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14. ABSTRACT

This report results from a contract tasking Bulgarian Academy of Sciences as follows: The Grantee will investigate the development of Langmuir probes for measuring space plasma. Tasks include:
- Integration tests of the Langmuir probes with the Hungarian Data Acquisition and Control Unit (in Budapest)
- Complex tests of the engineering models of the instruments with imitation signals fed to the sensors (in RKK
- Updating of the technological instruments (if proved necessary based on the results of the tests)
- Elaboration of two flight instruments
- Elaboration of Control Test System for the flight instruments
- Control tests of the flight instruments in Bulgaria
- Integrated tests of the flight instruments on the PWC
- Data processing and interpretation

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REPORT ON FA8655-08-1-3006 LANGMUIR PROBES FOR "OBSTANOVKA" EXPERIMENT ABOARD THE RUSSIAN SEGMENT OF THE INTERNATIONAL SPACE STATION

August 04, 2010

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SUMMARY

This report lists the work done on the research entitled "Langmuir probes for Obstanovka experiment aboard the Russian segment of the International Space Station".

INTRODUCTION

Two Langmuir electrostatic probes are included in the experiment "Obstanovka" ("Environment" in Russian) which is a plasma-wave complex consisting of several instruments. The main purpose of this experiment is to evaluate how such a big and highly energy consuming body as the International Space Station disturbs the surrounding plasma, and how the station itself is charged due to the operation of so many instruments, solar batteries, life supporting devices, etc. The present grant is for the elaboration and tests of these instruments.

The following work was done within this grant agreement:

- Integration tests of the Langmuir probes with the Hungarian Data Acquisition and Control Unit (in Budapest)
- Complex tests of the technological models of the instruments with immitation signals fed to the sensors (in RKK "Energia" – Moscow)
- Updating of the technological instruments - a new power supply block (PSB) was elaborated, which made it possible to remove the high frequency noise caused by the older PSB
- Two flight models of the instrument were manufactured.
- A change was made to the printed circuit board responsible for the communication with DACU. It is now possible to carry all the communication

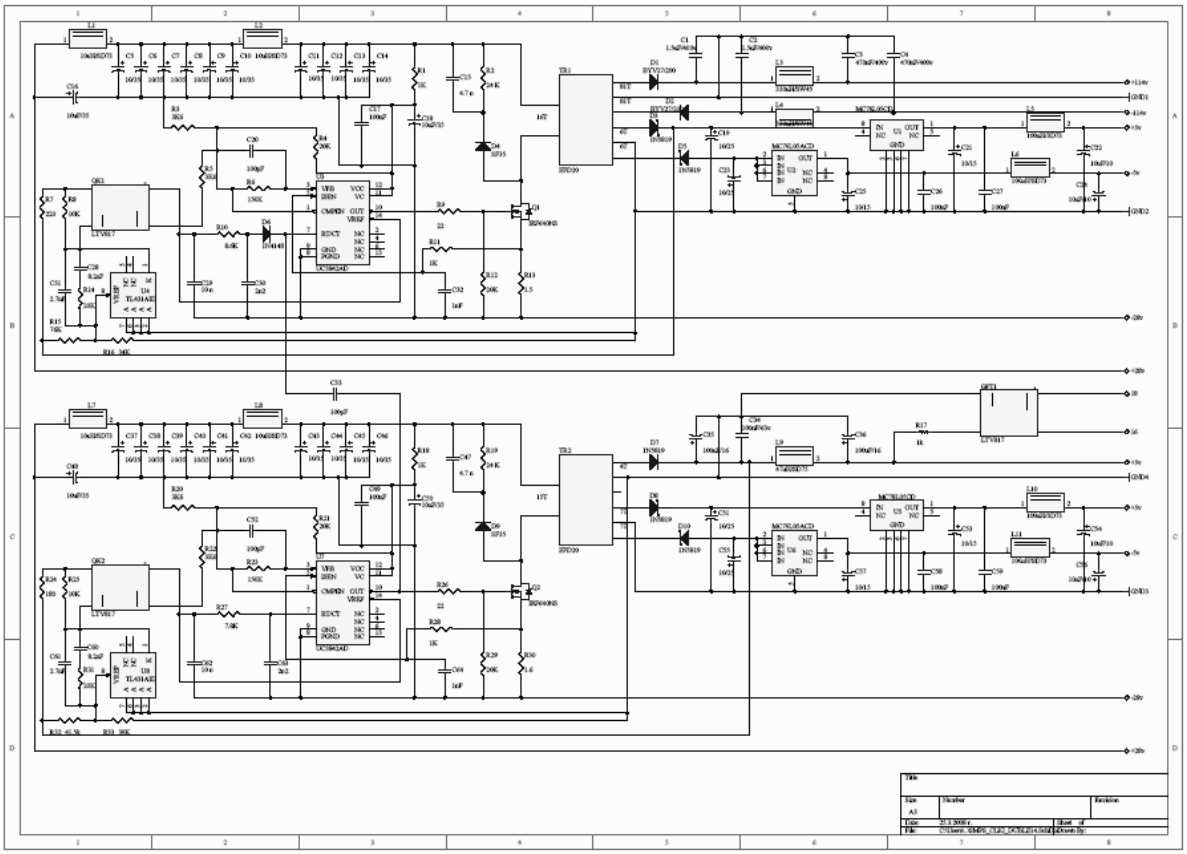
in a wireless way. A JenNet (modified ZigBee protocol) is used realized on JN 5138 modules of the firm Jennic

- Elaboration of Control Test System for the flight instruments
- Control tests of the flight instruments in Bulgaria
- Delivery and acceptance tests of the flight instruments in IKI - Moscow
- Control tests of the joint operation with DACU in Budapest Hungary.

METHODS, ASSUMPTIONS, AND PROCEDURES

1. Power supply block

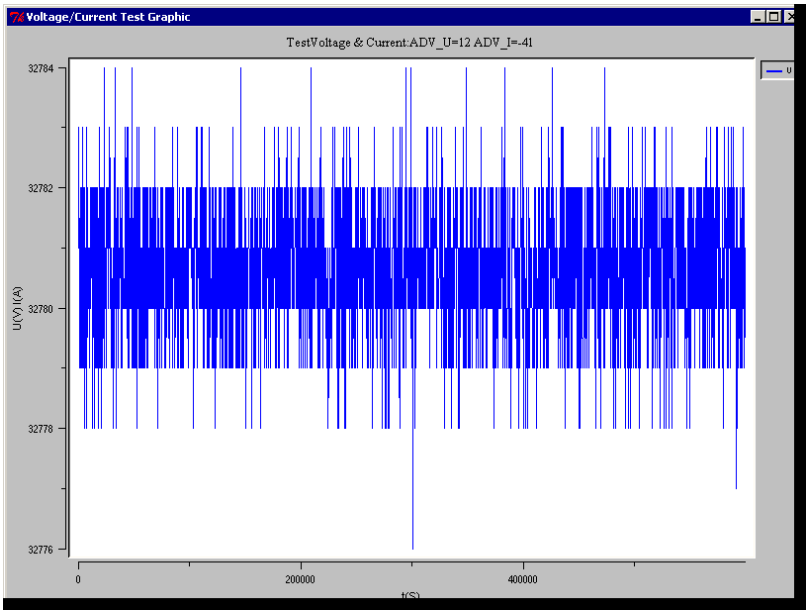
During the tests on the technological instruments, significant aperiodic disturbances were found in one of the voltages generated by our power supply block (PSB) which could not be stabilized. This made us seek a new design of the PSB. Now the PSB has already been designed, the printed circuit boards have been completed and their assembly and tests have been completed. Shown below is the block-diagram of the new PSB.



PCB block-diagram

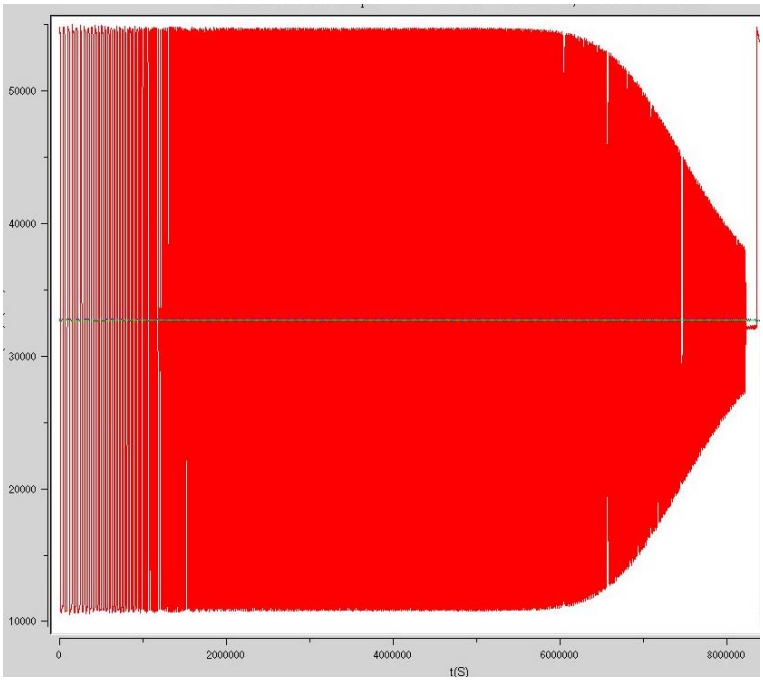
The Figure below demonstrates the stability of the voltage fed to the probe sensor by the sweep voltage generator. Along the X-axis ix the time in microseconds, and along the Y-axis – the voltage fed to the sensor at a fixed voltage measured in ADC units. As seen, the

variations are within the ADC accuracy which demonstrates that the PSB introduces no additional noise.



2. Amplitude-frequency characteristics

As it is impossible to calculate theoretically all the parameters of the capacitances at the input of the current-to-voltage converter, their precise determination had to be made experimentally, after which the amplitude-frequency characteristic of the instrument was measured. In all modes of operation, no deformations were observed up to 2 KHz which is more than enough for our purposes. Shown below is one of the graphics of these measurements.

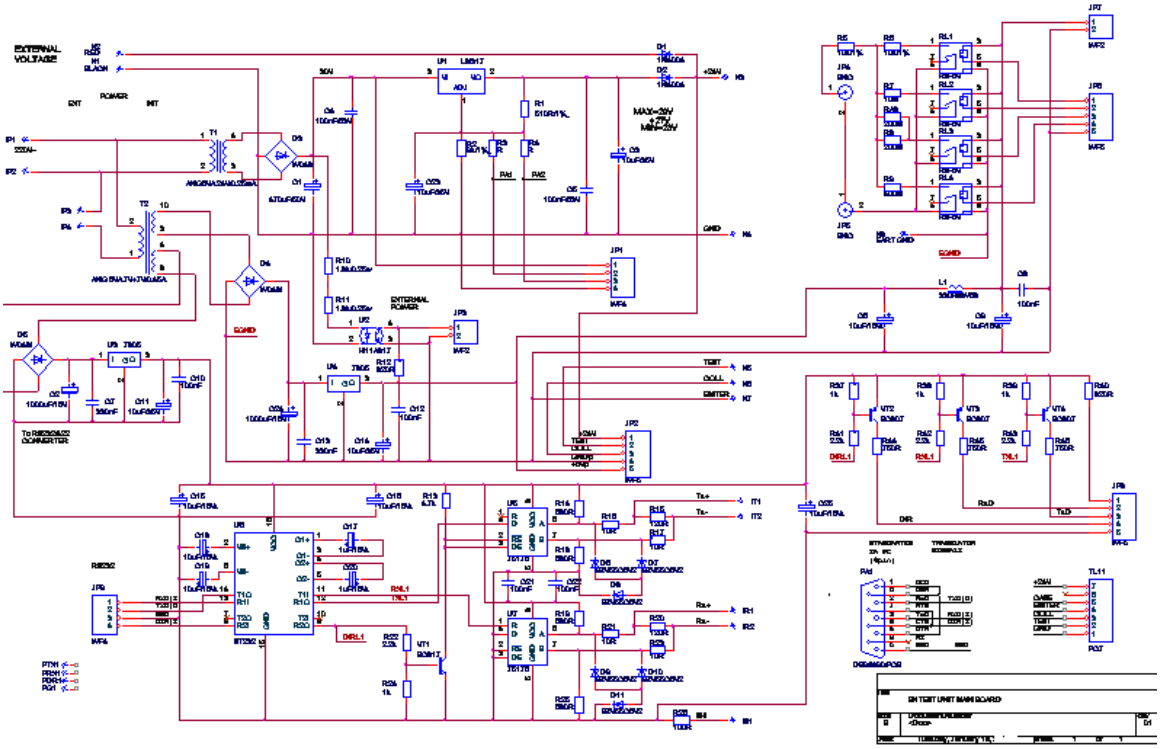


3. Control Test System for the flight instruments

For testing the instruments, a Control Test System (CTS) was elaborated. CTS consists of:

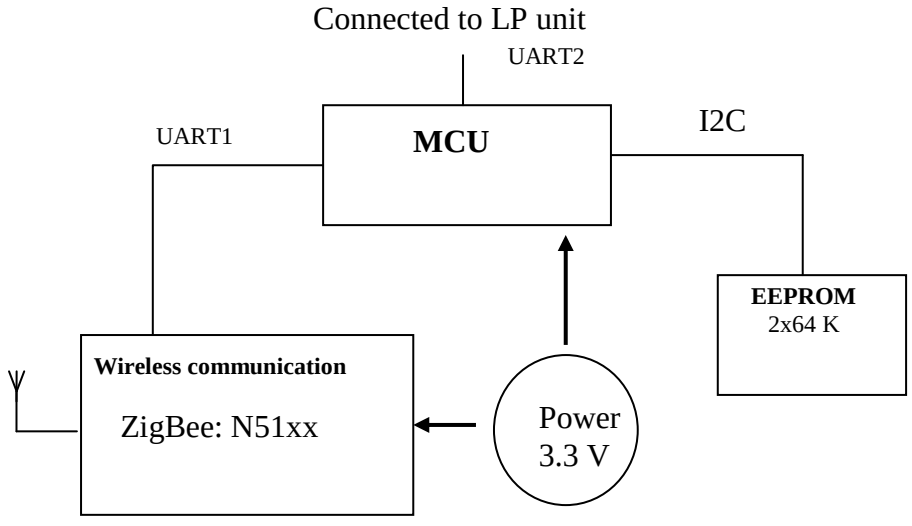
- onboard power supply immitator which can feed 23 V, 28.5 V, and 29 V;
- input signal immitator (weak currents 10^{-5}-10^{-9}A generator); These signals are fed to the sensor. Special measures are foreseen against noises especially in the 10^{-9}A range;
- signal converter from RS 232 C to RS 422
- Operator workstation (computer)
- DACU Data Acquisition and Control Unit emulator

The block-diagram of CTS is shown below.



Block-diagram of CTS

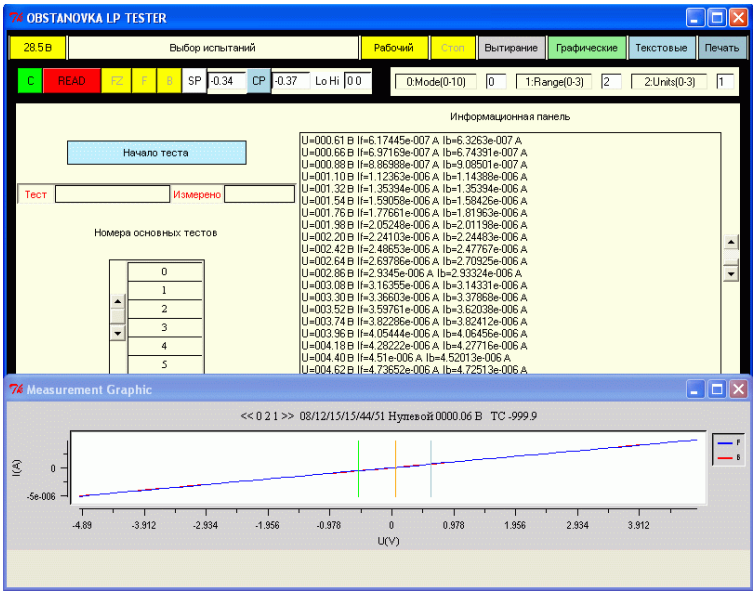
4. Wireless communication between measurement unit and Data Acquisition Control Unit (using Wireless Communication Module)



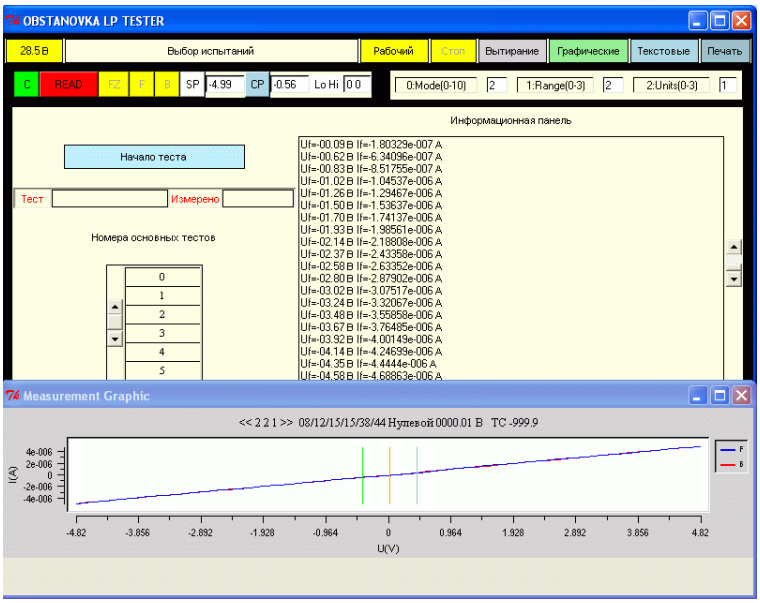
ZigBee is the newest wireless technology with the best characteristics regarding power consumption, and a lot of producers currently offer on the open market embedded products, so- called “Systems on Chip” (SoC). Those products integrate microcontroller, memory, radio –frequency features, analogue and digital inputs/ outputs and so on. Some of them have additional functionality as embedded protocol stack, AT commands etc., which makes it easier to add the wireless features to any system. Each of the units LP and DACU are supplied with communication module. That module replaces the serial cable (RS422) and allows remote data transfer between the units LP and DACU. The communication module is based on SoC module, produced by Jennic Company– JN5139

5. Software

CTS is complete with a set of software programs to tests the functioning of the instrument in different modes of operation and to immitate its work aboard ISS. Below is a snapshot of the CTS screen demonstrating a series of tests in one of the two basic operational regimes in which first the LP software chooses a sequence of fixed values of the potential so that the most informative current-voltage characteristic could be obtained, and then the current values are measured at these values of the potential, until a new sequence of values of the potential is set by the software. This allows to save telemetry resources because the values of the potential are only transmitted once, and then only the values of the current are transmitted.

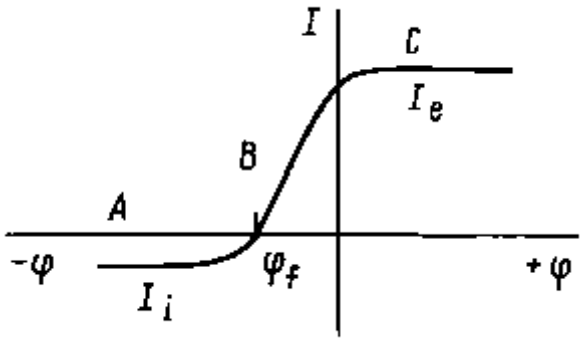


In the other basic regime two values are saved for each measurement: the potential fed to the sensor and the measured current. A snapshot of the CTS screen during the tests of this regime is shown below.

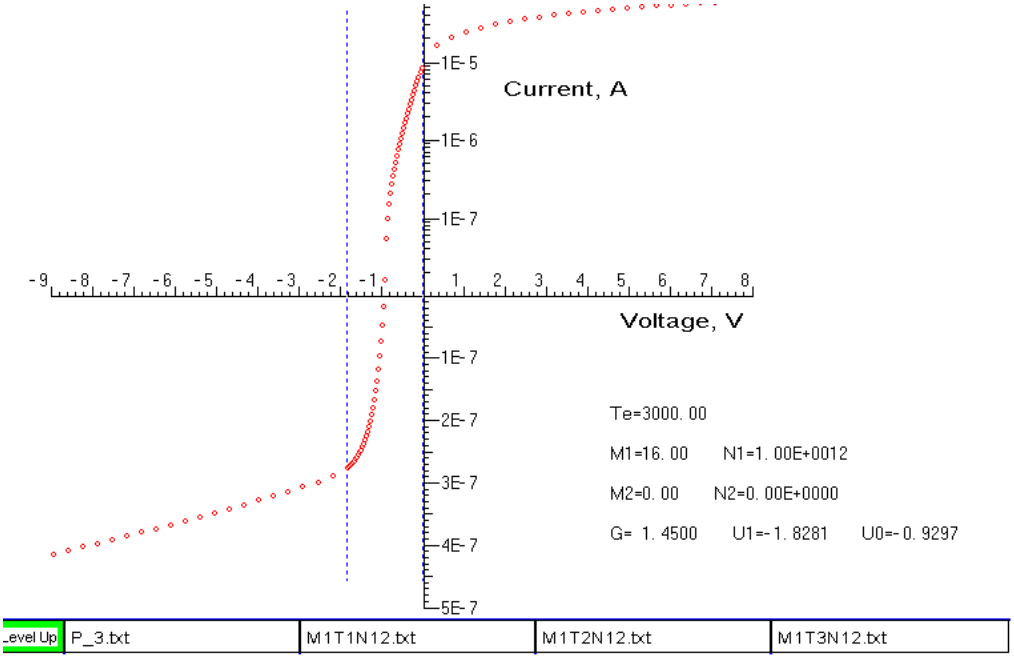


6. Algorithm of the instrument operation

One of the problems in processing data from instruments of the type of the Langmuir probe is the nonuniform rate of change of the current with voltage. The first part of the probe characteristic (A) is dominated by the ion current and *dI/dU* is relatively small. In the second part (B) from which the electron temperature is determined, *I* changes very quickly with *U*. Finally, in the third part (C) from which the electron concentration is determined, *dI/dU* is relatively low again. If the measurements are uniformly distributed along *U*, we will either have very few values in B region which will make it impossible to accurately determine the electron temperature, or we will have unnecessarily high number of measurements in A and C regions which means too much unneeded information sent to the Earth.



To overcome this problem, we have developed a flexible algorithm which detects the B region based on some preliminary measurements, so that as many measurements are made in B as total in A and C. The Figure below presents the result of the implementation of our algorithm.



RESULTS AND DISCUSSION

A set of instruments has been manufactured, 2 technological LP models and 2 flight LP instruments. After the tests of the technological models, improvements were made in the power supply block. Additionally to the general requirements, Wireless communication has been provided between the measurement unit and Data Acquisition Control Unit, and between the measurement unit and the Control Test System for the flight instruments.

The two flight LP instruments were tested in IKI – RAN in Moscow. The conclusion is that there are no remarks and "The flight models of the instruments ZL (LP) No 01 and ZL (LP) No 02 are admitted to further tests as parts of the flight complex PWC" (point 6 of the attached Protocol in Russian dated 16.03.2009 – 22.03.2009).

The information exchange between the flight LP instruments and the flight DACU was tested in RMKI, KFKI in Budapest, Hungary. After some modifications in the software it was concluded that there are no problems with the communication. Attached is Protocol dated 25 to 29 January 2010.

PRESENTATIONS ACKNOWLEDGING GRANT FA8655-08-1-3006

1. Kirov B., Batchvarov D., Krasteva R., Boneva A., Nedkov R., Klimov V., Grushin V., Georgieva K. An instrument for measuring the electrostatic charging of the International Space Station depending on space weather, Year of Astronomy: Solar and Solar-Terrestrial Physics 2009, Proceedings of the All-Russian Yearly Conference on Solar Physics, 11-15 July 2009, St. Petersburg, Russia, p.67, ISSN, 0552-5829

2. Kirov B., Batchvarov D., Krasteva R., Boneva A., Nedkov R., Klimov S., Grushin V., Langmuir probes for the International Space Station, IAGA 11th Scientific Assembly Sopron, Hungary 24-29 August, 2009 abstract No 306-THU-P1700-0316

3. Kirov B., Space weather effects on surface charging of space vehicles, and an instrument for measuring the surface charging of the International Space Station. Conference "Heliophysical Phenomena and Earth's Environment", 7-13 September 2009, Sibenik, Croati,a http://www.zvjezdarnica.hr/meeting, abstract book p.24

4. Kirov B., Georgieva K., Vassilev V., Spacecraft Charging and an Instrument for its monitoring aboard the International Space Station**,** 2010 EOS/ESD Symposium, October 3-8, 2010, John Ascuaga's Nugget Resort, Sparks (Reno), NV Abstract Accepted #71 http://www.esda.org/documents/2010SymposiumProgram.pdf

PAPERS WRITTEN AND SUBMITTED FOR PEER REVIEW ACKNOWLEDGING GRANT FA8655-08-1-3006

1. Kirov B., „An instrument for measuring the surface charging of the International Space Station", to be published in a special issue of Bulletin of the Faculty of Science, Cairo University, ISSN 1110-0966 with Proceedings of the IAGA Symposium "Space Weather and its Effects on Spacecraft", October 5-9, 2008.

2. Kirov B. "Space weather effects on surface charging of space vehicles, and an instrument for measuring the surface charging of the International Space Station." Sun and Geosphere, ISSN 1819-0839, in press 2010

CONCLUSIONS

All work foreseen by grant number FA8655-08-1-3006 has been finished. Pending are the complex tests of Obstanovka in Moscow, however for us they are to a great extend formal because of the successful control tests with the Data Acquisition and Control unit performed in Budapest, Hungary from 25 to 29 January 2010.

REFERENCES

Grant/Cooperative Agreement Award No FA8655-08-1-3006

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

ADC – Analog-to-Digital Converter
CTS - Control Test System
DACU - Data Acquisition and Control Unit
IKI–RAN – Space Research Institute at the Russian Academy of Sciences - Moscow, Russia
ISS – International Space Station
LP – Langmuir probe
PSB - Power Supply Block
PWC – Plasma Wave Complex
RMKI, KFKI
ZL – Zond Lengmiura (Langmuir Probe in Russian)