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THE ACTUAL SCIENTIFIC AND EDUCATIONAL PROGRAM OF SMALL SPACECRAFTS ENGINEERING

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The Siberian State Aerospace University and its strategic partners are described. Two satellites series are considered.

At the present time the Siberian State Aerospace University named after academician M.F. Reshetnev (the SibSAU) in cooperation with the strategic partners – the Joint-stock Company "Information Satellite Systems" named after academician M.F. Reshetnev" (JSC "ISS") and the Scientific Center of Krasnoyarsk under Siberian branch of Russian Academy of Sciences – implements the program of creation of the scientific and educational, technological microsatellites series [1-3].

The SibSAU is one of the leading Russian Universities in the aerospace technologies domain. The University develops on principles of the research university and implements the integrated system of preparation of specialists and scientific brainpower for the enterprises of space domain. The specialists preparation programs combine educational process, research activities and students work practice in the leading Russian space enterprises [4]. SibSAU implements the innovation educational programs [5–11] and performs scientific researches in close cooperation with the strategic partners – the base enterprise JSC "ISS" and the scientific institution – Scientific Center of Krasnoyarsk under Siberian branch of Russian Academy of Sciences, which have cooperatively created the subdepartments, scientific and educational laboratories and research centers [12, 13].

The JSC "ISS" is one of the leading enterprises of Russian space industry which possesses the technologies of complete space complexes creation cycle starting by the design to the spacecrafts control in all types of orbit – from low circular to geostationary. During its activities the enterprise has taken part in implementation of more than 30 Russian and international space programs in the domains of communication, retransmission, television, navigation, geodesy and scientific researches. The enterprise has designed, manufactured and launched about 1200 spacecrafts of 50 different types which distinguish by the high reliability and are intended for operation in low circular, circular, high-elliptical and geostationary orbits.

The objectives and tasks of the program for creation of the scientific and educational, technological microsatellites series being implemented [14, 15]:

- development of the integrated system of the engineering education (distance learning system, laboratory sessions performing using the ground stations of microsatellites control etc.);
- implementation of the design-oriented educational technology during formation of the space domain specialists professional capacities (students' participation in designing and manufacturing of satellites, service systems and scientific devices);
- scientific experiments in space (development of the Earth natural resources space monitoring methods, multifunctional nanomaterials, high-temperature superconductors and other intelligent materials use in space);
- technological development and obtaining of the flight qualification for the advanced service systems, devices and elements of the satellites (of the attitude determination and control subsystem, electric power subsystem, thermal control subsystem and other subsystems with the increased lifetime).

In 2007 the SibSAU in cooperation with the JSC "ISS" and the Scientific Center of Krasnoyarsk under Siberian branch of Russian Academy of Sciences have concluded the strategic partnership agreement on creation of students' small satellites series according to which the program of technological, scientific and educational satellites regular creation and following launch was adopted (smka.sibsau.ru). Due to this program the technological work-out in space and flight qualification obtaining will be provided for the new elements of satellites and space systems developed on the basis of the University. The SibSAU is the single Russian higher school which will perform the manufacturing of elements and the assembly of microsatellites, the mounting of technological and scientific instruments as well as the part of small satellites tests directly on the basis of the joint scientific and educational center "Space systems and technologies" and the industrial resource center "Spacecrafts and space systems" which has the clean room and production facilities for these purposes.

The "Yubileyniy" satellites series

In 2008 the first satellite of the "Yubileyniy" satellites series has been developed and put into operation (Fig. 1). Structurally the "Yubileyniy" satellite consists of the unpressurized instrumentation module formed by the hexagonal frame on which the solar array panels are mounted and by three transversal panels – upper, middle and lower. On-board equipment is accommodated in the instrumentation module as well as on the outer surface of the upper panel. On the upper panel which is directed towards the Earth during the satellite operation the attitude determination subsystem elements are located – magnetometer and transversal beams with balancers, receiving and transmitting antennas as well as the scientific equipment: three Earth sensors to receive the data on the Earth radiation in the infrared range of wave lengths and to research the space-time radiation of the Earth day-time and night-time atmosphere in the apparent spectral range.

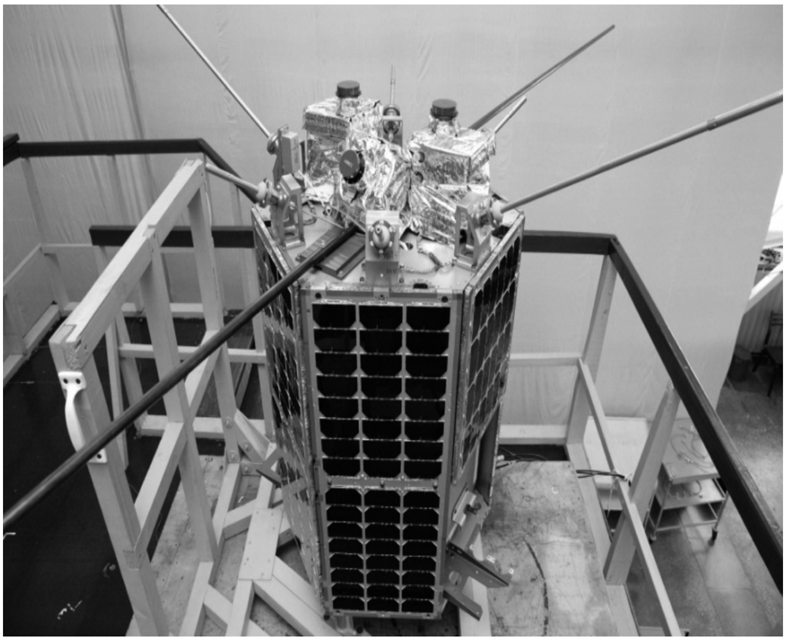

Fig. 1 Photo of the Small satellite “Yubileyniy”

On the middle panel the DOKA-B equipment is installed that includes on-board computer, receiving equipment operating in frequencies of 145 MHz, transmitting equipment operating in frequencies of 435 MHz and radionavigation on-board equipment.

On the bottom there are located: magnetic-gravitational attitude determination system providing the satellite longitudinal axis orientation towards the Earth in nominal mode, navigational equipment antenna, experimental sun sensor and “Radek” equipment dedicated to check the efficiency of application of the nano-coatings developed in the SibSAU for radiation protection of satellites’ electronic components.

One of the purposes of the unified platform of this satellite developed in the JSC “ISS” is to create conditions to perform the educational and scientific and technical experiments in space. As the satellite attitude control subsystem elements the self-deploying mechanical micro systems based on composite materials are used. Such mechanical systems allow creating the transformable large-size spatial structures based on lightweight tubular rods in space. The rods extension mechanisms allow spatially allocating the objects with the mass about 10 kg at distances of tens of meters.

The solar arrays panels mounted on the frame are made based on the three-stage gallium arsenide and allow providing electric power to the satellite on-board equipment in the sunlit part of orbit. The selected frame shape provides the required value of the solar array effective area, at different satellite position relative to the Sun. In eclipse orbit the electric power is provided to the equipment by the nickel-metal-hydride battery. The battery is not the separate unit, its elements are included in the instrumentation power and control unit which accommodates all the automatics of the electric power subsystem; all this is included in the DOKA-B equipment.

The peculiarity of this satellite is the passive thermal control subsystem: the required temperature conditions are provided by unregulated ratio of optical factors on object structure elements surfaces, heat-insulating elements, electric heaters and heat pipes which provide thermal conditions for the DOKA-B equipment.

In the frame of the project “Research of radiation shields efficiency at radiation effects of the Earth.

The telemetry data from the equipment are received, processed and stored in the SibSAU students’ Satellite Control Center.

The small satellite “Yubileyniy” ensured the performance of research, experimental and educational tasks.

The “Yubileyniy” satellite launch started the information program dedicated to the most important stages of the space exploration (speech messages, slides in SSTV format, simulation of signals of the first satellite).

It created conditions for use of information from the small satellite by the leading Russian higher schools in teaching and educational objectives.

Performance of scientific and technological experiments:

- Ensuring the flight qualification of promising Sun and Earth sensors;
- Acquisition of data on the Earth radiation in the infrared range of wave lengths;
- Research the space-time radiation of the Earth day-time and night-time atmosphere in the apparent spectral range;
- Working-out the satellite orientation assessment methods according to the information from the experimental Sun sensor and the compact magnetometer;
- Check of the efficiency of application of the nano-coatings developed in the SibSAU for radiation protection of satellites' electronic components;
- Ensuring the flight qualification of the promising multifunctional unpressurized platform for satellites with the mass of 30–100 kg;
- Working-out the technology of small satellite concurrent injection into the operational orbit by the "Rokot" launcher.

All the organizations that have taken part in development and creation of the small satellite obtained the significant scientific and technical groundwork for the future and made their contribution to the preparation of highly skilled specialists for the space industry of Russia.

The launch of the small satellite "Yubileyniy" together with three nominal satellites was performed from the "Plesetsk" launch site on the 23/05/2008.

Besides the scientific-technical and experimental tasks the small satellite was intended to perform one more function not less important. The creation of this satellite allowed performing preparation of young specialists on the basis of project-oriented educational technology for the first time. The students took part in all stages of satellite creation: from the design documentation development to the satellite in-orbit control.

Operation control of the satellite that has been successfully operating in space for four years is performed by the Satellite Control Center formed in the SibSAU with the JSC "ISS" participation. The students receive the telemetry information from the satellite in real-time mode there, learn to decode it and to control the satellite.

The Satellite Control Center main functions are control and coordination of interactions between technical means of satellite deployment, maintenance in nominal operation mode and replacement. The Center fulfills the following tasks:

- long-term and operational planning for the satellite and the ground control center technical facilities operation;
- organization of technical facilities synchronous operation in real time;
- control of the checking information packets generation and transmission on-board the satellite;
- reception, processing, display and archiving the telemetry information from the satellite;
- analysis and prediction of the satellite technical state;
- organization of the current navigational parameters measurements and their processing;
- organization of preventive measures and contingencies recovery;
- performing the Satellite Control Center technical facilities operability monitoring in accordance with the technical requirements;
- organization of information protocols, queues, priorities, flows, archives access;
- providing the automatic information exchange with the ground control center facilities and interacting complexes.

The "Mikhail Reshetnev" satellites series

On the second satellite "Mikhail Reshetnev" (MiR) has being launched in August 2012 and five new university developments will be approbated already. The students of SibSAU have developed and manufactured: on-board computer, remote data interface unit, Earth remote sensing camera and laser corner reflector intended to measure the distance from the satellite to the Earth. The function of the devices is the working-out the new control unit and the digital line of the Earth remote sensing information transmission in space.

The small satellite MiR is designed on the base platform of the "Yubileyniy" satellite with extended mass and power performances (Fig. 2).

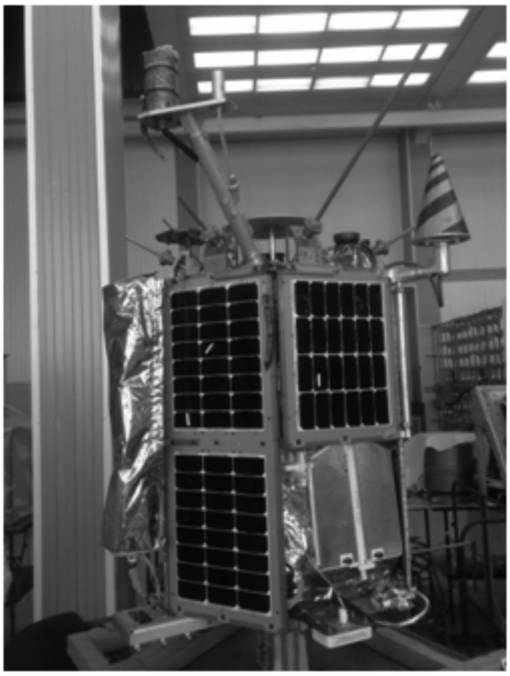

Fig. 2. Small satellite"MiR"

The tasks performed during creation and operation of the small satellite "Mikhail Reshetnev":

- Obtaining the scientific and technical groundwork in the field of competitive space technology and technologies of new generation for use in defense, scientific and commercial purposes;
- Creation and working-out in field conditions the experimental parts of small satellites and advanced satellites of the JSC "ISS";
- Obtaining the experience of creation and operation of the satellites for the Earth remote sensing;
- Improving the existing forms of project-and-team preparation of specialists for the JSC "ISS" with the participation of the SibSAU students on the basis of the joint scientific and educational center "Space systems and technologies" (SEC SST);
- Creation and launch of the satellite in honor of the fiftieth anniversary of the JSC "ISS" and the SibSAU.
- Working-out and acquisition of the contour heat pipes production technologies.

The opportunities for students

The students of technical specialities during studies have the unique possibility to directly control the Russian small satellites ("Yubileyniy", "Mozhaets", "Chibis" and future "Mikhail Lomonosov" and "Baumanets 2") and satellites of the Technical University of Berlin (DLRSAT, TUBSAT), receive and process the telemetry information (sat.sibsau.ru). In the center there are also studies on the program simulator of modern telecommunication satellite "Express-AM" that fully simulates operation of all satellite service subsystems and is used for test work-out of on-board control system and learning to operate the real satellite (joint development of SibSAU and JSC "ISS" specialists). The Students' SCC of the SibSAU is an important ground segment of the orbit group of technological, scientific and educational small satellites being created by the University and the partners.

In 2010 in the frame of the international project "Reformation of the educational programs in the field of space technology in Russia, Ukraine and Kazakhstan" (CRIST) according to the European Commission program TEMPUS the international distributed network of the University's small satellites control stations was created for the successful and full-scale small satellites control. This network included SibSAU, the Technical University of Berlin, the State Aerospace University of Samara, the Moscow Aviation University and several leading institutions of higher education of Russia, Ukraine and Kazakhstan. In 2011 in the frame of the project on the TEMPUS program SibSAU and the Technical University of Berlin were remotely united through the Internet. Thus the students of SibSAU obtained the unique possibility to receive the information from the Russian University's satellites and satellites of the Technical University of Berlin.

Conclusion

The speciality of the program on students' microsatellites series creation being implemented is that the JSC "ISS" uses them as an experimental field for working-out new devices and systems. The most part of the payload on-board equipment mounted on these satellites is used for the first time. The new equipment gets the flight qualification in-orbit, after that it could be used in creation of big spacecrafts.

As a result of implementation of the presented project in Krasnoyarsk due to the joint efforts of JSC "ISS", SibSAU and SCK SB RAS the successful integrated system is created for the space industry manpower development using the unique technologies of project-and-team students' work, balancing between innovations and traditions, education and scientific research and maintaining the flexibility in educational trajectory construction. It allowed organizing students' and postgraduate students' work on the real projects directly in the SibSAU starting from the design and the short-series manufacturing of space engineering devices and elements to the creation of small satellites.

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MEASUREMEN.T PHASE NOISE CRYSTAL OSCILLATOR

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One of the most important characteristics of high frequency oscillators (HFO) used in communication devices, navigation equipment, digital devices, systems orientation autopilot aircraft, missile guidance systems, radar equipment – is the phase noise generated oscillations, in other words , the distortion of the generated signal [1].

The ideal signal generated by a crystal oscillator (CG) should not be distorted shape, and location of its edges should exactly repeat from period to period, that is, it must exactly match their mathematical function, $U = U_o sin(t/T)$ for a sinusoidal signal where: T – the period of oscillation, t – current time.

Waveform distortion due to the nonlinear regime autogeneration, electrical frequency multiplication, and other factors, spectral analysis explains "admixing" to the basic ideal signal with frequency ω of its harmonics with multiple frequencies (2ω, 3ω, 4ω ...) and amplitudes corresponding to that signal distortion [2].

In that case, if the waveform distortion is random chaotic can speak of a phase noise in the signal . Phase noise in the reference oscillator leads to a deterioration of the radio systems: degradation of the radio communication, reduce the accuracy of location of objects in the GPS navigation data transmission losses, reduced sensitivity of radar and others. Today, phase noise is one of the main parameters of the CG, which reduce is of paramount importance .

Phase noise measurement is performed on special analyzers spectral analysis, determine how its power is distributed over the frequency range from zero to infinity. In practice, it is usually limited by the operating frequency detuning of the signal in the range from *0,1 Hz* to *100 kHz* (and sometimes from *0,01 Hz* to *1 MHz*) [3].

The measurement results are presented in the form of the curve $L(\Omega)$, where Ω – frequency analysis *Hz*; $L(\Omega)$ – logarithm of the spectral power density of the "noise" of the signal $S(\Omega)$, measured in a *1 Hz* bandwidth at a distance from the lasing frequency Ω: $L(\Omega)$, $dBc = 10Log[S(\Omega)/2]$.

The dependence of $L(\Omega)$ is divided into three zones differing slope $L(\Omega)/\Omega$: proximal zone occupies a range of from 0Ω to *10 Hz* has a slope $L(\Omega)/\Omega$ about *30 dBc* per decade (a decade – the change *Ω10 times*); middle zone , which occupies the frequency range Ω approximately *10 Hz* to *10 kHz*, is characterized by a slope $L(\Omega)/\Omega$ from *10* to *20 dBc* per decade; far zone (or noise-floor), starting from Ω = *10 kHz*, has almost no slope of $L(\Omega)/\Omega$.

In the formation of the CG noise involved various sources , concentrated in the oscillator circuit , temperature control system and a quartz resonator (CR). Their influence on the noise CG occurs by a complex interaction between them and the parameters of the resonator. Despite the well-known convention, it is assumed that the phase noise $L(\Omega)$ at different detuning Ω generated by various sources of noise.

Far field (noise-floor) is formed mainly intrinsic noise buffer amplifier. Thus , the higher the level of the generated signal at the input of the buffer amplifier , the lower the contribution of noise in the CG and the lower level $L(\Omega)$. Limit reduce noise-floor limited Johnson noise equal at room temperature – *174 dBm/Hz*. Therefore, the lower levels of phase noise reduction required temperatures CG [4].

The middle zone $L(\Omega)$ is formed by noise amplifier oscillator , closed through the CD positive feedback . At the level of phase noise in this area influences the loaded quality factor KR: the higher the Q_L, the lower the frequency of the upper middle zone and the middle zone of the transition frequency in noise-floor.

In the formation of the near field dependence $L(\Omega)$ involving the same sources as in the middle zone, but added to them related to the influence of noise on the resonator and the thermostat. Effect of noise on the thermostat due to fluctuations in its temperature , called through the thermodynamic effect of the frequency fluctuations of the CD. Usually this factor is concentrated in the range of $0{,}01\Omega$ to *5 Hz*, and can be reduced by optimizing the design of the oven and increase the thermodynamic stability of the CR.