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30 YEARS BULGARIAN EQUIPMENT IN SPACE

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Abstract

The first Bulgarian space device for ionosphere plasma parameter measurement was launched onboard the satellite Intercosmos-8 on December 1, 1972. Launching successfully its own scientific equipment in outer space Bulgaria became 18th "space country" on the list of the United Nations. Celebrating the 30th anniversary of this historical year, Bulgarian engineers can report large activity and achievements basically in the fields of Space Physics, Remote Sensing and Space Technology.

The history of Bulgarian developments of space scientific equipment dates since 1969 when a Group of Space Physics at Bulgarian Academy of Sciences was established. It continued successfully after this group grew into the Central Laboratory for Space Research in 1975 and the Space Research Institute in 1987. Bulgarian researchers participated successfully in the "Intercosmos" Program, developing equipment and carrying out experiments onboard the satellites "Intercosmos – 8, 12, 14, 19" and the geophysical rockets "Vertical - 3, 4, 6, 7, 10". The scientific programs and equipment for the flight of the first (1979) and the second (1988) Bulgarian cosmonauts were entirely designed by Bulgarian scientists. Two satellites were launched in 1981 with Bulgarian scientific equipment for ionosphere-magnetosphere measurements and remote sensing of the Earth. Bulgarian scientists also participated successfully in international programs such as VENUS-HALLEY (1985), PHOBOS (1988), AKTIVEN (1989), APEX (1990) and INTEBALL (1995-96). Special attention is paid to the recent achievements of Bulgarian scientists in the field of Space Biology and Medicine onboard the MIR Orbital Station and the new International Space Station.

1. Introduction

Bulgarian participation in space research began at the time when the first satellite of the Earth was launched. By the end of 1957 Bulgarian Astronautical Society was established. Under an agreement of 1967, eminent scientists from Eastern Europe, Cuba and Mongolia signed a complex program for international collaboration in space research and peaceful use of outer space, known as the "Intercosmos" Program. According to this program the countries could take part in space research in their favorite field of study with their own scientific instrumentation using free-of-charge the Russian spacecraft (satellites, rockets, etc.) and launching facilities. The main scientific trends within the "Intercosmos" Program

are in the fields of Space Physics, Space Meteorology, Space Communications, Space Biology and Medicine and Remote Sensing of the Earth. Some Bulgarian scientists headed by acad. L. Krustanov and acad. K. Serafimov took part in the establishment of the "Intercosmos" Program and the organization of Bulgarian space activity in it - the National Committee for Space Research was founded in 1968. The **Group of Space Physics** (GSP) at Bulgarian **Academy of Sciences Presidium was created in 1969** with the first scientific team dealing entirely with space research and technology development [1].

2. First Steps and the First Bulgarian Cosmonaut in the 70s

Bulgarian space era started with ionosphere studies in the field of Space Physics. The ionosphere is an atmosphere layer of great importance for the near space because even life on the Earth depends on it. The Earth gets from the Sun the main energy resources necessary to support life. But together with its life-giving energy the Sun emits the life-threatening X-rays, ultraviolet and corpuscular rays. Therefore, one of the problems of great scientific importance is to study how the Sun influences climate, harvest, man and the environment i.e. to determine the concrete forms of the solar-terrestrial connections and interactions.

The first Bulgarian space probe device, named P-1, was launched onboard the satellite "Intercosmos-8" on December 1, 1972. It was designed to carry out direct measurements of space plasma parameters in the satellite's proximity. A cylindrical Langmuir probe (for measurement of electron plasma parameters such as electron density and temperature distribution) and a spherical ion trap (for measurement of ion plasma parameters – ion concentration, temperatures, mass composition and energy distribution) was mounted on long rods projecting out of the protective satellite cover. The hardware was developed by a team of young engineers (S. Chapkunov - at the head, T. Ivanova and M. Petrunova), and technicians (G. Karamishev and S. Lesseva), using mostly Bulgarian electronic components and materials. The equipment was of enough high quality and passed successfully all accepting tests (vibration, impact, temperature and electromagnetic tests, etc.) required for the equipment to be allowed onboard. After an extremely exiting night start, filled with emotions for Bulgarian scientists who had developed the hardware, the "Intercosmos-8" satellite was launched successfully into orbit. **Sending in space its own scientific equipment Bulgaria ranked 18th on the list of the "space countries"**, according to a convention adopted by the United Nations in 1968.

Along with the equipment, our hopes for successful entering of Bulgaria in the space era which involves the brightest prospects of mankind for an all-round development of our civilization flied off in space, too. In the past 30 years these hopes were justified and Bulgarian scientists took active part in many interesting

projects in almost all fields of space research. A second scientific line, "Remote Sensing of the Earth", was created in the GSP in 1974, directed by acad. D. Mishev [2].

The Central Laboratory for Space Research (CLSR), based on the GSP, was established in 1975. Bulgarian scientists gained significant experience through their investigations in the field of Space Physics and their successful participation in the "Intercosmos" Program. A number of other Bulgarian instruments for direct ionosphere measurements were developed. The P-2 and P-3 instruments were launched onboard the satellites "Intercosmos-12, 14" and other modifications of this equipment – onboard the heavy geophysical rockets "Vertical-3, 4, 6, 7, 10". In 1978, along with the P-4 multipurpose probe instruments, the electrophotometer EMO-1 for investigation of the natural optical emissions flied onboard the Automated Universal Orbital Station (AUOS) "Ionozond-Intercosmos-19". AUOS is a heavy spacecraft using solar (not only chemical) batteries. Scientists from some other eastern countries participated in all these starts with their own instruments and the equipment complex was larger and more informative - valuable information was obtained about wide plasma spectrum and optical processes.

In the years that followed, an ever-growing number of Bulgarian scientists and institutes joined in the arrangement and implementation of space experiments. The scientific program and preparation for the flight of **the first Bulgarian cosmonaut Georgi Ivanov** were the most important and exciting event in our space activity to the end of the 70th. Bulgaria became the 6th country in the world with its own cosmonaut. The start took place on **April 10, 1979 onboard the spacecraft "Soyuz-33"** with the participation of the Russian cosmonaut Nikolay Rukavishnikov. The flight was exceptionally complicated and dramatic - the spacecraft couldn't dock with the SOLYUT-6 Space Station due to breakdown in the main engine. Even the return of the cosmonauts to Earth was under question!

The crew showed exceptional heroism, self-control and strength and they proved experimentally, for the first time, that a spacecraft of the "Soyuz" type could come safely back to Earth using a ballistic orbit. This inspired confidence in the success of the future space flights. And the best proof was the recent flight of two "space" tourists - Dennis Tito and Mark Shuttleworth on board of a spacecraft of the same kind. The equipment developed by Bulgarian scientists for this flight ("Spectar-15", "Duga", "Sredets", "Vital") was used by the next crews but Bulgaria had all the rights over the scientific results.

3. Apogee of Bulgarian Space Activity and the Second Cosmonaut in the 80s

One of the most significant Bulgarian scientific achievements in the field of space research was the "Bulgaria-1300" Program carried out in 1981, in honor of the

1300th anniversary of the foundation of Bulgarian State. Two satellites were launched for studying the ionosphere-magnetosphere interaction and for remote investigation of the Earth. **The first satellite "Intercosmos-Bulgaria-1300"** (IC-B-1300) was entirely equipped with Bulgarian scientific instrumentation for research in the field of Space Physics. This satellite was launched into orbit at a height of 900 km. The program also included Remote Sensing of the Earth by Bulgarian scientific instrumentation installed in **the second satellite "Meteor-Priroda"** flying along a lower orbit (600 km). Both scientific complexes had remarkably long life - more than 3 years of perfect work in space.

Bulgarian scientists developed and produced a lot of instruments functioning onboard the "IC-B-1300" such as instruments for measurement of energetic electron and proton flows, the quasi-constant electric field and the low-frequency electromagnetic field, the concentration and drift of plasma ion components, the ion and electron concentration and temperature, the quasi-constant magnetic field, and the flows of energetic ions. The data obtained was processed, analyzed and used by both Bulgarian and foreign specialists. The results concerned the structure and dynamics of the ionosphere-magnetosphere plasma parameters and their interaction with some ground-based phenomena - earthquakes, volcanoes, etc.

Using data from all the "Intercosmos" satellites, the global ionosphere-magnetosphere connections and interactions were explored. The mechanisms determining the concentration and temperature distribution and heterogeneity in the ionosphere and thermosphere were studied.

After the "Bulgaria-1300" Program, Bulgarian scientists directed their efforts to investigation of other planets of the Solar System. In 1984-86, Bulgarian scientists together with Russia and France developed a multi-channel system that worked successfully onboard the **VEGA Space Station** and studied the glow of the Halley comet tail under the VENUS-HALLEY Project.

The video-spectrometric and navigation complex PHREGAT was developed with the leading participation of Bulgarian scientists and mounted onboard the **PHOBOS-1, 2 Space Stations** in 1988. Unique pictures of the MARS planet and its satellite PHOBOS were obtained and after processing they were placed at the disposal of other scientists in the world working in the planetary research area.

In 1987, the CLRS became Space Research Institute (SRI). The accumulated experience and scientific knowledge helped Bulgarian scientists to develop the new scientific **"Shipka" Program for the flight of the second Bulgarian cosmonaut Alexander Alexandrov.** He was launched on board of "Soyuz-TM5" in 1988 in a crew with the experienced Russian cosmonauts Anatoly Solovyov and Victor Savinih. For this historical flight a wide scientific program and corresponding equipment complex for research in the field of space physics, remote sensing, space biology and medicine, space materials and microgravity technology was developed.

Dozens of scientific institutions in BAS and out of it with SRI as a leading institute were involved in this project. Fifteen research devices and complexes, that continued working onboard the MIR Orbital Station (OS) long after Bulgarian flight ("LIULIN" and "SPECTAR-256"), were developed and 49 scientific experiments were conducted. Detailed extensive research directed to study of fundamental problems of the Space and its influence on man were carried out and extremely interesting new data and results were obtained. The main Bulgarian equipment developed on the "Shipka" Program and its objective is shown on Table 1.

Table 1. The main Bulgarian scientific equipment developed for the flight of the second Bulgarian cosmonaut Alexander Alexandrov on the "Shipka" Program in 1988

Equipment	Objective
"ROJEN"	An astronomical complex for identifying of objects in the celestial sphere.
"PARALAX-ZAGORKA"	An image amplifier for recording of pictures of the polar oval small-scale structure.
"TERMA"	A pulse photometer for investigations of the natural optical emissions in the Earth atmosphere.
"SPECTAR-256"	A multi-channel spectrometric system for study of the spectral reflecting characteristics of various natural anthropogenic formations on the Earth surface.
"ZORA"	A computer system for acquisition and storage of information obtained during complex psycho-physiological study of man in long-lasting manned space flights.
"PLEVEN-87"	A computer system for psycho-physiological monitoring of the cosmonauts status.
"SAN-3"	A portable magnetic recorder for 12-hour non-stop record of physiological signals (electro-cardiogram and electro-encephalogram).
"LIULIN"	Space dosimetric complex equipment for investigations of the radiation environment.
"DOZA-B"	An autonomous kit containing integral detectors for evaluation of the distribution of radiation doses.

Another scientific line - "Space Biology and Medicine", developed in the framework of the "Shipka" Program, establishing itself as a priority direction in Bulgarian space research. Many scientific teams and institutions were involved there and the work along this line became a tradition. They were invited to participate in recent international projects in this field of Life Sciences.

For example, very important experiments such as: "Statokinetika" - to study the dynamics of changes arising in the systems for movement control during the critical period of adaptation, "Potential" - to study the state of the muscular fibers driving membranes and "Labirint" - to clear up the phenomena of rise, progress and prophylaxis of the so-called "space disease" in order to raise the operator's working capacity, were carried out using the "ZORA" equipment. The methods used and scientific results obtained were so good that Germany ordered a later "ZORA" modification, called Neurolab-B, used widely onboard the MIR OS in the 90s.

The dynamics of high-energy fluxes and space radiation doses in Earth radiation belts depending on the Solar and magnetic activity level were investigated in the period 1988-1994 using the "LYULIN" dosimeter – radiometer. The data provides to investigate the inner magnetosphere variations. The variations of the Galactic Cosmic Ray fluxes and doses were investigated as well. Long-term global investigations of the MIR OS radiation environment in quiet and solar proton event conditions were used for building up a new experimental model. The model provides to evaluate the risk of cosmic ray exposure in long-term manned space missions and was used for prediction of the expected doses and fluxes on the International Space Station (ISS).

4. Recent Achievements in the 90s of the 20th Century

The main space activity on research projects was centralized at Bulgarian Academy of Sciences - SRI and the Solar-Terrestrial Influences Laboratory (STIL), detached from the SRI in 1990. After closing the "Intercosmos" Program in 1991, the major part of the international scientific activity was organized based on bilateral collaboration with external financial support. Accounting for the interdisciplinary nature of space research and its significance for the national priorities in the field of ecology, agriculture, communication and national security, the Interinstitutional Committee on Space Issues at the Council of Ministers of Bulgaria was established and a National Space Program was elaborated.

The big international space projects with the participation of Bulgarian scientists in the fields of Space Biology and Medicine (SVET Space Greenhouse and Neurolab-B) for MIR OS and Space Physics ("Interball" Project) were successfully carried out till 2000 and they completed with unique results.

The first SVET Space Greenhouse (SG) is an automated system for precise measurement and control of the environmental parameters for higher plant growth under microgravity. Plants could be a major link of the

future Biological Life Support Systems (BLSS), providing the crew with food and oxygen during long-term manned space missions. SVET SG was developed and produced in the SRI (patent is issued), and the development was funded in whole by Bulgarian Government [3].

The SVET SG was launched onboard the Crystal module on a Bulgarian-Russian project and docked to the MIR OS on June 10, 1990. A series of total 680 days of successful plant space experiments was conducted in the SVET SG facility under different scientific programs ("Intercosmos" and MIR-NASA) during the period 1990-2000 [4]. A few months before MIR OS plunged into the Pacific (March 23, 2001), 4 species of different lettuce crops were grown in the SVET SG and tasted for the first time by the last, 28th crew.

Unique and very important results in the field of Fundamental Gravitational Biology were obtained during the plant flight experiments in the SVET SG. It was proven that the lack of gravity is not an obstacle for normal plant development in space. Reiteration of the full life cycle of plant growth was achieved (second generation wheat seeds were produsedl). It became clear that plants could be successfully used in the future BLSS [5].

Another recent project developed by a SRI engineering team in the field of Space Medicine is the **Neurolab-B system** for monitoring the astronaut psycho-physiological status. Neurolab-B was successfully launched from the Baikonur Space Center onboard the "Spectur" module to the MIR OS on April 22, 1996 and was immediately operational. Neurolab-B was developed in cooperation with the German Space Agency and the Russian Space Agency.

The Neurolab-B complex was adapted to work in hospitals and clinics on Earth. A small-sized multi-channel Holter system was designed for recording some physiological parameters: electro-cardiogram, breathing, blood pressure, temperature etc. The system has been successfully tested in English clinics.

Bulgarian scientists have been participating successfully in the "Interball" International Space Program, in the field of solar-terrestrial physics. The program was aimed at direct study of the plasma processes in the Earth magnetosphere. The **"Interball" Project includes two main satellites launched in orbit in 1995 and 1996,** accordingly, each one having a sub-satellite. The first of them is the Magnetosphere Probe launched at a very high orbit, 200 thousands of kilometers in apogee, which was used to study the interaction between the magnetosphere and the solar wind. The second satellite, the so-called Auroral Probe, was launched at the

height of 20 thousands of kilometers above the polar areas and used to study the polar caps and polar ionosphere.

Bulgarian scientists from STIL and SRI developed seven scientific instruments such as AMEI-2 - an ion mass and energy analyzer, IMAP-3 - a magnetic field meter, UVSIPS - a ultra-violet scanning spectrometer and KEM-3 - an electric field meter for supporting a series of space experiments. Both satellites transmitted unique data for the measured parameters till the end of 2000 and this data is at present processed and analyzed by scientists from over 20 countries participating in the project.

As an active participant in the "Interball" project Bulgaria was a host of the International Scientific Symposium, held through COSPAR in February 2002 to mark the 20th anniversary of the project. 120 scientists from all over the world took part in it to discuss on the experimental results.

5. Future prospects for the 21st century

Bulgarian engineers are developing a new generation of equipment for scientific experiments and investigations onboard the ISS during the next 10-15 years of the 21st century. A new Concept for the SVET Space Greenhouse, based on Bulgarian experience and "know-how", is developed in the SRI. Using the physiological parameter measurement data the controller evaluates the plant status and performs adaptive environmental control – "stress-free" plant growth and optimal experimental results under the condition of microgravity [6].

Modifications of the LYULIN device on the "Shipka" Program, developed in the STIL, will be launched on board the ISS for assessment of crew radiation risks [7]. Lyulin-5 is an active dosimetric telescope designed for measurement of the in-depth distribution of space radiation doses in a human platform on the Russian Segment of the ISS (a part of the international project MATROSHKA-R). Another Bulgarian instrument – the Radiation Risks Radiometer - Dosimeter (R3D) will measure the solar radiation and cosmic ionizing radiation in the EXPOSE facility (ESA project) that will be attached to the external platform of the ISS.

Nowadays, Bulgarian scientists, whose achievements are well known and acknowledged, are welcome partners for different international projects. In addition to the development of equipment for bio-medical research onboard the ISS, Bulgarian scientists take part in the space programs relating to other priority scientific directions – Space Physics, Remote Sensing of the Earth, and Space Material Science. The recent SRI activity is mainly in the European level projects, like IMAGE 2000, OSNET, COST-Action 283, including FP5 participation and FP6 proposals. The scientific

research results are published in monographs and hundreds of papers in scientific journals in Bulgaria and abroad.

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Fig.1

Fig.2.

Fig. 1 A team of the Space Physics Group – BAS, which has designed the first Bulgarian probe space unit, P-1, with its Head, Dipl. Eng. Stefan Chapkunov (above, in the middle) and his associates Tanya Ivanova (below), Mariya Petrunova (above, on the left), and Georgi Karamishev. Upon its launch on-board the "Intercosmoc-8" satellite on December 1, 1972, Bulgaria became the 18th space country on the UN's ranking list.

Fig.2. The "Intercosmos-Bulgaria-1300" satellite launched in 1981 on the occasion of the 1300th anniversary of the foundation of the Bulgarian State was furnished entirely with Bulgarian research equipment intended for studies in the field of space physics. Jointly with

the Russian coordinator, G.L.Gdalevich, from SRI-AS USSR, the leading researchers of the probe units, P6-IL and P7-ZL, Katya Georgieva, Tanya Ivanova, and Svetlana Sapunova (from left to tight) from the CLSR-BAS are shown.

30 ГОДИНИ БЪЛГАРСКА АПАРАТУРА В КОСМОСА

Таня Иванова, Светлана Сапунова, Иван Дандолов

Резюме

Първият български космически прибор за измерване на параметрите на йоносферната плазма беше изстрелян на борда на спътника "Интеркосмос-8" на 1 декември 1972 г. Изстрелвайки успешно своя собствена научна апаратура в космическото пространство България стана 18-та "космическа държава" в ранг-листата на ООН. Чествайки 30-та годишнина от тази историческа дата българските инженери отчитат разностранна дейност и постижения, основно в областта на космическата физика, дистанционните изследвания и космическите технологии.

Историята на българските разработки на космическа научна апаратура датира от 1969 г., когато беше основана Група по физика на Космоса към БАН. Тя продължи успешно след като тази група прерасна в Централна лаборатория за космически изследвания през 1975 г. и в Институт за космически изследвания през 1987 г. Българските изследователи участваха успешно в програмата "Интеркосмос", разработвайки апаратура и осъществявайки експерименти на борда на спътниците "Интеркосмос-8, 12,14, 19" и на геофизичните ракети "Вертикал-3,4,6,7,10". Научната програма и апаратурата за полета на първия (1979 г.) и втория (1988 г.) български космонавт бяха изцяло разработени от български учени. Два спътника с българска научна апаратура за йоносферни-магнитосферни измервания и дистанционни изследвания на Земята бяха изстреляни през 1981 г. Българските учени участваха успешно и в международни програми като ВЕНЕРА-ХАЛЕЙ (1985 г.), ФОБОС (1988 г.), АКТИВЕН (1989 г.), АПЕКС (1990 г.) и ИНТЕРБОЛ (1995-96 г.). Специално внимание е обърнато на последните постижения на българските учени в областта космическата биология и медицина на борда на ОС МИР и новата МКС.