РКЦ ПРОГРЕСС

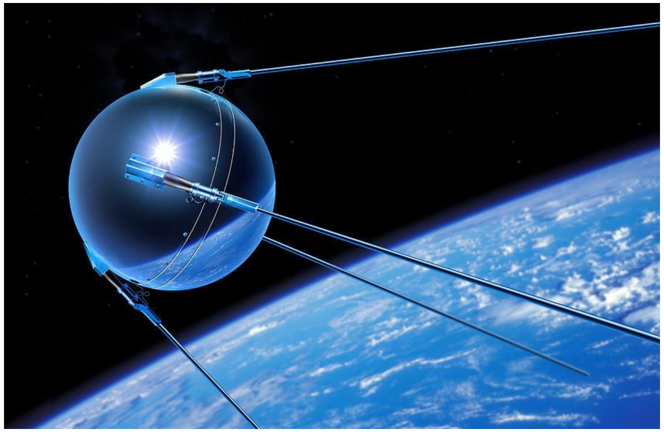
САМАРСКИЙ УНИВЕРСИТЕТ
SAMARA UNIVERSITY

Experiments and prospects for development of science and educational "AIST" micro-satellites

Ivan S. Tkachenko, Samara University
Evgeny V. Kosmodemyansky, SRC "Progress"

2017

Classification of spacecrafts



Sputnik-1 - the first Earth's artificial satellite

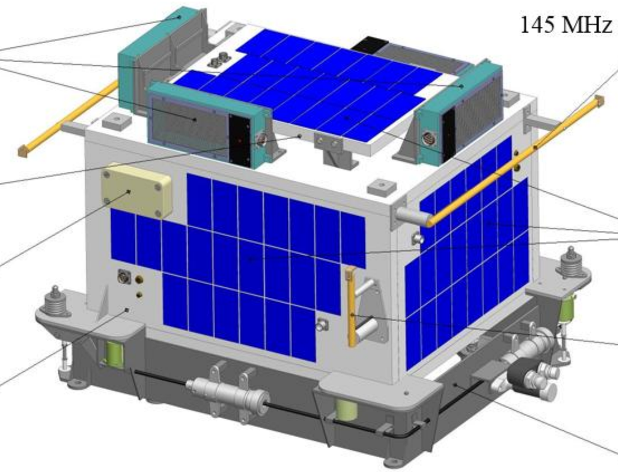
- Launch date — 4 October 1957;
- Decay date — 4 January 1958;
- Launch mass — 83,6 kg;
- Maximum diameter — 0,58 m;
- Inclination — 65,1°;
- Period — 96,7 min;
- Perigee — 228 km;
- Apogee — 947 km.

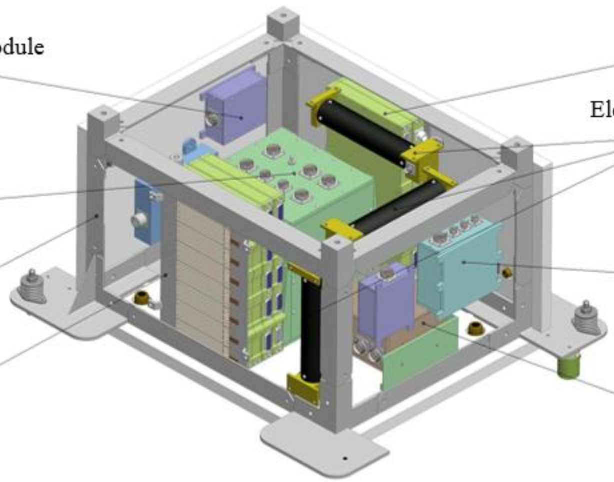
Satellite classification based on mass characteristics:

- femto — up to 100 g;
- pico — up to 1 kg;
- nano — 1–10 kg;
- micro — 10–100 kg;
- mini — 100–500 kg;
- small — 500–1000 kg;
- large — more than 1000 kg.

ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

Main technical characteristics:
- initial orbit parameters:
near-circular H = 575 km;
inclination i = 64,9°;
- mass – 38 kg (53 kg with adapter);
- dimensions: 400×500×600 mm;





- lifespan – up to 3 years;
- the spacecraft performs non-oriented flight;
- radio circuit: 2 receivers 145MHz,
  2 transmitters 435MHz.

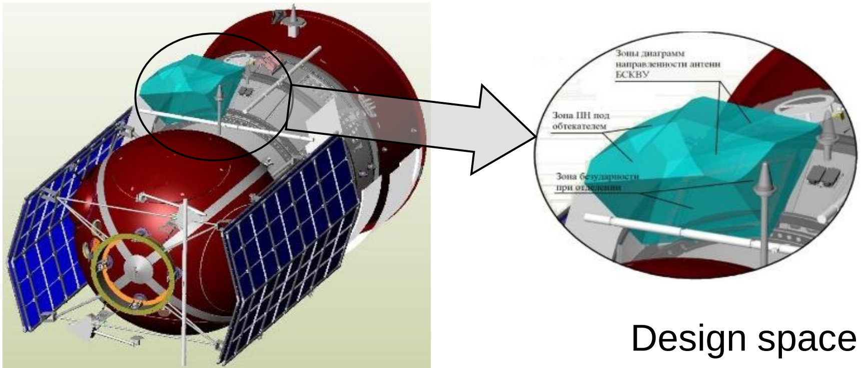
ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

Functional purpose of “AIST” small satellites

The “AIST” small satellite was designed to solve the following tasks:

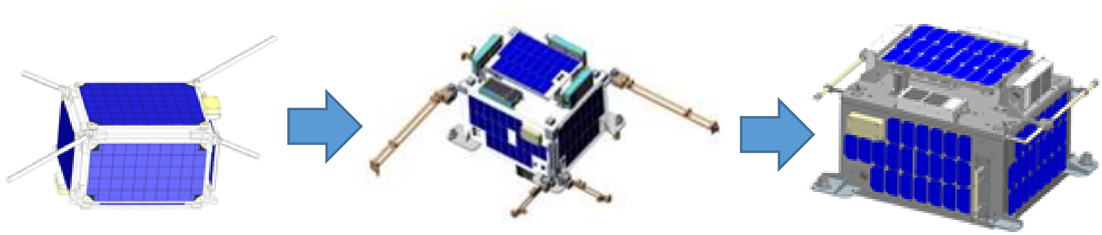
- development of a unified compact space platform with weight up to 100kg for long-term (up to 3 years) research, technological experimentation and implementation of modern educational programs;
- creation of an information link in the amateur frequency bands for communication of educational and scientific nature from the universities of Samara region to another Russian and foreign universities;
- monitoring the Earth's magnetic field and study of the problems of microgravity, the implementation of long-term compensation modes of the low-frequency acceleration component on board the spacecraft to a minimum value that does not exceed the range of values from 10^{-5} g_0 to 10^{-7} g_0 (“MAGCOM” scientific equipment);
- study of the behavior of high-speed mechanical particles of natural and artificial origin, interacting with the surface of the ionization sensor and the estimation of their parameters - mass and velocity; periodic measurement of the spatial position of the sun relative to the body axis coordinates of the spacecraft, followed by evaluation of the possible charged particle flows on its surface (“METEOR” scientific equipment);
- study of the level of electrification of the spacecraft and the dynamics of change in the surface charge;
- experimental space testing of new types of future photovoltaic arrays of gallium arsenide (GaAs), created using nanotechnology;
- development of the technology of associated launch of a small satellite into a working orbit with a heavy research spacecraft-carrier;
- development of production technologies for small non-hermetic spacecraft with highly integrated onboard equipment.

Manufacturing



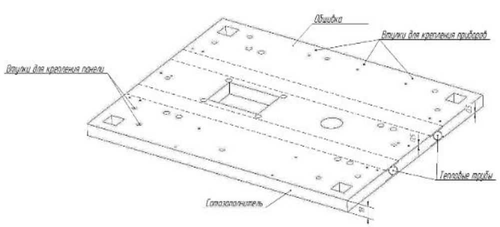
Design space
onboard of «Bion-M»
№1 satellite

A technological prototype was manufactured in order to comply with the industry standard of ground satellite testing (“AIST” testing prototype)

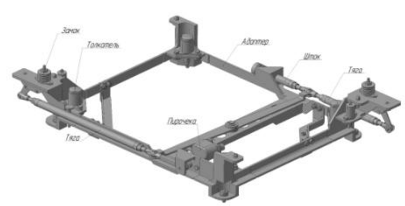


Development iterations of the project during design stage

Testing and flight
“AIST” satellites during
radio hardware testing



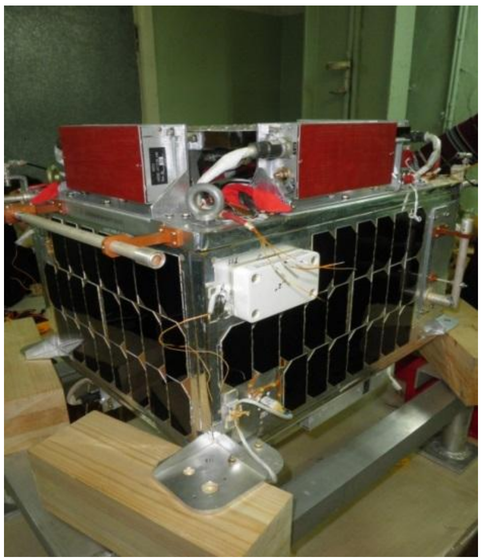
Satellite panel



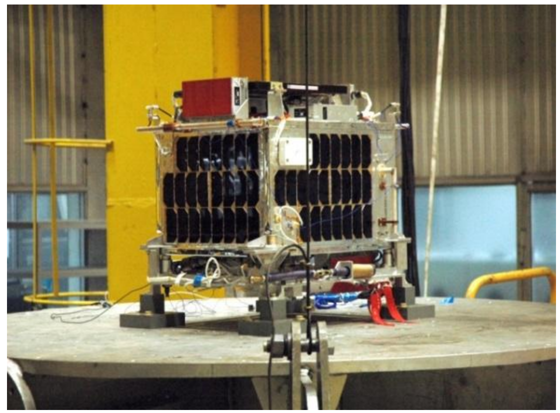
Separation device

Ground testing

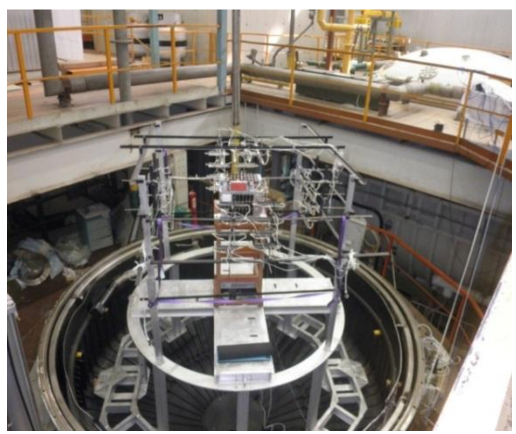
Development testing



Vibration strength testing



Thermal-vacuum test

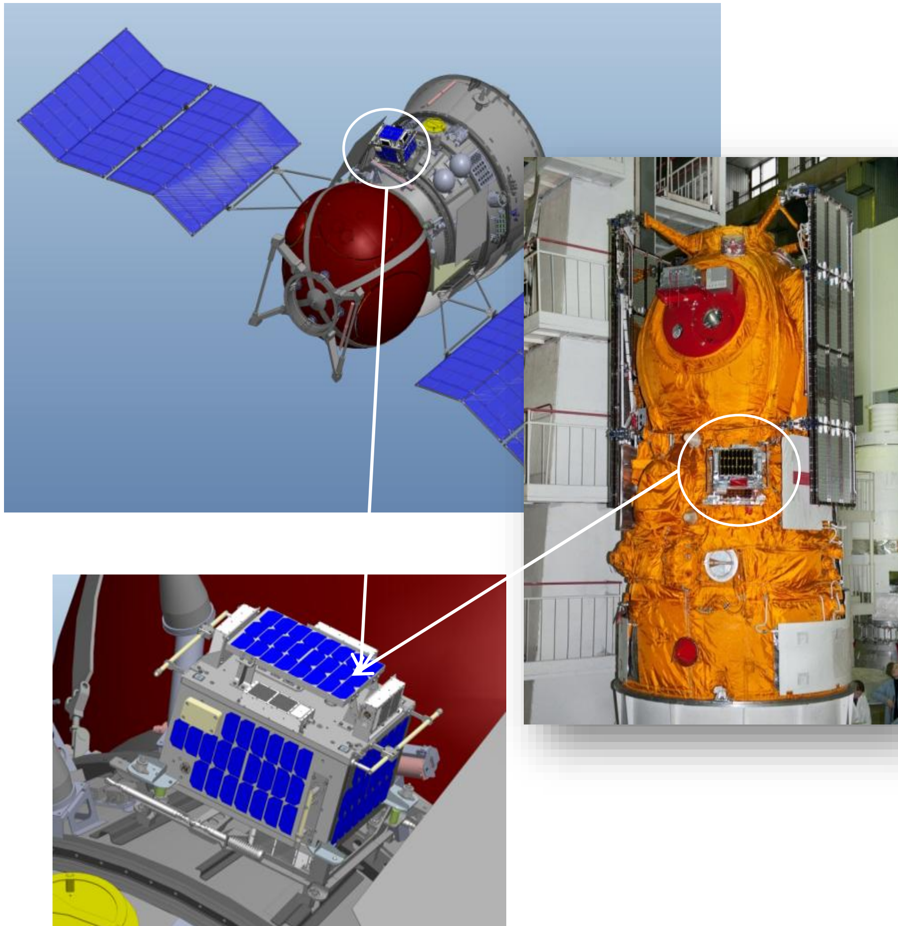


Ground testing of the separation device

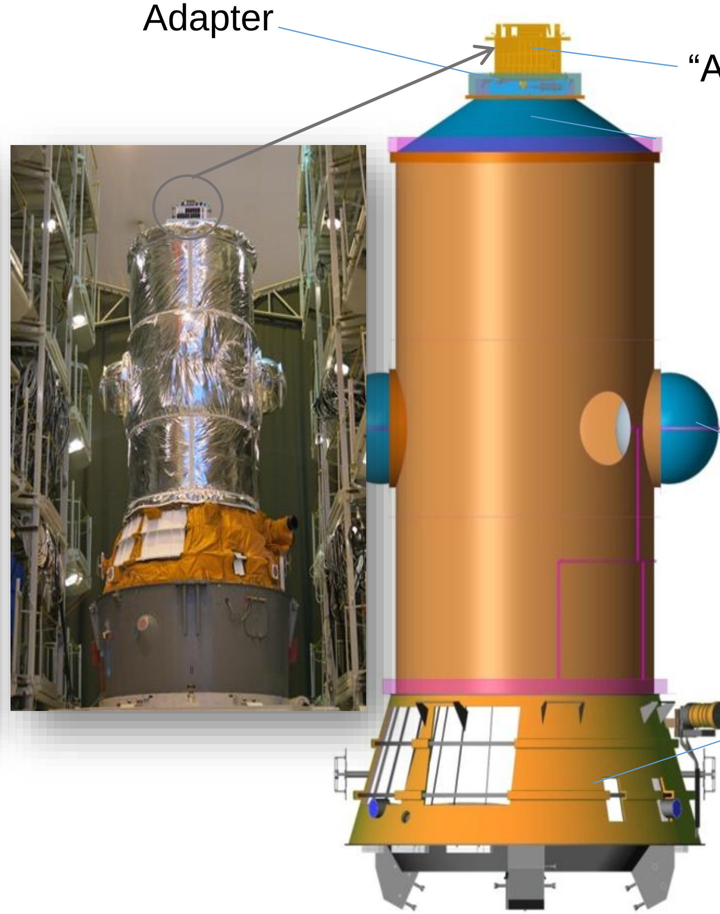
ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

Methods of orbital injection

Small satellite “AIST” RS43as as a part of spacecraft “BION-M” № 1 (associated launch)

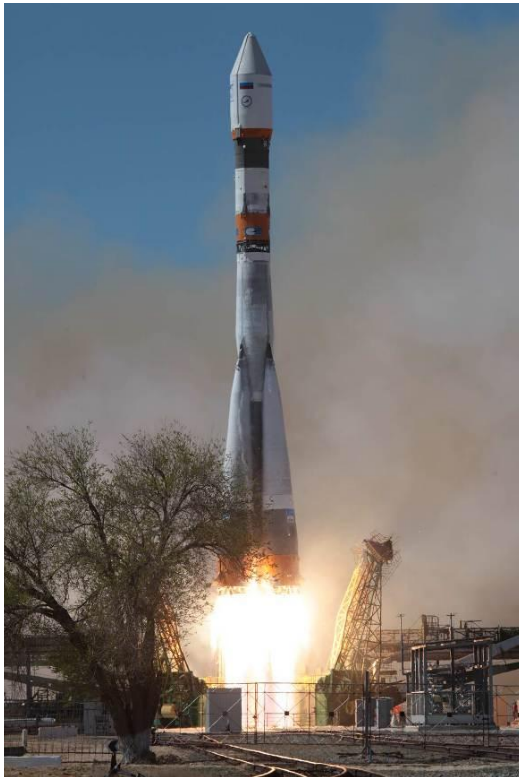


Small satellite “AIST” RS41at on "Volga" upper stage on rocket “Soyuz 2-1.v”

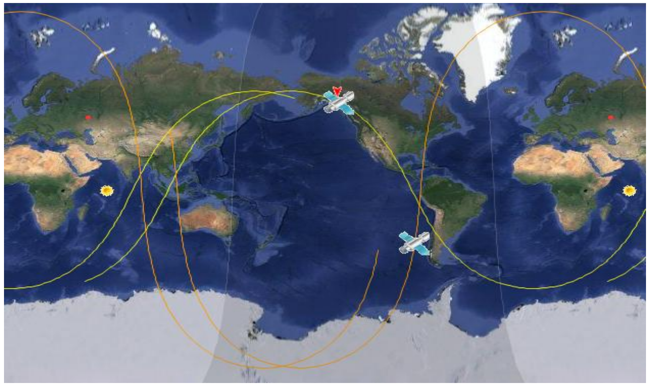


ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

Launch from Baikonur cosmodrome 19.04.2013 г.



“AIST” satellites trajectories based on the NORAD data



Launch from Plesetsk cosmodrome 28.12.2013 г.

Initial parameters of the operational orbit	
“AIST” RS43as	“AIST” RS41at
– Launch date: 19.04.2013 – Orbit altitude 575 km – Inclination 64,9˚.	– Launch date: 28.12.2013 – Orbit altitude 625 km – Inclination 82,4 ˚.

Main scientific results of the project

The method of "floating limit" in the scheme of solving design tasks

$$\begin{cases} p_i = \{p_i : p_i \in P_{Mod} \subset E^M\}, \quad i = \overline{(1,N)}, \\ p_{УП} = (p_{СЭП}, p_{СОТР}, p_{БКУ}, p_{Констр}, p_{БКС})^T , \end{cases}$$

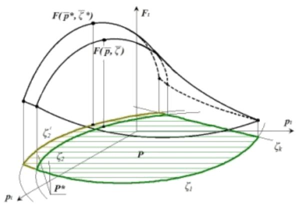
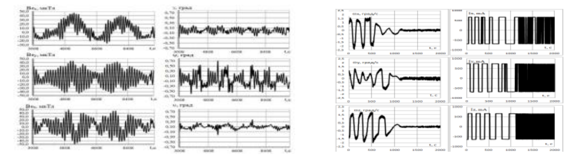


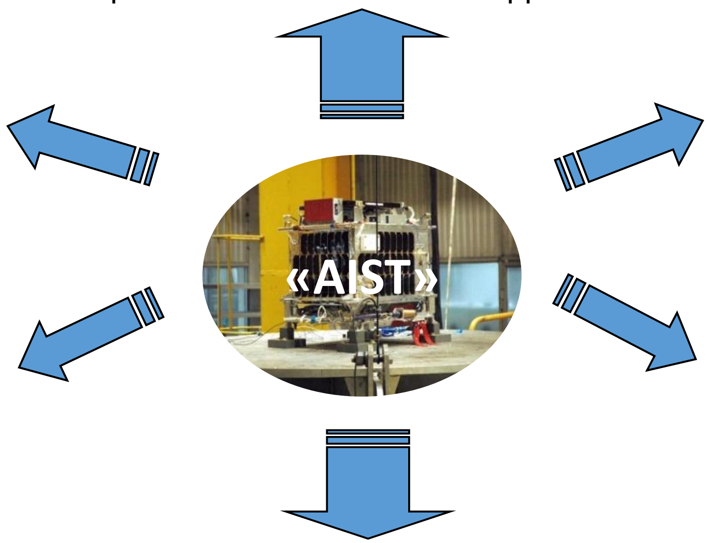
Diagram of average daily temperature values of satellite’s onboard systems

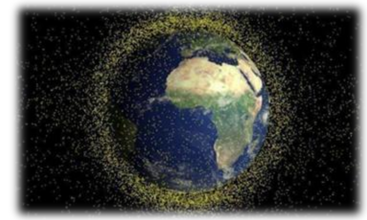


Parameters of the angular orientation of small satellite

Development of fundamental and applied science

Earth's magnetic field researches





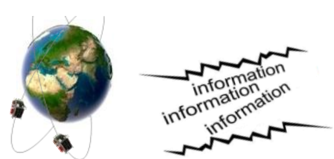
Formation of spatial maps of micrometeorites situation

Broad implementation of the results in the educational process

Development of multi-agent technology of work with satellites

Distributed space laboratory was created with orbital and ground segments

Orbital segment



Ground segment

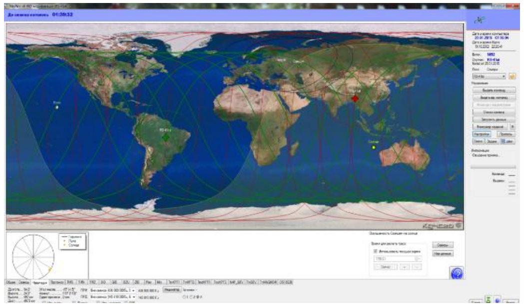
ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

Main educational results of the “AIST” project

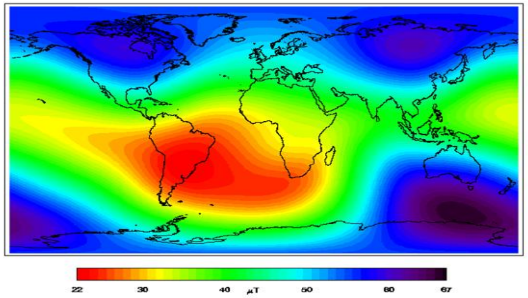
The telemetry data obtained from the “AIST” satellite constellation is deeply integrated into the educational process of Samara University, and are implemented into laboratory, practical and diploma work for bachelor, specialist and master students.

Research is conducted in the following areas:

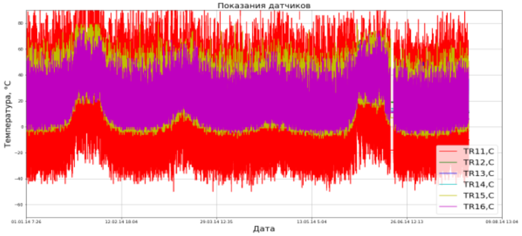
- Analysis of the navigational data of the "AIST" satellites acquired from the NORAD system in order to assess the evolution of orbits and to predict the position of the satellites in orbit at a given time.
- Determination of the zone of satellite visibility for different ground receiving stations at a given time.
- Analysis of the temperature values on the satellite’s surface (including temperature sensors on solar panels, payload, battery, command and control navigation system - 30 channels in total), depending on the light and shadow conditions in orbit and operating modes of equipment.
- Modeling of the Earth's magnetic field parameters according to the data of the "MAGKOM“ system in various orbits of "AIST" satellites; Study of the processes of orientation and stabilization of a satellite using magnetometers.
- Modeling the operation of the power supply system of the satellite, taking into account telemetry data on the charge-discharge level of the battery and the system’s voltage level.



Navigational data analysis



Research of Brazilian magnetic anomaly



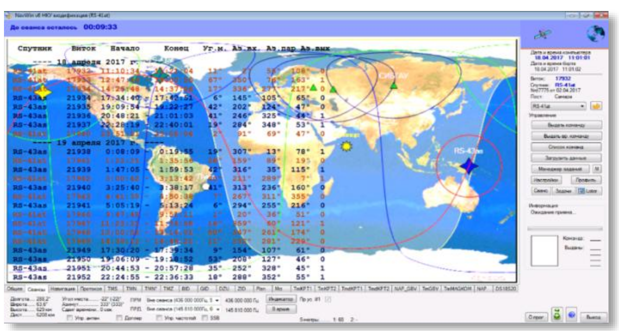
Research of telemetry measurements data

More than 50 diploma projects have been defended on the topic of creation of scientific and educational small satellites during the last 5 years, more than 20 graduate works of bachelors have been prepared, 9 master's and 7 candidate's dissertations have been defended.

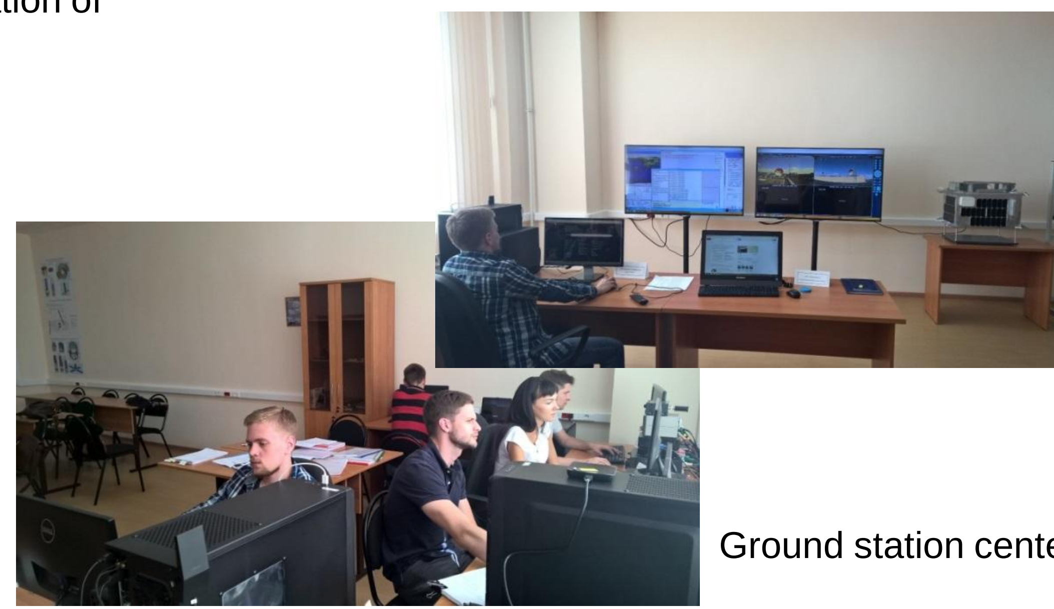
Ground control station in Samara University

Antenna complex of the Ground control station of Samara University

Operator’s workstation



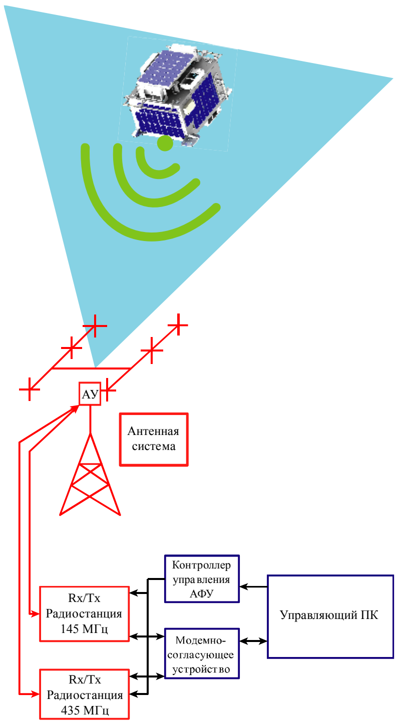
Ground station software



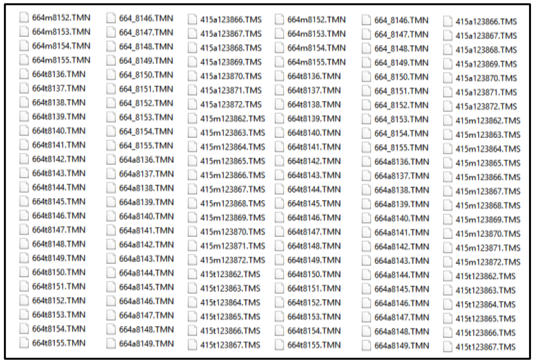
Ground station center

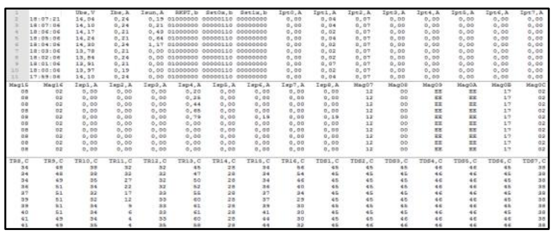
Telemetry processing

Primary processing of telemetric information



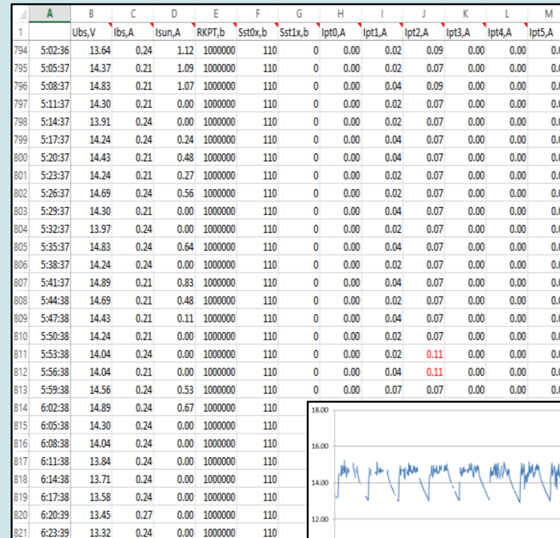
Ground control center scheme of Samara University



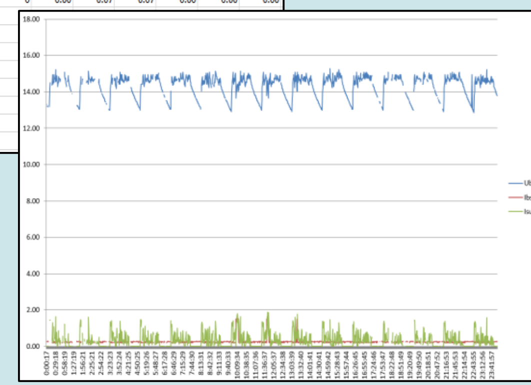


Results of primary processing

Secondary processing of telemetric information

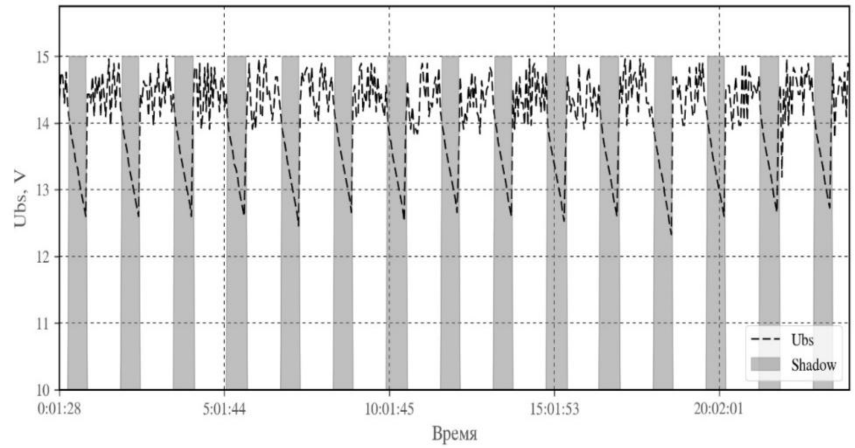


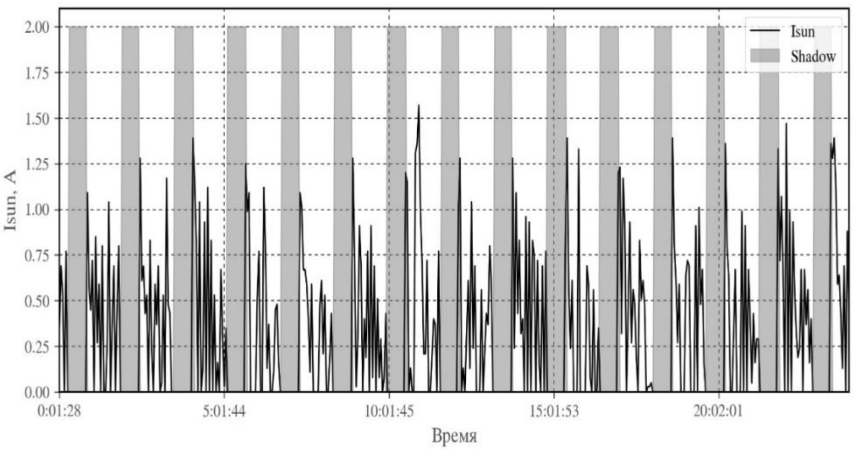
	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Ubs,V	Ibs,A	Isun,A	RKPT,b	Sst0x,b	Sst1x,b	Ipt0,A	Ipt1,A	Ipt2,A	Ipt3,A	Ipt4,A	Ipt5,A
794	5:02:36	13.64	0.24	1.12	1000000	110	0	0.00	0.02	0.09	0.00	0.00	0.00
795	5:05:37	14.37	0.21	1.09	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
796	5:08:37	14.83	0.21	1.07	1000000	110	0	0.00	0.04	0.09	0.00	0.00	0.00
797	5:11:37	14.30	0.21	0.00	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
798	5:14:37	13.91	0.24	0.00	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
799	5:17:37	14.24	0.24	0.24	1000000	110	0	0.00	0.04	0.07	0.00	0.00	0.00
800	5:20:37	14.43	0.21	0.48	1000000	110	0	0.00	0.04	0.07	0.00	0.00	0.00
801	5:23:37	14.24	0.21	0.27	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
802	5:26:37	14.69	0.24	0.56	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
803	5:29:37	14.30	0.21	0.00	1000000	110	0	0.00	0.04	0.07	0.00	0.00	0.00
804	5:32:37	13.97	0.24	0.00	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
805	5:35:37	14.83	0.24	0.64	1000000	110	0	0.00	0.04	0.07	0.00	0.00	0.00
806	5:38:37	14.24	0.24	0.00	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
807	5:41:37	14.89	0.21	0.83	1000000	110	0	0.00	0.04	0.07	0.00	0.00	0.00
808	5:44:38	14.69	0.21	0.48	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
809	5:47:38	14.43	0.21	0.11	1000000	110	0	0.00	0.04	0.07	0.00	0.00	0.00
810	5:50:38	14.24	0.21	0.00	1000000	110	0	0.00	0.02	0.07	0.00	0.00	0.00
811	5:53:38	14.04	0.24	0.00	1000000	110	0	0.00	0.02	0.11	0.00	0.00	0.00
812	5:56:38	14.04	0.21	0.00	1000000	110	0	0.00	0.04	0.11	0.00	0.00	0.00
813	5:59:38	14.56	0.24	0.53	1000000	110	0	0.00	0.07	0.07	0.00	0.00	0.00
814	6:02:38	14.89	0.24	0.67	1000000	110							
815	6:05:38	14.30	0.24	0.00	1000000	110							
816	6:08:38	14.04	0.24	0.00	1000000	110							
817	6:11:38	13.84	0.24	0.00	1000000	110							
818	6:14:38	13.71	0.24	0.00	1000000	110							
819	6:17:38	13.58	0.24	0.00	1000000	110							
820	6:20:39	13.45	0.27	0.00	1000000	110							
821	6:23:39	13.32	0.24	0.00	1000000	110							



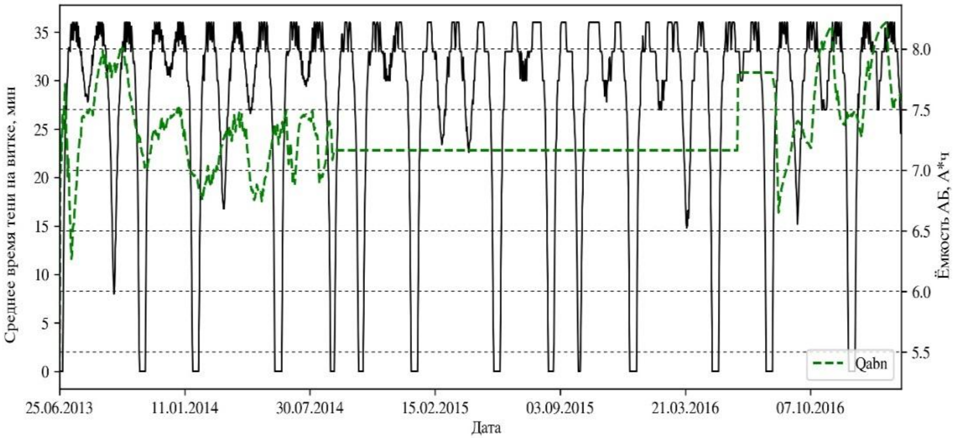
Results of secondary processing

Analysis of the influence of the light-shadow environment on the payload performance

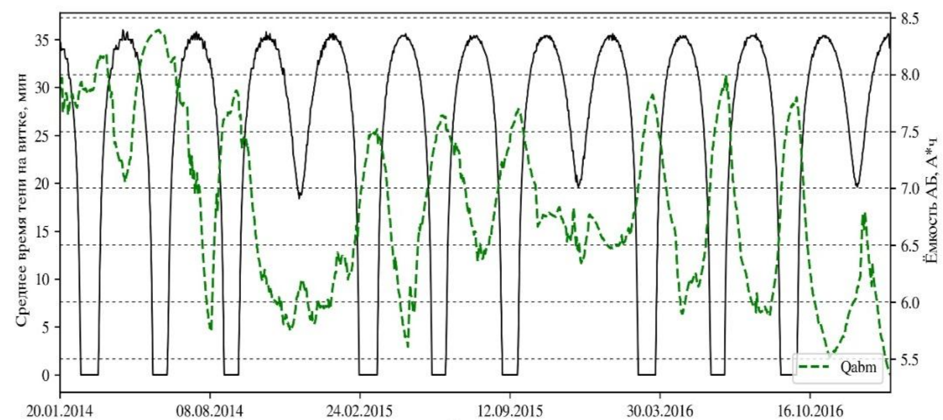




Influence of the light-shadow environment on the parameters of the power supply system

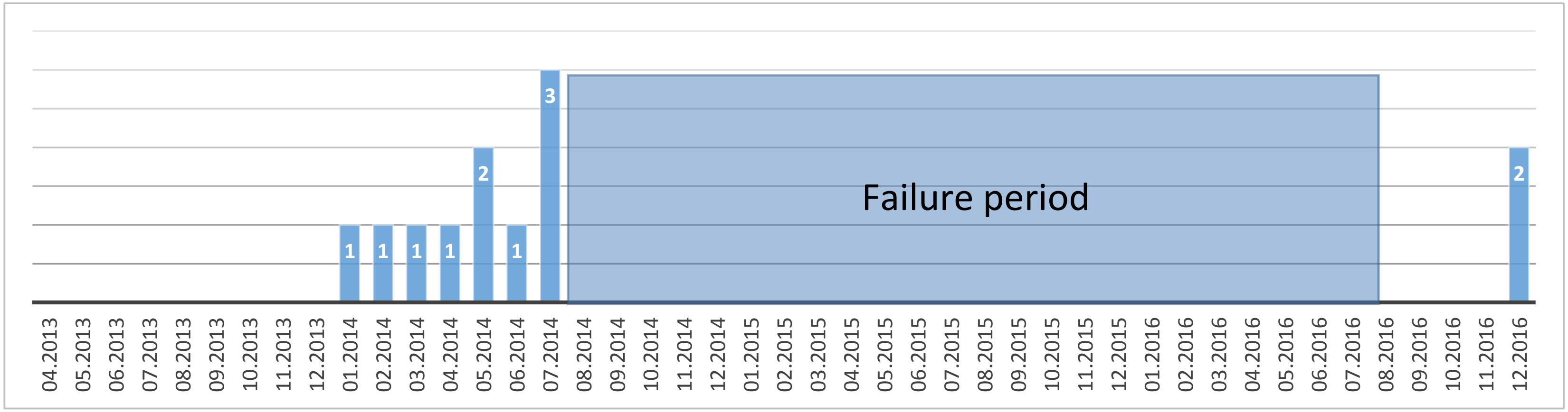


Minimum daily battery capacity, taking into account the light-shadow situation (satellite “AIST” RS41at)

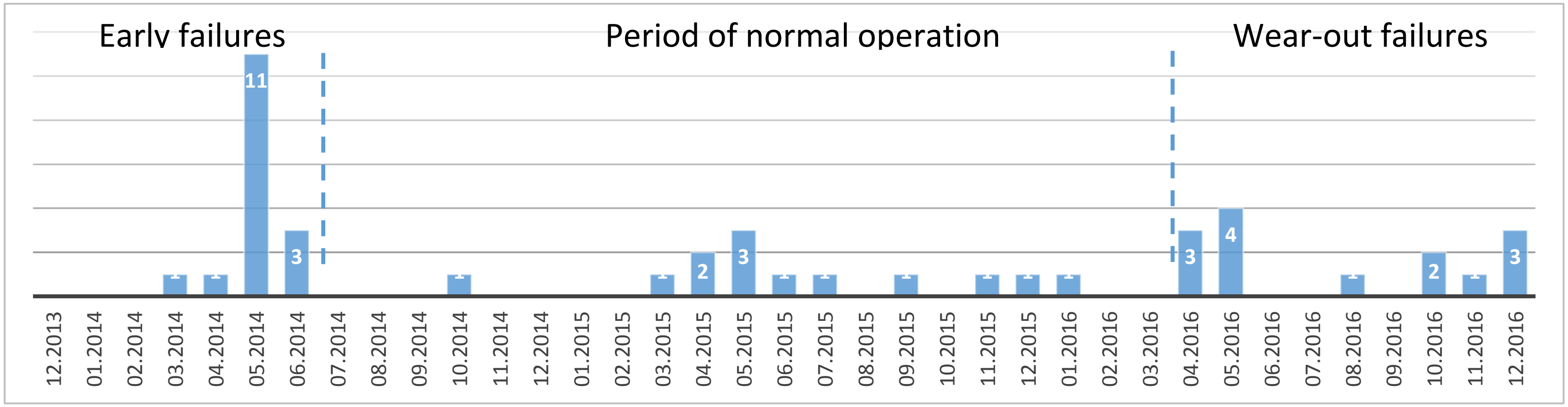


Minimum daily battery capacity, taking into account the light-shadow environment (satellite “AIST” RS43as)

Failure rate of the "AIST" satellites onboard equipment

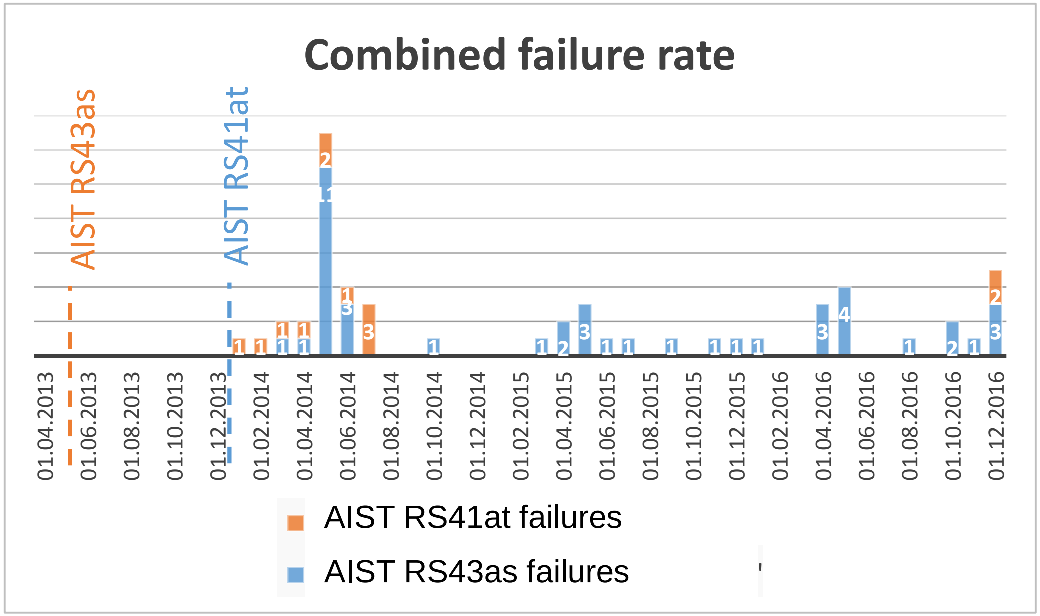


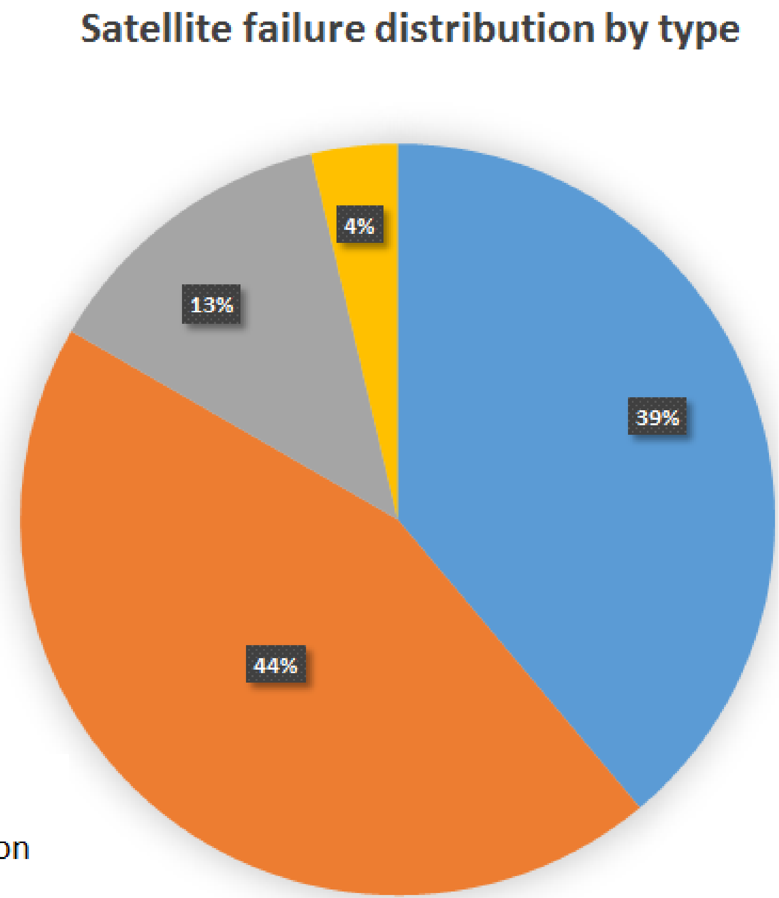
Failure rate of the "AIST" RS43as



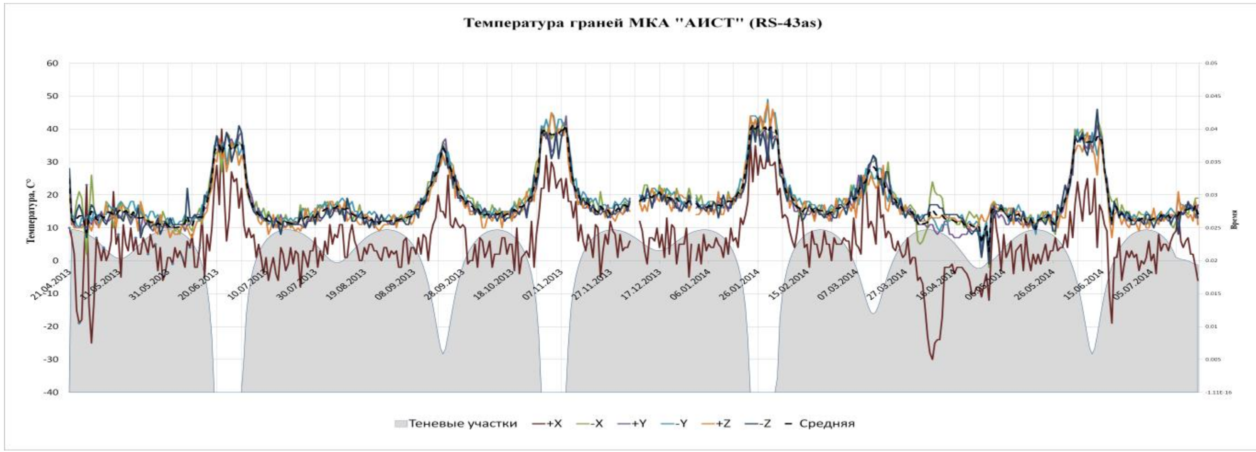
Failure rate of the "AIST" RS41at

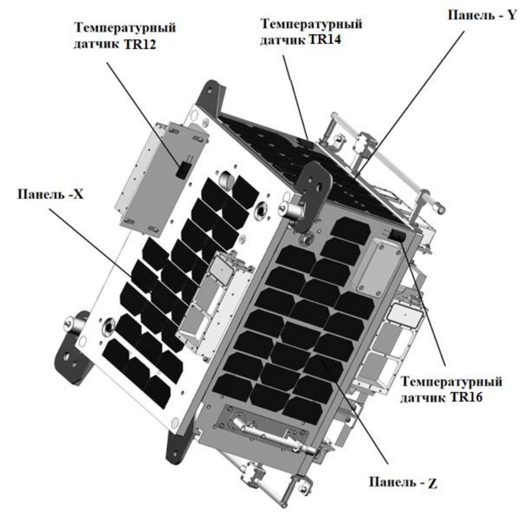
Failure types



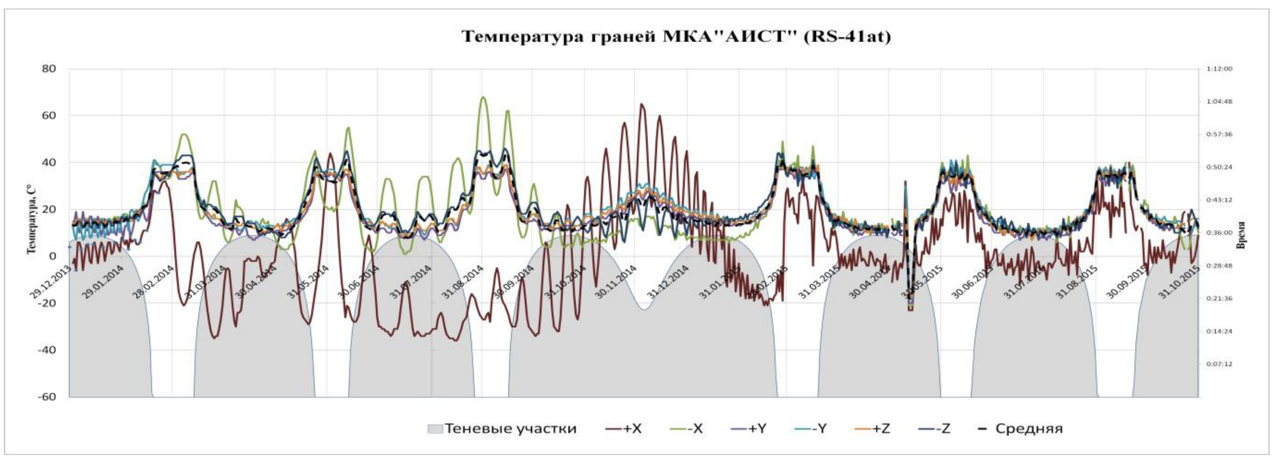


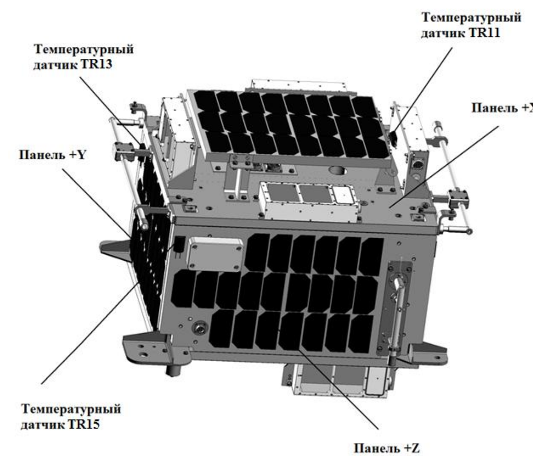
Analysis of the system for thermal regime





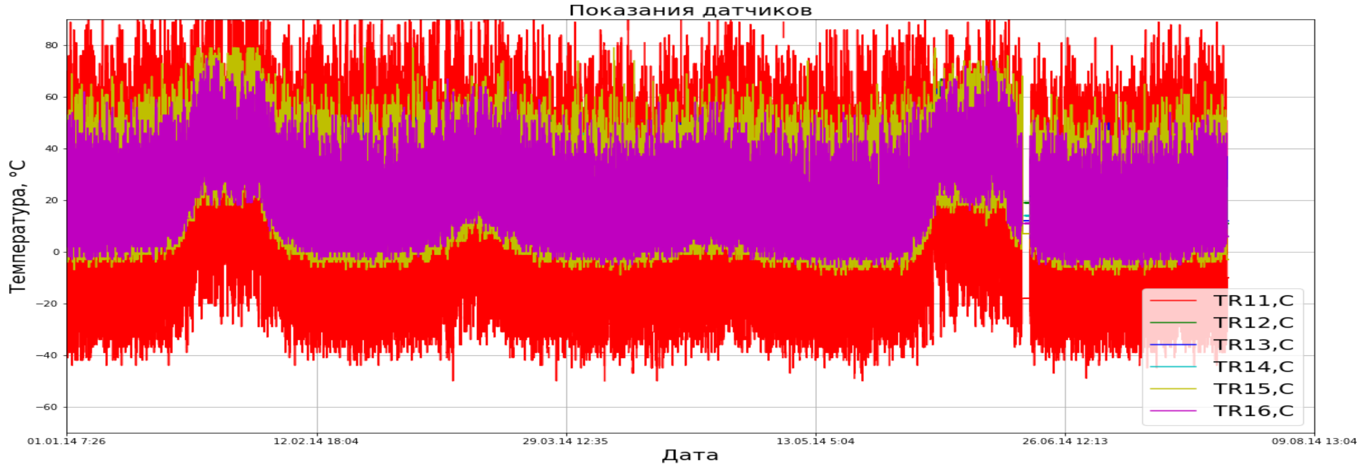
The average daily temperature of the outer side of the faces of the "AIST“ small satellite RS-43as lies in the range from +10 to +50 ° C, except for the panel + X



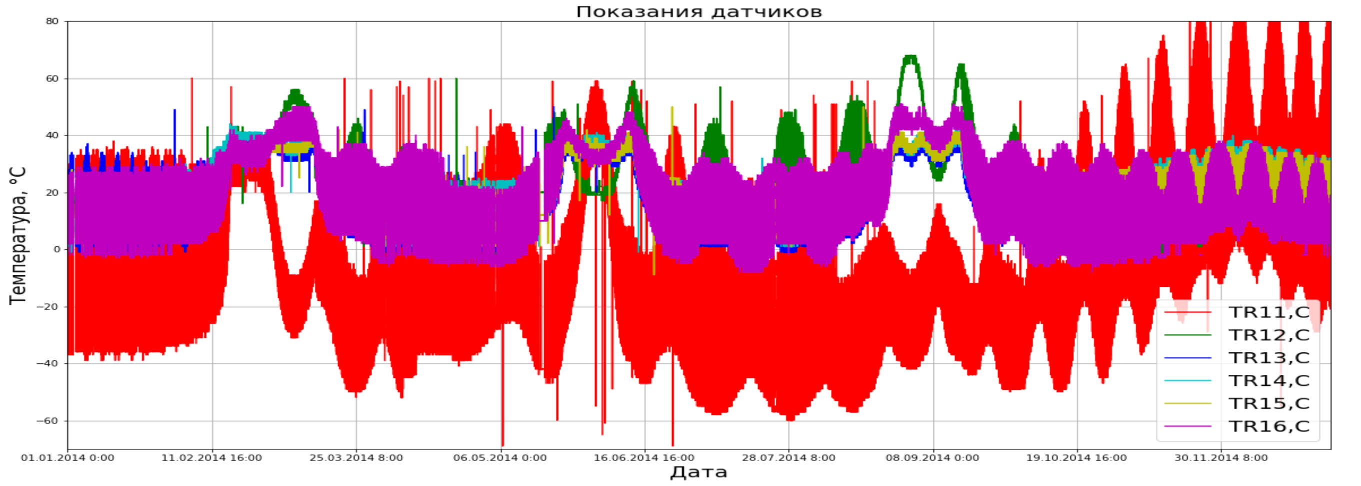


The average daily temperature of the outer side of the faces of the "AIST“ small satellite RS-41at lies in the range from +10 to +50 ° C, except for the panel + X

Indication of temperature sensors from the outside panels of the “AIST” satellites

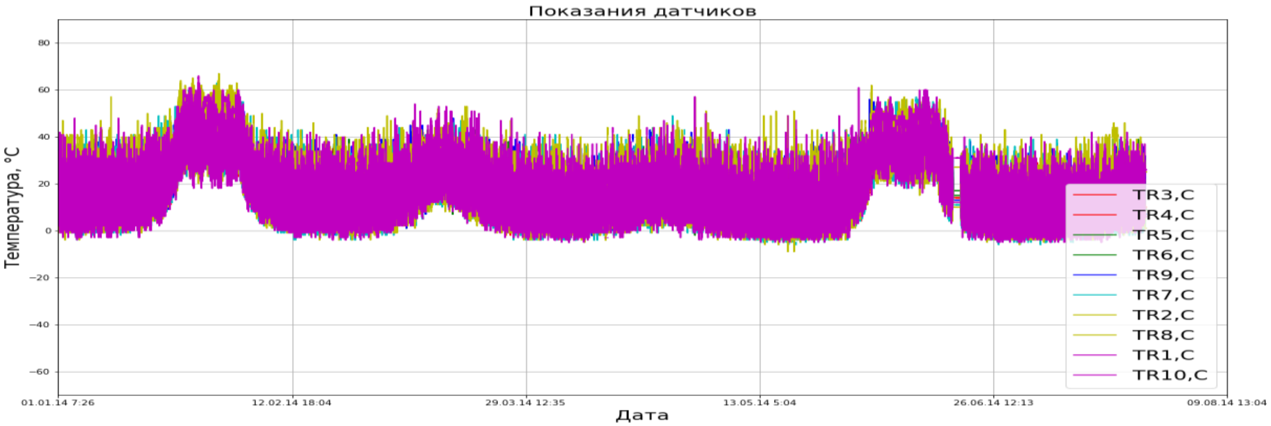


The average daily measured temperatures of the "AIST“ small satellite RS-43as lies in the range from 0 to +60 ° C, except for the panel + X

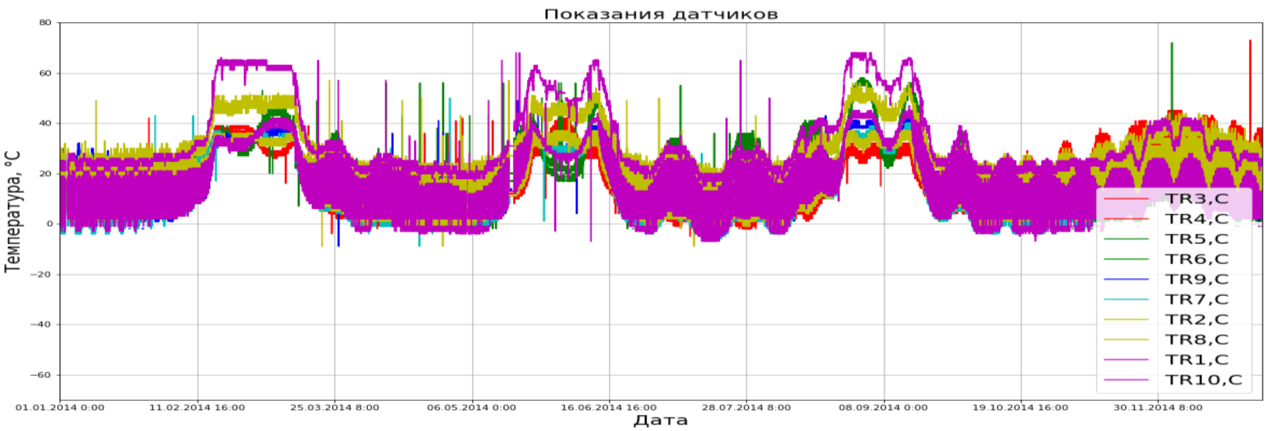


The average daily measured temperatures of the "AIST“ small satellite RS-41at lies in the range from 0 to +60 ° C, except for the panel + X

Indication of temperature sensors from the inside panels of the “AIST” satellites



The average daily measured temperatures of the "AIST“ small satellite RS-43as lies in the range from +10 to +60 ° C, except for the panel + X



The average daily measured temperatures of the "AIST“ small satellite RS-41at lies in the range from +10 to +60 ° C, except for the panel + X

“AIST-2D” small satellite

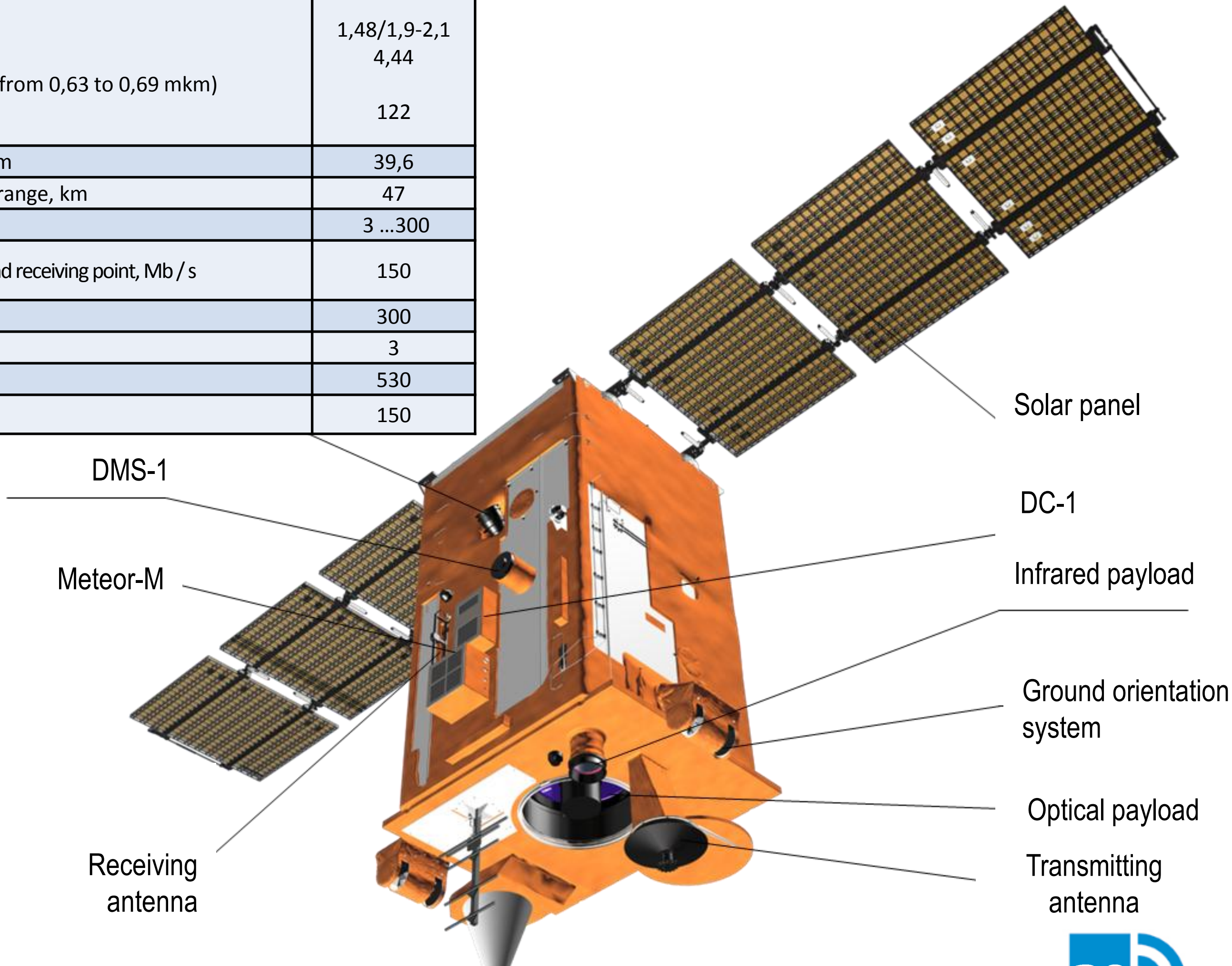
"AIST-2D" technological small spacecraft has developed in cooperation with SRC "Progress" in the framework of the complex project on creation of hi-tech production in accordance with the decree of the Government of the Russian Federation of 09.04.2010, №218.

"AIST-2D" was launched on 28 April 2016 from the new Vostochny cosmodrome by space rocket "Soyuz-2" phase 1A with upper stage "Volga".

ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

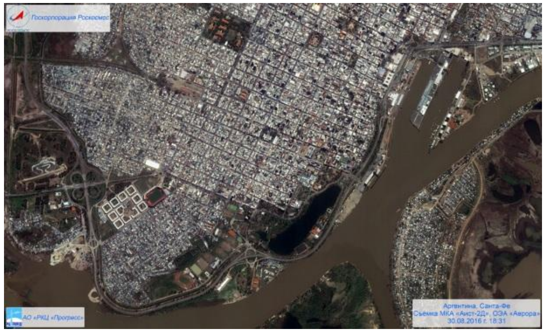
Overview of the "AIST-2D" small satellite

Parameter	Value
Operational orbit - orbit type - near-circular, average height, km	 SSO 490
Resolution, H=490 km, m - In panchromatic mode (from 0,58 to 0,80 mkm) - in multispectral mode (RGB from 0,45 to 0,52 mkm; from 0,52 to 0,60; from 0,63 to 0,69 mkm) - In infrared (from 8 to 14 mkm)	 1,48/1,9-2,1 4,44 122
The capture band for the visible range equipment, km	39,6
The capture band for the equipment of the infrared range, km	47
The duration of the survey route, s	3 …300
The speed of transmission of target information to the ground receiving point, Mb / s	150
Average daily payload power consumption, W	300
Active life, years	3
Mass, kg	530
Payload mass, kg	150



ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

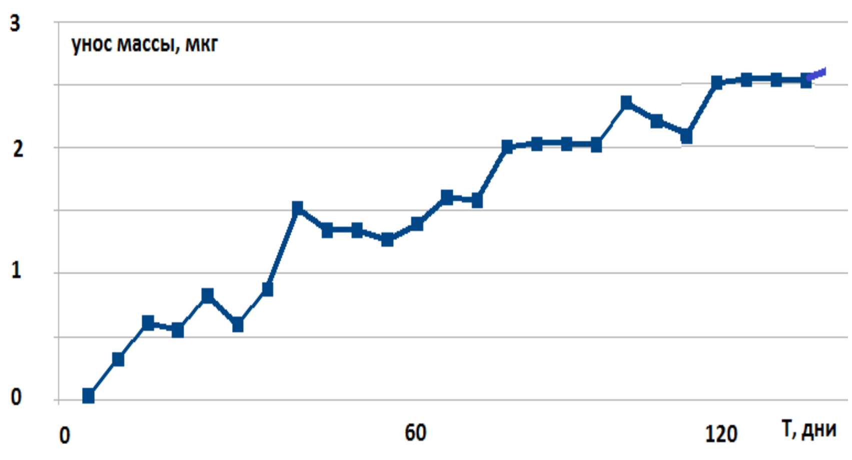
Images obtained with the “AIST-2D” satellite



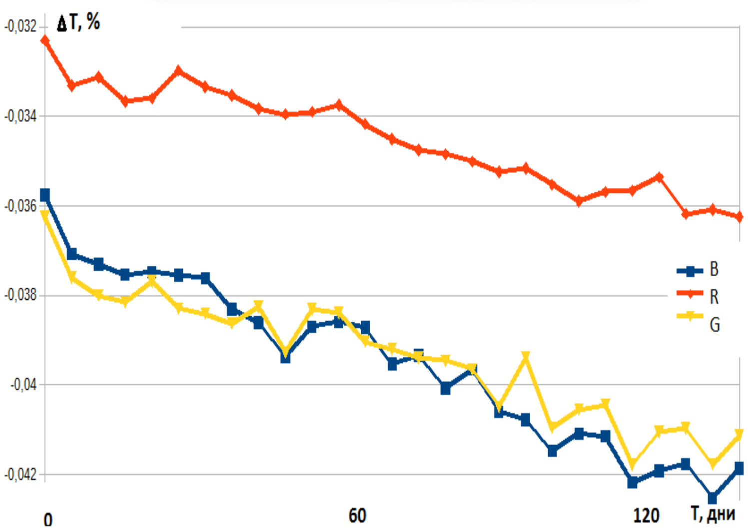
ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

On-board laboratory for experimental study of the influence of space environment factors on samples of optical elements, coatings and electronic components.

First scientific results, obtained in the first 4 months of operation:



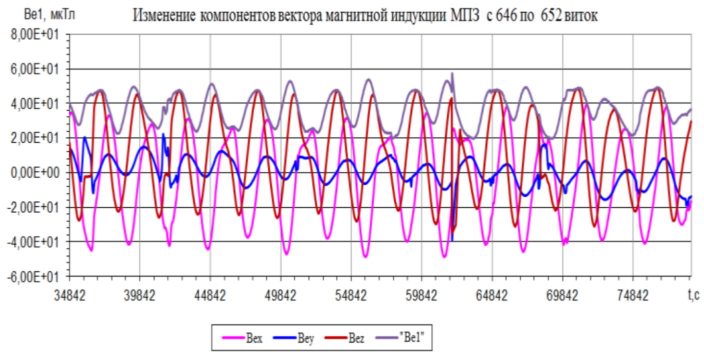
1. Weight loss of polyimide coating



2. The change in the coefficient of glass transmittance

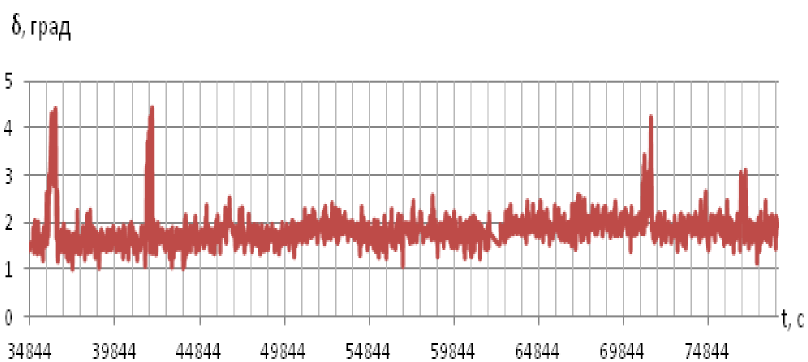
“KMU-1” scientific payload

Angle of declination



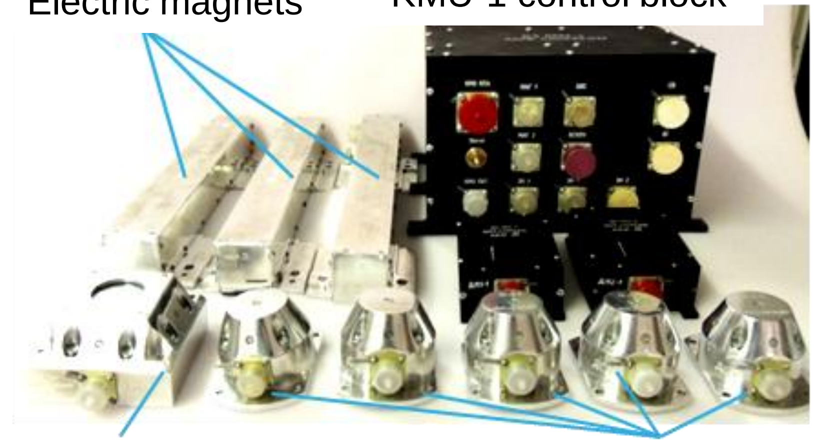
Variation of micro-acceleration modulus

Angle of declination



Electric magnets

KMU-1 control block

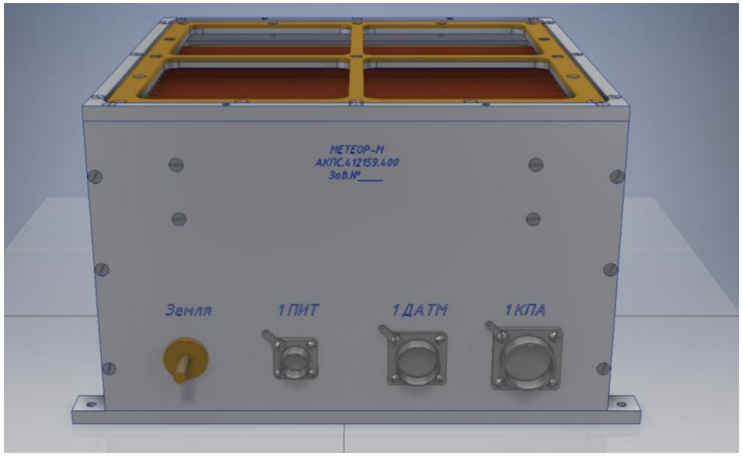


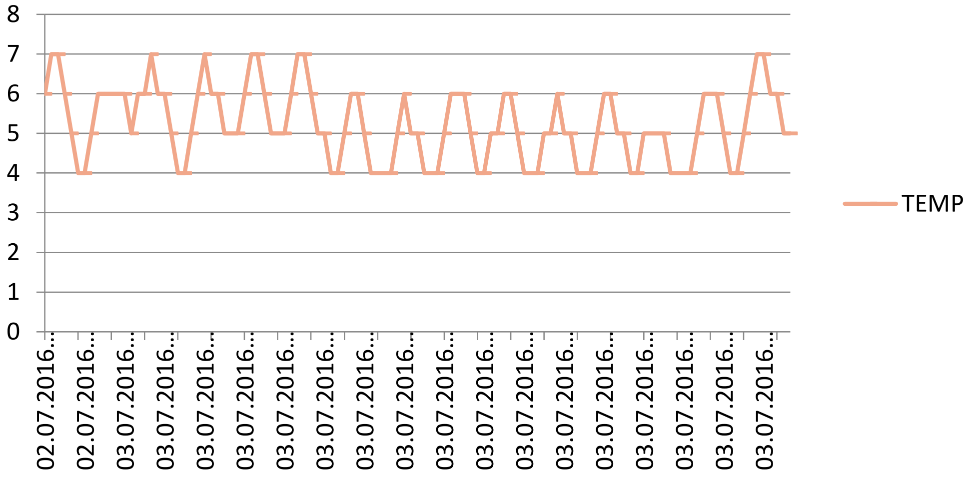
Solar sensor

Illumination sensors

“Meteor-M” scientific payload

“METEOR-M” is designed for recording the parameters of high-speed microparticles (micrometeoroids and debris particles) in the near-Earth space





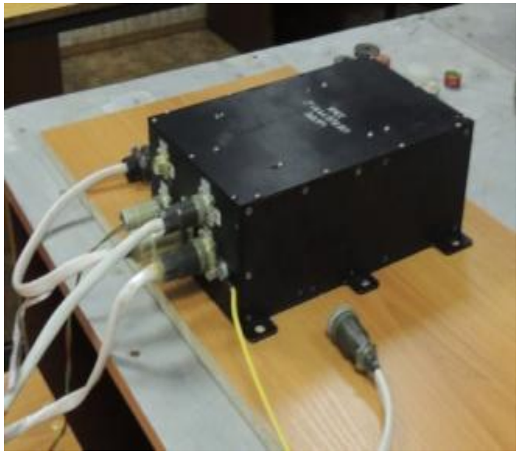
Dependence of measured temperature on time

First obtained results:

- The temperature of the unit is within the permissible value range from 0 to 9°C.
- Analysis of “METEOR-M” telemetry data has shown that the equipment is operating in the normal mode.
- Telemetry packages are generated without errors.
- The collision of high-speed microparticles with the target of the sensor has not yet been recorded.

Combined experimental payload

Purpose:
- Study of changes in the parameters of experimental lithium batteries in the charge-discharge cycle;
- The study of the change in the parameters of the elements of experimental solar batteries (VAC);
- An experimental study of a fiber-optic displacement sensor.



Control block

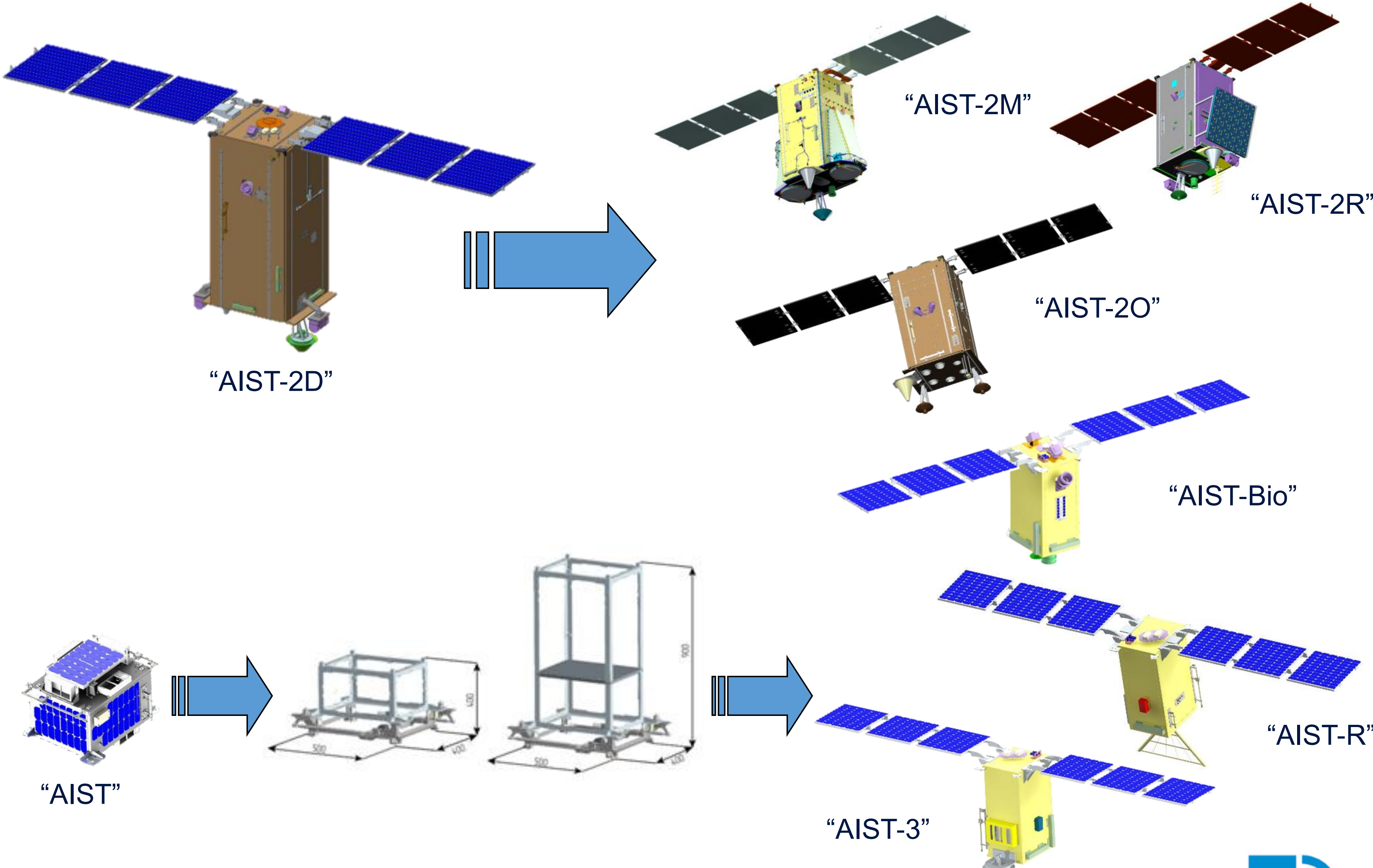
Experimental lithium battery

Experimental solar panel module

Production and testing facility for high-tech manufacturing of small spacecraft

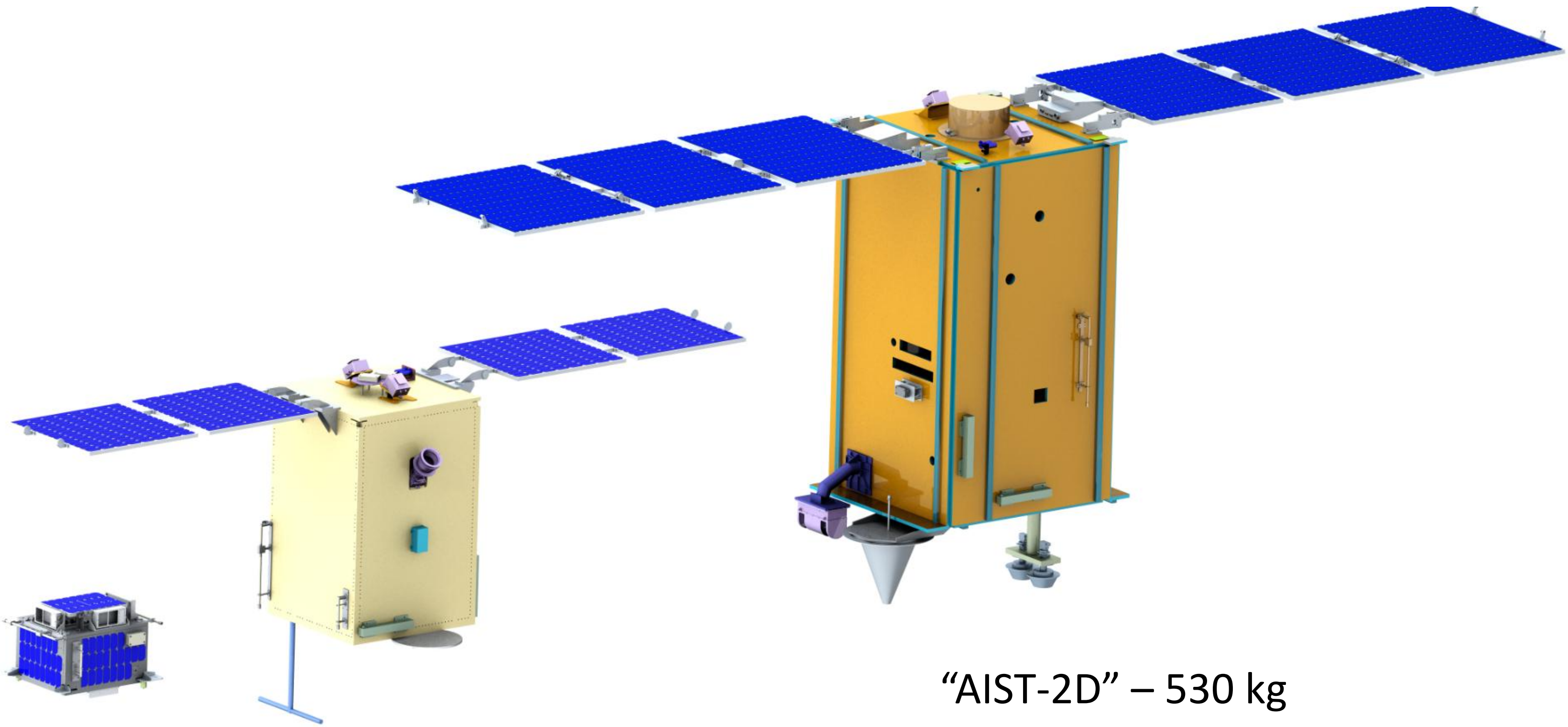
On the basis of Samara University established the production and testing facility for high-tech manufacturing small spacecraft for scientific and application purposes with various types of target equipment (remote sensing: electro-optical, hyperspectral, radar, infrared). The complex includes an assembly hall, cleanrooms (cleanliness class ISO 8,5), coordinate measuring machine ZEISS MMZ G 20/30/20, servo-hydraulic testing machine SHIMADZU EHF-EV100kN, vibration test system, Data Physics, LE-2016/DSA10-200K, thermal complex, climatic chambers and other high-tech equipment.

The development of the “AIST” project



ул. Московское шоссе, д.34, г.Самара, 443086, тел.: +7 (846) 335-18-26, факс: +7 (846) 335-18-36, сайт: www.ssau.ru, e-mail: ssau@ssau.ru

The range of small technological spacecraft of “AIST” series



“AIST-2D” – 530 kg

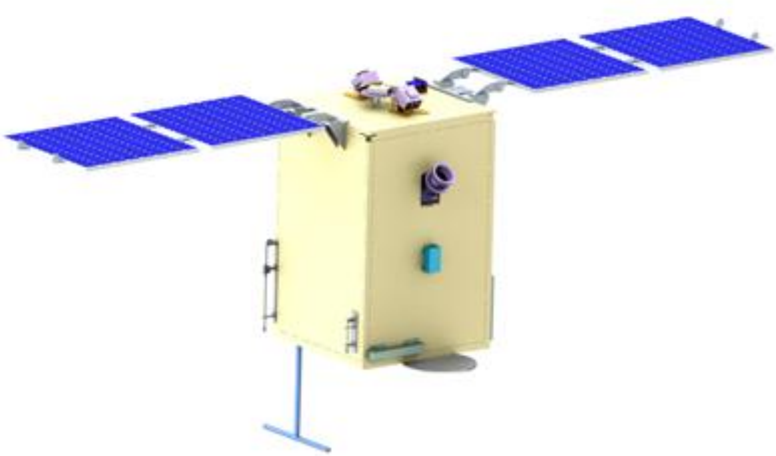
“AIST-3”- 170 kg

“AIST” - 39 kg

Project of small satellite “AIST-3” for remote sensing

Objectives of the project:

- development of target equipment of SPE "OPTEKS", ground controls, receiving and processing information and methods of processing remote sensing data with high resolution;
- development of monitoring system of radiation environment in outer space;
- check for new technological solutions, used in the manufacture of small satellites;
- development of program and technical means of the unified small space platform;
- development of new automatic identification system which serves to identify ships and providing relevant data about their size, date and other indicators.



Наименование	Значение
Operational orbit - orbit type - near-circular, average height, km	 SSO 400-700
The motion control system of a small satellite provides: - quieting a small satellite after separation from the launch vehicles; - uniaxial orientation of a small satellite by magnetic induction; - uniaxial orientation to the Sun; - the reorientation of a small satellite.	
The capture band on orbit of 490 km, km	11
Resolution on orbit of 490 km, m	1,375
The speed of transmission of target information to the ground receiving point, Mb / s	130
Active life, years	3
Mass, kg	till 170
Mass of payload, kg	till 20

САМАРСКИЙ УНИВЕРСИТЕТ
SAMARA UNIVERSITY

Thank you for attention!

sputnik@ssau.ru

ул. Московское шоссе, д. 34, г. Самара, 443086
Тел.: +7 (846) 335-18-26 , факс: +7 (846) 335-18-36
Сайт: www.ssau.ru, e-mail: ssau@ssau.ru