Space Research Institute of Russian Academy of Sciences

4. Information about Scientific Projects of the Federal Space Program of the Russian Federation with are at the Development (Working out) Stage

4.1. InterhelioProbe Mission

The InterhelioProbe space mission aimed at the study of the Sun and inner heliosphere from short distances and out-of-ecliptic positions was developed by the joint effort of Russian and foreign scientists and organizations in 2013-2015 in the frames of the Federal Space Program of the Russian Federation (2006-2015). The continuation of the InterhelioProbe mission development is supported by the new Federal Space Program of the Russian Federation (2015-2025). The main information about the mission is summarized in Table 1.

Two identical spacecraft of the InterhelioProbe mission will be put into heliocentric orbits oppositely inclined to the ecliptic plane and will move spaced by a quarter of a period to enable continuous out-of-ecliptic observation of the solar polar regions, Sun-Earth line, and ecliptic corona.

Table 1. General Information about the InterhelioProbe Mission

Funding	Russian Federal Space Agency (Roscosmos)
Leading scientific organization	Space Research Institute (IKI) of Russian Academy of Sciences
Principal Investigators	L.M. Zeleny (IKI), V.D. Kuznetsov (IZMIRAN)
General Concept	– Multi-wavelength solar observations at short distances from the Sun (up to $60R_S$) – Out-of-ecliptic solar observations (up to 30°) and

	observations of the Sun's opposite side – In situ measurements in the inner heliosphere (and) out of the ecliptic plane
Main scientific objectives	– Solar dynamo and solar cycle – Thin structure and dynamics of solar atmosphere – Corona heating and acceleration of solar wind – Solar flares, coronal mass ejections (CMEs) – Acceleration and transport of solar cosmic rays in the corona and inner heliosphere – Solar-terrestrial relations and space weather
Spacecraft design	Lavochkin Association, Russia
Number of Spacecraft	2
Spacecraft	3-axis stabilized platform, circle-shaped shield with windows, sizes 3.7×5.2×3.7 m^3
Orientation	Sun-pointing
Launcher	"Soyuz-2/1b" rocket with "Fregat" upper stage
Cosmodrome	Baikonur, Republic of Kazakhstan
Launch date	2026-2027
Orbit	Heliocentric, elliptical, Venus-resonance orbits with multiple gravity assists, perihelion 60-70 Rs, aphelion 250-260 Rs, inclination up to 30° to the ecliptic
Mission active operation time	5 years
Total mass of scientific payload	160 kg
Scientific payload	10 instruments for remote sense observations 9 instruments for local measurements
Cooperation in scientific payload development	Russia, Poland, France, Czech Republic, Austria, Germany, Ukraine, UK
Flight Operation Center	Lavochkin Association, Russia
Science Operation Center	IKI, Moscow, Russia
Ground stations	"Medvezgyi Ozera" (64-m antenna)

	"Ussuriysk" (70-m antenna)
Scientific traffic	Up to 1 Mbit/s

Main scientific goals of the InterhelioProbe mission:

I. To contribute to understanding of the solar dynamo mechanisms and solar cycle

II. To better imagine fine structure and dynamics of the solar atmosphere

III. To achieve progress in finding mechanisms of solar corona heating and acceleration of the solar wind

IV. Further understanding of the nature and global dynamics of the most powerful manifestations of the solar activity – solar flares and CMEs – and their influence on the heliosphere and space weather

V. To better recognize processes of generation and transport of energetic particles (solar cosmic rays) at the Sun and in the heliosphere

The scientific instruments of the InterhelioProbe mission and their principal characteristics are listed in Tables 2 and 3.

Table 2. InterhelioProbe instruments for remote-sensing observations

№	Instrument	Measurements	Characteristics	Mass [kg]	Power [W]
1	Multi-functional optical complex **TAHOMAG**	Stokes parameters. Vectors of magnetic and velocity fields at the photosphere. Intensity of white-light radiation.	FOV=500"×500"; dα=0.17"-0.35"; λ=6300.5-6303.5 Å, 3000 Å; dλ=32 mÅ; B=±4000 Gs; d B=2 Gs (line-of-sight)	36	40

2	Multi-channel solar photometer **PHOTOSCOPE**	Solar constant. Global oscillations of the Sun.	FOV=10°; λ=3000-16000 Å; dλ=100 Å; dt=16 s	6.5	12
3	EUV and SXR telescope **TREK**	EUV and SXR images of the Sun. Localization of active regions. Fine structure of the solar atmosphere. Observations of high temperature plasma.	FOV=0.7°-2°; dα=1.2"-3.5"; λ=131, 171, 304, 8.42 Å	14	15
4	Solar HXR telescope-spectrometer **SORENTO**	Images of solar HXR sources and their energy spectra.	FOV=1.5°; E=5-100 keV; dα=7"; dt=0.1 s	8	6
5	Solar coronagraph **OKA**	White-light images of the solar corona, eruptive events, transients, CMEs.	FOV=8°; dα=28"; λ=4000-6500 Å	5	7
6	Heliosphereic Imager **HELIOSPHERA**	White-light images of the outer corona and inner heliosphere, CMEs.	FOV=20°; dα=70"; λ=4000-6500 Å	5	7
7	X-ray spectrometer **CHEMIX**	Spectra of solar X-ray emission. Chemical composition of solar corona plasma.	FOV=10°; dα=5'; λ=1.5-9 Å	6	21.5
8	Hard X-ray polarimeter **PING-M**	Fluxes, energy spectra of solar soft X-ray emission. Fluxes, energy spectra, polarization of solar	E_x=1.5-25 keV; dE=200 eV (at 5.9 keV); dt≥0.1 s $E_{x,\gamma}$=20-600 keV; dE/E=0.12 (at E=60 keV); dt≥0.1 s;	13.5	19.5

		hard X-ray emission.	E_{polar} =18-150 keV		
9	Scintillation gamma-spectrometer **HELIKON-I**	Fluxes and spectra of hard X-rays and gamma-rays (of not only solar origin).	E=0.01-15 MeV; dE/E=0.08 (at E=662 keV); dt=0.001-8 s	10.5	10
10	Gas gamma-ray spectrometer **SIGNAL**	Fluxes and spectra of solar gamma-rays.	E_γ =0.03-5.00 MeV; dE/E=(1.7±0.3)% (at 662 keV) dt=0.1-60 s	5	20
				109.5	**158.0**

Table 3. InterhelioProbe instruments for in situ measurements

№	Instrument	Measurements	Characteristics	Mass [kg]	Power [W]
1	Analyzer of solar wind electrons **HELIES**	Distribution functions of solar wind electrons.	FOV=120°x360°; E=1-5000 eV; dE/E=0.18	2.5	3
2	Analyzer of solar wind ions **HELION**	Energy and angular spectra of solar wind ions.	Ions: FOV=120°x100°; E/q=0.04-12 keV/q; dE/E=0.07; dt=10-100s Electrons: FOV=15°x60°; E=0.35eV-6.30 keV; dE/E=0.16	1.8	1.5
3	Energy-mass-analyzer of solar wind plasma **PIPLS-B**	Energetic and mass composition of solar wind ions; distribution functions of solar wind	FOV=45°x45°; E=1-20 keV; m/q=2-9; m/dm=10-40; dα=2°-9°; dE/E=0.05; dt>1 min	2.5	4

		ions.			
4	Dust particle analyzer **PIPLS-A**	Interplanetary and interstellar dust particles.	m=10^{-16}-10^{-6} g; m/dm=100; v=5-100 km/s	2.5	9.8
5	Magnetometer **HELIOMAG**	Heliospheric magnetic field and its disturbances.	B=±1000 nT dB=2 pT	1.9	5
6	Electromagnetic wave complex **IMWE**	Fast variations of magnetic fields, ion fluxes.	f =300 Hz - 30 MHz E/q=0.05-5 keV/q; dE/E=5-7%; dt=0.031 s	9.5	18
7	Radiospectrometer **RSD**	Radio emission of solar corona and solar wind plasmas.	f=15 kHz – 300 MHz DR=80 dB	2.2	10
8	Charged particle telescope **SKI-5**	Energetic charged particles in the interplanetary space.	Electrons: E=6-40 keV, 0.15-10 MeV Protons: E=2-120 MeV Ions: E=10-200 MeV/nucleon	4.5	14
9	Neutron detector **INTERSONG**	Solar neutrons, hard X-rays and gamma-rays.	E_n=3-100 MeV; E_γ=0.03-10 MeV	6.5	15
				33.4	**80.3**

Expected scientific results of the InterhelioProbe mission:

I. *For the goal I (to contribute to understanding of the solar dynamo mechanisms and solar cycle):*

- Structure of magnetic field in the solar polar regions
- Meridional flows and magnetic field transport to the solar poles

- Solar constant and its variations at different heliolatitudes

II. *For the goal II (to better imagine fine structure and dynamics of the solar atmosphere):*

- Fine magnetic and plasma structures at the photosphere and in the solar atmosphere at various heliolatitudes
- Their dynamics and role in formation of the solar atmosphere and initiation of energy release at small scales

III. *For the goal III (to achieve progress in finding mechanisms of solar corona heating and acceleration of the solar wind):*

- Energy release processes at different scales and their role in heating of the solar corona and acceleration of the solar wind
- Wave and turbulent processes in the solar wind, their role in acceleration of the solar wind

  Properties of the solar wind at different heliographic latitudes and distances
- Structure of the heliospheric magnetic field

IV. *For the goal IV (further understanding of the nature and global dynamics of the most powerful manifestations of the solar activity – solar flares and CMEs – and their influence on the heliosphere and space weather):*

- Trigger mechanisms of solar flares and CMEs

- Links between flares and CMEs
- Effects of solar flares and CMEs on the inner and outer corona, and the heliosphere (magnetic clouds, shock waves)
- Heliolongitude and heliolatitude spread and dynamics of CMEs

V. *For the goal V (to better recognize processes of generation and transport of energetic particles (solar cosmic rays) at the Sun and in the heliosphere):*

- Acceleration processes of charged particles and processes of generation of neutrons, hard X-ray and gamma-ray emission in solar flares
- Acceleration processes of charged particles related with the formation and propagation of CMEs
- Relations between active processes at the Sun and energetic particles in the inner heliosphere
- Transport processes of energetic charged particles in the corona and inner heliosphere

References:

V.D., Kuznetsov, L.M. Zelenyi, I.V. Zimovets et al. The Sun and Heliosphere Explorer – The InterhelioProbe Mission // Geomagnetism & Aeronomy, Vol. 56, № 7, 2016 (accepted)

Oscillations of energetic ions flux near the Earth’s bow shock

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A new type of variability in the foreshock and magnetosheath is revealed with the recent energetic particle experiments monitor of electrons and protons (MEP) onboard Spectr-R spacecraft and solid-state telescope onboard Time History of Events and Macroscale Interactions during Substorms spacecraft, which have high time resolution.

Oscillations of energetic ion fluxes are observed in the broad energy range ~4–400 keV, with periods 10–30 s, often rather monochromatic waveform and accompanied with magnetic oscillations. Such events are not so rare (~100 cases are found for 2007–2012) but are associated mostly with high-speed solar wind.

Petrukovich, AA; Inamori, T; Balaz, J; Kudela, K; Slivka, M; Strharsky, I; Gladyshev, VA; Sarris, T; Sarris, E; ,Oscillations of energetic ions flux near the Earth's bow shock,Journal of Geophysical Research: Space Physics, 120, 4700-4710, 2015

“Zero” magnetic field and its role in interplanetary and near planetary expeditions

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The effects of zero magnetic field conditions on cardiovascular system of healthy adults have been studied. In order to generate zero magnetic field, the facility for magnetic fields modeling “ARFA” has been used. Parameters of the capillary blood flow, blood pressure, and the electrocardiogram (ECG) monitoring were measured during the study.

All subjects were tested twice: in zero magnetic field and, for comparison, in sham condition. The obtained results during 60 minutes of zero magnetic field exposure demonstrate a clear effect on cardiovascular system and microcirculation. The results of our experiments can be used in studies of long-term stay in hypo-magnetic conditions during interplanetary missions.

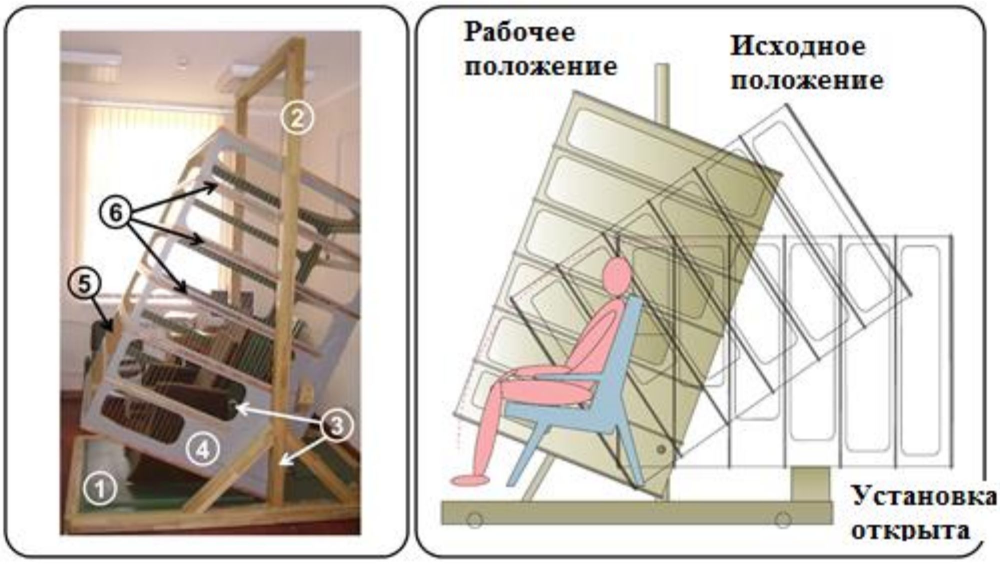

Figure 1. The facility for magnetic fields modeling - "ARFA"

Yu.I.Gurfinkel, O.Yu.At'kov, A.L.Vasin, T.K.Breus, M.L.Sasonko, R.Yu.Pishchalnikov, Effect of zero magnetic field on cardiovascular system and microcirculation, *Life Sciences in Space Research* **8** (2016)1–7.

Yu.I.Gurfinkel, O.Yu.At'kov, A.L.Vasin, T.K.Breus, M.L.Sasonko, R.Yu.Pishchalnikov, Effect of zero magnetic field on cardiovascular system and microcirculation, *Life Sciences in Space Research* **8** (2016)1–7.

Magnetic storms and variations in hormone levels among residents of North Polar area – Svalbard,

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Four examinations in 1991–1992 of the blood concentration of adrenal hormones (cortisol) and thyroid hormones (triiodothyronine (T3) and thyroxine T4) and their dependence on space and terrestrial weather parameters have been done for large groups of healthy inhabitants (980 persons) of high latitudes (Svalbard, the most northerly in the world year-round inhabited settlements). The aim of this study was to find the possible sensitivity of these biochemical parameters to variations of external natural factors at high latitudes.

The obtained data indicate that the most expressed dependence of concentration of the three studied hormones is on the level of geomagnetic activity (GMA). For two of the four seasons (June and October) with increasing levels of GMA a significant ($p < 0.05$) increase in cortisol concentration was observed. For T3 dependence was found only in summer.

Thus it was shown for the first time that at high geographical latitudes with increased level of GMA a significant change in the level of secretion of several hormones leads to the type of adaptive stress reaction.

T.K. Breus, E.R. Boiko, T.A. Zenchenko. Magnetic storms and variations in hormone levels among residents of North Polar area – Svalbard, Life Sciences in Space Research, Volume 4, January 2015, Pages 17–21.