2.3. Information on the Projects of the Federal Space Programme of Russia under Development

2.3.1. Space Research Institute of the RAS

2.3.1.1. PHOBOS-SOIL PROJECT

The main objective of the Phobos-Soil project is delivering soil samples to the Earth and their further comprehensive study in terrestrial laboratories. In addition to the soil sampling manipulators installed on the lander, there is also a set of scientific instruments designed for in situ measurements of the physical and chemical properties of the surface at the landing site.

At the same time, a study of the Martian system is planned that includes the Red Planet itself, its satellites, and the planetary space by remote measurements.

Thus, the main scientific objectives of the mission include a wide range of issues, primarily the genesis of the Solar System. The solution to this major objective should be achieved through studying the physical and chemical properties of relict material from Phobos.

Other scientific objectives include:

- the study of the physical and chemical characteristics of Phobos as a celestial body, which will help in understanding the origin of the Martian satellites and possibly the origin of satellite systems of other planets;
- the defining of the detailed parameters of the orbital and intrinsic rotation of Phobos for further
- studies of the internal structure of this small body and the evolution of its orbit;
- the investigation of the physical environment in the planetary space (electric and magnetic fields and characteristics of the interaction of solar wind with the plasma environment of Mars, including the registration of the oxygen ions "escaping" from the Martian atmosphere) that will broaden our understanding of the history of water on Mars; and —the study of various characteristics of the planet's atmosphere.

PHOBOS-SOIL SPACECRAFT

The spacecraft was developed by the Lavochkin Scientific-Production Association, the parent organization of the Russian space industry that created all of the Soviet lunar and interplanetary spacecrafts and that specializes in robotic spacecrafts. The Phobos-Soil spacecraft consists of an orbital module, propulsion systems, and a return rocket.

Fig. Spacecraft Phobos-Soil

The spacecraft complex also includes a Chinese minor Mars satellite YH-1. This unit will be sent together with Phobos-Soil to the elliptical orbit of Mars, then will be separated from the main system and perform a mission of scientific exploration of Mars and its planetary space. The program was developed by Chinese scientists.

Meeting the requirements of COSPAR on planetary protection is crucial for creating interplanetary spacecraft. While manufacturing Phobos-Soil, this issue was given particular attention, as this project, in accordance with the requirements of COSPAR, simultaneously pertains to two types of interplanetary missions: a spacecraft orbiting Mars, and collecting samples of extraterrestrial material and returning them to Earth for scientific study.

SCENARIO OF THE EXPEDITION

Ballistic and navigational support for the Phobos-Soil project was developed by the Lavochkin Scientific-Production Association and the Institute of Applied Mathematics, Russian Academy of Sciences, under the auspices of the Corresponding Member of the Russian Academy of Sciences E.L. Akim. The expedition scenario (Fig. 4) can be divided into several stages. The first stage is the launch of the spacecraft, its placement into Earth orbit and the modification of the orbit for the optimization of onboard systems, and placing the spacecraft in the departure trajectory. It is currently scheduled to be launched in October 2009 on a Zenit rocket delivery vehicle from the Baikonur spaceport. The Earth–Mars flight begins after placing the spacecraft in the departure trajectory and finishes with the approach to Mars at the minimum distance. The duration of this stage of the mission is 10.0–11.5 months.

Mars will be approached at a parabolic trajectory with a pericenter height of 700 km. One of the favorable conditions of the mission to Mars in 2009 is the fact that plane of the approach trajectory and the initial orbit can be close to that of the Martian equator. The braking impulse of the spacecraft while approaching Mars will place the spacecraft into the first elliptical orbit around Mars. The parameters of the orbit are follows: pericenter height, 700 km; apocenter height, 7000 km; and orbital period, 3 days. The next stage of the expedition is the orbiting of the satellite to rendezvous with Phobos. This stage was already fulfilled in a previous expedition to Phobos with a three-impulse scheme. In accordance with this scheme, the second impulse, originating in the apocenter, increases the spacecraft's pericenter up to an altitude slightly higher than the height of the orbit of Phobos. The third impulse in the pericenter forms a circular orbit with a radius of approximately 9900 km (~500 km above the orbit of Phobos) in the orbital plane of the moon.

The orbital period of the spacecraft for this circular orbit is 8.3 h. In this orbit, the spacecraft will approach Phobos at a distance of several hundred kilometers once every 4 days. Work on this observational orbit is necessary for accurate navigation measurements of the motion of the spacecraft and Phobos and for the transition closer to Phobos to its quasi-synchronous orbit.
The orbital period of the spacecraft is equal to that of Phobos, but is different in height (plus or minus tens of kilometers in different parts of the orbit). Moving along this orbit, the spacecraft will always be near Phobos at a distance of 50–130 km. Moreover, one of the features of the quasi-synchronous orbit is that the orbital period of the spacecraft in the Phobos coordinate system is 7.36 h. Investigational work on this orbit will help to clarify the relative position of the two bodies and study the landing sites on the surface of Phobos.
Landing is planned in the equatorial region of Phobos, from which it is impossible to observe Mars. This site was chosen because the spacecraft needs a certain amount of energy to operate, and landing on the Mars side of Phobos (as was planned previously) would result in a lack of the spacecraft energy because of the shadows from Mars. The landing site was chosen based on high-spatial-resolution images of the surface of Phobos made by Mars Express.

Preliminary coordinates of the landing site are 7°N to 21°N and 214°W to 233°W.

Landing the spacecraft on Phobos is the most critical stage of the expedition. It includes the docking of two bodies, one of them being passive (Phobos). The docking will be carried out at considerable distances from the Earth, and the ground support for these operations will be limited (the signal propagation time in one direction is approximately 20 min). In addition, Phobos is an irregular-shaped body and its gravitational field has not yet been fully explored; all of the available images of the surface are not sufficient for an accurate determination of the landing site. All of these particularities dictate that the final stage of the approach to the surface of Phobos and landing should be autonomous and automatic. The following instruments will be used to perform the autonomous landing of the spacecraft: television cameras for high-spatial resolution images of the would-be landing zone and defining the parameters of the spacecraft's motion on the surface, an altimeter for measuring the height of the spacecraft, and meters of the spacecraft's relative velocity.

As the gravity on Phobos is low (free fall acceleration being ~0.7 cm/s, 1400 times less than that on the Earth), low thrust engines will be turned on at the moment of touchdown, providing the spacecraft's restraint and its stability on the surface.

After the landing of the spacecraft and the preliminary studies of the soil by the scientific equipment onboard, soil sampling will be carried out. The spacecraft will have onboard equipment which will allow for the sampling of the regolith and the consolidated material (~1 cm) with a total volume of ~100 cm3.

The soil samples will then be placed in hermetically sealed container capsules. Then, the return vehicle is ready to take off from Phobos.

The time of landing the spacecraft on Phobos and the takeoff of the return vehicle is calculated on the basis of many factors, including the lighting conditions of the spacecraft, radio communications from the ground control, and reception of telemetry data.

Following the decision to start the return vehicle, mechanical pushrods are triggered to ensure the separation of the return vehicle from an orbital module (which remains on the surface of Phobos) and imparting the return vehicle with a relative velocity of around 1 m/s. As soon as the return vehicle flies off to a safe distance, its propulsion system is switched on. The vehicle enters a circumplanetary orbit of Mars with a height somewhat less than the height of the orbit of Phobos. After adjusting the orbit, the return vehicle is placed in an interplanetary Mars–Earth trajectory. The placement is carried according to the tri-impulse scheme similar to that used for the transfer of the spacecraft from the interplanetary trajectory to the circular orbit around Mars, but inversely. The time of the Mars–Earth flight is 10.5–11.5 months, and the approach to the Earth will occur between June 15 and July 20, 2012.

The mission does not finish upon the delivery of the soil samples from Phobos to the Earth. The orbital module still remains on the surface of Phobos to continue the scientific program of the expedition. Investigations on the surface of Phobos with the help of the complex of scientific instruments will be conducted for year.

LUNAR STUDY in 2010-2020

Program of Lunar study in 2010 – 2020 includes:

Luna-Glob Project 2013
- Orbiter
- Lander

Luna- Resource Project (together with ISRO) 2013

- Lander

Luna-Resorce-2 Projectypc ~ 2018

- Lunar-rover and samples return

Scientific goals

1. Science of the Moon:

- Regolith Volatiles near Lunar Poles
- Lunar internal structure
- Lunar magnetism (impact magnetism, internal processes, Lunar planetary dynamo
- Interaction solar wind, cosmic ray, micrometeorites with lunar regolith

2. Science from the Moon:

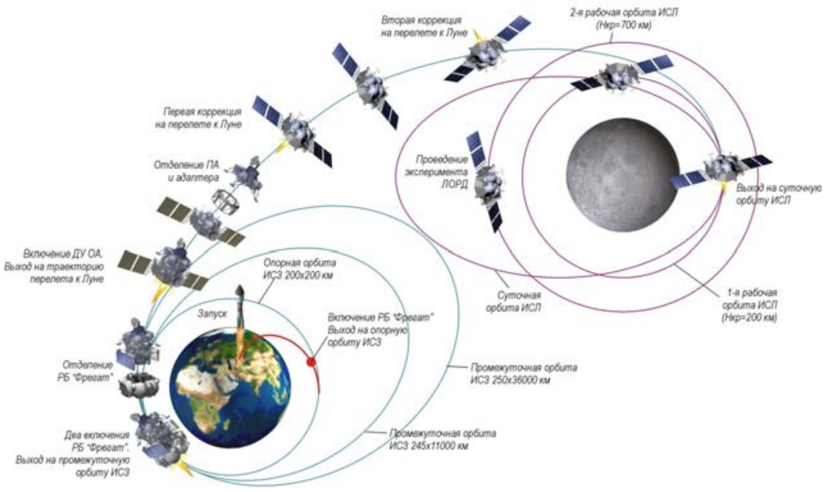
- **Space plasma and Terrestrial magnetosphere science**
  - Auroral Radio Emissions by the Terrestrial magnetosphere
  - Investigation of the magnetospheric tail (60 Re)
  - Monitoring parameters of the interplanetary environment (space weather)
- - **Moon-based Very Long-Wavelength Astronomy**

3. Science on the Moon:

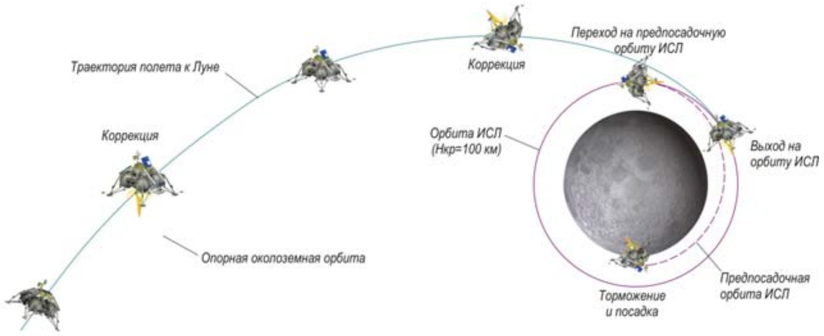
Ultra high energy cosmic rays

- Moon as a detector (a target with huge mass) for registration of cosmic rays and neutrino ultrahigh energy $>5x10^{19}$ eV
- Instrument: Radio complex, f=200-400 MHz

Luna-Glob spacecraft (launch configuration)



Orbiter mission profile



Lander mission profile

Lander for Luna-Glob and Luna-Resource missions

Federal space program for 2010m- 2020 includes also missions to mars, Venus, Europa

2.3.1.3. Europa Lander Mission: A Challenge to Find Traces of Alien Life

The main scientific questions of Europa exploration can be formulated as follows:

- Is there a liquid water beneath the ice crust of Europa?
- Does the global ocean really exist on Europa?
- What is the depth and distribution of the icy crust?
- Are environmental conditions on Europa suitable for life?
- Are there traces of extinct life on Europa?
- Are there evidences of life on Europa at present time?

Clearly, remote studies from the orbit around Europa would not be sufficient to fully characterize surface environment and to address astrobiology goals. Measurements on the surface are important for geodesy and geology, to study the Europa ocean and to characterize locally the ice crust. Laplace-Europa Lander project will tackle the fundamental questions of internal structure, surface environment, and habitability of Europa.

The main objectives of the mission will be to softly land on the chosen location, to collect multiple samples from one or multiple nearby sites to provide access to the shallow subsurface (to reach unaltered by radiation material). The landing site will be selected Europa Lander Mission 125 using the most accurate remote imagery to land on geologically youngest area, and to probe the material as recently exposed to the surface as possible. The following science and measurement objectives are being considered:

- To corroborate the theory of the liquid ocean, to characterize of the thickness and sti®ness of the icy crust, to study the internal structure by means of di®erent geophysical measurements; to characterize the seismicity of Europa, and to measure the magnetic feld on the surface
- To conduct a detailed study of surface material, characterize physical (electrical and heat conductivity, sti®ness, etc.) and chemical (pH, redox potential) parameters, analyze the composition of ice and admixtures, including isotopic ratios by means of gas chromatography with mass spectrometry (GCMS) and other methods;
- To characterize environment with particular attention to its capability to support life, and to search the traces of extinct or extant life in the surface and shallow subsurface (organic components, anions, cations, salinity, elements relevant to primary biological productivity, e.g. N, O, P, S, Mg, potential metabolism products), isotopic composition (13C/12C, 15N/14N, etc.) at high sensitivity, by means of GSMS, Raman spectroscopy, other methods;
- To conduct observations and measurements in regional, local and micro scales, to study morphology and mineralogy of the surface and to validate remote orbital observations;
- To perform local measurements of radiation conditions, secondary ions, exosphere of the satellite and volatiles near the surface (CH_4, NH_3, CO_2, etc.)

A list of potential experiments to be considered on the surface of Europa, and their relevance to three major classes of science goals: Conditions, Composition, and Habitability is presented in Table 1. This list comprises many experiments with duplicated science goals, and should not be considered as a model payload, but rather as a long list of potential candidates to the model payload. Most of these methods contribute to the assessment of the habitability of Europa, and many chemical analysis experiments have a high potential for biochemical detection of life (see Table 1). Speci¯c life-contrasting tests might include isotopic ratios (GCMS and TDLAS, but likely concentration needed); chirality (difficult detection by UV methods, Raman, could also be assessed by GCMS); wet chemistry set, and immuno-arrays.

A strategy to assess the feasibility of these experiments and a proper balancing between instruments proposed for a direct search of life and instruments for standard/advanced in-situ chemical and physical characterization of Europa is to be developed.

The most trustworthy experiments to be put on the surface of Europa identi¯ed so far are:

- seismometer, to estimate the thickness of the ice,

- a set of sensors for physical characterization
- chemical analytic package with high exobiology potential, based on GCMS
- IR spectrometer to link orbital and surface measurements
- a set of cameras, and microscopes

Three method to sample the surface, which are potentially compatible with the resources allocation of the lander are: the robotic arm/grinder, a drill to reach the depth of several tens of cm and to deliver the sample into the lander, and a melting probe with a mass of » 5 kg (1 kg instrument) to reach the depth of » 3 meters.

The science goals of the orbital element of the Laplace-Europa Lander mission are still to be considered. It is reasonable to duplicate some key investigations of NASA JEO, e.g., high-resolution imaging for landing site selection, lidar to characterize the figure of the satellite, near-IR mapping spectroscopy for surface composition, possibly a long-wave penetrating radar to map the thickness of the ice crust. A number of complementary measurements will be considered, to characterize in situ the ion and neutral composition of Europa environment, to measure the radiation dose, and to perform remote studies of Jupiter and other satellites.

Mission concept

A number of missions to explore Europa have been studied during the past decade. An analysis of mass allocation for various landing strategies shows that a classical soft lander is the most advantageous in terms of mass. A number of hard penetrator solutions are being considered for Europa. However, the high-velocity penetrator concept for an airless body is yet to be demonstrated. Russian Laplace-Europa Lander mission includes a soft lander (total mass of 1210 kg), and a small telecommunication and science orbiter (395 kg). Comparing with many previous landers with mass below » 400 kg, Laplace-Europa Lander is relatively large and may a®ord a considerable science package.

Two variants of the interplanetary cruise are possible. First, a conventional scheme, including chemical propulsion and a series of gravitational maneuvers around Venus and the Earth has been considered. Alternatively, electric propulsion during the heliocentric cruise coupled with a single gravitational maneuver near the Earth can be employed. In either case the mass of filled transport modules (propulsion system) for such class of mission takes up to 80- 85% from total mass of the spacecraft.

To enter into the orbit around Europa in the vicinity of Jupiter a series of gravitational maneuvers near Galilean satellites is required in order to save propellant mass. Extremely strong radiating belts of Jupiter have to be taken into account. Lengthy approach to the planet is unacceptable due to enormous cumulated radiation dose, destroying the subsystems of the spacecraft. The trajectory in the vicinity of Jupiter should be chosen in order to minimize the stay within Europan orbit, and to exclude whenever possible entering within the Io orbit. Estimations of charged particle fluxes and radiation doses under various shielding in different parts of the trajectory were made using different empirical models at each stage of the computations. The chosen sequence of gravitational maneuvers is shorter than two years. This stage is completed with the insertion into a circular polar orbit around Europa.

The calculations have shown, that even a heavy-class launch vehicle Proton with upper stage booster Breeze-M does not allow sufficient mass for both Orbiter and Lander to be delivered to Europa using chemical propulsion, even using multiple gravitational maneuvers. It is feasible, however when using the electric propulsion during the interplanetary cruise associated with gravitational maneuver near the Earth. In either case, a heavy-class launch vehicle is required to carry out the spacecraft (SC) to the escape trajectory.

This scenario, using the electric propulsion and one gravitational maneuver near the Earth is accepted as the basis for the further analysis. The ballistic scheme of mission consists of following basic stages:

- Transfer to low earth orbit (200 km) by Proton launcher
- Acceleration to interplanetary trajectory by upper stage Breeze; jettisoning of Breeze;

- Earth-Earth cruise using electric propulsion;
- Gravitational maneuver at the Earth;
- Earth-Jupiter cruise using electric propulsion; jettisoning of electric propulsion module;
- Breaking in the sphere of Jupiter attraction and insertion into initial high-apogee orbit;
- Increasing the pericenter altitude to Ganymede orbit;
- Multiple rendezvous with Ganymede and Callisto to reduce the relative speed of approach to Europa;
- Insertion into a circular orbit around Europa with an altitude of 100 km; jettisoning of the braking propulsion unit;
- Orbital °ight; separation of the landing module;
- Deceleration of the landing module, and landing.

Once the spacecraft arrives to Jupiter system, it approaches Jupiter (105 km) and enters into an initial orbit. During the first approach the orbit is inclined at 40 grad. with respect to the equator plane to minimize harmful influence of radiation belts of Jupiter.
This inclination is compensated by an impulse in apocenter, and the spacecraft enters in a transfer orbit with a pericenter of 9 £ 105 km, and an apocenter of 2 £ 107 km in the plane of Galilean satellites. During further flight at resonance orbit a series of rendezvous with the satellites is conducted, allowing to reduce propellant required for the insertion into the orbit round Europa. This stage will last » 23 months (see Figure 1).

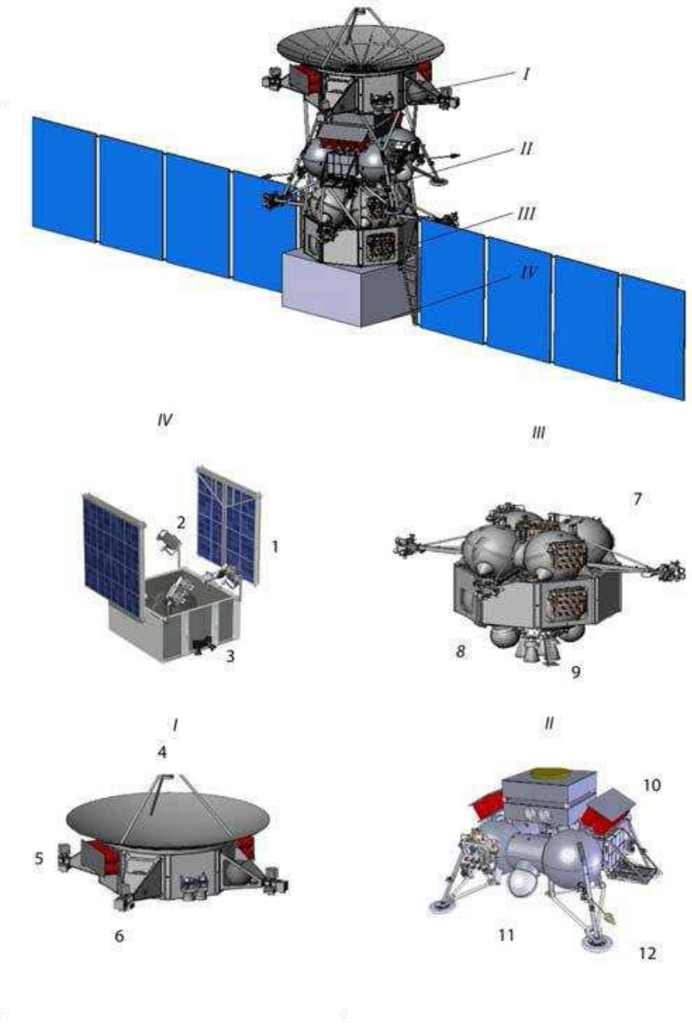


Figure 1. Europa Lander mission elements :
I.- Orbiter: 4 - High-gain antenna, 5 – attitude control thrusters, 6 - nuclear power units;
II. - Landing module: 10 - nuclear power units, 11 -science payload compartment; 12 - landing system;
III. - Braking propulsion system: 7 - propellant tanks, 8 - structure, 9 - main engine;
IV. - Electroroket propulsion system: 1 -solar panels, 2 - electrojet engines, 3 - attitude control thrusters. Xenon tanks are inside.

From this orbit remote studies of the surface will be conducted, and the landing site meeting certain topography conditions will be chosen. The landing module will be separated to perform an active soft landing onto the surface. The orbital module remains on the orbit and serves as a relay for the lander.

The landing is performed in two stages. First, the velocity of the landing module is reduced, than measurements of the altitude are performed, and the inertial speed of descent is de¯ned. Second, the lander is rendered along the local vertical, and the vertical speed is reduced from about 3 km/s to nearly zero at about 20 m above the surface.

Mission design

The spacecraft (see Figure 1) consists of four following basic elements:

- The electric propulsion transport module;
- The braking module.
- The orbiter;
- The lander.

The electrorocket transport module provides acceleration and deceleration during the heliocentric part of the °ight. It is also responsible for the attitude control and stabilization of the spacecraft during this period. The traction is provided by means of eight plasma engines SPD-140 with a thrust of »0.17 N each, and a specific impulse of 28000 m/s. The xenon is used as the propellant. The engines are integrated in four blocks, each of them includes two SPD-140 engines and a 1-axis deployment/attitude control mechanism. The velocity vector is controlled aligning simultaneously the orientation of the four engine blocks, and the solar panels. Measures are taken to prevent contamination of the solar panels, and the spacecraft itself with the plasma exhaust. The electric propulsion transport module with the solar panels is jettisoned from the spacecraft before the arrival to the Jupiter system.

Braking propulsion system module provides corrections during the cruise, and the braking impulses near Jupiter and the forming the orbit around Europa. The propulsion system module consists of two propellant tanks, the main cruise engine, four thruster units; it includes also valves and constructional elements. Four identical spherical tanks with a capillary intake are used; two are intended for the oxidizer, and two for the fuel. The cruise propulsion system consists of four engines with the general traction of »1600N and a specific impulse of 3000 m/s. The thruster units provide operating moments for attitude control and stabilization, and also velocity impulses for small trajectory corrections. Each block consists of four engines with traction of 50 and one engine with traction of 10 .

The orbital module is the principal structural element of the spacecraft. The systems of the orbital module provide the control at all stages of the flight, from cruise trough the insertion into the orbit around Europa. Redundant control system of the lander remains in reserve. This allows to increase the survivability of the spacecraft. The attitude control and stabilization of the orbiter is supported by reaction wheels, and a set of one-component chemical thrusters. The electric and thermal energy for the orbiter is provided by radioisotope thermoelectric generators (RITEG). Electric power generated by one standard RITEG is about 7 W. To provide for necessary power of 210W, the RITEGs are integrated in two identical blocks (15 RITEGs in each). During the cruise, maneuvers in the Jupiter system, and once inserted into the orbit around Europa the orbiter serves for science observations. After the lander is released, the main goal of the orbiter turns to relaying. The scientific instruments and service systems are located in the shielded compartment of the orbiter. The mass allocated for science instruments is 50 kg. A high-gain 4-m antenna for communication with the Earth is fixed on the top of the instrument container.

The lander systems should provide dV to deorbit Europa, soft landing on the surface, and the realization of science program. The distinct feature of the Europa lander (w.r.t. Lunar landers) is the use of the monocomponent fuel on the base of hydrazine for the main brake engine. It allows minimizing the pollution of the surface. The lander includes a block of fuel tanks of the propulsion system, realized in the form of four spherical tanks connected by cylindrical spacers. The landing feet are fixed to each fuel tank. Taking into consideration a high level of radiation, the scientific equipment and service systems are located in shielded instrument compartments with aluminum alloy walls of > 10 mm thickness. The mass allocated for science instruments and related subsystems (sampling systems, booms etc. is » 50 kg. Taking into account remoteness from the

Sun, the lander like the orbiter uses RITEG as a source of electric and thermal energy. Data exchange with the Earth is provided through the orbiter.
The heritage from previous developments. The Europa's Lander mission will extensively use the heritage from already developed modules, units and systems which have passed a full cycle of ground-based and flight. The electrorocket transport module is being developed within the Russian Federal Space Program as a unified service framework. The first flight opportunity will be in the frame of Electro-M geostationary meteo-satellite (2014). It will also be used for Interheliozond mission for solar studies, also targeting the launch date in 2014.
Most of the heritage comes from developments within the frame of Phobos Sapmle Return Mission (Phobos-Soil) in preparation for the launch in 2011.
The orbital module and the propulsion system are already developed and are the part of Phobos-Soil. Recently they have passed a full cycle of qualification. The same type of orbital module will be used for the Luna-Globe (2013) project and is planned as a basis of Mars-Net (2016) and Venera-D (2018) orbiters. Algorithms of landing are developed and will be renewed during another lunar mission Luna-Resource, which includes landing. Nevertheless, a number of the critical technologies has to be developed at the earliest stages of the project. A particular attention will be paid to electronic components tolerant to extremely high radiation doze. Radioisotope thermoelectric generators which developed now in the frame of Luna-Resource program, have to be qualified for application on Europa. A lot of ground experiments is required to test the technology of low-temperature of ice drilling.

2.3.2. V.N. Pushkov Institute of Terrestrial Magnetism, Ionosphera and Radiowaves Porpogation of the RAS

2.3.2.1. Interhelioprobe Project

The development of the Interhelioprobe project was continued in 2008-2009. The project is aimed at the study of the inner heliosphere and the Sun at short distances by using a spacecraft (SC) at heliocentric orbit formed by multiple gravity-assisted maneuvers at Venus. This ballistic scheme will bring the spacecraft to the working orbit around the Sun saving fuel and time and will allow conducting a series of unique observations and in-situ measurements in the nearest solar environment. High-resolution observations of the solar atmosphere combined with in-situ plasma measurements in the immediate proximity to the Sun will contribute significantly to the solution of the problems of heating of the solar corona, solar wind acceleration, and the origin of the major solar active events such as solar flares and coronal mass ejections. At the end of the mission, the gravity-assisted maneuvers at Venus can be used for inclining the SC orbit to the ecliptic plane and conducting the first out-of-ecliptic observations of the Sun, including its polar regions and ecliptic corona.

Approaching the Sun gradually by heliocentric spiral (Fig.1), Interhelioprobe will take different positions with respect to the Sun-Earth line and will perform multi-positional in-situ measurements in circumsolar space viewing the Sun from different sides, including those invisible from the Earth. At heliocentric distances, the spacecraft will have periods of corotation with the Sun, when high-precision observations of the solar surface can be carried out, and correlation can be established between the phenomena in the photosphere and heliosphere.

The SC orbit will enable a series of original observations and measurements:

High-resolution observations of the solar atmosphere at close range.

Corotation observations and measurements.

In-situ measurements in the vicinity of the Sun.

Out-of-ecliptic observations and measurements.

Stereo observations of the Sun (together with the Earth orbiters).

Observations of the invisible side of the Sun.

The out-of-ecliptic parts of the SC orbit will allow us to observe, for the first time, the solar polar zones and streamer belt in the equatorial plane and, thus, to estimate the longitudinal extension of coronal mass ejections and to monitor their propagation in the inner heliosphere.

Multiple positions with respect to the ecliptic plane will enable a detailed study of the extended coronal streamers and the associated acceleration of the slow solar wind. Regular observations of the fast solar wind will be also carried out during the SC passage over the polar regions at the stage of orbit inclination to the ecliptic plane.

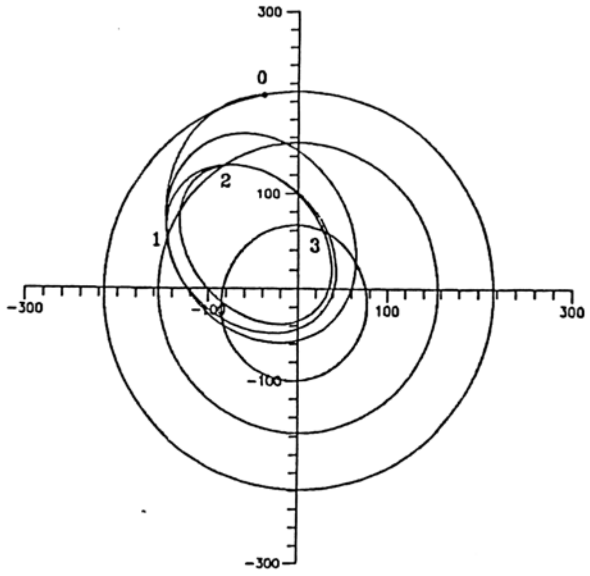


Fig.1.Interhelioprobe ballistic scheme.

Stage A of the Project was completed in 2008. At this stage, the ballistic scheme and scientific program of the mission were developed, and the composition of the scientific payload was determined, including the instruments for remote observations of the Sun (X-ray telescope-spectrograph, coronagraph, magnetograph, and photometer) and in-situ measurements in the heliosphere (magnetometer, solar-wind electron analyzer, plasma analyzer, analyzer of solar neutrons, detector of charged particles, gamma-ray spectrometer, X-ray spectrometer, and wave complex). Stage B, which started in 2009, is devoted to the development of technical proposals and draft of the mission.

2.3.2.2. Polar Ecliptic Patrol Project (PEP)

Stage A of the Polar Ecliptic Patrol mission (PEP) started in 2009. The mission is aimed at the study of the global pattern of solar activity, including its manifestations in the heliosphere and near-Earth space. The mission will comprise two small satellites on heliocentric orbits inclined to the ecliptic plane at an angle to each other and spaced by 0.5 AU (see Fig.2). The SC on the orbits will be shifted by a quarter of a period (~130 days) about one another.

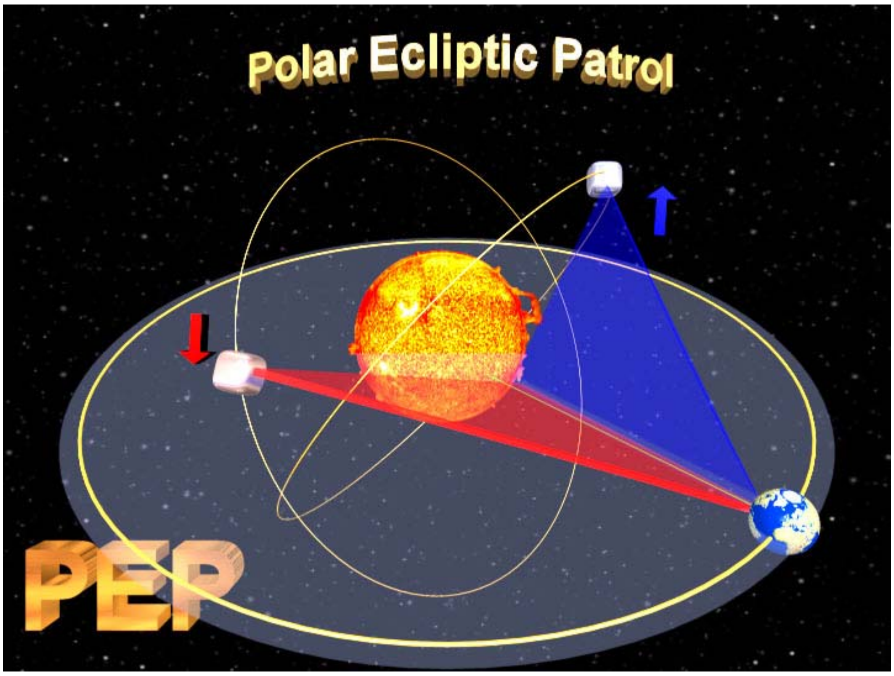


Fig.2.Ballistic scheme of the Polar Ecliptic Patrol.

Such a scheme will ensure continuous monitoring of the Sun-Earth line by one (and in some periods, by both) out-of-ecliptic SC. When one SC is in the ecliptic plane, another is over one of the solar poles; as the first SC goes away from the ecliptic plane, the second one approaches it. Thus, *simultaneous monitoring* of the near-ecliptic and polar regions is carried out providing a 3D pattern of the solar corona and ejections and enabling a continuous study of the slow- and high-speed solar wind. Observing solar ejections from two spaced SC and from out-of-ecliptic position will allow us to determine their exact direction relative to the Sun-Earth line and their heliolatitude and heliolongitude extension. This information is important to reliably predict the time when the ejections reach the Earth magnetosphere. In some periods, one SC and the Earth will be in different hemispheres with respect to the Sun-Earth line, so that the spacecraft will be able to observe the *back* side of the Sun invisible from the Earth. Thus, the PEP mission will ensure *continuous* monitoring of solar activity and solar wind, solar ejections and heliospheric disturbances moving towards the Earth, and observation of the *polar regions* and *back* side of the Sun.

The use of two spaced satellites makes it possible to conduct stereo observations of the solar environment that provide 3D images of plasma features in the solar atmosphere and 3D pattern of the solar corona and mass ejections.

The opportunity to observe the Sun from out-of-ecliptic positions, particularly, the polar zones and the active events concentrated mainly in the ecliptic plane will contribute significantly to our understanding of the origin of solar activity and will ensure continuous space-weather monitoring and forecast.

The main scientific objectives of the Project are:

- To study the global structure and evolution of the solar corona and solar wind; to obtain a 3D space-time pattern of the origin and propagation of coronal mass ejections.
- To determine the structure of the magnetic field and convection in the solar polar regions; to study the interaction between the rotation, magnetic field, and convection in the solar interior; to estimate the loss rate of the angular momentum of the Sun.
- To obtain the space-time pattern of propagation of high-energy particles accelerated in the solar active events.
- To forecast and register coronal mass ejections, shock waves, and other heliospheric disturbances arriving at the Earth; to monitor and forecast the heliospheric (space) weather at the Earth orbit.

– To study the true solar variability by measuring the solar radiation fluxes in different directions from the Sun.

The next task of stage A will be a detailed development of the ballistic characteristics of the mission, scientific problems and instruments, and the tentative outward appearance of the spacecraft.

2.3.2.3. Resonance Project

Within the Resonance magnetospheric project headed by the Space Research Institute RAS, the IZMIRAN team is engaged in the development of the magnetic experiment (FM 7R magnetometer) in cooperation with the Physical Instrument-Making Center of the Prokhorov Institute of General Physics and electric experiment (IESP-3R device) in cooperation with the Institute of Space Research of the Bulgarian Academy of Sciences. At present, the laboratory models of these instruments have been manufactured, and the designing documentation, including the ground-based tryout programs and specifications, has been developed.

2.3.2.4. IONOSAT Project

In order to study the ionosphere as indicator of the solar-terrestrial and lithosphere-atmosphere coupling, it is supposed to use satellite measurements at the altitudes of 400-500 km, which are an important method of investigation of these processes. Stage A of the IONOSAT Project started in 2009. Regular ionospheric measurements within the frames of the IONOSAT mission will be carried out by a cluster of three small satellites and will be conducted in cooperation with Ukraine and other participants. The satellite measurements will be aimed at the study of ionospheric effects of solar activity, such as flares and radiation bursts; effects of magneto-ionospheric phenomena (current systems, magnetic storms and substorms, particle precipitations); atmospheric phenomena (thunderstorms, typhoons, sprites, acoustic-gravity waves); lithospheric processes (earthquakes, volcanic eruptions); and effects associated with the human activity (rocket lunches, explosions, industrial activity, broadcasting, and heating facilities).

The variability is a fundamental property of near-Earth space. The ionosphere is subject to a strong influence of solar activity as well as of natural and man-made disturbances from below (thunderstorms, sprites, volcanic and seismic activity, electromagnetic effects caused by heating facilities, etc.). Some effects associated with the preparation of major earthquakes detected by satellite measurements in the ionosphere have stimulated the interest to the search for the earthquake precursors and effective prediction methods. This brings up the problem of separation and identification of the ionospheric effects from different sources for scientific and practical purposes. The solution of these problems requires regular ionosphric measurements that can be conducted by a cluster of small satellites.

The tentative ballistic scheme of the cluster of small satellites of the IONOSAT mission is represented in Fig.3.

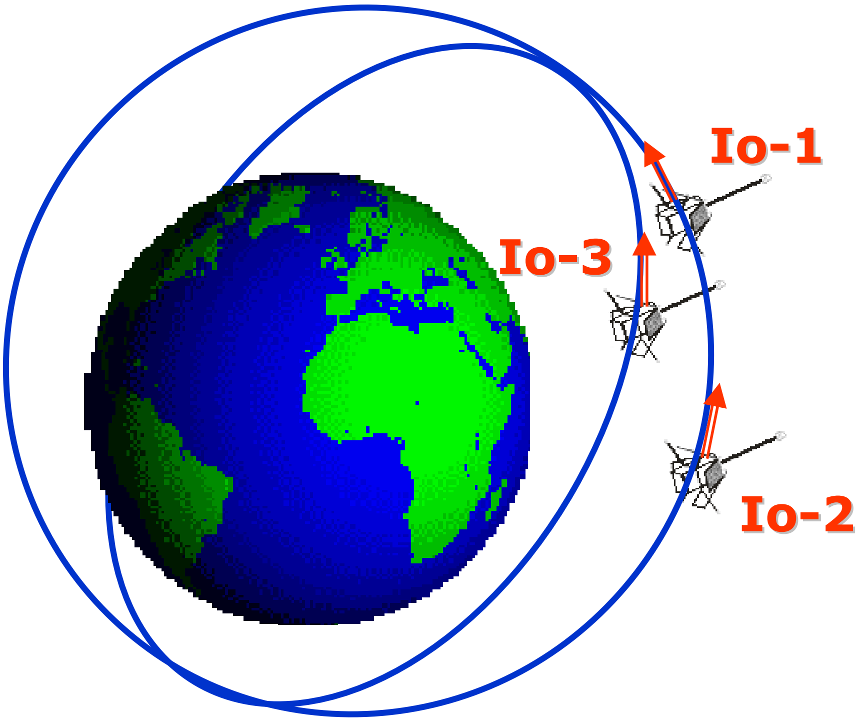


Fig.3.IONOSAT ballistic scheme.

Stage A of the Project is devoted to developing the methods of continuous and synchronous measurements of physical parameters of the ionosphere by a cluster of satellites (neutral component, magnetic, electric, and wave processes, charged and neutral particle fluxes, ozone, and minor gas constituents). The composition of the scientific payload and the optimum ballistic scheme of the cluster system will be worked out.

2.3.2.5. "Moon-Globe" and "Moon-Resource" Projects

Within the program of exploration of the Moon, IZMIRAN participates in the "Moon-Globe" (orbiter) and "Moon-Resource" (lunokhod) projects. In cooperation with the Physical Instrument-Making Center of the Prokhorov Institute of General Physics, IZMIRAN is engaged in the development of the FM-LG magnetometer for the lunar penetrators and FM-LP magnetometer for the lunokhod. The works started in 2009. The designing documentation has been developed, including the requirements specification for the magnetographs and check-test set and the technical documentation for manufacturing and checkout of the magnetometers and their models.

2.3.3. V.I. Vernadskiy Institute of Geochemistry and Analytical Chemistry of the RAS

2.3.3.1. FOBOS-GRUNT MISSION

The main scientific tasks can be decided only after return a samples of Phobos on the Earth, or partially without the return a samples. Complex of following scientific equipment for attestation of the place of landing for the spacecraft FOBOS-GRUNT develops and manufacture in Vernadsky Institute.

- ● gamma spectrometer FOGS
- ● mass spectrometer MAL-1
- ● thermodetector THERMOFOB
- ● seismometer SEISMO-1

Besides, the detector of a space dust the METEOR-F for studying of meteoric particles on a line of flight and in vicinities of Mars and a Fobos has been made.
By means of specified above devices following scientific problems will be solved:

- ● Studying of the abundance of the basic elements from hydrogen to iron and natural radioactive - elements potassium, thorium, uranium.
- ● Research of a composition of the gaseous component of Fobos regolith.
- ● Definition of thermo-physical properties of a regolith.
- ● Studying of an internal structure of Fobos.

• **Gamma-spectrometer FOGS** intended for determination of concentration of natural radioactive and main soil-forming elements: hydrogen, carbon, oxygen, magnesium, aluminum, silicon, potassium, calcium, titanium, manganese, iron, thorium and uranium in the soil layer with thickness of 1-2 meters. The device consists of two blocks: the detecting block including a scintillation detector on the basis of crystal CsI and a semi-conductor detector for studying of a stream of thermal neutrons and the multichannel peak analyzer of impulses (fig. 1). Neutron detector is part of gamma-spectrometer FOGS and intended for determination of concentration of hydrogen holding substances in the surface soil layer of Fobos.

Fig. 1

The experiment technique is based on registration of gamma radiation natural potassium radionuclide, thorium, uranium and the gamma radiation caused by nuclear interactions of space beams with elements of a Fobos regolith. According to the mission profile scientific equipments will work during tht flight on an hour per month for measurement of the background caused by nuclear interactions of space beams with constructive elements of the device and Spacecraft.

Technical characteristics are resulted in Table 1

• **Mass-spectrometer MAL-1** intended for investigation of composition of gaseous components of the soil. The device represents the exclusive mass spectrometer of flying type consisting of an ionic source, electrode system of the analyzer and of electronics block (fig. 2).

Fig. 2.

The technique of MAL-1F device operating is based on registration of a spectrum of weights flying a component of regolith, obtaining from chromatograph by IKI of the Russian Academy of Sciences.

Technical characteristics are resulted in Table 1.

Table 1. Scientific instruments and technical characteristics

Gamma-spectrometer FOGS	Mass of the instrument	5,4 kg
	That is measured.	Gamma-ray spectra. Thermal neutron flux.
	Range of measurements	<u>Нейтроны до 0,4 эВ</u> Gamma-ray energy: 0.3 MeV – 9.0 MeV Neutrons up to 0,4 eV
	Resolution	1-2 wt% for the maine rock forming elements
Mass-spectrometer MAL-1	Mass of the instrument	3,6 kg
	That is measured.	The mass of gas ions taken out of the Phobos' soil
	Range of measurements	1-400 a.m.u.
	Resolution	better 1 a.m.u.
Thermo-detector THERMOFOB	Mass of the instrument	0,3 kg
	That is measured.	Soil temperature
	Range of measurements	100 - 380 K
	Resolution	0,25 of degree
Seismometer SEISMO-1	Mass of the instrument	0,75 kg
	That is measured.	acceleration, velocity, displacement
	Range of measurements	No less than 100 db, $10^{-7}\div10^{-12}$ m
	Resolution	10%

Detector of space dust METEOR-F	Mass of the instrument	3,5 kg
	That is measured.	Mass and velocity of the meteoric particles
	Range of measurements	Velocity from 3 to 35 km/s Mass from 10^{-14} to 10^{-5} g
	Resolution	Mass – 30% Velocity 10% - interval 3-10 km/s 30% - interval 11-35 km/s

• T**hermo-detector THERMOFOB** intended for thermo-physical measurements in the surface layer of Fobos soil (There are common works together with Institute of Applied Mathematics of Russian Academy of Science). Structurally the device consists of three temperature-sensitive elements located in basic chassis of the landing device and the block of electronics (fig. 3).

Fig. 3.

The method is based on active thermometry with application of contact heating of a ground and registration of return thermal streams.

Technical characteristics are resulted in Table 1.

• **Seismometer SEISMO-1** intended for receiving of seismic data (seismograms) and recording of seismic noise data for solving of following fundamental and applied tasks: origin and internal structure of Fobos, gaseous-dust flows near Mars, structure and density of regolith, its mechanical properties. (There are common works together with Physics of Earth Institute of Russian Academy of Science). Structurally the device consists of three blocks: a narrow-band seismometer, a broadband seismometer and electronics block (fig. 4).

Fig. 4.

Technical characteristics are resulted in Table 1.

• **Detector of space dust METEOR-F** intended for determination of density of meteor flow near Mars, for receiving of data about physic-dynamic properties of meteor particles, belonged to dusty cover of Mars, for evaluation of meteor danger for flights of spacecrafts. Structurally the device is executed in the form of a monoblock including a hemispherical target, opened in a space, a collector of ions and electronics knot (fig. 5).

Fig. 5.

The method principle is based on the phenomenon of evaporation and ionisation of meteoric particles at high-speed impact of particles.

Technical characteristics are resulted in Table 1.

The most important result in 2008-2009 of the project "Fobos-ground" is the following:

1) Complex tests of technological samples of devices of mass spectrometer MAL-1, seismometer SEISMO-1, gamma spectrometer FOGS, thermodetector THERMOFOB, the detector of a space dust the METEOR-F in a complex of scientific equipment of "Fobos-ground" project in IKI of the Russian Academy of Sciences are made;
2) Samples of these devices are made.
3) The control instrumentation for each of devices is created;
4) The control instrumentation tests are made.
5) Flight samples (ЛО) devices of mass spectrometer MAL-1, seismometer SEISMO-1, gamma spectrometer FOGS, thermodetector THERMOFOB, the detector of a space dust the METEOR-F are made, their delivery to S.A. Lavochkina NPO is carried out;
6) Complex tests of flight samples of scientific devices are made;
7) Hardware-software of a land scientific complex for the given devices and the programmed-methodical documentation of devices’ operating during flight and on a Fobos surface is created.

2.3.4. P.N. Lebedev Physical Institute of RAS
Astrospace Centre
2.3.4.1. The International RadioAstron Mission

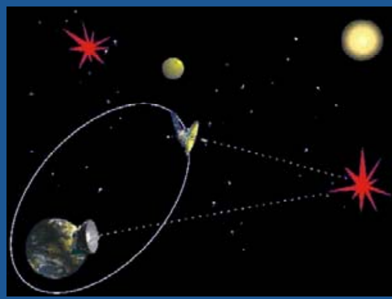
The International RadioAstron Mission – a Ground-Space Interferometer with orbit up to 350 000 km

The **RadioAstron Project** is designed by the Astro Space Center of the P.N. Lebedev Physical Institute of the Russian Academy of Science, and the S.A. Lavochkin Federal Research & Production Association, Roscosmos in cooperation with numerous Russian and international organizations.

Preliminary launch time - end of 2010.

The **goal of the project** is to carry out investigations of various types of astrophysical objects of the Universe with an unprecedent high angular resolution in the centimeter and decimeter wavelength bands.

Such resolution is attained by the 10 m **Space Radio Telescope** (on-board of the Spacecraft **Spectr-R**) working together with the largest **ground radio telescopes** in the interferometer mode.



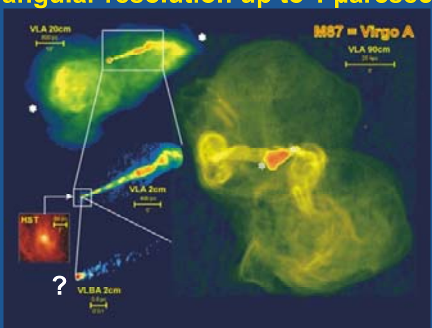
Parameters of the Orbit:

Period (variable)	7 - 10 days.
Major semi-axis	189 000 km.
Initial inclination	51.6°.
The perigee variation [orbit evolution due to the Moon gravity]	From 10 000 to 70 000 km.

Main Parameters of the RadioAstron Mission:

Frequency band [GHz]	0,327	1,665	4,83	18 - 25
Bandwidth, 2-pol. [MHz]	2 x 4	2 x 32	2 x 32	2 x 32
Fringe size at 350.000 km baseline [micro arcsec]	540	106	37	7 - 10
Detection limit 1-σ [mJy] (ground radio telescope GBT, 16/4 MHz bandwidth, 300 s integration)	42	4	4	10

The unprecedented super high angular resolution up to 1 μarcsec

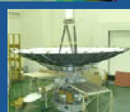


Investigations with the Space-Ground RadioAstron interferometer:

- obtaining the continuum, polarized and spectral images of various types of sources with moderate and ultra high angular resolution at the whole range of baselines projections;
- measuring the sources coordinates, proper motions and structure variations;
- high precision determination of the RadioAstron orbit parameters.

Design and Testing of the Space Radio Telescope:





http://www.radioastron.ru

The Scientific Program of the RadioAstron Observatory:

- Galactic nuclei (supermassive black holes, event horizon, particles acceleration, ultimate brightness temperatures, Faraday rotation, magnetic fields, cosmic rays, superluminal motion).
- Cosmology effects; redshift dependence of various physical parameters of galactic nuclei; dark matter and dark energy effects.
- Star and planetary systems formation, masers and Megamasers.
- Stellar mass black holes and neutron stars.
- Interstellar and interplanetary media.
- Fundamental astrometry and development of the high precision celestial coordinate frame.
- Development of the high precision model of the Earth gravitational field.

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Tel: +7 495 333-23-78, **http://www.radioastron.ru**

2.3.4.2. The International Millimetron Mission

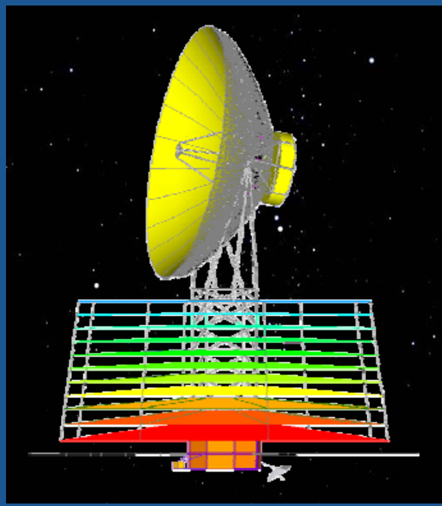
The International Millimetron Mission – Space Observatory with 12 m telescope in the 20 mm ÷ 20 μm waveband

The **Millimetron Project** is designed by the Astro Space Center of the P.N. Lebedev Physical Institute of the Russian Academy of Science, the S.A. Lavochkin Federal Research & Production Association and Information Satellite Systems Reshetnev Company of the Roscosmos, in cooperation with numerous Russian and international organizations.

Planned launch time: 2016.

The **goal of the project** is to carry out investigations of various types of astrophysical objects of the Universe with super high sensitivity (in single dish mode) and an unprecedentedly high angular resolution (in Earth-Space interferometer mode) at millimeter and IR bands.

Such parameters is attained by the 12 m **cryogenic (4.5 K) telescope** working together with the largest **ground radio telescopes** in the interferometer mode.



Main Parameters of the Millimetron Mission

The Single-Dish mode:

Photometer/Spectrometer/Polarimeter Arrays:

Frequency range	0.1-0.2, 0.2-0.3, 0.3-0.45, 0.72-0.76 and 1-15 THz
Spectral resolution	R=3 and R=1 000 ÷ 3 000
Array size (px)	16-1600
Bolometer sensitivity	~10^{-19} W/Hz$^{0.5}$

High resolution spectrometer:

Frequency range	0.5÷4.5 THz	Noise temperature	5 quantum limits
Spectral resolution	R=10^6	IF bandwidth	8 GHz

The Earth-Space Interferometer mode:

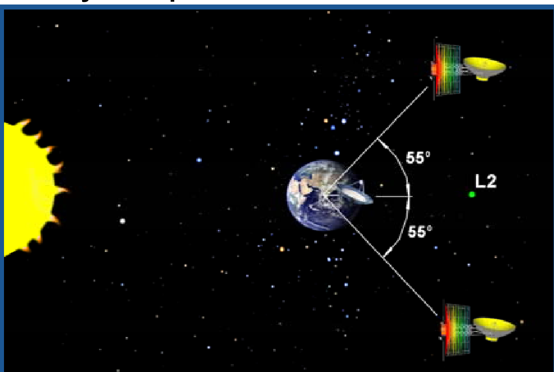
Frequency bands (GHz):
18-26, 31-45, 84-116, 211-275, 602-720, 787-950

Interferometer [VLBI] sensitivity:
4.0 mJy (at 950 GHz, noise T = 200 K); & 0.5 mJy (at 275 GHz, noise T = 50 K) [at bandwidth 1 GHz, 300 s integration and ALMA as the ground segment].

Fringe size:
$41 \cdot 10^{-9}$ arcsec at max. baseline ~1,500,000 km and wavelength 0.3 mm.

The Orbit around antisolar Lagrangian point L2

Period of oscillation around the L2 is 200.8 days.
Observatory's ecliptic latitude varies between b = ±55°:



The Scientific Program

- **Molecular content and physical conditions in the planetary atmospheres and their satellites.**
- **A study of the dust component of interplanetary matter, and of the objects belonging to the Van Allen's Belt and Oort's Sphere.**
- **Spectropolarimetry, mapping and variability of different types of stars, neutron and possible quark stars and black holes in our Galaxy.**
- **Exoplanets: detection and study of the star forming regions and their evolution. A search of life in the Universe.**
- **Submillimeter masers.**
- **A distribution of the dark matter in the Milky Way and Local System.**
- **Composition, dynamics and evolution of the gas-dust content and matter in galaxies and quasars; bursts of the star formation; megamasers.**
- **A detection of first galaxies in the Universe and a study of their evolution including an origin of stars, their gas-dust content, magnetic fields and dark matter.**
- **A search for the evidence of the astro engineering-like activity (SETI) in the Galaxy and in the Universe.**
- **A study of the extragalactic supernovae and determination of the cosmological parameters of the Universe.**
- **A chemical evolution of galaxies.**
- **A Hubble diagram in the sub-millimeter wavelength range.**
- **Angular fluctuations of the CMB (relic) radiation in the sub-millimeter wavelength range.**
- **A study of early stages of the Universe evolution from the epochs of recombination and re-ionization, first stars/galaxies formation, a search of the primordial black holes and wormholes.**
- **A study of physical processes in galactic nuclei close to the events' horizon of the supermassive black hole.**

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2.3.5. V.A. Kotelnikov Institute of Radio Engineering and Electronics of The RAS

2.3.5.1. Microwave L-band Radiometric Systems for Earth Remote Sensing from Space

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Introduction

Theoretical and experimental investigations show that L-band radiometry is very prospective (optimal) for soil moisture and sea surface salinity investigations. These measurements practically not influenced by weather conditions in the atmosphere. Now one of the most important problems for L-band radiometry is the problem of radio interference (RFI). RFI may be not so important in open ocean region, but are very strong in urban areas. The second important problem consists in necessity to make relatively large antenna for reasonable spatial resolution of the instrument. Despite this difficulties interest to investigations with use of microwave radiometers in this band is very high. One of the most powerful L-band instruments launched several months ago is European project SMOS [1]. It contains very complicated interferometric imaging radiometer MIRAS with synthetic aperture antenna. In USA under developments is a project SMAP with combination of microwave radiometer and scatterometer [2]. In Russia under development are simpler microwave radiometers for small satellite and for Russian segment of International Space Station (ISS) [3]. Time of SMOS and our instruments operation may overlap and it should provide the possibility to compare some results.

Space L-band microwave radiometric systems

Leading scientific organization for creation of payload for two space projects with use of L-band radiometers is Institute of Radioengineering and Electronics of RAS (IRE RAS). Head design organization of these radiometric systems is Special Design Bureau of IRE RAS (SDB IRE RAS). The first creating radiometric system PN1 consists of L-band microwave radiometer with 2 beams antenna. It is compact module and will be attached to the outer side of the small satellite (planed launching – 2010). General specification of the instrument is presented in the middle column of Table 1.

Table 1. General specification of the satellite radiometric systems

	PN1	**ALRS**
Main frequency, MHz	1410	1410
Bandwidth, MHz	20	20
Radiometric sensitivity, K	0,2-0,3	0,2-0,3
Polarization	linear	linear
Number of beams	2	8
FOW, km	350	50
Swath width (at orbit height 350 km), km	700	400
Power consumption, VA	≤ 60	120

	PN1	ALRS
Weight, kg	≤ 13	35
Size, mm radiometer antenna	 400x300x50 800x510	 1200x1920

Observation geometry of the small satellite system is presented in Fig. 1. Antenna of the radiometric system will be oriented for observation in nadir direction and provide spatial resolution about 350 km and swath width 700 km. In the main operational mode two beams of the system oriented across the flight direction in order to have wider swath width. In addition to this mode it may be possible to rotate the satellite so that two beams will be in a flight plane. This mode may be useful for calibration purposes and development of RFI suppression algorithms.

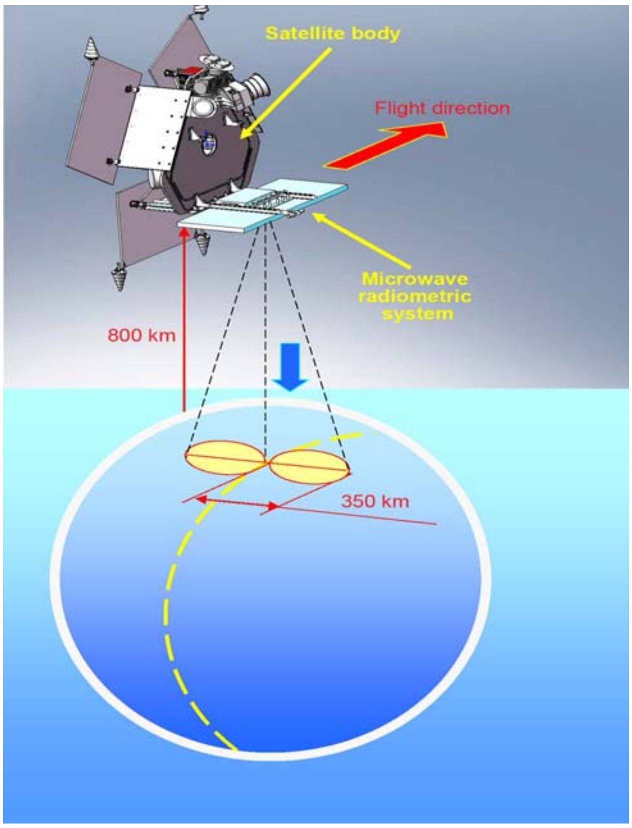

Fig.1. Observation geometry of the small satellite microwave system

Advanced L-band radiometric system (ALRS) will be installed on the module of Russian segment of International Space Station (RS ISS) (planed installation - 2010). General specification of the instrument is presented in the last column of Table 1. It is a set of radiometers with pushbroom 8 beams antenna. Each beam will have spatial resolution about 50 km. Observation geometry of the advanced microwave system is presented in Fig. 2.

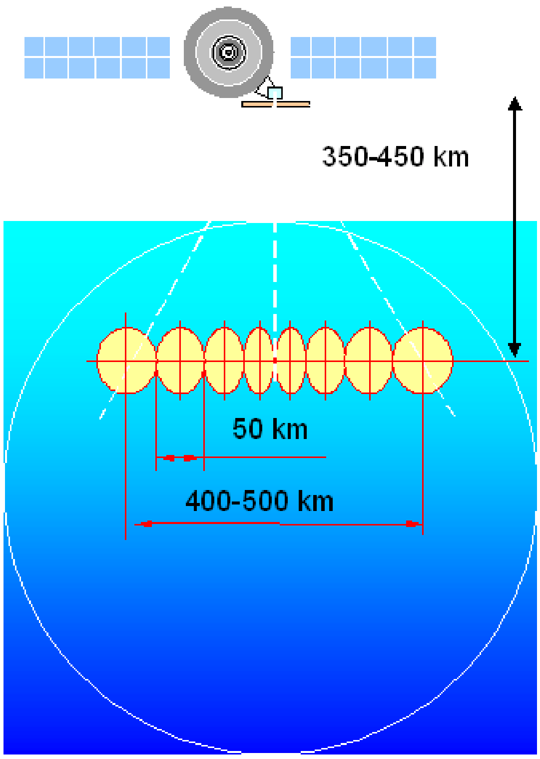

Fig.2. Observation geometry of the advanced microwave system

Due to relatively large size of the ALRS antenna and requirements to deliver instrument in compact state through the manhole it has folding elements and will be deployed manually. General view of L-band radiometric system in compact (transport) state is shown in Fig. 3.
Now both radiometric systems are made in technological versions and are in the procedure of laboratory testing. Results of testing are in a good agreement with technical requirements.

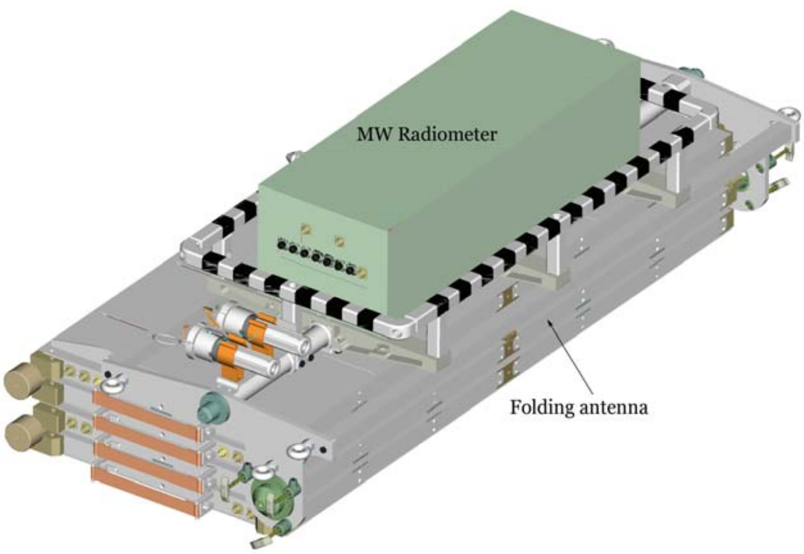

Fig.3. L-band radiometric system ALRS in compact (transport) state.

Scientific objectives and general features of the experiments

At the first stage of our space experiments the main goals are to develop and test new space microwave radiometric instrument in new band of electromagnetic spectrum in order to solve the following technical objectives:

- investigation of RFI situation in L-band all over the globe,
- development of in-flight calibration techniques,
- development of subpixel data processing algorithms for information simultaneously obtained from different satellites with different spatial resolutions.

During this stage we expect to select main regions with low level of RFI and made adjustments of preliminary prepared data calibration techniques.

Relatively low space resolution of the L-band radiometric systems restricts us in the list of possible applications. In the large field of view of the radiometer may be objects with quite different characteristics of emission. In this case high importance has development of algorithms for subpixel microwave data processing. During the data processing will be used simultaneous data from all available satellites with microwave and optical instruments having different space resolution.

At the second stage it is expected to concentrate more on the scientific objectives and environment investigations. Main directions are:

- soil moisture retrieval over the territories in regional and global scales,
- sea salinity estimation in open ocean,
- study of the geothermal activity regions,
- investigation of energy-exchange in the ocean-land-atmosphere system (in combination with the data of other sensors).

Conclusions

Experiments with space L-band microwave radiometers will provide new information on key characteristics of the oceans and land surface, mostly sea salinity and soil moisture. To achieve this goal it will be required to solve several technical problems concerning calibration, removing RFI effects and etc.

Scientific program of the experiments should be coordinated with similar programs of European and USA projects.

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[3] N.A. Armand, M.T. Smirnov, and Yu.G. Tishchenko "Hardware for scientific and applied studies in Earth resource remote sensing and in environment monitoring from the International Space Station Russian segment", *Cosmonautics and rocket engineering*, No 4 (49), 2007, pp 91-94 (in Russian)

2.3.6. D.V. Skobeltsyn Scientific-Research Institute Nucleus Physics of M.V. Lomonosov Moscow State University

2.3.6.1. . Studies of UV-radiation in the upper atmosphere

In 2009 the development of the new equipment for the studies of the UV radiation onboard the satellite "Universitetskij-Tatiana-2" was finished. This equipment consists of UV (300-400 nm), red radiation (600-700 nm) detectors and detectors of electrons with the area of 400 cm^2 and threshold energy of 1 MeV. For the first time using of the electrons detector will provide an opportunity to measure "splashes" of the electron flux simultaneously with the bursts of the atmospheric luminescence. In September 2009 the satellite "Universitetskij-Tatiana-2" was launched to the sun synchronous orbit at the altitude of 820 km and inclination of 98.8 degrees. Experimental data obtained by the experiment onboard the new satellite will provide an opportunity to answer the questions which were raised by the previous satellite:

1. what electron flux come to the magnetosphere during the electric discharges in the upper atmosphere, are there "splashes" of the electrons precipitating from the magnetosphere;
2. how are the discharges of different types distributed over the Earth's map;
3. are there correlation between the variation of the electron flux at the orbit and variations of the atmospheric luminescence near the equator;
4. what's the nature of the realtion between UV-bursts and Moon phases.

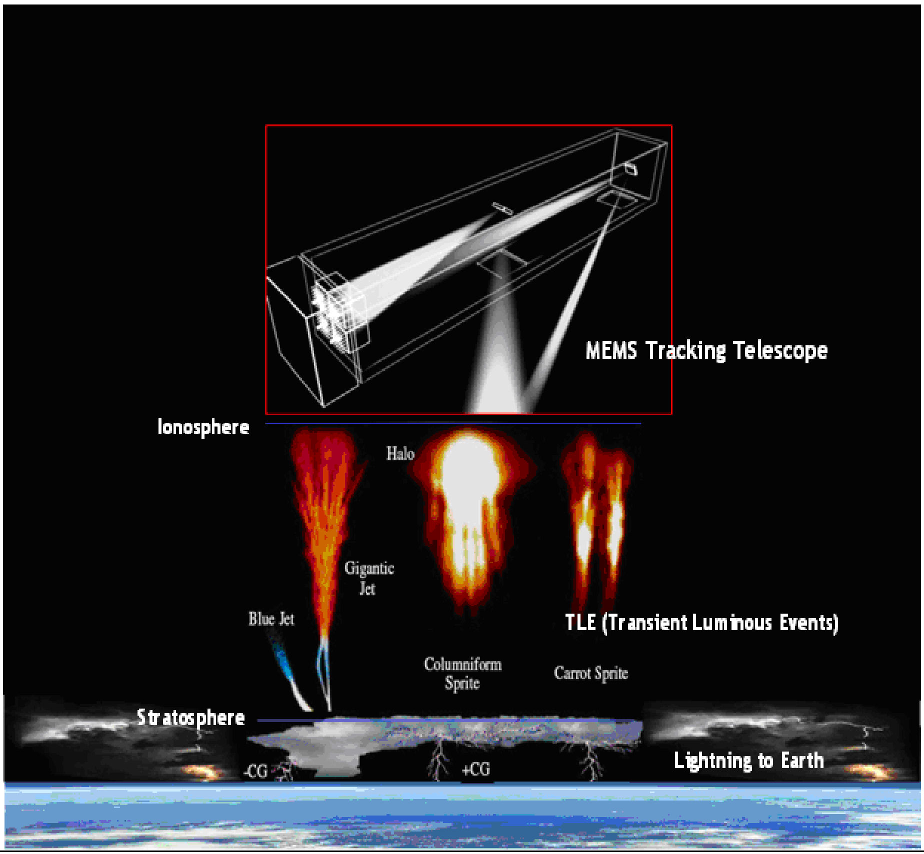


Fig.1 The scheme of the experiment MTEL for the investigations of the UV transients onboard the satellite "Universitetskij-Tataiana-2".

2.3.6.2. . Space dosimetry investigations.

Russian spacecraft “Laplas”: landing on the Jupiter's satellite Europe, search for the vital signs. Within the frames of the training program of the Russian mission “Laplas” towards Jupiter and its satellite Europe the following investigations were carried out:

- general methods for radiation conditions evaluation, information about the flight courses and space ionizing radiation which can influence the crew and the equipment during the mission were studied;
- the experimental data on the measurements of the magnetic field and charged particles flows in the near-Jupiter space are summarized;
- comparable analysis of the models of the Jovian main magnetic field and radiation belts is carried out;
- the radiation conditions at the trajectories of the gravitational maneuvers of the spacecraft in the near-Jupiter space are preliminary calculated;
- the charged particles flows and the radiation doses are calculated in the region of the Europe's orbit, the factors influencing barrier shielding of the charged particles flows by the Europe in its vicinity are estimated, and the preliminary calculations of the spatial distribution of the relativistic electron flows on the Europe's surface are carried out;
- the radiation conditions of the spacecraft's flight along the interplanetary part of the trajectory are preliminary evaluated.

The model of the electron flux distribution on the Europe's surface

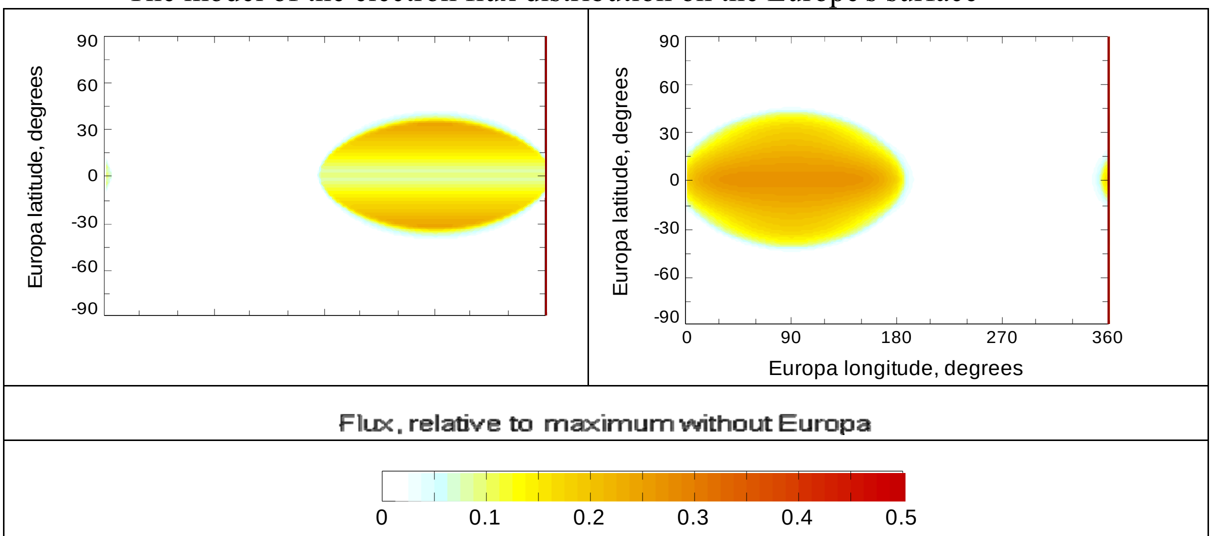


Fig.2. Influence of Europe on the decrease of the electron flux (5 and 50 MeV) of the radiation belt of Jupiter on its surface.

- Calculation methods for the prediction of the radiation conditions on the Moon, taking into account the attack of its surface with the cosmic rays flows (galactic and solar) and production of secondary protons and neutrons in its soil was developed in collaboration with the scientists from INR RAS in order to evaluate the radiation danger during the Moon exploration. The developed methods formed a basis for the calculations of the tissular dose on the lunar surface and in the lunar soil for the years of solar activity minimum and maximum.

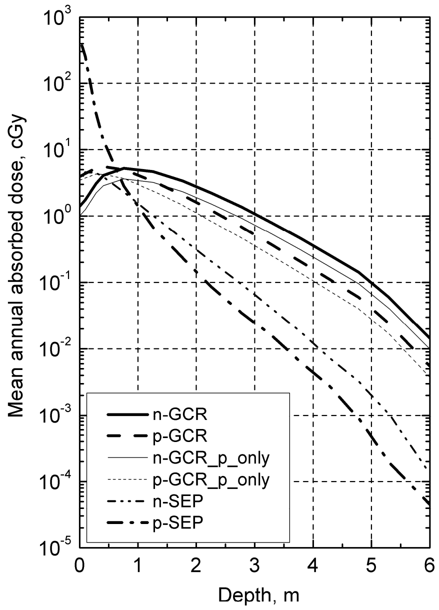
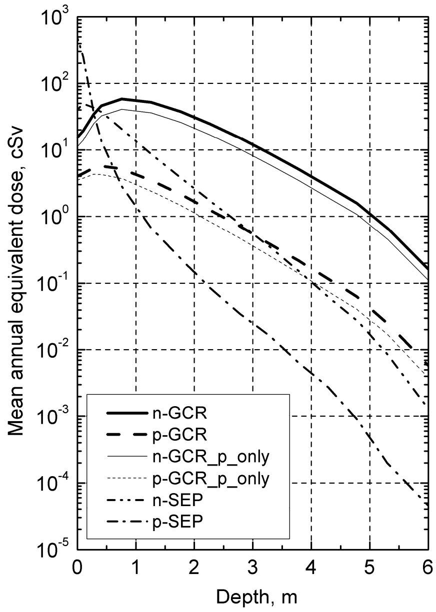
	
a	b

Fig. Contributions of protons (p) and neutrons (n) to the absorbed (a) and equivalent (b) doses on human being's skin as a function of depth inside the lunar soil. GCR protons contribution alone is shown separately.

2.3.6.3. The planned experiments.

The investigations of the solar energetic particles, the Earth's magnetosphere and radiation belts along with high-energy cosmic rays are of the top-priority topics in space-physics direction of the Institute's profile. The satellite experiments which are now under the development are presented below.

RELEC experiment onboard the Russian small satellite

The objective of the RELEC (RELativistic Electrons) project is to investigate the influence of the relativistic electrons on the upper atmosphere, the transient lightning effects in the upper atmosphere, the precipitation of the relativistic electrons and drop-outs of the energetic electrons during radiation diffusion and interaction with the electromagnetic waves in the dynamic magnetosphere.

Additional purposes of the project concern the studies of the interaction of the lithosphere and the ionosphere (earthquakes problem), relations between the atmosphere and the ionosphere (thunderstorms problem), dosimetry and single errors problem taking into account the neutron radiation component.

The main features of the project are the following:

- simultaneous measurements of the relativistic electrons in the near-Earth space and wide-range monitoring of the upper atmosphere (UV, X-ray and gamma);
- measurements of the relativistic electrons within the wide energy ranges (up to 10 MeV) with time resolution of about 100 ms;
- possibility for spectra and pitch-angular distributions measurements;

- measurements of small fluxes of relativistic electrons due to large geometric factor of the detector (2010).

GLONASS, "Electro", "Meteor-M"

The program of the experiments onboard satellites GLONASS and "Electro" at geostationary orbits and "Meteor-M" at the polar one is continued on the basis of the developed in the Institute spectrometers of new generation in order to detect the charged particles within the wide energy range (from dozens keV up to MeV).

«Interhelios» (2014-2015)

The objective of the experiment is to study the neutral component of the solar flare radiation (neutrons, X-ray and gamma-radiation) near the Sun (at the distance up to 25 solar radii).

«NUCLEON» experiment

«Nucleon» experiment is aimed on the studies of the primary space radiation. The main scientific purpose is to measure the elementwise energetic spectra and chemical composition of galactic cosmic rays within the extremely wide energy range 10^{12}-10^{15} eV in order to investigate the main sources of the cosmic rays, determine the acceleration mechanisms of the cosmic rays and to obtain quantitative characteristics for the propagation of high-energy cosmic rays in the Universe.

GAMMASCOPE

«Gammascope» is a space experiment with a wide-angle gamma-telescope of a new generation. For the first time in this device the gamma-range images of large areas of the sky (up to a half of the celestial sphere) are taken in order to study the temporal astrophysical phenomena and to observe the regular long-term astrophysical sources.

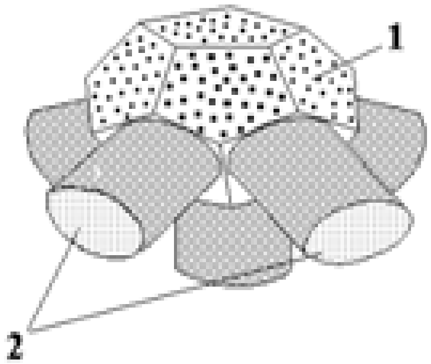


Fig.4. GAMMASCOPE

The program of scientific-educational satellites.

Russian-Indian satellite YouthSat

The objective of the YouthSat project is to implement the space experiment on studies of the solar flare activity onboard microsatellite. Using of microsatellite includes participation of young researchers, i.e. students and postgraduates, at all stages of the development and realization of the experiment. So the project provides both scientific and educational goals.

The main scientific purpose of the project concerns the studies of the solar activity by means of complex monitoring of the processes of energy production at the Sun within the wide electromagnetic ranges along with charged particles production. These measurements will be useful for short-term prediction of the particles' flux emergence in the interplanetary space and near the Earth being dangerous for both manned and automatic space missions. Scientific equipment includes SolRad device, which will measure time profile of solar flares within the hard X-ray range (10-100 keV). Broadband spectrum (0.02-10.0 MeV) will be measured as a part of the device's operation mode. Another part of the device is intended for the measurements of the electron and proton fluxes within the energy range 0.3-3.0 MeV and 3-100 MeV, respectively. (2010)

The small scientific-educational MSU satellite “Mikhailo Lomonosov”

An experiment “TUS” will be conducted onboard the University satellite “Mikhailo Lomonosov”. The project TUS (the track detector) is intended for the investigations of the cosmic rays energy spectrum at the energy above 10^{19} eV by means of optical detector onboard the spacecraft. The special mechanism for the mirror's deployment in space is developed for the experiment. (2011)

2.3.7. National research nuclear university MEPhI

2.3.7.1. The GAMMA-400 Project: investigation of high-energy gamma-rays

Lebedev Physical Institute (Russia), National Research Nuclear University “MEPHI” (Russia), Institute for High Energy Physics (Protvino, Russia), Space Research Institute (Russia), Ioffe Physical Institute (St. Petersburg, Russia), Lavochkin Research and Production Association (Russia); Istituto Nazionale di Fisica Nucleare, Sezione di Trieste (Italy); Istituto Nazionale di Fisica Nucleare, Sezione di Roma 2, and Physics Department of University of Rome “Tor Vergata, Rome (Italy); Istituto Nazionale di Fisica Nucleare, Sezione di Firenze, and Physics Department of University of Florence, Florence (Italy)

The GAMMA-400 gamma-ray telescope is intended to research space gamma radiation in the energy range 0.1-3000 GeV, detect cosmic-ray electrons and positrons with the energy more than 0.1 GeV, search for gamma-ray bursts in the energy range more than 1 GeV, search for solar flares.

The GAMMA-400 scientific problems:

• Search for new and studying of known galactic and extragalactic discrete gamma-ray sources in the energy range 0.1-3000 GeV, which can be, in particular, supernova remnants, pulsars, accretion objects, microquasars, active galactic nuclei, blazars, quasars; measurement of their energy spectra and luminosity.

• Identification of discrete gamma-ray sources with known sources in other energy ranges, as well as with discrete sources detected by the ground-based gamma-ray telescopes for the energy more than 10^{12} eV.

• Monitoring of luminosity and ultrahigh energy spectra of gamma-ray sources to study the nature of their variability.

• Search for gamma-ray bursts in the ultrahigh energy range (more than 1 GeV).

• Measurement of energy spectrum of galactic and extragalactic diffuse gamma radiation. Search for spectral anomalies. Search for “gamma-ray lines" in the energy spectra of discrete gamma-ray sources, in the diffuse gamma radiation arising at annihilation and decay of dark matter components.

• Measurement of electron and positron fluxes with the energy more than 1 GeV and their energy spectra, revealing of features in their energy spectra, which could be connected with the processes of annihilation and decay of dark matter components.

• Detection of high-energy gamma radiation, electrons, and positrons from solar flares.

The GAMMA-400 physical scheme is presented in figure.

The GAMMA-400 gamma-ray telescope is the next generation of gamma-ray telescopes with enlarged energy range, better angular and energy resolutions. The comparison of GAMMA-400 and FERMI-LAT performances is presented in table.

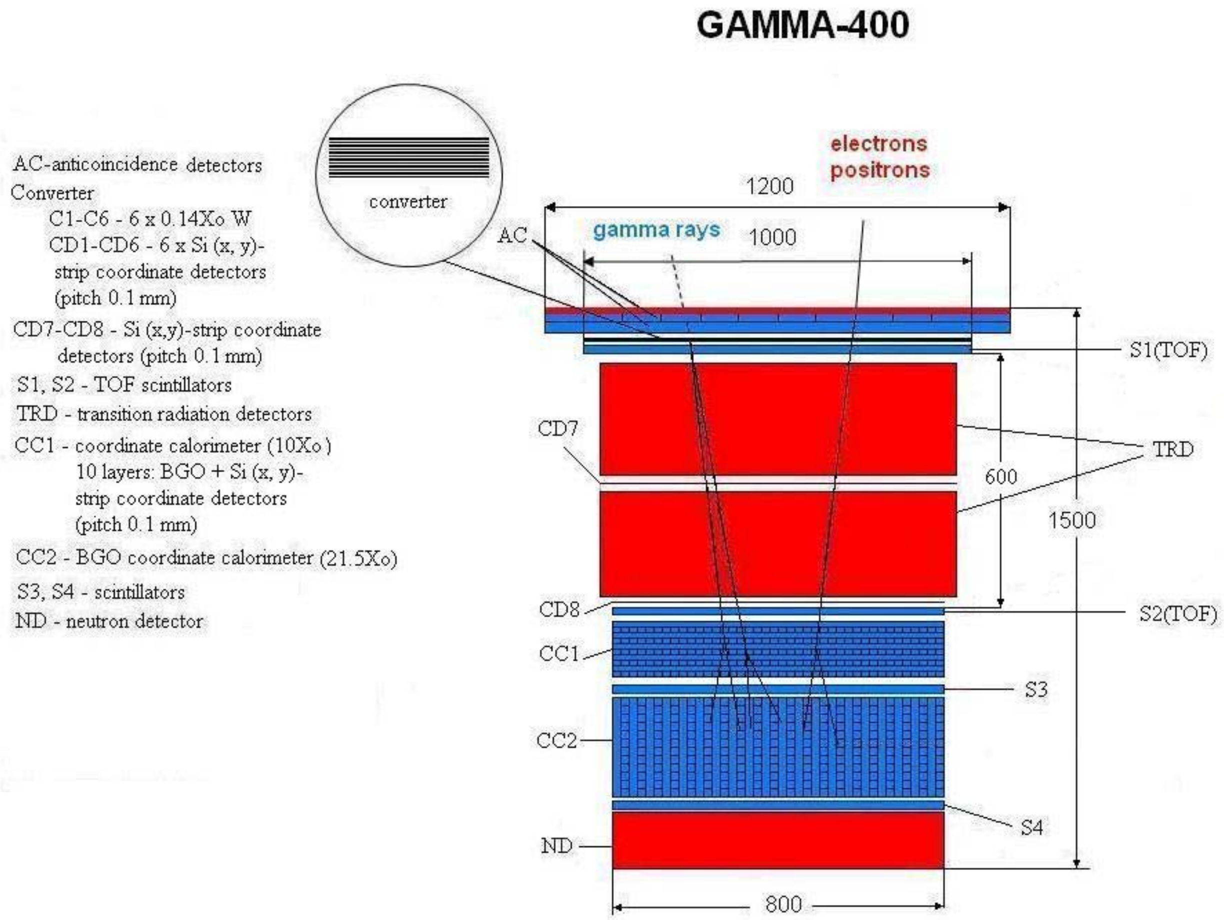


Fig. 1 Physical scheme of telescope GAMMA-400

	GAMMA-400	FERMI-LAT
Orbit	**500-300000 km**	**560 km**
Gamma-ray energy range	**100 MeV - 3000 GeV**	**100 MeV - 100 GeV**
Sensitivity area	**0.64 m^2**	**1.6 m^2**
Coordinate detectors	**Si strips with 0.1-mm pitch**	**Si strips with 0.22-mm pitch**
Angular resolution (Eγ > 100 GeV)	**~0.01°**	**~0.05°**
Calorimeter - thickness, r.l.	**BGO + Si strips** **31.5**	**CsI** **8.5**
Energy resolution (Eγ > 10 GeV)	**~1%**	**~10%**
Proton rejection	**10^6**	**10^4**
Point source sensitivity, $ph/cm^2 s$ (Eγ > 100 MeV)	**$\sim 5 \times 10^{-9}$**	**$\sim 5 \times 10^{-9}$**

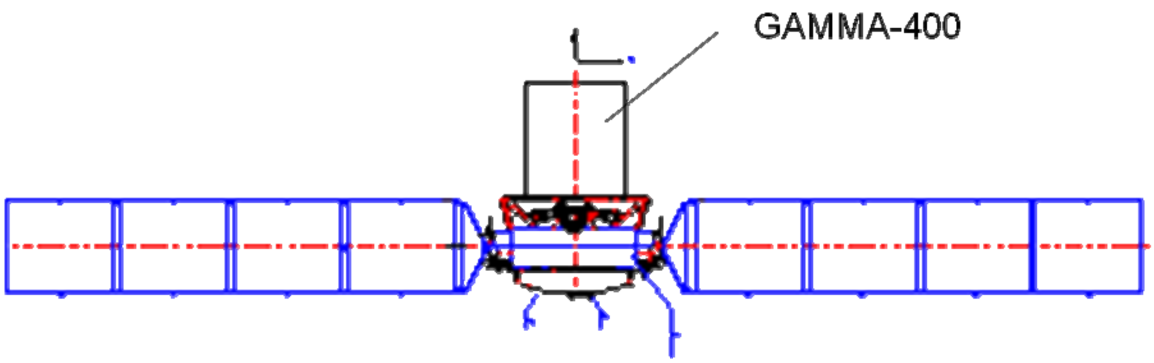


Fig. 2 GAMMA-400 on the board of spacecraft "Navigator"

2.3.7.2. The MONIKA project: analysis of ionic composition of Solar flares

National Research Nuclear University "MEPHI" (Russia)
Lebedev Physical Institute (Russia)
Joint Institute for Nuclear Research (Russia)
Lavochkin Research and Production Association (Russia)

Scientific objectives of MONIKA project are the study of cosmic ray generation mechanisms in active processes on the Sun and in the heliosphere, monitoring of nuclear, isotope and ion composition of cosmic rays in the near-Earth space.
The main tasks of space experiment «MONICA» are:

- Measurement of ionic charge composition of SCR fluxes from He to Ni in 10-300 MeV energy range for individual solar events and its evolution during event; for study of ion composition the Earth magnetic field will be used as separator.
- Measurement of the isotope composition and energy spectra of SCR fluxes in energy range 10 - 300 MeV/n and evolution of these characteristics during development of active processes on the Sun.
- Study of CR penetration into Earth magnetosphere under conditions of its strong disturbances during the solar-magnetosphere events.
- Measurement of ACR ion composition with energies more then 10 MeV/n, including new elements and isotopes, measurement of ACR energy spectra.
- Measurement of GCR and ACR fluxe modulation with the purpose of study of conditions of particle propagation in heliosphere.
- Observation of heavy elements inside radiation belt, measurement of the characteristics of their fluxes as well as albedo nuclei.

For implementation of these goals and tasks the continuous measurements will be carried out for fluxes of hydrogen till nickel in energy range 10 - 300 MeV per nucleon.

MONIKA instrument consists of detector system, front-end electronics, trigger logic system, unit of scientific information picking up.

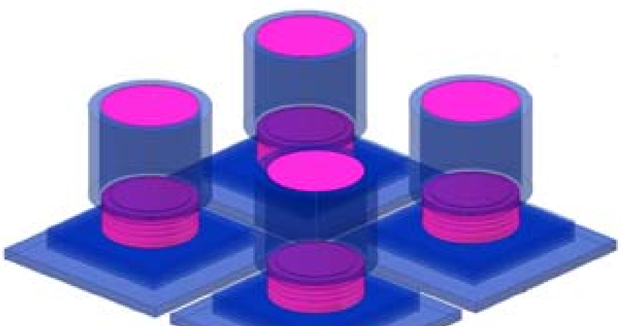


Fig. 1

Detector system (fig.1) consists of spectrometer and proton monitor. Each spectrometer includes four stand alone telescopes which are the semiconductor detector spectrometer-telescope, scintillator calorimeter and anticoincidences. Each spectrometer registers the nuclei with energies 10÷300 MeV per nucleon in instrument field of view, their identification, energy and angle of incidence measurements. The proton monitor consists of calorimeter and anticoincidences. It will detect the proton Solar cosmic ray fluxes inside three narrow energy ranges from 20 till 120 MeV.

The performances of MONIKA instrument
Energy range for nuclei: 10–300 MeV per nucleon.
Angular resolution is 1 degree.
Energy resolution – 1%.
Geomfactor more then 100 cm^{2}sr.
Time knowledge accuracy - 10^{-3}s.
Field of view – 90 degrees (±45 degrees).
Mass – not more 50 kg.
Outline dimensions – 650×650×300 mm.
Energy consumption – not more 80 W.
Mass memory volume - 1 Gbyte, provides the information storage during one day.

The conditions of carrying out of the experiment MONIKA.

The instrument is installed on board of Small Spacecraft developed by “Lavochkin Association”.

Orbit is circular, polar with altitude of 600-700 km. Instrument should be pointed to zenith (+Z axis) with accuracy not worse then 0.5°. The orbit inclination is not less then 80°. The axis “+X” is in orbital plane and pointed to the spacecraft flight velocity. The axes “+X” and “+Y” could change their orientation being known the position in space with accuracy better 0.5° for each moment of time. The knowledge of center of mass position of instrument not worse then 1 km. The time of active life of spacecraft is not less then 3 years.

During the experiment it is expected
to detect $10^4 \div 10^5$ O nuclei and
about 10^3-10^4 Fe nuclei in case of powerful solar event,

10^4-10^5 anomalous O, 10^3 anomalous Ne and of order 10^3-10^4 GCR Fe nuclei per one year under condition of solar activity minimum.

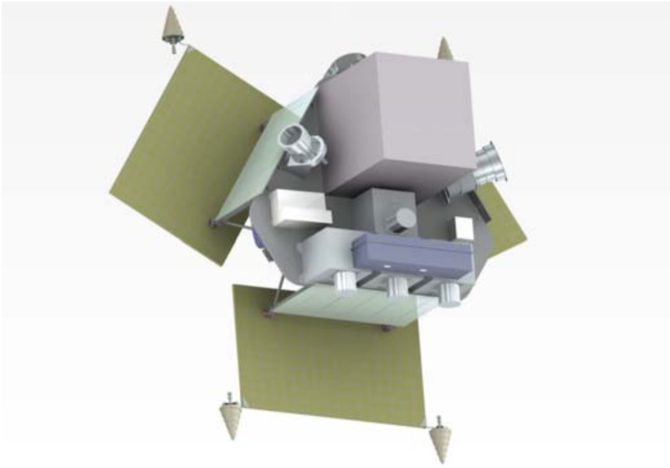
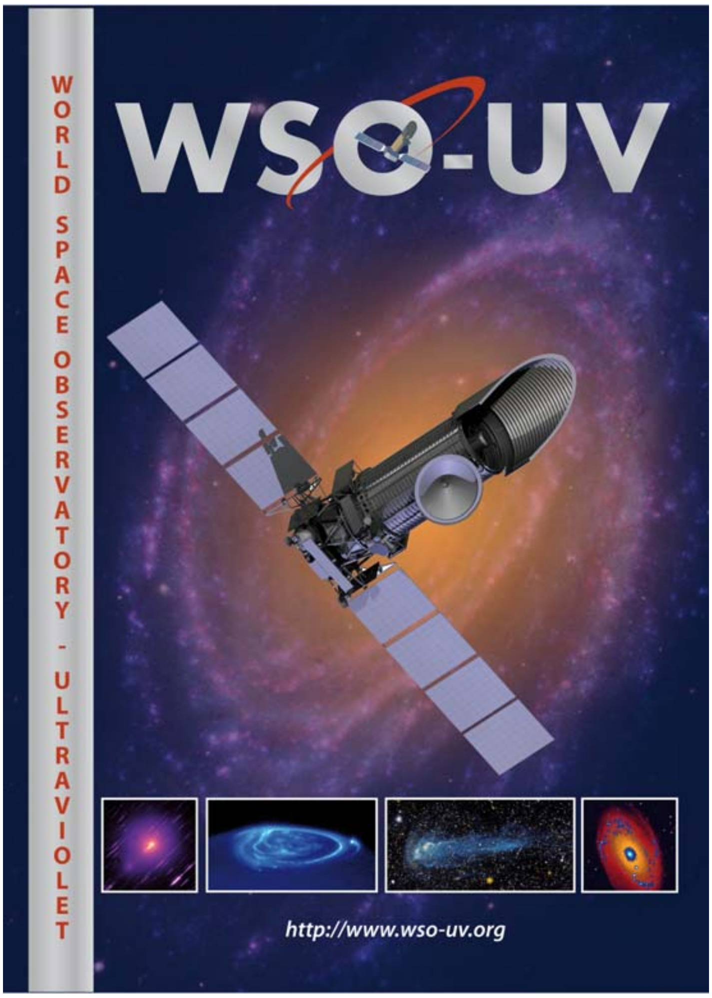


Fig.2.

2.3.8. Institute Of Astronomy RAS

2.3.8.1. World Space Observatory - Ultraviolet (WSO-UV, Spektr-UF)



The World Space Observatory - Ultraviolet (WSO-UV) is a large space project for operation in unreachable in ground-based observatories ultraviolet spectral range (110-300 nm). The main instrument of the observatory is space telescope with 1.7 m diameter of the primary mirror. The telescope will be equipped by high and low resolution spectrographs and imagers for UV and optical domain. Such a set of instruments allows us to solve a wide range of scientific tasks. The WSO-UV will work as a targeted scientific observatory. Three scientific programs will be carried out at the observatory: Core Program of scientific observations, which deserves large amounts of observing time, will be defined by the WSO-UV Science Committee to allow the conduction of high impact or legacy scientific projects; Funding Bodies Program is the guaranteed time granted to each one of the national bodies funding the WSO-UV project; Guest observer program for everyone, or Open Program, consists of astronomical observations obtained with the WSO-UV by astronomers who may or may not belong to the WSO-UV international consortium. It is open to excellent scientific projects from the world-wide community. The main research areas of Core and Russian National programs are: a) physics of early Universe; b) star formation and galactic chemical evolution; c) accretion processes in astrophysics; d) interstellar matter; e) stellar atmosphere physics, mass loss, chromospheric activity; f) physics and chemical composition of planetary atmospheres and comets.

By its capabilities the WSO-UV project is close to Hubble Space Telescope with some characteristics that are even higher.

The observatory will be put into a geosynchronous orbit with inclination $51.^{o}4$. Geosynchronous orbit was chosen based mainly on the following criteria: a) launcher capabilities; b) time of stay in the Earth Radiation Belts; c) continuous visibility zones; d) minimum stay in the Earth shadow; e) stability of the orbit; f) available technical equipment of the Space and Ground Segments for radio communication. The mission is planned to be launched in 2014 by a Zenit-2SB medium-class launcher equipped with a Fregat accelerating module.

The WSO-UV project is currently funded by national space agencies of Russia and Spain with participation of Germany, Ukraine and Kazakhstan.

2.3.9. Ioffe Physical-Technical Institute of the Russian Academy of Sciences

2.3.9.1. KONUS-UF experiment on cosmic gamma-ray bursts and soft gamma-repeaters study onboard 'Specter-UF' spacecraft

Principal Investigator – corresponding member of RAS E.P. Mazets

KONUS-UF experiment on cosmic gamma-ray bursts and soft gamma-repeaters study is planned to be carried out onboard 'Specter-UF' spacecraft starting in 2014yr. Its main purpose is the research of cosmic gamma-ray burst and their rare class – sources of repeating soft gamma-ray bursts which were discovered in earlier experiments by Ioffe Institute and were named gamma-repeaters (SGRs). All these phenomena are originated from extremely high explosive energy release of electromagnetic emission the nature of which is one of the most important unsolved problems in astrophysics. Reliable and adequate for the purpose scientific instrument KONUS was designed by Ioffe Institute and has been uninterruptedly operating for 15 years onboard American spacecraft 'Wind'. Joint Russian-American experiment KONUS-WIND yields light curves, energy spectra and data on fast spectral variability of gamma-ray bursts. These data are widely called for in complex multiwave investigations of the phenomena by international network of space and ground-based telescopes. For such observations the strongly elongated Wind's orbit with apogee at 0,5 – 1,5 mln. km is exceptionally favorable, the orbit provides a survey of the entire celestial sphere without substantial losses of information while crossing radiation belts near perigee. Distant from Earth orbit of 'Specter-UF' spacecraft is optimal for such kind of studies too. Russian-American experiment KONUS-WIND by importance, quality and completeness of the information obtained has come to the forefront of studies of the most powerful explosive events in the universe. The aim of the new experiment is to continue these studies after the flight program of KONUS-WIND experiment has been completed.

To realize the experiment, based on the capabilities of 'Specter-UF' spacecraft, there was proposed a system consisting of one electronic unit 'KONUS-UF-BE' and two detector units 'KONUS-UF-D' with 2π steradian field of view relatively to the detectors' axis of symmetry. Placement the detector blocks on the coupling girder between the base module NAVIGATOR and scientific equipment complex of 'Specter-UF' spacecraft T170 telescope provides indispensable for the experiment opportunity to survey a celestial hemisphere by each of two detector units.

The scientific instrument for the experiment is a scintillation gamma-spectrometer consisting of two identical detectors and electronic unit to register and to preprocess signals from the detectors. Each detector contains high-tech spectrometric crystal NaI(Tl) 130 mm diameter and 75mm hight inserted in thin-walled aluminum container with the beryllium entrance window and PMT-side window of high transparent lead glass to protect the crystal from background radiation in soft specter band coming from the spacecraft. Such design of the detector gives a low energy registration threshold 10 keV, gamma-radiation registration range is up to 10MeV with energy resolution 8,5 – 9,0 % at 660 keV Cs137 line and burst detecting sensitivity 10{-7} erg sm{-2}. The detectors of KONUS-UF instrument have no analogues in world practice of cosmic gamma-ray burst registration.

Organization of measurement of gamma-ray burst characteristics in KONUS-UF experiment is the development of approaches and methods applied in KONUS-WIND experiment. It is distinguished by being much more informative through the usage of modern element base on digital signal processors, precision analogue-digital converter with low “dead” time and high capacity RAM chips. In background mode each detector performs measurements of cosmic gamma-ray emission intensity in twelve energy bands from 10keV to 1MeV with accumulation time 1s and in ten energy bands from 280keV to 10MeV with accumulation time 4s. Simultaneously in the background mode the detailed measurements of emission spectra are carried out in two energy bands 10keV-1MeV and 280keV-10MeV, those bands are divided in 112 and 154 quasi-logarithmic channels respectively. Spectra accumulation time in background mode is 1 minute. In a burst mode the intensity of emission is measured in the same energy bands with time resolution from 100 ms to 2 s. In the instrument there is a special ‘integral’ channel provided for the research of particularly rare extremely intensive giant bursts from gamma-repeaters. The instrument offers extensive opportunities to adjust the gain of linear paths by the set of digital commands. KONUS-UF instrument has the weight 25kg, the power consumption 10-12W, the daily volume of telemetry information 50Mb.

The KONUS-UF experiment is the necessary step towards further highly efficient development of national research program in this actual field of space astronomy.