National Heliogeophysical Complex of the Russian Academy of Sciences
In the field of solar physics:
Large Solar Telescope/Coronagraph;
Multi-wave radioheliograph;

In the field of near-Earth space physics:
Radiophysical complex;
Lidar-optical complex;
Chain of stations Norilsk–Irkutsk, Arctic network of coherent HF radars.

The project “National Heliogeophysical Complex of RAS” (NHGC) includes interrelated sub-projects (instruments):

The Russian Government
Government Decision № 1504, December 26, 2014
Public funding for the design and construction of the National Heliogeophysical Complex of the Russian Academy of Science
Space weather is an urgent problem of space exploration

**Space weather effects**

- Space radiation effects on spacecraft and aircraft instruments, astronauts and high-flyer crews;

- Changing conditions of radio wave propagation and impact on radio, radar and navigation systems;

- Changing spacecraft orbits due to heating of the upper atmosphere;

- Geomagnetically induced (earth) currents in extended conducting systems: pipelines, cables, power and communication lines, railway roads in high latitudes;

- Modification of the atmosphere chemical composition and properties;

- Impact on biological objects and humans.
Objectives of the “National Heliogeophysical Complex of RAS” project:

- Get to a new level of development of experimental (ground-based) research in the field of solar-terrestrial physics,
- Solve urgent fundamental and applied problems in the interests development of new space technologies.

**Lines of basic research:**

- Studying solar activity (magnetic fields, flares, plasma ejections, and other) and its effect on space weather;
- Studying the magnetosphere–ionosphere–atmosphere system and effects imposed on it by solar factors and meteorological and lithospheric processes.

**Applied research and developments:**

- Effects of space factors on operation of spacecraft and various engineering systems – radio communication, radar, GPS-GLONASS and other;
- Monitoring of near-Earth space, spacecraft and space debris;
- Developing methods for solar activity and near-Earth space monitoring and prediction to the benefit of different consumers.
The Complex is developed on the basis of the ISTP observatories equipped with a great variety of instruments including unique ones.
Large Solar Telescope/Coronagraph with 3-m mirror;

**Basic scientific mission:**

- Studying the structure of the solar atmosphere with previously impossible spatial, time and spectral resolution;
- Studying the nature of solar magnetism and solar periodicity;
- Studying the processes of energy release in flares and other dynamic phenomena;
- Monitoring solar processes and forecasting solar activity.

Earth’s size as compared to solar spot
Overall specifications of the Large Solar Telescope: LST-3

- Entrance pupil diameter: 3 meters
- Primary mirror focal distance: 5.65 meters
- Spectral range: 0.38-2.3 μm
- Field of view:
  - FOV in coronograph mode: 5.5 arcmins
- Coronograph aperture: 70 cm
- Equivalent focal distance (telecentric beam):
  - coudé: 40 and 80 meters
  - Nasmyth: 20 meters
- Spatial resolution: better than 0.1 arcsec
- Main scientific instruments:
  - Long slit spectrograph
  - Integral field spectrograph
  - Narrow band filtergraphs (Fabry-Pérot, Lyot type)
  - Wide band filter system
- Full Stokes vector polarimetry unit: after M2 mirror (before scientific instruments)
Presumable view of LST-3 telescope with the technology building in the Sayan Observatory
Multi-wave radioheliograph for 3–24 GHz frequency range

Radio observation with high spatial, time and spectral resolution will enable us to do the following:

Determine structure of coronal magnetic field – the energy source of explosive processes in the solar atmosphere;

Develop reliable forecasting methods;

Reveal the regions of magnetic field energy conversion into plasma particles;

Identify mechanisms of electron acceleration, flare heating, and processes of energy transfer in the solar atmosphere.

Layout of antenna field: three T-shaped arrays with beam length up to 1 km:
3-m diameter – 129 antennas,
1.8-m diameter – 192 antennas,
1-m diameter – 20 antennas.
Radioheliograph (aerial view)
A complex of spectropolarimeters

- Monitoring of solar activity in crucially broad range of 0.05–40 GHz;
- Calibration of intensity measurements with radioheliograph in Badary Radio Astrophysical observatory ISTP SB RAS;
- Developing systems and testing instruments for global Russian network.
Multi-purpose Incoherent Scatter Mesosphere–Stratosphere–Troposphere Radar (IS-MST radar)

Main purposes of IS-MST radar:

- Measurements of the neutral atmosphere parameters within 10–100 km altitude range. Monitor physical processes and relationships in the lithosphere–atmosphere system.

- Observations of plasma parameters at 100–2000 km altitudes. Monitor physical processes and relationships in the atmosphere–ionosphere–magnetosphere system.

- Development of control systems for events of artificial influence on the ionosphere.

- Monitoring the near-Earth space. Monitor the state and trajectory parameters of spacecraft and study space debris distribution.

- Radio astronomy observations of radiation of the Sun and other radio sources.

- Environmental monitoring of the atmosphere and circulation processes over and around Lake Baikal.

- Development of promising methods of diagnostics and forecasting of the near-Earth space conditions.
Basic characteristics of present-day multi-purpose IS-MST radar

**Basic specifications:**
1. Working frequency ~ 160 MHz
2. Peak radiation power – 2 MW
3. Radiation cycle covering – 33%
4. Receiving bandwidth – up to 5 MHz
5. Pulse length – 10–5000 µs
6. Recurrence frequency – 75–2000 Hz
7. Arbitrary pulse modulation
8. Circular polarization – right and left
9. Antenna type – phased array

**Configuration of antenna system**
provides maximum spatial coverage of the region to be sounded and creates conditions for interferometric measurements. For the purpose, the antenna system of IS-MST radar is split into two areas in the magnetic meridian direction, sized ~ 40×40 m, distance between them is about 100 m.
The prospective antenna elements
Diagnoses of dynamics in the lower and middle atmosphere using the MST method.

Lake Baikal ecology
Altitudes 10–100 km.

Study interactions within the ionosphere – plasmasphere system.
Measure variations in the ion composition and tracks of plasma fluxes.
Altitudes 500–2000 km.

Radio astronomy observations of radiation of the Sun and space radio sources.
Studying radio storms and radio signal scintillations.

Studying interactions in the atmosphere–ionosphere system using the IS method.
Multi-parameter diagnostics of the ionospheric plasma.
Interferometry.
Altitudes 100–500 km.

Monitoring of spacecraft and "space debris".
Development of methods to enhance accuracy and data rate of space monitoring.
Altitudes 100–5000 km.

Comprehensive diagnostic of phenomena occurring upon powerful high–frequency impact on the ionosphere.
IS-MST radar near Lake Baikal
Russian segment of the network of coherent HF radars

**Main purposes**
- Solar wind interaction with the magnetosphere and ionosphere;
- Atmospheric gravity waves;
- Natural and artificial plasma inhomogeneities.
EKB Radar (Ekaterinburg)

**HF radar specifications**

- **Type of antennas**: Phased antenna array (16 elements)
- **Peak power**: 16.6 kW
- **Frequency range**: 8–20 MHz
- **Diagram beam width**: 3.6°
- **Azimuthal scanned sector**: 52°
- **Pulse length**: 100–300 µs
Optical studies of the Earth middle and upper atmosphere and the near space

Objectives:
- studying atmospheric and ionospheric processes and phenomena;
- measurements of profile characteristics: temperature, wind, energy fluxes, aerosols, content of atoms, molecules, ions, and electrons, naturally and under heliogeophysical disturbances of various origin.

Applied effects (phenomena):
self radiation, scattered radiation.

Measurement technology:
photometry, laser sounding.
Draft view of technology building to install optical instruments
Monitoring of atmospheric processes and phenomena

Passive optical instruments: interferometers, spectrographs, spectrometers, photometers, all-sky cameras.
Mesosphere-Stratosphere Lidar

Parameters measured:
- wind temperature, velocity, and direction;
- aerozol concentration in strato- and mesosphere;
- optical properties of Na layer in mesosphere;
- ozon in stratosphere.
Altitudes studied: up to 100–120 km.

Applied effects of laser radiation interaction with the atmospheric medium:
- elastic (Mie), molecular (Rayleigh) scattering;
- Raman scattering;
- differential absorption;
- resonant scattering (fluorescence).

Area of receiving antenna – 4.7 m², laser pulse energy – 1.6 J.
DATA CENTRE

Data storage for all NHGC facilities
Estimated capacity: 250 PetaBytes
Storage duration: 25 years
Server racks: ~ 240
Power: 7 MW