SCIENTIFICAL AND TECHNOLOGICAL EXPERIMENTS ON UNIVERSITY "AIST" TYPE SMALL SATELLITES CONSTELLATION

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On April 19, 2013, at 10:00 UTC 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 named after academician S. P. Korolev (national research university) (SSAU) and the JSC "Space-Rocket Centre "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.

On December 28, 2013, at 12:30 UTC 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.

The small university satellite "AIST" design project was initiated in 2006 by SSAU students and young specialists. The satellites of the "AIST" family are created in cooperation with "TsSKB-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 development of perspective nano-technologies gallium arsenide solar batteries.

Research equipment used for "AIST" small spacecraft includes the "MAGCOM" and "METEOR" research equipment complexes developed by SSAU spacecraft instrument engineering institute.

"MAGCOM" equipment is designed 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 equipments in order to bring low-frequency microacceleration on board of the spacecraft to the minimum, not exceeding the $10^{-5}g_0$ to $10^{-7}g_0$ 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.

The "METEOR" equipment consists of:

- six mutluparameter actuators;
- the electronics module;
- data link connecting the "METEOR" electronics module with flight control and navigational system.

The purpose of development and experimental approbation in space of "METEOR" equipment is improvement of meteor and technogenic particle resistance of spacecraft.

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 are 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 Figure 1. The external view of the small satellite "AIST", in launch configuration with undocking unit, is represented in Figure 2. The external design of the satellite was changed in the course of development due to the need to resolve certain

constructional and design problems. The evolution of the small spacecraft looks is represented in Figure 3.

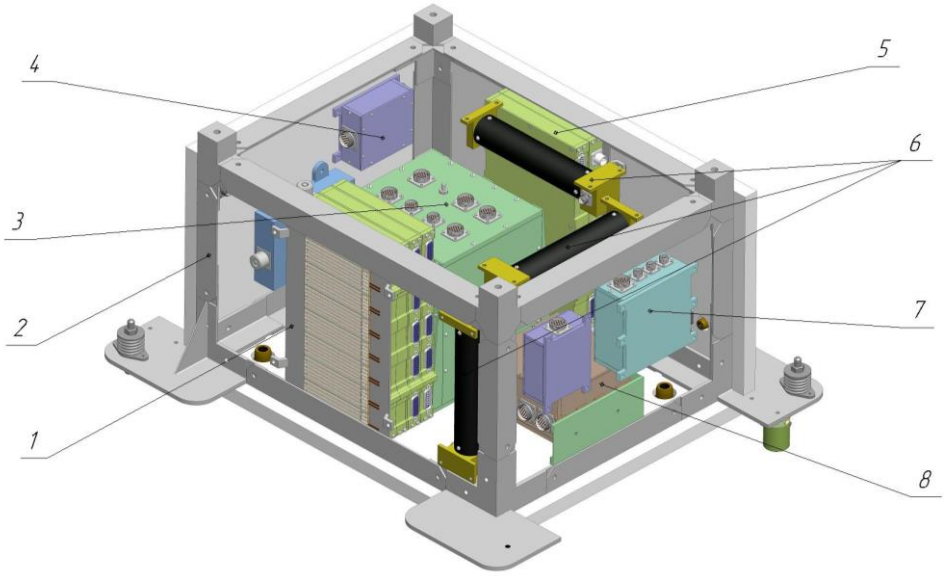

Fig. 1 - The inner arrangements of small spacecraft "AIST" units: 1 - flight control and navigational system; 2 - the skeleton of the body; 3 – "MAGCOM" unit; 4 - magnetic sensor module; 5 - battery unit; 6 - electric magnets (3 units); 7 - electric magnets control unit; 8 – "METEOR" control unit

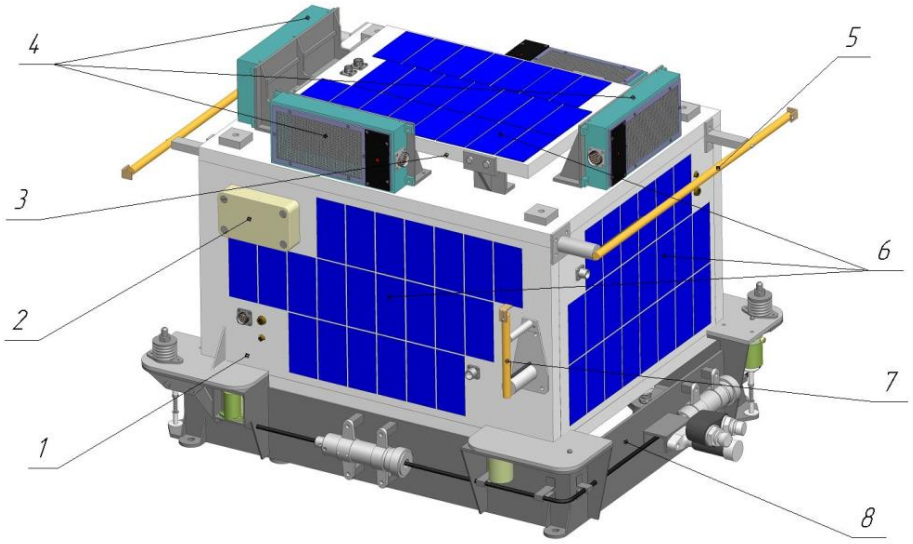

Fig. 2 - External view on the "AIST" small satellite: 1 - spacecraft body; 2 - the user navigational unit antenna; 3 - solar battery panel; 4 – "METEOR" sensor (6 units); 5 - the 145 MHz receiver antenna; 6 - photocells; 7 - 435 MHz transmitter antennae (2 units), 8 - undocking module

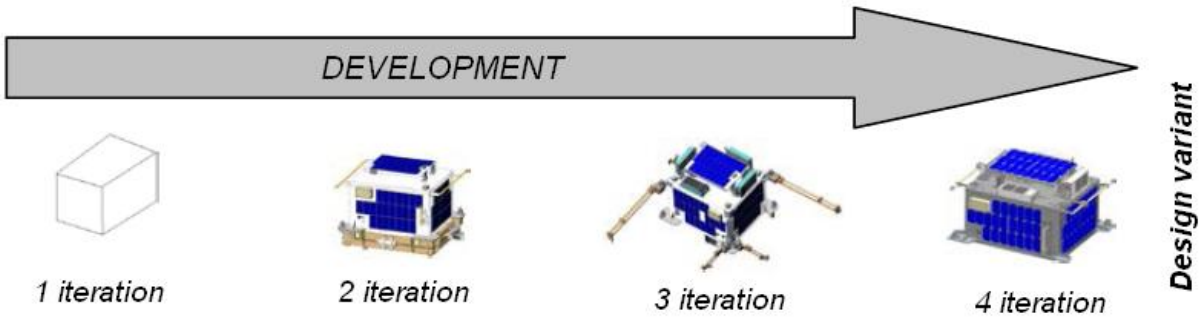

Fig. 3 - Iteration scheme of small spacecraft design

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. 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 onboard systems were operating normally, was received at the "Space-Rocket Centre "Progress" control center. From April 22, 2013 the information from the spacecraft is being received by SSAU students in addition to "Space-Rocket Centre "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.

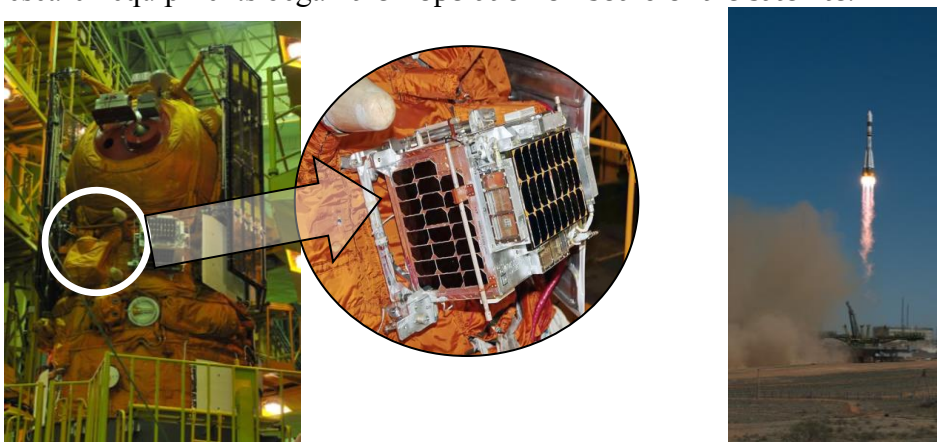

Fig. 4 - Preparation for the launch and launching of the small satellite “AIST” from the Baikonur Cosmodrome on April 19th, 2013

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. The launcher put into space an experimental production sample of small satellite “AIST”.

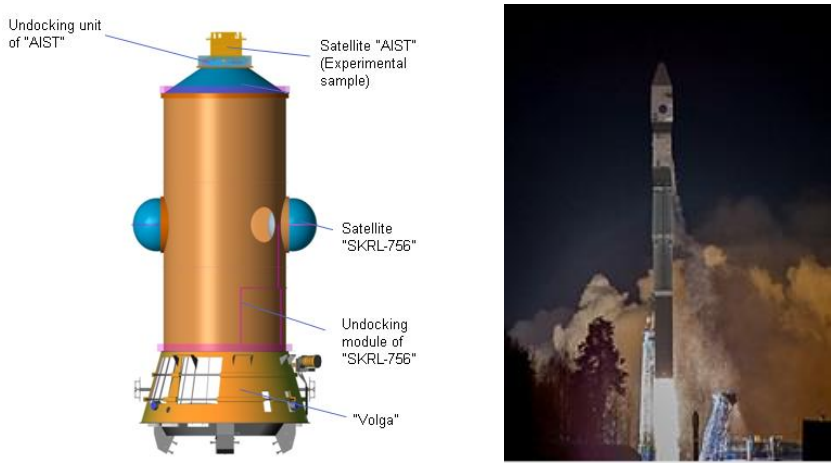

Fig. 5 - Launch of the small satellite “AIST” from Plesetsk cosmodrome

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

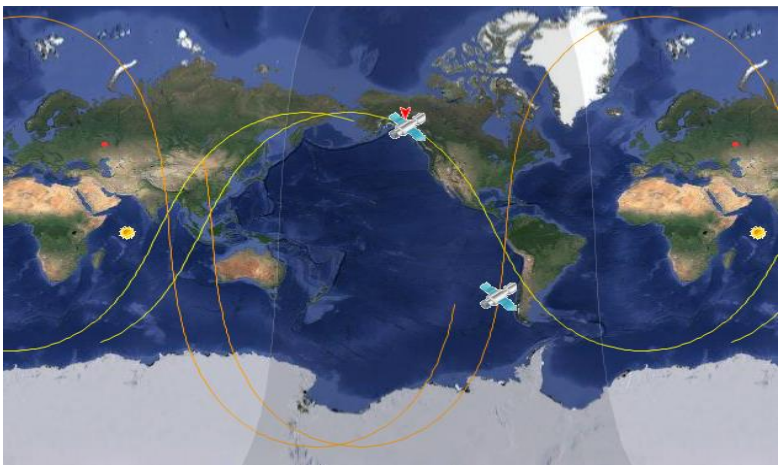

Fig. 6 – The orbit constellation of small satellites “AIST” №1 (NORAD ID: 39133) and “AIST” №2 (NORAD ID: 39492), according to www.n2yo.com

At present, the research data from the satellites is received and processed by both "Space-Rocket Centre "Progress" researchers and the SSAU young researchers. Some of the data from the spacecrafts' research units is represented in Figure 7.

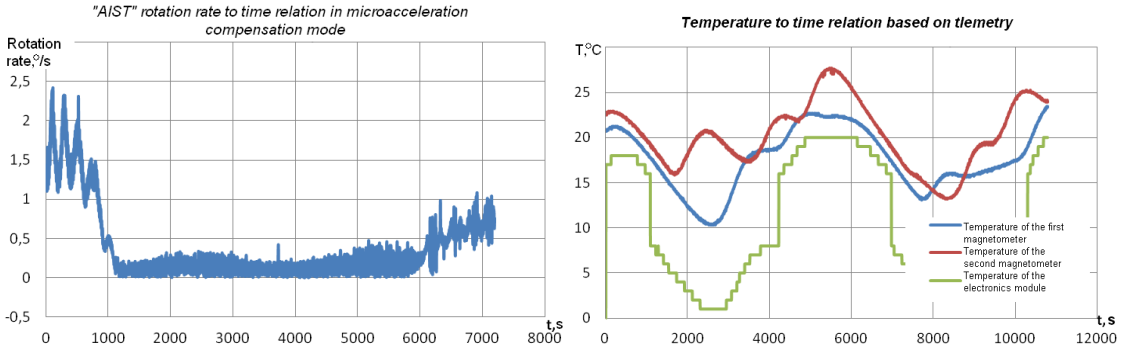

Fig. 7 - Research data supplied by “MAGCOM” units

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.

At present, the creation of a new small satellite “AIST-2” (Figure 8) is in progress. This spacecraft will serve the purpose for remote sensing of the Earth.

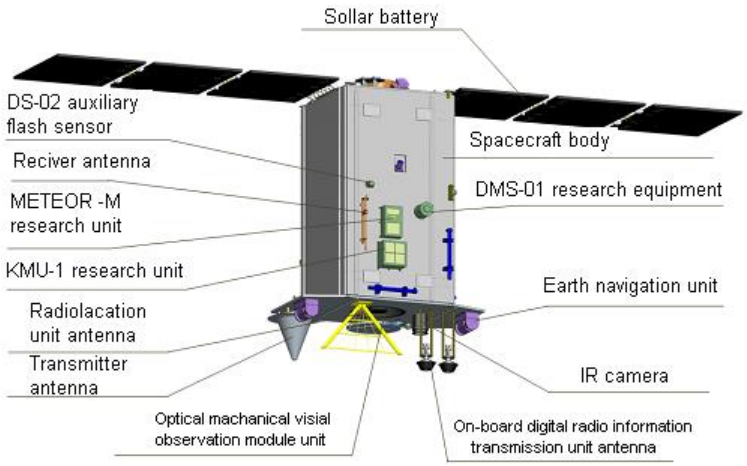

Fig. 8 - Satellite “AIST-2”

The spacecraft is developed as part of the SSAU and "Space-Rocket Centre "Progress", cooperation project "Development of high-tech production of small satellites for hyperspectral sensing in the interests of Russia's social and economical development and international cooperation", under Russian Federal Government Decree №218 of April 9, 2010.

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