

## **CFP-15-GirlSAT 2015**

**Marie Timurová**

Student, Czech Republic, MaryTimur@gmail.com

**Anna Gasparjan**

Student, Czech Republic, anngasparjan@gmail.com

**Abstract:** The 2015 European CanSat Competition is organized by the European Space Agency (ESA) in collaboration with AeroEspaço– Air and Space Science Center. The finished CanSats will be launched on a rocket to an altitude of 1 km from the Santa Cruz Air Field, 60 km north of Lisbon, Portugal, on 24-28 June 2015.

The European CanSat competition is part of ESA's initiative to inspire young people to follow a career in science or engineering, with a view to ensuring the availability of a highly qualified work force in the space industry of the future.

GirlsSAT 2015 is one of the 18 secondary school teams that will participate in the 2015 European CanSat Competition.

Primary mission was to measure air temperature and air pressure after release and during descent. As a secondary mission our team chose 3D acceleration measurement and 3D measurement of magnetic field of Earth. Furthermore, we have decided to add 3D gyroscope and GPS for positioning CanSAT.

We made structure and mechanical design using T-minus kit and for cover of satellite we decided to use plastic jar made from cleaner.

For measuring mentioned information we decided to use MKI124V1 STEVAL module, because it contains pressure sensor, 3D accelerometer, 3D magnetometer and 3D gyroscope and temperature sensor (LM92). Next we used real-time circuit, GPS and micro SD card module to insure finding cans and store data in the event of non-acceptance of data from TCVR. Our firmware is written in Arduino. We use 9V battery.

For data analysis we have written code in C# in computer and also in Android for tablet. We have made two ground stations each for one program just to make sure we get data from satellite. In main ground station with computer, we have used T-minus tcvr, in the backup one we used TRC105. We have used our home made YAGI antenna for main ground station and bought antenna for backup.

For recovery system we have computed area about 0.1 m<sup>2</sup>.

Close to launch of the rocket we find out that we break off a cable in our main ground station, we tried to fix it, but we didn't catch, so we used only backup station. We have successfully received data from CanSAT and analysed it.

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### I. INTRODUCTION

The 2015 European CanSat Competition is organized by the European Space Agency (ESA) in collaboration with AeroEspaço– Air and Space Science Center. The finished CanSats will be launched on a rocket to an altitude of 1 km from the Santa Cruz Air Field, 60 km north of Lisbon, Portugal, on 24-28 June 2015.

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When choosing a secondary mission, measuring the Earth's magnetic field, we were inspired by the tradition of measurement Earth's magnetic field through a series of satellites Magion.

MAGION is the name of a series of small MAGnetosphere and IONosphere satellites produced in the Institute of Atmospheric Physics Academy of Sciences of the Czech Republic (led P. Tříška a J. Vojta) [1] and was discharged as sub satellites of Russian scientific satellites. The satellites are designed to measure the parameters of space plasmas. They use the system of simultaneously measuring in two not very distant points.

### II PROJECT DESCRIPTION

We made structure and mechanical design using T-minus kit and for cover of satellite we decided to use plastic jar made from cleaner.

For measuring mentioned information we decided to use MKI124V1 STEVAL module, because it contains pressure sensor, 3D accelerometer, 3D magnetometer and 3D gyroscope and temperature sensor (LM92). Next we used real-time circuit, GPS and micro

SD card module to insure finding cans and store data in the event of non-acceptance of data from TCVR. Our firmware is written in Arduino. We use 9V battery.

For data analysis we have written code in C# in computer and also in Android for tablet. We have made two ground stations each for one program just to make sure we get data from satellite. In main ground station with computer, we have used T-minus tcvr, in the backup one we used TRC105. We have used our home made YAGI antenna for main ground station and bought antenna for backup.

For recovery system we have computed area about 0.1 m<sup>2</sup>.

### II.I Materials and structural design

We have decided to use CanSAT kit from T-Minus Engineering B.V. so we have determined by the dimensions of the PCB our blocks of sensors.

The following figure (Fig. ) we can see the example of the PCB. It has four holes of 3.2 mm diameter, which serve for putting on plates foursome threaded bolts M3. The whole structure example is on following figure (Fig. ).

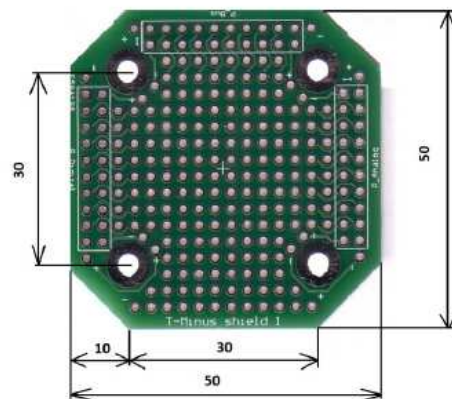


Fig. 1: "Clear" PCB

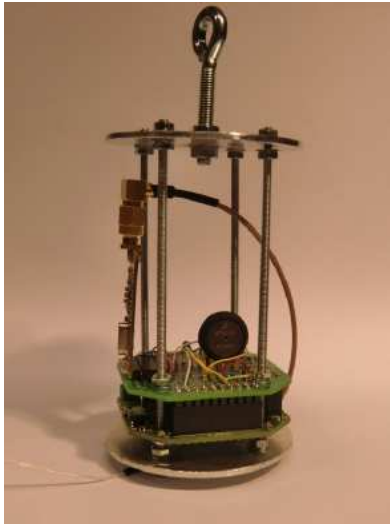


Fig. 2: Mechanical structure of CanSAT example

We have used 4 steel bolts (Fig. 3 and Fig. 4). There is pitched aluminium circle on those bolts. This circle is one of main parts which determine the structural strength. There is a hole in the centre of this circle which is reserved for the antenna (Fig. 5 and Fig. 6). There are also PCBs (Fig. 7 and Fig. 8) on those bolts which are separated by spacers (Fig. 9). On the top of the construction there is similar circle like on the bottom but there is bigger squared hole for GPS module (Fig. 10). Whole this construction is inserted in plastic jar which is made from cleaner (Fig. 11). This jar has holes in the middle which serves for ventilation (Fig. 18) and holes on the top side for recovery system holders and GPS module (Fig. 19). On the bottom side of this jar is whole construction held by sealing ring (Fig. 20).



Fig. 3: Steel bolt model



Fig. 4: Steel bolt sketch

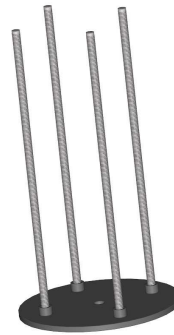


Fig. 5: Bottom of construction model

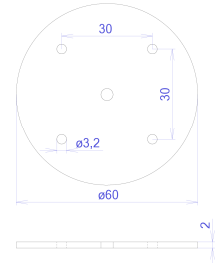


Fig. 6: Bottom of construction sketch

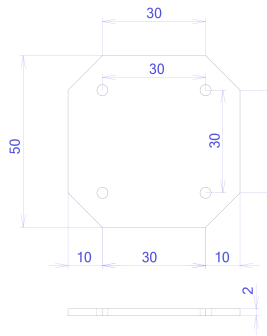


Fig. 7: PCB for microSD and battery

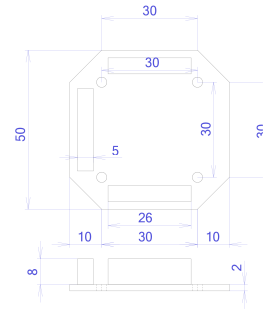


Fig. 8: PCB with sockets and battery

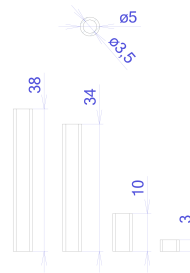


Fig. 9: Spacers

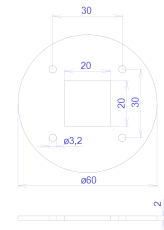


Fig. 10: Top of the construction

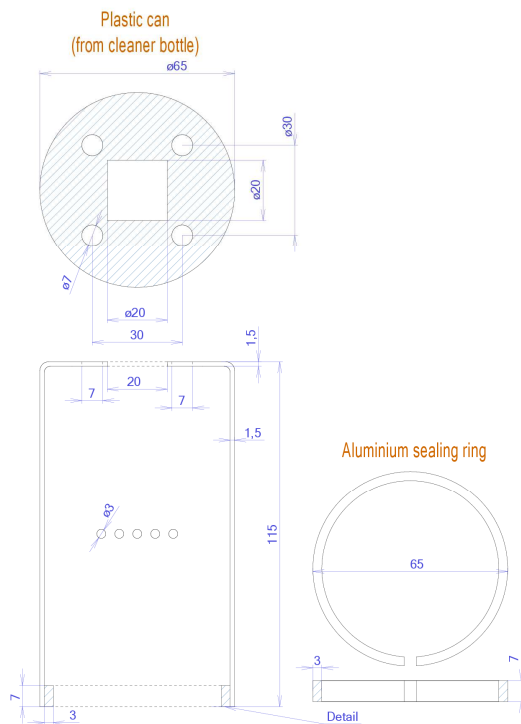


Fig. 11: Plastic jar with sealing ring

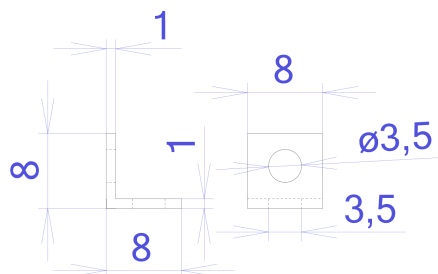


Fig. 12: Recovery system holders



Fig. 13: Model of construction 1-layer

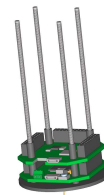


Fig. 14: Model of construction 2-layer

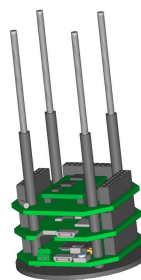


Fig. 15: Model of construction 3-layer

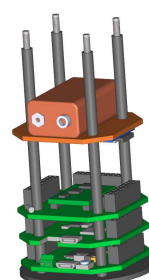


Fig. 16: Model of construction with battery

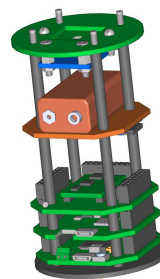


Fig. 17: Whole construction model



Fig. 18: Construction in jar model



Fig. 19: Model with recovery system holders



Fig. 20: Detailed view of bottom side model

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### II.II Electrical design

#### Block of sensors

We use sensors for pressure, temperature, 3D accelerometer, magnetometer 3D and 3D gyroscope from STMicroelectronics. Developing these boards are based on the article [2]. We used MKI124V1 STEVAL module (Fig. 21), which contains LPS331AP (pressure sensor), LSM303DLHC (3D accelerometer, 3D magnetometer) and L3GD20 (3D gyroscope). This module communicate using I2C. Because max voltage of this module is 3.6 V and Arduino T-minus has 5 V power, we have to use some converter. This converter must be bidirectional, because I2C signals SDA and SCL are bidirectional also. For this convertor we used transistor BSS138.

This desk we designed the same way like on-board computer and transceivers, so there are also three connectors with 2x10 pins.

On I2C bus we have also connected temperature sensor and real-time circuit. Real-time circuit we'd like to have because of data acknowledge.

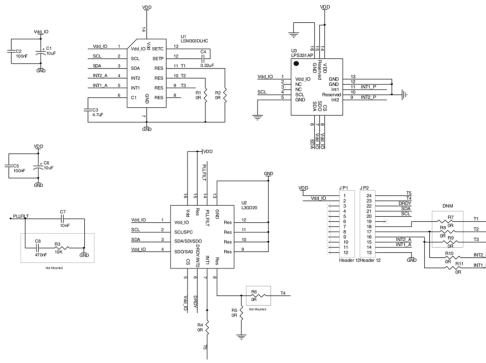


Fig. 21: MKI124V1 STEVAL module wiring

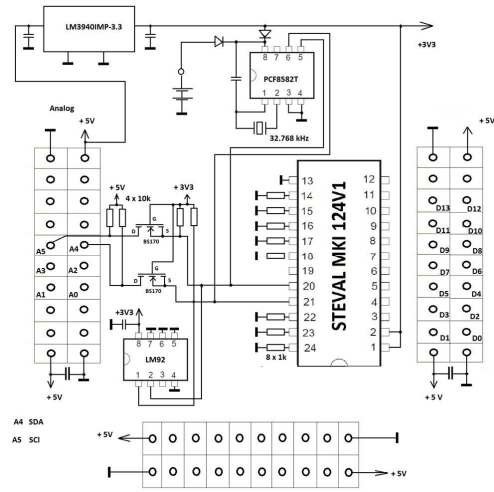


Fig. 22: Block of sensors schema

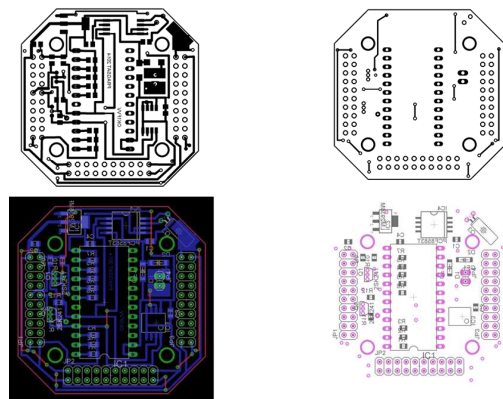


Fig. 23: Sensors module PCB

#### GPS sensor

To record the GPS position we used factory-made module GPS: GY - GPS6MV1 (also called GY - GPS6MV1 NEO -6M GPS6 module).

#### Micro SD card

To prevent data receiving lost, we decided to record measured data also on the micro SD card. To communicate with it we use four SPI signals: MOSI, MISO, SCL and SC.

#### Transceiver

We decided to use T-minus block. Unfortunately we didn't find detailed documentation so we used reverse engineering with this results:

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The base transceivers circuit is TRC105 firm RFM. The transmitter can work with two types of modulation either OOK (on-okeyed) or FSK (frequency-shift keyed). If is set OOK, then log 1 means full power and log 0 is without power. It is thus the period of operation A1. Supply voltage is 2.1 to 3.6V. Receiver sensitivity -112 dBm. Maximum transmitter power is +13 dBm. Managing microcontroller is TCVR XMEGA32A4U. Transceivers working on one of 24 channels in the band 70 cm with a spacing between channels 90 kHz.

### II.III Software design

#### On-board computer firmware

Creating software (firmware) is relatively simple due to use development environment and language Arduino and Arduino library system for serial communication UART (with transmitter as GPSD), I2C (with sensors) and SPI (with micro SD card).

Each sketch (program) consist of three parts. First we need to define which libraries we'd like to use. Then is function setup(). In this function are set up parameters, serials starting and all needed commands that should be run only once.

After this setup is started loop() function, which runs over and over until the power on chip is sufficient. All sensors that we use have sample example for using them so we only have to check if our sensors are ok and then put this code together.

Our firmware is designed to send (and save) data in JSON format.

#### Data processing in LabVIEW

For data processing we used graphical programming language LabVIEW, which we used on computer that is connected to data receiver. Our program has block diagram figured on Fig. 24 and its output example is on Fig. 25.

Block Diagram

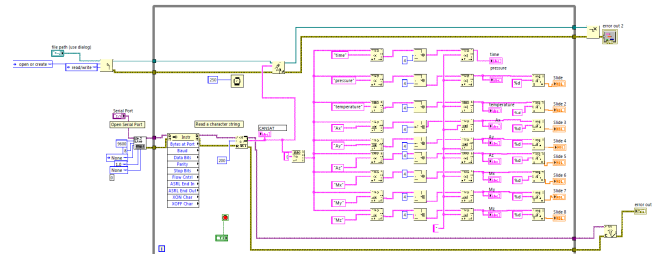


Fig. 24: Block diagram in LabVIEW

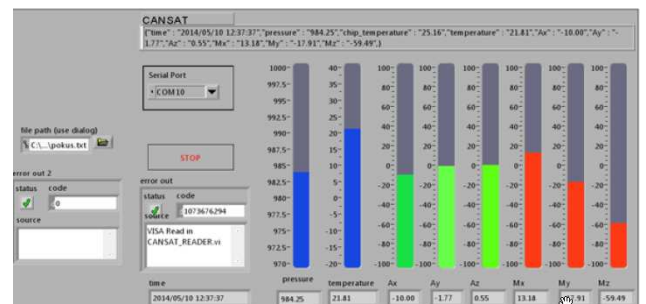


Fig. 25: LabVIEW output

#### Data processing in C#

For data processing we also use our own program in C# language, which is made for this particular problems.

First we have to get data from receiver, so we have made class SatDataSource which connect our program to COM port and when some data received is called new Event. For data processing and validating is used SatData class. All retrieved data are saved in XML file to eliminating data lost if program falls. For data plotting is used code in Form1 class method Display().

On following print screens are figured outputs of our program.



Fig. 26: Acceleration graph

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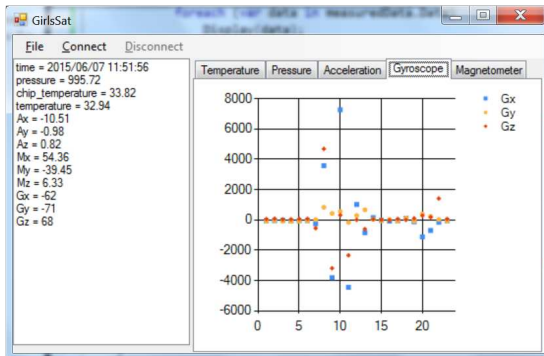


Fig. 27: Gyroscope graph

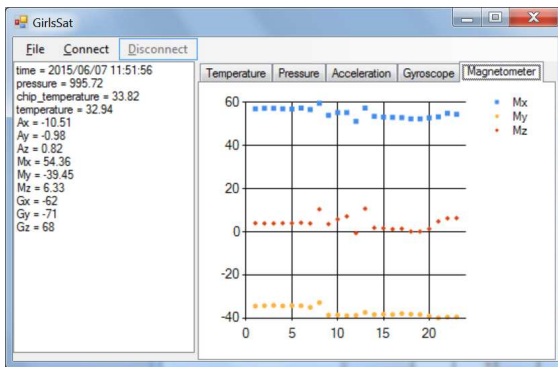


Fig. 28: Magnetic field graph

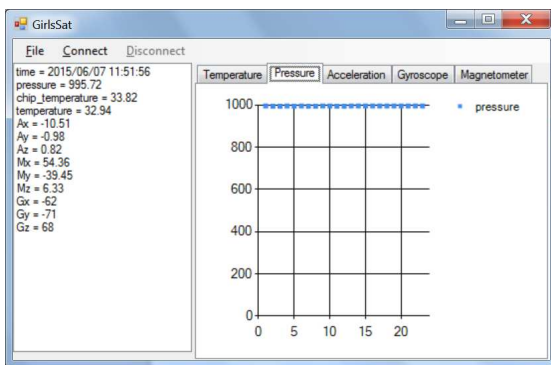


Fig. 29: Pressure graph

On Fig. 30 you can see one retrieved data from CanSAT. When you click on any data, graph of all received is plotted (Fig. 31).



Fig. 30: Android program example



Fig. 31: Android graph example

### Data processing on Android system

On android system is first running method onCreate in which is set design and some initialization. Connecting to COM port and data receiving is similar like in C#. For data plotting is used GraphData class which is created in GraphViewLibrary (com.jjoe64.graphview.GraphView). Own data plotting is doing automatically when notifyDataSetChanged method is called.

### II.IV Recovery system

Our CanSAT is very light, it has only about 180 grams without battery and about 210 grams with battery, so we used minimal weight which can be used – 300 grams for our recovery system counting.

We have prepared some calculation using following:

$$mg = \frac{1}{2} q v^2 c_d S$$

where

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- m is weight of completely system [kg]
- g is gravitational acceleration  
9,80665m/s<sup>2</sup> [m/s<sup>2</sup>]
- q is air density 1.225 kg/m<sup>3</sup> [kg/m<sup>3</sup>]
- v is velocity [m/s]
- c<sub>d</sub> is drag coefficient 0,75 [-]
- S is the surface area of the parachute [m<sup>2</sup>]

Because we need to compute size of parachute, so we have to express S from this equation:

$$S = \frac{2gm}{\rho c_d v^2} m^2 = \frac{2 \cdot 9.81 \cdot 0.3}{1.225 \cdot 0.75 \cdot 8^2} m^2 = 0.1 m^2$$

When we'd like to use round canopy, diameter is found by the formula:

$$D = \sqrt{\frac{4 \cdot S}{\pi}} m = \sqrt{\frac{4 \cdot 0.1}{3.14}} m \cong 36 cm$$

We decided to use octagon shape our area would be computed as 0.828\*D<sup>2</sup>, so it'll be 0.1 m<sup>2</sup> when we use 36 cm as diameter.

### II.V Ground support Equipment

For ground support we'd like to use YAGI antenna (Fig. 32 and Fig. 33), T-minus tcvr (Fig. 35) which is connected to UART/USB interface FTDI (FT232RL) because of drivers for Android (and Windows and Linux), computer and android tablet (Fig. 36).

We made our YAGI antenna by using book from Jacek Matuzczyk [3]. The yard is made from rectangular tube 20x20 mm. Reflector and dipole are made from aluminium tubes with 8 mm diameter. We used Metal mounting clamps to join it together.

The dipole impedance 200 Ω have to be adjusted by using loop 4:1 made from coaxial cable RG-58 of length 215 mm.

Technical parameters:

Frequencies: 430-440 MHz

Power gain: 11 dB

Impedance: 50 Ω

Angle of decommissioning: 30°

Length: 1.5 m

Weight: 1 kg

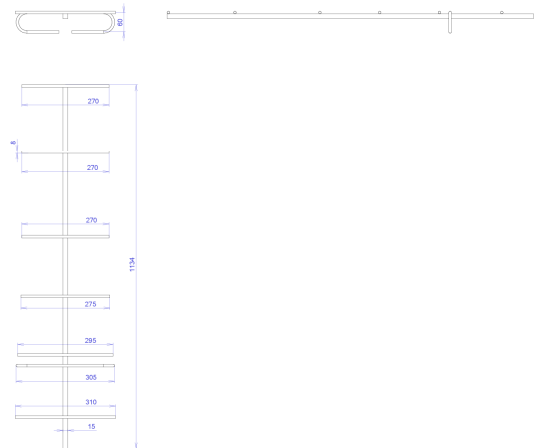


Fig. 32: YAGI antenna sketch

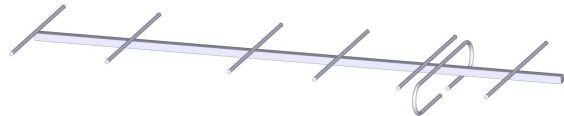


Fig. 33: YAGI antenna model

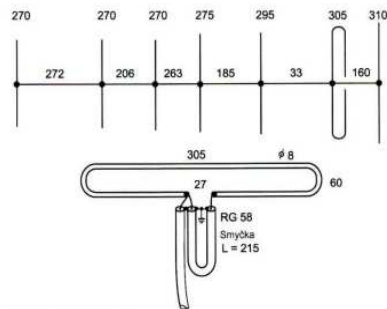


Fig. 34: YAGI antenna loop sketch



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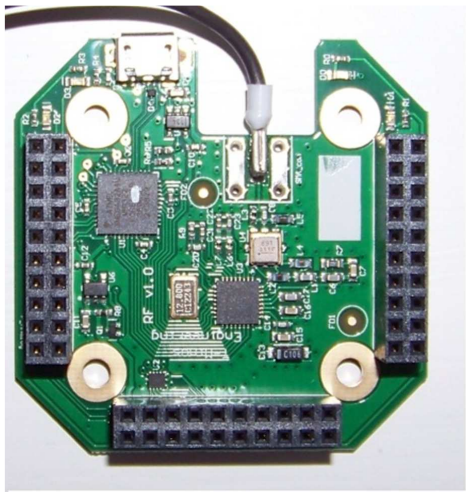


Fig. 35: T-minus data receiver



Fig. 36: Ground station

altitude. The pressure is linearly dependent on altitude. The temperature was the highest on CanSAT launch and lowest on landing.

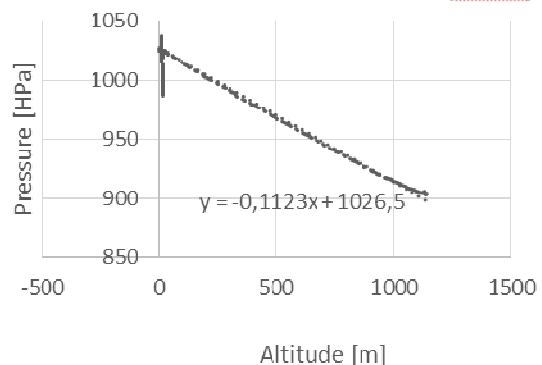
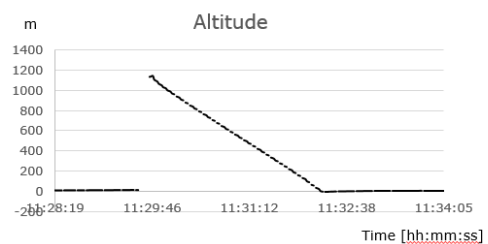
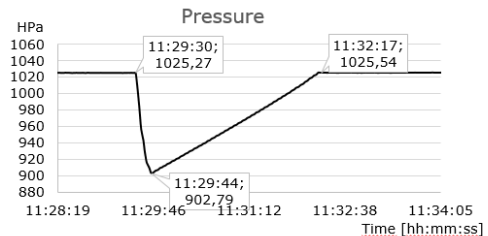


Fig. 37: Pressure depending on altitude

### III SCIENTIFIC RESULTS

|                              |                             |
|------------------------------|-----------------------------|
| Altitude on cansat launch    | 1143,5 m                    |
| Altitude after landing       | 7,6 m                       |
| Flight height                | 1135,9                      |
| Start of descending          | 11:29:46                    |
| End of descending            | 11:32:19                    |
| Duration of flying           | 0:02:33                     |
| Duration of flying in second | 153                         |
| <b>Descend per second</b>    | <b>7,42 ms<sup>-1</sup></b> |

#### III.I Primary mission

The primary objective of the mission was to measure the pressure and temperature during flight of CanSAT. On (Fig. 37, resp. Fig. 38) is shown dependence of pressure (resp. temperature) on

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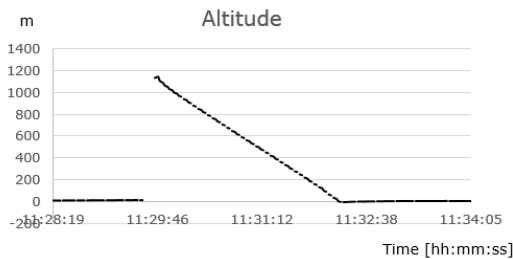
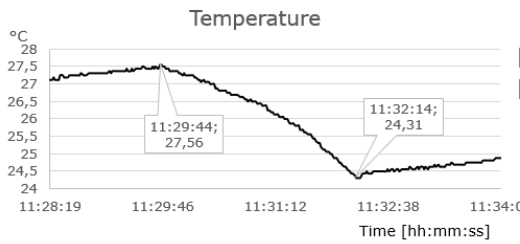


Fig. 38: Temperature depending on altitude

### III.II Secondary mission

On secondary mission we measured 3D magnetism (Fig. 39), acceleration (Fig. 40) and gyroscope (Fig. 41) depending on time. On this figures is shown that CanSAT was in still position before and after flight. The biggest acceleration was in time of launch rocket in z-axis.

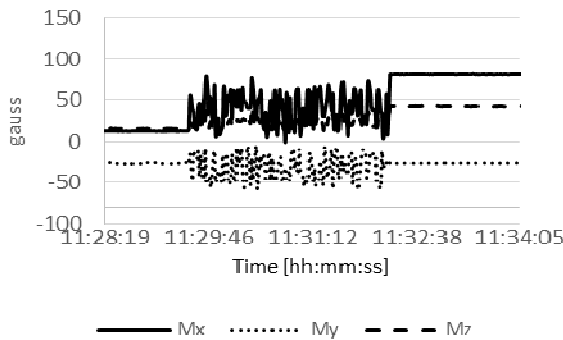


Fig. 39: Magnetism depending on time

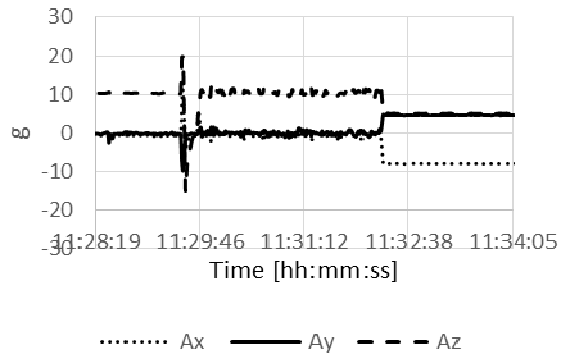


Fig. 40: Acceleration depending on time

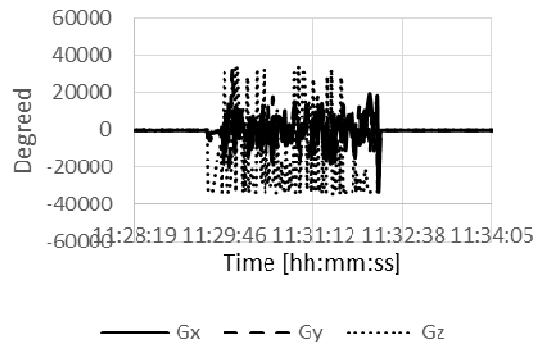


Fig. 41: Gyroscope data depending on time

### IV DISCUSSION

Our descent speed was little bit slower than  $8\text{ms}^{-1}$  so our recovery system should have smaller area.

On the graph (Fig. 37) you can see, that pressure is linear depending on altitude that is that we expected.

The temperature should have other process, we expected that we will have data according dry (or wet) adiabat, but as you can see on graph (Fig. 38) the temperature was the highest on CanSAT launch and then falls with time. This is probably caused by specific conditions on this place and date. On this graph is also shown that our CanSAT have probably lied on wet place, because the temperature on landing place was above  $3^{\circ}\text{C}$  lower than on take-off place.

On acceleration measure is show that the biggest changes was on z-axis. The main peaks are on racket start and then on land.

Data from gyroscope sensor shows that our flight was restless mainly in x and y-axis, so the CanSAT was rotating. The z-axis is more regular

and it shows that it was not swinging so our recovery system worked well.

### V CONCLUSIONS

We have successfully obtain data from CanSAT, we get all data to fulfil primary and secondary mission. We have some problems with our hardware and software so we have drawn a lesson from this.

On this content we have learned many lesson from technical and programming. We know how to design a circuit, how to test that it is correct, where and how to get the necessary sensors and circuits, how to solder, how to assemble and develop firmware for sending data.

Furthermore, we have improved the programming, we learned how to process the incoming signal to process the data and display it in a graph within the program.

We also have built own antenna, created a parachute.

Equally important lesson was that work in team is quite different than working as individuals and it is necessary to continue to develop these skills.

One of the big lessons was also the need to properly plan and carry out tests in order to better learn how to act in emergency situations.

We have also learned how to find sponsor and where we can present our project on public.

We know that we have to continue develop our skills to get bigger progress.

### VI REFERENCES

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