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Scientific and Technological Experiments on Automatic Space Vehicles and Small Satellites

Small satellites "AIST" constellation - design, construction and program of scientific and technological experiments

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Abstract

In 2013 two small satellites of "AIST" series were launched into an orbit. This is the first joint project of Samara State Aerospace University (SSAU) and Space-Rocket Center (SRC) "Progress" which was crowned with full success. In the article the main tasks solved by spacecrafts are described, the design shape of the satellites is presented. The scientific equipment of small satellites, their principle of operation is described, some results of experiments are given.

Work on creation of small satellites of "AIST" series became a starting point for high-quality growth of competences of SSAU and SRC "Progress" young specialists, and also for students who were engaged in the project. Besides, this project allowed to modernize essentially educational process in the field of space technics and technologies.

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1. Introduction

At 10:00 UTC on 19 April 2013, the launch vehicle “Soyuz 2.1A” blasted off from the Baikonur Cosmodrome, as a way cargo with “Bion-M” №1 satellite, put to orbit a Russian university small satellite created on the “AIST” platform. The satellite platform was developed by a joint project between Samara State Aerospace University (SSAU) and JSC “Space-Rocket Centre “Progress” (SRC “Progress”) with the goal to demonstrate and fine-tune small spacecraft design technologies. The initial orbit parameters were: inclination - 64,9°; orbital period 96,1 min.; aphelion 583 km; perihelion 569,8 km.

At 12:30 UTC on 28 December 2013, in the course of the debut launch of the new light launcher “Soyuz 2.1v” developed by “TsSKB-Progress”, the second small satellite on the “AIST” platform was put into orbit from the Plesetsk Cosmodrome. The initial orbit parameters were: inclination 82.4°; orbital period 96,9 min.; aphelion 632.8 km; perihelion 604.6 km.

SSAU students and young specialists initiated the small university satellite “AIST” design project in 2006. The satellites of the “AIST” family are created in cooperation with SRC “Progress” and supported by the Samara Region Administration. SSAU plays a leading role in education of the most highly qualified professionals in the field of small spacecraft development. By taking part in all stages of spacecraft creation - from design to manufacture and operation - a whole generation of active young researchers learns the skills which enable them to solve the most serious scientific and applied problems. Small satellite “AIST” is developed for the purpose of resolving several educational, scientific, technological and experimental problems.

Within the project, the following scientific and technological experiments are carried out:

- ensuring flight capacity of advanced multifunctional non-hermetic platform for spacecraft weighing 30 to 60 kg;
- geomagnetic field measurement and methods of small spacecraft microacceleration measurement and compensation (“MAGCOM” equipment);
- research into problems of microgravity;
- research into natural and artificial high-velocity mechanical particles behavior (“METEOR” equipment);
- perfection of “way cargo” satellite launch technology and shock-free undocking of small satellite from carrier spacecraft;
- creation of amateur bandwidth communication links to provide a channel for multiagent technologies information exchange;
- outer-space experimental tests of perspective gallium arsenide solar batteries [1].

2. Construction

The construction of the vehicle represents non hermetic compartment which is formed by a spatial frame with arms. The body panels are mounted on this frame.

The on-board support systems of the small satellite “AIST” include the flight control and navigational system, electric power supply system including solar panels and accumulating batteries, thermal regulation system and the on-board cable network.

Two of the satellite's body panels house the navigation and control system modules including the on-board computer, 145 MHz receiver, 435 MHz transmitter and on-board radionavigational unit.

The solar panels is mounted on the satellite body with photoelectric converters glued directly to five of six body panels. In addition, another solar panel is attached to the sixth body panel of the spacecraft. The photoelectric elements are built on the three-stage gallium arsenide photocell. On the shadow parts of the orbit the spacecraft is powered by the nickel-metal hybrid battery.

The thermal control system is of a passive type. The desired temperatures are ensured by unregulated relation of the optical coefficients on the spacecraft body, thermal insulation elements, electric heaters and heat pipes which ensure the necessary thermal mode of the flight control and research units.

The inner arrangements of the elements of the spacecraft, with the basic on-board systems and research equipment modules, is represented on Fig. 1. The external view of the small satellite “AIST” in launch configuration with undocking unit see Fig. 2.

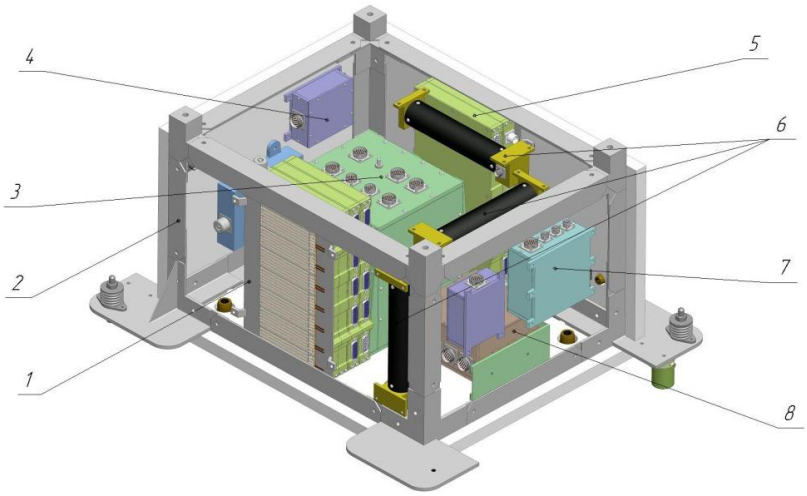

Fig. 1. The inner arrangements of small spacecraft “AIST” units: 1 - flight control and navigational system; 2 - the skeleton of the body; 3 – “MAGCOM” unit; 4 - magnetic sensor module; 5 - battery unit; 6 - electric magnets (3 units); 7 - electric magnets control unit 8 – “METEOR” control unit.

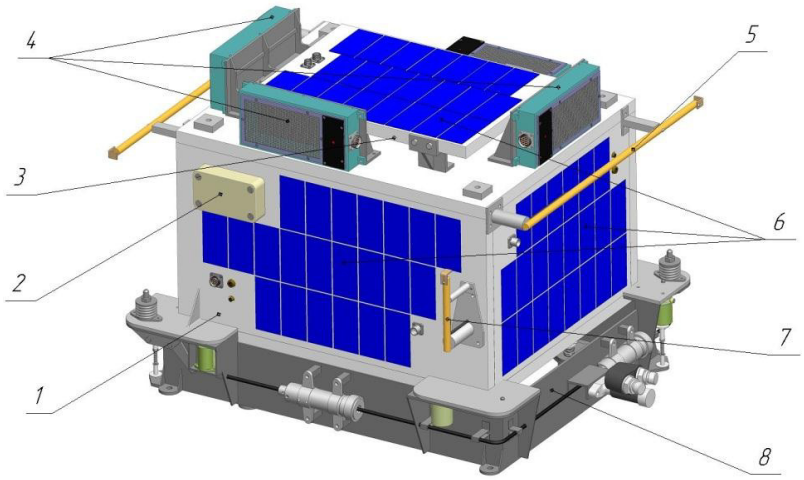

Fig. 2. External view on the “AIST” small satellite: 1 - spacecraft body; 2 - the user navigational unit antenna; 3 - solar battery panel; 4 – “METEOR” sensor (6 units); 5 - the 145 MHz receiver antenna; 6 - photocells; 7 - 435 MHz transmitter antennae (2 units), 8 - undocking module.

3. Research equipment and scientific experiments

Research equipment used for “AIST” small spacecraft includes the “MAGCOM” and “METEOR” research equipment complexes developed by Institute of spacecraft instrument engineering of SSAU.

“MAGCOM” equipment was created to confirm the effectiveness of magnetic microacceleration compensation devices on board of small satellite “AIST” and to improve the methods of design objectives development for such devices. The “MAGCOM” research equipment ensures the solution of the following problems:

- operating calculation of controlling magnetic moment of the equipment for the low-frequency part of the microacceleration on the basis of magnetic induction vector of geomagnetic field measurements and orbital movement parameters;

- to improve the modes of the equipment in order to bring low-frequency microacceleration on board of the spacecraft to the minimum, not exceeding the 10^{-5}g0 to 10^{-7}g0 range. Development of small satellite platform with these characteristics, unparalleled in the world, is expected to attract the clients interested in carrying out unique experiments on board of the spacecraft both in this country and internationally;

- to form a large body of data including magnetic induction vector measurement, orbital movement parameters, and controlling magnetic torque calculations.

The "MAGCOM" equipment comprises:

- two ternary magnetometers for geomagnetic field measurements;
- the electronics module;
- actuator components control module;
- three electric magnets;
- data link connecting the "MAGCOM" electronics module with the flight control and navigational system.

The "METEOR" equipment is designed for the following tasks:

- high-velocity dust particles mass and velocity evaluation by contact with the induction sensor;
- time and spatially relation of the high-velocity dust particle measurement results in order to consequently determine the incoming direction of the participle and its identification as micrometheoroid or technogenic particle;
- regular measurement of the spatial orientation of the Sun in relation to interconnected coordinates of the spacecraft, with subsequent estimation of charged particles inflow onto the small satellite surface and the dynamics of the surface charge change.

Any spacecraft is exposed to streams of dust particles during the flight. The following effects are observed under the particles exposure on materials and structural elements: surface erosion, particles appearing from own outer atmosphere (OOA), spacecraft surface contamination by the precipitating products of OOA, increasing light background in the vicinity of spacecraft due to the scattering of light by particles OOA and luminescence, the increase in leakage current in open high-voltage devices and decline in their electric strength [2].

Recently, there has been a trend of increasing concentrations of man-made (technogenic) high-speed dust particles in Earth orbit [3]. Given all the increasing demands on reliability and durability of the spacecraft, as well as the emergence of many new materials, further development of research into the processes of interaction of dust particles with high material elements of spacecraft design is essential [4]. To determine the parameters of micrometeoroids and space debris we need sensors that convert shock impact into electrical signals.

Methods and equipment for recording dust particles can be classified as follows: according to the method of particle interaction with the device methods are divided into contact and contact-less; converters are characterized by having one informative output dependence or more; methods for speed and duration of the registration device differ according to generating output pulse signals. In practice, ionization method is the most sensitive to the effects of micro-meteoroid.

The "METEOR" equipment consists of:

- six multi-parameter sensors;
- the electronics module;
- data link connecting the "METEOR" electronics module with flight control and navigational system.

Each of the multi-parameter sensor has a temperature sensor, an ion gauge of high-speed dust particles, a solar sensor and electrification sensor.

The main purpose of development and experimental approbation in space of "METEOR" equipment is improvement of meteor and technogenic particle resistance of spacecraft. As a result of the "METEOR" equipment operation within the specified time of operation of two small satellite into the orbit, several events were recorded, about 15 of which can be classified as high-speed micro-particle impact.

4. Launch into orbit

Initially, a number of variants of putting the small satellite into orbit were considered, including the "way cargo"

with larger "Bion-M" satellite. This method is characterized by limitations imposed on the size and weight of the satellite and the direction and speed of undocking from the carrier spacecraft in terms of the absence of shock.

On April 19, 2013, at 10:00 UTC, the first small spacecraft developed on the “AIST” platform was put into orbit from the Baikonur Cosmodrome as a way cargo with a “Bion-M” № 1 satellite by “Soyuz 2.1A” launcher (see Fig. 3). On April 21, 2013, the “AIST” successfully undocked from the “Bion-M” and went into its own orbit. On April 22, 2013, the first telemetry data, indicating that all on-board systems were operating normally, was received at the “TsSKB-Progress” control center. From April 22, 2013 the information from the spacecraft is being received by SSAU students in addition to SRC “Progress” employees. On April 23, 2013, the transfer to the spacecraft's own navigational system was carried out. On April 25, 2013, the “MAGCOM” and “METEOR” research equipments began their operation on board of the satellite.

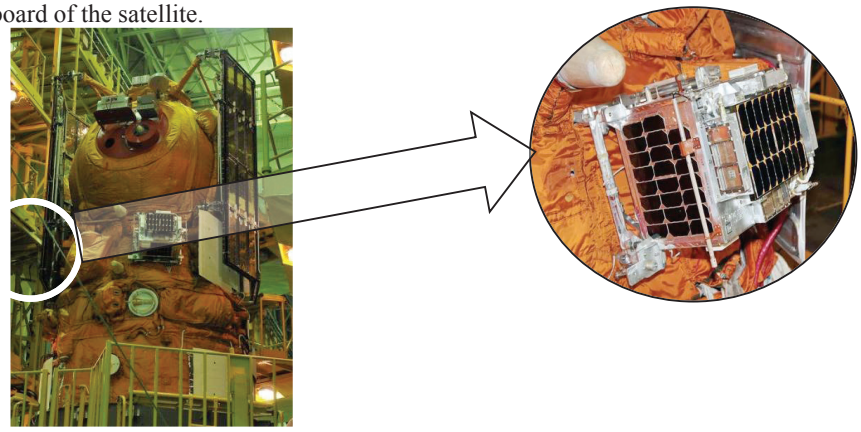

Fig. 3. Preparation for the launch of the small satellite “AIST” .

On December 28, 2013, at 16:30, Moscow time, the debut launch of the new light launch vehicle “Soyuz 2.1v” with the insertion stage vehicle “Volga” was performed at the Plesetsk cosmodrome (see Fig. 4). The launcher put into space an experimental production sample of small satellite “AIST”.

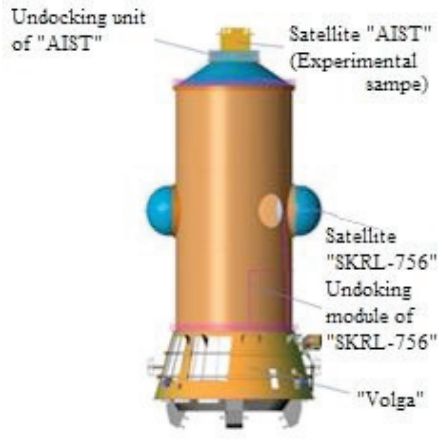

Fig. 4. Accommodation small satellite “AIST”.

Therefore, at present a constellation of two “AIST” satellites, designed to solve educational, experimental and technical problems, is operating at the orbit (see Fig. 5).

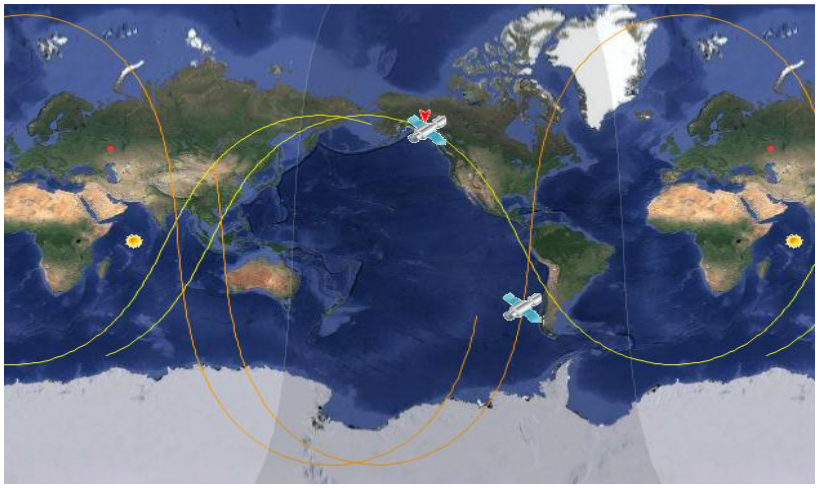

Fig. 5. The orbit constellation of small satellites “AIST” №1 (NORAD ID: 39133) and “AIST” №2 (NORAD ID: 39492), according to www.n2yo.com.

5. Receiving data

At present, the research data from the satellites is received and processed by both SRC “Progress” researchers and the SSAU young researchers in “Samara” Earth remote sensing data acquisition, processing and distribution center (see Fig. 6). At present time such a center for ground control and for receiving and processing data from small satellites “AIST” is under construction in SSAU to make the access of university students and young scientists simpler.

Fig. 6. “Samara” Earth remote sensing data acquisition, processing and distribution center and antenna.

Some of the data from the spacecrafts' research units is represented in Fig. 7.

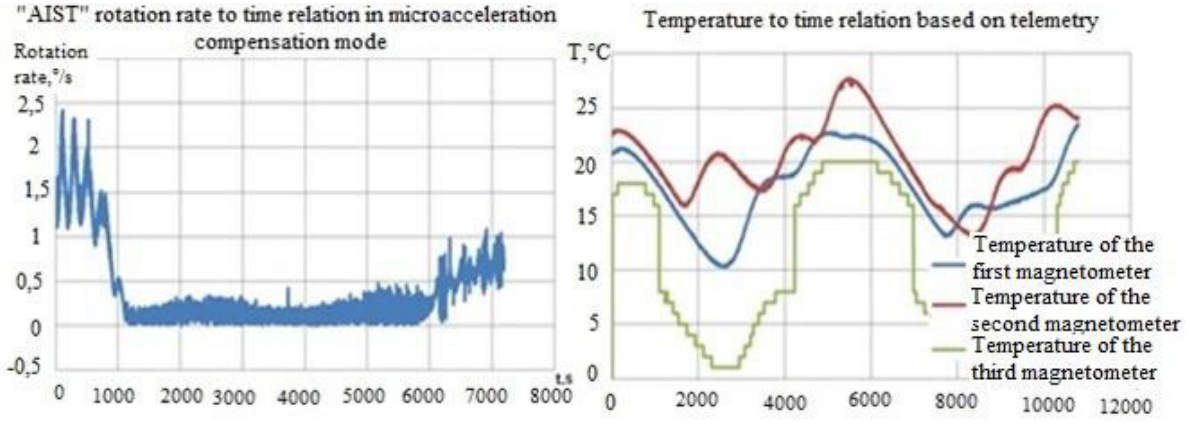

Fig. 7. Research data supplied by “MAGCOM” units.

6. Conclusion

Since 2006, over 100 students took part in the “AIST” program, most of them after graduation were employed at research institutions or high-technology manufacturing enterprises. Over the period, more than 50 specialists' graduate projects and over 20 bachelors' graduate papers were completed, 9 MS and 5 Candidate of sciences degrees were obtained on the basis of the project.

The constellation of “AIST” series satellites is the cosmic segment of SSAU's educational and research laboratory, which not only forms the basis for fundamental and applied research projects, but also ensures education and training of highly qualified professionals who are competent in real-life design, improvement and operation of spacecraft. In the nearest future, the access to receiving and processing data from satellites will be provided also to the SSAU's international partners, European aerospace universities, for the purpose of improvement of multiagent technologies in space.

Acknowledgements

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