

# Russian Solar Terrestrial Missions

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## 1. Introduction

International cooperation in geophysics has long been vital for global coverage of observations and for effective data exchange. For magnetospheric and solar-terrestrial studies, the space agencies making up the Inter-Agency Consultative Group agreed to coordinate national efforts by forming an international fleet of spacecraft in mutually complementing orbits during 1995-2000. Now a new International Living With a Star program is being shaped for 2005-2012.

This report describes current and future solar-terrestrial space missions of the Russian Federal Space Agency. We provide information on several missions that are at different stages of realization: CORONAS-F, CORONAS-PHOTON, INTERHELIOPROBE, RESONANCE. Also, as well as about space plasma experiments accompanying other national space missions SPECTR-R/PLASMA-F, Phobos-Grunt, and international missions with Russian participation, in particular, planetary missions.

## 2. CORONAS Program

The international CORONAS Program is aimed at investigating the Sun in different phases of the 11-year cycle. On July 31, 2001 the CORONAS-F satellite was launched into orbit with an inclination 82.49 deg, perigee of 500.9 km, apogee of 548.5 km, and period of 94.859 min. The main scientific objectives of the mission are as follows:

- Solar global oscillations, seismological and interior studies.
- Powerful dynamic phenomena of solar activity: active regions, flares, and mass ejections, observed in a broad wavelength range from optical to gamma radiation.
- Acceleration of cosmic rays in active solar events, their outflow, propagation through the interplanetary magnetic field, and impact on the Earth's magnetosphere.

The mission WWW site is <http://coronas.izmiran.ru>.

## 3. CORONAS-PHOTON Mission

The CORONAS-PHOTON mission is the third satellite of the CORONAS program to be launched in 2007. The main scientific objectives of the mission are: temporal dynamics,

spectroscopy and polarization of hard electromagnetic radiation, solar neutrons, solar cosmic rays from the full disk and active regions in a wide energy range from EUV to 2000 MeV.

The Moscow Engineering Physics Institute (MEPhI) is responsible for the scientific payload. The principle investigator is Dr. Yuri Kotov (MEPhI, kotov@mephi.ru). The mission WWW site is [http://iaf.mephi.ru/english/e\\_photon.htm](http://iaf.mephi.ru/english/e_photon.htm)

## 4. PLASMA-F Mission of Opportunity

Plasma and magnetic experiment PLASMA-F (payload of opportunity) will be launched in 2007 onboard radio-astronomical spacecraft SPECTR-R. The SPECTR-R satellite on an orbit with apogee about 350 000 km will be almost permanently in the near-Earth interplanetary medium (7-8 days out of 9-day orbit) and is a good platform for solar wind monitoring. Scientific tasks of the experiment are:

- Investigation of fast solar wind and interplanetary magnetic field variations in the rarely studied frequency range up to 15 Hz.
- Interplanetary medium monitoring in the interests of space weather research and forecast.
- Investigation of magnetospheric acceleration of energetic particles.

Experiment includes magnetic field instrument with two DC and two AC magnetometers, solar wind instrument with six Faraday cups, energetic electron and proton detector and data processing unit. Experiment is conducted by Space Research Institute, with international participation of Slovakia, Czech republic, Greece, Ukraine, China.

## 5. RESONANCE Project

The aim of the RESONANCE project is to study plasma dynamics and wave-particle interactions in the Earth's inner magnetosphere from an orbit corotating with the magnetic flux tubes on L-shells around 5, which are rarely visited by scientific spacecraft. It is a joint project of the Space Research Institute (IKI Moscow) and the Institute of Applied Physics (IPF N.Novgorod) with participation of many other scientific institutions from Russia, France, Finland, Germany, USA, and Ukraine. Currently the project is in the development phase towards the launch in 2009.

The scientific program of the project consists of two parts.

The first, "passive", part, is aimed at the investigation of natural magnetospheric phenomena:

- Ring current and outer radiation belt formation and evolution, MeV electron dynamics.
- Plasma injection development, magnetic field reconfigurations.
- Plasmasphere dynamics and refilling, sub-auroral zone physics.
- The magnetospheric cyclotron maser and its long-term evolution.
- The role of small-scale phenomena in the global dynamics of magnetospheric plasma.
- Mid-altitude auroral zone, polar cap and cusp physics.

Investigations in the frame of the second, "active", part, will focus on the joint experiments of the RESONANCE satellite(s) with ground-based HF heating facilities. We expect that parameters of the natural magnetospheric oscillatory system will change if powerful HF electromagnetic emissions heat the ionosphere and thus modulate the ionospheric mirrors.

The novel type of a magnetosynchronous orbit proposed and designed for this project will allow the satellite to conduct measurements within (approximately) the same magnetic flux tube for sufficiently long time intervals. Preliminary orbital parameters are as follows: apogee: ~30 000 km, perigee: ~1800 km, and inclination: 63.4 deg.

## 5. INTERHELIOPROBE

The INTERHELIOPROBE mission is a part of the future solar program. The Interhelios mission (a prototype of the INTERHELIOPROBE and the Solar Orbiter) was conceived in 1995 as a joint project of IZMIRAN and MPAE. In 1998, the Russian Academy of Sciences and Russian Space Agency adopted the project for further development in stage A and the IZMIRAN and IKI institutes combined their efforts to design a joint mission called INTERHELIOPROBE. Proximity to the Sun will enable imaging of the solar surface with improved spatial resolution, correlated remote sensing observations of the solar surface and heliospheric in situ measurements in the co-rotation mode, unprecedented in situ measurements of fields and particles in the previously unvisited inner heliosphere, and observations of solar and heliospheric events undetectable from the Earth's orbit (microflares, neutrons, etc.). The basic trajectory of the INTERHELIOPROBE mission will be formed with a series of gravity assisted maneuvers at Venus (VGM) realized with a low-thrust engine will place the spacecraft into the operational heliocentric orbit that has a co-rotation interval near perihelion (30-40 solar radii). After at least two co-rotation intervals the following VGM will be used to incline the orbital plane with respect to the ecliptic plane.

## 6. Planetary Missions with Plasma Experiments

### 6.1 Phobos- SOIL Project

The PHOBOS-SOIL (Phobos sample return) project is the only national planetary project in the current decade and it has the highest priority in the Federal space program. About 30 proposals for scientific experiments have been received for the

project from Russian scientific teams. The proposal have been selected from scientific and technical point of view. Mass of the scientific payload is 50 kg. The Lavochkin Space Association is the main contractor of the spacecraft.

In addition to the main scientific objectives such as study of Phobos regolith and subsurface layers in situ and under laboratory conditions to obtain information on the properties of primordial matter of the Solar system, and study of the role of asteroidal impacts in the formation and evolution of terrestrial planets, the mission will address such aspects as study physical conditions of the Martian environment (dust, gas, plasma components) and monitoring of Mars from Phobos orbit. The payload includes plasma-wave sensors set being developed in IKI. Phobos-SOIL is scheduled for launch in October 2009 using Soyuz-2 rocket. Spacecraft arrives to Mars in 10-11.5 months and will remain operational in the vicinity of Mars for about one year.

### 6.2 Mars Express ESA Mission

The ESA/Mars Express Orbiter was inserted into Mars orbit on 25 December 2003. Most of science objectives of Mars Express were inherited from Mars-96 Russian mission and Russian Co-Is are present in six experiments of the mission out of seven. Roskosmos has funded Russian hardware contribution to three experiments: OMEGA, PFS and SPICAM. The latter is dedicated, among other objectives to the study of the upper atmosphere and the ionosphere in the UV spectral range. ASPERA-3 experiment (led by Sweden; Russian Co-Is) is focused on studying the interaction of the Martian atmosphere with the solar wind, especially, the rate in which the atmospheric particles are lost, or "picked up", by the flow of the nearby solar wind. The particle instrument consists of several individual detectors that detect ions and electrons. But its main detectors will measure fast neutrals produced by the direct interaction between the solar wind ions and the atmospheric neutrals.

### 6.3 Venus Express ESA Mission

The ESA/Venus Express mission is scheduled for launch in October 2005. The mission is dedicated to the study of the Venus atmosphere, and will carry an instrument set similar to that of Mars Express. Russian participation is mostly in joint SPICAV/SOIR and PFS experiments. ASPERA-4, a replica of the ASPERA-3 and SPICAV similar to SPICAM, will be the plasma instruments on this mission.

### 6.4 Bepi Colombo

ESA Cornerstone mission Bepi Colombo is scheduled for launch in 2012 to reach Mercury in four years. It consists of two orbiters, MPO on lower orbit and Japanese MMO at highly elliptical 400x12 000 km polar orbit. MMO instruments focus in particular on the study of fields, waves and particles in Mercury's environment. Roskosmos contributes to MPO instruments, with one potential national instrument (Gamma-spectrometer MGSN), and participation to UV spectrometer PHEBUS and ion camera PICAM (part of SERENA package), and to one MMO instrument: sodium camera MSASI. All these experiments excluding MGSN are dedicated to the studies of hermean exosphere and its interaction with the solar wind.