Multi-satellite project Universat – SOCRAT of cubesat grouping for spacecraft and aviation radiation hazard warning system and first experience of Moscow university cubesat missions

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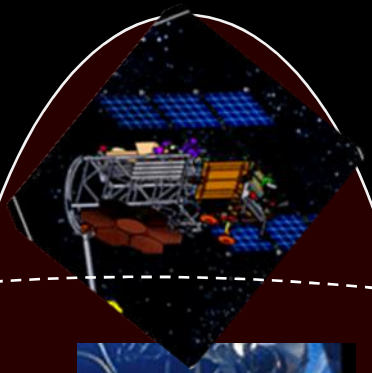
Space treats monitoring objectives

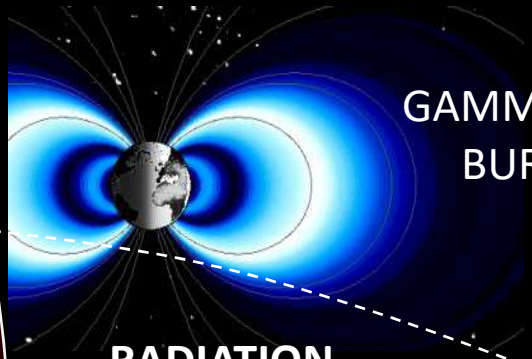
- **The natural and "man-made" space environment together makes a serious risks for the implementation of space mission both robotic and human involving.**
- **The risk is determined by the planned missions specifics. It consists of mission duration, localization in outer space and parameters of orbits.**
- **The specifics of the natural environment in outer space (a variety of physical parameters of the radiation fields, features of the ballistic trajectories of natural space objects) , as well as human activity effects (man-made debris pollution in outer space) make the real difficulties for their modeling and risk calculation, as a rule.**
- **The real-time monitoring of natural and man-made space objects (potential threats) is the best and most effective way to reduce the risks.**
- **Potentially hazardous phenomena for aviation**

Space threats

SOLAR
HIGH-ENERGY
PARTICLES

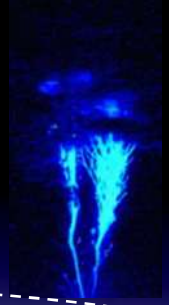
ASTEROIDS,
SPACE DEBRIS

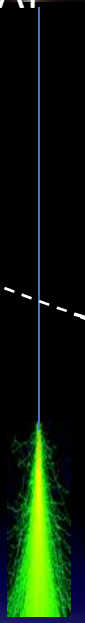




RADIATION

GAMMA-RAY
BURSTS





ELECTROMAGNETIC
TRANSIENTS

УНИВЕРСАТ

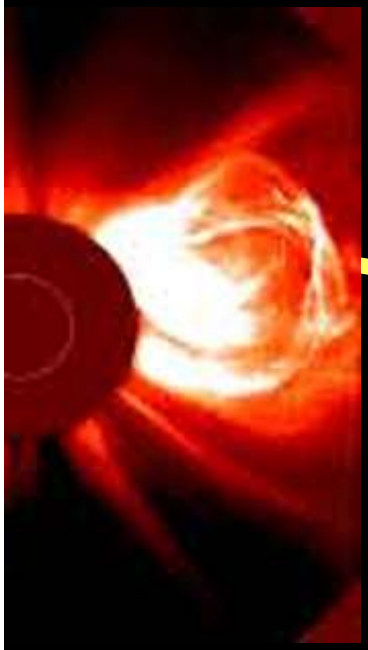
Project mission

The development of satellites grouping for real-time monitoring in near-Earth space.

Monitoring of:

- **radiation situation;**
- **potential dangerous objects of nature (asteroids, meteors) and man-made (space debris) origin;**
- **electromagnetic transients;**
- **potentially hazardous phenomena for aviation**

Space radiation in the vicinity of the Earth



Galactic Cosmic ray

Earth's magnetic field

Solar energy particles

Radiation belts

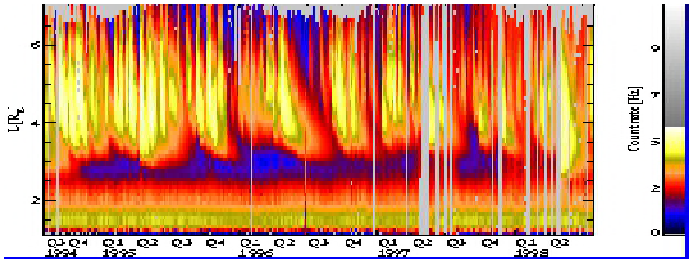
Models of Earth's radiation belts

NASA AP8/AE8 – 1970 - .

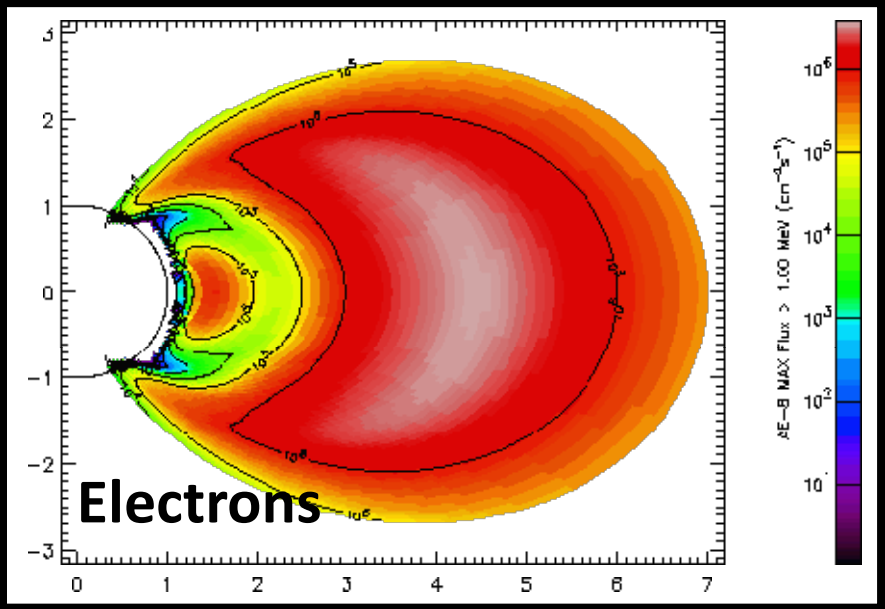
NASA AP9/AE9 – modern.

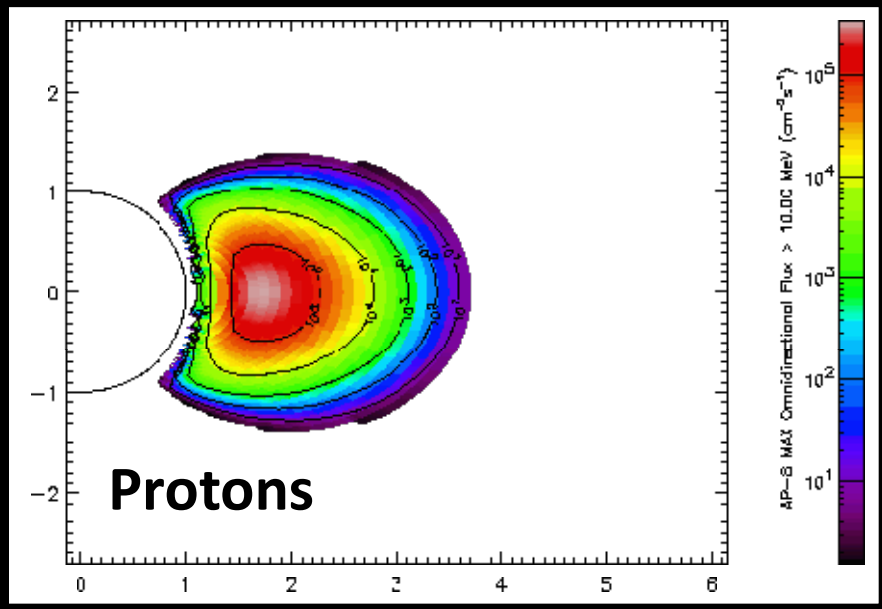
SINP MSU– 1980'

Variations of RF particle flux



Highly dynamic!





RF quasi-stationary models describe the spatial and energy distribution of protons with energies > 10 MeV (on the right) and electrons with energies > 1 MeV (on the left). In reality, particle flux are extremely dynamic (top right).

#2.The danger of space debris

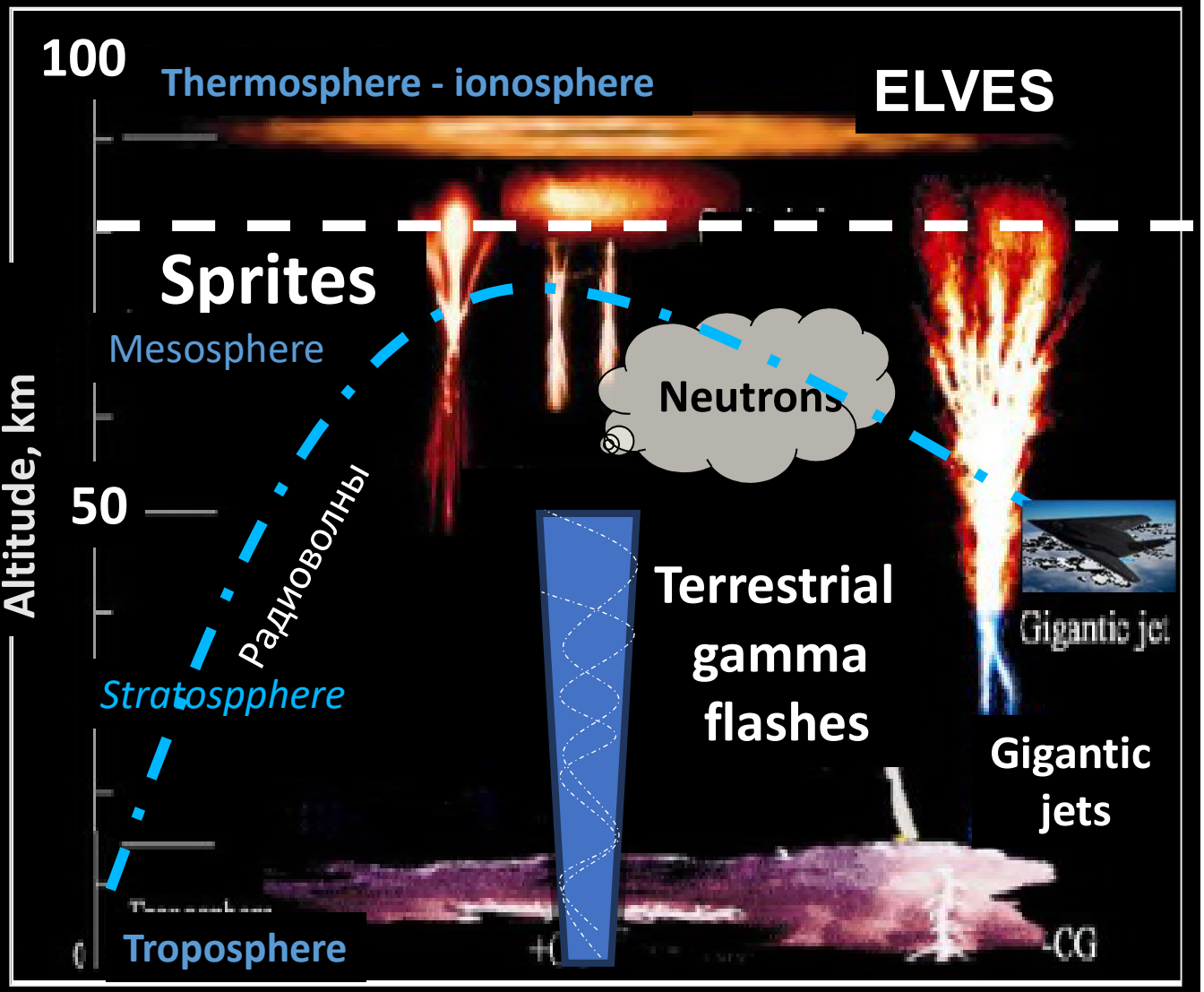
As of August 31, 2015, the total amount of man-made space objects in outer Space is 17 thousand 250 space objects. Of which 1 thousand 362 space objects are live spacecraft, while the remaining 15 thousand 888 objects are space debris.
The information is from databases of warning system of dangerous situations in near-Earth space.

The danger of asteroids (meteors)

An object is considered as potentially dangerous, if it crosses the earth's orbit at a distance of less than 0.05 a. u. (approximately 19.5 distances from the Earth to the Moon), and its diameter exceeds 100-150 meters. Objects of this size are large enough to generate unprecedented destruction on the land, or a huge tsunami in case of getting to the ocean. Events of this magnitude occur about once in 10 000 years. On the basis of information received from the WISE Space Telescope, scientists estimate the presence of 4700 ± 1500 potentially dangerous objects with a diameter of more than 100 meters.

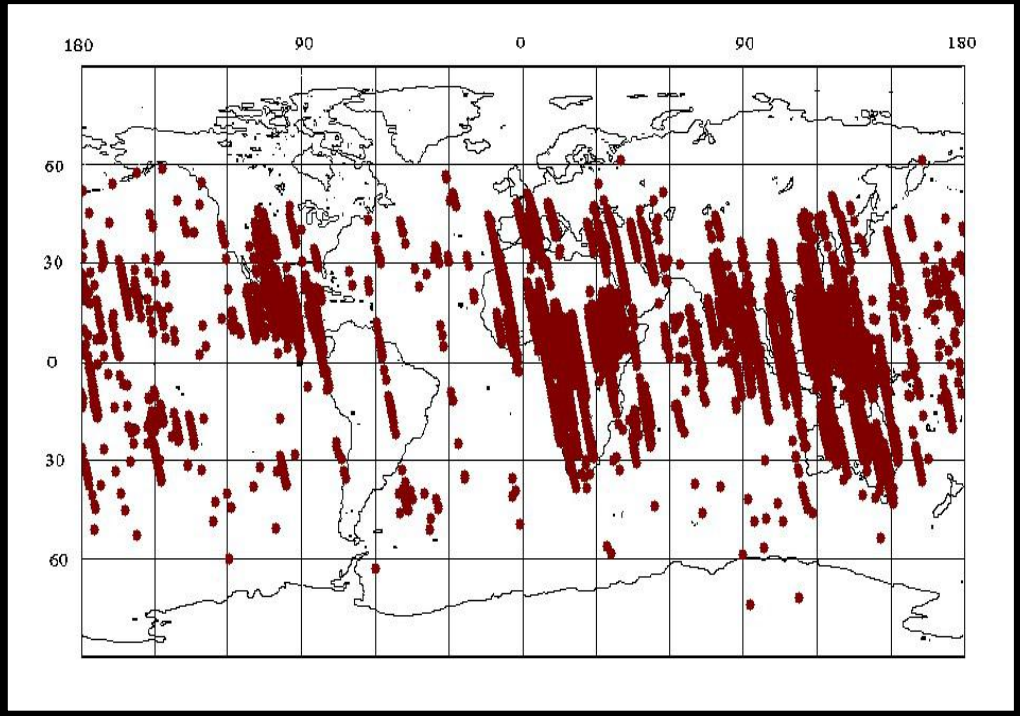
3. The danger of electromagnetic transients

Transient electromagnetic phenomena in the upper atmosphere (tens of kilometers) are observed in a variety of wavelengths range — from gamma to infrared one. Transient luminous events (TLE) are most frequently observed and they appear everywhere from the auroral latitudes to equatorial ones



The MSU results on transient light phenomena in the atmosphere of Earth

1. Geographical distribution demonstrates the global nature of the phenomena, both at the storm area and far beyond.



"Vernov" satellite data: among the famous equatorial thunderstorm regions, the flashes observed over the oceans and in high latitudes

Radiation dynamics monitoring – concept

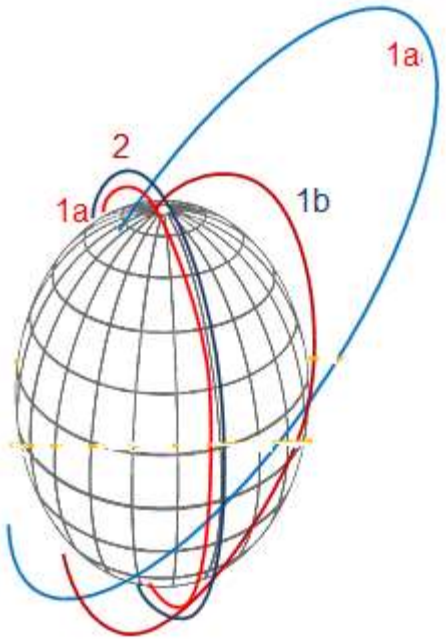
Concept of the Universat-SOCRAT multi-satellite mission

Minimal variant – main group from 3 satellites:

1a) small satellite (~150 kg payload) to be launched on **SSO**, <600 km; **two micro satellites (~40 kg payload) to be launched on elliptical orbit, apogee ~9 000 km, inclination 64°**

1b) small satellite (~150 kg payload) to be launched on **SSO**, <600 km; **one micro satellite to be launched on elliptical orbit, apogee ~9 000 km, 64° , other micro satellite to be launched on 1400 km, 82,5° circular orbit**

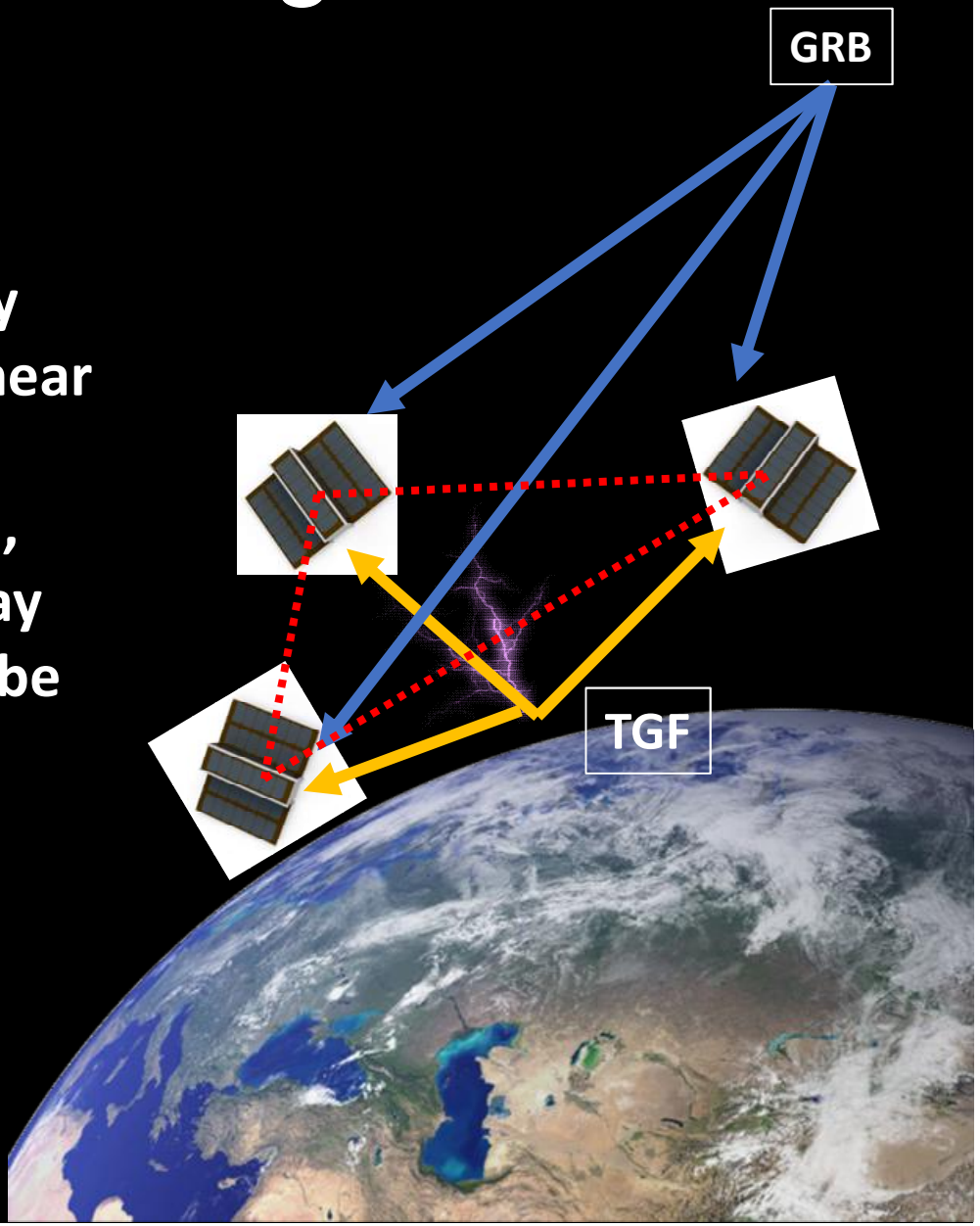
2) Main group should be added by the number of cubesats (3U to 6U) to be launched on different LEO



**not in scale!*

Cubesats for TGF triangulation

To realize the triangulation technique in minimal variant 3-4 cubesats are necessary. Optimally they should be launched on the near circular solar-synchronous orbits with altitude about 400 – 600 km, inclination about 98^{o} in such a way that distance between them will be no more about 1 000 km.

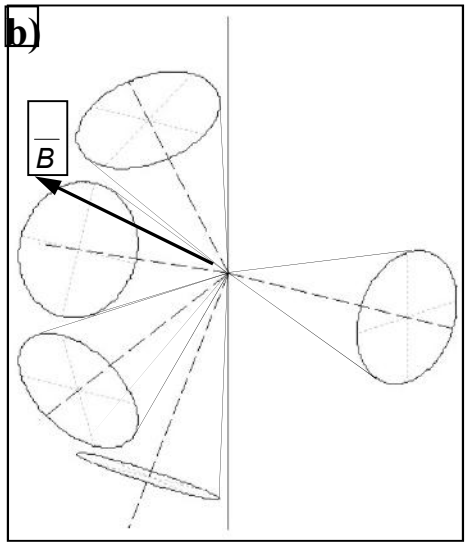


INSTRUMENTS ON THE MAIN SATELLITE

RADIATION MONITORING

-number of spectrometers of protons with energies from 2 up to >160 MeV and electrons with energies 0.15–10 MeV designed in such a way that to measure pitch-angle distribution and omnidirectional fluxes.

- three-component magnetometer.



SPACE DEBRIS AND ASTEROID MONITORING

- wide-field optical cameras (mini-telescopes) of MASTER-SHOK type
- scanning telescope with an input window diameter of

120–250 mm and an operating field of view of up to 100 square degrees.

ELECTROMAGNETIC TRANSIENT MONITORING

Instruments for electromagnetic transient monitoring in ultraviolet and optics

- small lens telescope with high time resolution for spectral

measurements of TLE and lightning

- UV and infra-red (IR) detector-photometer

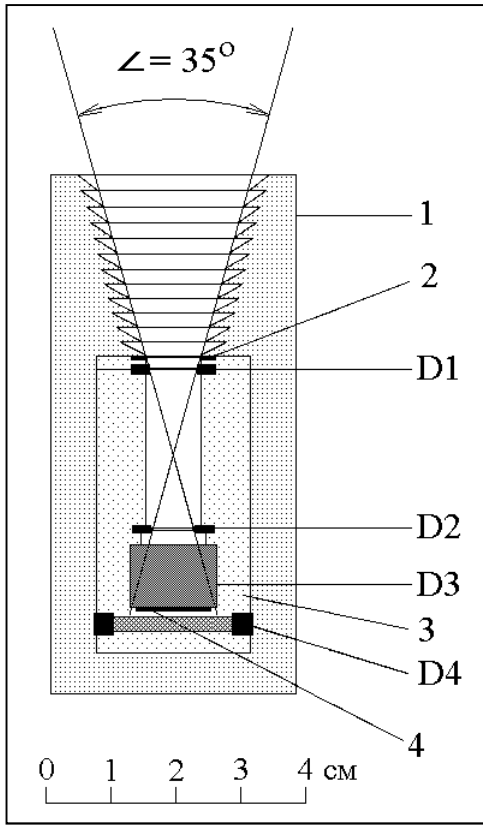
Instruments for gamma transient monitoring

- gamma-ray flash monitor (GFM)
- tracking gamma-ray spectrometer (TGS)

INSTRUMENTS ON MICRO SATELLITES AND CUBESATS

RADIATION MONITORING

- detector of charge particles (protons with energies 2 - 100 MeV, electrons with energies 0.15–10 MeV.



ELECTROMAGNETIC TRANSIENT MONITORING

Instruments for electromagnetic transient monitoring in ultraviolet and optics

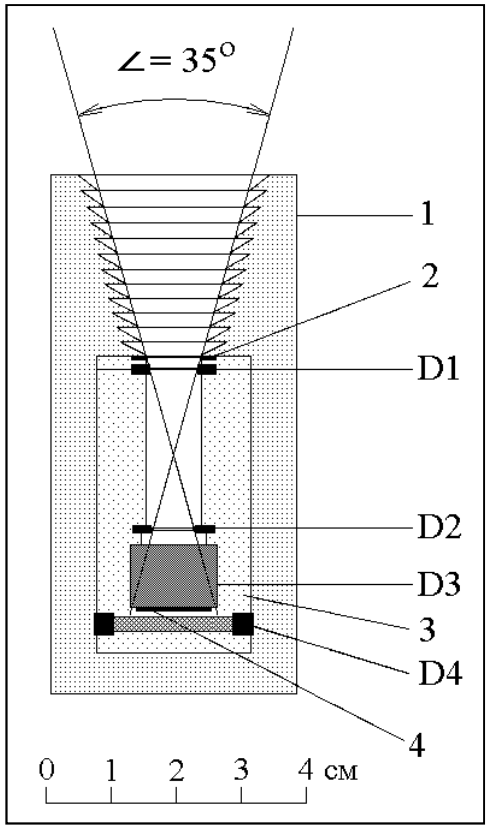
- compact UV detector with a wide field of view (AURA-2) or its improved version, i.e. telescope (AURA-2T)

Instruments for gamma transient monitoring

- compact space radiation (X-, gamma- rays, charge particles) detectors of DéCoR type (DéCoR-2)

Electrons and protons spectrometer

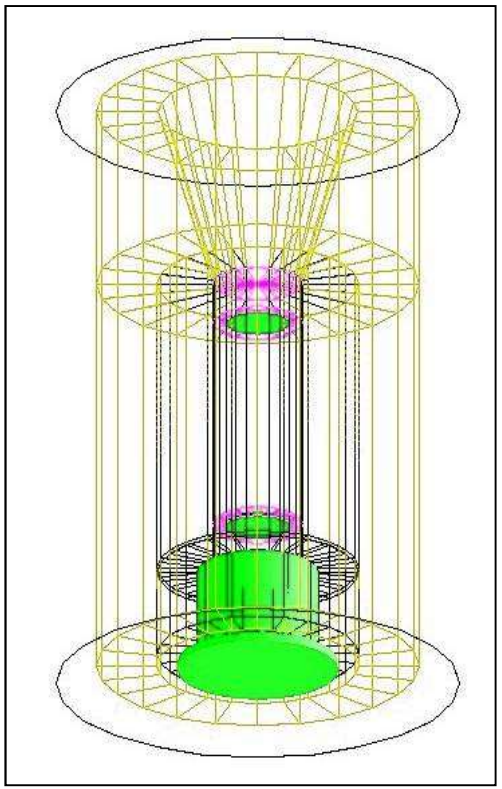
Electrons and protons spectrometer



Ranges of registered energies of particles :

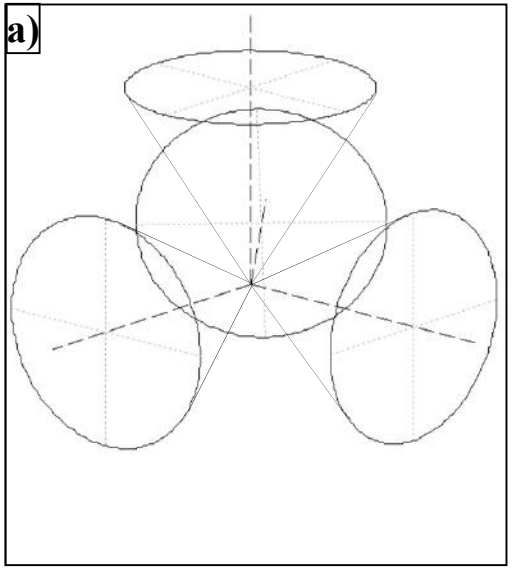
0.15–0.35, 0.35–0.6, 0.6–1, 1–2, 2–4, 4–10 MeV;

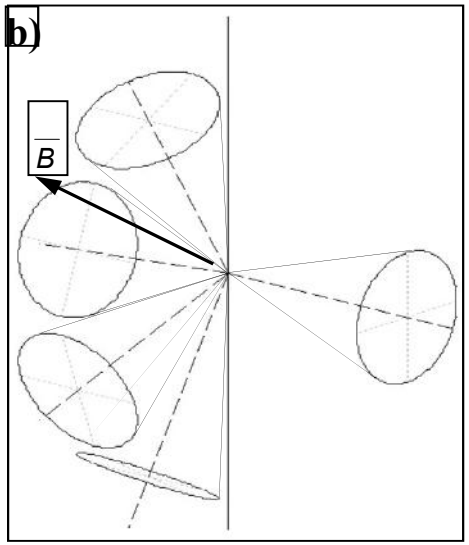
protons: 2–4, 4–9, 9–15, 15–30, 30–53, 53–100, 100–160, >160 MeV



Electrons and protons spectrometer

Method #1: Multidirectional measurements to determine omnidirectional fluxes of particles;



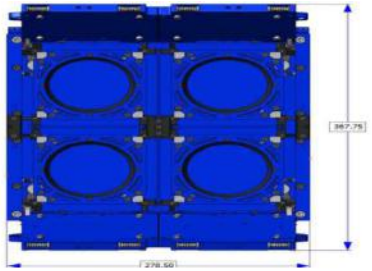


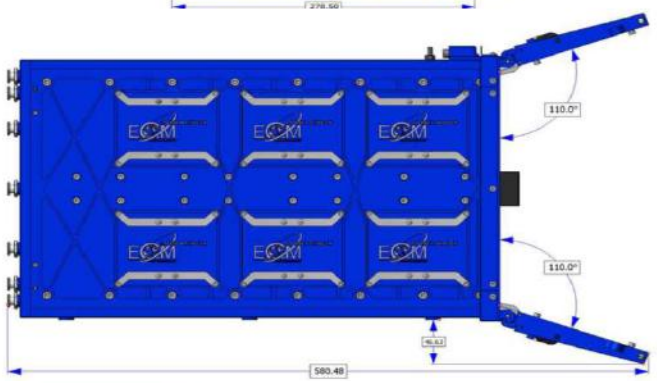
Two versions of distribution the particle spectrometers to determine omnidirectional fluxes

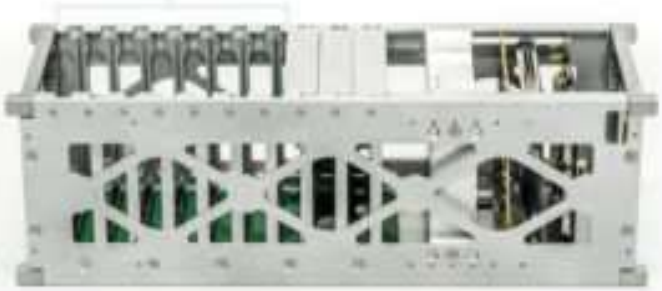
GERMAN ORBITAL SYSTEMS

Cooperation with German Orbital Systems GmbH

НИИЯФ МГУ





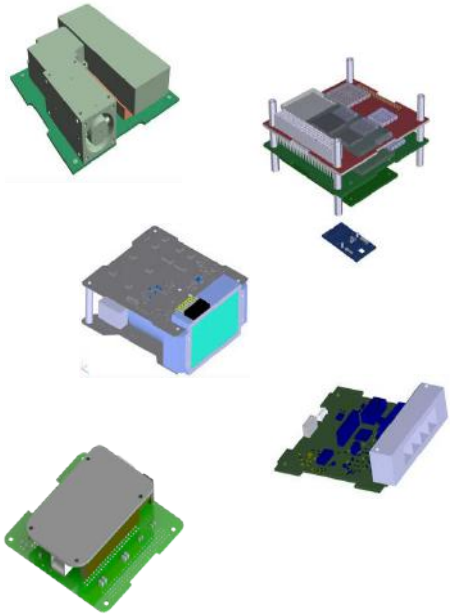


3U CubeSats as a pilot mission

3U CubeSats – payloads

One bus – 3 spacecraft – 6 payloads

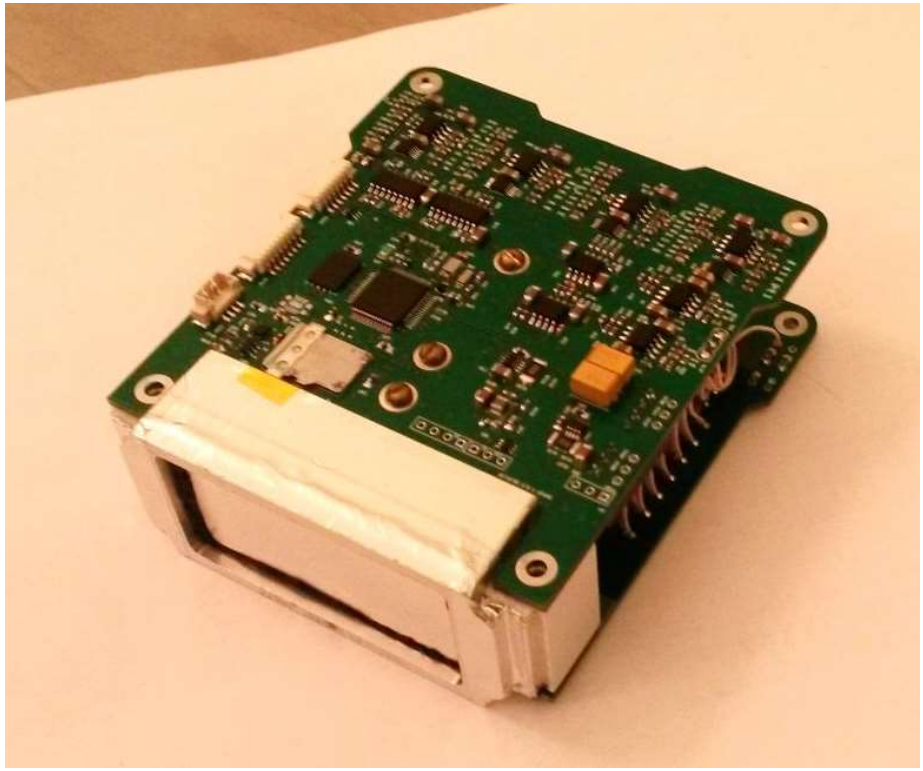
- Socrat
- AmurSat (DeCoR)
- VDNH-80 (DeCoR , AURA)



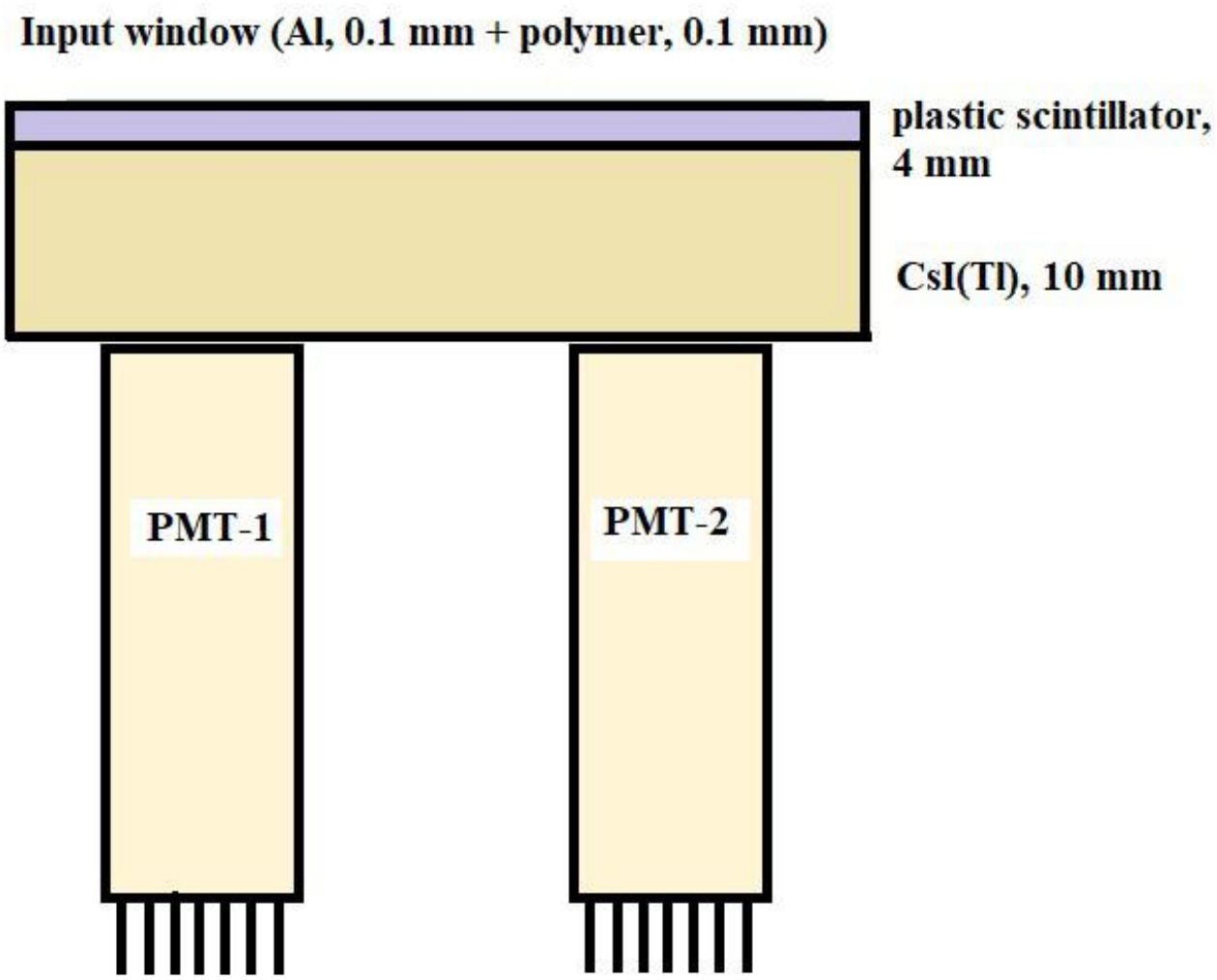
Main supplier of the bus components: GOS Gmbh

- Radiation measurements
- UV TLEs
- ADS-B receiver

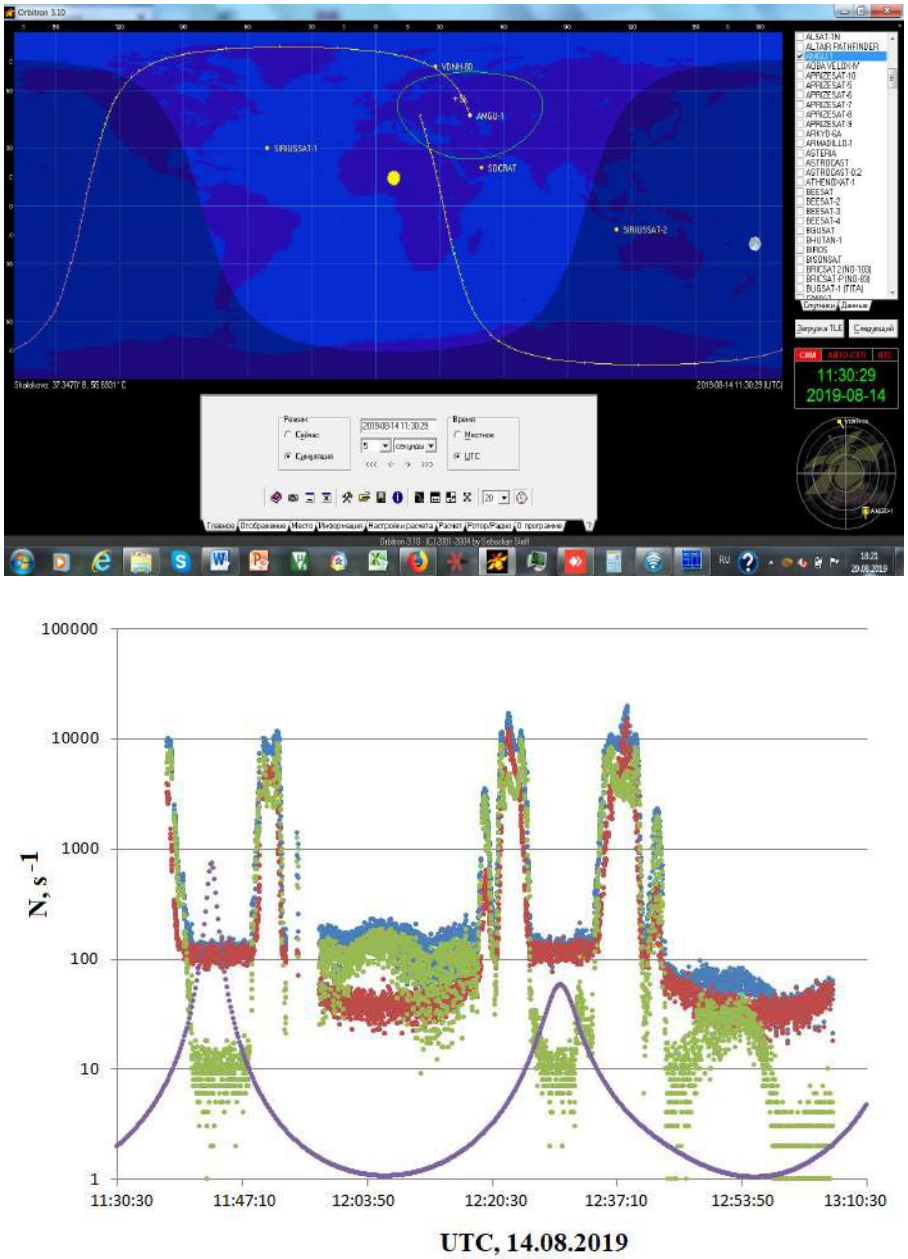
Parameters of DeCoR instrument



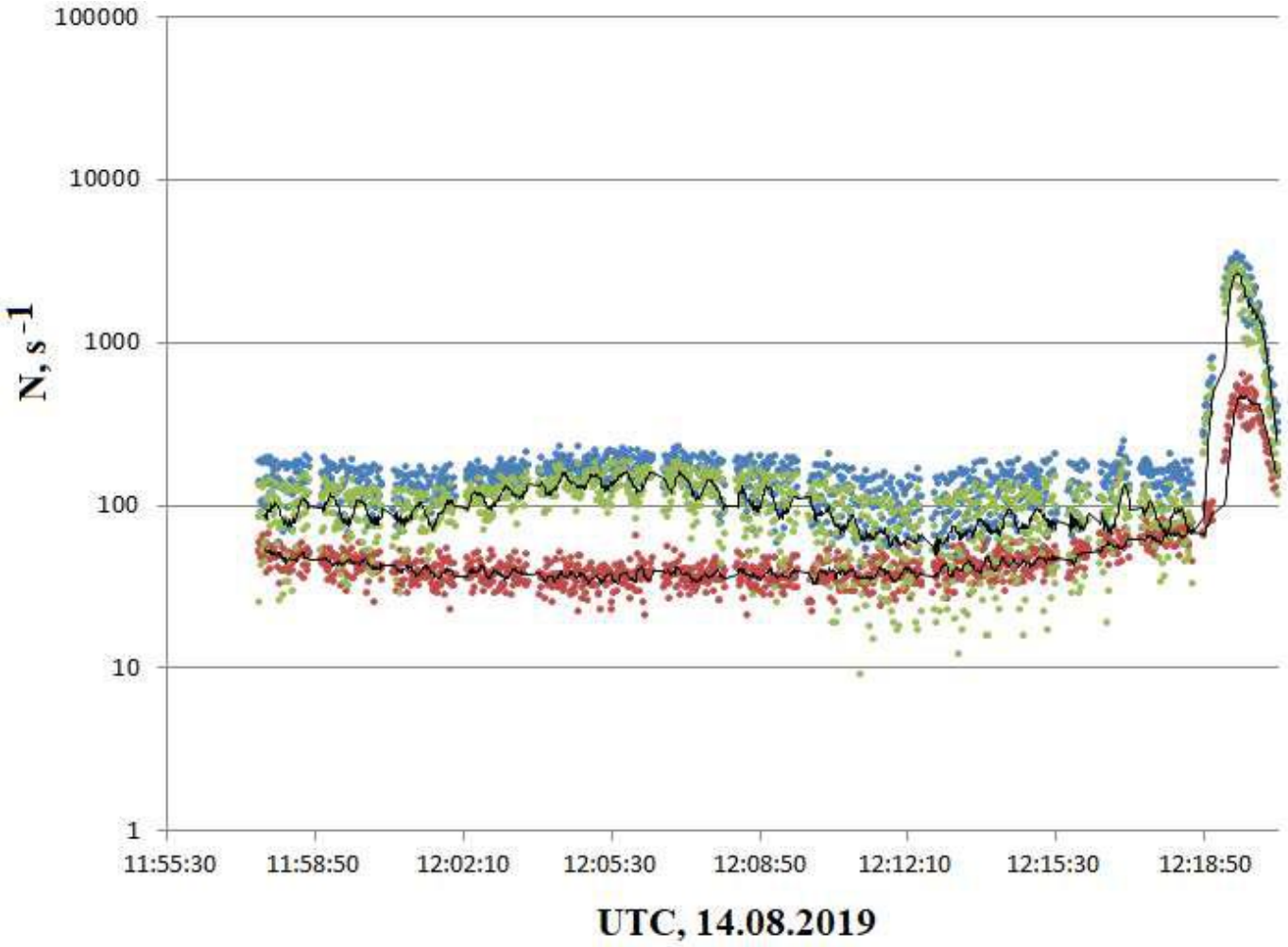
Types of detected particles and quanta	Gamma quanta, electrons
Range of energy release, MeV	0.1 – 2.0
Effective area, cm^2	18
Dynamical range:	
Monitoring of fluxes, $cm^{-2}s^{-1}$	0 - 1000
Measurements in event by event mode, $cm^{-2}s^{-1}$	0 - 25
Time resolution, mcs	20
Size, mm	102x90x36
Mass, g	400
Voltage, V	7.5
Power consumption, W	0.7



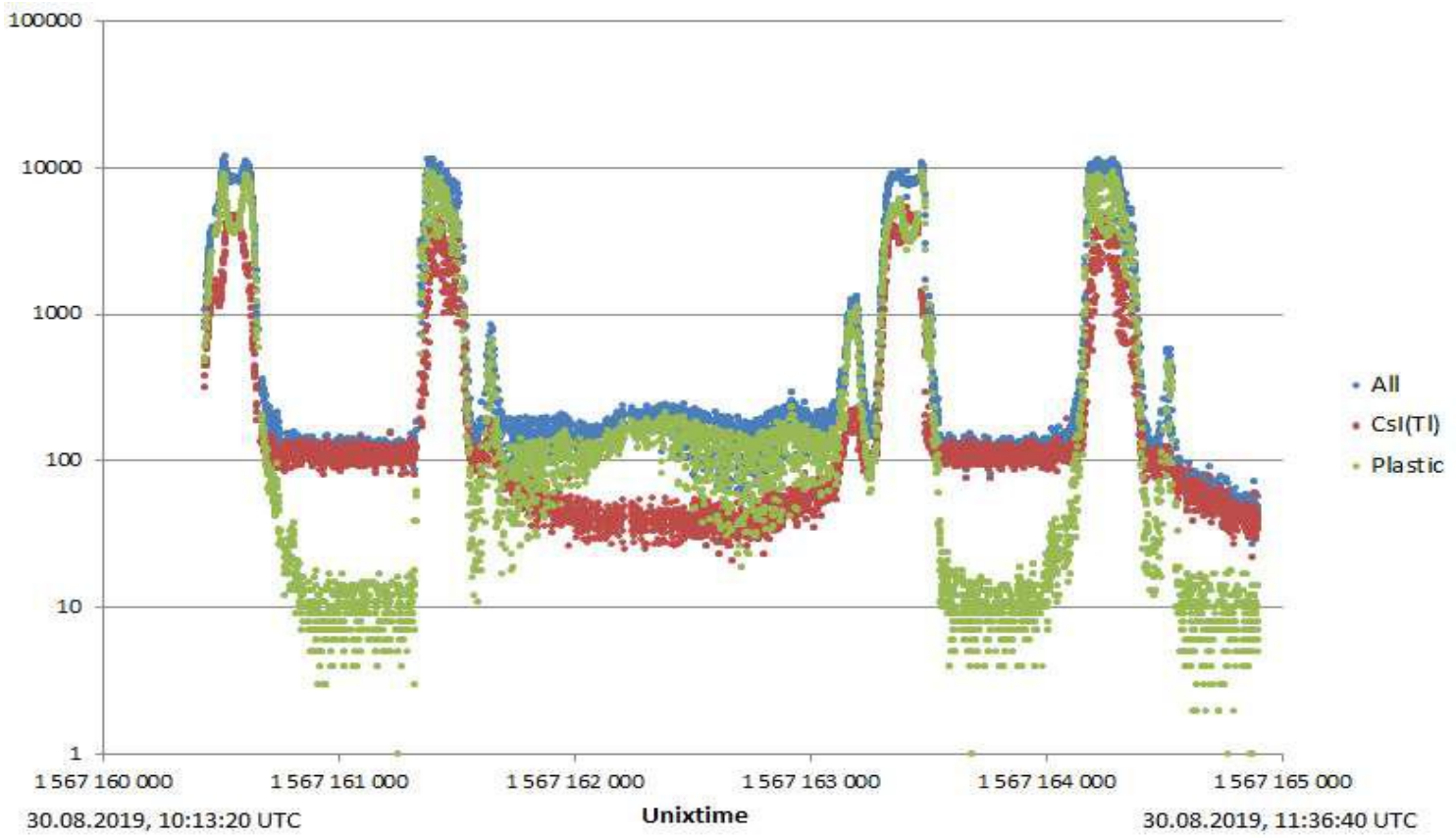
The general view of DeCoR instrument



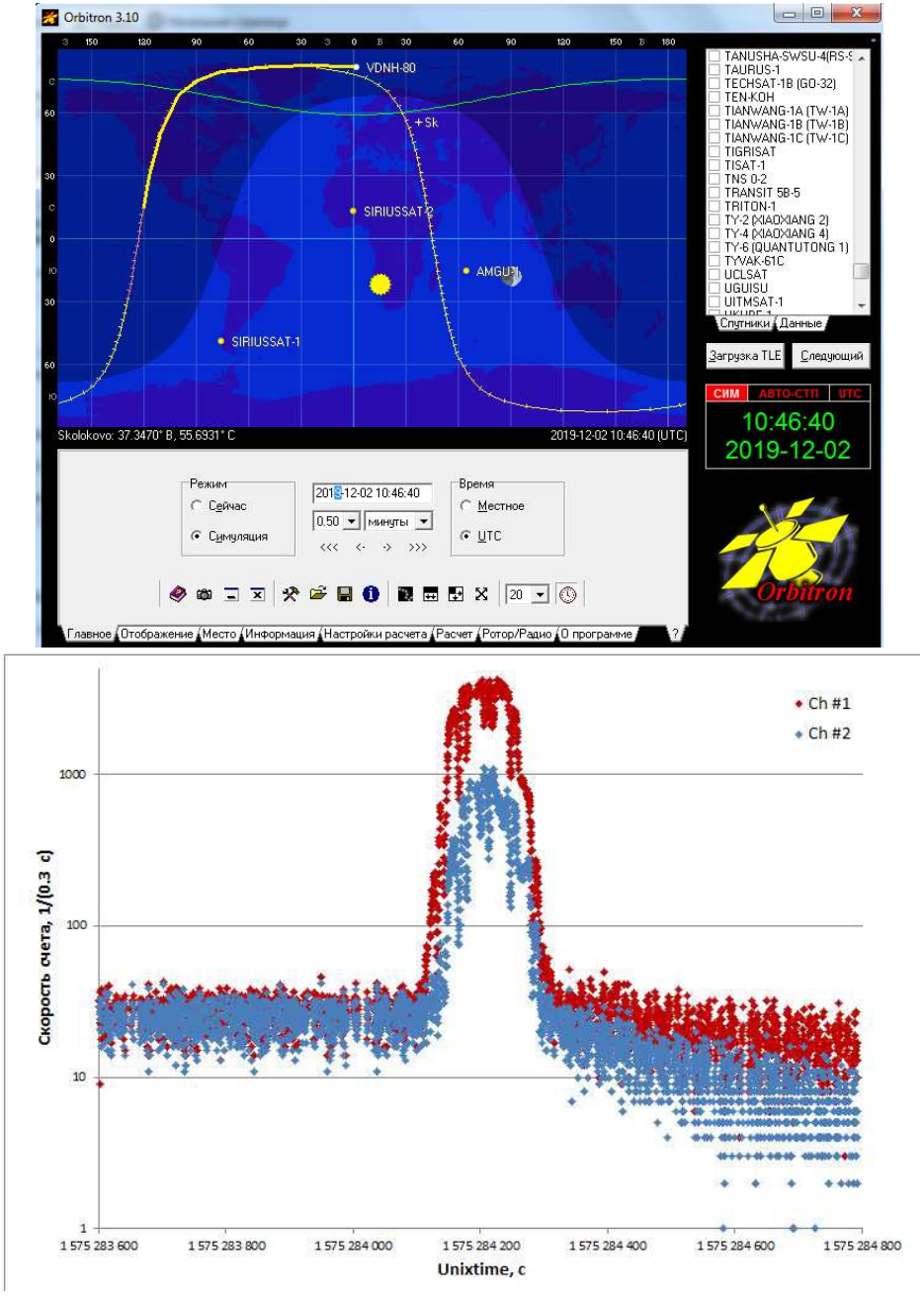
Top panel: AmurSat orbit projection on the map. Bottom panel: time dependences of counting rate during one orbit in plastic scintillator (green points), CsI(Tl) (red points) and total (blue points). The dark blue line represent the corresponding McIlwine parameter (L).



Monitoring counting measured near Equator 14.08.2019 in plastic scintillator (green points), CsI(Tl) (red points) and total (blue points). The dark lines represent the moving averages of corresponding counting rates.



Monitoring counting measured 30.08.2019 during one orbit in plastic scintillator (green points), CsI(Tl) (red points) and total (blue points).



Top panel: VDNH-80 orbit projection on the map. Bottom panel: time dependences of counting rate during one orbit in CsI(Tl) (blue points) and sum in plastic and CsI(Tl) (red points).

4.Educational and promotional goales

Basic goals :

- The introduction of modern space researches in university and school education;
- Popularization of space science basis;
- The attraction of students and schoolchildren to modern space researches

University space project UNIVERSAT – SOCRATES

- The successful realization of the Universat-SOCRAT project will make it possible for the first time in the world to create a prototype of a space system for monitoring hazards for both ongoing and planned space missions, including high-altitude atmospheric aircraft.
- During the project realization, the following tasks should be solved:
- – real-time estimation radiation environment in near-Earth space for evaluation of the radiation risks of space missions and the producing of alert signals for decision accept on their control;
- – verification of modern computational models of radiation fields in the near-Earth space;
- – real-time control of potentially dangerous objects of natural and technogenic origin in the near-Earth space;
- – control of electromagnetic transients in the upper Earth atmosphere and space (GRBs, Solar flares).
- Also the interactive model of forecasting of radiation background at aircraft flying altitudes will be elaborated. This model will be based on the data obtained in real time measurements of space radiation in different areas of near-Earth space and from monitor observations of electromagnetic transients.
- The first stage of this project was beginning from the launching of three cubesats in July, 2019. The prototypes of the instruments, which should be used in future Universat-SOCRAT missions were tested in these orbital experiments with cubesats. Results of these tests confirmed that instruments operate well asin terms of command control and in terms of detector parameters.

ACKNOWLEDGMENTS

Financial support for this work was provided by the Ministry of Education and Science of Russian Federation, Project № RFMEFI60419X0237.


SPACE
PROGRAM
LOMONOSOV
2016
VERNOV
2014
TATIANA-2
2009
CUBESAT
AURORA-AMICAL
2019
TATIANA-1
2005
NUCLEON
2014
YOUTSAT
2011

Thank you