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

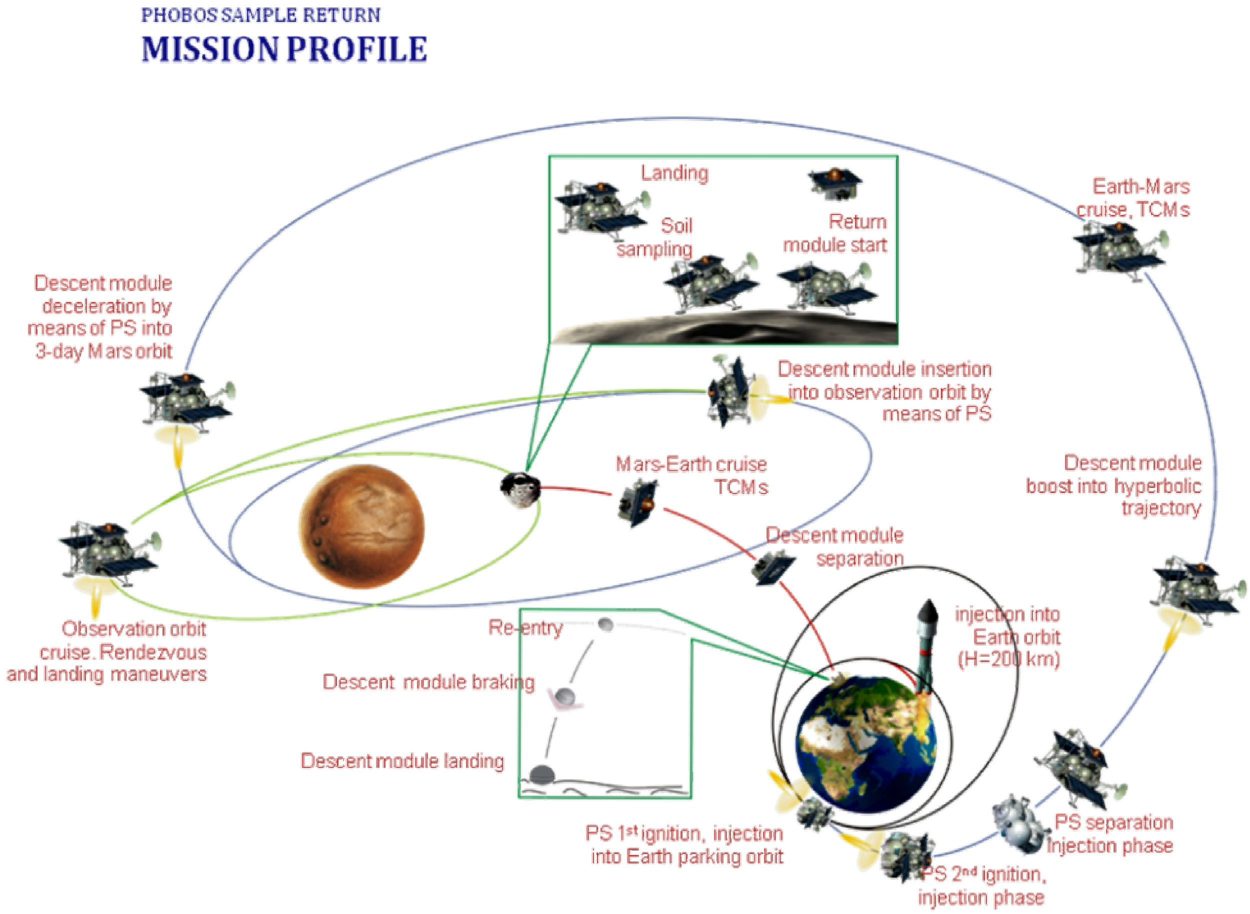
The Phobos Sample Return mission (PhSRM or Phobos-Soil) is under development now by the Russian Academy of Sciences and the Russian Space Agency.

The main goal of the mission is the delivery of the Phobos surface material to the Earth for laboratory studies of its chemical, isotopic, mineral composition, age, etc. Other goals are "in situ" studies of Phobos (regolith, internal structure, peculiarities in orbital and proper rotation), investigations of the Martian environment (dust, plasma, fields). The mission will provide an opportunity to solve or to reach better understanding of the following problems of the Phobos - Mars system science:

- physical and chemical characteristics of Phobos regolith (this can provide data on properties and evolution of the relict matter in the Solar system);
- a role of collisions of small bodies at the early stages of the Solar system evolution in formation of terrestrial group planets and evolution of their atmospheres and surfaces;
- understanding of the origin of the Martian satellites and their relation to Mars (the progress in this problem can become a key to understanding of an origin of satellite systems at other planets);
- precise measurements of the orbital and proper rotation parameters of Phobos (important for the Phobos internal structure and evolution of its orbit);
- characteristics of the physical processes of the Martian environment – interaction of the solar wind with the ionosphere and remnants of the relict magnetic fields of Mars;
- electric and magnetic fields;
- investigation of a hypothetical dust tori near the Phobos orbit;
- temporal variations of the Martian atmosphere.

The spacecraft (SC) includes four main elements: a transfer-orbital module (TOM), a main propulsion system (MPS), a return module (RM) and a return capsule (RC). Picture of these elements and the assembled spacecraft are presented in the figure.

The mission scenario includes several stages. The spacecraft will be launched from Baikonur and will be inserted into a 200 km circular based orbit with the inclination 51.8 degrees. Additional impulse made by the braking engine will transfer the spacecraft into an interplanetary Earth-Mars trajectory. The spacecraft will be directed to the fly-by hyperbolic trajectory with the minimum distance to Mars about 700–1000 km. This stage of the mission will take about 11 months. The spacecraft will be inserted into the first elliptical trajectory with a nominal altitudes of the pericenter ~800 km, and the apocenter ~79 000 km, having 3 days orbital period. After 3–4 revolutions (10–12 days) an active maneuver made at the orbit apocenter will transfer the spacecraft into an intermediate elliptical orbit with the pericenter ~9910 km (about 500 km higher than the Phobos orbit). Then the braking impulse made at the pericenter will transfer the spacecraft into a circular orbit $R \approx 9910$ km (about 535 km higher than Phobos orbit, $T \approx 8.3$h.). The spacecraft will operate at this “orbit of observation” during several months, and then after a small correction it will be transferred into a quasi synchronous orbit (QSO), very close to the Phobos (distance between the Phobos surface and the spacecraft will be 50–150 km) and having the same orbital period. The quasi synchronous orbit will be used for the detailed measurements of the Phobos orbital parameters, and search for a landing site. Taking into account various conditions of the luminosity of the spacecraft at the Phobos surface and communication with the Earth, the landing site of the spacecraft has been chosen at the side of Phobos opposite to Mars (5°N – 5°S, 230–250°W). The approach with the Phobos surface and landing will be implemented by the autonomous active maneuver using data of the TV-system, the laser altimeter — roll stabilizer, and the Doppler instrument. After the landing the sampling device will take a regolith samples and put them into the capsule of the return module. This will be one of the critical stages of the mission. The sampling device will use a robotic arm to collect regolith from the surface. The transfer-orbital module will stay at the Phobos surface after the launch of the return module and will implement a scientific program of the mission using the package of the scientific instruments during one terrestrial year.



The return module will be launched from the transfer-orbital module, which will stay at the Phobos surface and after several modifications (three impulse scheme) of its orbit around Mars, will be directed to the Earth along the interplanetary trajectory. After about 11 months of the interplanetary flight the return module will reach the Earth vicinity, RC will be separated from RM and re-enter into the Earth atmosphere. The landing of RC will be in the Kazakhstan republic (hard landing).

There are several approaches to study the Martian satellites in the Phobos Sample Return mission. First of all it is sample return. Remote sensing can provide global coverage data important for understanding of both the surface and internal structure of Phobos: global geologic mapping; size, shape, mass, bulk density; colour, albedo, photometric scattering and thermal properties; mapping of global elemental and mineral composition, magnetic properties, internal structure, landing site selection and certification. Operation of the spacecraft at the elliptical orbits and at the circular Phobos-like orbits will provide an opportunity to study the Phobos dust tori (like a planetary ring), the Martian plasma environment, interaction of Phobos with the solar wind, and to investigate the peculiarities of its orbital motion, free and forced librations. *In situ* measurements at the Phobos surface will provide the opportunity to establish the verification of the remote sensing measurements and to accomplish the detailed study of regolith near the landing site, specifically: elemental and mineral composition, volatile components, physical and mechanical properties of the regolith, state of magnetization.

The payload of PhSRM includes scientific instruments, which will provide various data for studies of Phobos as a celestial body, *in situ* measurements of chemical and mineralogical composition of the Phobos regolith, its thermal and mechanical characteristics, and the Phobos internal structure. Other instruments included in the payload have goals to investigate characteristics of the Martian environment: plasma, fields, waves, dust. The payload consists also two instruments for celestial mechanics experiments.

One of the most complicated instruments of the payload is the Gas-Chromatograph Complex. This complex consists of three instruments: Thermal Differential Analyzer (TDA), Gas Chromatograph (ChG), and Mass-Spectrometer (MSP). The Complex measures the quantity of individual gas components in a complex gas mixture, which is evolved from the soil sample by pyrolysis, due to their separation by the time of retention in chromatographic columns. The instrument identifies chemical composition of gas components by their calibrated time of retention and by spectroscopy of specific absorption lines for H_2O, CO_2, and CH_4 gases. Neutron and Gamma-ray Spectrometers, included in the payload (HEND-2 and FOGS) will search hydrated materials or/and water ice in the subsurface of Phobos and the chemical elements concentration at the Phobos surface: the rock-formed elements (from H to Fe) and the natural radioactive (K, Th, U) ones. Laser Time-of-flight Mass Spectrometer (LASMA) is an active experiment. Laser irradiation focused on the surface of the regolith evaporates and ionizes a sample. The emerged ion cloud comes in the field of the electrostatic reflector and is directed to the detector where different ions are registered as mass peaks. This instrument designed for quantitative analysis of elemental and isotopic composition of the Phobos' regolith. The Long-wave Planetary Radar (LPR) mounted at the spacecraft will probe the Phobos surface and subsurface to detect rock layers on the depths of 1–100 m. This instrument will allow to investigate the Phobos inner structure (together with data recieved by the Seismometer, SEISMO) and electrical characteristics of the regolith.

The plasma-wave Martian environment will be studied by Plasma-Magnetic System (PhPMS). This system includes several detectors: ion and electron spectrometers, and magnetometers. The main goals of these investigations include the solar wind interaction with Phobos and Mars, peculiarity and effects of this process: erosion rate of the Martian atmosphere; investigation of kinetic processes in the Martian bow shock; the role of planetary ions, captured by solar wind, in bow shock formation; analysis of physical processes in the vicinity of magnetopause / upper boundary of interplanetary magnetic field pile up region; investigation of plasma boundaries dynamics at Mars; 3D distribution functions for different plasma components in the Martian magnetosphere tail; identification of physical processes of ion acceleration; chemical composition of secondary ions sputtered from Phobos soil by the solar wind. The plasma-waves instruments will measure spectral characteristics of the solar wind and the Martian surrounding plasma during revolution of the spacecraft at different orbits. We hope these data will provide valuable information in addition to plasma-field data returned by the

PHOBOS-2 mission and the Mars Global Surveyor [Mars' Magnetism and Interaction with the Solar Wind, 2004].

Scientific teams from several European countries participate in the development of PhSRM

2.3.1.2. Project "RESONANCE"

Scientific Problem

The space project RESONANCE is directed to study wave-particle interactions and plasma dynamics in the inner magnetosphere and the auroral region. The main goals of the RESONANCE project are the following:

1. Long-term observations of the natural phenomena in the near equatorial region:
   - Dynamics of magnetospheric cyclotron maser.
   - Ring current formation.
   - Refilling of plasmosphere after magnetic storms.
2. Investigation of auroral region:
   - Generation and propagation of AKR, structure and characteristics of its source.
   - Acceleration region — role of small-scale phenomena in the global plasma dynamics.
3. An artificial influence on the operation of magnetospheric maser. Basic options following are:
   - Artificial excitation and/or stimulation of wave modes.
   - Modification of the flux of precipitating particles.
   - Variation of maser Q-factor by modifications of the reflection index at the ionospheric footprint of the selected magnetic flux tube.

Orbits and Mission Scenario

Two pairs of satellites will be launched in the magneto-synchronous orbit. This orbit will let satellites to locate up to forty minutes in the selected flux tube, with footprint in the ionosphere over the heater: while one pair will be in the northern hemisphere, another one will be in the southern.

Parameters of selected orbits are following: orbital period 8 h; altitude in apogee 28 000 km; altitude in perigee 500 km; inclination ±63,4°. The distance between satellites of one pair can be varied from 1 km to few thousands km by using onboard engine. On the first phase of project, the distance will be short for study space distribution of small-scale parameters of the source region. On the second phase the distance well be enlarged so as one satellite of the pair will be in acceleration region and second — out of it, to study phenomena of particles acceleration.

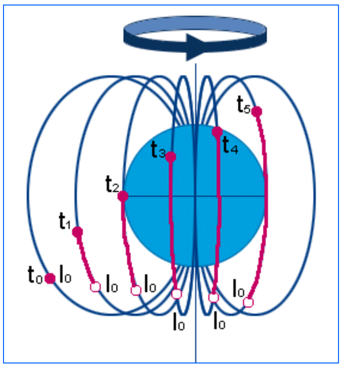


Figure 1: The magneto-synchronous orbit formation. Satellites co-rotate with magnetic flux tube and moves along it. Positions of flux tube and satellites on it are presented in different moments.

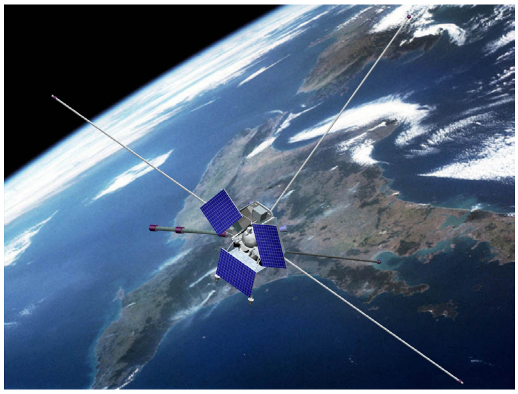


Figure 2: Artist's view of "Resonance" satellite with deployed booms and solar panels.

Scientific experiments and satellite

Scientific experiments for measurements of DC and AC electromagnetic field, thermal and suprathermal plasma parameters and energetic particles will be installed on "Karat" satellites, designed in Lavochkin association. Total mass of payload will be about 60 kg and mass of satellite with nitrogen for engine - about 230 kg.

SPECTRUM-RG

Spectrum-RG is Russian project of X-ray astrophysical observatory designed in close cooperation with western collaborators. Germany is responsible for development of main telescope of the mission — X-ray grazing incident mirror telescope eROSITA. The second major experiment is X-ray Calorimeter (SXC) developed by wide international cooperation, including Netherlands (SRON), Japan (ISAS/JAXA and Tokyo Metropolitan University), USA (GSFC/NASA and University of Wisconsin) and Germany (MPE/MPG). The third major experiment ART-XC— X-ray mirror telescope, with harder energy band in comparison with eROSITA telescope, is developed by Russia (IKI, Moscow and VNIIEF, Sarov) in cooperation with MSFC/NASA, SAO, USRA (USA) and MPE/MPG (Germany). The wide-field X-ray monitor Lobster developed by Leister University (UK) was considered earlier as part of SRG scientific payload too. However due to problems with financing, the development of the experiment was stopped and one may not expect the full recovery of the experiment in framework of SRG project.

Scientific payload will be established on Navigator bus, developed by Lavochkin Association (Russia). This platform will be used soon for other projects developed by Roskosmos

The inclusion of Calorimeter experiment on SRG payload (happened in 2007 y.) has increased the total mass budget on about 500 kg and power on 600 Wt. This considerable increase of important mission parameters has required to reconsider the preferable orbit. The launch into Lagrange point L2 looks as more advantageous in comparison with early considered low Earth orbit. To realize this scenario the transition on more powerful launcher than preliminary planned Soyuz-2 rocket is essential. It will allow of solving the mass budget deficit problem.

The mission will conduct the first all-sky survey with imaging telescopes eROSITA and ART-XC in the 0.1-15 keV band. It will allow discovery of all obscured accreting Black Holes in nearby galaxies and many (~millions) new distant AGN and detection of all massive galaxy clusters in the Universe. In addition to the all-sky survey, it is planned to observe dedicated sky regions with high sensitivity and thereafter to perform follow-up pointed observations of selected sources, in order to investigate the nature of dark matter and dark energy. The X-ray Calorimeter will permit observations of the brightest clusters of galaxies with record energy resolution in pointing mode and coarse mapping of the hot intergalactic medium in the survey mode and (potentially) warm-hot intergalactic medium over the soft energy band.

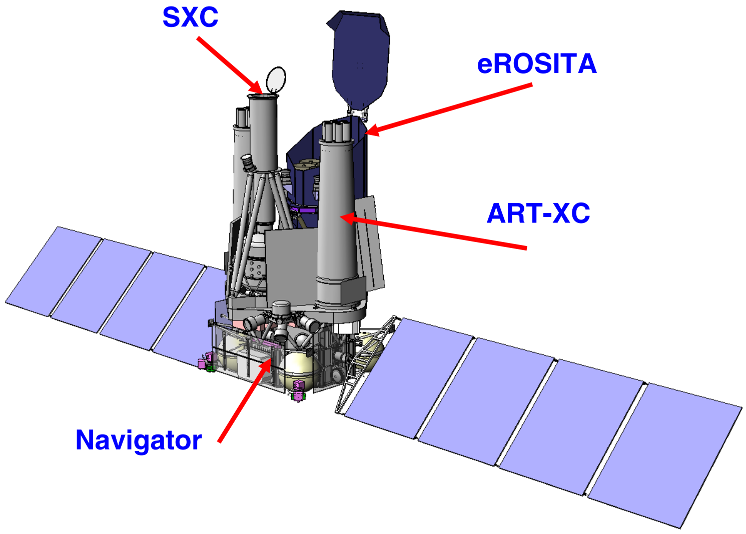


Figure 1: SRG: Scientific payload on Navigator platform.

The SRG will be launched in 2011. The observational program will last for 6-7 years. The first half a year will be devoted to observing of several dozens of richest galaxy clusters. The next 4 years will be devoted to all-sky survey. The rest of the mission lifetime is planned to spend on observations of selected objects as most interesting galaxy clusters and AGNs. These observations will be done at pointing observational mode.

2.3.1.3. LEND neutrons telescope for NASA "Lunar Reconnaissance Orbiter" mission

The main aim of LEND (Lunar Exploration Neutrons Detector), a Russian experiment onboard NASA's "Lunar Reconnaissance Orbiter" mission is to map hydrogen composition and search for water resources on the Moon, as well as producing measurements of radiation background needed to prepare manned missions to the Moon. LEND neutrons telescope will measure neutrons flux from Moon's surface with high spatial resolution of 5-20 km using neutrons collimation technique that allows assuring narrow field of view (pic. 5). Following scientific tasks will be resolved with the help of LEND instrument during the mission:

– Measurements of radiation conditions on orbit around the Moon, including the flux of neutrons with energies higher than 10 MeV.
– Creating the map of hydrogen composition over the surface of the Moon with sensitivity of 0,01% in mass and horizontal resolution of 5-20 km.
– Search for water ice deposits in cold traps inside polar craters and their mass estimation.

LEND instrument is developed at the Space Research Institute by the order of Federal Space Agency (LEND PI is prof. Igor Mitrofanov). LEND launch onboard NASA spacecraft "Lunar Reconnaissance Orbiter" is scheduled for October 2008.

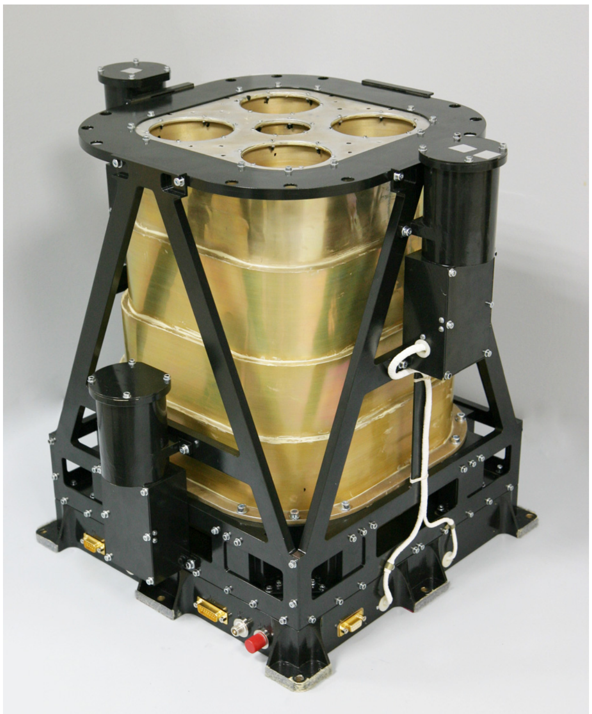


Figure 5: Russian neutrons telescope for NASA mission "Lunar Reconnaissance Orbiter".

2.3.1.4. Active neutrons detector DAN for NASA "Mars Scientific Laboratory" rover

The main goal of DAN (Dynamic Albedo of Neutrons), a Russian experiment onboard NASA "Mars Scientific Laboratory" is to measure water or water ice in Mars' soil to the depths of 0,5–1 m and with surface resolution of 1 meter along rover's path. This experiment's main method is to induce high energy neutron pulses into the surface of Mars with immediate measurements of spectral and time characteristics of secondary neutrons emission from the surface of Mars (neutron-neutron activation analysis method). To meet the measurements requirements, DAN instrument should provide solutions for the following scientific tasks:

- Carry out neutron-neutron activation analysis of Mars soil along the path of the rover to estimate water deposits.
- Carry out passive measurements of natural neutrons emission from the surface of Mars along the whole path of rover.

DAN instrument is being developed at the Space Research Institute by the order of Federal Space Agency (DAN PI is prof. Igor Mitrofanov). DAN launch onboard NASA "Mars Science Laboratory" rover is scheduled for 2009.

2.3.1.5. Experiments for the ESA Interplanetary Spacecraft "BepiColombo"

Neutrons and gamma spectrometer MGNS

MGNS (Mercury Gamma and Neutron Spectrometer), a Russian experiment, aims to define elemental composition of upper Mercury soil layers and experimentally check the hypothesis of water ice deposits in the polar regions. To accomplish these tasks, the instrument should provide the following:

- Conduct global mapping of Mercury neutrons flux in broad energy range from thermal neutrons to neutrons with energy up to 15 MeV to define hydrogen composition on the surface of the planet and verify the hypothesis of polar ice deposits.
- Conduct global mapping of Mercury surface in the range of most intensive gamma lines of nucleus of chemical elements with energetic resolution no higher than 3 % to define the composition of main rock-forming and natural radioactive elements.

MGNS instrument is developed in Space Research Institute by order from Federal Space Agency (MGNS PI is prof. Igor Mitrofanov). MGNS launch aboard interplanetary ESA spacecraft "BepiColombo" is scheduled for 2012–2014.

PHEBUS, MSASI and PICAM experiments

Although Mercury possesses no permanent atmosphere, it retains a rarified media called exosphere, neutral atoms of which do not collide. The exosphere atoms are originated from the surface, hit by highly-energetic photons and ions of the solar wind or by meteoroid impacts. Therefore the exosphere studies allow to address the chemical composition of the surface. Five elements of Hermean exosphere, oxygen, hydrogen, neon, sodium and potassium were discovered by Mariner 10 and ground-based observations. Also, Mercury captures helium of the solar wind.

PHEBUS, MSASI and PICAM instruments are dedicated to the studies of the exosphere.

The UV spectrometer PHEBUS is being developed jointly by France' Japan and Russia for the MPO Bepi Colombo satellite. It is dedicated to remote sensing of Mercury exosphere in the UV and EUV spectral range (55–422 nm). PHEBUS will address the following main scientific objectives relative to Mercury's exosphere: composition and vertical structure, dynamics: day to night circulation, active to inactive regions, surface release processes, sources: e.g. regolith, meteorites, etc., search for ionosphere and its relation with neutral atmosphere, exosphere/magnetosphere exchange and transport processes, escape, source/sink balance, geochemical cycles. Also, it will search for ions, noble gases, surface mineralogical and ice signatures, and study of interplanetary hydrogen and helium in the vicinity of the Sun. The Russian contribution to the instrument is the entry optics including the scanning system allowing to rotate the optical axis of the instrument over 360°.

The MSASI instrument (Japan and Russia) on MMO satellite is dedicated to mapping of sodium exosphere in the D2 sodium line 589 nm with a vertical resolution of better than 40 km, including sunlit disk of the planet. This will allow study the dynamics of the exosphere and to discriminate among different outgassing mechanisms: internal release process such as diffusion, evaporation of volatiles, volcanic activities, and the external release process such as photon-stimulated desorption, ion sputtering, meteoritic vaporization etc. The Russian contribution to the experiment is the scanning system allowing imaging.

Austrian instrument PICAM with Russian participation on the MPO satellite is dedicated to in-situ investigation of charged particles in the Mercury exosphere. The instrument is a part of SERENA suite. PICAM is based on a novel concept of an all-sky camera with 2π instantaneous field of view in which 3-D velocity distribution and mass composition of charged particles will be studied. The Russian contribution to the experiment is the ensemble of the instrument's optics.

Experiment "RUSALKA" for measurements of greenhouse gases from the Russian Segment of ISS

The understanding of natural and anthropogenic processes affecting the distribution of atmospheric carbon dioxide precise and localized measurements of CO_2 concentration are required. The largest quantities of this gas, its sources and sinks are located near the surface. For remote sensing it is therefore necessary to enable precise measurements of CO_2 atmospheric column contents. Orbital measurements of CO_2 atmospheric concentration would allow a new level of understanding of the global carbon cycle on the planet, but the data available to date do not allow the desired precision. Spectroscopic measurements in the near-IR spectral range allow precise measurement of CO_2 and CH_4 in the atmosphere provided the spectral resolution is high enough to measure isolated non-saturated spectral lines of these gases, and the air mass is well known.

RUSALKA experiment is proposed for exploratory measurements using this method on ISS by cosmonauts. The experiment includes measurements of carbon dioxide and methane concentration in the atmosphere using the solar light scattered or reflected (solar glint) by the surface by using a near-IR high-resolution spectrometer. The high-resolution echelle-spectrometer employs an acousto-optical filter for diffraction orders sorting. The resolving power of the instrument is superior to 20000, and it operates in the spectral range of 1.58, 1.6, 1.65 µm in the absorption bands of CO_2 and CH_4. To estimate the air mass, molecular oxygen O_2, is measured in the bands 0.76 and1.27 µm. To account for atmospheric aerosols (clouds, hazes, fogs, industrial smoke plumes) a standard photographic camera is employed. The instrument can be operated manually by cosmonauts and in an automated mode. The anticipated accuracy to measure CO_2 is better than 0.3%. RUSALKA instrument has been tested and is being prepared for realization during 18th ISS expedition (2008-2009). Light-weight RUSALKA-type instruments can be further widely used for monitoring of green-house gases on various automated platforms, including microsatellites, once the method of near-IR spectroscopic measurements is validated on ISS.

2.3.2. V.N. PUSHKOV INSTITUTE OF TERRESTRIAL MAGNETISM, IONOSPHERE AND RADIOWAVES PROPAGATION OF THE RAS

2.3.2.1. CORONAS-PHOTON: Solar and Solar-Terrestrial Physics

Helioseismic monitoring of the Sun in the SOKOL/CORONAS-PHOTON experiment

The CORONAS-PHOTON mission (to be launched in 2008) will continue helioseismic studies with the multichannel photometer SOKOL (Solar Oscillations). The instrument was designed at IZMIRAN (Fig.1). It will be used to conduct continuous, high-stability measurements of the solar emission intensity aimed at the study of global oscillations of the Sun. The proposed instrument is a modified and updated version of the DIFOS photometer, which carried out similar observations on board the CORONAS-I (1994–2001) and CORONAS-F (2001–2005) missions. By its observation method and technical characteristics, this instrument closely resembles the SOHO/SPM solar photometer. Observations with the SOKOL photometer will cover a broad emission spectrum from the near UV to infrared wavelengths (280–1500 nm) (see Table 1). The photometer will observe the Sun as a star, which will enable registration of solar oscillations of low order ($l < 3$). Tables 2 and 3 provide, respectively, comparative characteristics of the helioseismic devices SOKOL/CORONAS-PHOTON, DIFOS/CORONAS-F, and SOHO, as well as the mutual position of their spectral bands.

The main technical characteristics of the multichannel photometer SOKOL are as follows:

- The photometer was designed for measuring the intensity fluctuations of the solar optical radiation in order to obtain the spectrum of global oscillations of the Sun.
- The intensity measurements will be taken simultaneously in 7 optical spectral channels: 280, 350, 500, 650, 850, 1100, and 1500 nm with the bandwidth equal to 10% of the central frequency (Table 1).
- The relative resolution in intensity is 10^{-6} of the total solar irradiance in the 30 s time interval.
- The time interval between the intensity counts is 1 s.
- The spatial resolution is absent.
- The field of view of the photometer is 2°.
- The resolution of the position detector of the photometer is 5 arcsec.

Table 1. Spectral bands of the photometer SOKOL and their widths.

Band number	Central wavelength of the spectral band, nm	Width of the spectral band, nm
1	280	30
2	350	35
3	500	50
4	650	65
5	850	85
6	1100	110
7	1500	150

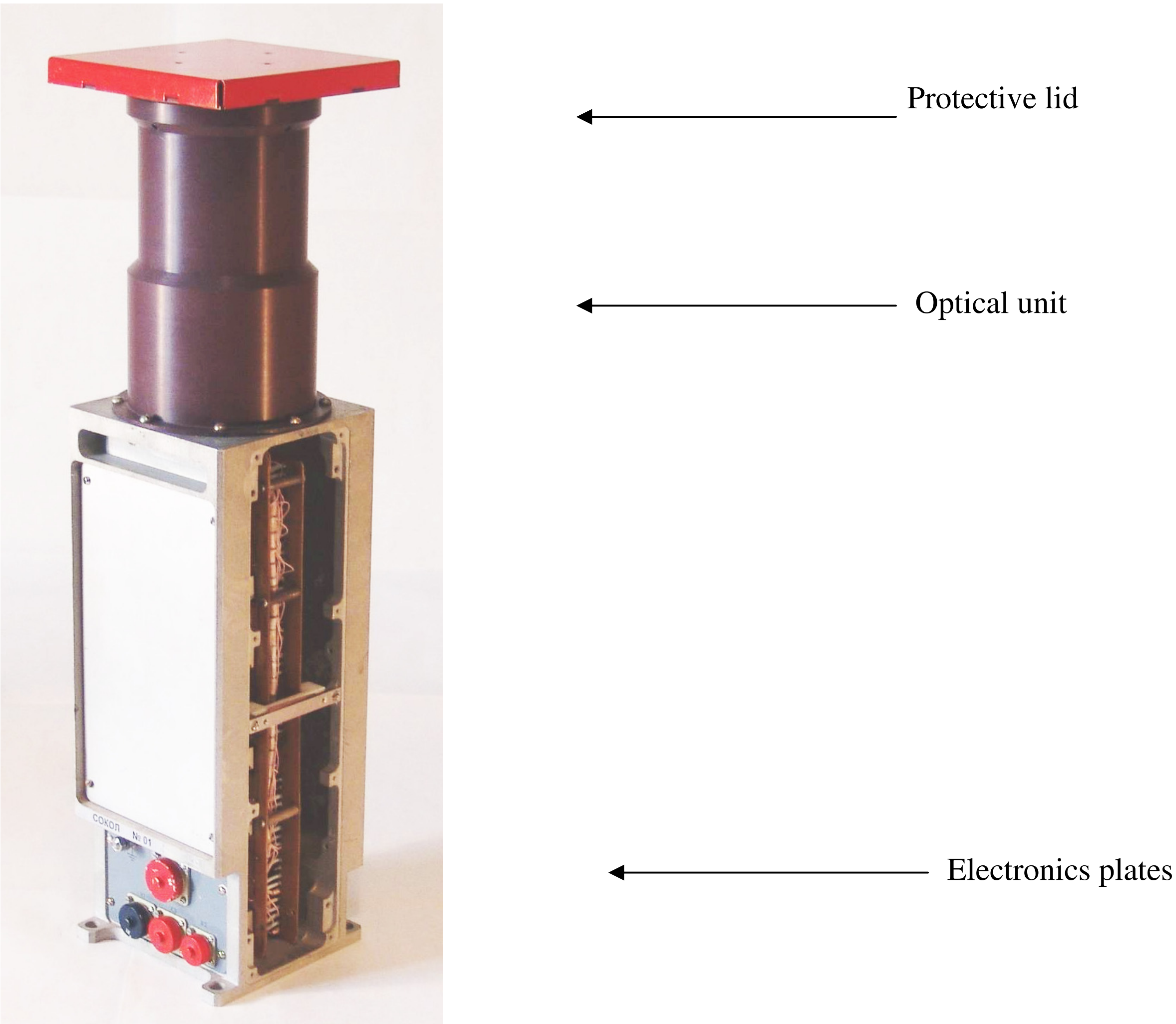
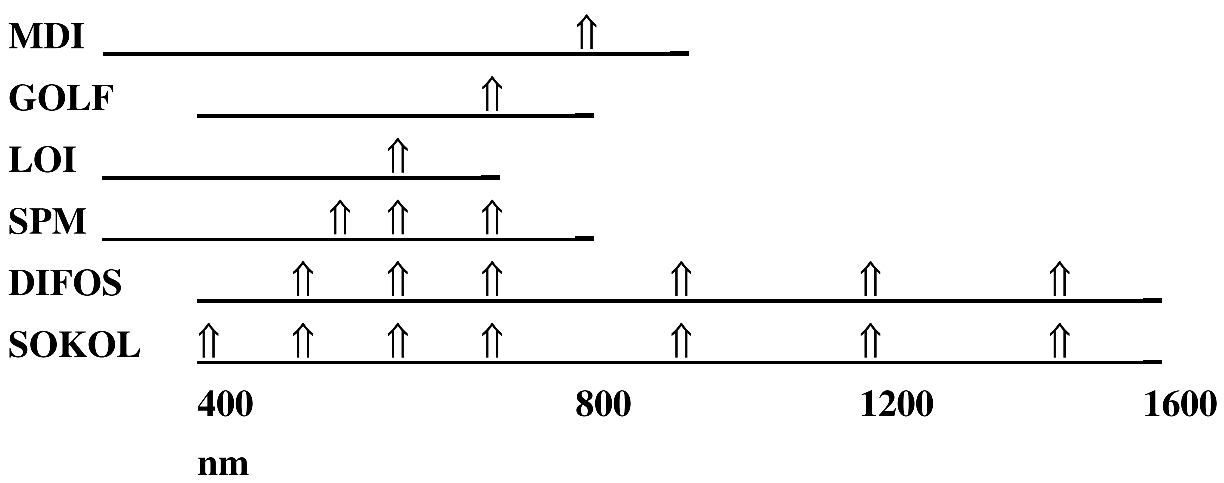


Figure 1: Multichannel photometer SOKOL/CORONAS-PHOTON.

Table 2. Comparative characteristics of the SOKOL-DIFOS-SOHO helioseismic instruments

Mission	*Device*	*Method*	*Observational spectral band, nm*	*Spatial resolution*
SOHO	MDI	Fourier tachometer, velocity oscillations	676.8	CCD martix 1024×1024 pixel, l = 0–4500
	GOLF	Resonance cell with sodium vapor, velocity oscillations	589.0	Absent, l = 0–3
	LOI (VIRGO)	Emission intensity oscillations	500	12-element photodiode, l = 0–7
	SPM (VIRGO)	Emission intensity oscillations	402 500 862	Absent, l = 0–3
CORONAS-F	DIFOS	Emission intensity oscillations	350 500 650 850 1100 1500	Absent, l = 0–3
CORONAS-PHOTON	SOKOL	Emission intensity oscillations	280 350 500 650 850 1100 1500	Absent, l = 0–3

Table 3. Mutual position of the spectral bands



2.3.3. P.N. LEBEDEV PHYSICAL INSTITUTE OF RAS

2.3.3.1. The TESIS Experiment on EUV Imaging Spectroscopy of the Sun

The experiment TESIS (Fig. 1) dedicated to EUV imaging spectroscopy of the Sun is scheduled to be started at the middle of 2008 on board the Russian spacecraft CORONAS-PHOTON with the aim to provide complex observations of solar energetic phenomena in the transition region and lower and outer corona with a set of imaging instruments. The organization responsible for the experiment TESIS and its instrumental equipment is the Laboratory of X-ray Astronomy of the Sun (Laboratory XRAS) of the P.N.Lebedev Physical Institute of Russian Academy of Science (http://tesis.lebedev.ru).

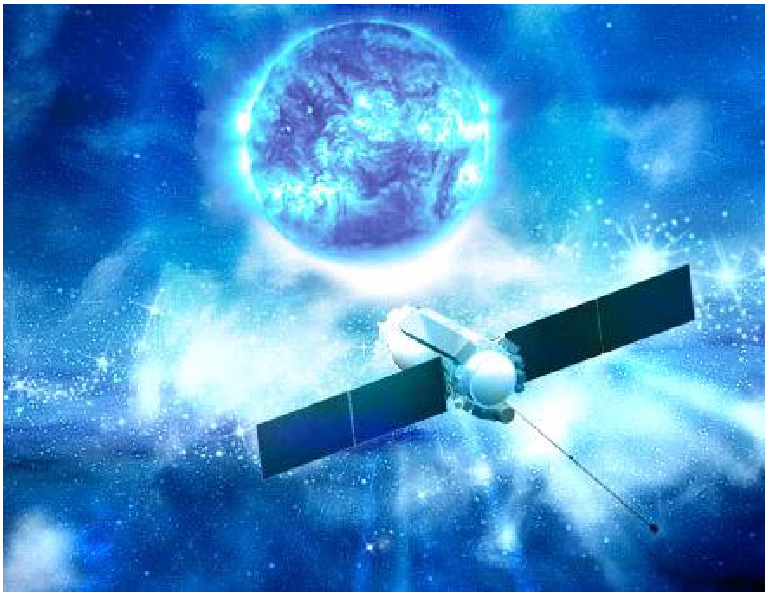


Figure 1: “Coronas-Photon” with TESIS EUV telescopes.

The experiment is directed at acquiring data on the physical parameters and spatial structure of plasma in the transition region and in the inner and outer corona with the aim to solve the following fundamental problems of solar physics: (1) the study of mechanisms of solar wind generation and coronal heating, (2) the development of methods for space weather forecasting, (3) the study of the production and evolution of high-temperature plasmas in the corona, and (4) the analysis of processes of magnetic energy accumulation and release before and during flares. Spatial, spectral and temporal characteristics of the TESIS are improved significantly compared with characteristics of its predecessor, SPIRIT launched in July 31, 2001. This is largely determined by the last year's progress in production of high-resolution optics based on multilayer normal-incidence mirrors.

The TESIS includes five instruments.

(1) The MISH is an imaging spectroheliometer for registration of monochromatic images of the Sun in the narrow spectral region, which covers a resonance doublet of the hydrogen-like ion MgXII with wavelengths 8.418 and 8.423 A. This spectral region is chosen to get information about the temperature, spatial distribution and dynamics of high-temperature plasmas in active regions and solar flares. The spectroheliometer is dedicated to high-cadence observations with temporal interval less than 10 seconds in the full frame mode.

(2) The EUSH is an imaging spectroheliometer operating in the band 285–335 A. This band covers HeII, SiIX, SiXI, FeXIV-FeXVI, MgVIII, NiXVIII, CaXVII, AlIX, FeXXII and other spectral lines formed at temperatures through from $5 \cdot 10^4$ to $1.2 \cdot 10^7$ K. The optical layout of EUSH includes objective grazing incidence diffraction grating and normal incidence multilayer parabolic mirror. The EUSH is aimed at multi-wavelength spectral diagnostic of coronal plasma.

(3) The FET includes two normal-incidence Herschelian telescopes with multilayer mirrors. The first telescope operates in 130–136 A spectral region with FeXX 132.84 A and FeXXIII 132.91 A lines. The second one covers 290-320 A spectral region centered at the HeII 303.8 A line. The images obtained by first telescope will provide data on spatial distribution and dynamics of very hot coronal plasma with a temperature higher than 10^7 K. Intense emission in the line HeII 303.8 A is mainly produced in the transition layer with a temperature lower than 10^5 K. The telescopes may operate simultaneously or in a sequence depending of operating mode.

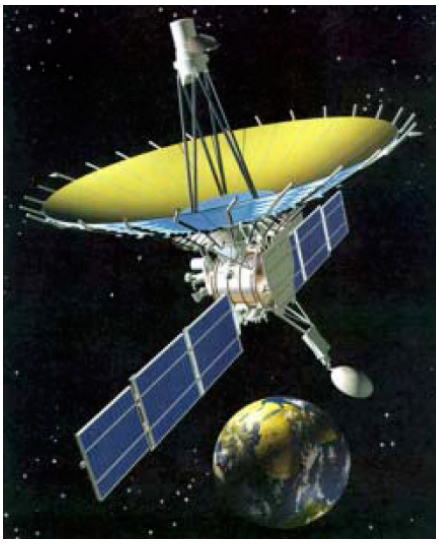
(4) The SEC is a solar coronograph based on the Ritchey-Chretien scheme. The SEC operates in the spectral band 290-320 A centered at the lines SiXI 303.3 A and HeII 303.8 A. Its field of view is equal to 2°.5 which covers the inner and outer corona through from the solar limb from 0.7 to 4 solar radii. The intense light from solar disk is reduced with an occulting mask coated on the surface of CCD.

(5) In addition to instruments listed above, the TESIS includes X-ray photometer-spectroheliometer SphinX designed by Space Research Center of Polish Academy of Science.

The total volume of scientific information provided by TESIS is assumed to be about 2 Gb per day, that will be in 100 times more than the volume of information from SPIRIT – the complex of space instruments aboard the CORONAS-F satellite. Comparing it with the size of one compressed image (~200 Kb), we expect that TESIS will provide about 1000 high-resolution images of the full Sun every day. The size of one decompressed images will be 2048×2048 pixels with space resolution of about 1 arcsec for all the TESIS channels except the coronagraph and the spectrometer. About 10 % of the daily TESIS images will be free for use and for downloading from the TESIS data center that is planned to open 2 months before the TESIS launching at http://www.tesis.lebedev.ru.

TESIS will become an important part of the international program of collaborative observations of the Sun with ground-based and near-Earth telescopes during the razing phase and the maximum of current cycle of solar activity. Solar flares have many aspects, which may be completely clarified only with cooperation of optical, radio and X-ray observations. the TESIS will make important contribution, to this cooperation, which will increase our knowledge about the Sun and the mechanisms of solar activity.

2.3.3.3. Project RADIOASTRON — The Ground-Space Interferometer “Radio telescope much larger than the Earth”



Astro Space Center of P.N. Lebedev Physical Institute and Lavochkin Association develop the Spectr-RadioAstron project. This project presents the Ground-Space interferometer that is dedicated to the investigation of the structure of various objects in the Universe at centimeter and decimeter wavelengths with an angular resolution of up to a few millionth of an arcsec (i.e. millions of times better than the human eye’s resolution). Such resolution is achievable for the radio interferometer which consists of a space telescope with a 10 m mirror antenna orbiting with an apogee of up to 350,000 km and the largest ground-based radio telescopes. A super high angular resolution is the key parameter of this project. Due to the very long baseline, close to the Earth-Moon distance, the ground-space radio interferometer RadioAstron is able to determine radio source dimensions, their structure, proper motions and distances, as well as spectral and polarization imaging - up to ten times better than achievable by any existing ground-based radio interferometers.

The orbit of RadioAstron, gravitationally perturbed by the Moon, has the following parameters:

Perigee radius:	>10,000 km
Initial inclination:	51.6 grad.
Average apogee radius:	350,000 km
Average period of revolution:	9.5 days

Launch of the mission is in the first half of 2009.

2.3.4. V.A. KOTELNIKOV INSTITUTE OF RADIO ENGINEERING AND ELECTRONICS OF THE RAS

2.3.4.1. L-Band Radiometric System for Space Investigations

Main goal of space L-band radiometric system “Zond-PP” design — is the development of radiophysical methods for the Earth remote sensing in a promising range of electromagnetic waves (wavelength ≈21 cm) for investigation of events and processes in the atmosphere - earth surface system. For scientific investigations the Russian small satellite will be used. Head design organization — Lavochkin Research and Production Association (Lavochkin NPO). Launch of satellite is scheduled on year 2008. Leading scientific organization — Institute of Radioengineering and Electronics RAS (IRE RAS). Head space L-band radiometric system design organization — Special Design Bureau IRE RAS. Radiometric system “Zond-PP” consists of 2 channel microwave radiometer and 2 beam folding antenna.

Technical specification of the radiometric system:

Number of beams	2
Polarization	linear
Main frequency, MHz	1410
Bandwidth, MHz	20
Fluctuation sensitivity, K	<0.3
Dynamic range, K	10–320
Power supply, V	+28
Power consumption, VA	<60
Weight, kg	<10
Size, mm	
radiometer unit	400×300×50
antenna	800×510×40

The flight configuration of satellite and radiometric system “Zond-PP” is shown on Fig. 1.

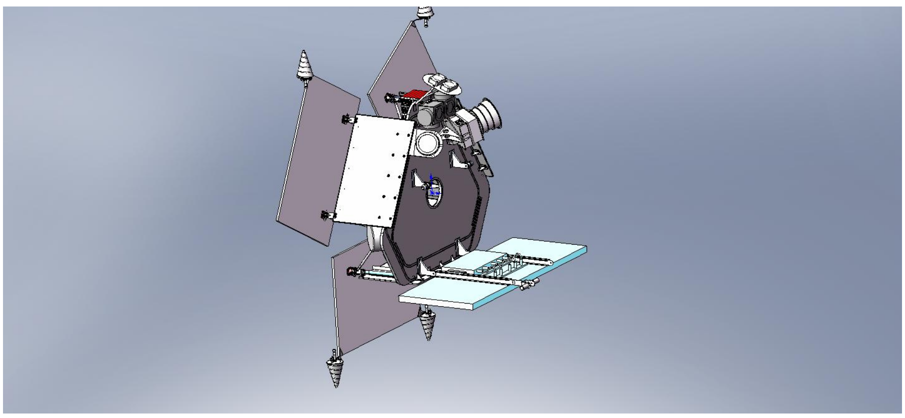


Figure 1: Flight configuration of satellite and radiometric system “Zond-PP”.

Main objective of space experiments and investigations is to develop new remote sensing instrument for:

1. soil moisture mapping (including under the forest cover) over the territories of regional and global scales;
2. temperature-moisture state of the forest-swamp systems investigation;
3. vegetation biometrical characteristics investigation;
4. sea salinity investigation;
5. frozen grounds and glaciers investigation;
6. investigation of the energy-exchange in the ocean-land-atmosphere system (jointly with the data of other sensors);
7. study of the geothermal activity regions, estimation of their borders and temperature conditions;
8. radio interference situation all over the globe;
9. calibration issues;
10. development of methods of the joint processing data with various spatial resolution.

Expected results of space experiments and investigations:

1. soil moisture mapping (up to 5 levels);
2. vegetation biomass mapping (up to 3 levels);
3. sea salinity mapping (2-3 levels);
4. estimation of heat exchange parameters between ocean and atmosphere;
5. mapping of regions with uniform microwave brightness temperature.

The example of expected space results is presented on Fig. 2. Soil moisture map reconstructed from microwave radiometer data at 21 cm wavelength from airplane based measurements is shown (moisture content is in g/cc).

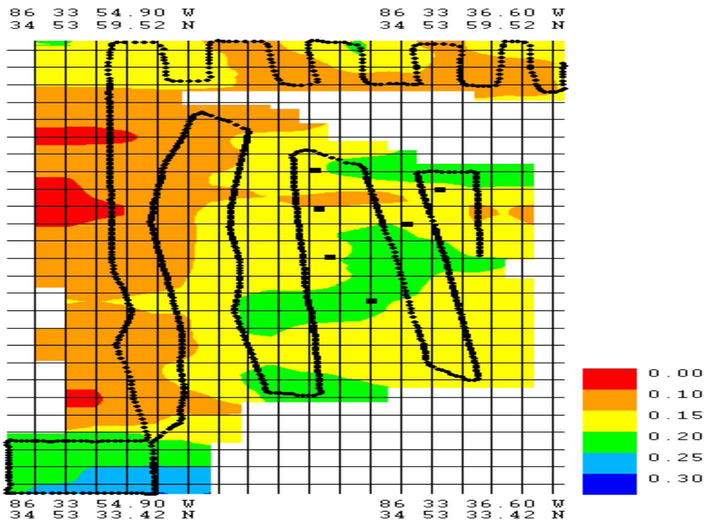


Figure 2: Soil moisture map from airplane based measurements (wavelength ≈21 cm).

2.3.5. V.I. VERNADSKIY INSTITUTE OF GEOCHEMISTRY AND ANALYTICAL CHEMISTRY OF THE RAS

2.3.5.1. FOBOS-GRUNT Mission

1. Scientific problems

In 2009, in accordance with Federal space program of Russia, there will be performed launching of FOBOS-GRUNT spacecraft. Academician E.M. Galimov is supervisor of studies related with FOBOS-GRUNT project.

The main scientific tasks can be decided only after return a samples of Phobos on the Earth, or partially without the return a samples (Table 1).

Table 1. Problems to resolve

Is Phobos matter kindred to the matter of Mars and SNC meteorites?
O^{16}- O^{17}- O^{18}, Kr/Ar/Ne ratio (Fig. 1, Fig. 2)

Are there particles ejected from Mars on Phobos?
Search and analysis of such material.

Does Phobos contain traces of protosolar material?
Isotope ratios

Is organic matter on Phobos?
Presence of aminoacids, nucleine basics, etc.

Is Phobos composed by primary or differentiated material?
REE ratio. Mineralogy.

Age of Phobos.
1. Sm/Nd; 2. Hf/W; 3. U/Pb /Rb/Sr

Which type of meteorites Phobos material is close to?
$\delta^{13}C$, δ D, δ ^{18}O - δ ^{17}O - δ ^{16}O, H_2O (fig.1, fig.2)

Internal struructure of Phobos
Seismic sounding

Phobos surface morphology.
TV – images, delivered soil sample.

Sample return is required

Sample return is not required

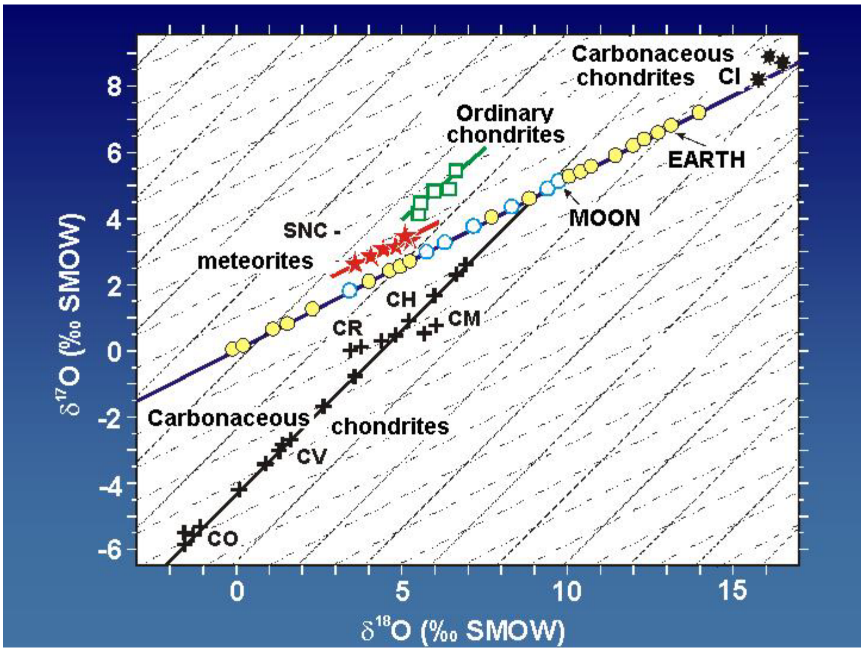


Figure 1

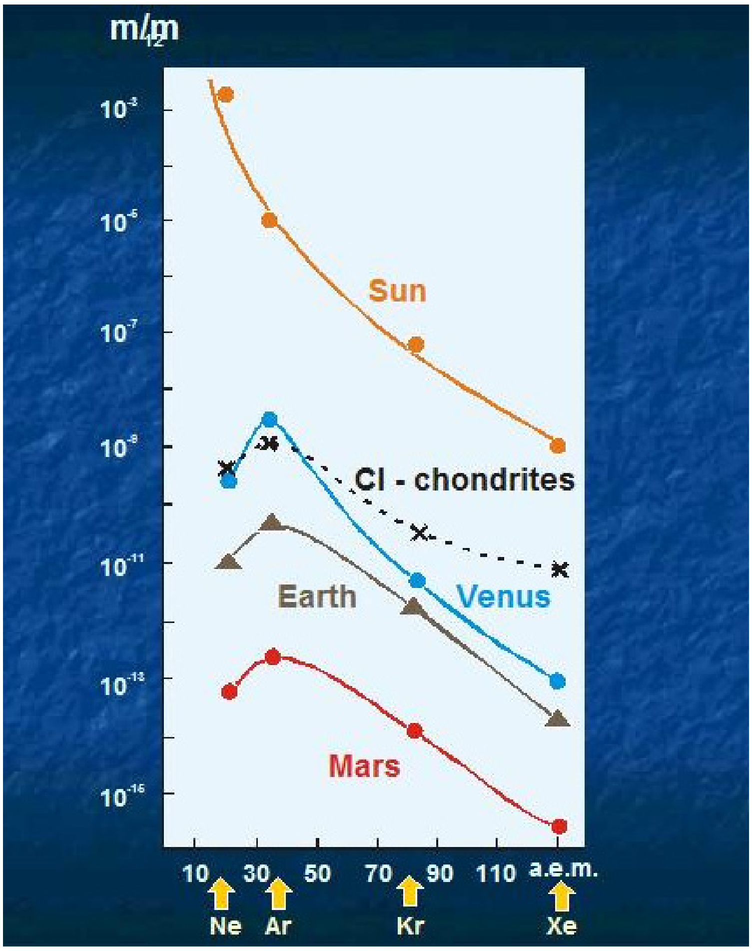


Figure 2

2. Scientific instruments and technical characteristics

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** 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;
- **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;
- **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;
- **mass-spectrometer MAL-1** intended for investigation of composition of gaseous components of the soil;
- **thermo-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);
- **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).

Table 2. 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	Gamma-ray energy: 0.3–9.0 MeV Neutrons up to 0,4 eV
	Resolution	1–2 wt% for the main rock forming elements
Mass-spectrometer MAL-1	Mass of the instrument	3,6 kg
	What 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
	What 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
	What is measured	Acceleration, velocity, displacement
	Range of measurements	No less than 100 db, $10^{-7}…10^{-12}$ m
	Resolution	10 %
Detector of space dust METEOR-F	Mass of the instrument	3.5 kg
	What 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

In the frames of FOBOS-GRUNT experimental design works, there were developed and issued set of scientific-technical documentation, including draft project, technical task on complex of scientific equipment, drawings with overall dimensions, diagrams of electrical connections etc. There were manufactured models, thermal equivalent and engineering models of instruments.

Instruments photo Fig. 3–7.

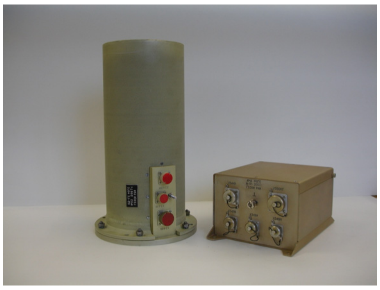


Figure 3. Gamma-spectrometer FOGS

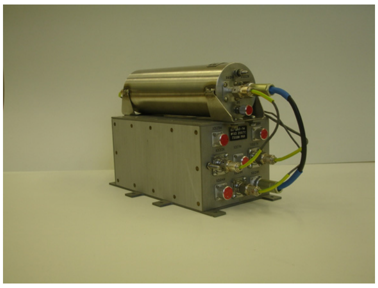


Figure 4. Mass-spectrometer MAL-1

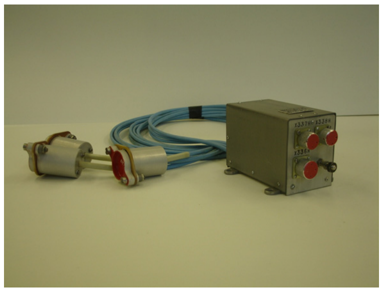


Figure 5. Thermo-detector THERMOFOB

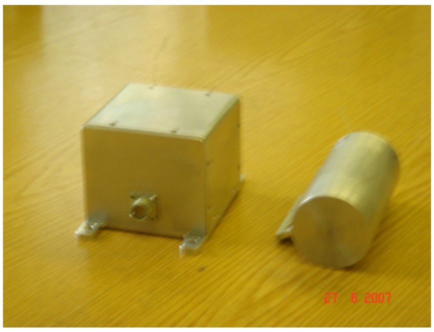


Figure 6. Seismometer SEISMO-1

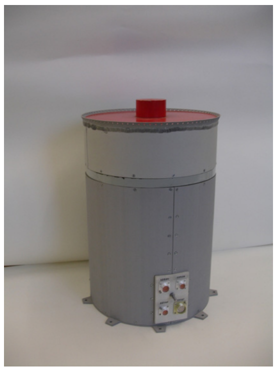


Figure 7. Detector of space dust METEOR-F

3. Planned of explorations and experiments results

The main task of FOBOS- GRUNT project is collecting and bringing to Earth from Fobos the samples of its soil. The studies of soil samples will permit to throw light upon the process of formation of planets.

This is first of all important for understanding of an early history of Earth, including origin of life on Earth and this will permit to clear up the structure and composition of substance from which planets were formed. If Mars, Earth and Moon were smelted, differentiated and changed by secondary processes, then Fobos, as an "undercollected" material of Mars, is unique one for understanding of mechanism of planet formation.

2.3.5.2. LUNA-GLOB Mission

In 2012, in accordance with Federal space program of Russia (2006–2015), there will be performed launching of LUNA-GLOB spacecraft.

The main scientific tasks of project:

1) investigation of lunar internal structure;

2) investigation of the lunar south pole crater.

1. Investigation of the lunar internal structure

Investigation of Moon and its inner structure gives a key for understanding early history and evolution of planets of Earth group, satellites of other planets and, main thing, for solving the problem of the origin of system Earth-Moon. Today, there are three basic hypothesis: hypothesis of accumulation the Moon from planetesimales, hypothesis of megaimpact, hypothesis of formation of a twin system. Given hypothesis are presented in diagram form on Fig. *8*.

The size of lunar core is geochemical parameter for the choice of the most likely scenario of origin and evolution of Moon. Hypothesis of megaimpact and accumulation of the Moon from planetesimales are consistent with small size lunar core (the less 1 % of lunar mass). The forming of Moon as twin system from collapse cloud needs the considerable core (~5 % of lunar mass).

Always hypothesis about a formation of lunar matter must satisfy the well-known geochemical criterions, which were clearly recognized as a result of rock sample examination of lunar soil, namely: deficit of iron, depleted volatile elements, specific character of sierophile elements, high concentration of refractor elements. Enrichment of the Moon in the refractory elements would mean existing of a high-temperature stage in its formation (model of collapse cloud).

At present there is no reliable appraisals of the concentration of refractory elements in the bulk Moon. However, elastic properties of the mantle depend on its chemical and mineral composition, in particular, on Al_2O_3-content. There should be correlation between refractory elements content and size of the lunar core. The lower concentration refractory elements in the Moon, similar to Earth, is consistent with small core or lack of the core at all.

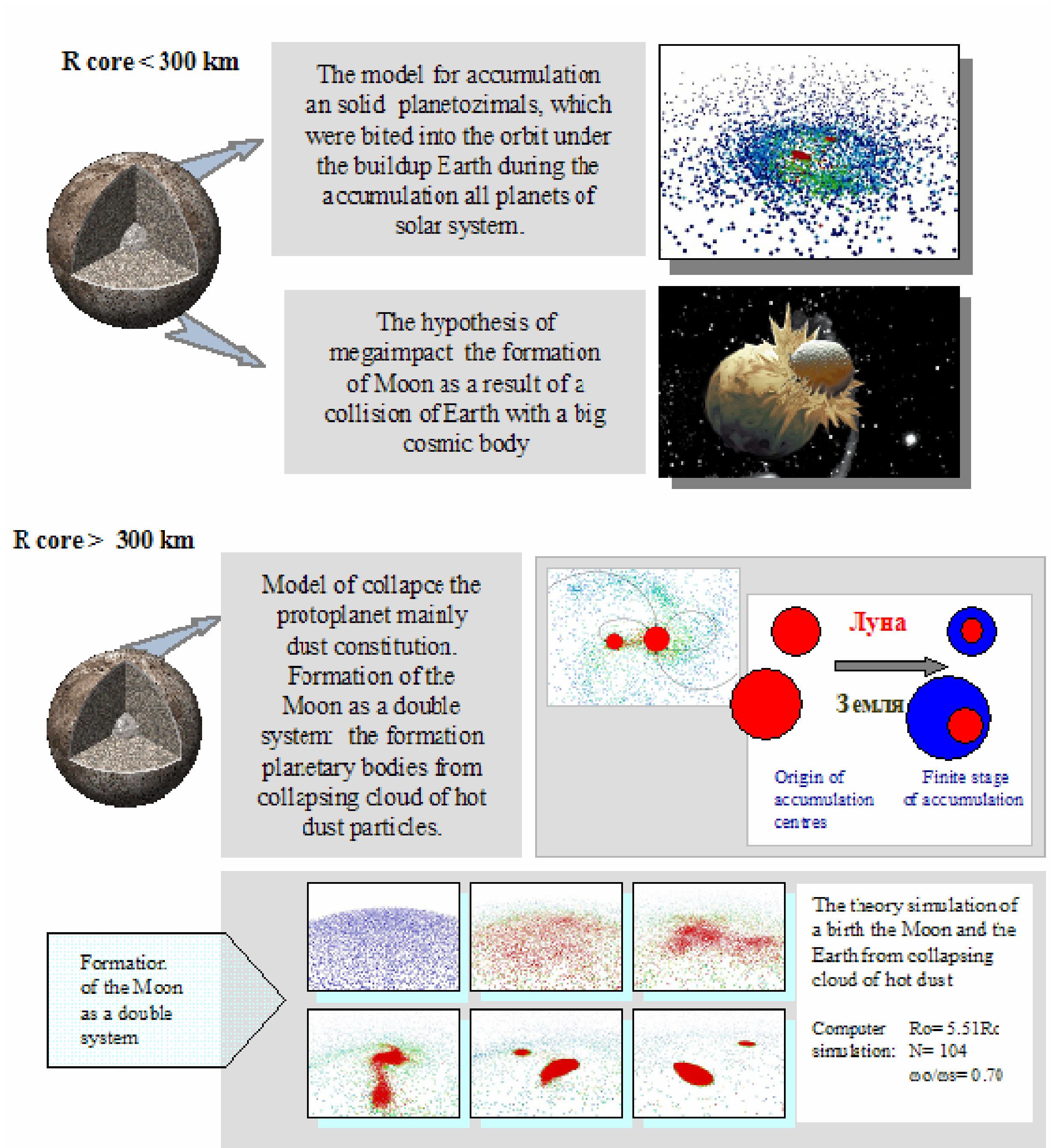


Figure 8

The concentration of Al and other refractory elements may be estimated through the seismic data only.

The Apollo seismic data do not allow to get seismic profile and other characteristics of lunar interior for the depths more than 1000 km (Fig. 9).

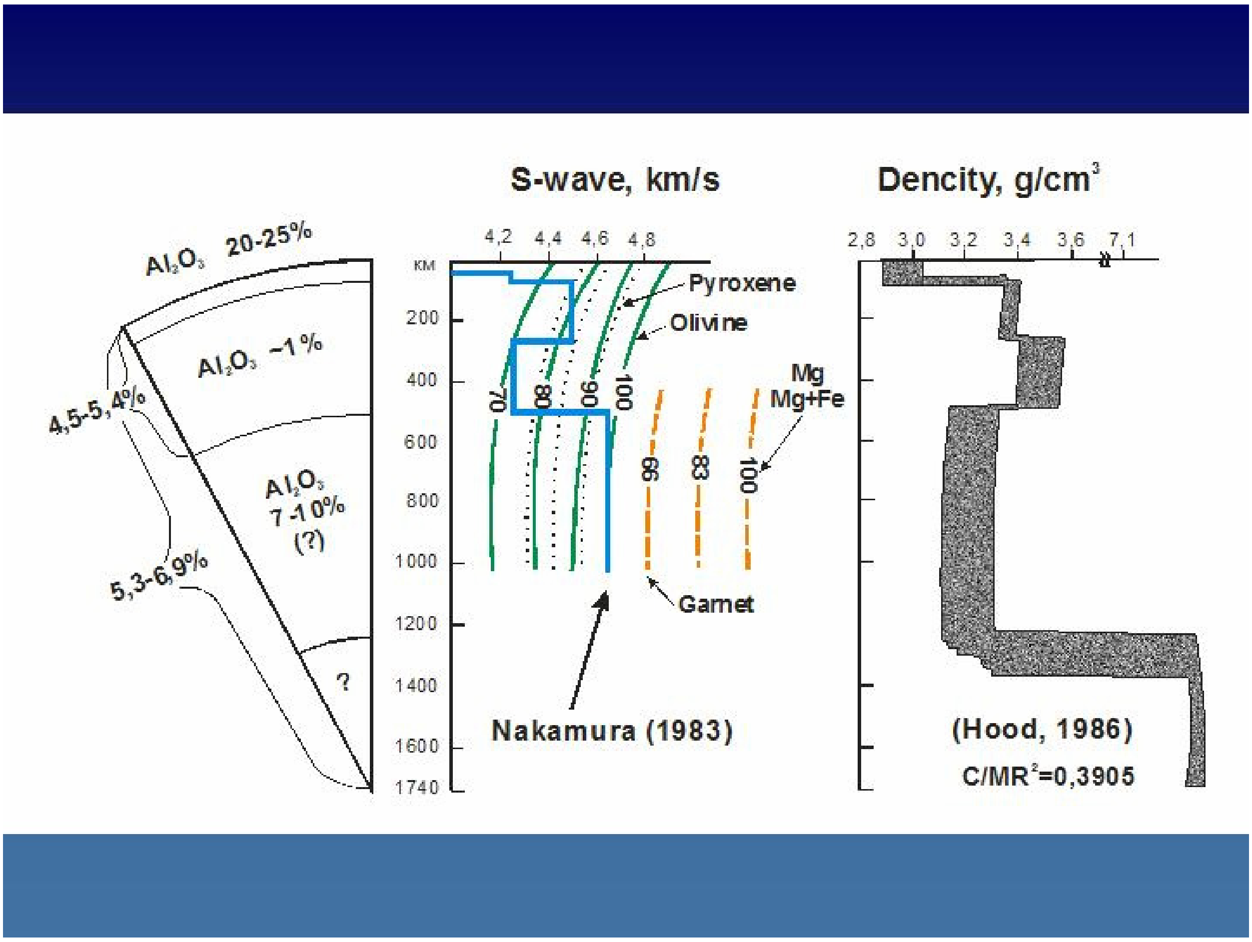


Figure 9

The current interpretation of seismic profile in lunar interior is rather consistent with the higher Al_2O_3-content. However the seismic data available are scarce for the choice of hypothesis about lunar formation using given parameter.

The penetrators are the instrument for study of the lunar internal structure.

Expected results. The structure of lunar interior and size of lunar core, based on Luna- Glob seismic experiment, should provide a basis for the choice of the most likely scenario of origin and evolution of system Earth–Moon.

2. Investigation of the lunar south pole crater

The anomalous temperature conditions are basic distinctive feature of polar region of Moon. The formation and evolution lunar soils are taking place under low-temperature condition with negligible solar illumination or lack the illumination at all. The shaded regions during a long time not far from lunar south pole can be serve as a cold traps for volatile elements and matter.The main scientific task of the lunar south pole crater investigation is the study of the volatile matter CH_4, C_2H_6, CO, CO_2, N_2, H_2, H_2S, H_2O, SO_2, COS, CS_2 and the availability of water. The investigation of the volatile matter composition is of interest from scientific viewpoint and give a chance to discover origins of life.

The investigation of the lunar south pole crater allow to determine water-supply for the farther expeditions and for the lunar bases construction.

The task of the lunar south pole crater investigation will be incarnated with help of landing spacecraft with complex of scientific instruments.

2.3.6. D.V. SKOBELTSYN SCIENTIFIC-RESEARCH INSTITUTE OF NUCLEAR PHYSICS OF M.V. LOMONOSOV MOSCOW STATE UNIVERSITY

2.3.6.1. Experiment SolRad on-board Russian-Indian University Satellite YouthSat

The main goal of the project YouthSat is the realization of space experiment on the study of solar flare activity on-board micro-satellite. The use of micro-satellite means the involving of young researchers, i.e. students and post-graduate students in all the stages of preparation and realization of space experiment. Thus this project has scientific and educational goals.

The main scientific goal is the study of solar flare activity by the complex monitoring of solar energetic events in broad-band electromagnetic radiation and charge particles. Such measurements should be used for the short-term forecast of appearance in the interplanetary and near-Earth space particle fluxes, which could be dangerous for human as well as for automatic missions. The unique method of study of solar flares and radiation prognosis is the complex analysis of data obtained in as wide as possible range of types and energies of solar flare manifestation. The joint detection of flare's high-energy gamma rays (with photon energies hundreds and thousands keV) and *in situ* measurements of electron fluxes in the same energy ranges as well as proton fluxes with energies >10 MeV are the most informative for radiation prognosis. Temporal behavior of high-energy gamma rays and its spectrum dynamics during flares give the accurate time of energetic particles appearance on the Sun and their energy. Correlation between gamma ray and interplanetary electron and proton fluxes will be also obtained.

The main educational goal is the involving of students and postgraduated students by studying the problem of solar activity to obtain the real experience in space experiment preparation, realization and data processing.

Mission and Status:

Mission to be launched on the solar-synchronous orbit with the height about 600 km in December, 2008. The engineering model of scientific payload is prepared and tested. It is ready to be supplied to Indian side. The flight example is manufactured and tests now.

Scientific payload:

The scientific payload includes the SolRad instrument. The solar flare time profiles in hard X-rays (10–100 keV) and wide-band spectra (0.02–10.0 MeV) would be measured as part of SOLRAD payload. The other part of payload is meant to detect the electrons and protons at the energy ranges 0.3–3.0 MeV and 3–100 MeV respectively. This allows one to search correlation between solar flare activity in hard electromagnetic radiation and intensity of charge particles accelerated in flare.

Both detectors would be mounted in one detector box and based on simple design. The hard X-ray and gamma ray detector consists of scintillator NaI(Tl)/CsI(Tl) and photo-multiplier tube (PMT) phoswich system. The charge particle detector is a combination of four silicon plates. Both measurements using scintillator and silicon detectors provide information on the solar energetic event features, which are meaningful for clarification of accelerator mechanisms in solar flares.

The instrument should consist from the detector module (box of detectors, BD) and from the electronic module providing on-board data processing and connection of instrument with satellite power, telemetry and command systems (box of information, BI). The general view of both boxes (engineering model) is given in the Fig. 10, 11.

Figure 10. The general view of the detector box (BD) of SOLRAD instrument.

The detector module should include the wide-field spectrometer of hard X and gamma rays (based on the phoswich NaI(Tl)/CsI(Tl) – plastic scintillator) and the telescope from four silicon detectors. The detector box also includes the electronic circuits and construction elements. The electronic module should include the processors and store for data collecting from the detectors and data preliminary processing. This module also contains the electronics providing connection with satellite on board systems and transmission of the power and commands to the detector module.

Figure 11. The general view of the information box (BI) of SOLRAD instrument

The SOLRAD detector properties are summarized in Table 1.

Table 1. SOLRAD Detectors Specifications

	NaI(Tl)/CsI(Tl) phoswich	**Silicon telescope**
FOV	Omni-directional	30×30 deg
Spectral Resolution	~10% (661 keV)	—
Collecting area	~50 cm^2	~6 cm^2
Efficiency	>90%	>99 %
Spectral Range	0.01-10.0 MeV (γ-quanta)	0.3–3.0 MeV (e); 3–100 MeV (p)

2.3.6.2. Experiment “Tatiana-2”

The aim of the experiment is the investigation of flashes of electromagnetic radiation in the upper atmosphere using complex of scientific devices giving the possibility to observe radiation in the wide range of wave lenses and to obtain space and time flare images.

Charge particle detectors are used jointly with detectors of electromagnetic radiation (see Fig. 12) in the experiment on the study the nature of flares.

The scientific payload is prepared by scientific centers – participants of scientific/educational collaboration including Lomonosov Moscow State University, Womens University Evha (South Korea), Autonomous University of the town Pueblo (Mexico). Institute of Nuclear Physics of the Moscow State University realize the coordination of research works.

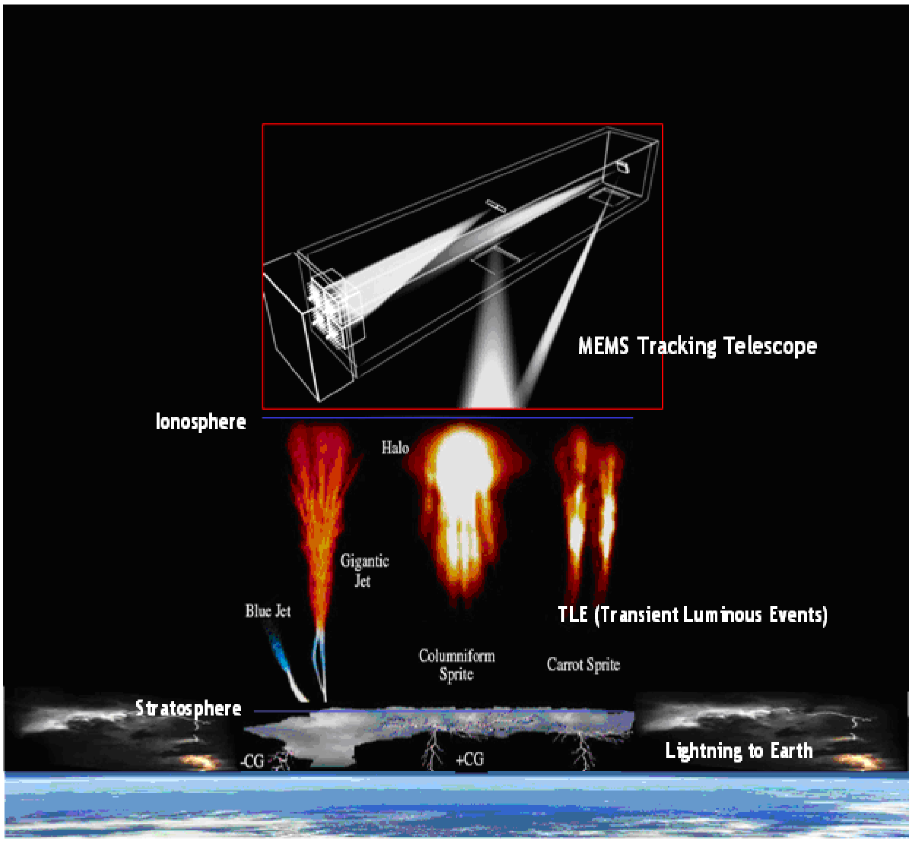


Figure 12. Scheme of experiment on the satellite “Tatiana-2”

The scientific payload includes:

- The detector of flare image in ultraviolet (UV) range.
- UV spectrometer of flare.
- UV and red light detector.
- Detector of charge particle background.

2.3.6.3. Experiment RelEc on-board Russian Small Spacecraft

The main goal of the project is to study relativistic electron influence on the upper atmosphere, to research the transient lightening events in the upper atmosphere, to study the relativistic electron precipitation and dropout of energetic electrons in process of radial diffusion and interaction with electromagnetic waves in dynamic magnetosphere.

Additional goals of the project are to study lithosphere-ionosphere connections (problem of earthquakes), atmosphere-ionosphere connections (problem of thunderstorms), dosimetry and single event upsets problem taking into account neutron component of radiation.

The main features of the project are

- simultaneous measurements of relativistic electron fluxes in the near-Earth space and wide-band monitor observations of the upper atmosphere (UV, X-ray, gamma-),
- detection of relativistic electrons in wide energy range (up to 10 MeV and more) with time resolution is ~100 ms,
- possibility of spectral and pitch-angle distributions measuring,
- detection of low fluxes of relativistic electrons due to the large geometry factor of detectors.

Mission and Status

Mission is to be launched on the circular near-Earth orbit with the height about 600 km not earlier than 2010. The instruments of scientific payload is under preparation now.

Scientific payload

The scientific payload includes following instruments (see Fig. 13, 14):

- complex of X-ray, gamma-ray and high energy electron detectors includes two detector units directed toward the Earth and one unit directed in the local zenith;
- optical and near-UV imager intended for lightning events detection;
- complex of detectors of charge and neutral particles;
- radiometry complex;
- dozimetry complex.

Ranges of space radiation components which should be measured in experiment:

Electrons	0.2–10 MeV
	>10 MeV
	>0.3 MeV
Protons	0.3–60 MeV
	>50 MeV
	3–150 MeV
	>150 MeV
Gamma	0.05–1.0 MeV
Neutrons	0.1–30 MeV
X-rays	10–100 keV
UV	300–400 nm

RelEc payload parameters (total):

Mass	27 kg
Power	36 W
Data flow	10–20 Mb/day

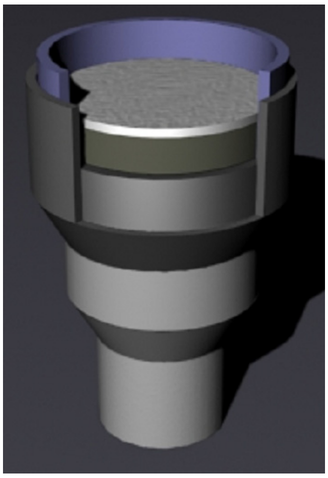


Figure 13: The general view of the detector unit of X-ray, gamma-ray and high energy electron detector in experiment RelEc.

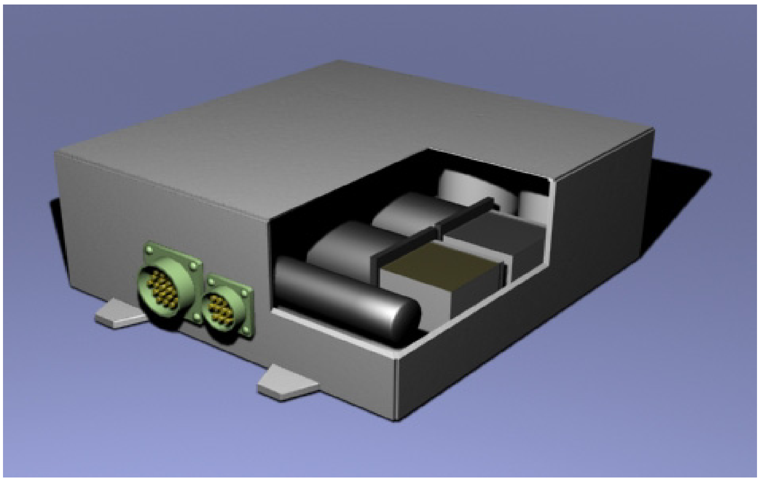
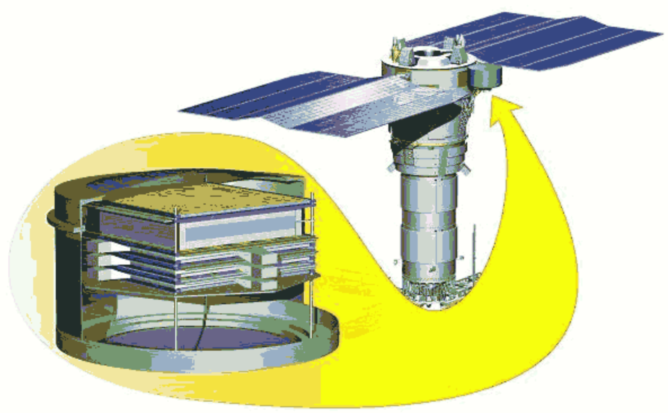


Figure 14: The general view of the detector of charge and neutral particles in experiment RelEc.

2.3.6.4. Experiment "NUCLEON"

Experiment "Nucleon" (see Fig. 15) aimed at investigations of primary cosmic rays. The main scientific objective of the project is the measurements of the energy spectra of different nuclear species of Cosmic Rays (CR) and their chemical composition in the extremely wide energy range $10^{12}\ldots10^{15}$ eV/particle with the aim to establish main types of CR sources in Galaxy, mechanisms of their acceleration, to get qualitative characteristics of CR diffusion in Galaxy in a high energy range.



Figrку 15: Experiment "Nucleon" scheme

The development of a scientific instrument with a small weight (<200 kg) and size (<1 m^3) being able to decide actual problems of CR physics in the energy range $10^{12}\dots10^{15}$ eV and being suitable for an exposition as an additional payload on board the Russian regular satellites at long duration specific missions is planned.

A significant reduce of the instrument mass is reached due to application of a new approach to energy measurements based on modified kinematic methods. In contrast to usually applied thin calorimeters this method does not require a large amount of absorber, but it needs only thin target of about 20 g/cm^2. The instrument will be sited on board of the new space craft of distinct probe of the Earth, developed in FGUP KB “Arsenal”.

Technical parameters of the Nucleon experiment

The total additional payload is 265 кг: scientific device (165 кг), the system of information collection and translation, the elements of the fastening, cable network.

- Power consumption is 120 W.
- The flight duration is near ~5 years.
- The scheduled time of the launch is 2009–2010.

The NUCLEON instrument structure

The scientific instrument represents a multi-layer structure (see Fig. 16) with the overall dimensions 500×500×270 mm.

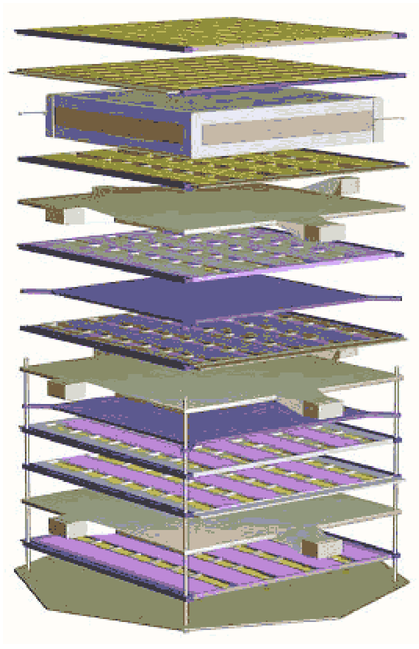


Figure 16: Scheme of detectors in Nucleon experiment.

It consists of:

- 4 layers of pad silicon detectors (with a pad size ~2.5 cm^2) aimed at precise measurements of a particle charge;
- 6 layers of micro strip silicon detectors (with a readout step ~450 mkm), aimed to measure energy and to locate a particle track in the instrument;
- 6 layers of position sensitive scintillator detectors aimed to elaborate a trigger signals.

2.3.6.5. Experiment "TUS"

The main goal of "TUS" experiment is to study ultraviolet (UV) transient events in the atmosphere.

Construction of the space detector of UV radiation (see Fig. 17) generated in the atmosphere by avalanche of secondary particles initiated by the cosmic rays of extreme energies (starting from energy of about 100 EeV). An interesting feature of the detector is that in parallel to the main goal of studying the cosmic ray of extreme energies it will be used in search for transient UV events (which could be associated with the events of extreme energy cosmic ray particles), and also in search for small mass meteoroids (dust grains). In 2007 construction of the mirror-concentrator of area 2 m^2 has been started. Electronics for 256 pixel photo receiver was designed and the first boards were produced. The launch of TUS is planned for 2010 on board of the space platform separated from the "Bion" satellite.

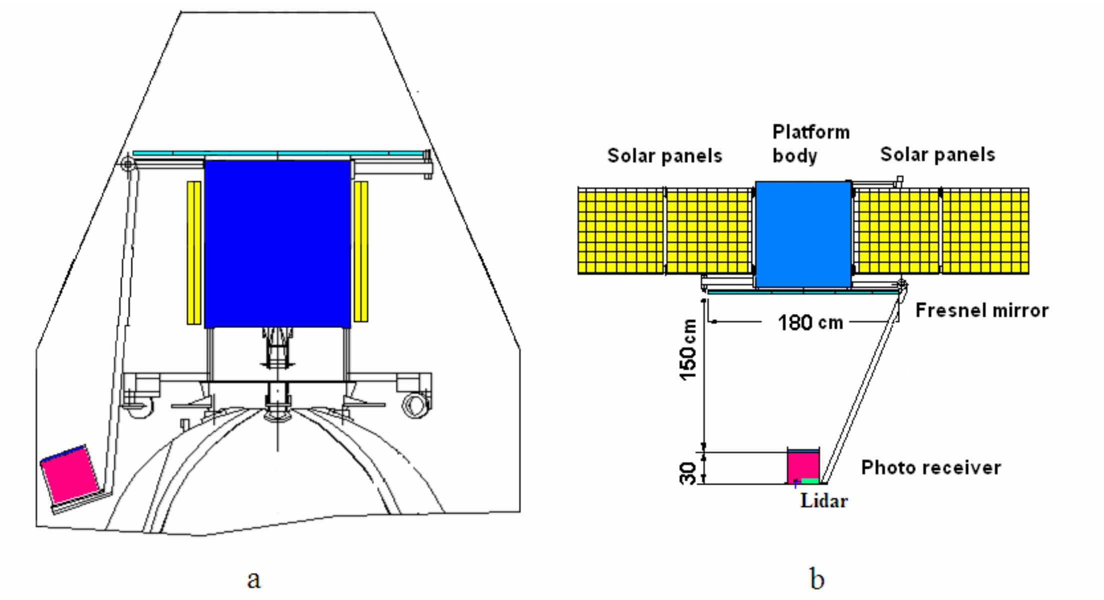


Figure 17: TUS detector onboard of space platform separated from the "Bion" satellite:
a — transportation mode, *b* — operation mode.

2.3.7. INSTITUTE OF COSMOPHYSICS OF THE MOSCOW INSTITUTE FOR ENGINEERING AND PHYSICS

2.3.7.1. Satellite Experiment ARINA for Study of Seismic Effects in the High Energy Particle Flux in the Earth's Magnetosphere

1. Introduction

In recently years the opportunity to use space methods for earthquake prognosis is widely discussed. In particular, it is suggested to observe various earthquake precursors in the near-Earth space such as composition and density variations of ionosphere plasma, generation of electromagnetic emission in wide frequency range, quasi direct electric and magnetic field variations and others. In ARINA experiment the seismo-magnetospheric phenomenon — high-energy charged particle bursts appearing in the near-Earth space several hours before an earthquake is studied.

For the first time such seismo-magnetospheric phenomenon was observed in 1985 in the MARIYA experiment conducted by MEPI onboard the "Salyut-7" orbital station. Later, extensive experimental (based on data of satellite measurements: MARIYA-2, GAMMA-1, NINA, NINA-2, ELECTRON, PET/SAMPEX and others) and theoretical studies were carried out, and physical processes of the relationship between the particle bursts and Earth's seismicity were found.

Low frequency electromagnetic emission (ULF, ELF and VLF ranges), generating in and over the epicenters of preparing earthquakes, propagates into the ionosphere and magnetosphere and interacts with high-energy particles, trapped by geomagnetic fields, in the radiation belt region (fig.1), As a result of this interaction particles precipitate below the atmospheric boundary of the radiation belt and drift along L-shells, forming a wave of precipitated particles (called GKV wave). Such a disturbance of the particle flux has a global feature because GKV wave moves along the drift shell (L-shell) around the Earth and fill all shell during the time of dozens seconds — few minutes. So, the particle burst of seismic origin can be observed in any places of the near-Earth space, where satellite intersects this disturbed L-shell, but not only over the epicenter of earthquake. It was shown in that, measuring the characteristics of a particle burst (the place of its recording, energy spectra, and time profiles) one can find the geographic coordinates of the region over which the particle precipitation occurred, i.e., the earthquake epicenter location.

At present time a study of prognostic characteristics of earthquake precursors in the near-Earth space is issue of the day. If to concern the problem of particle bursts as earthquake precursors then it is necessary to investigate the following tasks: to determine the efficiency (probability) of the appearance of the particle bursts — earthquake precursors, to study a possibility of identification of the seismic bursts of particles and particle bursts having different physical origin (solar-magnetospheric, thunderstorm and others), to reveal the relationship between the earthquake magnitude and particle burst characteristics. ARINA experiment, started by launching of "Resurs-DK1" satellite in June 2006, can do a new step in solving of goals listed.

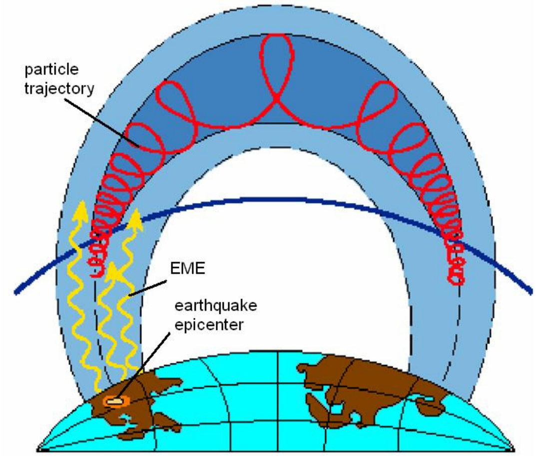


Figure 1: EME – electromagnetic emission of seismic origin;
line — lower boundary of the radiation belt.

2. Conditions of carrying out of ARINA experiment

The ARINA experiment is conducted on board the low-orbital Resurs-DK1 satellite which has been successfully launched in the orbit on June 15, 2006 with the orbital parameters: the height within 350–600 km and inclination of 70°. The position of ARINA instrument on board the satellite is shown in Fig. 2. The main orientation of the satellite is the orbital one. In this case the ARINA spectrometer axis is perpendicular to the plane of the spacecraft orbit, and optimal conditions for detection of precipitating particles below the radiation belt are realized.

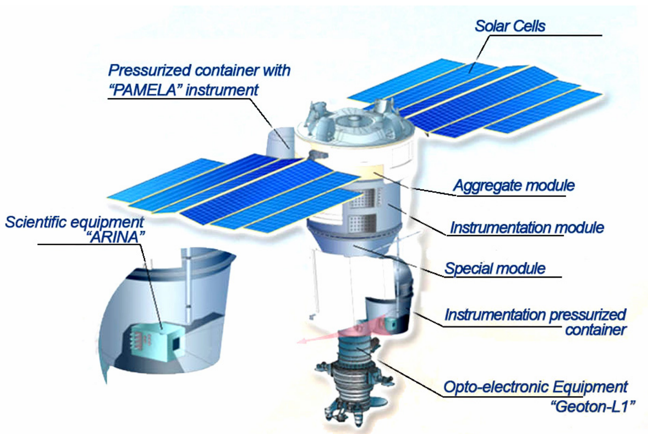


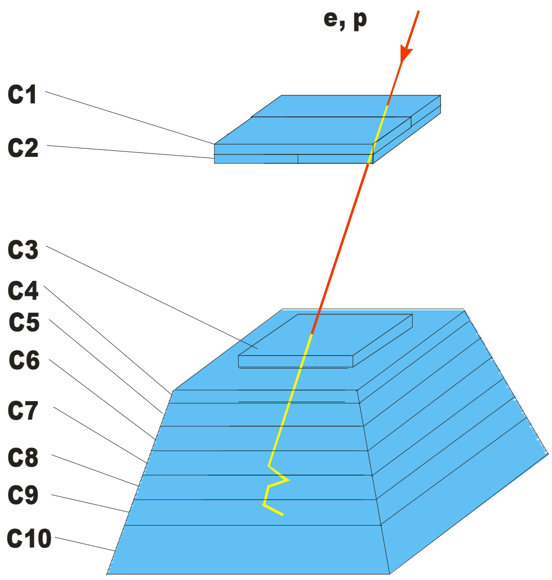
Figure 2: Scheme of Resurs-DK1 satellite.

The measurements of particle fluxes are conducted continuously. It is planned that both the experiment duration and the period of spacecraft functioning in the orbit will be no less than 3 years.

3. ARINA instrument description

The specialized instrumentation for detection of bursts of high-energy electrons and protons has been developed in MEPI. A multi-layer scintillation detector (C1, C2, …, C10) which registers the particles stopped in it (electrons with energies of 3-30 MeV and protons with energies of 30--100 MeV) is the basic instrument (Fig. 3). The electron-proton separation is performed on the basis of the energy release in the detector system. The particle energy is determined using their path length. The energy and angular resolutions of the spectrometer are 10–15% and 10°, respectively.

The spectrometer makes it possible to conduct measurements of the particle energy spectra and their evolution and to determine time profiles of particle bursts with high time resolution. It can operate in high-intensity particle fluxes.



Geometric factor	10 sm^2 sr	
Acceptance angle	±40°	
Energy range	protons	(30–100) MeV
	electrons	(3–30) MeV
Energy resolution	protons	10 %
	electrons	15 %
Time resolution	100 нс	
Mass	8.6 kg	
Power consumption	13.5 W	

Figure 3: Layout of ARINA instrument.

The instrument acceptance is 10 cm^{2}sr, which is by a factor of a few tens higher than the acceptance of the instrument with the help of which the main results on observation of seismic effects in particle fluxes were obtained.

4. First experimental results

Observation of high-energy charged particle bursts. During the first year and a half of continuous measurements of particle fluxes several dozens of particle bursts were detected (at the level >5σ). An example of observation of one of the bursts is shown in Fig. 4. Combined analysis of spatial and temporal distributions of particle bursts and solar data, geomagnetic activity indices, geomagnetic pulsations, geophysics phenomena showed the different origin of particle bursts: solar-magnetospheric, seismic, or thunderstorm. It was estimated the part of seismic bursts of particles (earthquake precursors): 15–20 % among all bursts registered.

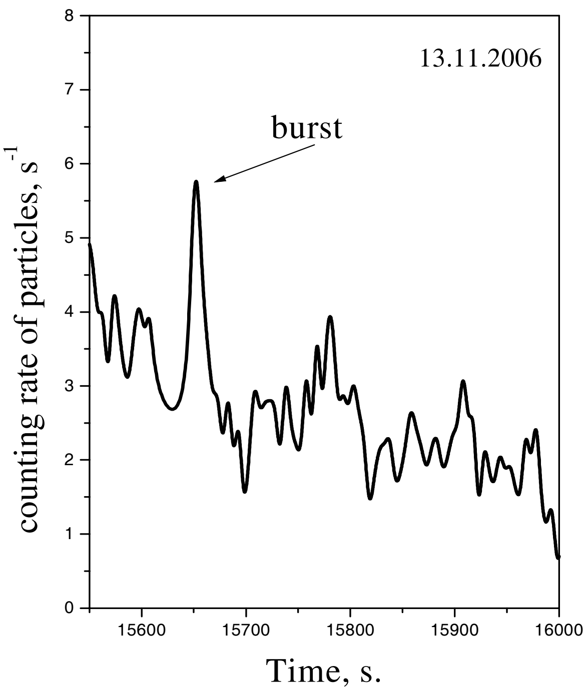


Figure 4: An example of observation of high-energy electron burst (L = 2.2).

Geographical locations of high-energy charged particle bursts observed in ARINA experiment during considered time period are presented in fig.5 (black stars; more large symbols — the bursts, possible precursors of earthquakes; in case of these bursts earthquakes occurred several hours later at L shell of bursts). Also in this figure the locations of the epicenters of some earthquakes are shown (red stars), red arrows connect earthquakes and particle bursts – their possible precursors.

At present time the following approach can be realized for using of particle bursts as a means of remote diagnostics of local magnetospheric and geophysical disturbances, including seismic one. If particle spectrometer on the satellite registered particle bursts, then it is possible to determine the location (latitude) of local disturbance of the radiation belt. This disturbance must be positioned on L shell of particle burst. In the case of seismic disturbance, generated during preparing earthquake, latitude of the epicenter of forthcoming earthquake will be determined. If the difference in times of observation of particle groups with different energies is registered, then, analyzing the temporal structure of burst and energy spectra of particles, it is possible to obtain the limitation for longitude range of locations of possible radiation belt disturbance, that is for longitude of forthcoming earthquake epicenter. Fig.6 illustrates such an approach. It is necessary to note that preliminary data obtained in ARINA experiment shows that particle bursts can give additional useful information for operative prognosis of earthquakes.

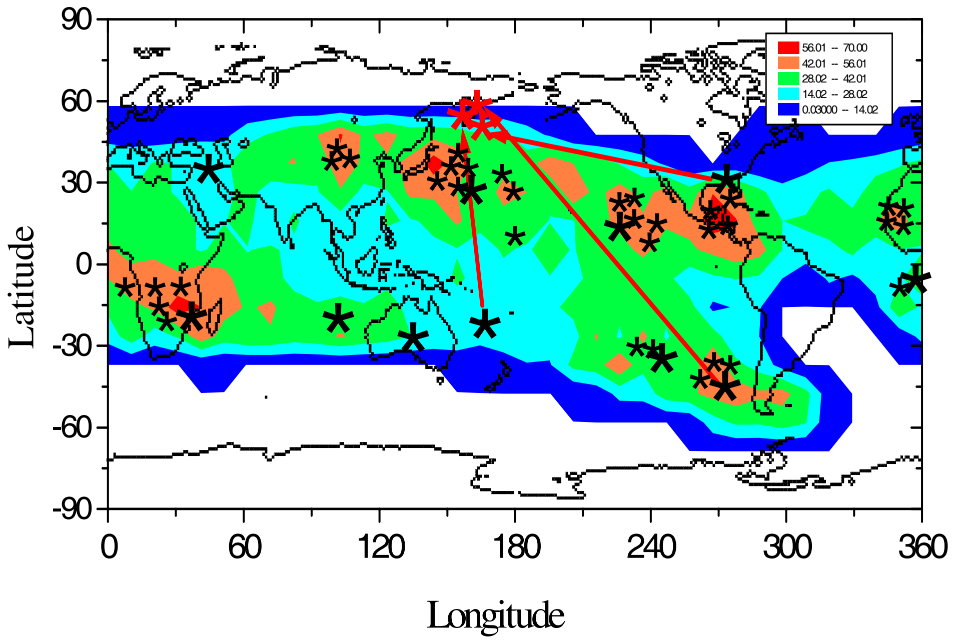


Figure 5: Geographical distribution of high-energy particle bursts, plotted on data of experiments: MARIYA-2, GAMMA-1, SAMPEX/PET and ARINA. Separate symbols (black stars) are plotted for ARINA bursts.

Observation of solar-magnetospheric events. Together with the main goals, a study of variations of the proton and electron fluxes coming from the interplanetary space is carried out in the ARINA experiment. Such particles are recorded in high-latitude sites of the orbit. They are galactic and solar cosmic rays, and also particles accelerated by shock waves in the interplanetary space and generated by planetary magnetospheres (for example, by that of Jupiter). There were observed several increases of particle fluxes, caused by solar events. Most strong variations of fluxes of protons and electrons were measured in December 2006 after series of powerful solar flares. Special analysis of different counting rates of trigger signals pointed out the increase of gamma ray flux (3–20 MeV).

Comparison data obtained in ARINA experiment with measurement results on proton and electron fluxes in other satellites (GOES, POES, PAMELA etc.) shows consistent picture of observational data in a whole. But at that some additional features were revealed in ARINA experiment, caused seemingly by the differences in satellite orbits and energy ranges of particles registered.

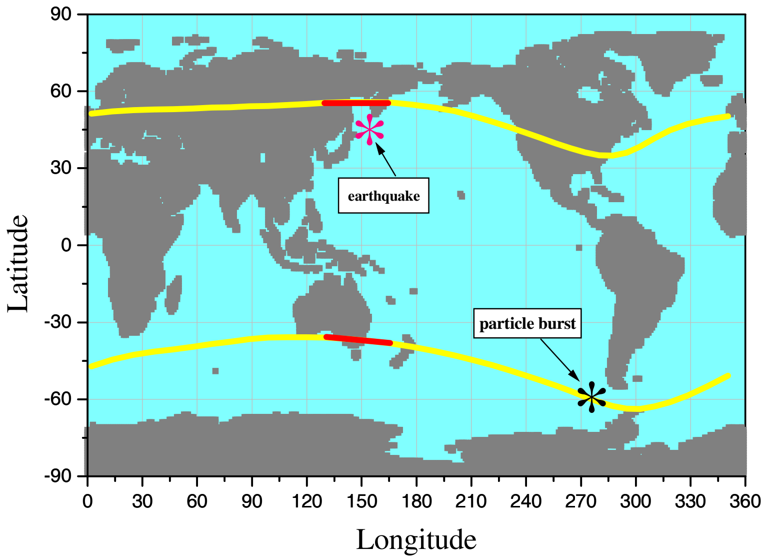


Figure 6: Events 13.11.2006: particle burst (4h 20m) and earthquake $M = 5.0$ (6h 30m).

2.3.7.2. The Project "MONICA": "Monitor of Cosmic Ray Nuclei and Ions"

1. Scientific objectives

The main project scientific objectives are:

- Study of cosmic rays 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.

2. Research subjects and tasks of experiment

The research subjects of project MONICA are the fluxes of solar energetic ions, as well as of anomalous and galactic cosmic ray ions in the energy range 10–300 MeV/n in vicinity of the Earth, whose magnetic field will be used as a separator of ionic charge.

The main tasks of space experiment MONICA are the following:

- Measurement of ionic charge states, as well as elemental, isotope composition and energy spectra of SEP fluxes from He to Ni in 10-300 MeV/n energy range for individual SEP events (including small impulsive SEP events). Study the evolution of these characteristics in time during development of active processes on the Sun.
- Measurement of ACR ion ionic charge and isotope composition, including new elements and isotopes, which have been observed on ACE (sulfur, isotopes of oxygen and neon and others); measurement of ACR energy spectra.

- Measurement of GCR and ACR fluxes modulation with the purpose of study of conditions of particle propagation in heliosphere.
- Study of CR penetration into Earth magnetosphere under conditions of its strong disturbances during the solar-magnetosphere events.

3. Instrumentation

The monitoring of CR fluxes from hydrogen to iron in the energy range 10–300 MeV/n is proposed to realize with the high acceptance spectrometer-telescope MONICA, developed on the base of a stack of silicon strip detectors having the high spatial, mass and energy resolutions. The detectors of similar type were applied earlier in space experiments NINA, NINA-2, PAMELA prepared by Moscow Engineering Physical Institute (MEPhI), Lebedev Physical Institute (LPhI) and Ioffe Physics Technological Institute (PhTI) in collaboration with National Institute of Nuclear Physics of Italy (INFN).

The MONICA instrument physical scheme is presented in fig. 1. Spectrometer consists of 22 detector planes D1-D22 of various thicknesses (from 0.230 μ to 1 mm). Each plane represents a set of silicon coordinate sensitive detectors. The full thickness is about 5 g/cm^2. First two planes D1, D2 define the aperture of the instrument (±45°). They have sizes 160×160×0.230 mm, distance between them is 160 mm. The planes D3-D22 form calorimeter. The sizes of planes D3–D22 are chosen so that they correspond to the telescope aperture. The thickness of planes D3–D22 is optimized to achieve the best spectrometer mass resolution. The overall dimensions of calorimeter are 320×320 mm. Under the stack of silicon sensors the anticoincidence detector AC (plastic scintillator detector with thickness of 10 mm) is mounted. Side anticoincidence detectors SAC1-SAC4 (plastic scintillator detector with thickness of 10 mm) and bottom anticoincidence detector AC are used to reject background from secondary productions inside the instrument induced by high energy CR particles.

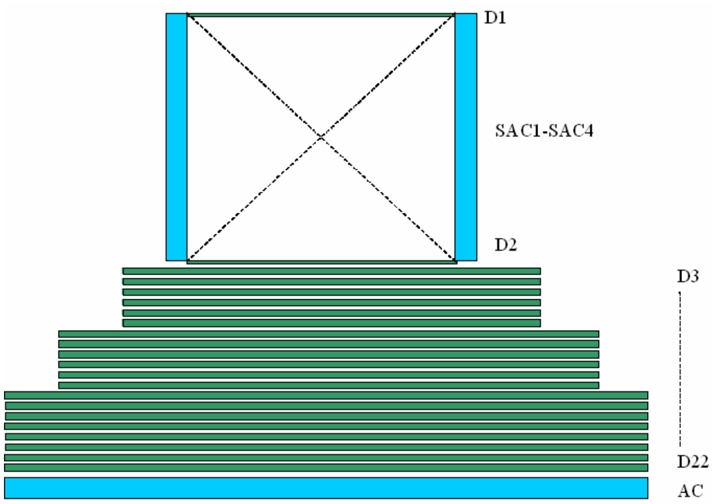


Figure 1: MONICA instrument physical scheme.

The main first level trigger is following: D1×D2×ANTI (AC+ SAC1+SAC2+SAC3+SAC4). To optimize the CR particles detection in different background conditions some configurations of trigger are foreseen, when the signals from separate segments of planes D1, D2 are switched in the coincidences.

The identification of particles (charge, mass), detected by spectrometer MONICA, is carry out by the ΔE-E method and its modifications. The particle incident angle is defined by coordinates of hitted strips in detectors D1, D2. The energy of detected particle is determined as by range and by energy deposits in each detector.

Spectrometer MONICA has the geometrical factor two times more, than similar instruments onboard ACE and at 20-30 times more, than instruments used in experiments in orbits inside the Earth magnetosphere (SAMPEX, NINA and NINA-2).

Main physical and technical performances of telescope-spectrometer MONICA are presented in Tables 1 and 2 correspondingly.

Table 1. The physics characteristics

Geometrical factor	100 cm^2 sr
Aperture	±45 degrees
Angular resolution	1 degree
Energy range for H	7–70 MeV
He	7–70 MeV/n
O	16–150 MeV/n
Si	20–210 MeV/n
Ca	24–260 MeV/n
Fe	25–290 MeV/n
Ni	27–310 MeV/n
Energy resolution	1 %
Mass resolution (A.E.M.)	
H	0.02
CNO	0.08
Fe	0.2
Time resolution	50 ns
Dead time	<1 ms

Table 2. The MONICA technical performances

Outline dimensions, mm	520×520×450
Mass, not more, kg	50
Power consumption, not more, W	80
Power supply voltage, V	27
Matter in aperture not more, g/cm^2	0,05
Information download, session per day	1 day^{-1}

The MONICA instrument will be installed onboard the small-size satellite SSA n.2, developing by Lavochkin Science and Production Association. Moscow Engineering Physical Institute (MEPhI), Lebedev Physical Institute (LPhI), Ioffe Physics Technological Institute (PhTI) and Joint Institute for Nuclear Research (JINR) will participate in developing of spectrometer MONICA and realization of the experiment. The Moscow Engineering Physics Institute is the leading institution for the MONICA project.

The SSA n.2 orbit parameters will be specified to achieve the MONICA scientific objectives. The required orbit parameters are: type – near-Earth circular; altitude – 600-700 km; inclination - 98°. MONICA instrument should be pointed to zenith.

The experiment will be started in 2011. The observations will be carried out continuously as monitoring mode. Duration of the mission is not less than 5 years.

2.3.8. STATE RESEARCH INSTITUTE FOR APPLIED MECHANICS AND ELECTRICAL DYNAMICS

2.3.8.1. Space Experiment "Impulse Stage 1" "Ionosphere Modification by Pulsed Plasma sources"

Experiment purpose: Study for the ionosphere disturbances and modification at the injection of pulsed plasma flows from the ISS Russian segment.

Space experiment tasks:

- registration and study for electrophysical parameters near the service module of the ISS Russian segment under various conditions of the ISS flight and under different heliogeophysical conditions in the ISS orbit;
- study for the pulsed plasma flow influence on the electrophysical parameters of environment near the surface of the ISS Russian segment, study for the discharge processes on the service module surface;
- registration and study for the spatial-temporal parameters of ionosphere artificial disturbances by the ground measurement means;
- registration of low-frequency broadband signals and emissions by ground means during the plasma injector operation;
- analysis for the signals and electromagnetic wave emissions of ELF/VLF range being the result of the plasma injector operation and study for their propagation down to the Earth surface;
- radar observations and study for the influence of artificial disturbances of ionosphere on the radio wave propagation in the frequency ranges of ultrashort and short waves;
- experimental verification for the ionosphere disturbances monitoring procedure by analyzing waveguide propagation of VLF signals and emissions: amplitude-phase measurements for the signals of ground stations of the radio-navigation system "Alpha" during the plasma flow injection from the ISS Russian segment.

The following should be studied as a result of this space experiment:

- regularities of the electric field disturbance and relaxation around the service module during the injection of pulsed plasma flows;
- regularities of the electron density disturbance and relaxation in the ionosphere during the injection of pulsed plasma flows;
- regularities of ELF/VLF emission generation and propagation down to the Earth during plasma injection from ISS;

- regularities of VLF navigation signal propagation at the presence of plasma formations.

Name of the scientific equipment complex: "NA IPI – SM"

NA IPI – SM composition:

- pulsed plasma injector IPI-100;
- electrophysical parameter monitoring set (KKEP).

IPI-100 performance:

- operation mode - pulsed;
- pulse repetition frequency 2 Hz;
- pulse duration 10…15 μs;
- power consumption 100 W;
- plasma flow mean-mass velocity 15 km/hour;
- ion velocity in the flow, up to 40 km/s.

KKEP performance:

- DC electric field intensity 0.5-6 kV/m;
- AC electric field intensity 0.1-10 kV/m;
- pulsed field counter $10\text{-}2{\cdot}10^4$ Hz;
- current to the probe $(0.1\text{-}1)10^4$ A.

All measurements will be made along the ISS axes X and Y.

Ground measuring complex:

- Troitsk, Moscow region;
- Paratunka, Kamchatka region;
- Vladikavkaz, North Ossetia;
- Vasil'sursk, Nizhny Novgorod region;
- Yakutsk, Republic of Sakha.

The following methods will be used for the diagnostics of artificial disturbances of ionosphere:

- vertical and oblique sounding of ionosphere by ionosondes;
- radar measurements within the ranges of ultrashort and short waves;
- ground observations with the use of ULF/ELF/VLF receivers.

All locations selected for ground measurements are characterized by low background noises that being important in view of the low level of wanted signals generated at plasma injection.

NA IPI – SM delivery to the ISS is planned for November, 2008.

Equipment connection and experiment start are planned for the 1 half-year of 2009.

The experiment should be finished in 2011.