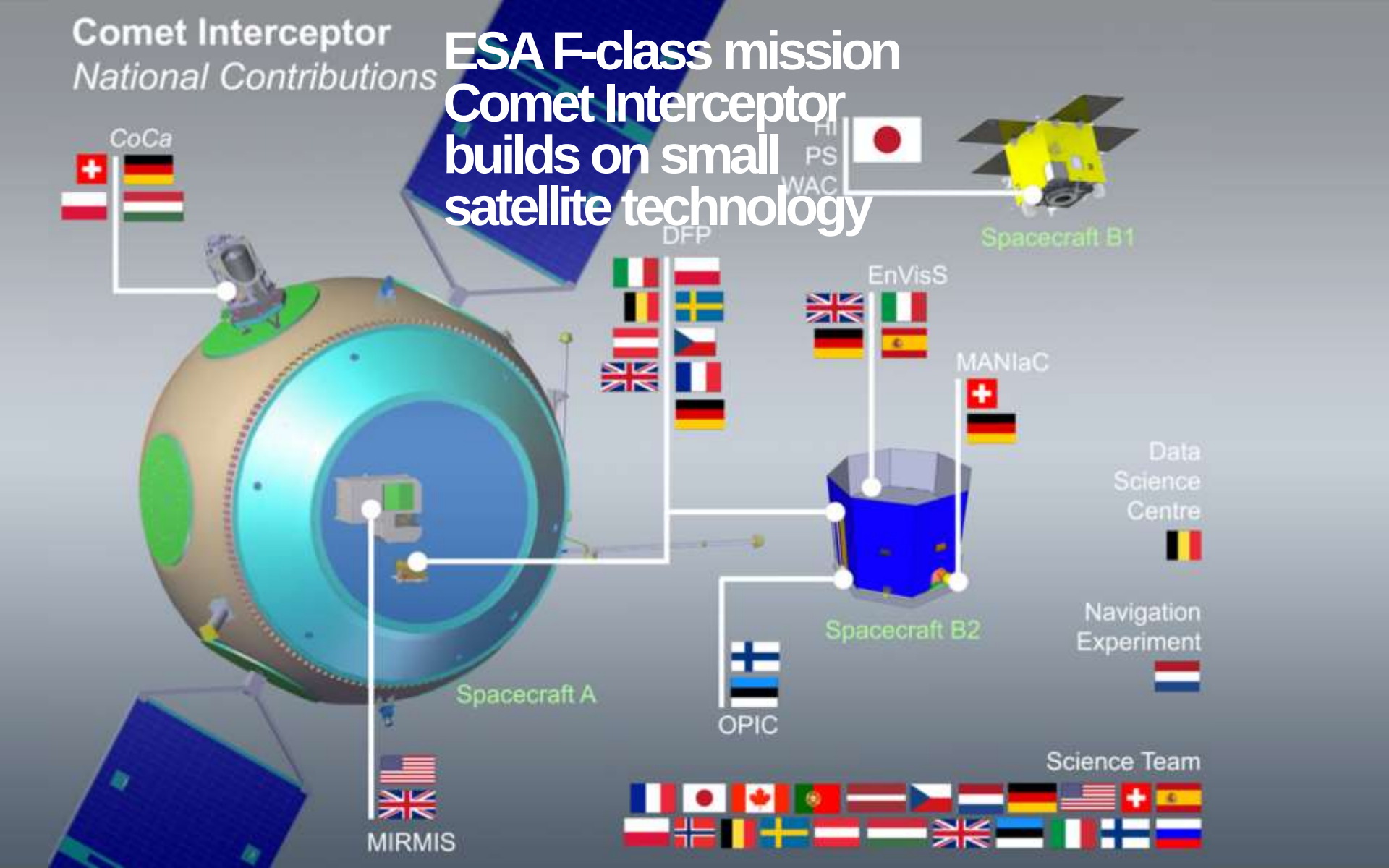
- W-band (75 GHz) & Q-band (37.5 GHz) beacons
- Novel concentric ring antennas
- Left and right handed polarization switching

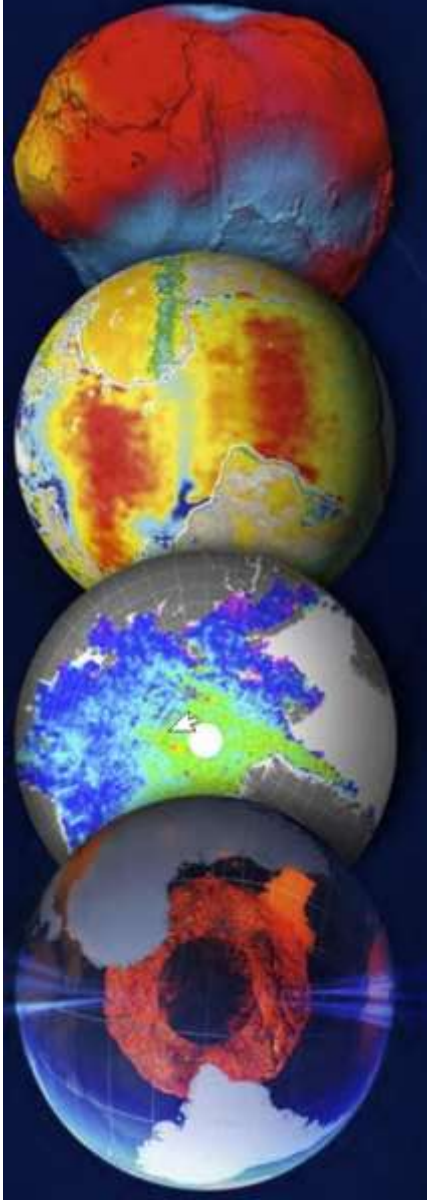
XFM (ESA)

X-ray spectrometer
in orbit demonstration

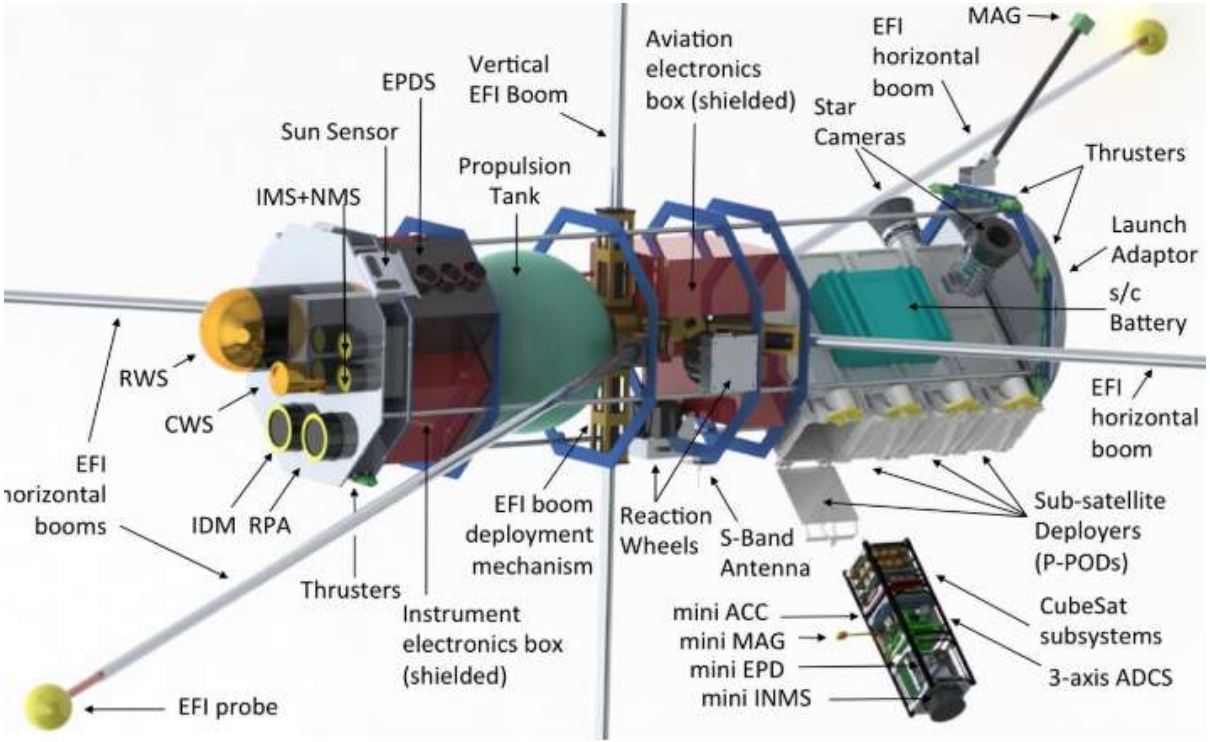
Launch Q1/2021




Comet Interceptor
National Contributions
ESA F-class mission
Comet Interceptor
builds on small
satellite technology
CoCa
HI
PS
WAC
Spacecraft B1
DFP
EnVisS
MANIaC
Data
Science
Centre
Spacecraft B2
Navigation
Experiment
Spacecraft A
OPIC
MIRMIS
Science Team



ESA Earth Explorer 10
Daedalus mission build on CubeSat technology



ASPECT / APEX (ESA)

VTT Reaktor Space Lab

Asteroid prospecting

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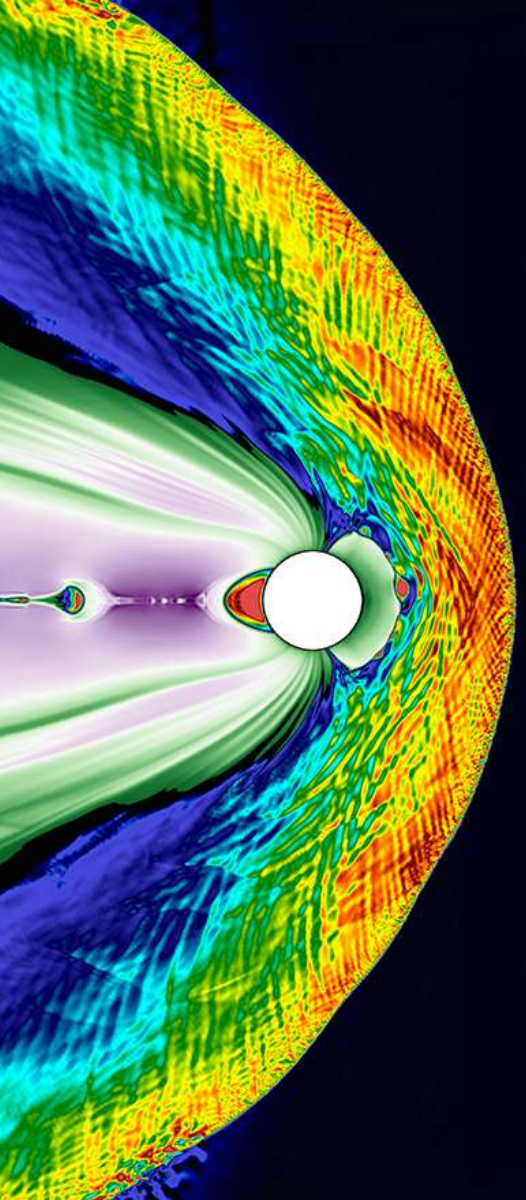
SUOMEN AKATEMIA
FINLANDS AKADEMI
ACADEMY OF FINLAND

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Aalto University

UNIVERSITY OF TURKU

FINNISH METEOROLOGICAL INSTITUTE



Combining best space environment models, particle instruments and nanosatellites in Finland to develop technology for more sustainable space.

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Goals

- Better knowledge of radiation physics in space
- Awareness of sustainability issues
- Science Space Program for Finland
- Deorbiting technologies for small satellites
- Solutions for radiation tolerant CubeSat platform
- Science instruments for future space
- Renewal of space scientists and engineers

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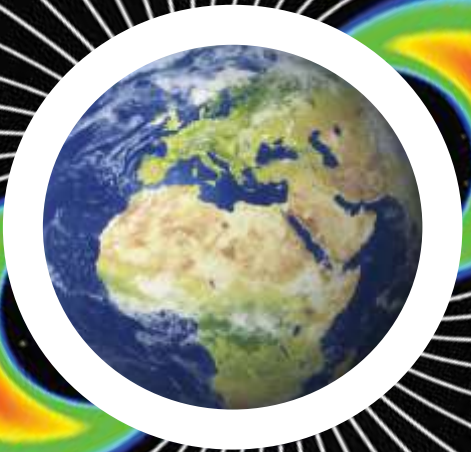
Foresail-3

2024
Mission to
Solar Wind

Foresail-2

2022
Mission to
GTO



Foresail-1

2020
Mission to
LEO

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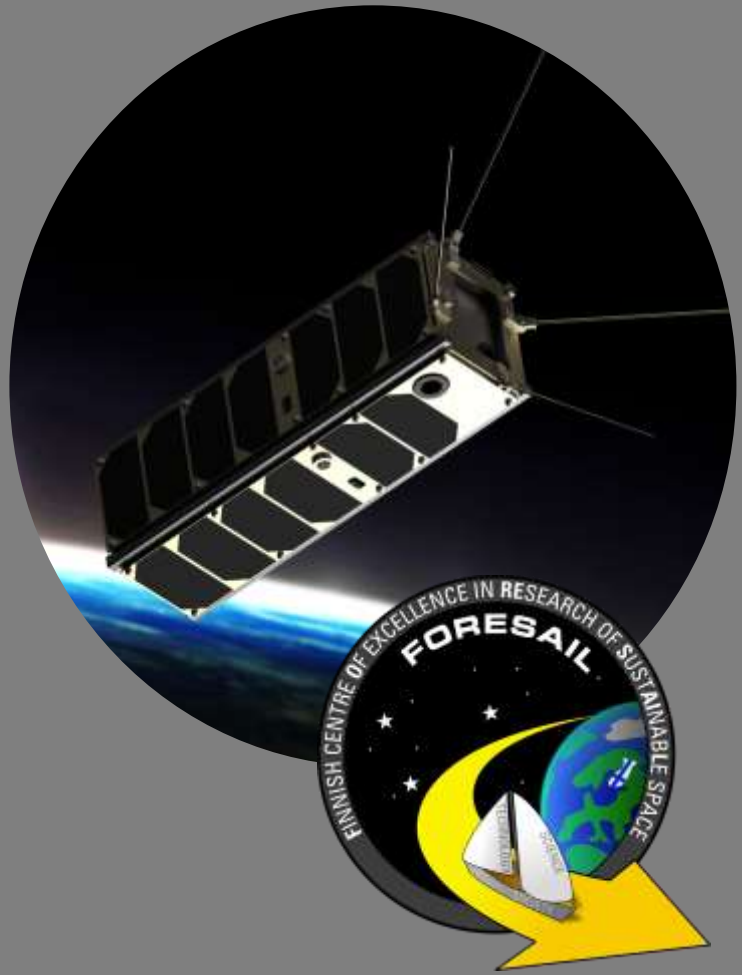
FORESAIL-1 mission



Mission goals

- **Measure the energy and flux of energetic particle loss to the atmosphere** with a representative energy and pitch angle resolution over a wide range of magnetic local times.
- **Measure energetic neutral atoms (ENAs) of solar origin**, to improve solar eruption energy budget estimations.
- **Demonstrate a orbit maneuver with e-sail technology.**

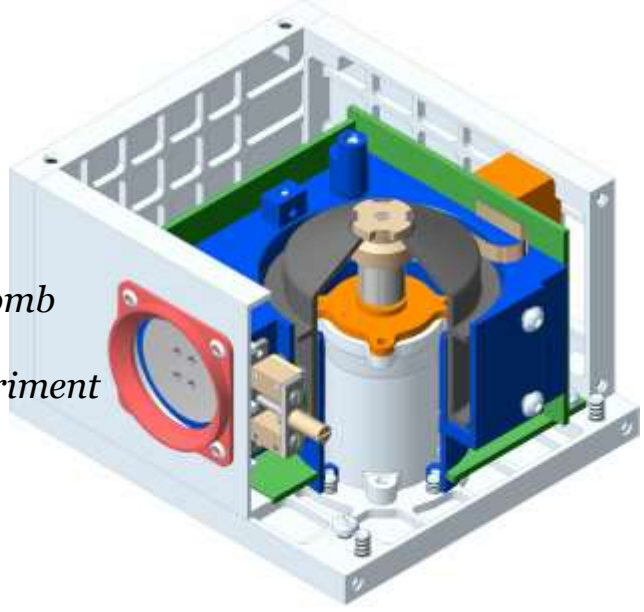
M. Palmroth et al. “FORESAIL-1 cubesat mission to measure radiation belt losses and demonstrate de-orbiting” JGR: Space Physics on 21 May 2019, arXiv:1905.09600 [physics.space-ph]

FORESAIL-1

Payloads

Plasma Brake (PB):
Deploying a long charged tether; measuring the strength of Coulomb drag in ionospheric plasma ram flow

Particle Telescope (PATE):
Defining pitch-angle and energy signatures of electrons precipitating from the radiation belts, and measuring solar ENAs.



Coulomb Drag Experiment

Orbit: ≈ 600 km altitude
Mission duration: 5 years
Launch date: 2020

Particle Telescope

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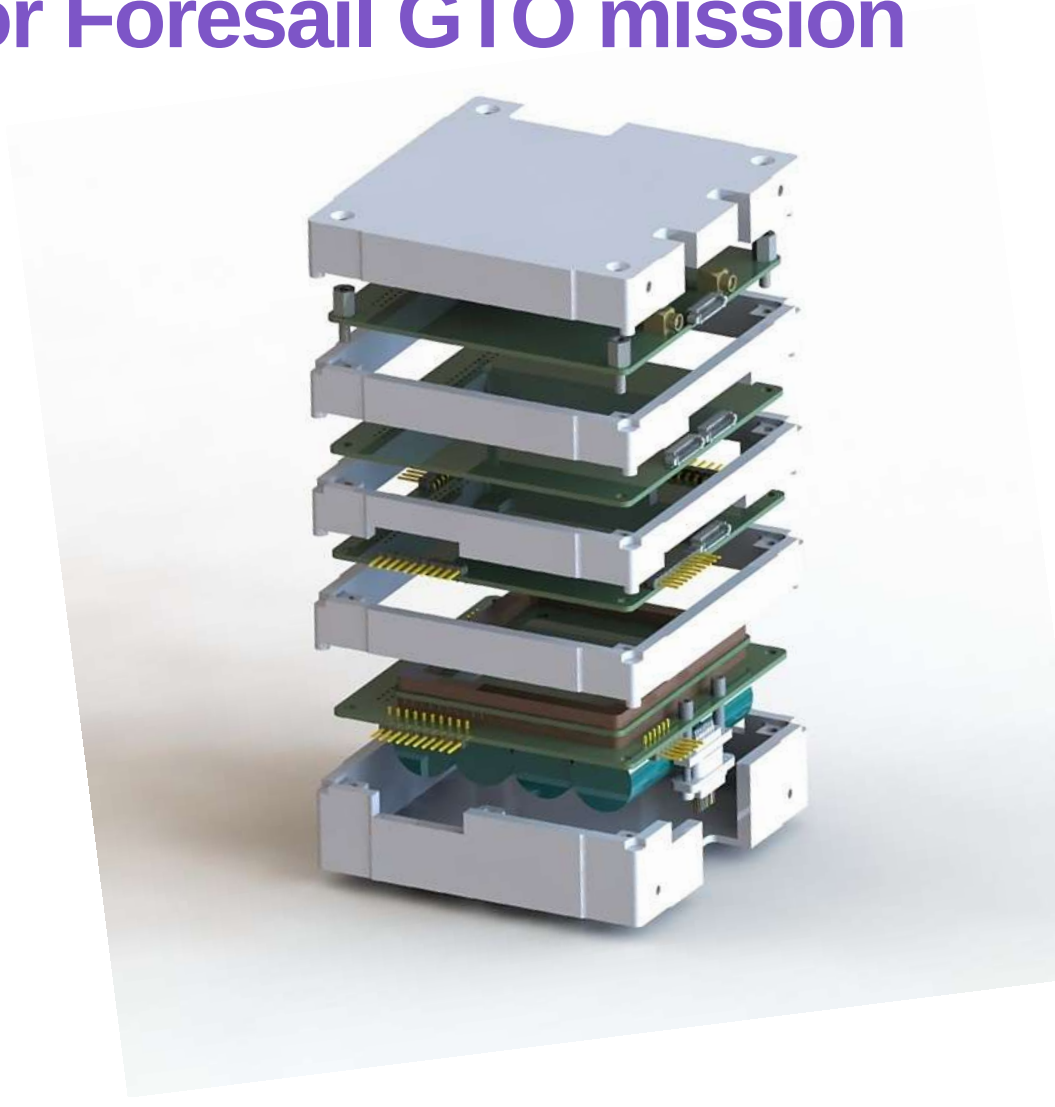
CubeSat platform for Foresail GTO mission

- **Radiation tolerant avionics**
- **Radiation tolerant software**
- **Modular shielding structure**
- **CubeSat attitude solution for GTO**
  - (developed in collaboration with Aurora Propulsion)



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Platform integration

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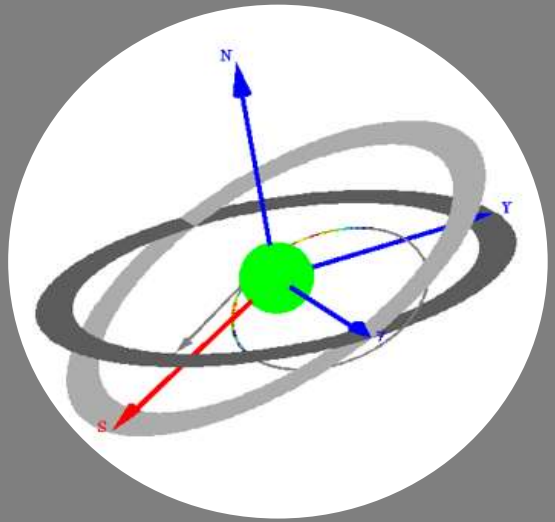
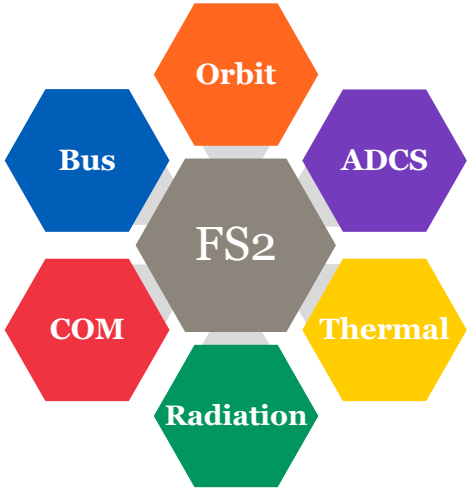


FORESAIL-2 mission

FORESAIL-2

Support ULF plasma wave modeling in Vlasiator



Coulomb Drag Experiment (CDE):
Deploying a long charged tether; measuring ambient plasma density, and the strength of Coulomb drag in different plasma densities

Relativistic Electron and Proton Experiment (REPE):
Measuring electron and proton spectra, to monitor the dynamics of the most penetrating radiation in the Van Allen belts

Magnetic field measurements

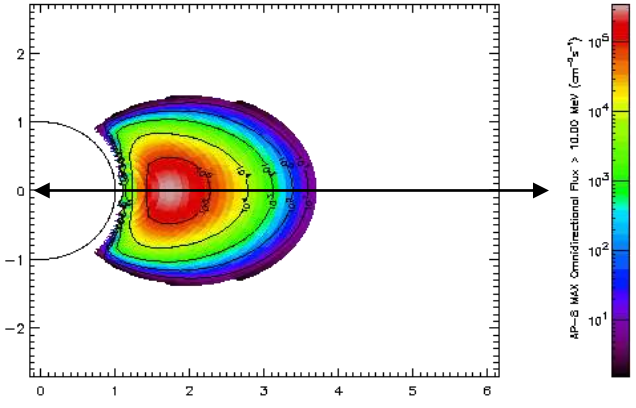
Mission duration: 6 months
Launch date: 2022
Required orbit: Geostationary Transfer Orbit;
Very demanding, will impose heavy constraints on the platform

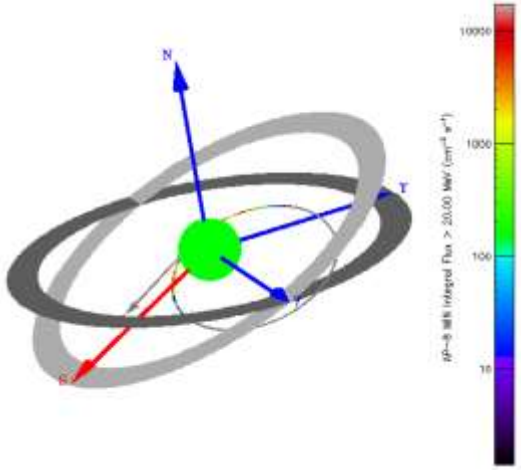
FORESAIL-2

Mission constraints : Radiation environment

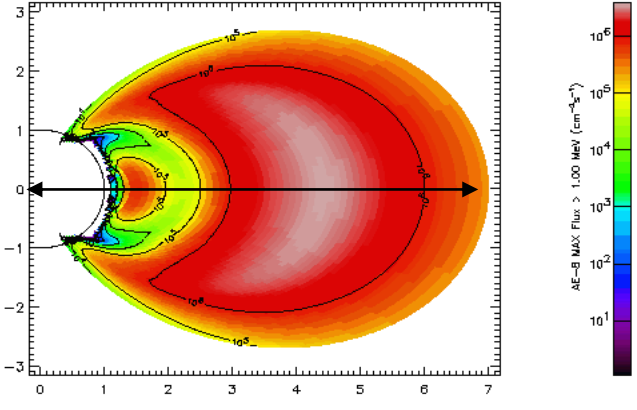
Source: SPENVIS

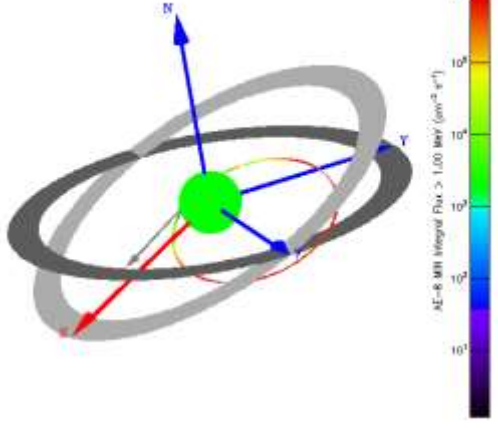
Proton flux > 10 MeV

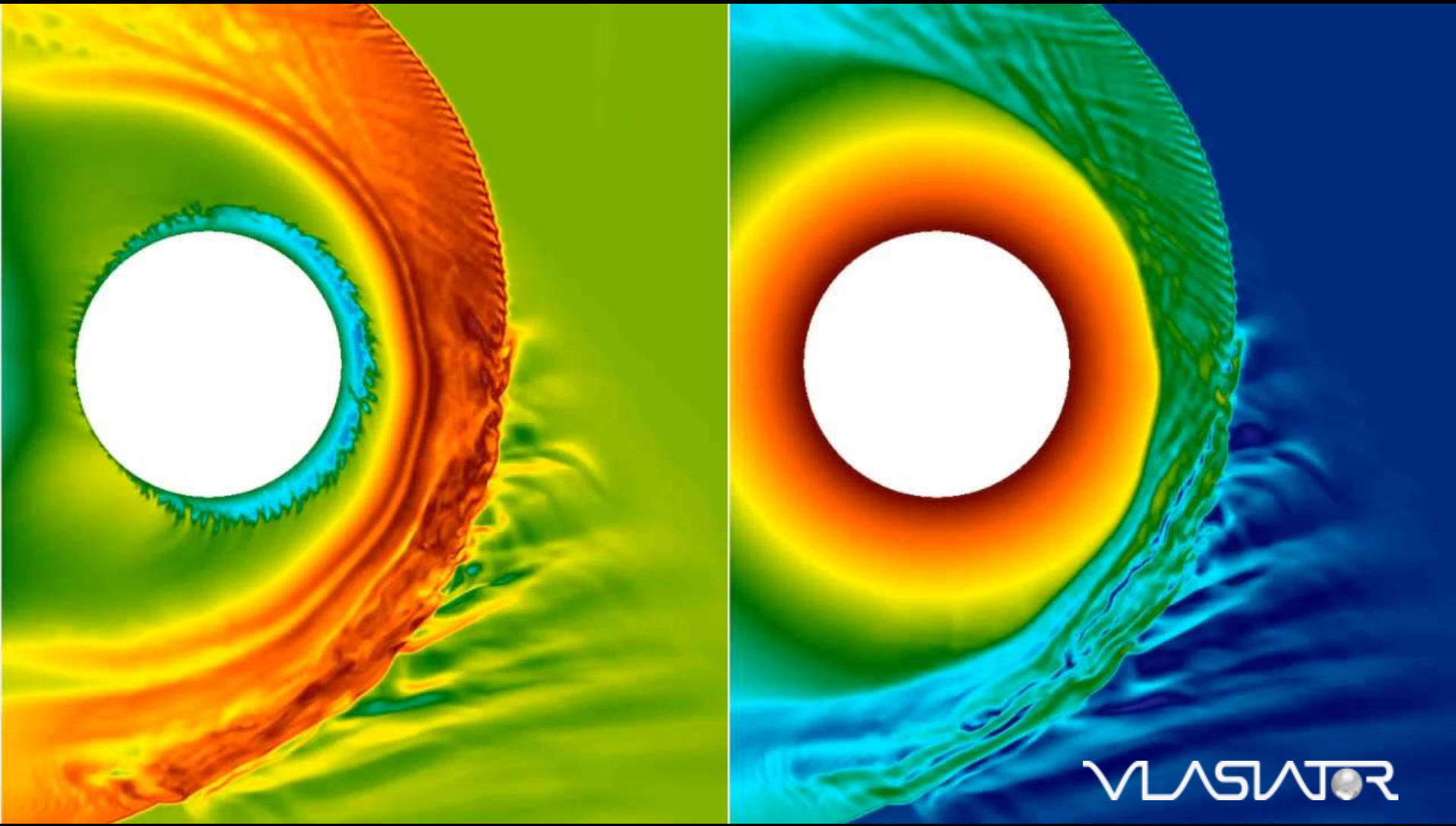


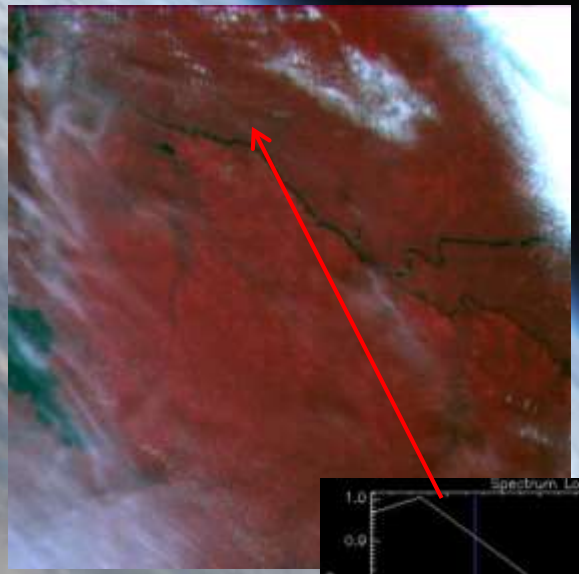


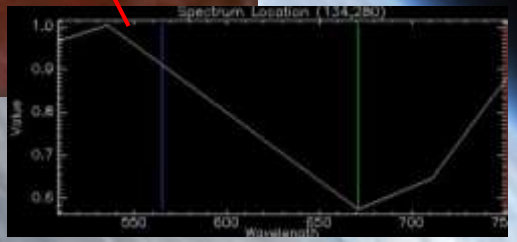
Electron flux > 1 MeV





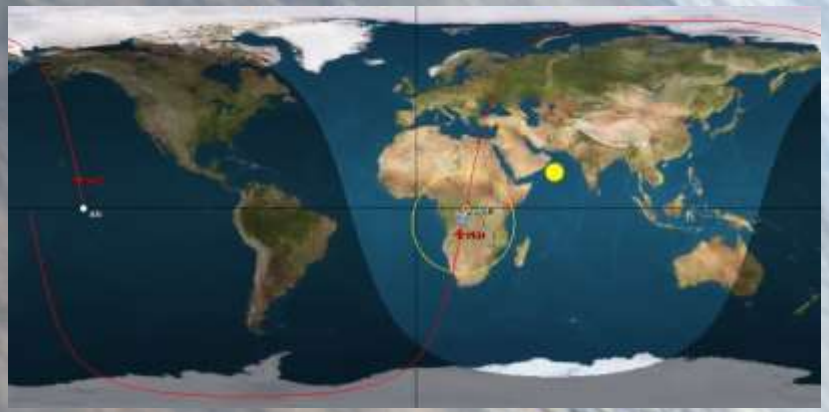

VLASIATOR

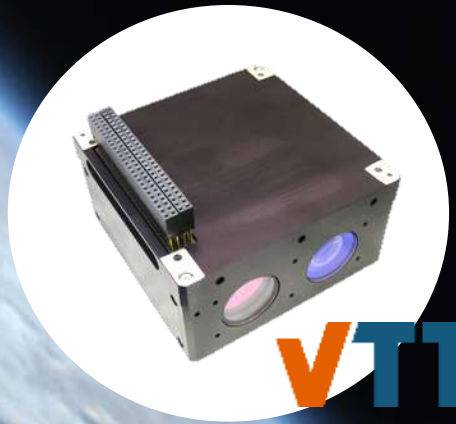




First IOD of miniature Fabry-Perot EO spectral imager August 2018:

Mass: 592 g
Power: max 2.5 W
500-900 nm
Configurable ~20 nm spectral lines





Aalto-1

VTT

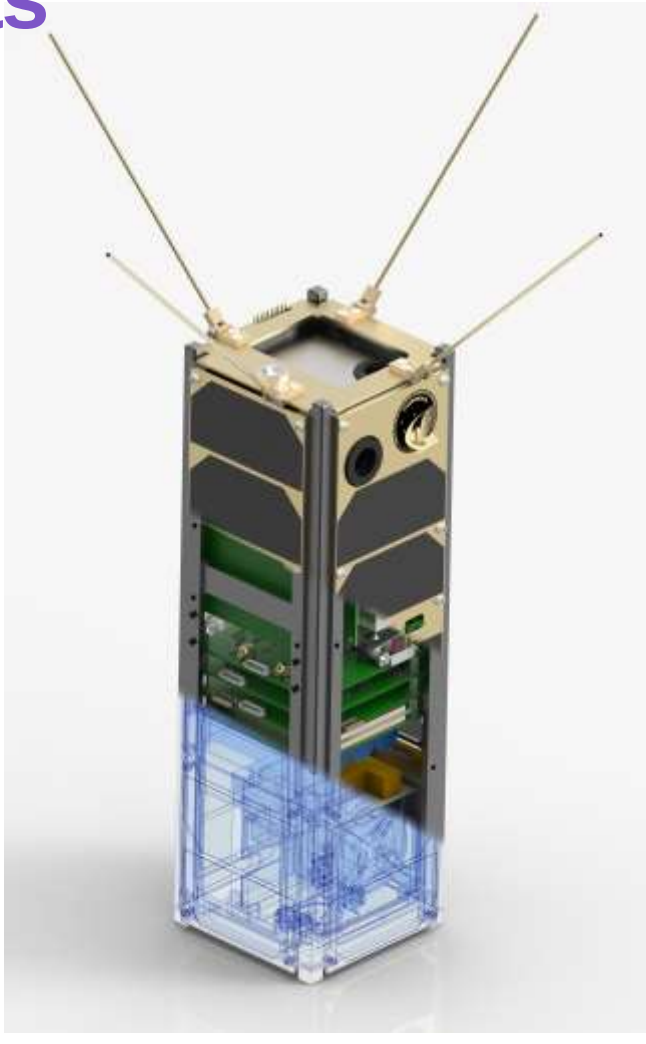
esa

Design drivers and constraints

3U CubeSat standard (ISI-POD variant) compatibility
Lifetime for 5 years in LEO
3-axis attitude knowledge at accuracy (1°)
3-axis attitude stabilization in terms of rotation modes

- Rotation mode for PB payload (Rotation rate 180°/s)
- Pointing mode for PATE (3° pointing accuracy of rotation axis)

Communication to ground station with average daily download capacity (TBD)
Power for payloads missions during mission lifetime (TBD)
Pointing ability after the PB experiment
Attitude control ability with deployed tether and changed center of mass
Conductivity requirement for spacecraft surface area (TBD)
Openings and access ports for payloads (TBD)
Retro-reflector for platform (TBD).



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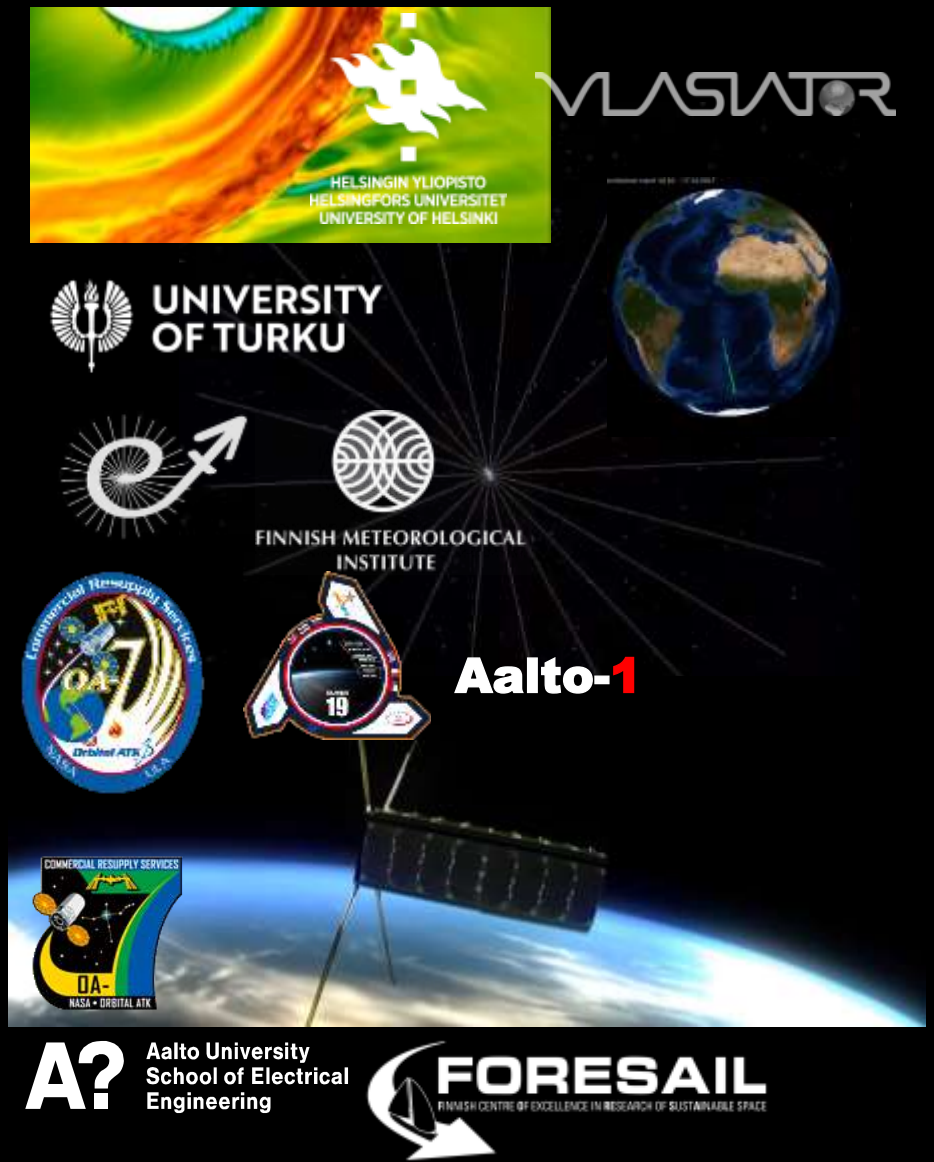

Modelling team
University of Helsinki

Instruments team
University of Turku

Propulsion team
Finnish Meteorological Institute

Platforms team
Aalto University

Observations team
University of Helsinki