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PHYSICAL EXPERIMENTS ON BOARD OF MICRO-SATELLITES, RELATED TO THE ECOLOGICAL MONITORING

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Abstract

According to the priority of micro-satellites and our study in space physics, we present the possibility to perform physical experiments onboard of micro-satellites. We explain the essence of these experiments and how they may help for the investigation of the Space-Earth relation. It is shown the importance of the cosmic radiation flow influence over the environmental conditions. For a successful solution of the problems, we propose to use some kind of detectors.

Introduction

In 90's, as a result of development of radio and electronic space technologies, began considerable miniaturization in the field of space physics experiments. It opened the possibility for constructing and launch of small-size satellite platforms - microsatellites. Most of the projects, concerning the usage of these satellites are aimed to education, communication and specific scientific experiments.

The Earth is just a part of Space Family and she is not a close physical system. The Earth is exposed under influence of various Space objects and we couldn't neglect the space radiation stream, part of which penetrate trough the earth atmosphere.

According to our studying, we make a inference that the micro-satellites give a possibility to perform a several of physical experiments for explaining above processes and deciding the relating problems.

The aim of this paper is to scrutinize these possibilities and to give an idea of beneficially using microsatellites platforms.

In the first section, we present in structural mode the satellites and most fundamental physical experiments performed on their board, relating to the investigations in the last 10-15 years in all over the world.

In the second section we make a review of some instruments, which are be able to use and place on board of microsatellites.

Finally, in a conclusion we present our proposal for possible physical experiments on board of a future microsatellite.

I. The classification of microsatellites over year, country and physical experiments on their board (Sat.ND, Small Sat. Catalog).

Satellite	Year	Mass (kg)	Country	Purposes and tasks	Orbit parameters
SNOE	1998	115	USA	Measure nitric oxide density in the terrestrial lower thermosphere (100-200 km altitude) and analyze the energy inputs to that region from the sun and magnetosphere that create it and cause its abundance to vary dramatically an ultraviolet spectrometer to measure nitric oxide altitude profiles, a two-channel auroral photometer to measure auroral emissions beneath the spacecraft, a five-channel solar soft X-ray photometer.	529 km x 581 km, 97.7 deg
FASat Bravo	1998	55	Chile	Ozone Layer Monitoring Experiment (OLME) Experiment This experiment is very important for Chile because of the geographic location of the country within the depletion area of the Ozone Layer in the Antarctic. This experiment is based on the measurement of the ultraviolet solar backscattered radiation in frequency bands around 300 nanometers. The experiment will have two types of devices in order to measure that radiation: Ultraviolet cameras, based on special CCDs and Ultraviolet photodiodes.	821 km SSO
PANSAT	1998	70	USA	extreme ultraviolet experiment	552 km x 563 km, 28.46 deg
Astrid 2	1998	30	Sweden	investigations of electric and magnetic fields in the upper ionosphere by measuring UV reflection and absorption near the polar caps	978 km x 1013 km, 83 deg
SAC A	1998	59	Argentine	magnetometer to take scalar measurements of the Earth's magnetic field	388 km x 401 km, 51.6 deg
Oersted	1999	62	Denmark	The principal research topics are in two areas: studies of the generation of the magnetic field in the fluid core and the magnetic and electrical properties of the solid earth; and studies of earth's magnetic field as the controlling parameter of the magnetosphere and of all the physical processes that take place in the earth's plasma environment, including phenomena like aurora and magnetic storms.	630 km x 850 km, 96.1 deg

SunSat	1999	63	South Africa	studies of the earth magnetic field, gravity field, atmosphere, and ionosphere plus intercomparison of GPS and SLR precision orbits.	400 km x 838 km, 93 deg
SACI 1,2	1999	60	Brazil	investigate plasma bubbles in the geomagnetic field, air glow and anomalous cosmic radiation.	732 km x 747 km, SSO
Megsat 0,1	2000	33, 56	Italy	measure UV emissions from the aurora borealis to determine their correlation with solar activity in oxygen lines, measure night time UV emissions	650 km x 650 km, 65 deg
Tiungsat 1	2000	52	Malaysia	a cosmic ray detection	650 km x 650 km, 65 deg
STRV 1A,1B	2000	52	UK	Surface Charge Detector (DRA/SIL) Langmuir Probe (DRA) Cosmic Ray & Dosimetry monitor (DRA/UKAEA) Radiation Dose Rate Sensor (DRA/MMS) Infra-red Detectors (BMDO/JPL) Radiation Environment Monitor (ESA-ESTEC/PSI)	GSO
Simplesat	2001	52	USA	carries a telescope - 30 cmm diameter optics	?
Starshine 3	2001	90	USA	measured the magnitude of the daily decrease of period and deduced the density of the earth's upper atmosphere that produced the drag that shortened the satellite's orbital period. They also kept track of fluctuations in intensity of extreme ultraviolet radiation from the sun, as measured by instruments on the SOHO satellite. They related fluctuations in intensity of solar activity to changes in the rate of decay of the satellite's orbit and thereby to variations in atmospheric density.	467 km x 474 km, 67 deg
Kolibri-2000	2002	21	Russia, Australia	Instruments on-board include a flux-gate magnetometer, particle and electric field analyzer	385 km x 388 km, 51.6 deg
FedSat	2002	58	Australia	provide a research platform for Australian space-science, communication and GPS studies. NewMag: The NewMag magnetometer is a very sensitive and rapid-sampling device for measuring the strength of the Earth's magnetic field.	?
CHIPSat(Unex 1)	2003	60	USA	The Cosmic Hot Interstellar Plasma Spectrometer Satellite (CHIPSat). carry out all-sky spectroscopy of the diffuse background at wavelengths from 90 to 260 Å with a peak resolution of /150 (about 0.5 eV) (EUV). CHIPSat data will help scientists determine the electron temperature, ionization conditions, and cooling mechanisms of the million-degree plasma believed to fill the local interstellar bubble. The majority of the luminosity from diffuse million-degree plasma is expected to emerge in the poorly-explored CHIPS band,	586 kmx 594 km, 94 deg

				making CHIPS data of relevance in a wide variety of Galactic and extragalactic astrophysical environments.	
Larets	2003	21	Russia	determine variations in the rotational characteristics of the earth and to measurement changes in the earth's gravity field. For the high resolution determination of the parameters of the gravity field the satellite must be launched into the lowest possible orbit	696 kmx 675 km, 98.2 deg
MOST	2003	60	Canada	MOST (Micro-variability and Oscillation of Stars) is designed to detect brightness oscillations in stars down to a level of a few parts per million - the amplitude of the Sun’s five-minute oscillations seen in integrated light. Those oscillations (caused by turbulent sound waves propagating within the Sun) allow us to probe seismically the otherwise hidden solar interior	?
MIMOSA	2003	66	Czechoslovakia	measure atmospheric drag, The only scientific payload is an electrostatically compensated, six degrees of freedom accelerometer with cubic proof-mass. The accelerometer can detect quasi-steady accelerations of extremely low magnitude of about 10-11 ms-2. The accelerometer is mounted at the center of gravity of the MIMOSA satellite.	?
STSAT 1	2003	100	South Korea	payloads are: FIMS (Far-ultraviolet IMaging Spectrograph), SST (Solid State Telescope) , DCS (Data Collection System), NAST (Narrow Angle Star Sensor), SPEAR (Spectroscopy of Plasma Evolution from Astrophysical Radiation)	SSO
Demeter	2004	130	France	study the ionospheric disturbances related to seismic activity, study the ionospheric disturbances related to human activity, study the pre- and post-seismic effects in the ionosphere, contribute to understand the mechanisms generating those disturbances, give global information on the Earth's electromagnetic environment at the satellite altitude. The scientific component includes the following sensors: IMSC: a triaxial set of 3 magnetic sensors (Search Coil), ICE: a 4 electrical sensor system, IAP: a plasma analyser, ISL: a Langmuir probe	?

				IDP: a particle detector.	
ST5 (NCT)	2006	25	USA	demonstrate and space-test the ability of "smart" satellites to identify scientific events and implement cooperative data-taking strategies, the smallsats will fly in various location points within the magnetosphere, the region that surrounds our planet like a "suit of armor." Magnetometers onboard each of these miniaturized satellites will measure energetic particles in the magnetosphere,	300 km x 4500 km, 105.6 deg
NPSat1	2006	80	USA	Experiments on-board NPSAT1 include two Naval Research Laboratory (NRL) payloads: The coherent electromagnetic radio tomography (CERTO) experiment and a Langmuir probe. The CERTO experiment is a radio beacon which, in concert with ground station receivers, is used to measure total-electron-content (TEC) in the ionosphere. The Langmuir probe will augment CERTO data by providing on-orbit measurements.	560 km x 560 km, 35.4 deg
FalconSAt 3	2006	50	USA	will provide sophisticated characterization of plasma turbulence in the F region ionosphere. The three primary experiments include the Flat Plasma Spectrometer (FLAPS), a planar electrostatic analyzer used to measure ion spectra differential in energy with a DE/E ~ 4%; the Plasma Local Anomalous Noise Environment (PLANE) experiment, a bifurcated retarding potential analyzer capable of distinguishing between ambient and spacecraft-induced turbulence; and the Micro-Propulsion Attitude Control System (MPACS), consisting of a set of Teflon-fueled pulsed plasma thrusters used to stabilize satellite attitude.	560 km x 560 km, 35 deg
THEMIS (MIDEX5)	2006	100	USA	will elucidate which magnetotail process is responsible for substorm onset at the region where substorm auroras map (~10Re): a local disruption of the plasma sheet current or that current's interaction with the rapid influx of plasma emanating from lobe flux annihilation at ~25Re. THEMIS answers critical questions in radiation belt physics and solar wind - magnetosphere energy coupling. The Science Payload consists of: 3D FluxGate and Search Coil Magnetometers (FGM, SCM) obtain 1024 vector/s waveforms. 3D Electric Field Instrument (EFI) obtains DC to 1024 vector/s waveforms. Electrostatic Analyzer (ESA) measures i+/e- of energy 5eV-30keV (over 4p str once per spin). Solid State Telescope (SST) measures i+/e- of 20keV-1MeV (over 108° x 360° once per spin).	

Sloshsat-FLEVO	2006	127	Netherland	investigate the behavior of liquids in weightlessness The objectives of the Sloshsat-FLEVO experiment are to: Obtain flight data to verify the adequacy of existing analytical fluid dynamics models, and indicate where improvement is needed Obtain flight data to verify adequacy of existing computational fluid dynamics software numerical models, and indicate where improvement is needed. Characterize the dynamic interaction between liquid motions and spacecraft Provide understanding of the motions of liquid with a free surface in a low gravity environment Generate phenomenological information on less well organized flow patterns as a basis for further mathematical modeling Provide relevant information for the design of liquid management techniques in micro-gravity Obtain data on diagnostic instruments performances. and to develop and qualify a low-cost small spacecraft (S/C)-Bus	
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II. The instruments and experiments

In this section we make a review of the instruments and correspondent physical experiments, which are be able to loaded on microsatellite board.

1. HETE (High-Energy Transient Experiment)

The prime objective of HETE (Sat. ND 1995-2002) is to carry out the first multiwavelength study of gamma-ray bursts with UV, X-ray, and gamma-ray instruments mounted on a single, compact spacecraft. A unique feature of the HETE mission is its capability to localize GRBs with ~10 arc second accuracy, in near real time aboard the spacecraft, and to transmit these positions directly to a network of receivers at existing ground-based observatories, enabling rapid, sensitive follow-up studies in the radio, IR, and optical bands.
The following two instruments are used to performing these experiments:

Omnidirectional Gamma-Ray Spectrometer

Instrument type	NaI(TI); cleaved
Energy range	6 keV to > 1 MeV
Timing resolution	4 ms
Spectral resolution	~40% of 6 keV; ~7% of 1 MeV
Effective area	120 cm^2 (total for 4 units)
Sensitivity (10 sigma)	3 x $10^{-8 erg/cm/s}$ for 8 ÷ 1000 keV
Angular resolution	~ 1 sr

Wide Field X-ray Monitor

Instrument type	2 1-dim Coded aperture cameras, with
Energy range	2 to 25 keV
Timing resolution	1 ms
Spectral resolution	~18% of 6 keV
Effective area	200 cm^2(each of 2 units)
Sensitivity (10 sigma)	8 x $10^{-9 erg/cm/s}$ for 2÷10 keV
Angular resolution (1 sigma)	about 10 arcmin (location accuracy better than that)

3. Micrometeorite Impact Detector (MMID)

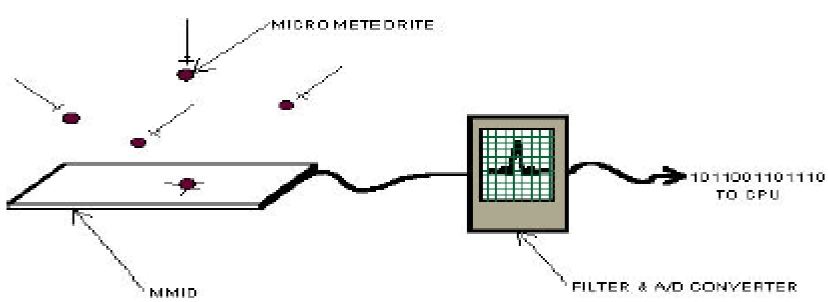

Figure 1. The block scheme of using MMID

When an impact on the sensor occurs, it outputs a voltage spike, the strength of which is linearly related to the impact force of the moving particle.

The MMID may used to record both event occurrence and event magnitude (Coyle et all. 2002). Every collision that occurs is recorded as a voltage pulse, which will then be recorded on the computer. More specifically, the electrical signal from a collision will go through a band-pass filter to eliminate thermal disturbances; into a comparator, to determine whether or not the event is above a programmable threshold voltage (Vref), then into an analog-to-digital (A/D) converter. At this point, the signal will then interrupt the main processor, prompting it to record the reading into a register and time-tag it.

A peakhold built into the MMID circuitry downstream from the comparator will send the maximum event voltage to the CPU for recording. The circuitry will then be reset in preparation for the next event.

Usually the MMID sensor is a standard, 0.008-inch thick, pre-cut rectangular strip of a polyvinylidene fluoride (PVDF) piezoelectric film.

2. Infrared Spectrometer

The infrared spectrometer with dispersion grid has a possibility to obtain a temperature portrait of the earth surface. Blacken in photocells with photo-electro multiplier is converts to photo flux, which defines intensity for wavelength.

4. GRBs Detectors

Housed in the BMT (Telescope module) are the two detector assemblies (Nousek 2004). Each detector assembly consists of detector window, a S20 photocathode, three Micro-Channel Plates (MCPs), a phosphor screen, tapered fiber-optics, and a CCD (Figure 2). The CCD has 385 x 288 pixels, 256 x 256 of which are usable for science observations The photocathode is optimized for the UV and blue.

Photons arriving from the Beam Steering Mirror (BSM) enter the detector window and hit the photocathode. Electrons emitted from the photocathode are then amplified by the three successive MCPs, which in turn illuminate the phosphor screen. The photons from the phosphor screen are then sent through the fiber-optics to the CCD. This affords an amplification of 10^6 of the original signal. The detection of photons is accomplished by reading out the CCD at a high frame rate and determining the photon splash's position. Unlike most UV/optical telescopes, because UVOT's CCD is read out at a high frame rate, the UVOT is operated in a photon-counting mode.

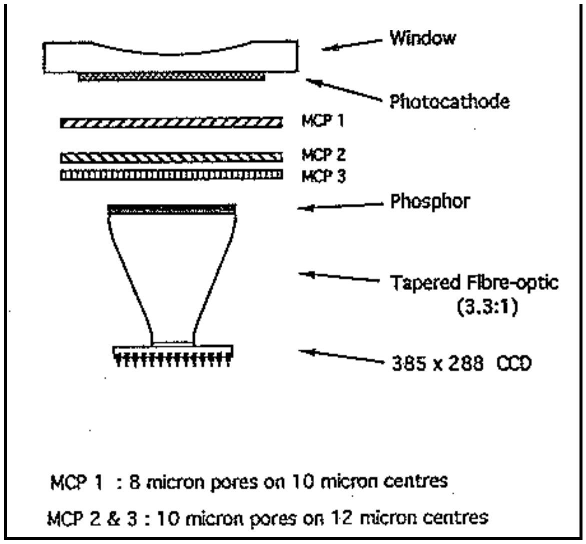

Figure 2. UVOT Detector

As with all photon-counting devices there is a maximum count rate limit. Details of this dead time correcting will be provided after launch. In addition, care must be taken when observing bright sources as the local sensitivity of the photo-cathode is permanently depressed. Autonomous operations diminish the time spent on bright sources. The detector's dark noise is extremely low and can be ignored when compared to other sources of background noise.

5. Semiconductor detectors

The gas-filled detectors have two disadvantages. The first one is that the gas density is very low and the losing energy from the particles in the detector area is small, and in this reason the registration of high energy and weakly ionized particles is not so effectively. The second one is that the energy, necessary for the electron-ion pair is much great ($30 \div 40$ eV), which increase relatively fluctuation of the charge numbers and the energetic resolution decreases.

Because of this is more advisable to use semiconductor detectors.

All solid state X-ray detectors consist semiconductor material, subdivided by impurity doping into regions of differing conductivity, within which a charge collecting electric field can be established by the application of appropriate bias voltages to a set of surface contacts.

The most often-used semiconductor materials are Silicon and Germanium. It is proved from many authors (Fraser 1989, Nousek 2004) that the disadvantage of these detectors is that they must be cooled. The other more effective material is HgI_2 crystal, which is expedient for X-ray astronomy experiments.

III. Conclusion

Following the presented information in above sections and with the purpose of understand the nature of Space influence on the Earth, we consider it necessary to implement next physical experiments on a board of microsatellite:

- To detect a flow of X-ray photons over the flying territory: its location, intensity and spectrum;
- To locate and analyze the space phenomena as a result of receiving data from radiation flow hitting the detector;
- After receiving the results from detector to compare the data with spectrometer measurements and evaluate the injurious space radiation over the Earth atmosphere;
- To distinguish the effects of Space and Earth's origin for a more correctly evaluation of the phenomenon;

Earth atmosphere absorb a sufficient amount of cosmic radiation. So all these experiments we must carry out from the space.

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