FER STUDENT
SATELLITE PROJECT

FERSAT mission

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Mission objectives:

(1) Demonstrate measurement of light pollution (form space): identify the type of light sources contributing to light pollution and determine the fraction of solid-state lighting in overall lighting.

(2) Demonstrate a simple ozone thickness measurement using solid-state detectors.

(3) Implement efficient high data-rate downlink in the X-band for images and payload data.

Launch a nanosatellite (CubeSat) in 2021.

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Funding and resources:

- Croatian Science Foundation (HRZZ IP-2018)
- Croatian industry: Croatel, Geolux, Ultima.
- Multiple donations

- Ten faculty members and 50 students involved.
- Collaboration with Faculty of Mechanical Engineering and Naval Architecture (FSB) and with the Faculty of Science (PMF) in Zagreb

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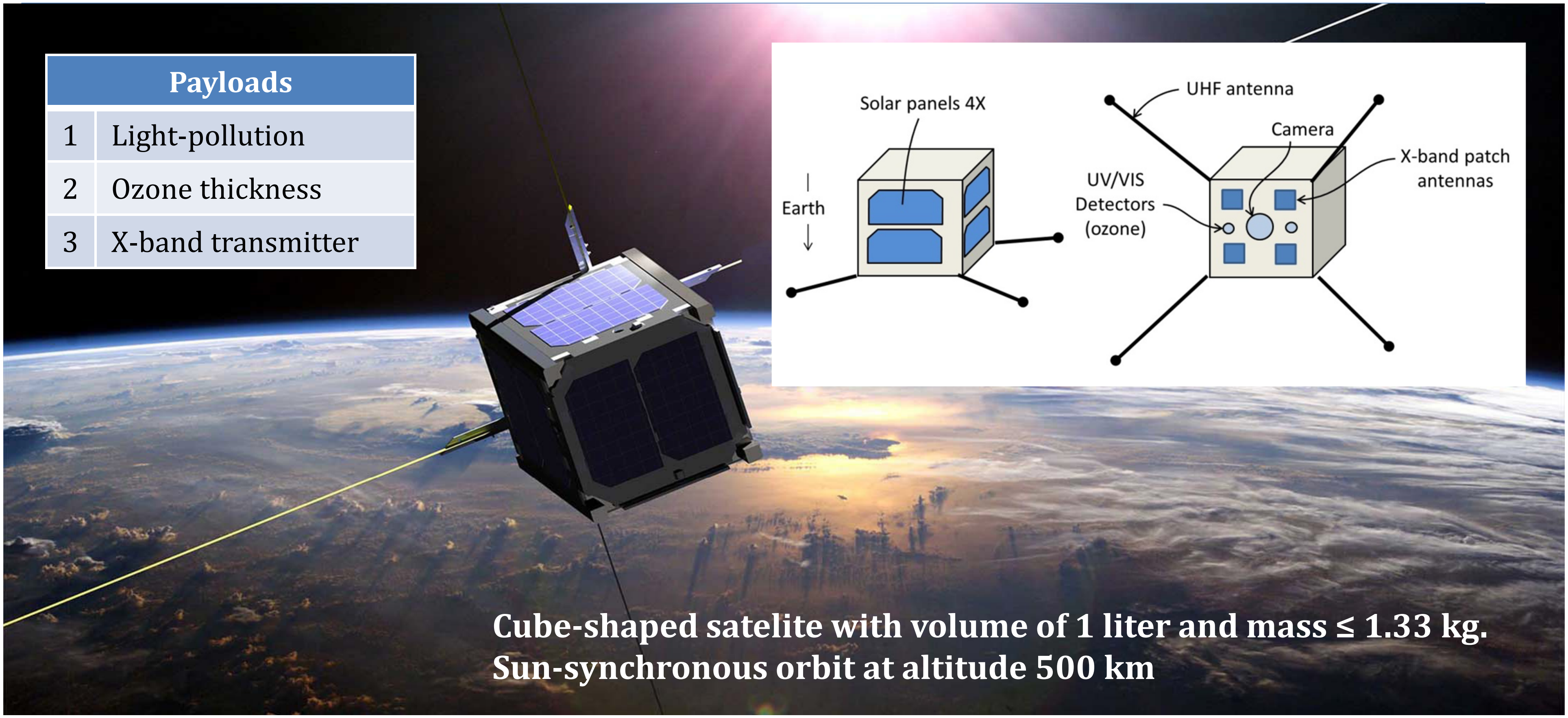
FERSAT nanosatellite

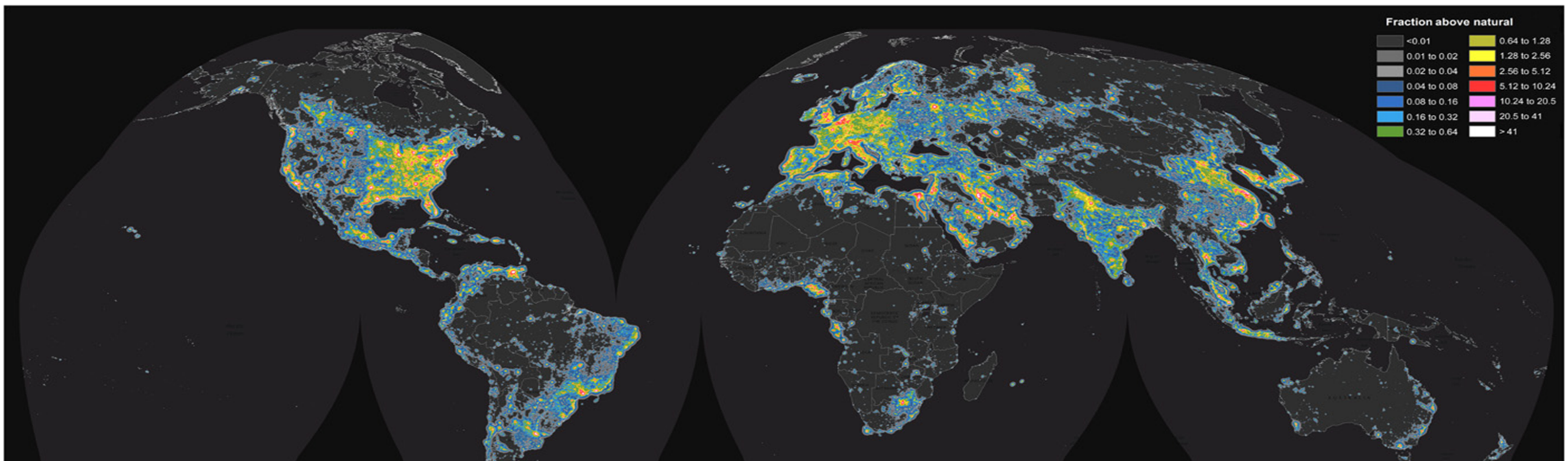


Payloads	
1	Light-pollution
2	Ozone thickness
3	X-band transmitter

Cube-shaped satelite with volume of 1 liter and mass ≤ 1.33 kg.
Sun-synchronous orbit at altitude 500 km

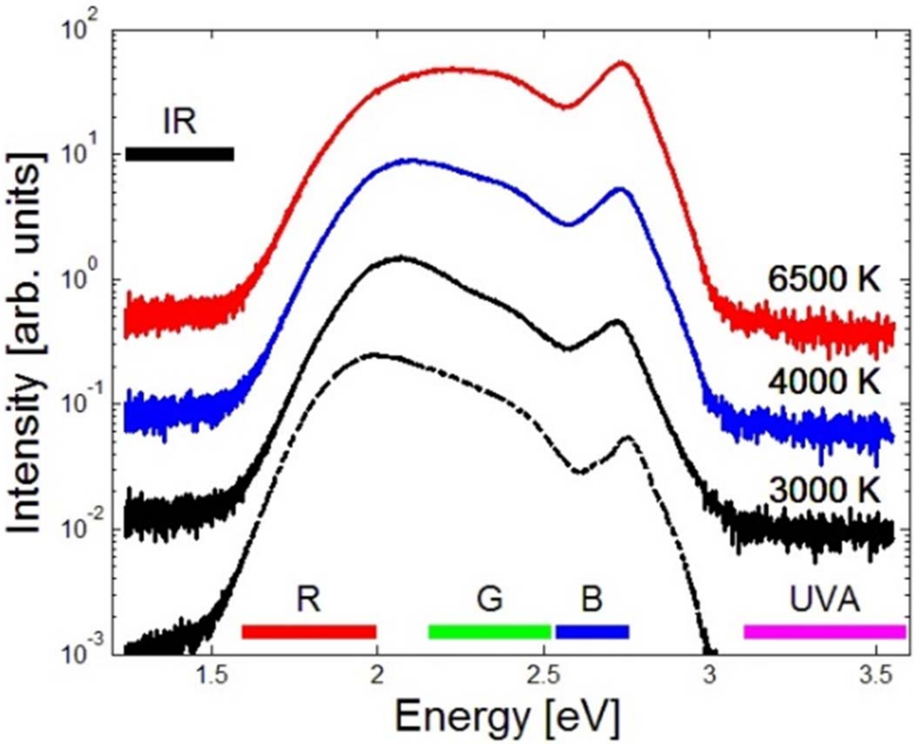
Payload 1: Light pollution measurement

- World illumination is changing: conventional sodium/mercury lighting is being replaced with solid-state ligthing (LED).
- **Question:** Can we estimate the fraction of global lighting has been converted to LEDs?



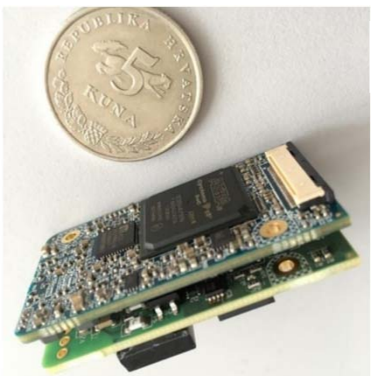
Payload 1: The challenge

- LED lighting exhibits high intensity of **blue light**, which disturbs animal behavior and human circadian rhythm.
- Light pollution data is available from satellite images (LandSat), but only in the 500–900 nm wavelength range, which we found is not sufficient to resolve the light source. Sentinel satellites take only daylight images.
- To be the best of our knowledge, light-source identification in light pollution is presently not publicly available information.



Payload 1: Objectives

- Develop an **algorithm** to extract the contribution of LED lighting in world illumination.
- Demonstrate the algorithm using a CCD camera and/or a miniature spectra-photometer on a CubeSat.
- Provide a world-wide map of LED installation.

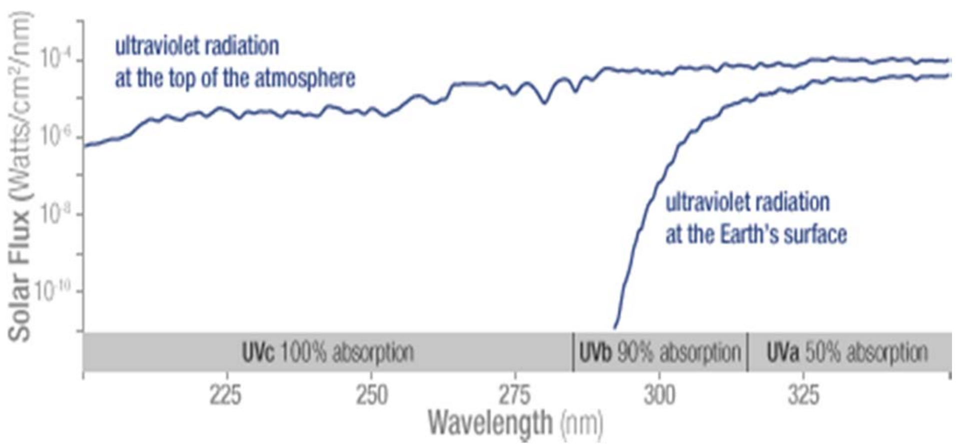


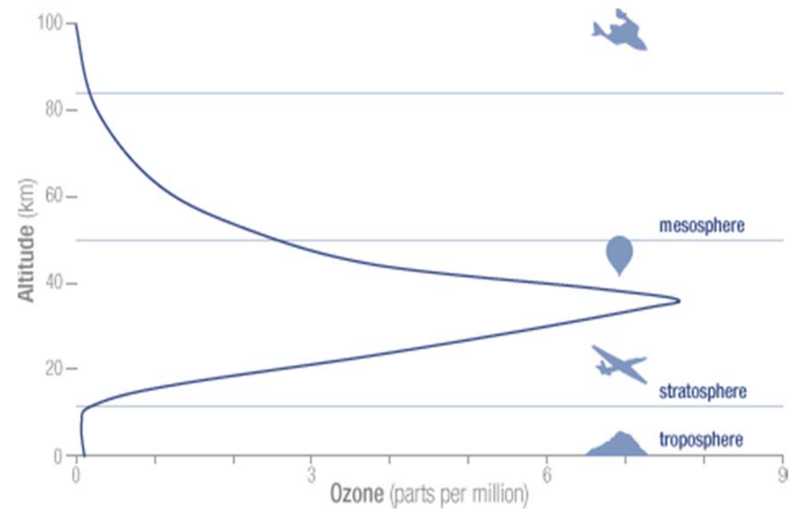
2.1MPix VIS+IR camera (Geolux/Zagreb)

Miniature USB-controlled spectra-photometer (350–1000 nm range)

Payload 4: Ozone layer thickness

- Ozone is distributed from the surface of the Earth to the stratosphere (~100 km).
- Ozone layer absorbs most of the harmful ultraviolet radiation coming from the Sun



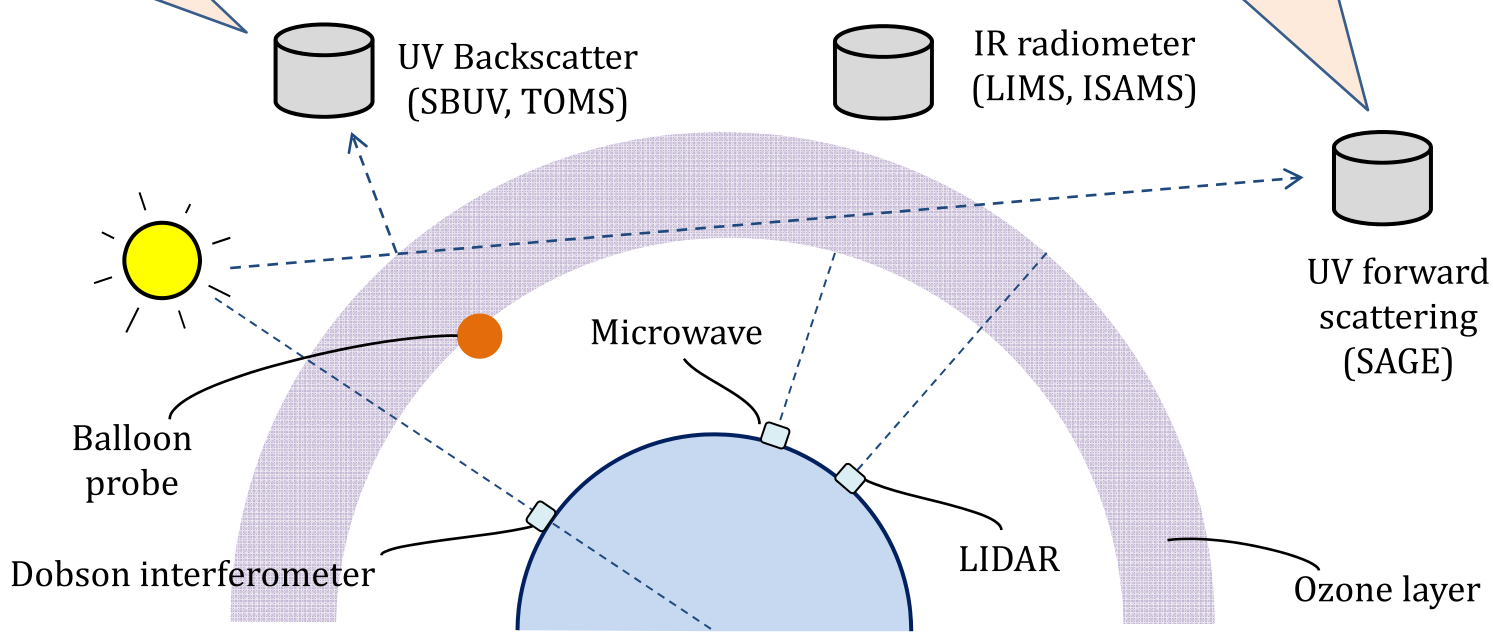


- https://ozonewatch.gsfc.nasa.gov/facts/SH.html

Payload 4: Ozone measurements

FERSAT will make UV backscatter measurements

and possibly UV forward-scatter measurements



Payload 4: Objectives

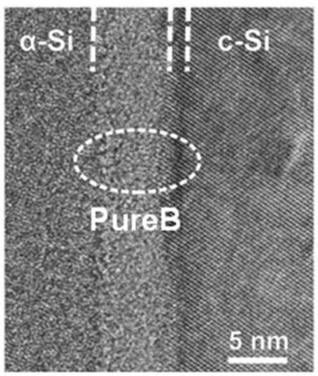
- Develop a simple optical technique, suited for a nanosatellite, to measure total thickness of ozone layer.
- Demonstrate operation of Pure-B (UV) detectors in space.
- Provide world-wide scan of ozone thickness using a nanosatellite.

Method:

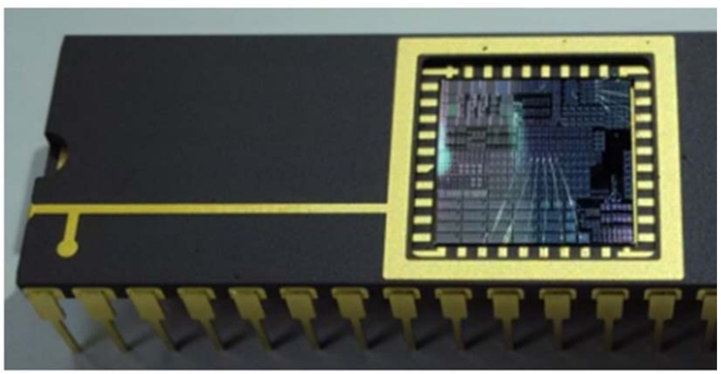
- Comparing the outputs of UVA and UVB detectors and a blue visible-light detector (similar approach as in the Dobson Spectra-photometer).
- Spectral resolving done using optical filters.
- Detectors will be nadir-pointing.
- Results to be expressed in Dobson Units.

Payload 4: Pure-B ultraviolet detectors

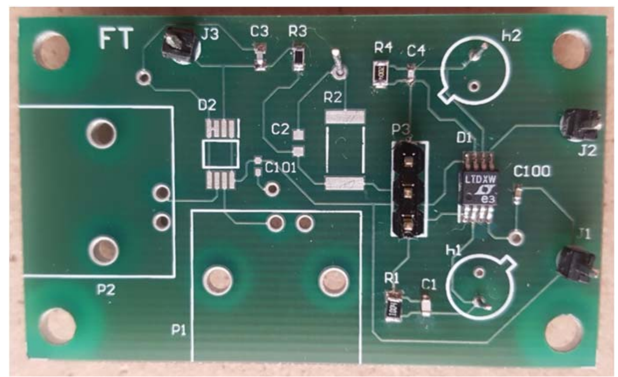
PureB detectors (elemental boron deposited on silicon) are being used for electron detection in scanning electron microscopes, but are also **excellent UV detectors**.



TEM image of PureB/Si interface



PureB detectors packaged for characterization



Dual transimpedance amplifier

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Payload 5: Implement X-band downlink

- CubeSat downlinks are generally in the VHF/UHF amateur radio band and it takes multiple satellite passes to download 2MPixel image.
- **Question:** Can we speed this up to download tens or hundreds of images per satellite pass?

The objective:

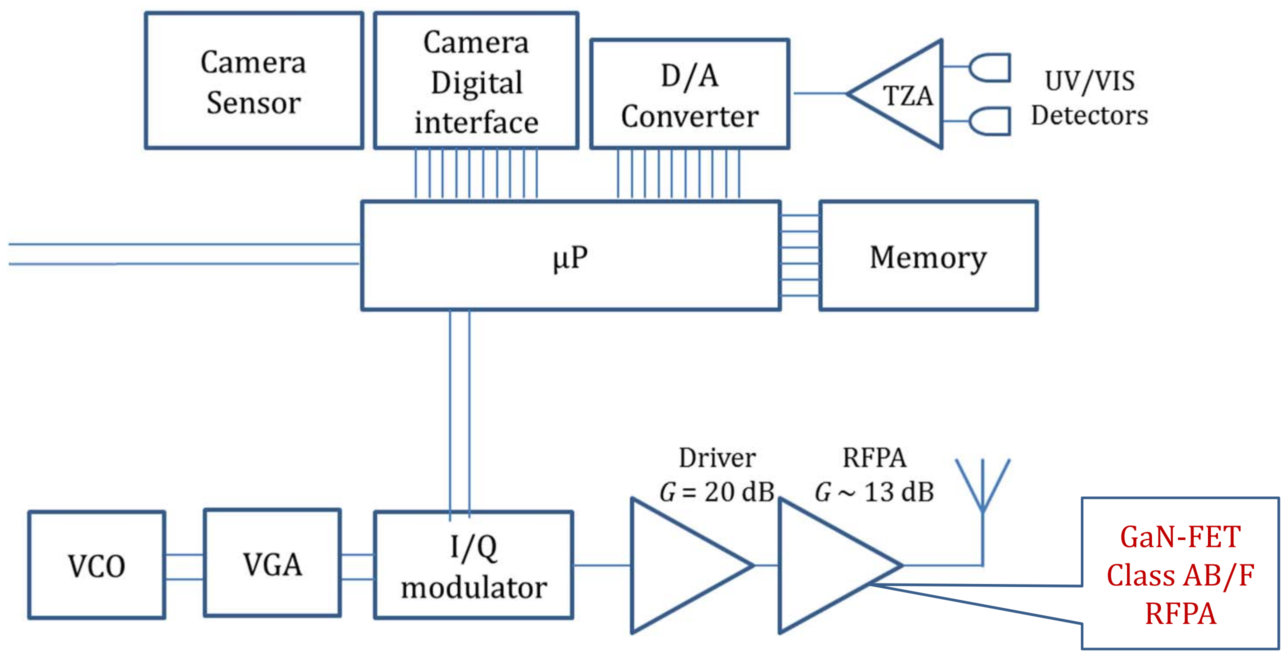
- Demonstrate a high-efficiency X-band communication between a 1U CubeSat and Earth station at at least 5 Mbps line rate.

Payload 5: Challenges and approach

Challenges: CubeSat power budget and weight budget is very limited, while commercial X-band transmitters dissipate a lot of power (> 10 Watts).

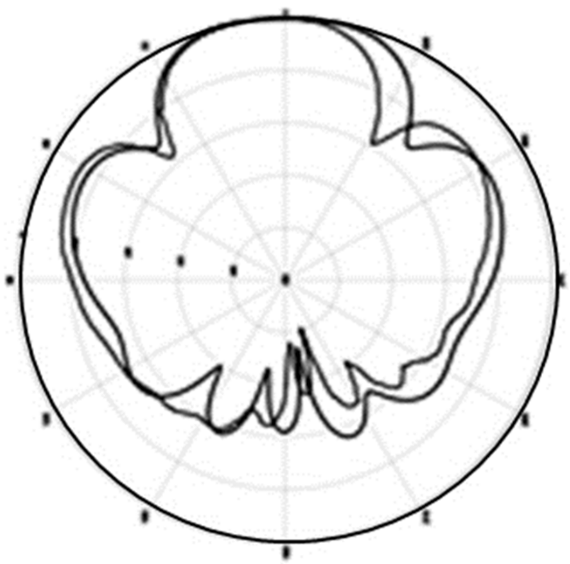
The approach:

- Phase-only modulation (BPSK or QPSK) allows for higher amplifier efficiency.
- Modulation bandwidth is at least 5 MHz
- Design AlGaN/GaN HEMT Class F RFPA

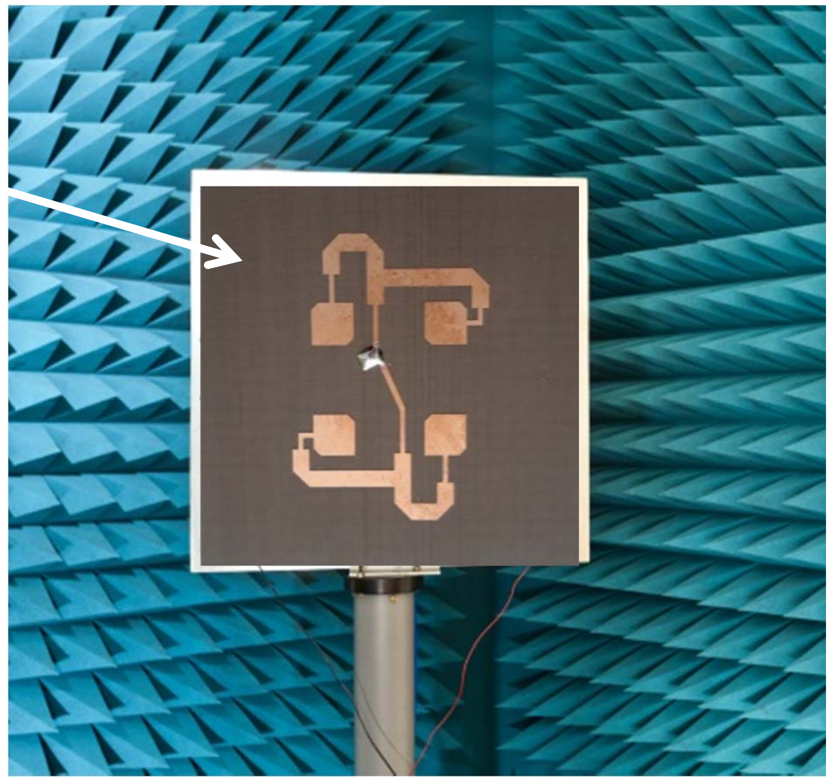


Payload 5: Approach

4 patch-antenna array with circularly polarized emission

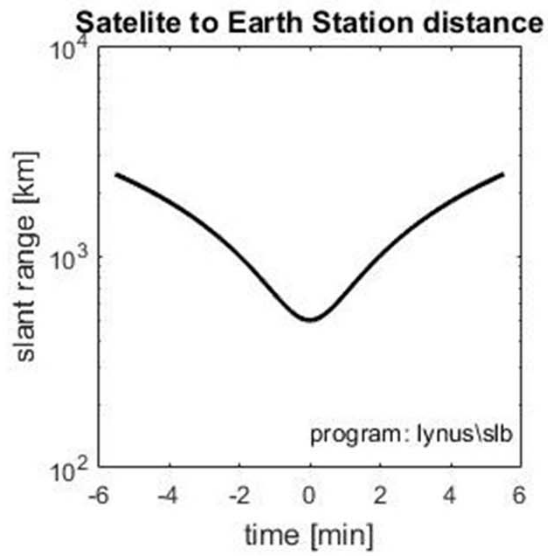


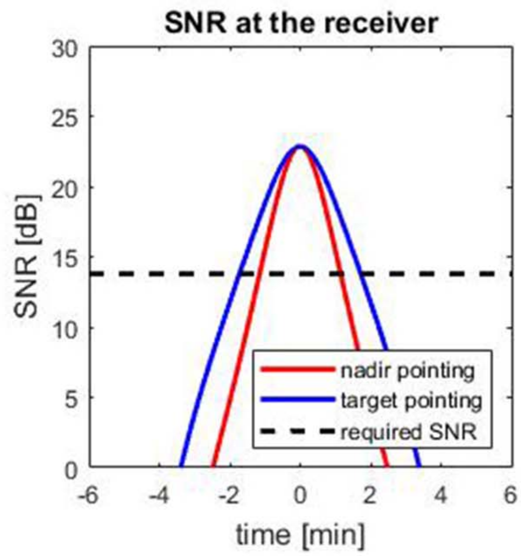
Radiation patterns



X-band ground station

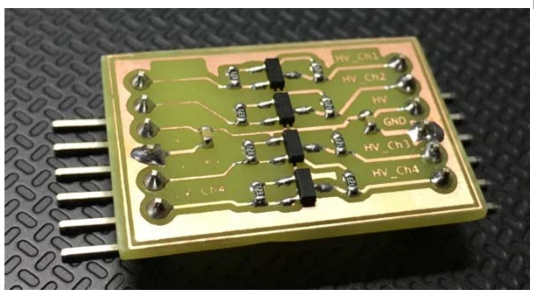
- Antenna requires very high gain (~50 dB achievable with 3 m parabolic antenna).
- Frequencies: 8 GHz (Earth Observation) and 10.45 GHz (Amateur Radio)
- Link budget for h = 500 km, BPSK/10.45 GHz shows about 3 min visibility.



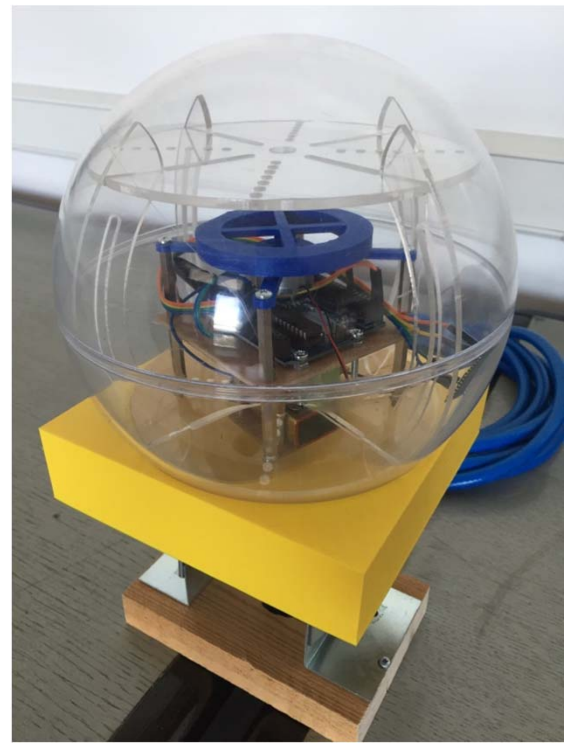


Satellite build is an interdisciplinary engineering project

- energy harvesting
- attitude control
- control software
- communication electronics



- sensor data acquisiton electronics
- image and signal processing



FERSAT development team

plus 50 students