Bauman Moscow State Technical University

Cubesat Technology Development – BMSTU Heritage

Prof. Vera Mayorova,
Dmitry Rachkin,

Yareelo №1, №2 mission

The «Yareelo» mission

Two satellites Yareelo No1 and No2 with CubeSat1,5U size

Purposes:

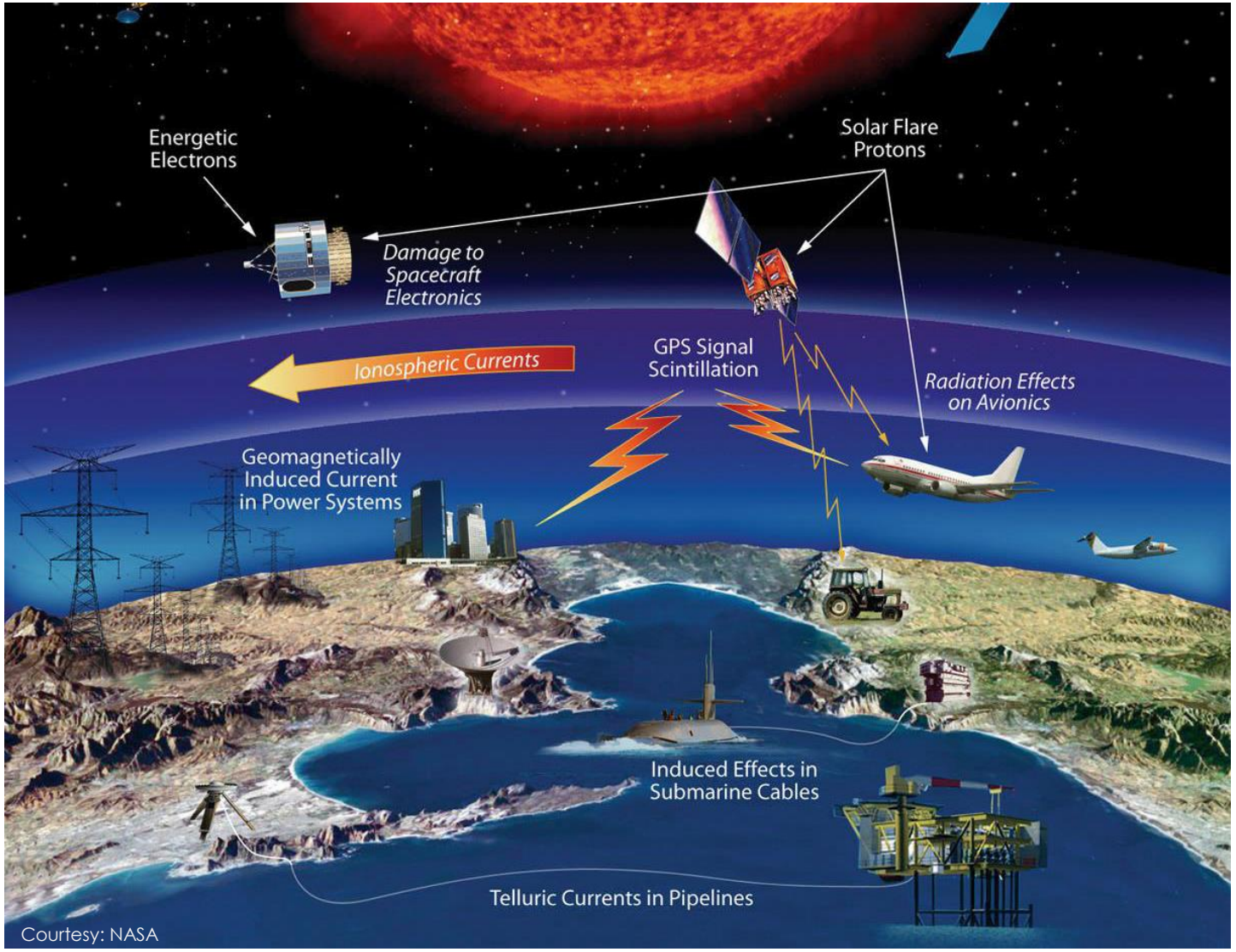
- Scientific research of the Sun and solar-terrestrial relations;
- Space weather monitoring;

Objectives:

- To launch two 1,5U CubeSats in one P-POD;
- To register the solar activity and the radiation situation;
- To prove the possibility of a long-term nanosatellite group flight;

Volume
1U=100mm x 100mm x 113mm

Space Weather



- Space weather has a lot of affects for technical and biological systems especially in Arctic region

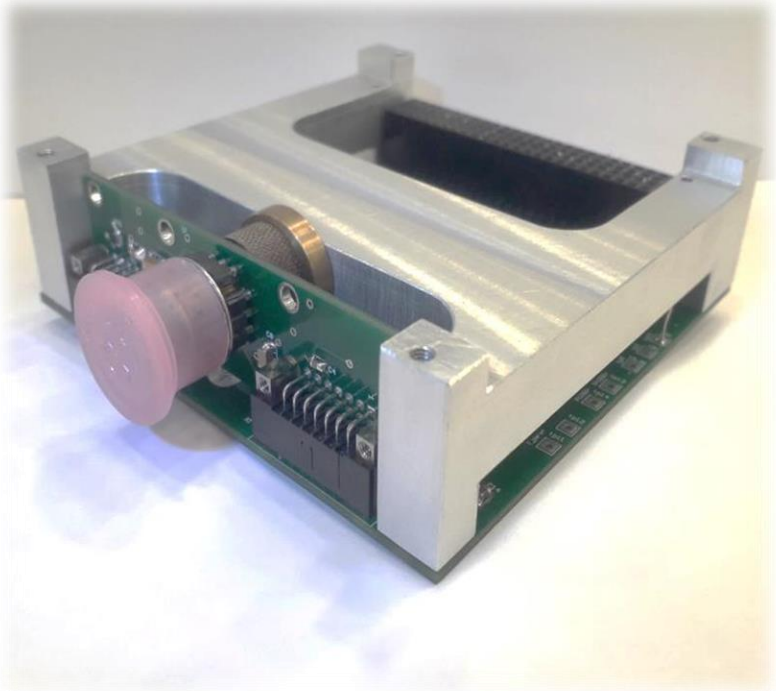
Payload: X-ray Spectrophotometer

Functional area:

- Receiving non-stop and quick information about solar activity;
- Space weather forecasting;
- Registering of the solar flares (0.5-15 KeV).

Device technical features:

- Power consumption: 0,5 W (on the average);
- The accuracy of orientation
- to the Sun: cone with half angle 10° (sensor field of view);
- Data volume: 128 B/s



P.N. Lebedev Physical Institute of the Russian Academy of Sciences
Физический институт имени П.Н.Лебедева
Ф И А Н

Spectrophotometer developed by Lebedev Physical institute of Russian Academy of Science

Payload: Gamma radiation and charged particle detector

Functional area:

- Study fast variations of electron flows in the gaps between radiation belts
- Study the particle flows and gamma radiation dynamics in low orbits depending on geomagnetic conditions in the range of 0.3-3 MeV.

Device technical features:

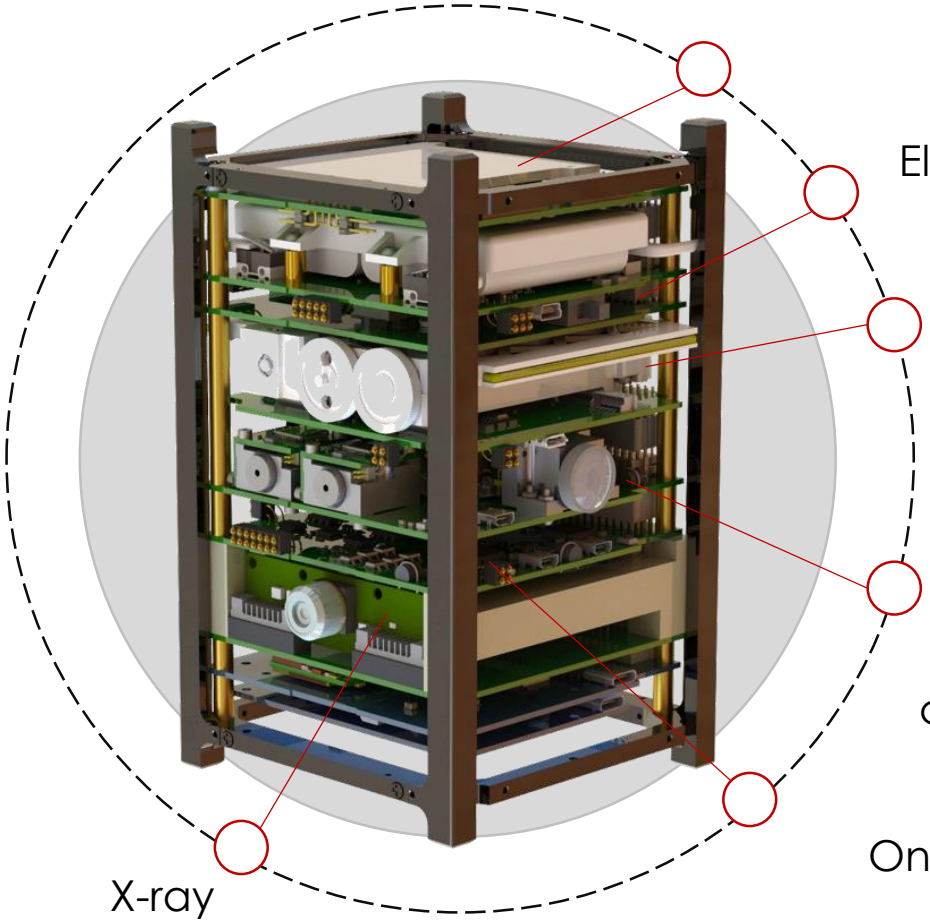
- Energy extraction: 0,1-2 MeV
- Input power: 0,8 W;
- No device orientation required;
- Daily data output : 300 KB

НИИЯФ МГУ

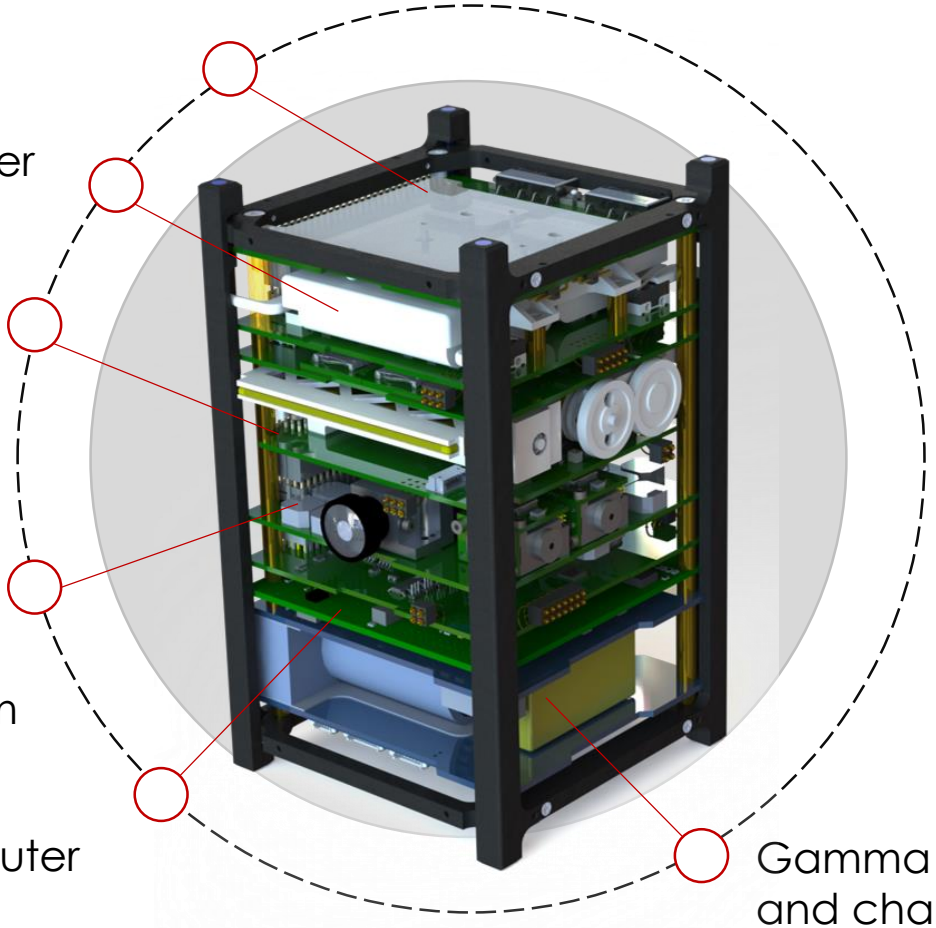
Gamma radiation and charged particle detector developed by Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University.

Internal design

Yareelo №1



Yareelo №2



Transceiver

Electrical power system

Drag sail unit

Reaction wheel attitude control system

Onboard computer

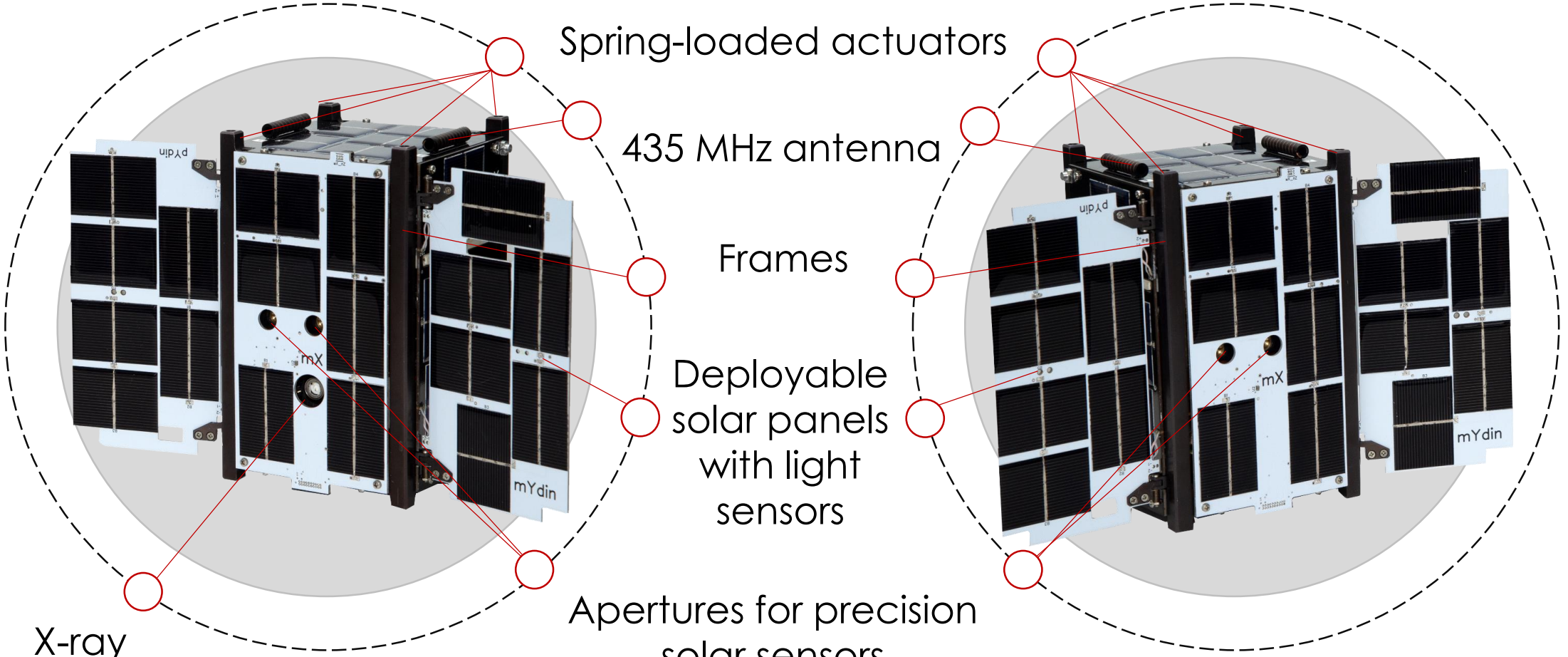
X-ray Spectrophotometer

Gamma radiation and charged particle detector

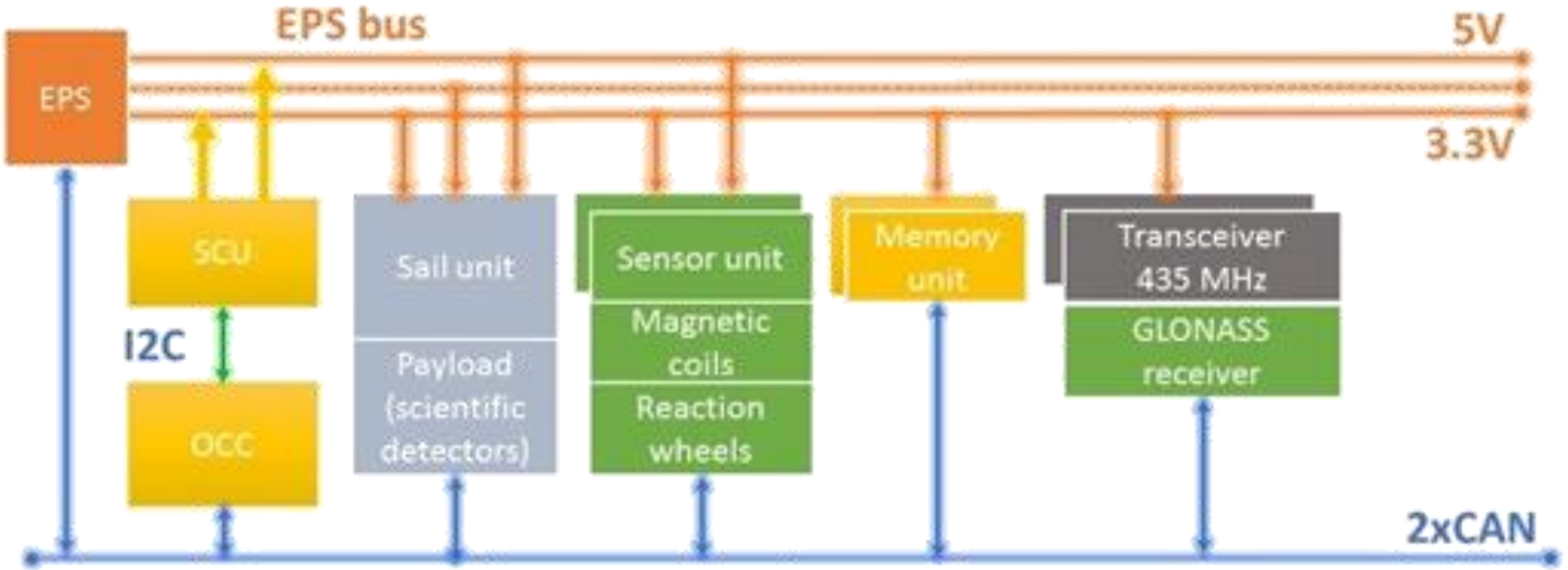
Outer design

Yareelo №1

Yareelo №2



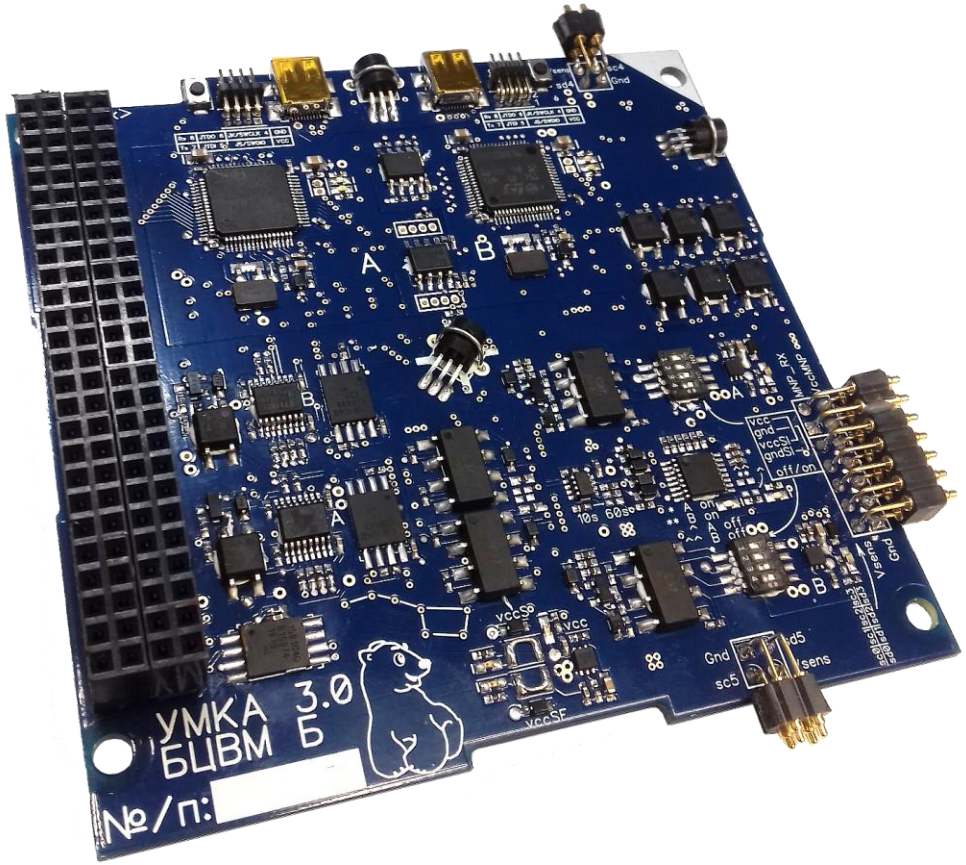
Satellite electrical architecture



Power system buses		
Unregulated buses	2.8 – 5.5 V	Up to 5 A
3.3 V	3.0 – 3.6 V	Up to 2 A
5 V	4.5 – 5.5 V	Up to 3 A

Data transmission interfaces				
CAN	I2C	UART	RS-485	SPI

Unified central microcontroller



Developed by students team

- Management of all on-board systems;
- Processing data from a GPS / GLONASS receiver, light and temperature sensors, payloads;
- Execution of onboard algorithms that process input data and provide control actions

Technical characteristics

Processor, frequency	ARM Cortex-M3, 8-120 MHz.
OS	FreeRTOS
MCU	STM32F205xx
External RAM	512 KB (FRAM)
MCU's ROM	512 KB (Flash)
One-fault resistant	

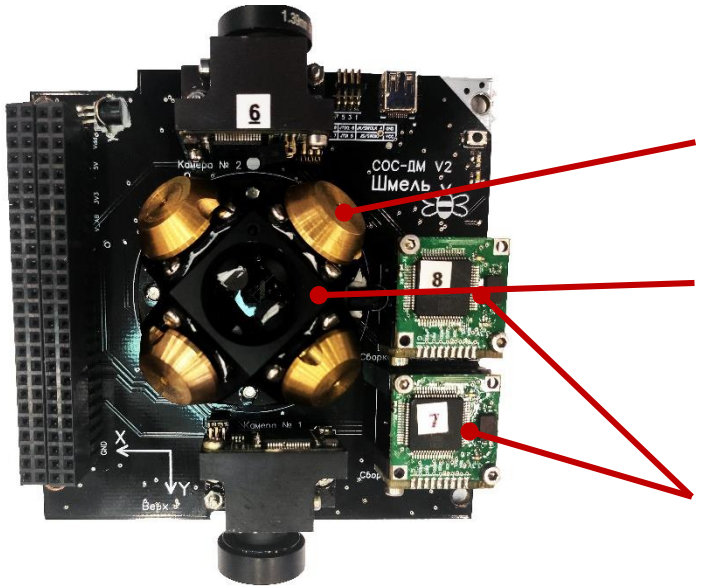
Attitude control systems

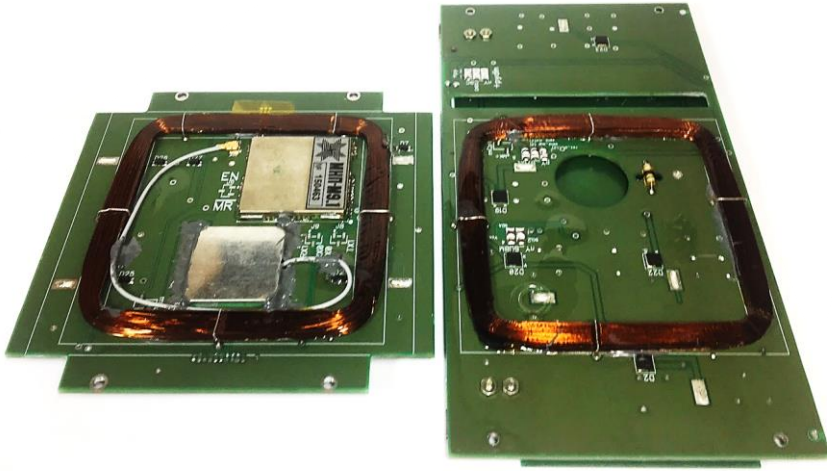
Reaction wheel attitude control system

Maximum rotational velocity	10000 rpm
Kinematic momentum	$0.32 \cdot 10^{-3}$ $m^2 \cdot kg/s$
Control torque	$0.1 \cdot 10^{-3}$ $N \cdot m$
Number of flywheels	4

Magnetic coil attitude control system

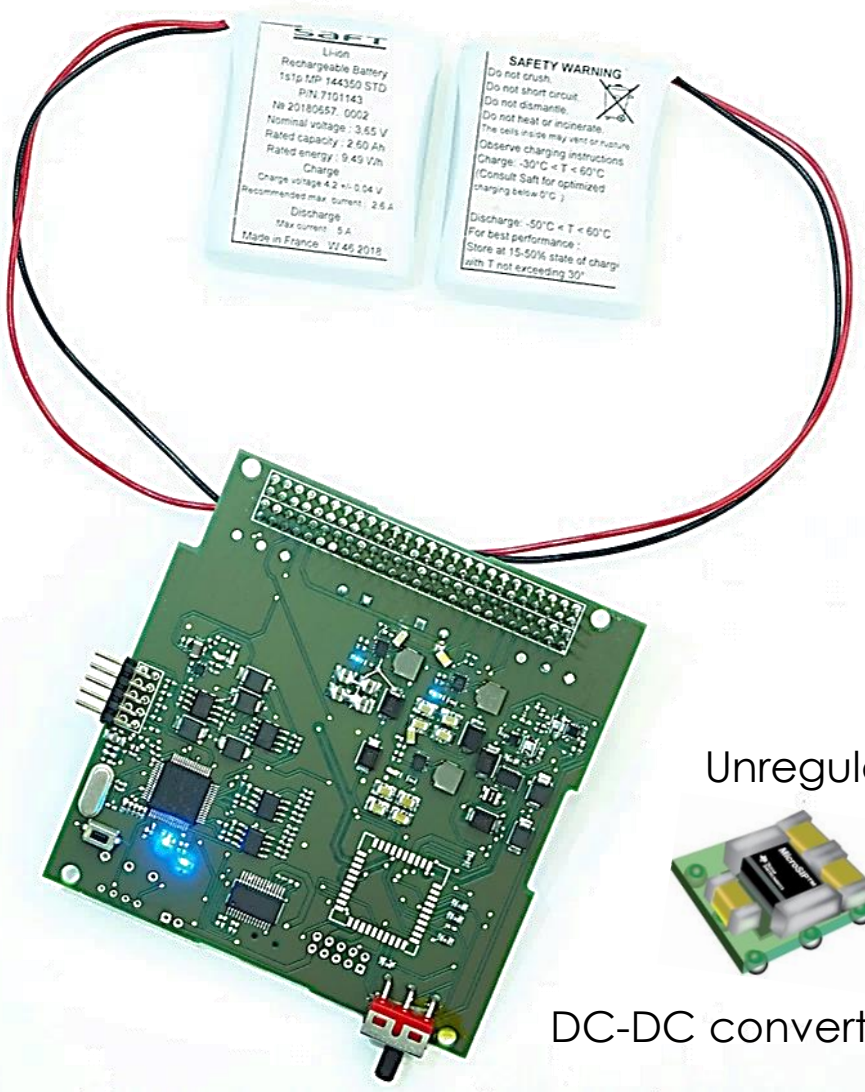
Number of windings	600
Resistance	157 Ω
Power	0.16 W
Magnetic moment	0.07 $A*m^2$
Number of coils	3





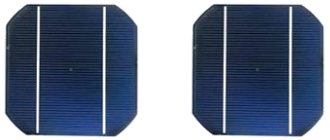
Developed by students team

Power generation control system



Sun exposure:
61 % of single pass;

Input power:
7 W



Efficiency of solar panels: 21%
Solar panels area: 0.0243 m^2

Output power:
≤ 5,13 W

MPPT; EFF ≈ 90 %

Unregulated power bus

DC-DC converters: EFF 80…90%

Charging the batteries:

EFF of the chargers: 90 %

Battery capacity: 5200 mAh

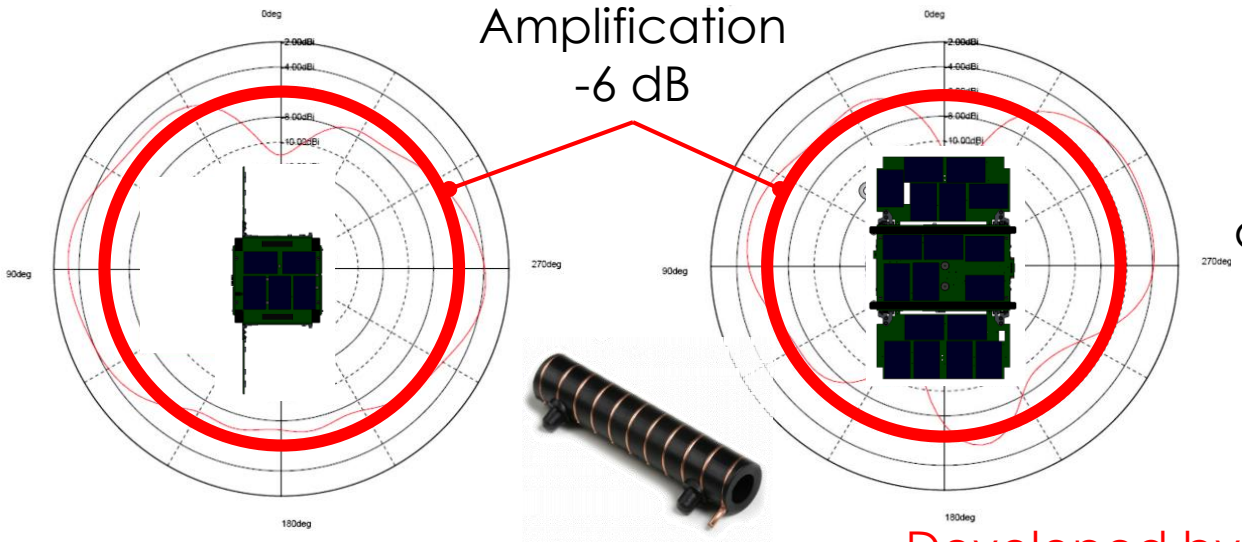
(2 pieces);

Developed by students team

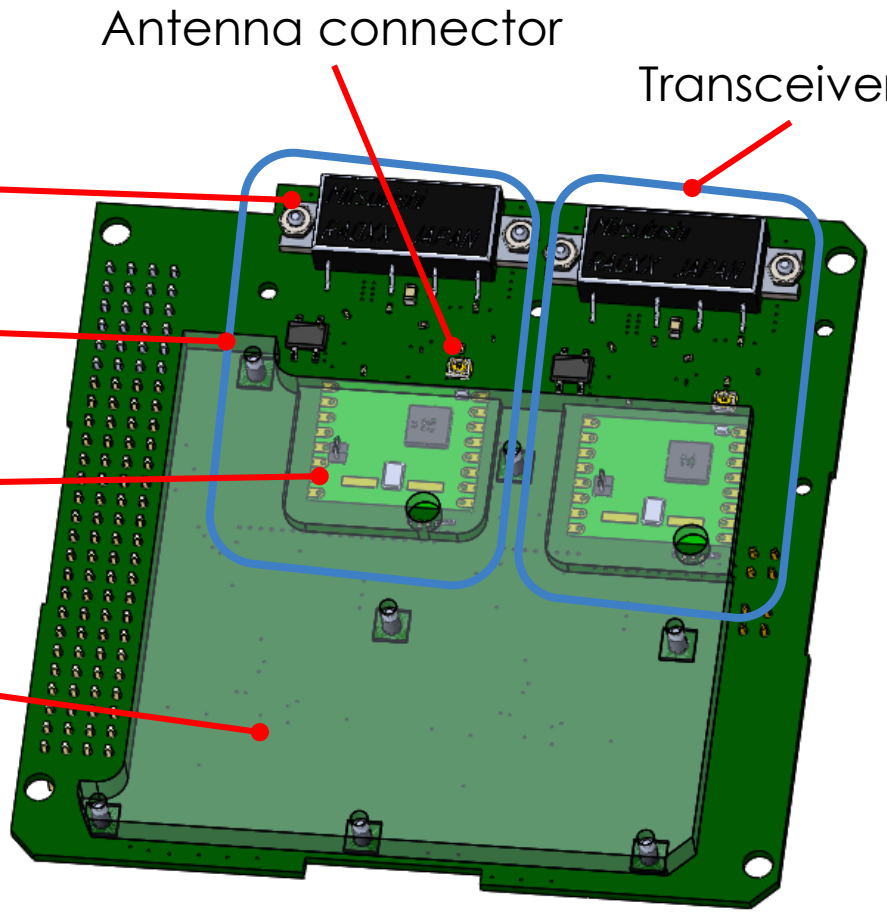
Average output power per single pass:
≈ 2,7 W

Radio communication system

- Half-duplex radio communication between CubeSats and ground control complex based on the MCC BMSTU.
- Half-duplex radio communication between «Yareelo № 1» and «Yareelo № 2»
- Frequency range : 430 - 440 MHz
- Transmission speed to ground control complex: 9600 BPS – 38400 BPS
- Data exchange rate between satellites: at least 1200 BPS



Angular pattern



Developed by students team

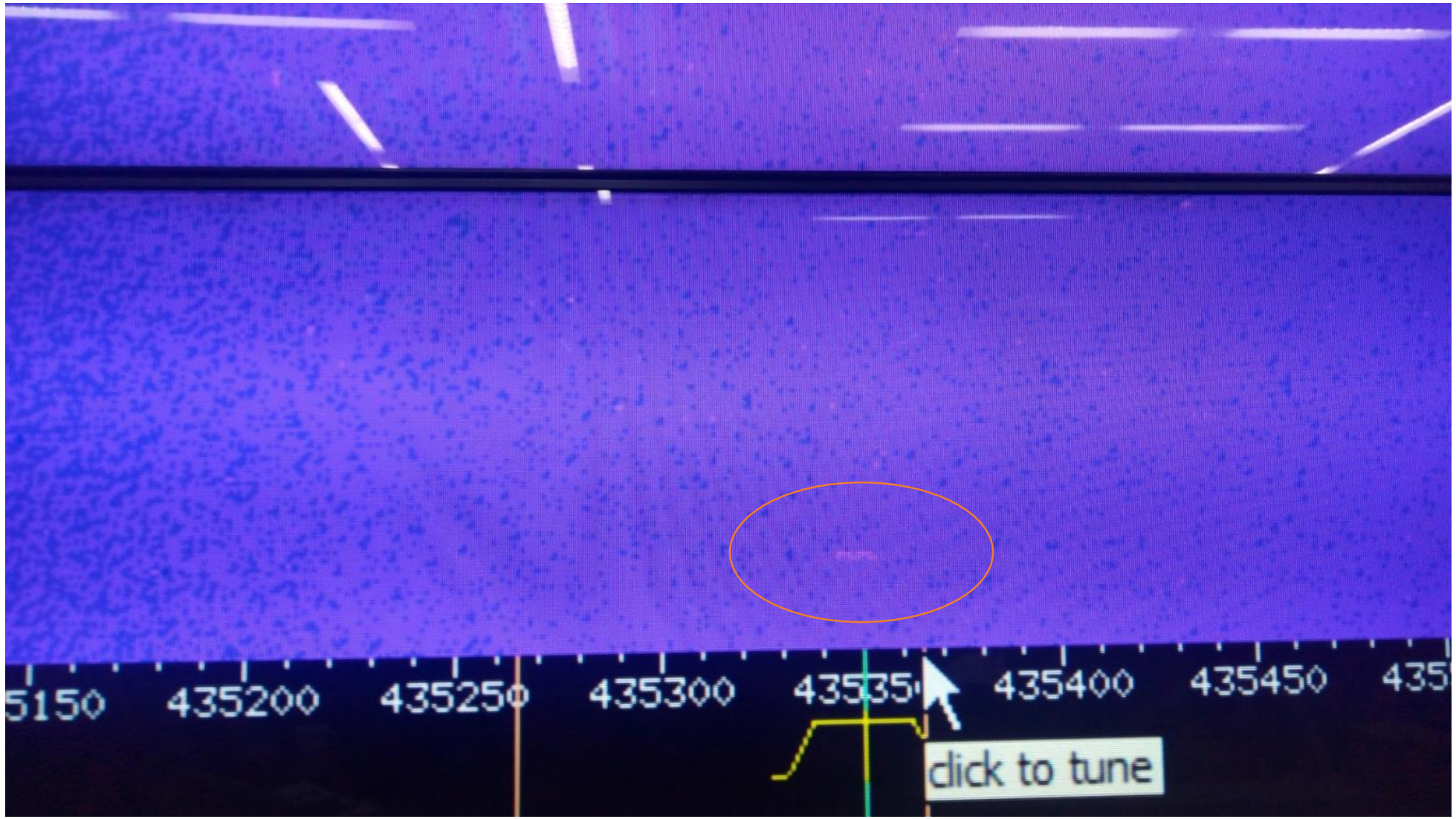
Two transceivers board

Yareelo Launch campaign

Launch from «Plesetsk» spaceport 14:20 28.09.2020

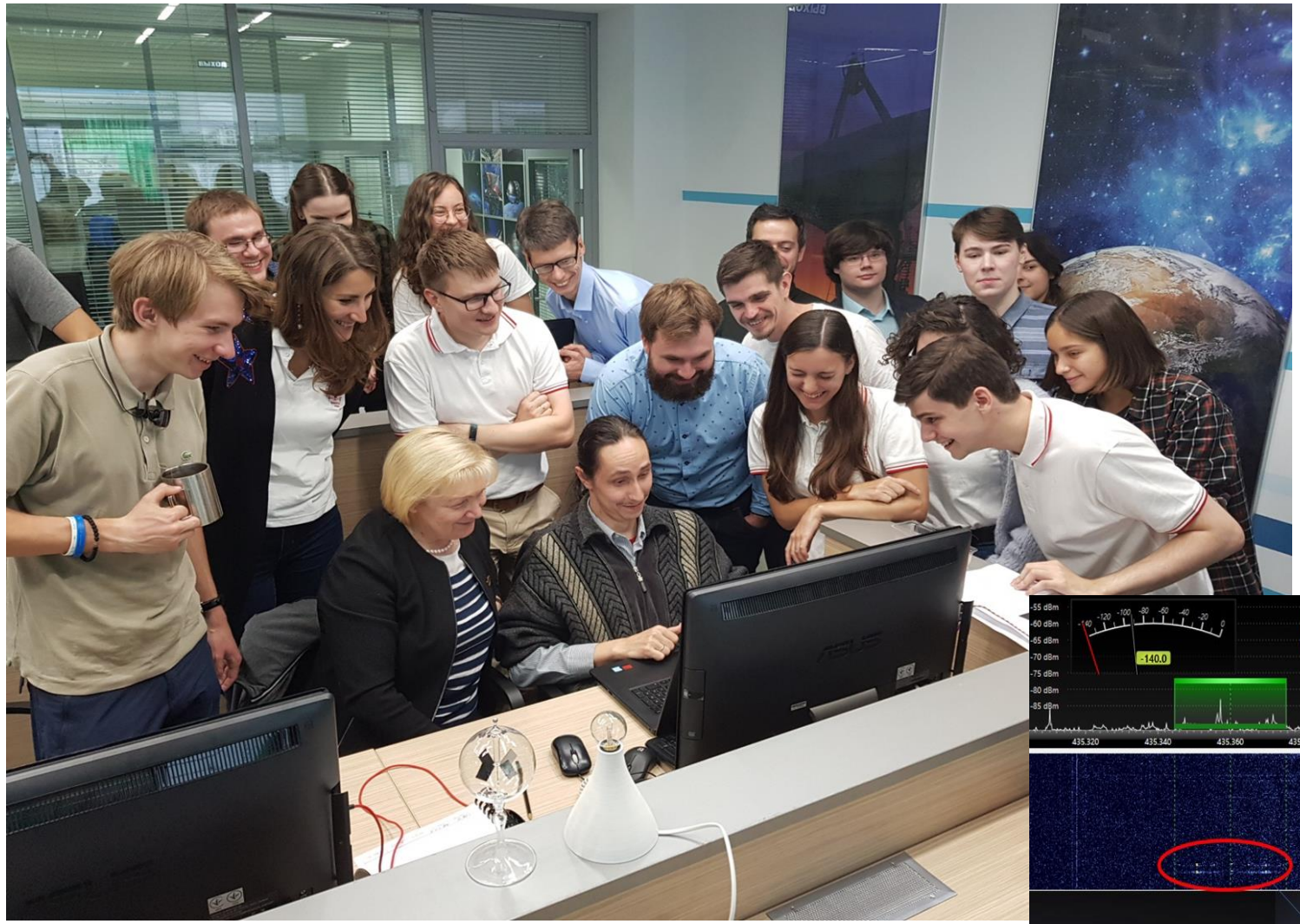
Launch done by Roscosmos as a part of “Universat” program – free launch program for Russian Universities

First received signal

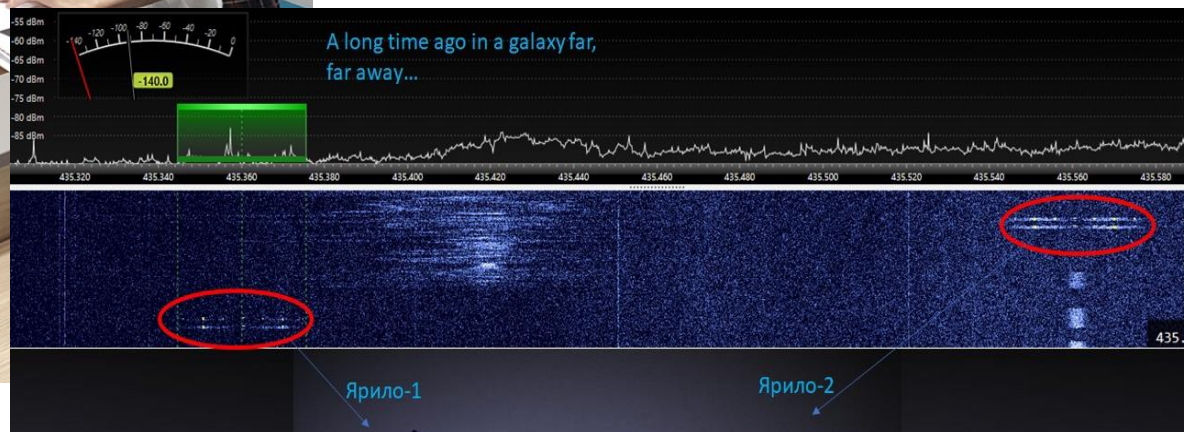


Signal was received by WebSDR service in South Africa
00:40
29.09.2020

First emotions



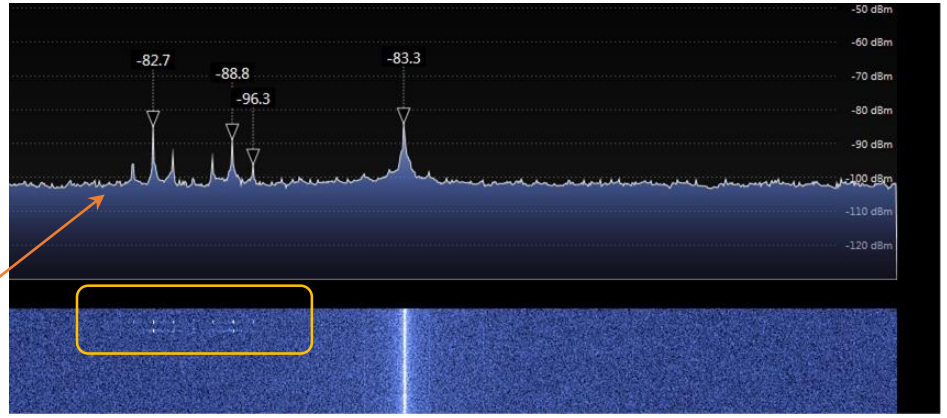
02:09 29.09.2020 moment of first signal decoding



Mission control center equipment

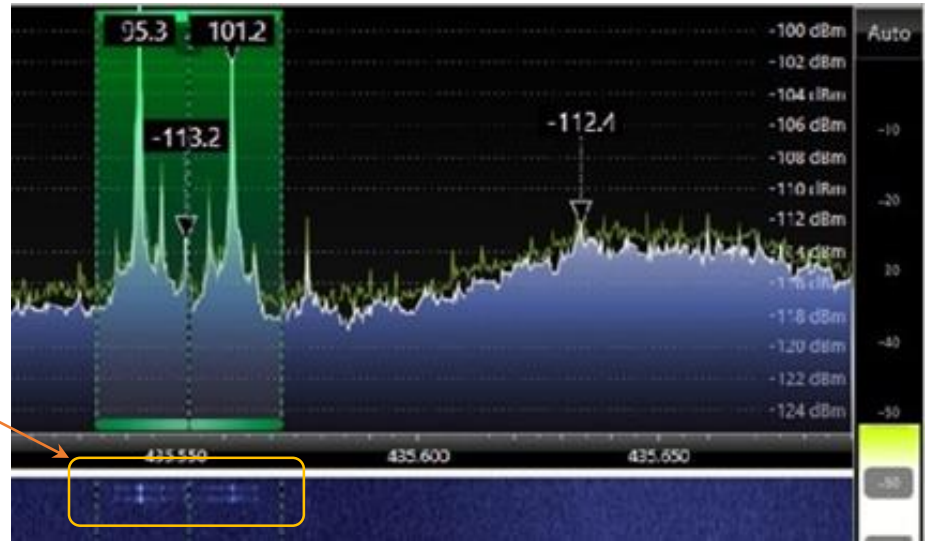
Antenna
«Yagi–Uda» 15dB,
LNA Mirage Kp-2 20dB,
receiver RTL-SDR

Signal/noise: ~8 dB



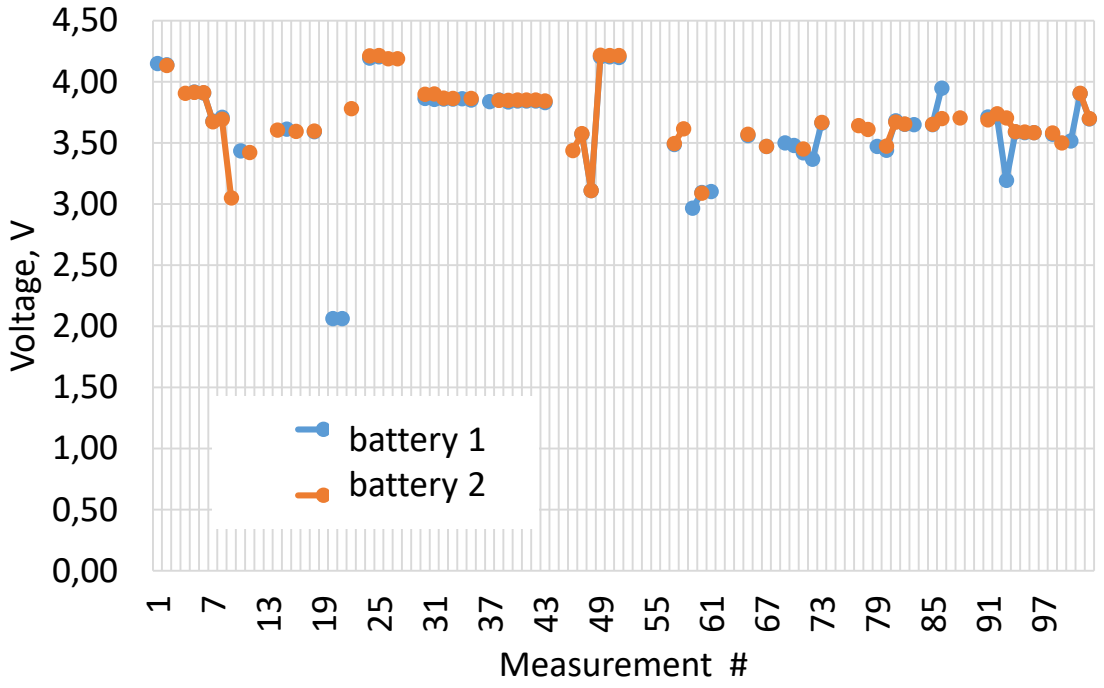
Antenna
«parabolic» 3,7m 22dB,
LNA VHF Design 26dB,
receiver LimeSDR

Signal/noise: ~15 dB

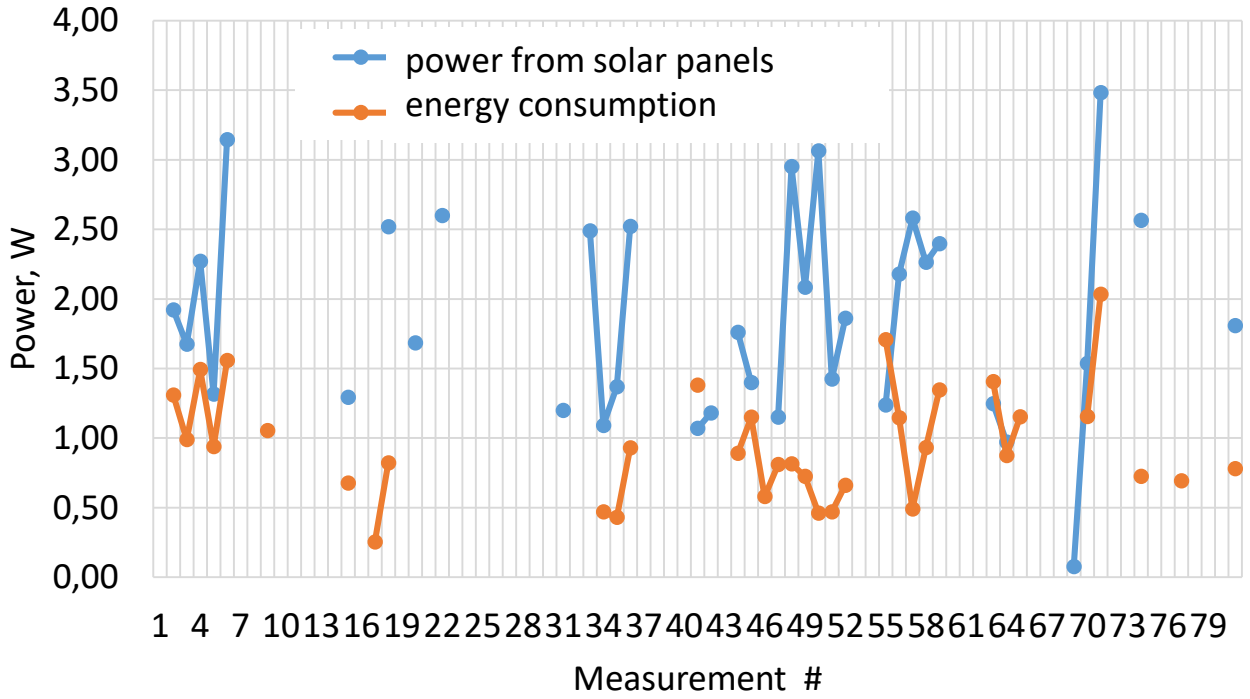


Power Supply System flight results

Batteries voltage



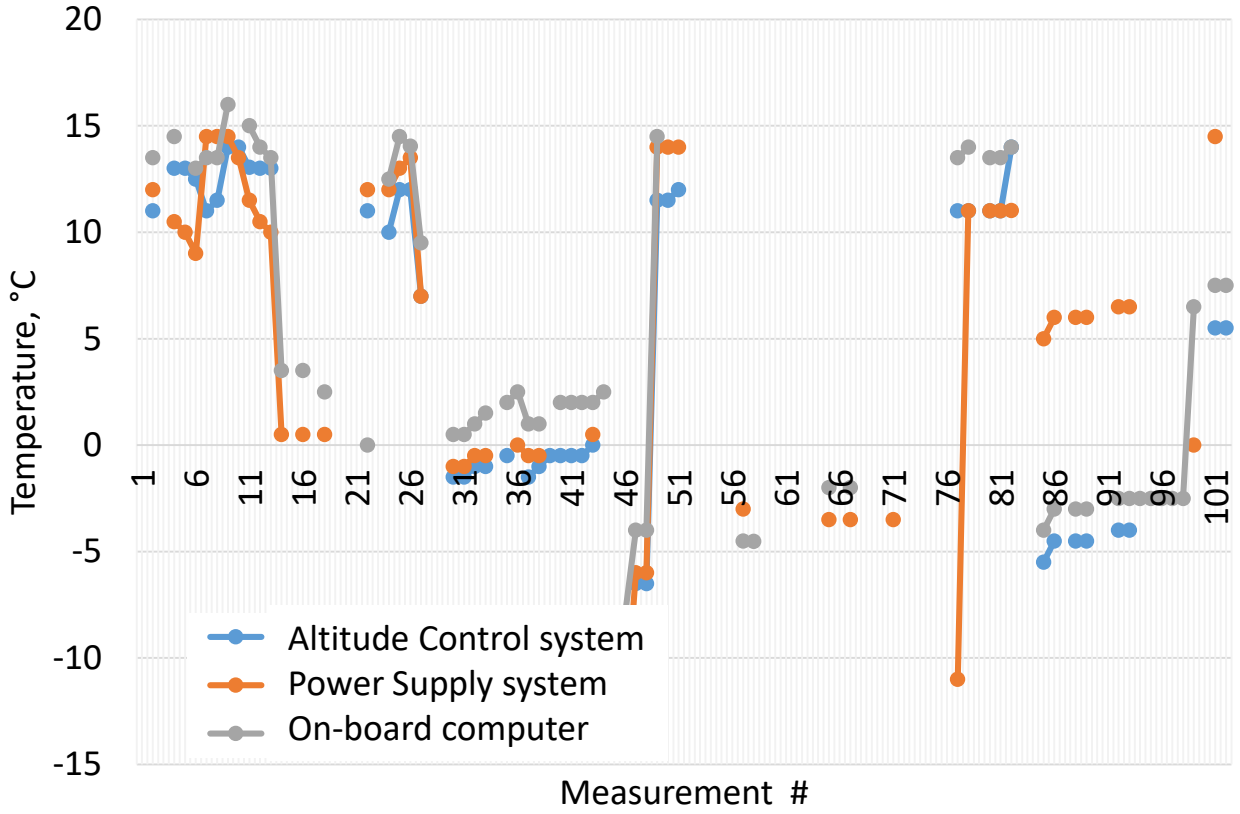
Power output, and energy consumption

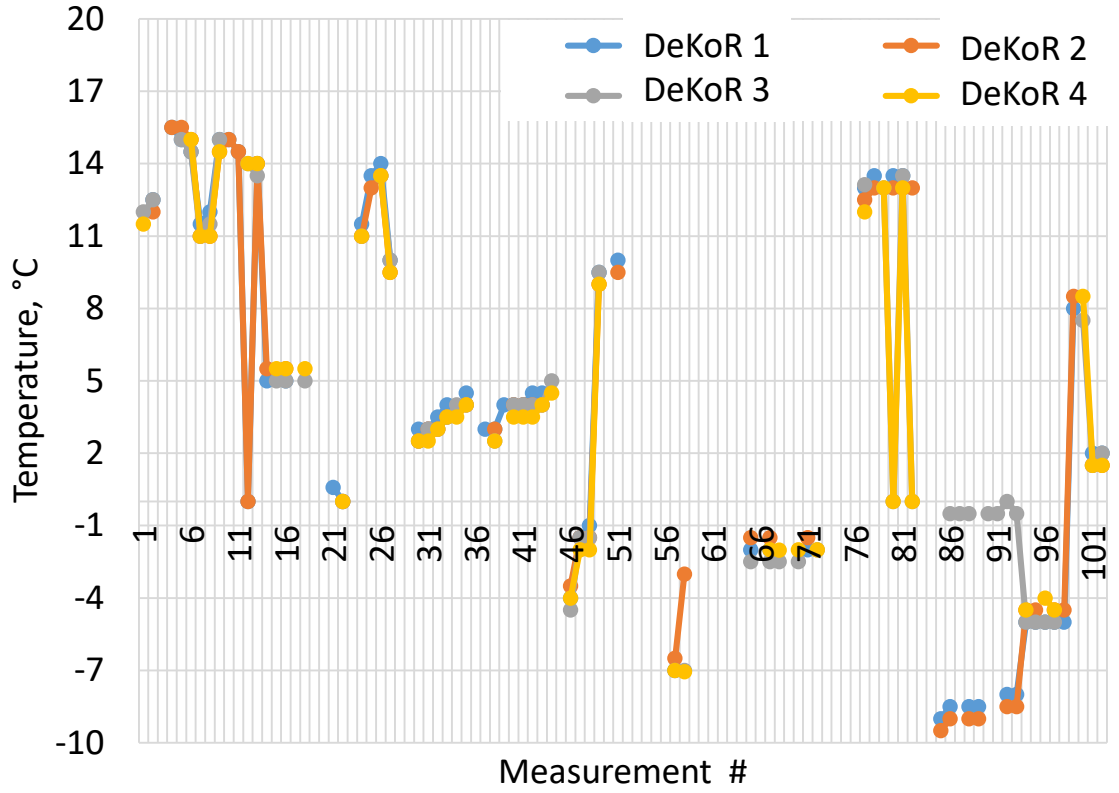


- The power supply system is functioning correctly
- The voltage on the batteries dropped from 4.2 to 3.9 V for ~ 5000 charge/discharge cycles (1 year of flight). It corresponds to a degradation of about ~15% incapacity.
- There is no significant degradation of solar panels.
- There is no significant change in energy consumption.

On-board Computer flight results

There is a switch between two half-sets of main controllers about once a week. Presumably, this is caused by software flaws.





Temperature data from the onboard computer telemetry during the operation

Yareelo №3, №4 mission

Yareelo No3, No4 mission

Scientific goals:

- Measurements of Earth Radiation Budget: IR flux from Earth (albedo);
- Earth magnetic field measuring;

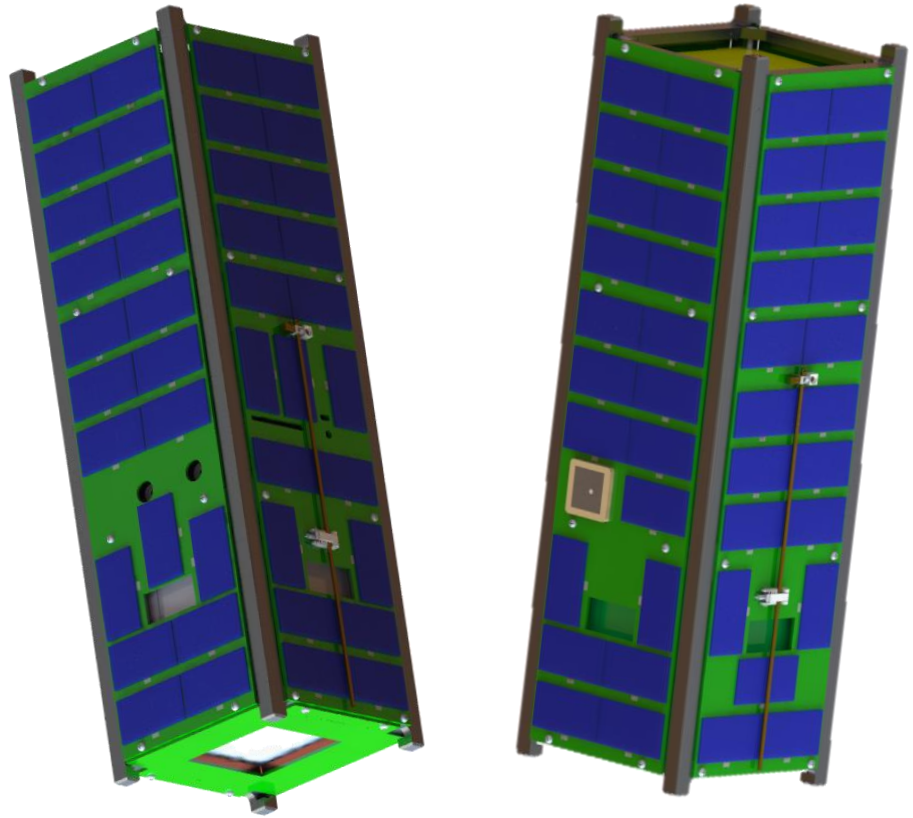
Technological features and demonstration:

- Deployable carbon composite gravitation boom for magnetometer placing;
- Inflatable structure for satellite end of life utilization;

Launch

- Q2 2022 piggy back on Soyuz 2 rocket from Vostochny spaceport (Roscosmos Universat program)

Two satellites Yareelo No3 and No4 with CubeSat 3U size

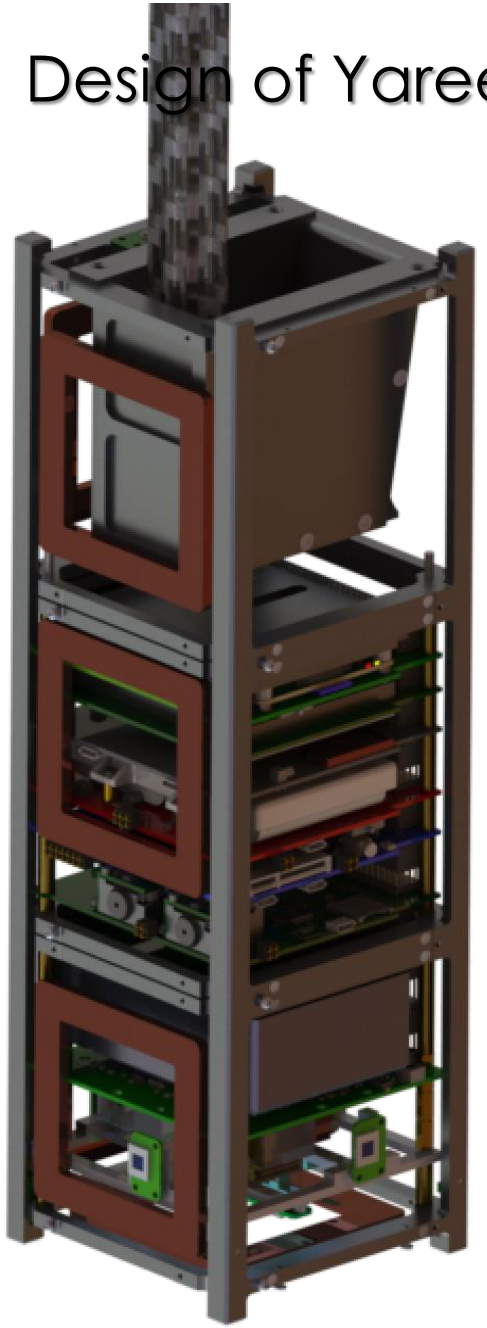


Yareelo No3, No4 mission

Two satellites Yareelo No3 and No4 mockups

	Yareelo 3	Yareelo 4
Size	Cubesat 3U	Cubesat 3U
Mass, kg	4	4
Orbit	500-600km, SSO	500-600km, SSO
Average power consumption	1,6 W	1,6 W
Memory	8 GB	8 GB
Transceiver frequency	435-440 MHz, 2,4GHz	435-440 MHz, 2,4GHz
Payload	short-wave reflected and direct solar radiation detector, magnetometer	short-wave reflected and direct solar radiation detector
Technological feature	deployable composite fibre boom	inflatable structure
Launch	Q2 2022 piggy back on Soyuz 2 rocket from Vostochny spaceport	Q2 2022 piggy back on Soyuz 2 rocket from Vostochny spaceport

Design of Yareelo No3 and No4 satellites



Deployable Gravitational boom

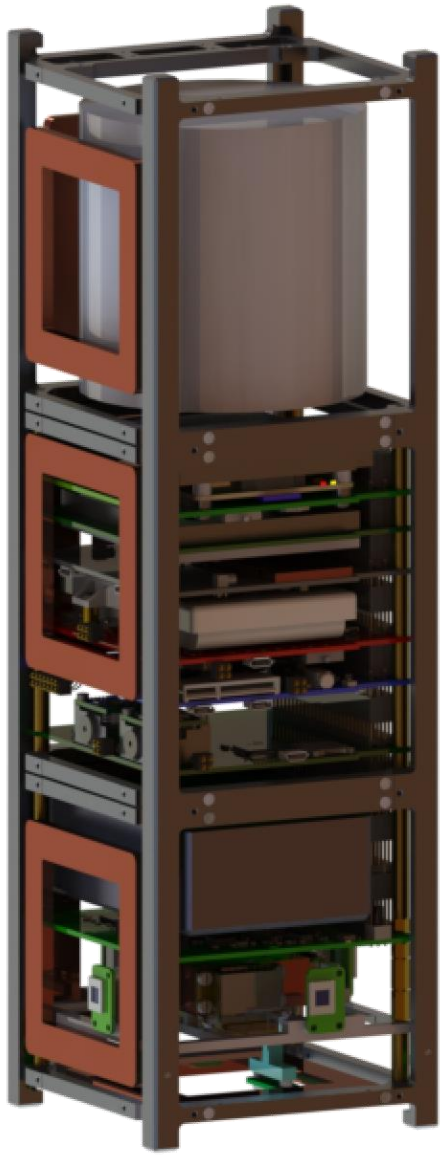
Service bus

Earth radiation sensors (MIRA)

Container with inflatable structure

Service bus

Earth radiation sensors (MIRA)



MIRA

Payload specification

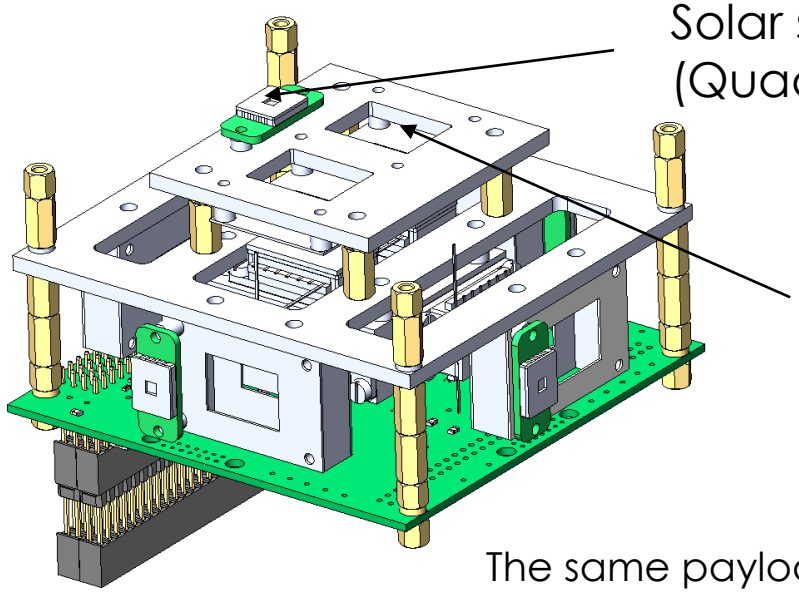
- Irradiance spectral measurements in 2 IR ranges (0,2-5 micron and 5-50 micron);
- Solar flux direction measurements

Technical specification

- Power consumption: 0,5 W (on the average);
- Sensitivity 0,15 A/W
- Data volume: 10 B/s

Developer

- ISMIRAN Russian Academy of Science design



The same payload "IKOR" have flight proven on Russian meteorological satellites : Meteor, Meteor-M, Electro-L, Arctica-M.

$$R = E(1-A) - F = E - EA - F$$

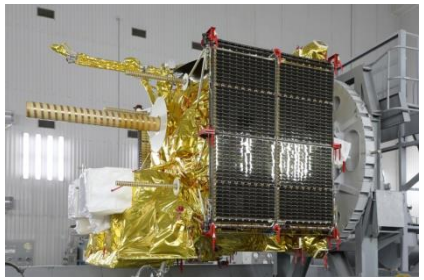
$$E = \frac{E_0 \cos Z_0}{r^2},$$

EA – 0,2-5 micron IR flux

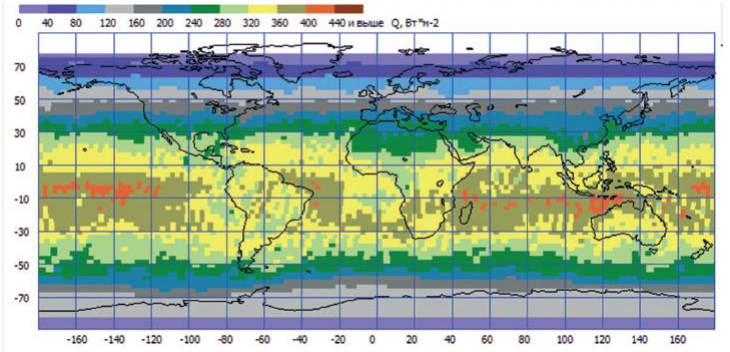
F - 5-50 micron IR flux

Z – sun zenith angle

Direct mesurements from MIRA

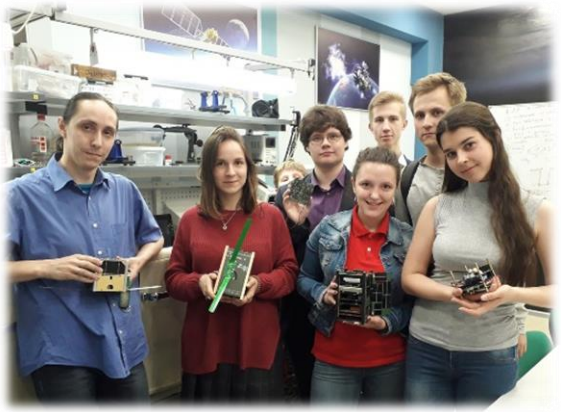


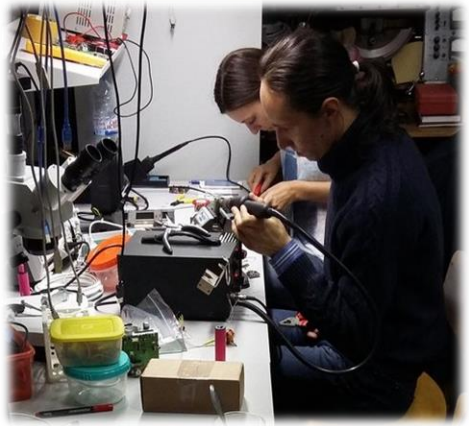
Arctica-M satellite (Roscosmos)



Example of Earth albedo map from Meteor (Rosgidromet)

Thank you for your attention!





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