Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 104 (2015) 139 – 146

Procedia Engineering

www.elsevier.com/locate/procedia

Scientific and Technological Experiments on Automatic Space Vehicles and Small Satellites

SSAU Project of the nanosatellite SamSat-QB50 for monitoring the Earth's thermosphere parameters

Evgeniy Shakhmatov[a], Igor Belokonov[a], Ivan Timbai[a], Efim Ustiugov[a], Andrey Nikitin[a], Stepan Shafran[a] *

[a] *Samara State Aerospace University named after academician S. P. Korolyov (National Research University), 34, Moskovskoye Shosse, Samara, Russia, 443086*

Abstract

SamSat-QB50 nanosatellite design was considered. The main subsystems are described. The basic principles of transformation structure from CubeSat 2U to CubeSat 3U are shown. The passive attitude stabilization system based on hysteresis rods and aerodynamic stabilization principle is suggested for satisfaction of the keys QB50 orientation requirements.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of organizing committee of the Scientific and Technological Experiments on Automatic Space Vehicles and Small Satellites (SPEXP2014)

Keywords: CubeSat; QB50; Satellite; Atmosphere; Stabilization; Attitude control

1. Introduction

This paper describes Samara State Aerospace University's (SSAU) CubeSat project (SamSat-QB50) as the part of international project QB50. The main idea of the project is to launch 50 CubeSats on LEO (low Earth orbit) with identical science unit (SU) payload to measure thermosphere parameters. Each of 50 universities design their own CubeSat taking into account the main requirement is providing the SU normal work (the longitudinal axis oriented along the orbital velocity with required accuracy). Other subsystems and technical solutions for each university

* Corresponding author. Tel.: *+7-927-654-89-33*.
E-mail address: efim163@gmail.com

1877-7058 © 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of organizing committee of the Scientific and Technological Experiments on Automatic Space Vehicles and Small Satellites (SPEXP2014)
doi:10.1016/j.proeng.2015.04.105

could be original. One of the main problems for all QB50's CubeSats is a low orbit (approximately 400 km) on which CubeSats supposed to be launched. The main design idea of the SamSat-QB50 is using atmospheric influence for obtaining needed orientation. For achieving this goal the transformable construction providing aerodynamic stability and hysteresis rods for oscillation energy dissipation is proposed.

2. Goals of SamSat-QB50 design

The main goals of SamSat-QB50 design are to achieve the main results of QB50 project and to design fully passive and robust ACS. In design process the team was guided by QB50 System Requirements and Recommendations [1]. According ACS part of QB50 System Requirements SamSat-QB50 shall be able to recover from tip-off rates of up to 10º/sec within 2 days. It also requires to provide the longitudinal axis orientation around incident flow vector with an error less than ±20º. In a Preliminary Design Review (PDR) phase was shown that it is possible to comply the orientation accuracy requirement could be achieve by using low effective passive ACS.

3. SamSat-QB50 design overview

SamSat-QB50 design is based on using commercial off-the-shelf (COTS) components for service subsystems and design in-home attitude control and determination subsystems (ACDS). The external view of SamSat-QB50 is shown on the figure 1. The first stack (bottom stack) layout and the second stack (top stack) layout are shown on figures 2 and 3. As main bus used PC/104 connector (ESQ-126-39-G-D) with provide the 3.3V, 5V, 7.4V, I2C to each boards in stack. Power and data connections between subsystems are shown on figure 4.

SamSat-QB50 has following subsystems: science subsystem, structural subsystem, attitude determination subsystem (ADS), attitude control subsystem (ACS), electrical power subsystem (EPS), on-board computer and on-board data handling (OBC/OBDH) subsystem and communication subsystem. Detail subsystem table is shown below.

Table. SamSat-QB50 subsystem table.

Subsystem	Description
Science	– FIPEX science unit (project payload)[TRL 7]
	– FIPEX science unit integration board (design in-home) [TRL 4]
Structural	– 2-Unit CubeSat structure (design in-home) [TRL 7]
ADS	– Navigation receiver (design in-home) [TRL 6]
	– 3 axis magnetometer (COTS components, integrate in NanoMind) [TRL 9]
	– Sun sensors (COTS components, integrate in NanoPower) [TRL 9]
	– Gyro-scopes (COTS components, integrate in NanoPower) [TRL 9]
ACS	– Passive aerodynamic ACS (design in-home) [TRL 4]
	– Magnetorquer(COTS components, integrate in NanoPower) [TRL 9]
EPS	– EPS controller (COTS components, NanoPower) [TRL 9]
	– Battery pack (COTS components, integrate in NanoPower) [TRL 9]
	– Solar array (COTS components, NanoPower) [TRL 9]
OBC/OBDH	– On-board computer(COTS components, NanoMind) [TRL 9]
Communication	– Radio amateur transmitter (COTS components, TRXUV) [TRL 9]
	– Antenna system (design in-home) [TRL 4]

QB50 science unit (SU) FIPEX connected to main bus by using design in-home FIPEX integration board (FIB). FIPEX has connection only with FIB. All power distribution, analog and digital data goes through FIB. FIPEX has six analog temperature sensors which digitizing by FIB. Science data volume is 0.3 MBits per day. Nanosatellite's main bus data interface is I2C, but FIPEX data interface is USART. FIB isn't just interface converter, FIB digitizes SU's analog data, collects all digital data from SU and duplicates it on two SD cards and sends SU's data to I2C by command from on-board computer (OBC).

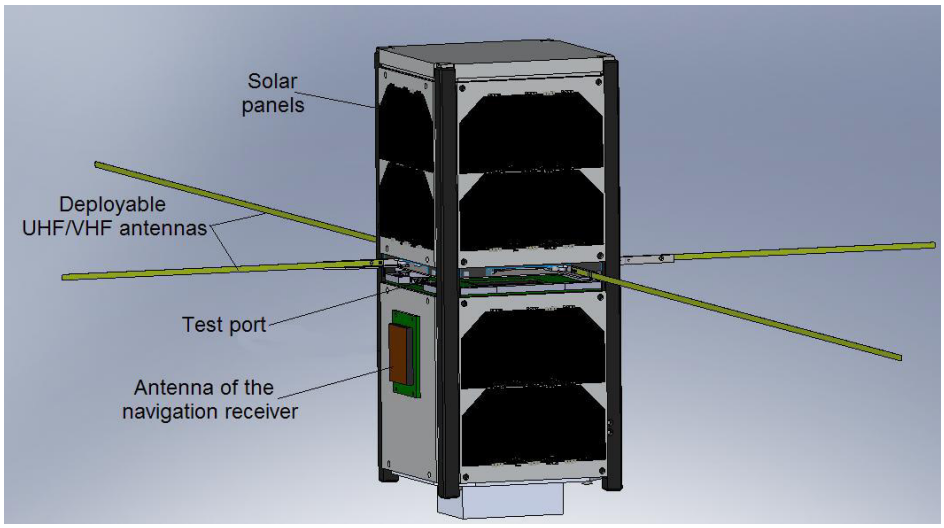

Fig. 1. The external view of SamSat-QB50

The main feature of SamSat-QB50 is transformation from CubeSat 2U to CubeSat 3U. The transformation is realized by opening aerodynamic stabilizer. The goal of transformation is to shift the pressure center relatively mass center. This shift allows to provide static stability of the nanosatellite [2].

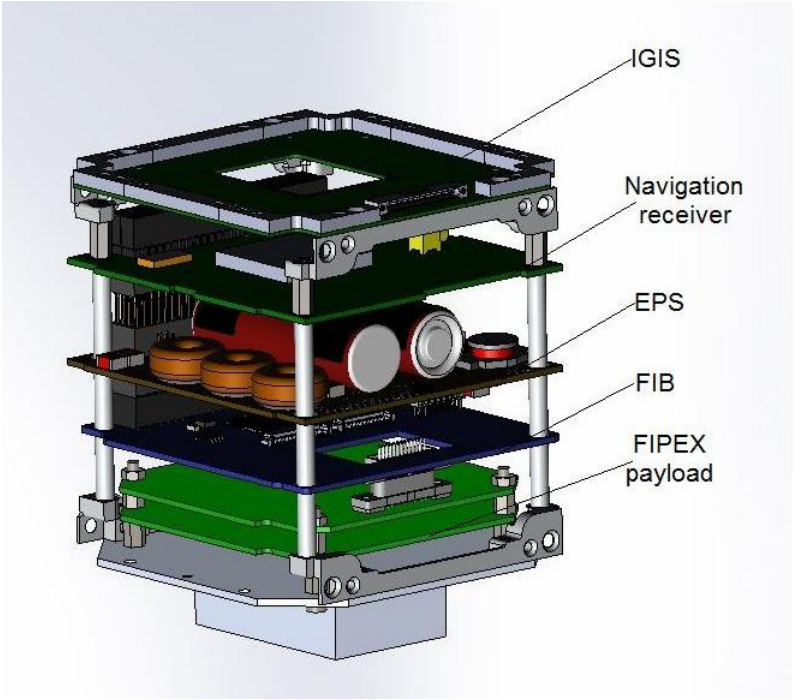

Fig. 2. The first stack layout

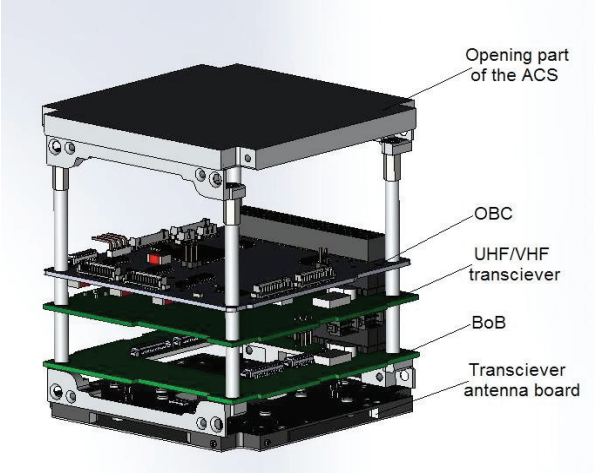

Fig. 3. The second stack layout

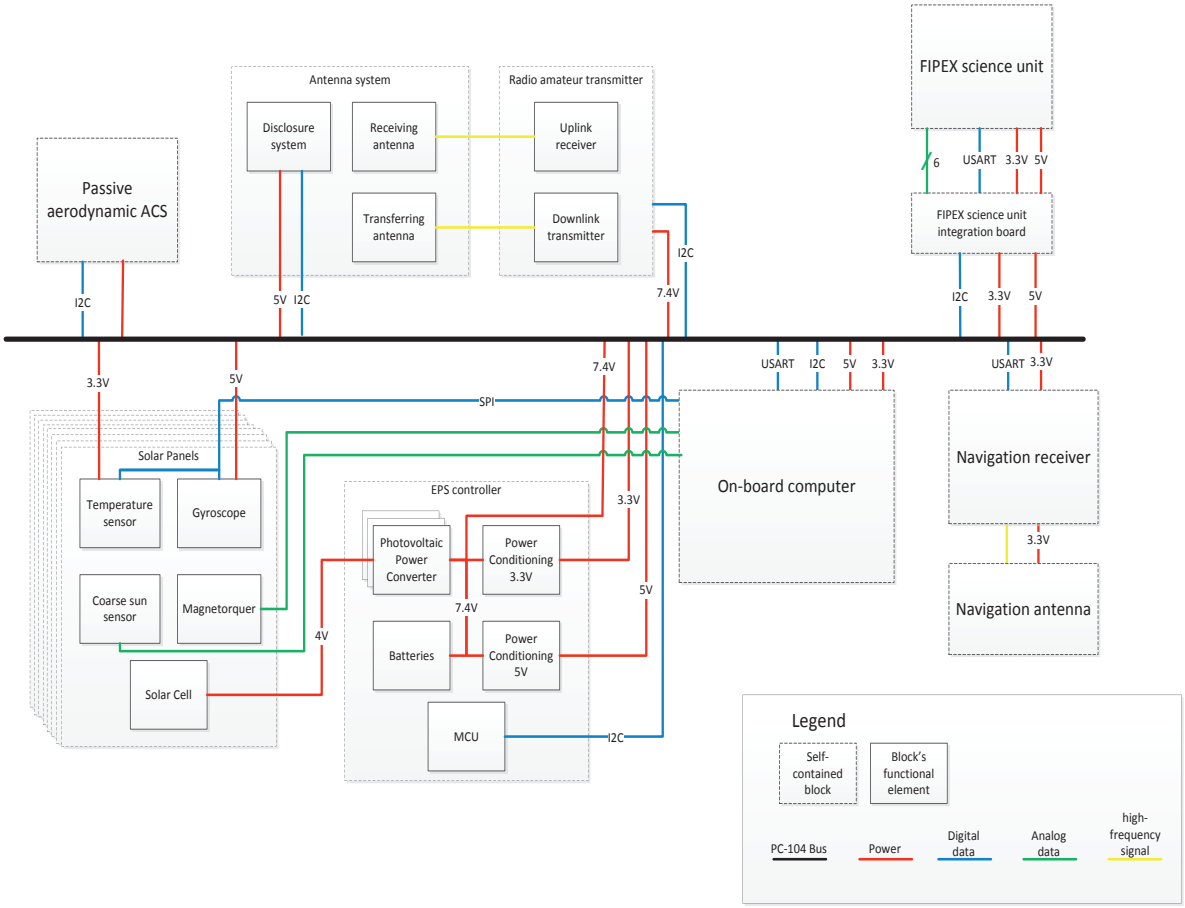

Fig. 4. Power and data connections between different SamSat-QB50 subsystems

4. In-home design components for SamSat-QB50

4.1. Passive aerodynamic stabilizer

Passive aerodynamic stabilizer has a complex design. This stabilizer is transformable because according QB50 requirements (QB50-SYS-1.1.6) the CubeSat's center of gravity shall be located within a sphere of 20 mm diameter, centered on the CubeSat's geometric center. Realized in this case 10 mm reserve of static stability is too low for robust ACS. The transforming force produces by hermetic balloon. The aerodynamic stabilizer structure is shown on figure 6.

After transformation the reserve of static stability is increased from 19.6 mm to 54.8 mm (plus 35.2 mm to initial reserve). Using the balloon as main part of stabilizer allows to design a very light structure with 77 mm extension. Wherein the mass center shift is very low (about 2 mm). It means that designed stabilizer is effective as low weight structure.

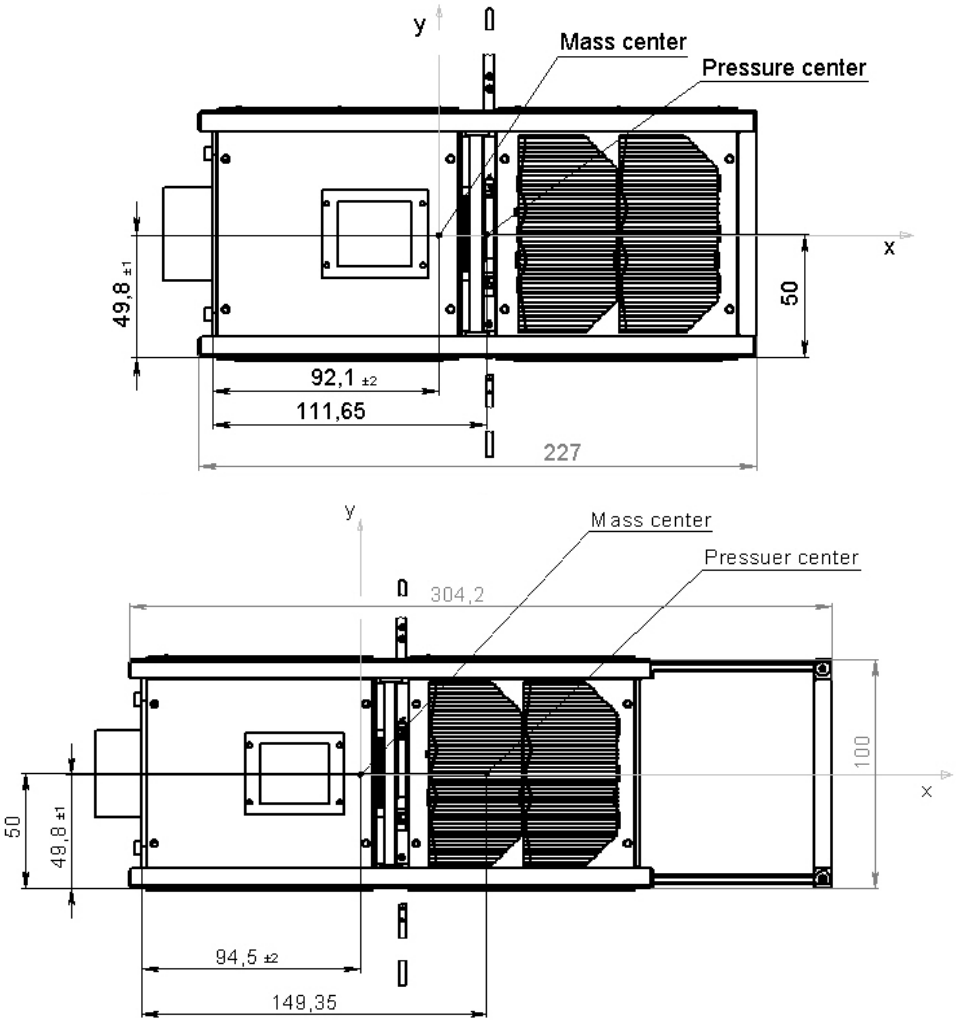

Fig. 5. SamSat-QB50 before and after transformation

On flight preparation phase the balloon is blow off until clamps will contact but as it is hermetic there will be some air inside. On the ground the overpressure is zero, but on the orbit the overpressure will be about 1 atm. This pressure will produce the force for stabilizer opening. Because separation adapter isn't hermetic the balloon is trying to open just inside the adapter. To control the opening of stabilizer it is used burning wire mechanism [3]. It is allows to open stabilizer by command from OBC. It means that stabilizer top and bottom plates are under the load about 1 atm. Calculation of preliminary top plate deformation is shown on figure 7 (the maximum deformation is about 1 mm in the middle of the plate).

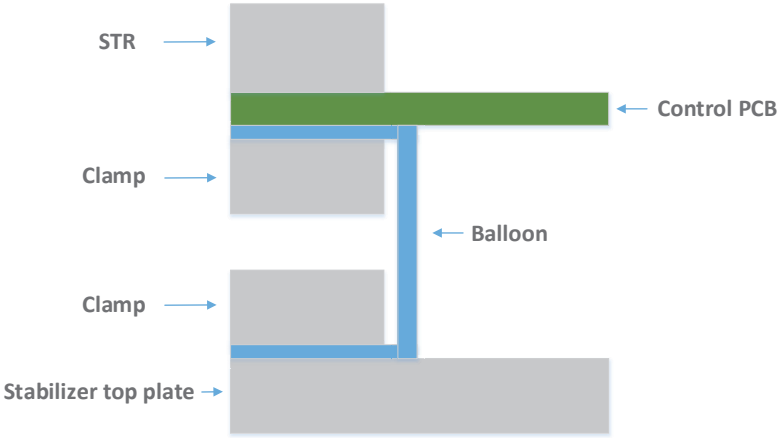

Fig. 6. The aerodynamic stabilizer structure

It is supposed that after separation SamSat-QB50 obtains an angular velocity less than 10º/sec, but after transformation the inertia moment is increased and angular velocity is decreased to less than 8.8º/sec.

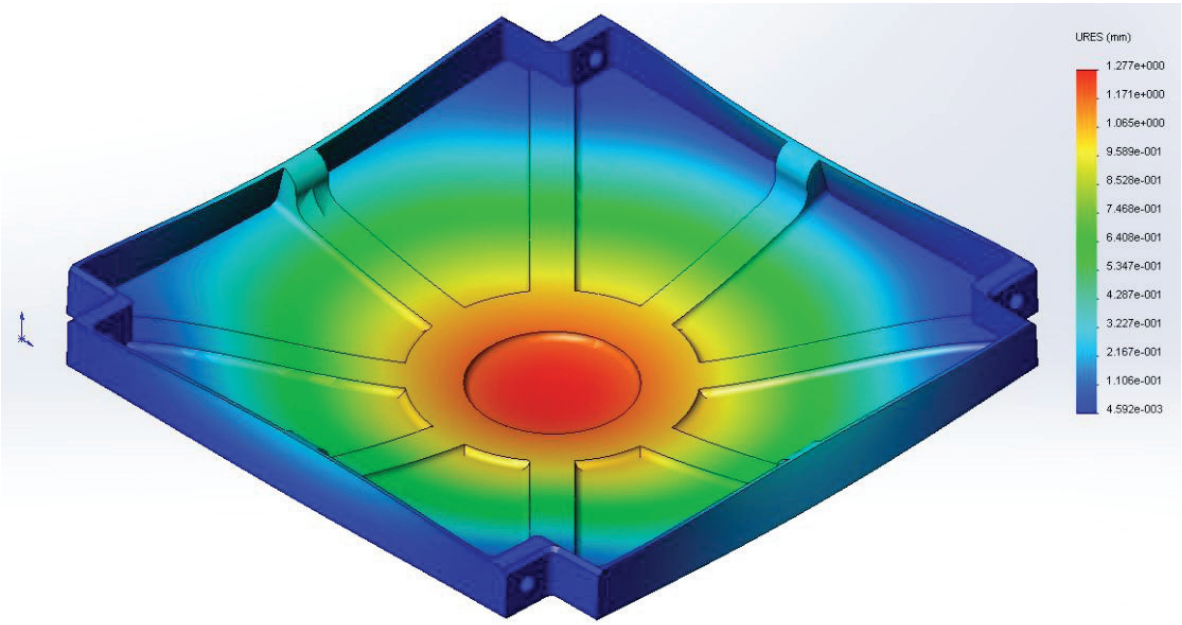

Fig. 7. Aerodynamic stabilizer top plate deformation

4.2. SamSat-QB50 structure

SamSat-QB50 structure (STR) is part of ACS. It has special holes for hysteresis rods, which are located inside CubeSat before transformation. On figure 8 is shown how hysteresis rod placed into STR. For hysteresis rod good motion is used a special lubricating fluid. STR is produced from aluminum alloy AMg 6.

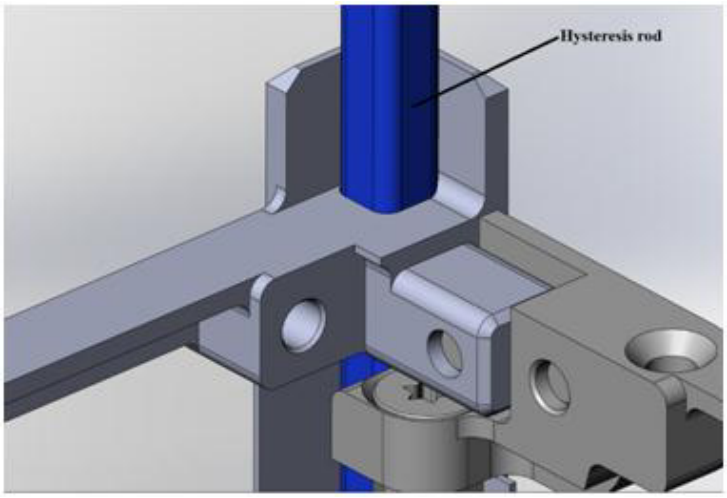

Fig. 8. Hysteresis rod placed into STR

4.3. SamSat-QB50 ACDS

The aerodynamic stabilizer without additional damping device can provide required orientation only in case of low initial angular velocity and low initial angle of attack [4]. As a damping device was suggested to use four hysteresis rods installed inside of aerodynamic stabilizer rails. This mechanism allows to achieve stable ±20º orientation within 2 days.

For increasing of required orientation reliability it is used spare ACS consisted of three magnetorquers placed inside of COTS solar panels. This approach allows to design reliable ACS.

ADS is based on using navigation receiver for updating actual TLE (two line elements) parameters [5]. For determination motion around mass center uses magnetometer, gyros and digital sun sensors.

The reported study was partially supported by RFBR, research project No. 13-08-97015-r_Volga region_a.

References

[1] QB50 System Requirements and Recommendations, Issue 6, 9 July 2014

[2] Selection of design parameters of aerodynamically stabilized nanosatellite for thermosphere research within the QB50 project / 5th European CubeSat Symposium, Book of Abstracts, 3-5 June 2013, Ecole Royale Militaire, VKI, Brussels./ I.Belokonov, L.Gluhova, D. Ivanov, A. Kramlikh,M. Ovchinnikov, I. Timbay, E. Ustiugov

[3] SamSat–QB50 nanosatellite. Burning wires mechanism for antenna system and aerodynamic stabilizer/ 6th European CubeSat Symposium, Book of Abstracts, 14-16 October 2014, Estavayer-le-Lac, Switzerland./ E. Ustiugov, A. Nikitin, S. Shafran

[4] Low-orbital transformable nanosatellite: research of the dynamics and possibilities of navigational and communication problems solving for passive aerodynamic stabilization/ Proceedings of 2th IAA Conference on Dynamics and Control of Space System, Roma, Italy, 24-26 march 2014, IAA-AAS-DyCoSS2-14-04-10/ I.V. Belokonov, A.VKramlikh, I.A. Timbai

[5] Joint use of different types of information in the spacecraft orientation determination algorithms/ 20th Saint Petersburg International Conference on Integrated Navigation Systems, ICINS 2013; Saint Petersburg; Russian Federation; 27 May 2013 through 29 May 2013; Code 102708/ Grigoreva, M.E., Kramlikh, A.V.