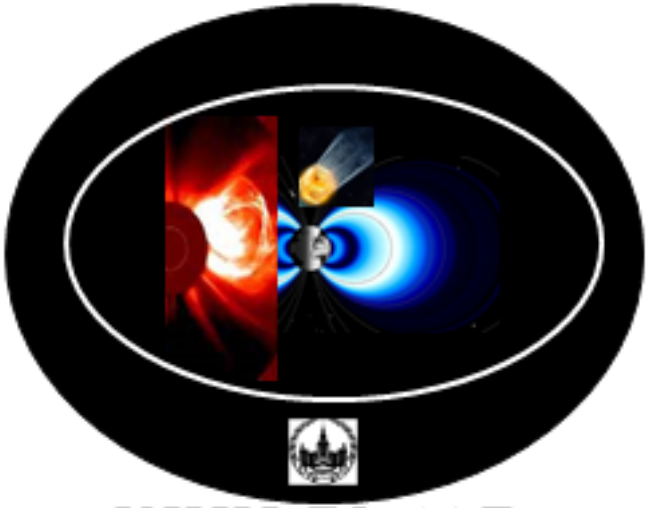
Multi-Satellite Universat-SOCRAT Mission for Technogenic and Natural Hazards Monitoring



The development of small space satellites grouping for monitoring and prevention of natural and man-made space threats

Lomonosov Moscow State University, 2018

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.**

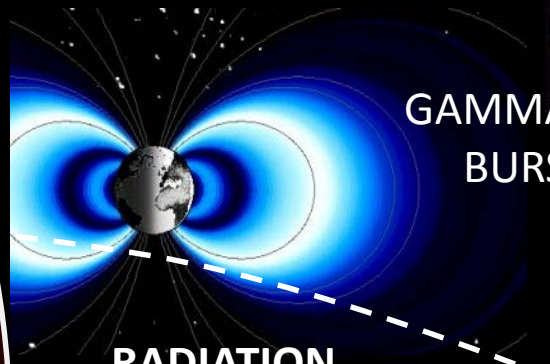
Space hazards

- 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.

Space threats

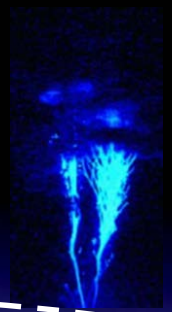
SOLAR
HIGH-ENERGY
PARTICLES

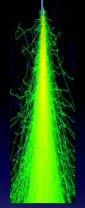
ASTEROIDS,
SPACE DEBRIS



RADIATION

GAMMA-RAY
BURSTS



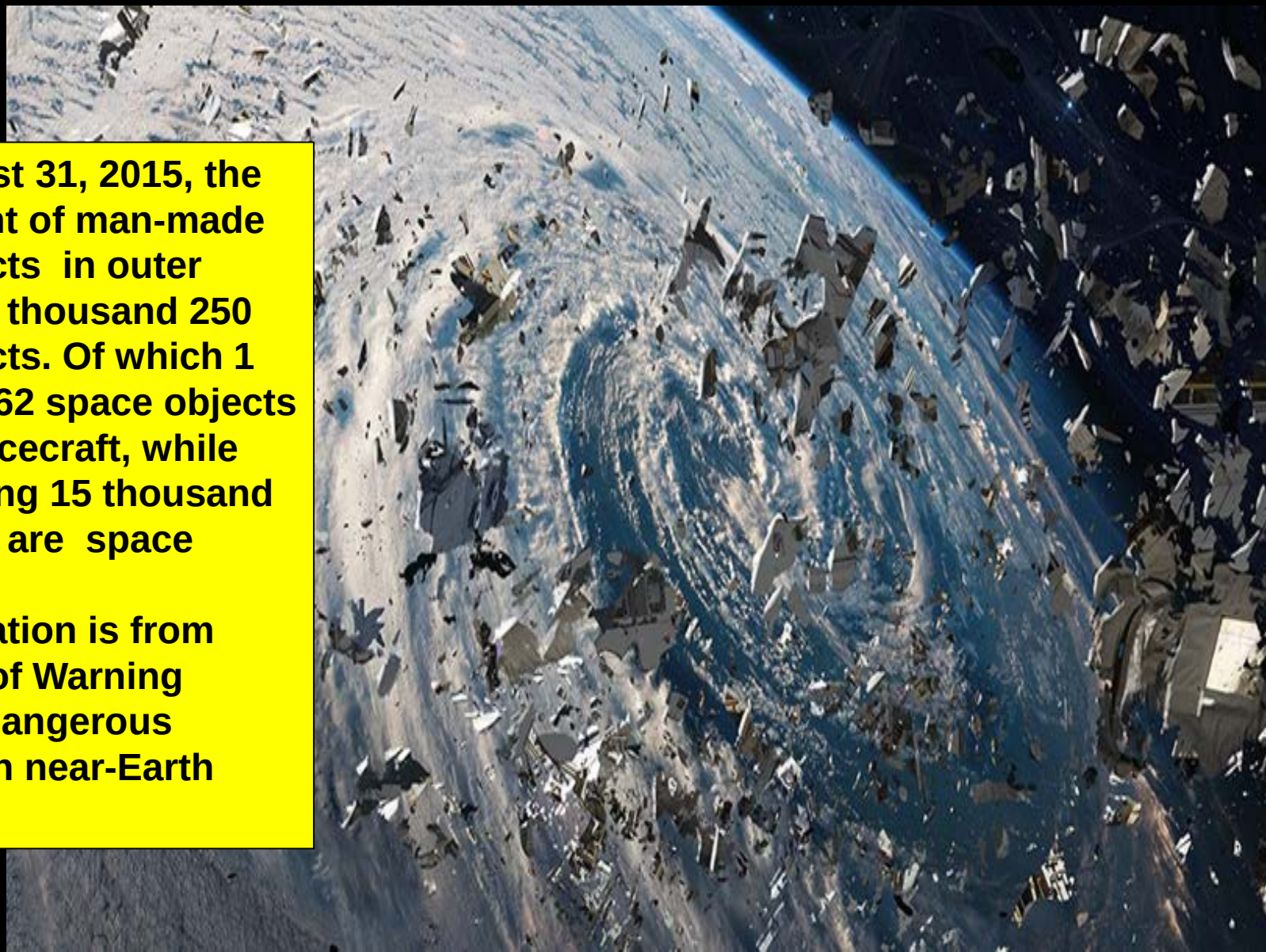


ELECTROMAGNETIC
TRANSIENTS

УНИВЕРСАТ

Space radiation on the outskirts of the Earth

The danger of space debris



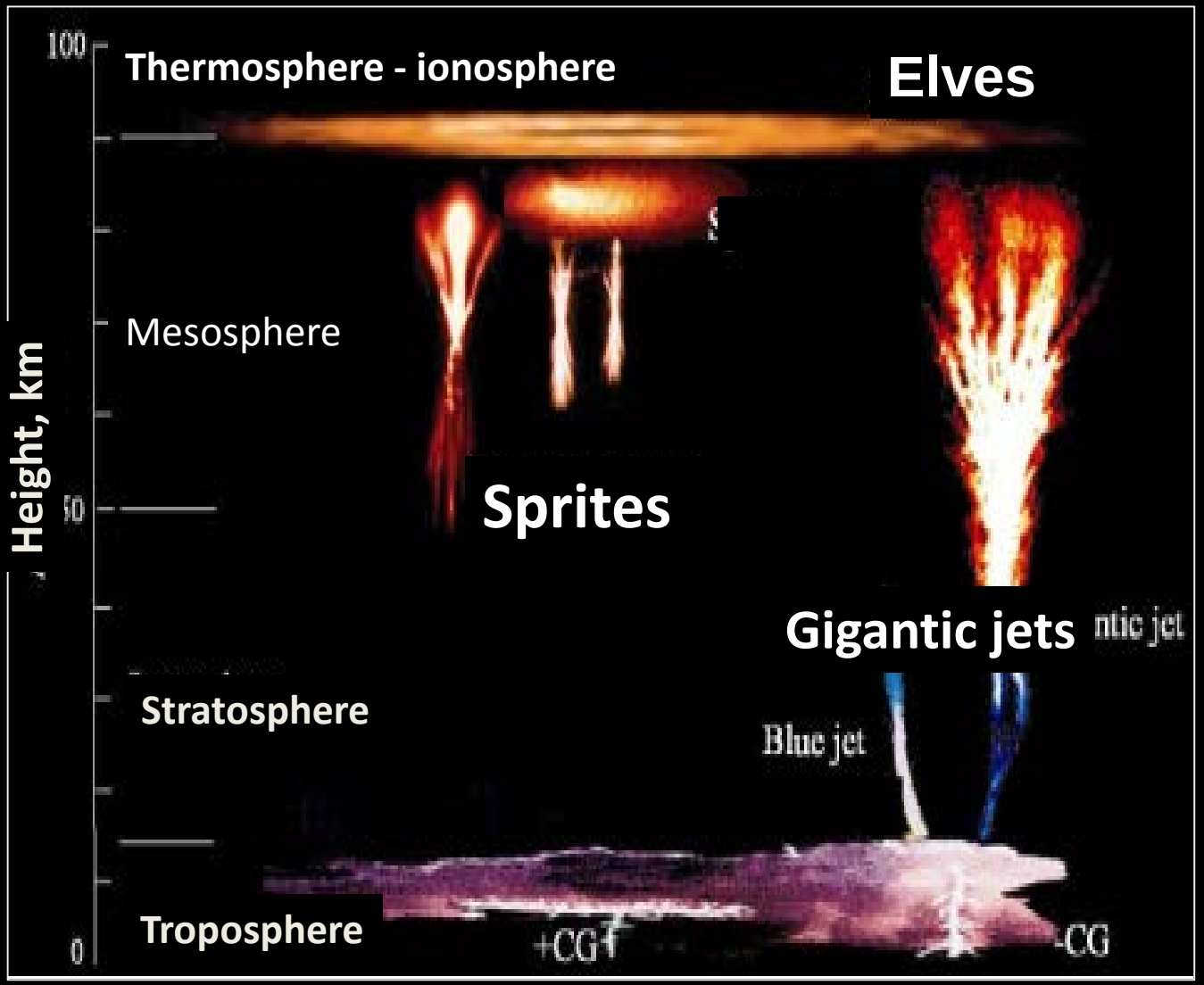
As of August 31, 2015, the total amount of man-made space objects in outer Space is 17 thousand 250 space objects. Of which 1 thousand 362 space objects are live spacecraft, while the remaining 15 thousand 888 objects are space debris.
The information is from databases of Warning system of dangerous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

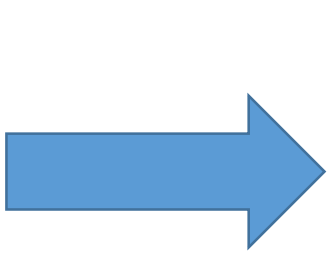
The danger of electromagnetic transients

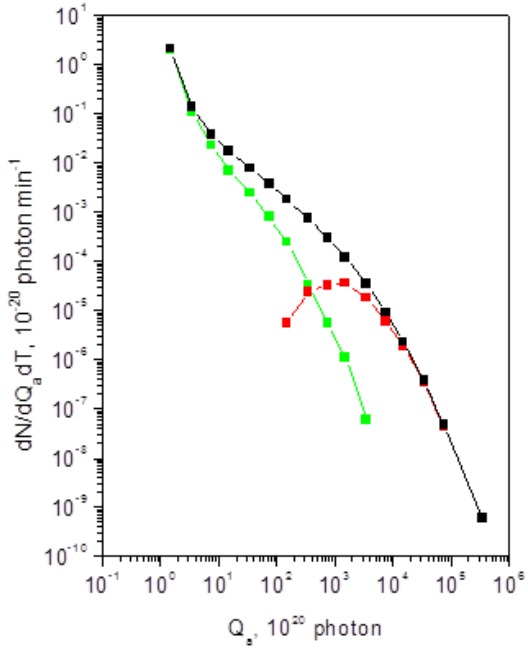
Transient electromagnetic phenomena in the upper atmosphere (tens of kilometers) are observed in a variety of wavelengths range — from gamma to infrared one. Transient luminous events (TLE) are most frequently observed and they appear everywhere — from the auroral latitudes to equatorial ones.



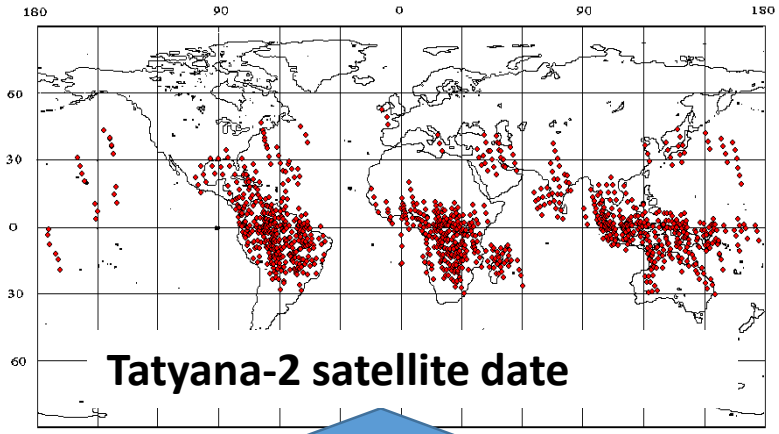
The MSU results on transient phenomena in the atmosphere of Earth

2. UV flashes have a very wide energy distribution (in numbers of photons), from tens of joules to very high values — 100 MJ!



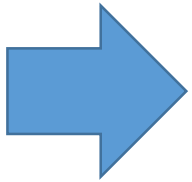


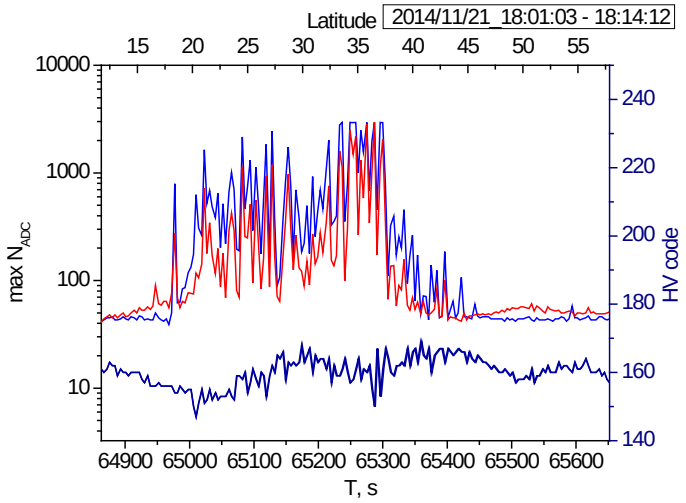
Vernov satellite data
Black dots - all events
Green ones - short flashes
Red ones - long flashes



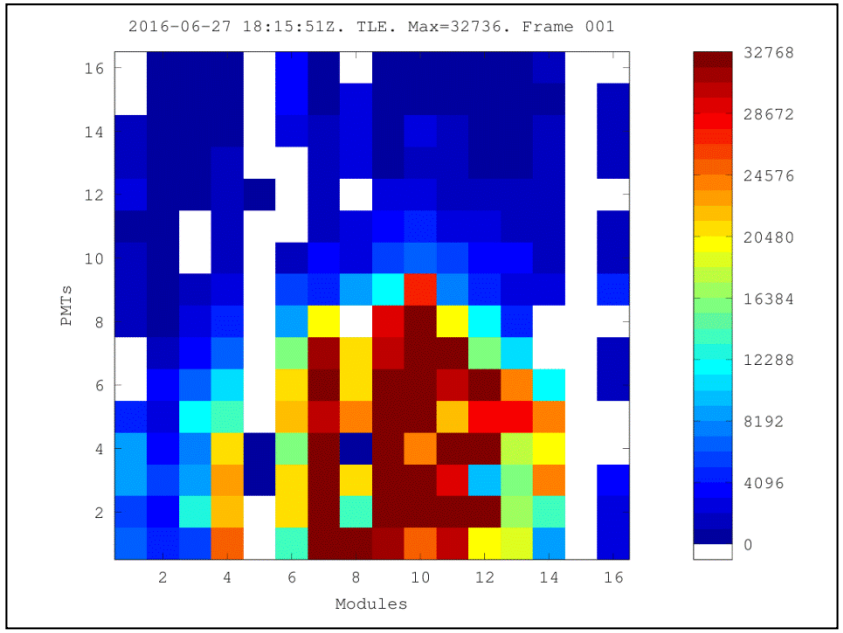
Tatyana-2 satellite date

3. There are a long series of flashes over thousands of kilometers.
An example of a series of flashes for 8 minutes (4,000 km along the trajectory of Vernov satellite)

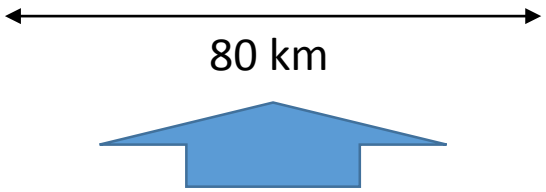


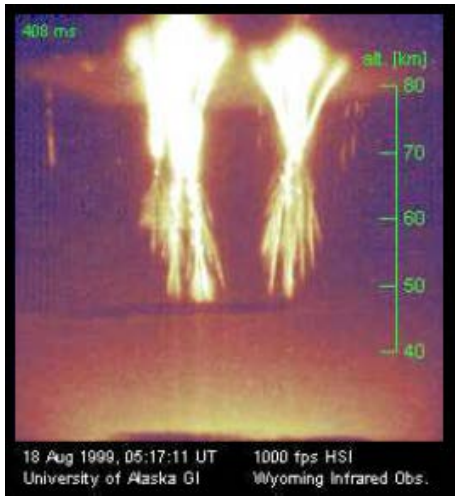


The MSU results on transient light phenomena in the atmosphere of Earth



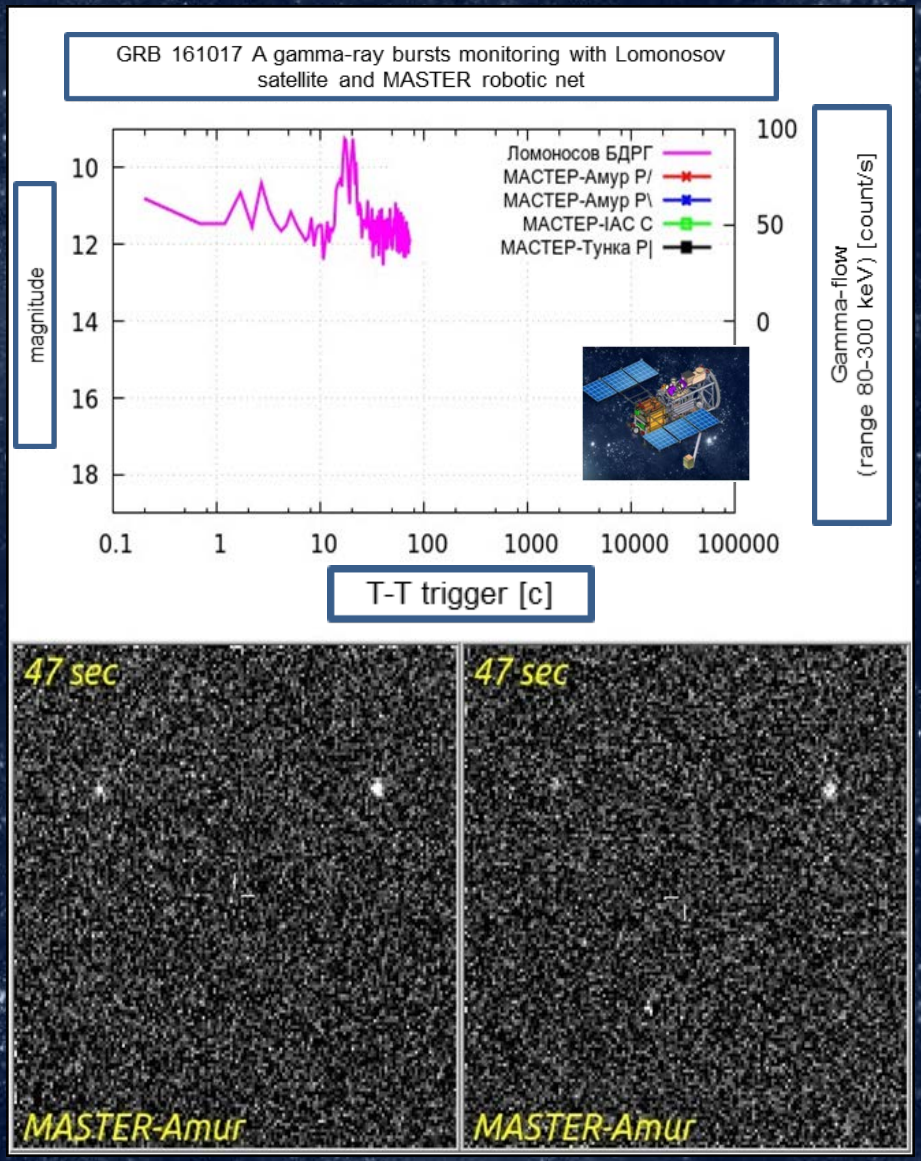
4. Powerful events have complex spatio-temporal structure and dynamics. They occur in a large volume of the upper atmosphere (up to 100 km altitude and a 100 km in the horizontal direction)





Lomonosov satellite data
Powerful flash of UV radiation.
The nearest lightning was at the distance of 3500 km from the observed phenomenon (according to WWLLN network)!

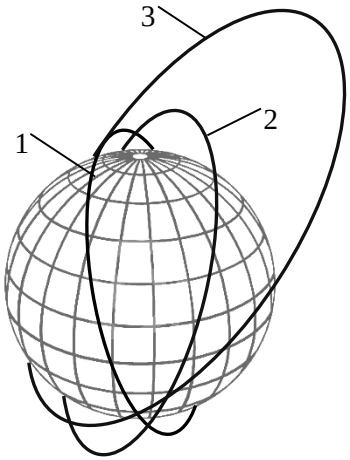
Gamma-ray bursts. The potential danger of space.



Concurrent observations of GRB 161017A in September 17, 2016 at 17:52:17 UT on Lomonosov Space Observatory in gamma-spectrum and on Master Grand Observatory in visible spectrum.

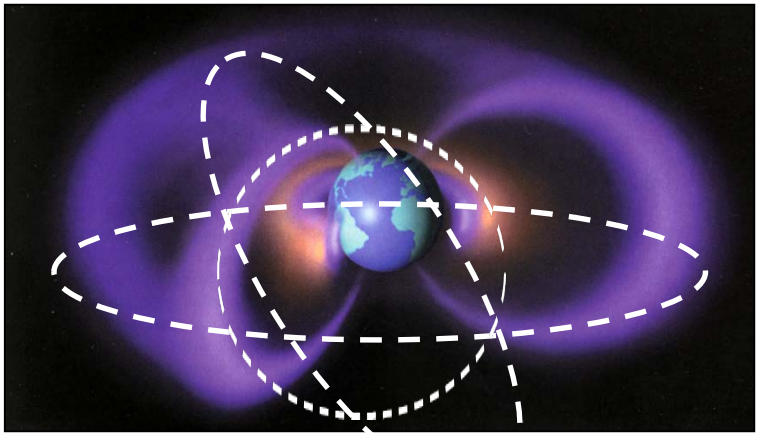
The exposure effect of rare powerful gamma-ray bursts to the atmosphere of Earth could bring to disastrous consequences. And this effect is poorly understood.

The grouping of orbiting spacecraft and requirements to the parameters of orbits



Within the framework of the Universat-SOCRAT project a few small satellites should be placed into specially selected orbits. For the minimal version, the group of satellites could consist of three satellites . One spacecraft of medium mass (small satellite) should be launched on a low solar-synchronous orbit with an altitude of about 500-650 km and an inclination of 97-98°. Two other satellites of lower mass (micro satellites) should be launched on an orbit close to circular with an altitude of about 1400-1500 km and an inclination of ~80° and on an elliptical orbit with an apogee of about 8000 km, a perigee of about 600-700 km and an inclination of 63.4°.

The concept of small spacecrafts grouping for monitoring of Earth's radiation environment

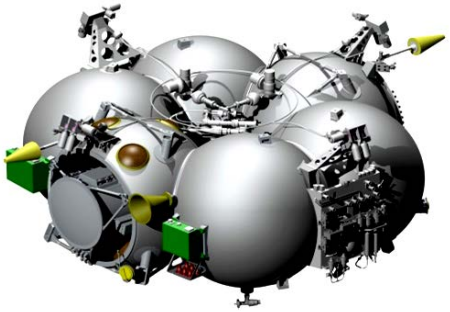


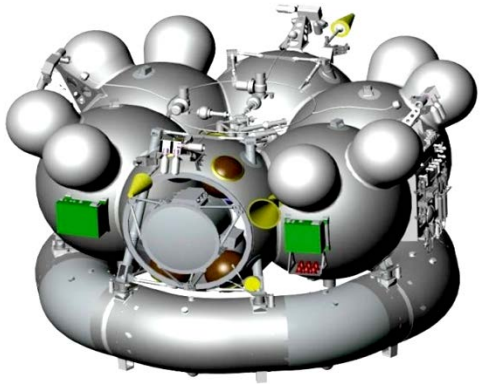
Aims:

1. 1. On-line evaluation of radiation conditions in near-Earth space to assess radiation risks of space missions realization and to develop alert signals to make decisions on their control.

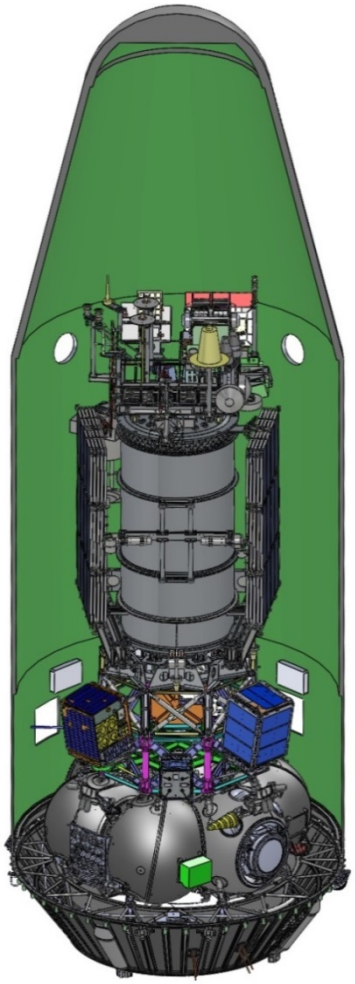
2. Verification of the modern computational models of radiation fields in near-Earth space.

The concept of small spacecrafts grouping for monitoring of Earth's radiation environment





"Fregat-M/MT/SB"

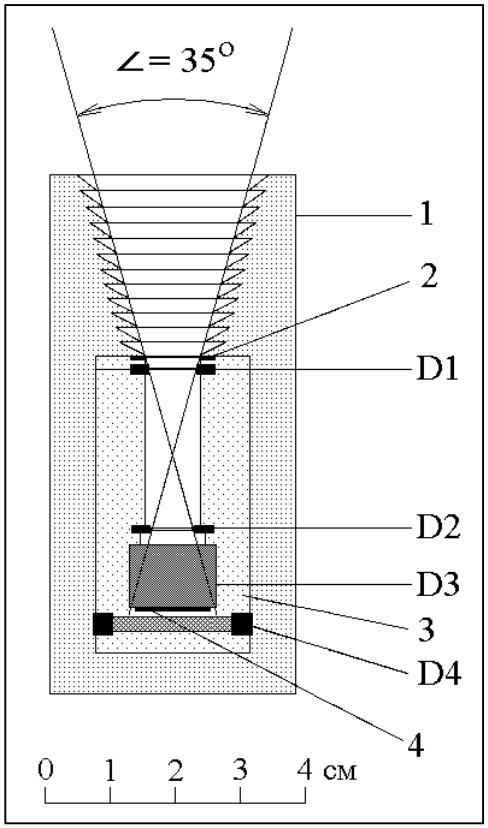


Version #1: The passing launch of SC on a "Soyuz" rocket with the use of "Fregat" upper stage

"Fregat" upper stage is developed in NPO Lavochkin. It has been successfully tested in 55 launches of more than 100 SC. "Fregat" is used as autonomous launching device without ground control infrastructure.

Electrons and protons spectrometer

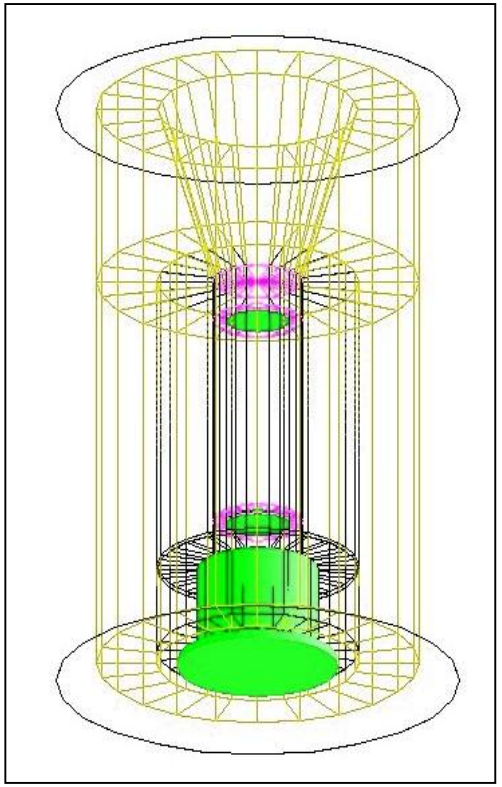
Electrons and protons spectrometer



Ranges of registered energies of particles :

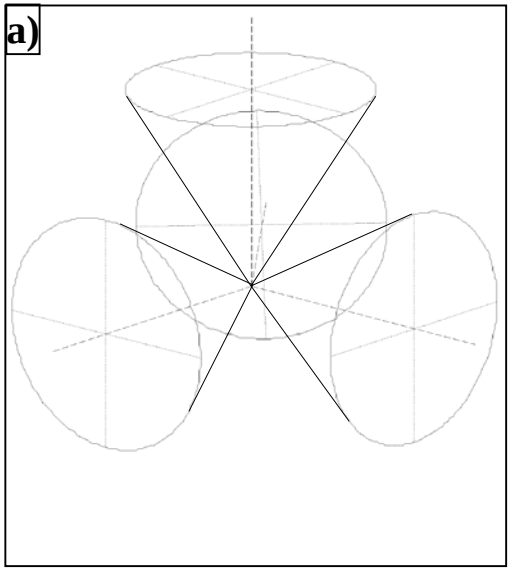
0.15–0.35, 0.35–0.6, 0.6–1, 1–2, 2–4, 4–10 MeV;

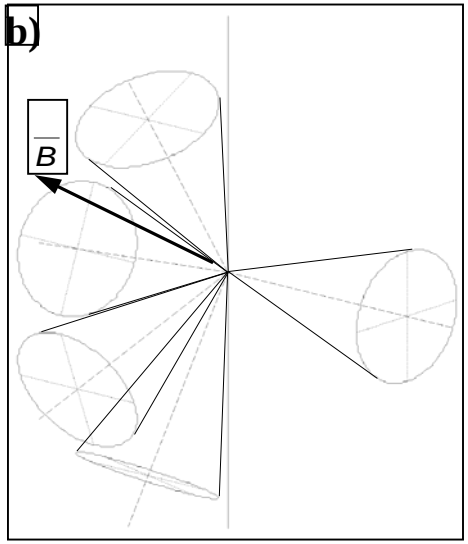
protons: 2–4, 4–9, 9–15, 15–30, 30–53, 53–100, 100–160, >160 MeV



Electrons and protons spectrometer

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

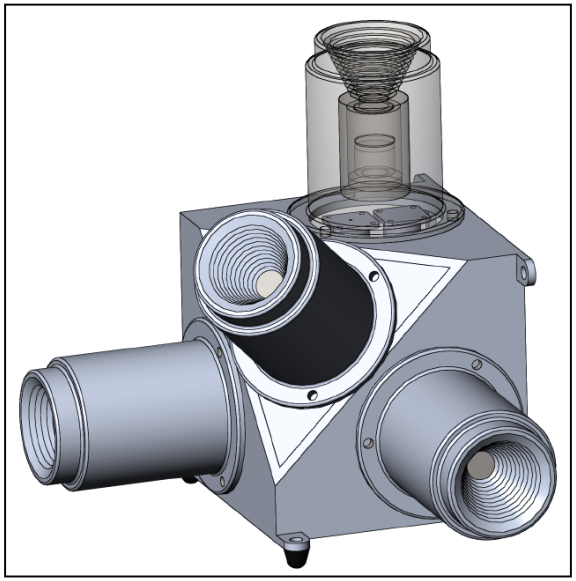


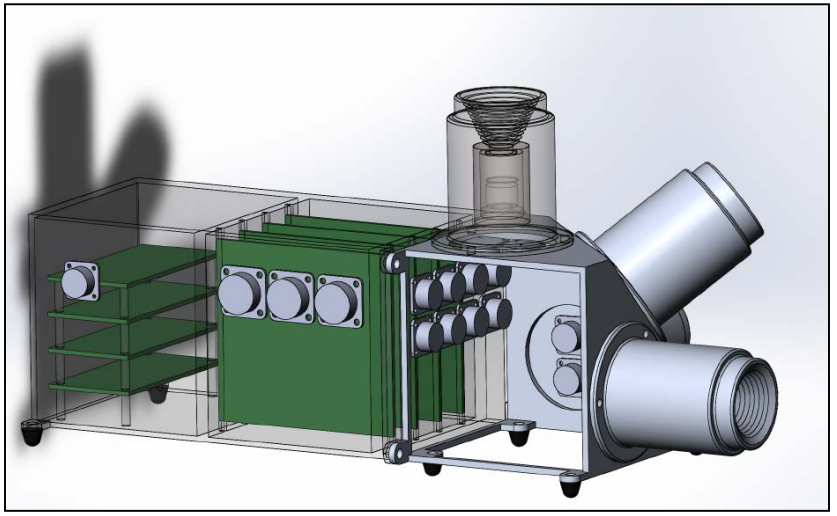


Two versions of distribution the particle spectrometers to determine omnidirectional fluxes

Electrons and protons spectrometer

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





3D model of 4 blocks of electrons and protons spectrometer (on the left) and in combination with the processor block (on the right)

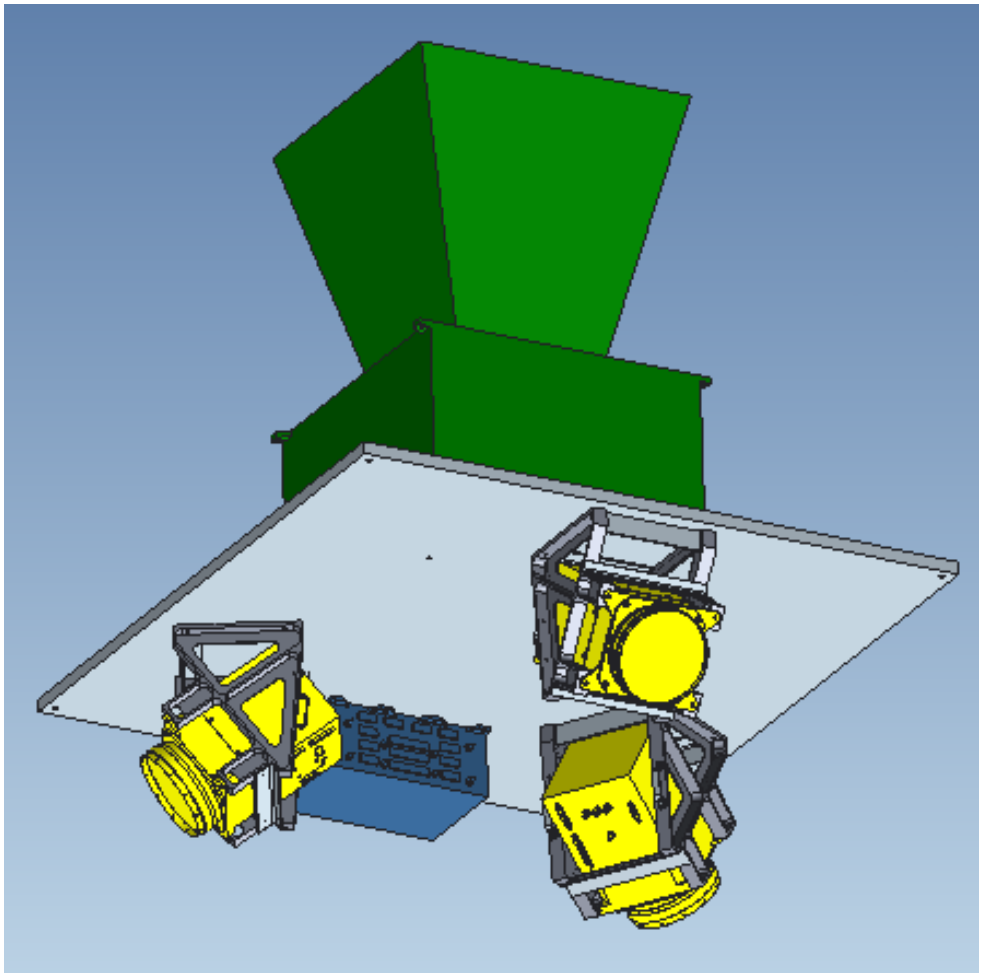
Full instrument weight — 6 kg (2 kg — processing unit)

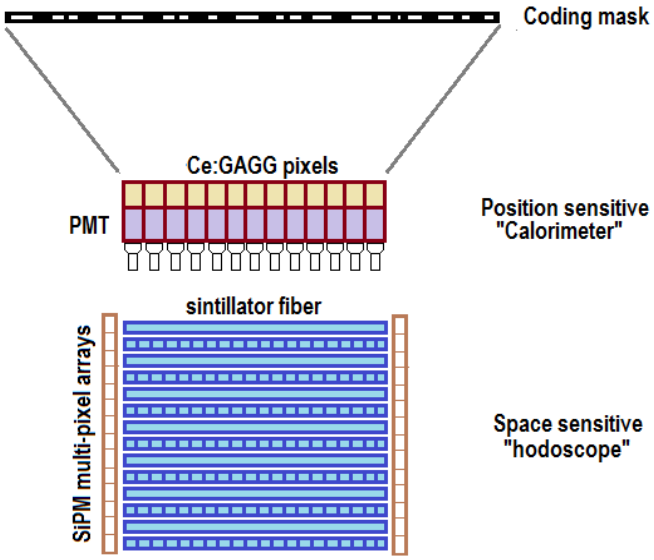
Conplex of instruments for gamma transients monitoring

✓Three wide-field scintillation gamma ray detectors for control of upper Atmosphere and sky survey in the range 10-3000 keV

✓Track gamma ray spectrometer of high resolution and sensitivity.

Axes of three detectors should be normal to each other and directed along the mutually normal cube edges, as if forming a Cartesian coordinate system. The main diagonal of the cube should be oriented to the Nadir.

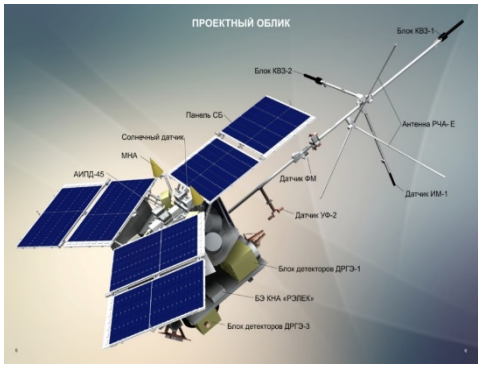


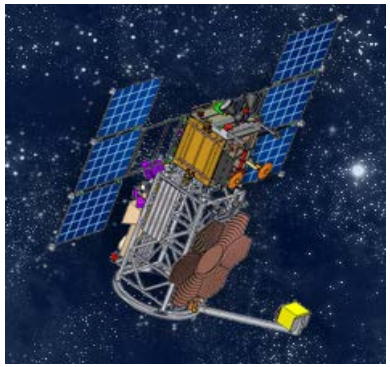


Tracking gamma ray spectrometer parameters

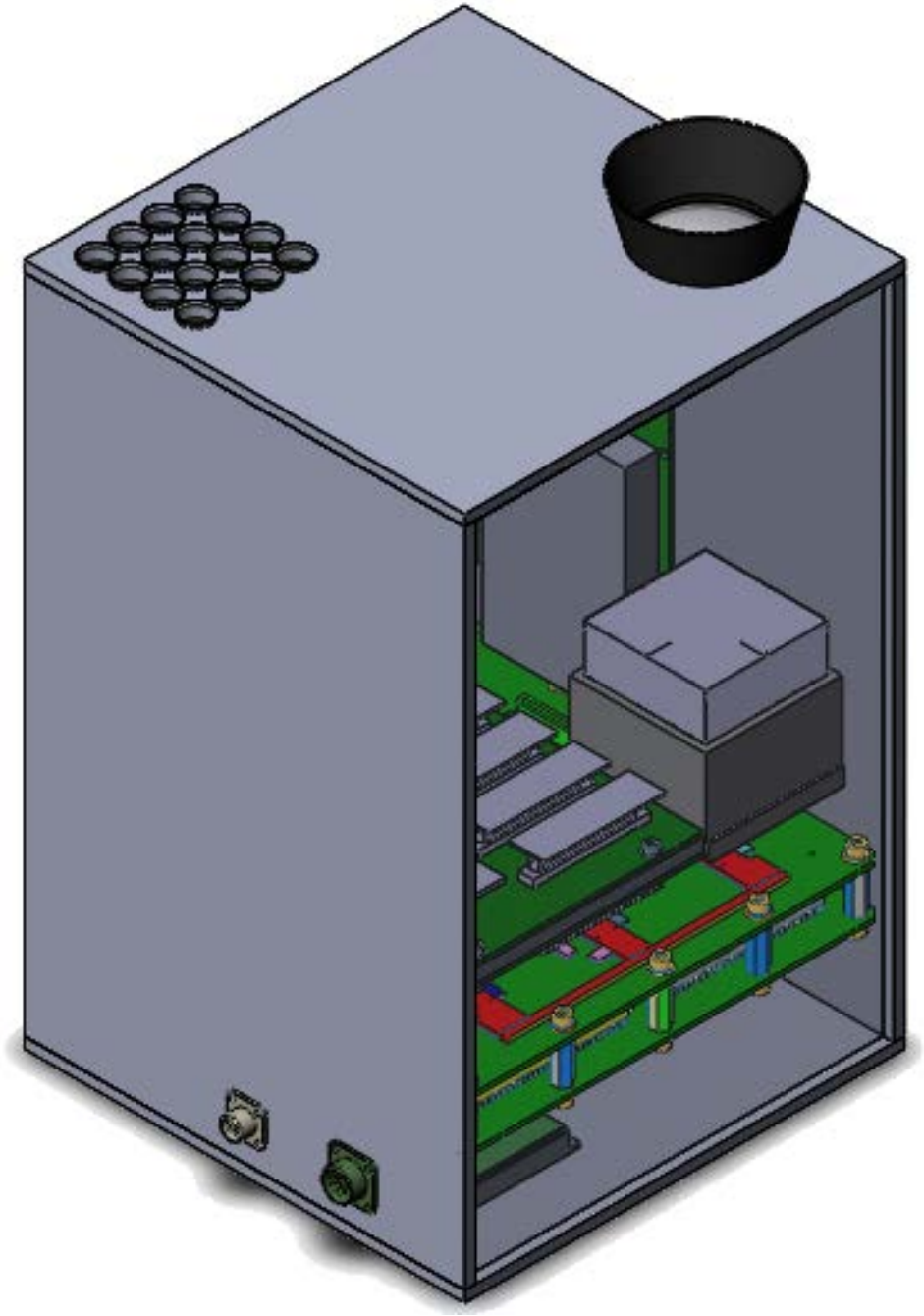
Parameter, units	Value
Energy range for gamma quanta, MeV	
All interactions	0.02 – 10.0
Coding mask telescope	0.02 – 1.0
Double Compton imaging	0.5 – 10.0
Effective area, cm^2 (all interactions)	~250
Angular resolution	
Coding mask telescope	~2^o
Double Compton imaging (at 1 MeV)	10-15^o
Time resolution, ns	5
Energy resolution (at 1 MeV)	5%
Sensitivity to the 1 ms burst detection, cm^{-2}	~$3x10^{-2}$
Energy range for neutrons, MeV	3 - 100
Effective area for neutrons, cm^2 (at 40 MeV)	13
Mass, kg	40
Information capacity, MByte/day	~500
Power consumption, W	60

Detectors of UV and IR radiation on the MSU satellites





	Tatyana-1	Tatyana-2	Vernov	Lomonosov
The number of measurement channels	1	2	2	256
Spectral range	240 - 400 nm	240 - 400 nm 600 - 800 nm	240 - 400 nm 600 - 800 nm	240 - 400 nm
Temporal resolution	16 mcs	1ms	0,4 ms	0,8 mcs 25,6 mcs 0,4 ms 105 ms
The effective area of optics	0,4 sm^2	0,4 sm^2	0,4 sm^2	1,6 m^2



The complex of scientific equipment for the study of TLE in the UV and optical ranges should include a spatially sensitive spectrometer MLT - a small lens telescope with a high temporal resolution for measuring the optical emission spectrum of TLE and lightning and detectors of UV and IR radiation – DUFIK.

The measurement of the spectrum is necessary to determine the type and altitude of the TLE generation, as well as the isolation of lightning discharges at 777 nm (and the absence of a signal in the region of the oxygen absorption line of 762 nm).

The MLT instrument should consist of a lens wide-angle lens and a multi-anode PMT position-sensitive detector, as well as a set of PMTs to measure long time series of a TLE signal with high sensitivity and high temporal resolution. There are 16 spectral channels..

The DUFIK instrument should consist of three PMTs, the input windows of which are closed with light filters that provide operation in infrared (600-800 nm), near UV (240-400 nm), and solar-blind (100-300 nm) ranges. In addition, it should include an optical detector based on a microchannel plate, which ensures the detection of photons in the range from far UV to soft X-ray.

The monitoring of natural and technogenic dangerous objects in near-Earth space

MASTER

SHOCK

LOMONOSOV

SHOCK widefield optical cameras:
12 megapixels CCD 24 * 36 mm - 2 pcs

LOMONOSOV : SHOK instrument

11th star's value for single shot or
13th star's value for 100 serial shots (5 shots/sec)

Прибор ШОК на борту КА Ломоносов
11 звездная величина на одиночном кадре
13 звездная величина на сумме 100 снимков
5 кадров в секунду

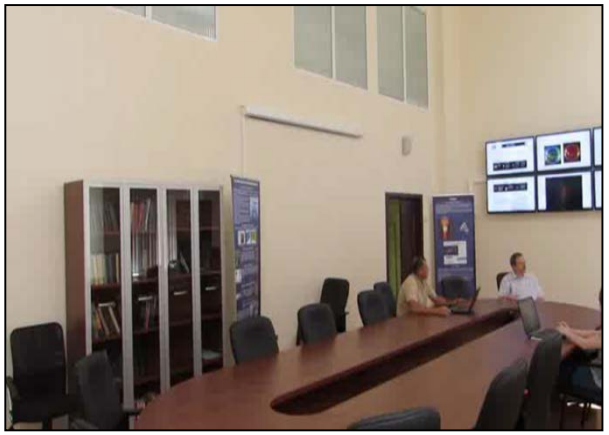
- **Field of view of each camera is about**
- **1000 square degrees,**
- **and maximum framing rate is about 5-7 frames/sec.**
- **In fact, cameras record "a movie" continuously,**
- **and is case of gama-burst detection part of this**
- **movie can be transmitted to the Earth**
- **using GLOBAL STAR space system.**

Тестовый (фокусировочный) кадр летного образца ШОК. Экспозиция 5 с.
Предел – 12 звездная величина
Москва, ГАИШ МГУ июль 2011 года.

On ground test of SHOCK instrument in MSU
(exposure- 5 sec, distance limit –the 12 -th star's value

Reception and data analysis

- Development of the method of on-line analysis and forecasting of outer space condition
- Development of models of outer space factors
- Organization of the reception and of automated processing of space data
- Development of analysis and space weather forecasting system on the basis of satellite information (data assimilation and modelling)
- Development of the information display system
- Development of decision-making procedures about danger situation alert (working out of alerts)



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Educational and promotional activities

Basic aims :

- 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

Conclusion

Success in project realization allows:

- **For the first time in the world to create a prototype of space monitoring and space threats prevention system for both ongoing and planned space missions, including high-altitude atmospheric aircraft.**
- **To create the new and innovative technologies in the sphere of instrumentation and methods for solving information problems in real time.**
- **To develop a new educational standards and specialist training methods in the new field of applied space researches.**
- **To strengthen the international cooperation in space researches.**

Acknowledgements: This research is supported under the Contract with Ministry of Science and Education of Russia, grant No 14.607.21.0175, 26.09.2017.