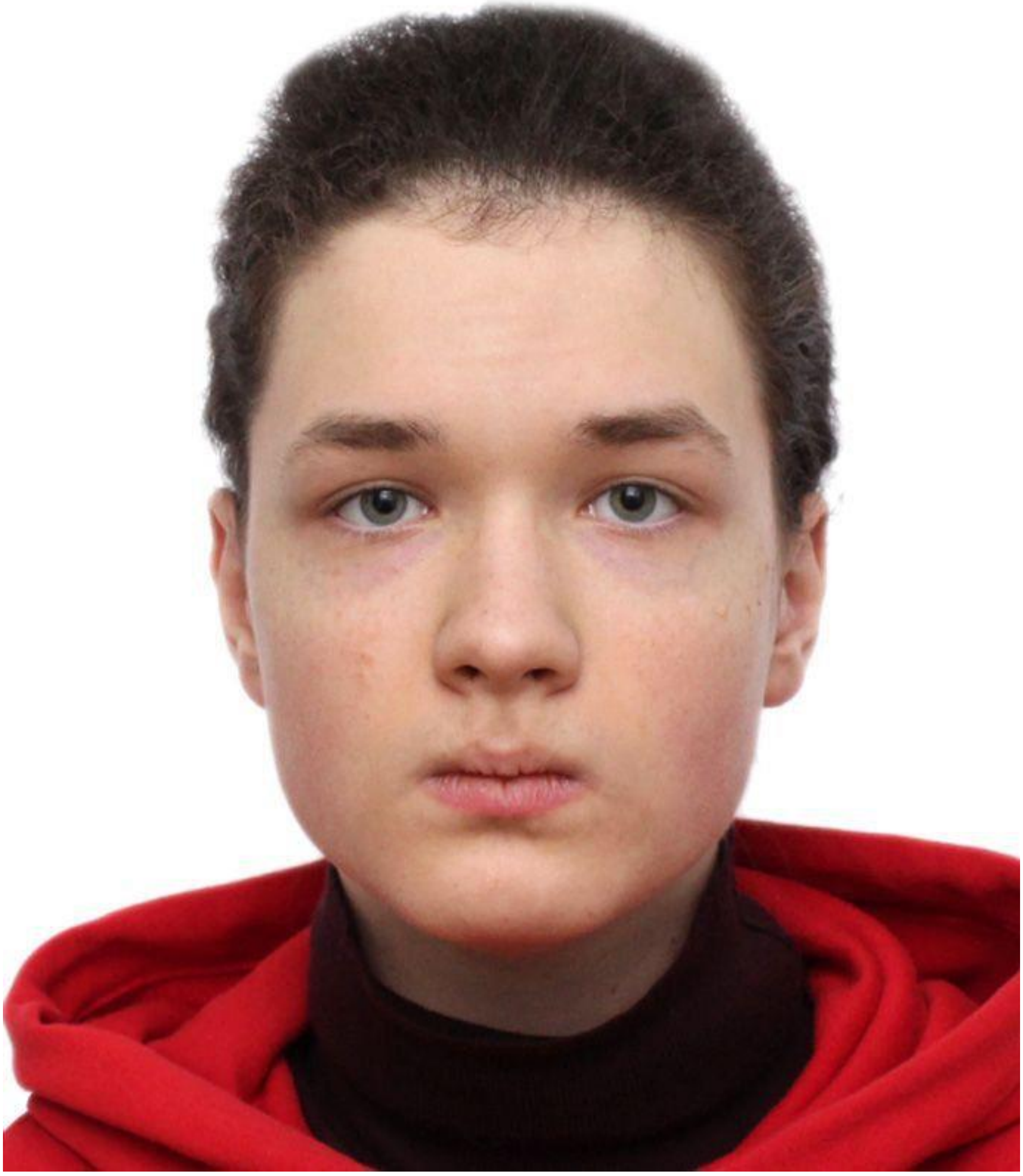
2023 年臺灣國際科學展覽會
優勝作品專輯

作品編號	**100038**
參展科別	工程學
作品名稱	**DECREASING CANSAT ANGULAR VELOCITY USING DEPLOYABLE FINS**
得獎獎項	

國　　家	**Russia**
就讀學校	**Sakha Junior Science Academy**
指導教師	**Andrey Petrov**
作者姓名	**Artem Mardin**

關鍵詞　**CanSat, aerodynamics、stabilization、PID**

作者照片



1. Abstract:

CanSat (a can-size satellite) flight data revealed the occurrence of high spin angular velocities along the vertical axis of a CanSat during a parachute descent phase. A novel aerodynamic stabilization system of deployable fins was designed to decrease angular velocity. Deployable fins were attached to servomotors (rotary actuators) to provide control authority during the CanSat descent phase. Deployable fins positions were calculated based on an onboard gyroscope data using a PID (proportional-integral-derivative controller) regulator and a moving-average filter. After the assembly and the initial testing, the system was flight-proven by dropping it from a drone with and without enabling the stabilization system.

2. Introduction:

Recent advances in space exploration made satellites and spacecraft, especially CanSat - a can-size satellite, designing and engineering an interesting subject study for students and CanSats in particular as an affordable satellite format. [1]

Flight data analysis from one of the CanSat launch showed an occurrence of a high angular velocities along the vertical axis of a CanSat. In order to stop this rotation a novel stabilization system design was required.

In this study a novel aerodynamic stabilization system design suitable for installation on CanSat vehicles was developed and tested in a series of uniformly controlled launches at the Sakha Junior Science Academy sounding rocket launch facility at 61°39'46.6"N 129°23'26.7"E.

3. CanSat platform description:

CanSat stands for "satellite in a can". The name implies that the payload must fit inside a can (typically, a regular soda can). Due to its small size, it has a minimum construction cost. In this study a CanSat was designed in accordance the Moscow State University Aerospace Engineering School CanSats Launching Competition guidelines.

The following devices were installed in this CanSat:

1. GY-801, a precise 9-axis sensor module which includes L3G4200D (Gyroscope), ADXL345 (Accelerometer), MMC5883MC (Magnetometer) and BMP180 (Barometric Pressure/Temperature) ICs with I2C protocol for communication;
2. Servo actuator to deploy the parachute system;
3. Arduino Micro to control the satellite.

The satellite body was made of a cardboard tube approximately 200 mm high, 76 mm in diameter. Onboard electronics was installed into the body with the help of plastic bushings. Devices were wired to each other using a soldering breadboard. Figure 1 shows the assembled device, figure 2 shows the scheme of onboard systems. The satellite was mounted on a sounding rocket and launched to 350 meters up. After separation from the rocket, the satellite descended on its parachute. During the entire flight, data were recorded on an SD-card, telemetry was also transmitted using radio.

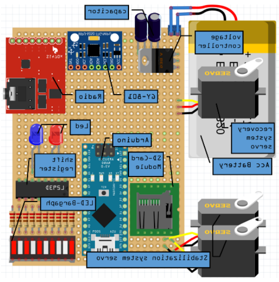


Fig. 1

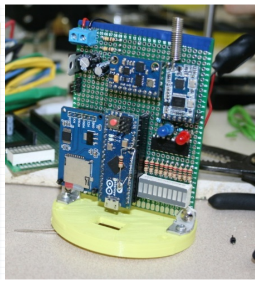


Fig. 2

The basic design of the satellite does not include any stabilization system, therefore the CanSat rapid rotation phenomenon occurred during this CanSat parachute descent stage. Figure 3 shows a graph of angular velocity during one of the launches. The satellite rotated at a speed of more than 300 deg/sec, after which the gyroscope went beyond the measurement limits.

4. Stabilization system design

A reaction wheel or compressed air thrusters of aerodynamic stabilization options were chosen on a least energy-consuming basis.

Deployable fins are two body sections that open from the upper part of the vehicle from opposing sides. The fins follow the shape of the CanSat body.

The fin deployment mechanism used a taut thread and a spring. After the deployment of the parachute system, the thread fastening the fins was burned with a nichrome wire. Afterwards springs flipped the fins to the sides, and then the system began to work. Figure 3 shows fins in half-deployed and fully deployed states.

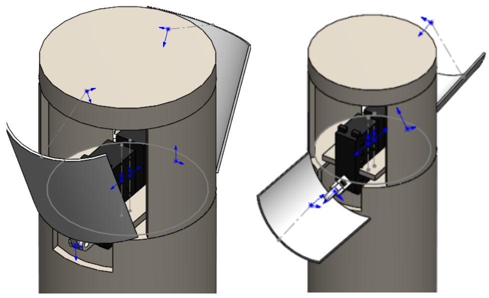


Figure 3. Stabilization system

Servomotors controlling these deployable fins were designed for a load of 13 kg-cm and considered sufficient. These servomotors were connected to pins D11 and D10 of the Arduino.

The software to control the stabilization system was written in C++. It receives angular velocities in degrees per second from the gyroscope, passes them through a moving-average filter and calculates a fin deflection angle. Source code has been published on GitHub (https://github.com/gfb123shinigami). The software was uploaded on the testbench and the PID coefficients were chosen empirically.

A CanSat parachute was attached on a freely rotating mount to increase performance efficiency. It was noted that during the CanSat descent, that the parachute slings were tangled, creating various pulling forces.

All components were built in SolidWorks and later printed on a 3D printer. Before real flight testing an engineering analytics of the rotation phenomenon and its spin degrees were shown on Figure 4.

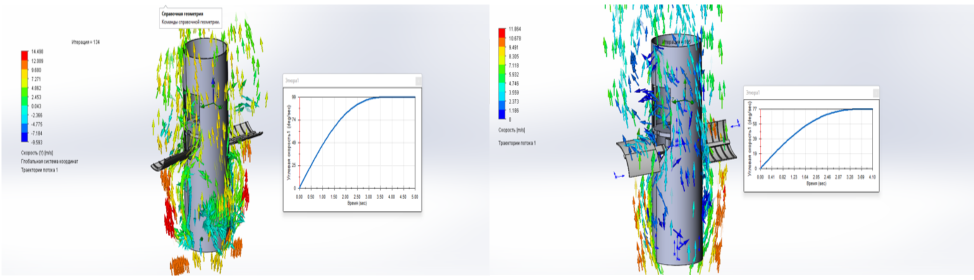


Figure 4. Solid Flow Simulation

5. **Results:**

Figures 5 and 6 show graphs of angular velocity during descent without and with the stabilization system active.

In the first case, the separation from the drone occurred at the 109th second of flight. Y-axis angular velocity (vertical axis of the CanSat) reached 500 degrees/sec and did not decrease until landing at 122nd second. Fluctuations of angular velocity after landing were caused by the swaying of the tree on which the test vehicle landed.

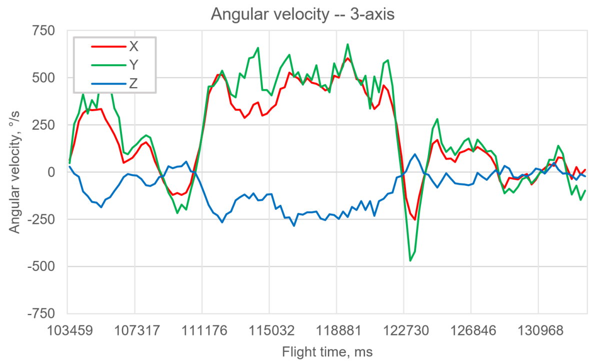


Figure 5. Angular velocity (no stabilization)

In the second case, separation from the drone occurred after 102 seconds. Angular velocity in the descent phase did not exceed 250 degrees/sec. The aircraft landed in the snow after 116 seconds of flight. In both drop tests, the average descent rate was 8m/s.

2-times decrease in angular velocity along the vertical axis was observed during the tests.

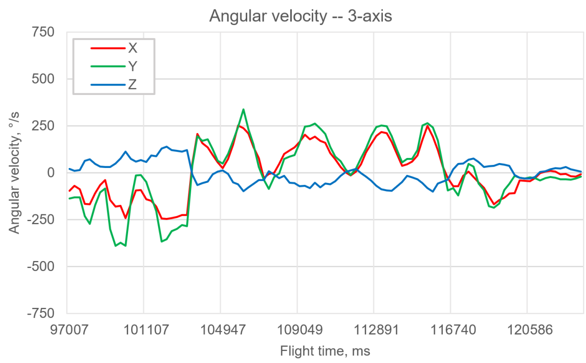


Figure 6. Angular velocity (stabilization active)

6. **Discussion:**

The stabilization system allowed us to reduce the angular velocity of the vehicle from 500 to 250 degrees/sec, which, nevertheless, is not enough to operate advanced payloads on the CanSat. Also, Figure 10 shows angular velocity oscillation in the region of 125 degrees/sec.

To increase the efficiency of the stabilization system and to eliminate the mentioned problems, the following solutions are possible: 1. Careful PID controller tuning.

2. Calibrating the gyroscope and changing the data filtering algorithm.

3. Increasing the area of aerodynamic fins.

4. Installation of faster servos.
These changes will eliminate angular velocity oscillations and potentially stop the vehicle rotation completely. However, they will not compensate for wind gusts and other random environmental effects due to the high reaction time of the system.
After these changes are made, the system will be re-tested. We also plan to run simulations to determine the optimal area of the fins and to tune PID coefficients

7. Conclusion:
The following conclusions from the results:
1.The designed system provides stabilization along the vertical axis.
2. Overall efficiency can be improved by modifying the design and software.
3. The testing methodology needs to be improved.
The designed system has proven its flight performance and is suitable for use on CanSat satellites.

8. I would like to express my gratitude to Dr Vasilii Pavlov, principal, staff of the Sakha Junior Science Academy and Kvantorium for providing the equipment for the scientific project, to Yury Romanov, Ivanov Karl and Andrei Petrov for project supervision

9. 1)CanSat format description - https://en.wikipedia.org/wiki/CanSat
2)MSU Aerospace Engineering school guidelines - http://roscansat.com
3) Physics 8th grade / Ed. A.V. Peryshkin. - 4th ed., revised. Vertekal, 2016. - 240 p.
4) What is a PID controller and how to work with it? - https://alexgyver.ru/lessons/pid/
5) Ó Avilov M.N. Rocket models M.: DOSAAF, 1968. 71 p.
6)Satellite Sensors / Kuskov S. Ed. Ed. by Evgeny Venin. 2nd edition. 2017, 16 p.
7) Satellite electronics/Stepanov M. Ed. Eugenia Venina. 1st edition. 2017, 18 p.
8) Feodosiev V.I. Fundamentals of rocket flight engineering M.: Nauka, 1979

【評語】100038

1. The work proposes the use of deployable fins to attenuate the angular velocity of a cansat in its descent phase. Such a device may be valuable in enhancing the cansat mission for image acquisition and scientific observation.

2. The concept，however，can be further elaborated in terms of design details (when and how to release) and analysis scopes (deployment effect at different attitude and speed).

3. Explanations of the experiment setup and procedure can also be enhanced to fully verify and validate the design.