Table 1. Scientific payload proposed for the «Environment» experiment.

| Device | Measurement | Weight |
|---|---|---|
| Wave probe WZ | Electric current density $J$: Frequency range 0.1 Hz ... 40 kHz, Noise $10^{-12}$ A/cm$^2$Hz$^{1/2}$ Magnetic field $B$: Frequency range 0.1 Hz ... 40 kHz Noise $10^{-13}$ T/Hz$^{1/2}$ Electric potential $\varphi$: Frequency range 0.1 Hz ... 40 kHz Noise $10^{-6}$ V/Hz$^{1/2}$ | 240 g |
| Electric probe ES | Electric field E: Frequency range 0.1 Hz ... 200 kHz Noise $10^{-6}$ V/Hz$^{1/2}$ | 120 g |
| Flux-gate magnetometer FGM | Frequency range DC — 20 Hz Noise $10^{-11}$ T | 36 g |
| Search-coil magnetometer SC | Frequency range 10 Hz ... 200 kHz Noise $10^{-14}$ T/Hz$^{1/2}$ | 110 g |

veniently placed in any location onboard the ISS by the astronaut. The nano-satellite booms should be manually deployed and the side (SP) should be oriented properly by the operator. The operation of a nano-satellite will be controlled by the ISS control system using short-range telemetry (TM). A set of such nano-satellites placed along and across the ISS will reproduce a spatial structure of the ISS electromagnetic environment and will allow localizing anomalous areas for further monitoring.

The nano-satellite design is a miniaturized copy of a micro-satellite structure [2]. Moreover, it will be simplified because no orientation system or automatic booms deployment system is needed. A special scientific payload will be manufactured (wave and electric probes, flux-gate and search-coil magnetometers). The main parameters of the scientific payload are given in Table 1. It should be noted that a wide frequency and dynamic range of measurements of the electromagnetic parameters ensures integration of the problems of local diagnostics and remote sensing. Short-range telemetry will be developed by the same principles as the already existing systems. The simplest embodiment seems to be based on the cellular phone technology. To avoid any additional electromagnetic interference, it is very attractive to apply the principles of infrared communication systems for development of the short-range telemetry. Such a possibility was already studied by the RSC «Energiya».

Use of such space-saving and cost-efficient nano-satellites is highly promising. It is subsequently planned to complement nano-satellites by the stellar imager and to use nano-satellites in the tethered or free-floating mode. It would enable the structure of electromagnetic environment of space stations, as well as the micro-formations in ionosphere, to be closely monitored.

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«Aeros» Experiment

# PHYSICAL AND AERONOMICAL EXPERIMENTS ABOARD THE ISS


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The purpose of the «Aeros» experiment is to conduct a series of basic physical and aeronomical experiments on study of gas and plasma environment of the ISS by means of space-borne mass-spectrometric (MS), spectrophotometric (SP) and other measuring instruments [3]. The main objectives of these experiments are as follows:

— study of effective cross-sections of scattering of the atoms and molecules of various gases in the multi-component free stream of the Earth's upper atmosphere;

— study of the mechanisms of the ISS glow and of its influence on the spacecraft systems operation;

— study of variations of the molecular content of the upper atmosphere during the maximum of solar activity;

— study of physical processes in the upper atmosphere and ionosphere to reveal the factors, which could be messengers of earthquakes and of other cataclysms.

Numerous theoretical and experimental results on studying the short-range intermolecular forces were accumulated over the past three decades. The principal results of measurement of the scattering cross-sections were obtained in experiments with high-energy beams ($E \approx 1$ KeV) in accelerators. The medium energy region ($E \approx 10$ eV), which is responsible for the interaction of the spacecraft with the atmospheric free stream, is not fully studied, whereas most of the theoretical and applied problems of rarefied gases kinetics require accurate data on potentials of intermolecular forces exactly in this energy region. The problem of formation of a proper external atmosphere in the vicinity of a spacecraft at high altitudes could be classified among this kind of problems [2].

Collision processes are largely responsible for the luminescence in the Earth's atmosphere and above the spacecraft surface in the shadow parts of the orbit. There is convincing data from satellite experiments on anomalous luminescence of the atmosphere in various wave ranges, which precede the earthquakes. The total seismicity of Earth, as well as the seismicity of its individual regions depends on 11-year cycle of solar activity. The frequency of the most powerful earthquakes (magnitude > 7.5) is increased in the maximum of the cycle, while the periods of their occurrence are connected with the active processes in the Sun.

Spacecraft glow gives rise to adverse effects on space-borne systems of optical sensors. Just the first steps are currently taken to provide a quantitative description of these phenomena [5].

Properties of rarefied gas of the upper atmosphere are defined by the solar energy transfer through the interrelated «magnetosphere — thermosphere — lower atmosphere» system. This circumstance is responsible for the complexity and inadequacy of analysis of the available experimental data. Therefore, further space experiments are needed to revise theoretical concepts of the nature of physical-chemical processes in the upper atmosphere. Even the most adequate models of the upper atmosphere developed abroad and in our country (MSIS-77, CIRA-72-78-86, DTM*, AEROS, GOST-74*) are still far from the optimal description of variations in the content and density of the upper atmosphere. In particular, it concerns the conditions of the high solar and geomagnetic activities, as these models have been developed with use of the data from the American «Atmospheric-Explorer» program conducted in 1973-1990 years (minimum of solar activity). The best currently available models are approximately equally valid and differ by the value of relative error of about 20-30 %. However, the error of the models can reach 50-100 %, when sporadic disturbances are arising in the atmosphere (solar flares, geomagnetic storms).

The first experiments onboard the ISS will be performed during the period of maximum of solar activity (2001-2002 yrs). So, there is a unique opportunity to study also the solar-terrestrial links under the extreme conditions of the active Sun.

*Conception and methods of measurement.* The following algorithm is proposed to determine the effective scattering cross-sections and parameters of the station glow:

— a controlled source of working gases is installed onboard the ISS (the parameters of the flow from this source should be known with high accuracy);

— the selected working gases should be those, which are absent in the upper atmosphere and which have essentially different molecular weights, for instance, Ne, Kr, Xe;

— a sensitive MS device is mounted onboard the ISS, which registers both the flows of atmospheric components at a given altitude and the re-entered flows of injected gas which is scattered on the multi-component free stream;

— a SP device is also mounted onboard the ISS, which registers the radiation from the region of the station glow;

— the sought cross-sections from the selected model of intermolecular interaction and matching photometric characteristics will be determined by on-board measurements and by the results of numerical simulation of this experiment to obtain the desired apparatus functions.

We have extensive experience of laboratory measurements of the total cross-sections for scattering of inert gases in the region of relative energies of interaction of about 7-17 eV [1] as well as verified algorithms of mathematical simulation of the flows of rarefied gas [4]. It will enable several procedures to be proposed for determination of cross-sections for scattering of gaseous particles in the full-scale experiment at the altitude of 200-500 km [3].

The experiment will be conducted with application of the instrumentation developed at the Physics and Engineering Institute for Low Temperatures of

* Cyrillic abbreviator of name.

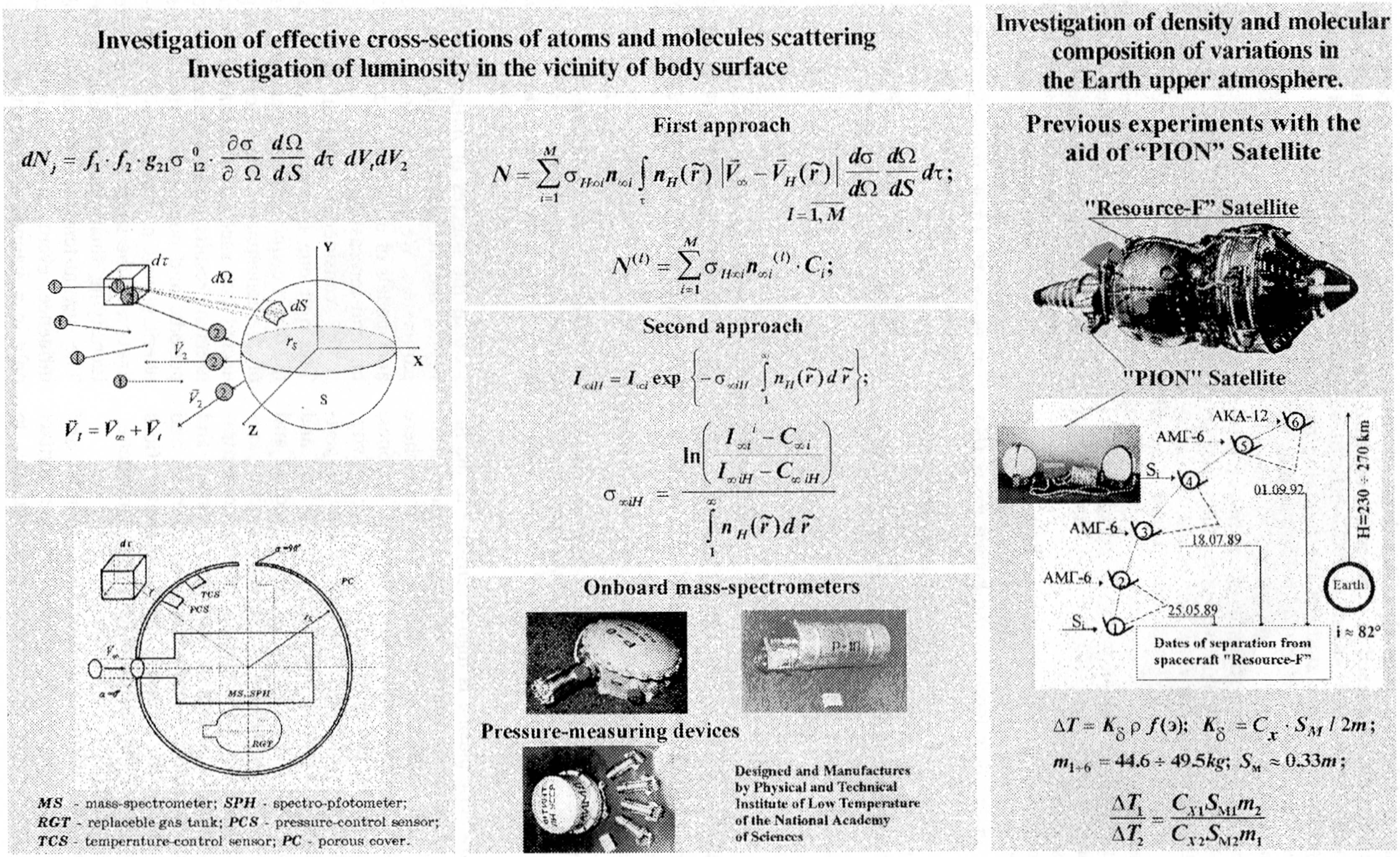


Fig. 2. «AEROS» Experiment (Institute of Technical Mechanics NANU-NSAU). Realization of fundamental aerophysical and aeronomical experiments aboard of ISS

the NAS of Ukraine (Fig. 2). This kind of instrumentation has been used in experiments onboard the «Kosmos-1643» and «Kosmos-2007» satellites. An integrated laboratory study of the following parameters should be performed before setting up the proposed experiment in the URM:

— response angle coefficients of space-borne instrumentation at interaction with a running gaseous flow with the energy of 7-17 eV against the background of intensive UV radiation; calibration of instrumentation;

— parameters of outgassing of a full-scale model of a spherical shell ($r$ = 0.3 ... 0.4 m) made of a porous material;

— parameters of the atmosphere both inside of a spherical shell volume and in its vicinity for the rate of the flow levels of the known gases (Ne, Ar, Kr, Xe, etc.);

— parameters of permeability of a spherical shell and evaluation of stability of these parameters.

The dynamic calibration of instrumentation will be completed using the supersonic Vacuum Aerodynamic Plant (VAP-2M) and a cryogenic pumping down system. The VAP-2M belongs to the Institute of Technical Mechanics of the NAS and NSA of Ukraine.

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«Diagnostics» Experiment

# DIAGNOSTICS, MONITORING, AND STUDY OF A SET OF PARAMETERS OF THE IONOSPHERIC PLASMA AND ENVIRONMENT NEAR THE ISS

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The ionospheric plasma is highly sensitive to the influence of external sources of solar, space, technogenic, and anthropogenic origin. The ionosphere responds to the solar and seismic activity, cyclones, magnetic storms, power explosions, volcanic activity, pollution of the troposphere, as well as active experiments during launches and flights of rockets and satellites. This is manifested as the periodical and non-periodical fluctuations of the main kinetic parameters of the ionospheric plasma, namely concentration of charged and neutral particles, pressure and degree of ionization, temperature of charged and neutral particles, electric and magnetic field strengths, energy spectrum of charged components, plasma potential.

The purpose of the experiment is to monitor and to study the ionospheric plasma by the contact methods for solving the inverse task, namely, to localize the sources of natural cataclysms by identifying the fluctuations of the main plasma kinetic parameters. We are also planning to develop methods and models of ecological and anthropogenic monitoring and forecasting.

The considered problem has two components. The first one is connected with implementation of the direct contact plasma diagnostics in the $F_2$-region of the ionosphere. The second component is connected with such items as interpretation of the measurement results, establishment of interconnection of periodic and non-periodic fluctuations of the ionospheric plasma parameters with spatial-temporal localization of the sources of external effects, as well as identifying their characteristic features and origin. The spatial-temporal synchronism of the external influence, event, and measurement can be ensured only in a manned spacecraft.