

## UNIVERSITY SATELLITES DEVELOPMENT PROGRAM

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**Abstracts.** Moscow State University has experience in developing and constructing small scientific and educational satellites. Young scientists, doctoral, and graduate students are participating in the development of the satellites and processing scientific data from the experiments. Not so far ago the program for satellites development was started in the MSU.

The "Universitetsky-Tatiana-2" satellite was launched in September, 2009. Its main scientific goal – the detection of transient light effects in the atmosphere and the ionosphere – was raised after the "Universitetsky-Tatiana" experiment with UV detector. Now two more university satellites are being developing – "Lomonosov" ("MVL-300") and "YouthSat" satellites.

The "Lomonosov" is planned to be launched in the end of 2011, its main scientific goals are:

- The study of the high-energy CR and their sources;
- The on-line monitoring of the gamma-ray bursts with simultaneous study of their effects in ionosphere and atmosphere;
- And the investigation of the radiation environment of high-inclination orbits and Radiation Belts study.

The project of the Russian-Indian scientific-educational satellite "YouthSat" is developed in cooperation with the Indian Organization of Space Research. The Russian party - M.V. Lomonosov Moscow State University - provides the development of the scientific equipment SolRad for the studies of the solar activity. All the Russian equipment now is successfully mounted onboard and passed the preparation tests. The satellite is now ready to launch.

Also this article presents the new nanosatellites development and launch program. This program starts in the Moscow University and it is assumed to cooperate many educational and research centers all over the world.

### History

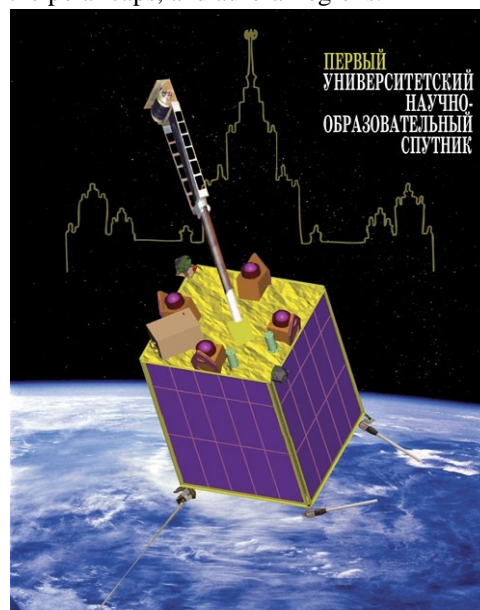
From the second soviet satellite till nowadays the equipment manufactured at the Skobeltsyn Institute of Nuclear Physics of Lomonosov Moscow State University has been installed on every scientific spaceship and on many spaceships of special purpose. This equipment was aimed to explore the radiation belts of the Earth, galactic and solar cosmic rays, hot magnetospheric plasma as well as radiation conditions onboard the piloted and non-piloted spaceships (Logachev, 1998).

In 2002 the first scientific-educational microsatellite "Kolibri-2000" was launched. One of its primary goals was to attract school and university students to attend the space investigations (). This experience gave the MSU an opportunity to develop a first university satellite.

### Universitetsky-Tatiana

On the threshold of 250th anniversary of the Moscow State University, January 20, 2005, The "Universitetsky-Tatyana" was launched into a circular polar orbit with an altitude of ~1000 km and inclination ~83°. The satellite axis was directed along the "satellite-Earth" radius-vector (zenith-nadir). When moving along this orbit, the satellite regularly crossed (in the northern and southern hemispheres)

the following main structures of the Earth's magnetosphere: the outer and inner radiation belts, the polar caps, and auroral regions.



**Fig. 1.** The emblem of the "Universitetsky-Tatyana" satellite.

During the operation of the satellite there were realized several scientific goals:

- charged particles measurements, including solar cosmic rays and their penetration into magnetosphere during the solar flares, radiation belts particles and their dynamic, relativistic electrons below the earth's radiation belts;
- UV measurements (atmospheric glow, auroras in both hemispheres, UV flashes from the transient light events);
- studying single event upsets in memory microcircuits behind different shielding.

For solving these problems, the scientific payload intended for recording the charged particles fluxes (electrons, protons,  $\alpha$ -particles) in wide energy ranges (from 1 keV to 200 MeV) and ultraviolet radiation of the Earth's atmosphere was installed onboard the microsatellite.

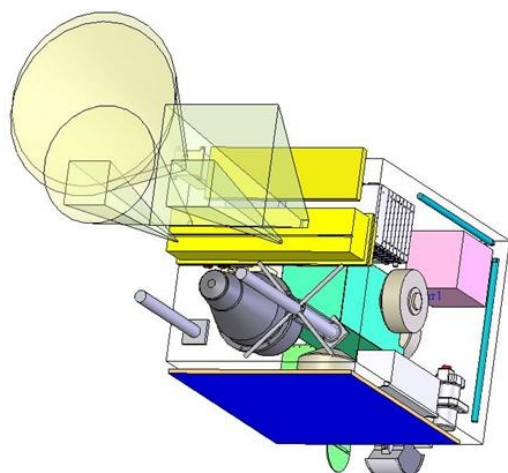
During two years of operation the onboard payload had shown stable operation of detectors, electronics and photomultiplier of DUV detector at airless design of the microsatellite and passive stabilization of temperature (Sadovnichy et al., 2007).

From the very first hours on the orbit, the satellite was taken part in the research: its launch coincided in time with a solar flare.

At the March, 2007 the connection to the satellite was abruptly lost, although it is still been tracked by ground navigation systems. Now MSU studies possibilities to reanimate the satellite.

### Universitetsky-Tatiana-2

The Tatiana-2 satellite was launched in September, 2009. Its main scientific goal – the detection of transient light effects in the atmosphere and the ionosphere – was raised after the “Universitetsky-Tatiana” experiment with UV detector. The project was developed by the collaboration of the universities and the institutes of Russia, Korea and Mexico. (Dmitriev et al., 2009)



**Fig. 2.** The model of the Tatiana-2 satellite. The fields of view of optical detectors are shown on the figure.

The scientific equipment consist of 3 main devices:

- detector of ultraviolet and red radiation (UV and R) with the operation ranges of wavelengths for two photo-receivers (photomultipliers) of 300-400 nm and 600-700 nm, correspondingly;
- scintillation detector of the charged particles flux with scintillator's area 400 cm<sup>2</sup>;
- detector MTEL for study of transient events (telescope and spectrometer).

### YouthSat

The YouthSat is a Russian-Indian scientific and educational university satellite. The collaboration of its development includes Moscow State University, Glavkosmos Company, and Indian Space Research Organization.

The total power assumption of the satellite is up to 215 W, the payload assumption is 25...30 W. It can download up to 8 Mbytes of data per day. It is prepared to be launched at circle solar-synchronous orbit.

The satellite includes several main instruments. The Russian party - M.V. Lomonosov Moscow State University - provides the development of the scientific equipment SolRad (Solar Radiation). There are two main goals of the instrument:

- the scientific goal is to register hard X-rays and gamma-rays from solar cosmic rays and GRBs, high-energy charged particles into the magnetosphere and upper atmosphere. This is need to investigate their influence on the near-Earth magnetosphere;
- the educational goal is to attract students and postgraduates to advanced studies in the space physics in general and Solar-to-Earth connections in particular.

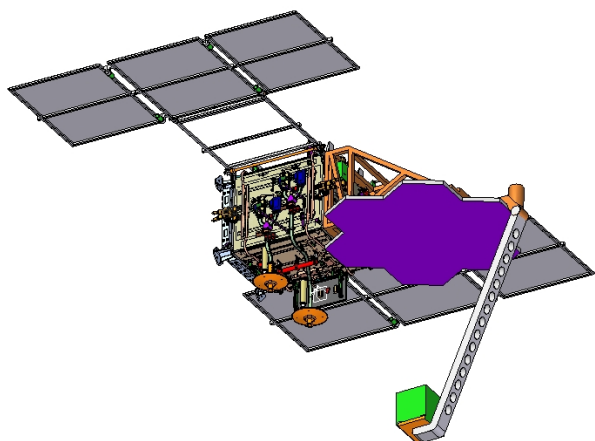
The SolRad consists of detectors module including hard X- and Gamma-rays spectrometer (0.1...10 MeV), electrons (0.4...4 MeV), protons (4...100 MeV), alpha-particles (4...100 MeV/n) and electronics module with processing unit and inner-satellite interfaces. The instrument detects solar flares with fluxes  $\geq 10^{-8}$  Erg/cm<sup>2</sup>. The solar forecasts models should be upgraded based on the scientific data from the instrument.

All the Russian equipment now is successfully mounted onboard and passed the preparation tests. The satellite is ready to launch in the end of 2010.

### Lomonosov

The Lomonosov program prepares a new satellite for fundamental study of the ultra-high energy cosmic rays and gamma-bursts, transient light events in the Earth's atmosphere and dosimetric investigations for high-latitude manned space missions.

The satellite will be launched at circle solar-synchronous orbit at 500...600 km altitude. Its total mass not exceed 400 kg including up to 150 kg of payload. The total power consumption is about 300 W, and telemetry channel allows to transmit up to 8...9 GBytes scientific data per day.



**Fig. 3.** The model of the Lomonosov satellite. The mirror of the main scientific instrument is shown on the foreground.

1. The main instrument of Lomonosov scientific equipment is TUS device. It consists of the 2-meter in diameter segmented mirror that reflects the light from the night atmosphere and focuses it on the block of 255 photomultipliers. Thus the Earth's atmosphere is used as a huge scintillator for detecting the ultra-high energy cosmic rays particles. The area of ground spot mirrored to the detector is about  $5000 \text{ km}^2$ . The upper threshold of registering particles is  $5 \cdot 10^{19} \text{ eV}$ .

2. There are two types of detectors for gamma-ray bursts investigation. Automated optical cameras ( $3 \times 12 \text{ Mpx}$  matrixes) picture the sky and track optical events. Hard X- and Gamma-ray detectors are placed along the same axes. They form the trigger signal to the optical system and measure temporal and spectral characteristics of a burst. The system checks if high levels of X- and Gamma fluxes are reasoned by high energy charged particles to reduce the false triggering. The information of new GRBs is downloaded online to the Earth.

3. The study of transient events in the upper atmosphere of the Earth is already a tradition for the Moscow University. The UFFO/UBAT device continues the attempts to understand the methods of generation and logic of localization in the atmosphere such high-energy effects as the red sprites and the blue elves.

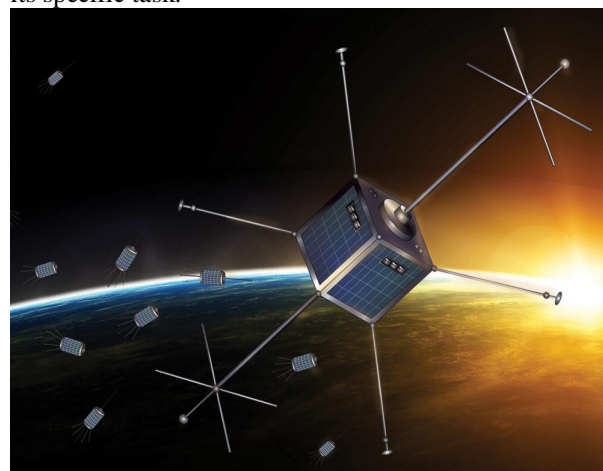
4. The dosimetric system of the Lomonosov is presented by two devices: DEPRON dosimetric device and ELFIN detector. The first one is a complex

### Constellation project

The main idea of the project is to integrate small and cheap nanosatellites into a group of satellites. The effect of this integration is similar to GRID-systems – total efficiency of the system will increase much faster than their number and will be greater than the sum of its components.

The “Constellation” system is capable of simultaneously implementing a number of tasks. The

head unit holds onboard up to thirty identical nanosatellites, each of them is configured to perform its specific task.



**Fig. 4.** The concept of the “Constellation” system: main satellite and a group of nanosatellites.

Tasks can be performed by several devices simultaneously or sequentially, during their resource expire. To control the position of satellites after separation from the mother platform special converging orbits are counted, i.e. the devices can "meet" each other over short distances or even gather all the group. During these meetings, rapid data exchange and intercalibration of sensors are possible, and even a partial redistribution of tasks could be implemented.

Each of the satellites has onboard an identical microprocessor, which operates the platform, intersatellite links, and the data download. The line connection is realized using one or several wireless standards (Wi-Fi, Wi-Max, GSM, 3G, 4G, or other standards), in terms of which each satellite is actually a normal subscriber.

This allows one to organize the work of all the satellites as the work of usual personal computers in the local network with the access to the main apparatus (server).

This eliminates the need of experiment participants to develop their own satellites with telemetry and vehicle, and the whole task of their developing program is transferred to the payload manufacture, experimental observation and data processing. To simplify and reduce the total cost only space-tested technologies and solutions will be used during the system development.

### The educational ideology of the project

The basic idea is that university microsattellites are just a flying training laboratories in which students of any university can meet the challenge of natural science workshop, or diploma project. Indeed, the near-Earth space is an inexhaustible natural laboratory for studying various physical processes. Mechanics, Electrodynamics, Plasma Physics, Statistical Physics, Wave processes and optics,

atomic and nuclear physics - this is not a complete list of areas of physics, which may occur in near space. Each university could find its own place in the cooperation:

- participate in the mothership developing and creating, mounting its payload;
- participate in the nanosatellites developing;
- develop and manufacture payload equipment for the own nanosatellite or series, in accordance with its scientific program;
- download information from the "Constellations", proceed it and use in the educational process;
- create methodic, textbooks, manuals or other parts of educational process in cooperation with other project participants.

### **The scientific ideology of the project**

The wide spectrum of scientific goals could be realized during the experiment:

- near-Earth space monitoring, studying of fundamental space physics problems;
- space weather;
- the systems of the near- and long-distance communication testing in the harsh conditions of outer space;
- monitoring the Earth's surface for ecological programs (earthquake prediction, environmental monitoring of natural or artificial disasters), and for the needs of geology, agriculture or industry;
- the production of super-pure materials, requiring low gravity;
- astronomy;
- local relay satellites;

- medical and biological researches;
- the base platform for nanotechnology investigations, nanocomponents and nanomaterials testing;
- etc.

With its own manufacturing and test facilities, MSU is able to quickly build spacecraft. A full industrial cycle from research and design to production and testing of finished products is running in the SINP MSU. This project could be realized in 2-4 years.

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