INVESTIGATION OF THE GASEOUS AND PLASMA ENVIRONMENT OF THE ISS BY MEANS OF CONTACT DIAGNOSTICS («Environment» Project)

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Introduction. Interaction of space vehicles with plasma environment and solar radiation results in some effects which should be taken into account during the long-term operation of both the constructions of the ISS itself and of various electromagnetic systems of the station. Such effects include the following:

— polarisation of constructions;

— emission of a wide spectrum of the molecular constituents of structural materials due to bombardment by the solar corpuscular flow, as well as by flows of atmospheric gas and dust microparticles;

— appearance of glow in the ISS environment;

— development of perturbations of the electric and magnetic fields in the vicinity of the moving ISS and of the resultant plasma instability and a wide spectrum of heterogeneity;

— additional ionisation stipulated by chemical emissions of engine systems and by injection of charged particles, as well as by operation of radio transmission systems.

These phenomena call for an integrated approach to measurement and analysis of the basic parameters of gaseous and plasma environment of the station (concentration of particles, mass content, temperatures of electron and ion components, power spectra, effective scattering cross-sections, plasma potentials, pressure, electric and magnetic intensities, etc.).

Most of the above parameters could be measured by means of devices developed in Ukraine by the captive technology. In terms of sensitivity, the sensor devices made in Ukraine are on a par with the best world models and, in some cases, their performance is higher. The need for simultaneous measurements of the local and distant plasma parameters should be emphasised. Comparison of the parameters of the environment disturbed by the presence of the ISS with the natural background values, as well as with their spatial-temporal variations will permit solving technological and scientific problems of a long-term exploration of orbital stations.

«Environment» Experiment

STUDY OF ELECTROMAGNETIC ENVIRONMENT OF THE ISS

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Long-term operation of «Mir» OSS has revealed some effects connected with the heterogeneous distribution of charges on its surface and with the higher level of electromagnetic (EM) fields in its environment. A series of active experiments onboard the «Mir» and the STS-3 experiments onboard the Space Shuttle showed the existence of local wakes and turbulence, sometimes provoking the plasma heating and luminescence, etc. Due to non-homogeneous surface conductivity, the active processes onboard the station create local anomalous charges and high EM noises, which are dangerous both for the spaceborne equipment and human health. It is also important to localize the places with minimal noise/ charge level along space stations for installation of scientific equipment.

The goal of the experiment is to ensure EM monitoring of the station environment, which will be necessary both for scientific research and for derivative control action. It is proposed to design automatic mini-buoys or nano-satellites with the fully autonomous and short-range telemetry. Various operational modes are envisaged, namely installation on the outer side of the station, free floating and tethered operation mode. The latter two mentioned modes offer the following advantage. It will be relatively easy to realize the extremely high EM sensor response onboard the nano-satellites that is not possible even using micro-satellites.

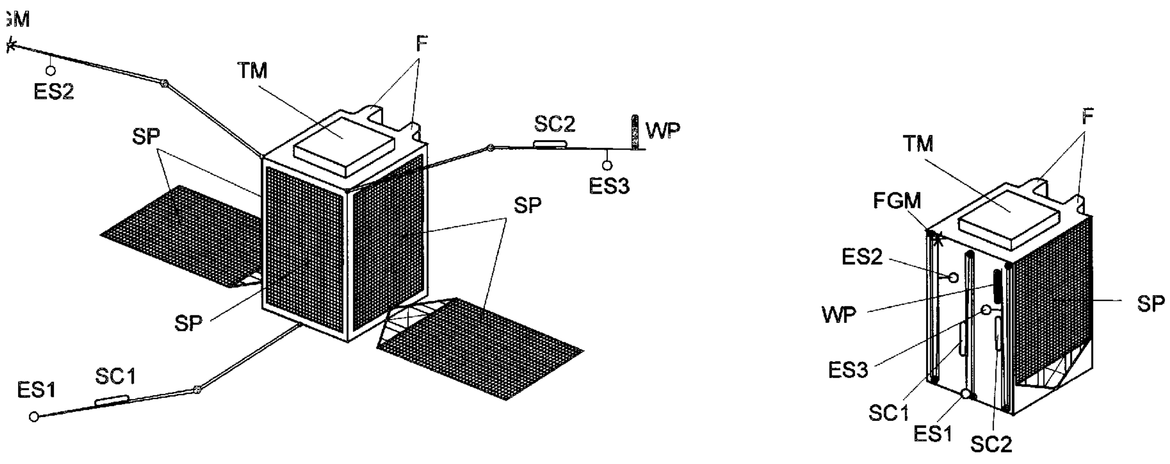
The reaction of non-conductive and semi-conductive surfaces of various structural materials to bombardment by space particles in the presence of highly non-homogeneous electric and magnetic fields and currents is not clear so far. Supposedly, these effects were the cause of the «Mir» cables insulation failure.

In addition to the technological purposes of the proposed experiment, it is very important to complete monitoring of the electric and magnetic fields in the ionosphere for solving some of the geophysical problems. Among such problems is investigation of plasma-wave processes developing as a result of solar-magnetosphere and atmosphere-ionosphere connections that is important for space weather study and forecast. A substantial factor also is to provide a long-term monitoring of these processes at least during one cycle of solar activity (11 years).

The methodology of electric and magnetic measurements onboard a spacecraft was developed intensively at the early stages of space research (see, for example, [1]). Some theoretical problems, however, concerning the interaction of large space constructions and space plasma, and the influence of active experiments are still to be studied. A break-through in our understanding can be achieved by the regular long-term investigation of these processes both in space and on the ground during at least one cycle of solar activity. The project proposed will allow making a significant contribution to such a study. The ISS crew during their extra-vehicular activity could search for locations-indicators of anomalous behavior and locations with a minimal level of interference for monitoring system installation.

We propose a new concept of space buoys or nano-satellites. This concept includes development of space-saving and fully autonomous measuring systems (up to 10 kg). Each of the systems will have the following units (Fig. 1, a): flux-gate magnetometer (FGM); search-coil magnetometers (SC); wave probe; electric sensors (ES); self-contained power supply (solar panels (SP) and inner long-term battery); short-range telemetry (TM); manually deployed booms and solar panels; one-side fixing arm (F).

Such a nano-satellite will take little space in the stowed position (Fig. 1, b) and could be easily delivered to the ISS as a piggyback cargo. Using the fixing arm (F), a nano-satellite can be con-



a) Deployed b) Stowed

Fig. 1. Sketch of a nano-satellite («Environment» experiment)

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 φ: 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.

References

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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;