Pre-Launch Report (PLR)

Team Name: HATALOM

Country: Czech Republic

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INTRODUCTION

○ Team organisation and roles

Our team consists of six members and a mentor. All of us are from the same school - Gymnázium Opatov - and we are moreless the same age. Thanks to the fact that we have know each other for eight years the formation of our team was pretty easy. Some of us even participated in an earlier project, constructing a Wilson Cloud Chamber in our school. We meet basically every day at school corridors and we can consult anything as fast as possible. Every team member works on his own and if needed others provide help. In addition we meet as a whole team on weekends when necessary.

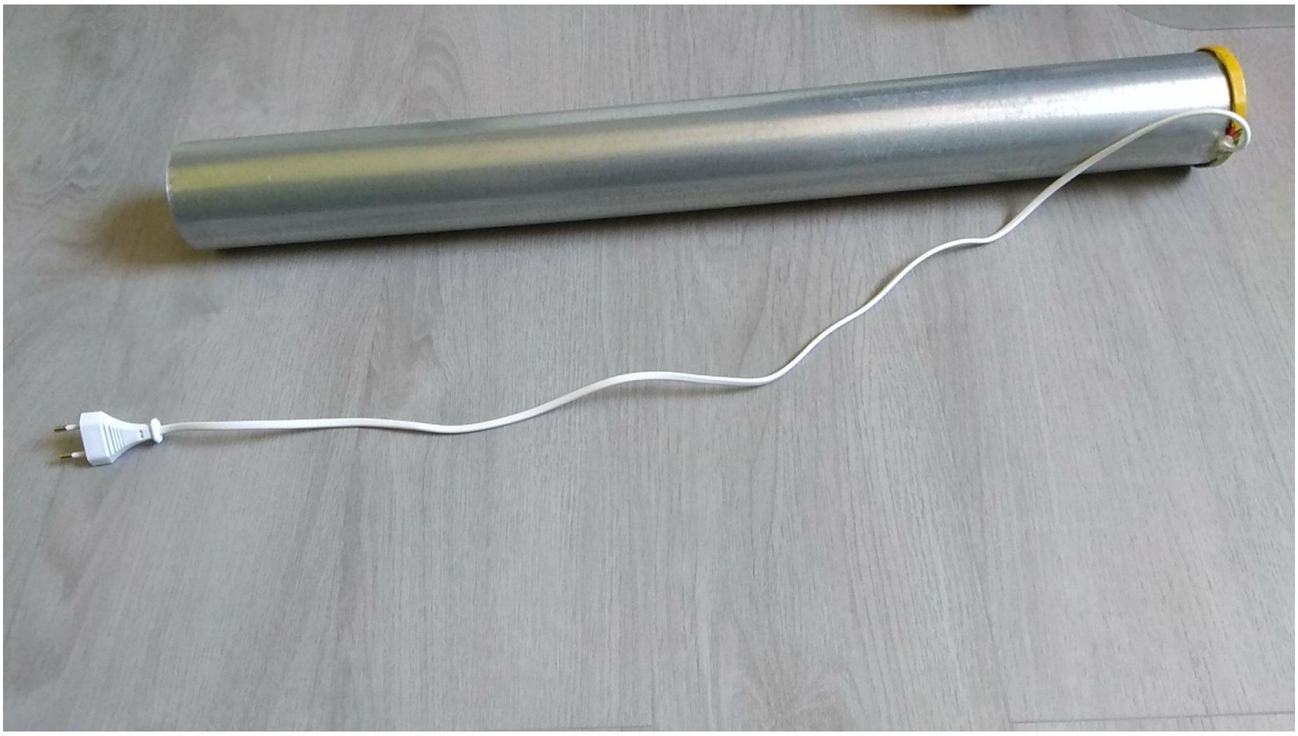
- Lenka Vinklerová
  - Our mentor and physics teacher
  - Interested in astrophysics
  - Helps in assigning tasks and provides other help
- Patrik Novotný
  - Chief Executive Officer
  - Astronomy and astrophysics enthusiast
  - The driving wheel of our team
  - Biologist
- Jakub Suchánek
  - Chief Technical Officer
  - Interested in informatics, physics and engineering
  - Head of all technical related tasks
- Lukáš Völfl
  - Constructor and drone master
  - A huge fan of drone racing
- Jan Janoušek
  - Head of PR and HR

    - Interested in physics, especially aeroplane related stuff
- Jakub Zeman
    - Constructor and safety officer
    - Interested in electronics and everything around it
- Martin Vítek
    - Programmer and web designer
    - Interests include IT, physics

- **Mission objectives**

We are simulating a sample retrieval mission to a potentially habitable exoplanet, where a sample of soil, video and numerous data assessing the probability of Earth-like life existing on the planet will be retrieved. As international law prohibits contamination of the planet until existence of life has been ruled out, a sample retrieval mission is necessary before people may be sent there.

The directed landing and return to orbit will be simulated using a quadcopter incorporated into the CanSat that will land on a chosen spot and return close to the starting area. There will be a backup parachute in case the quadcopter fails to stabilize or the batteries run out too soon. The soil sample will be retrieved with a small servo. To prevent forward contamination the CanSat will beforehand be sterilized with UV-C light. In addition, UV-C light produces an antibacterial gas - ozone.



UV-C light tube

The main goal is to detect life and conditions for it such as concentration of various gases and as such is the necessary objective for the launch to be considered successful. Other goals are to land the CanSat in a predefined location and to broadcast live data and video to the internet.

The main result we expect is a proof of at least microscopic life existing on the target planet and to determine that the planet is most likely habitable for Earth life. As the launch is happening on Earth we hope that the measured and calculated data will be within a calculated errors of the real values which are known for Earth. This way we will be sure that the CanSat is well-calibrated and suitable for an exoplanet mission.

We are going to measure concentrations of oxygen, ozone and carbon dioxide, using electromotive or variably resistive sensors. We will also measure humidity, temperature, pressure, magnetic induction, acceleration and GPS data. From the measured vector of magnetic induction we can get a simple model of the magnetic field. From the GPS data and pressure reading, density of the atmosphere can be determined. We also measure three different wavelengths of light so that we may be able to perform basic spectroscopy of the atmosphere. All the data will be transmitted during the flight. The data will be inserted into prepared spreadsheets and simulations to calculate all the additional data and respective errors. All data will be available on our website as soon as we receive it.

We plan to retrieve a sample of the soil, which we are going to analyze in our airtight chamber. In there we will be able to measure the pH of the soil and have various microorganisms from the sample grow in our agar, where they will be able to be identified using reagents and a microscope.

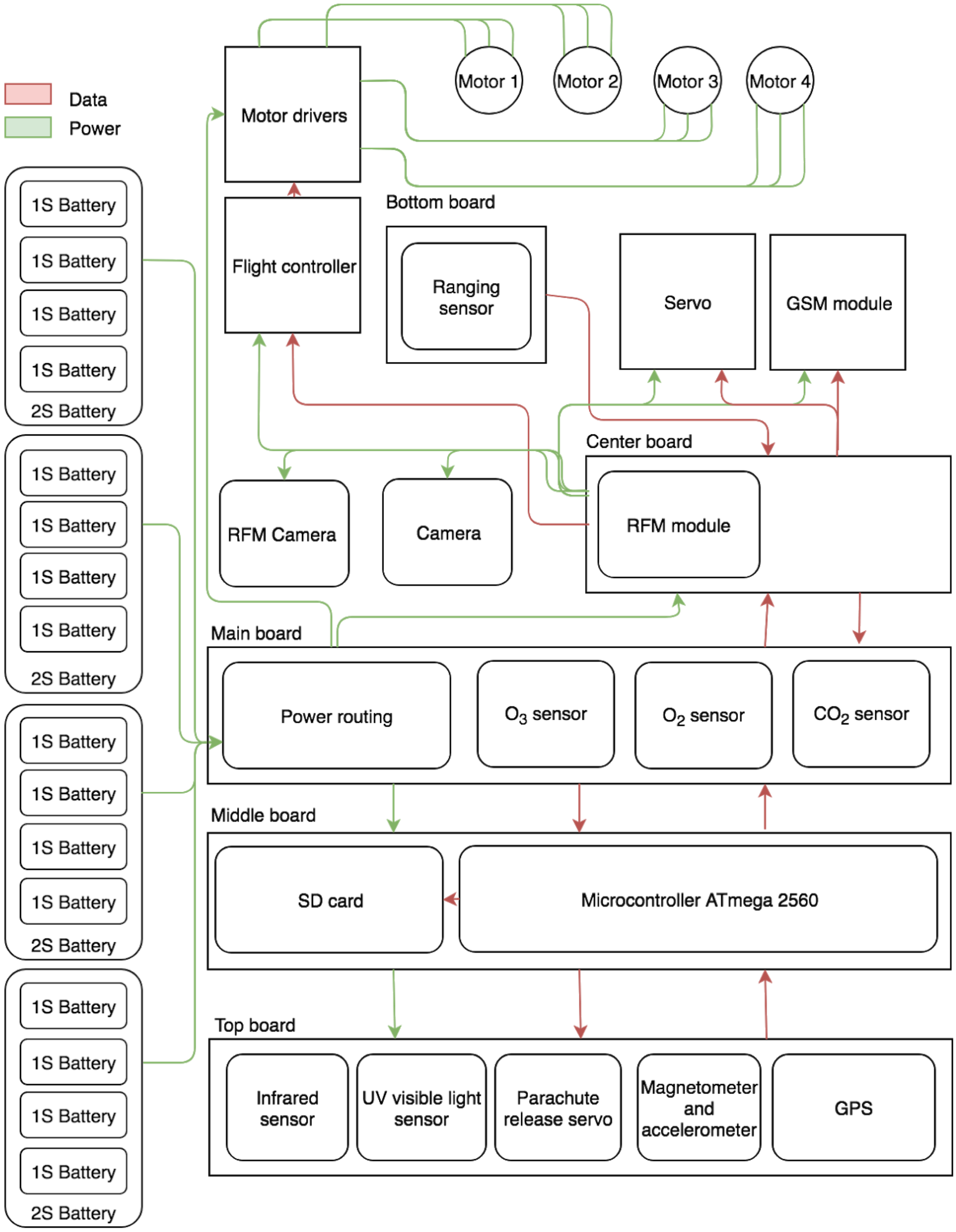
A tiny camera will be contained in the CanSat allowing signs of macroscopic life to be identified in the footage.

CANSAT DESCRIPTION

- **Mission overview**

The CanSat is to descend using it's four electric motors to a predefined location. In case of failure the CanSat ejects a parachute to land safely. During flight it will measure data specified in previous chapter and it will transmit those data to ground station where all communication will be saved and processed. After landing the CanSat takes a sample of soil and moves to a little closer to us (simulating the return to space). Our biologist then takes the sample and places it into a special container where one of us will look for signs of life. Measured data will be processed and analysed into a clearer format.

Block diagram:



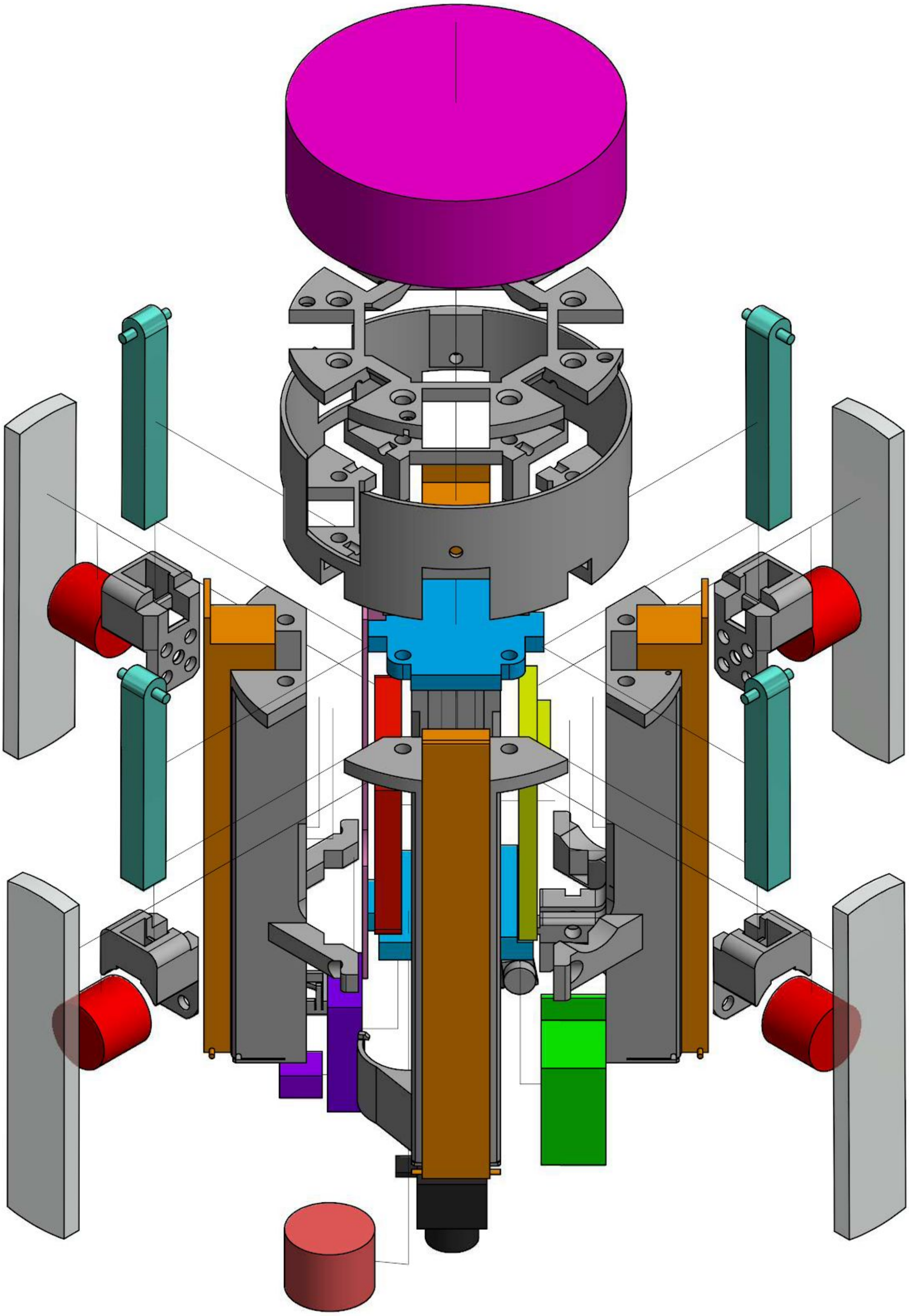
- **Mechanical/structural design**

The main structural body consists of 6 hull parts, which are 3D printed and are screwed to each other. The hull is round at the top and consists of four pillars in the remaining space. To the top part four arms made out of carbon rod and fixed in such way that they can easily move themselves into horizontal position. At the ends of the arms there are printed motor holders for secure and tight fit. In the pillars there are 16 batteries providing the whole CanSat with enough power for the flight and measurements.

The space inside is filled with various electronic parts. On the top, there is a three-part main circuit board, which is the “brain” of whole CanSat and on which most of sensors are placed. In the lower inside area there are a flight controller, a GSM module, a power regulator, a servo and two cameras - one saves the recording to an SD card and the other one broadcasts the whole flight to the ground - all connected to a vertical PCB interconnecting everything and attaching it to the main PCB.

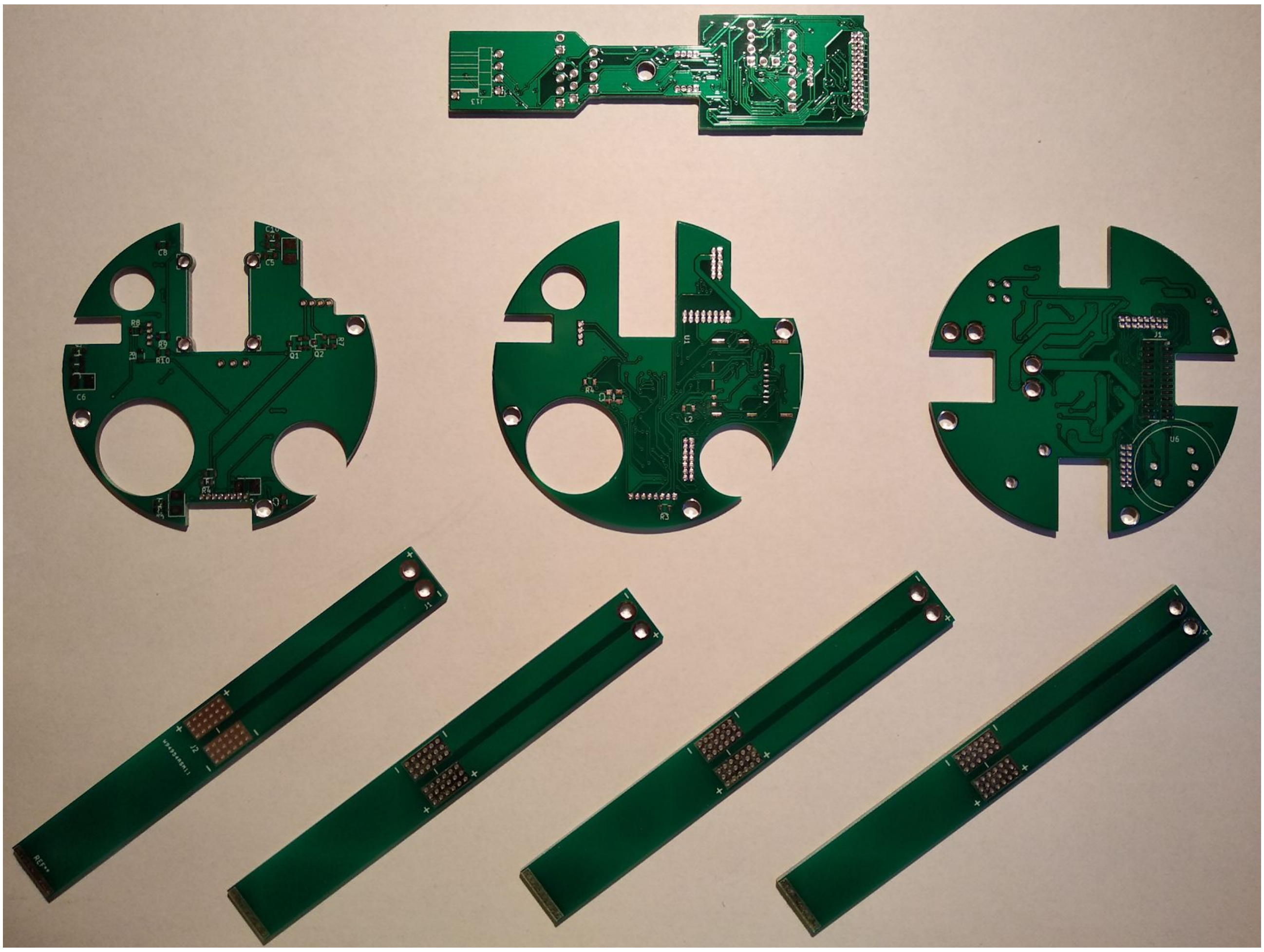
For 3D modeling we used Autodesk Inventor and all schematics are available at github.com/suchanekj/CanSatGOSA/tree/master/CanSat2.0/Schematics/Model

Exploded view of the model:



- **Electrical design**

The CanSat contains nine custom PCBs. In the top part three parallel round PCBs are located. The top one contains sensors - GPS ublox neo-m8n, humidity sensor SI7021, light sensors TSL25911 (visible and infrared) and VEML6070 (ultraviolet), pressure and temperature sensor MPL3115 and a magnetometer and accelerometer LSM303AGRTR. On the middle board there are a ATmega2560 microcontroller and a SD card. The lower board takes care of power routing and regulation and also contains gas sensors MG812 (CO_2), MEO2 (O_2) and SP3-61 (O_3).



Nine custom PCBs; from top left: center, top, middle, main and four battery pillars

Batteries are connected four in parallel on each pillar PCB which have connectors for charging and connection. To the bottom of the main PCBs is connected a vertical PCB to which all modules or devices are connected. In that space motor drivers, flight controller, gamma detection board, sample collection servo, and two cameras are located.

For transmitting RFM69HW is used alongside a GSM module that can send emails as backup transmission. All data is also saved to an SD card.

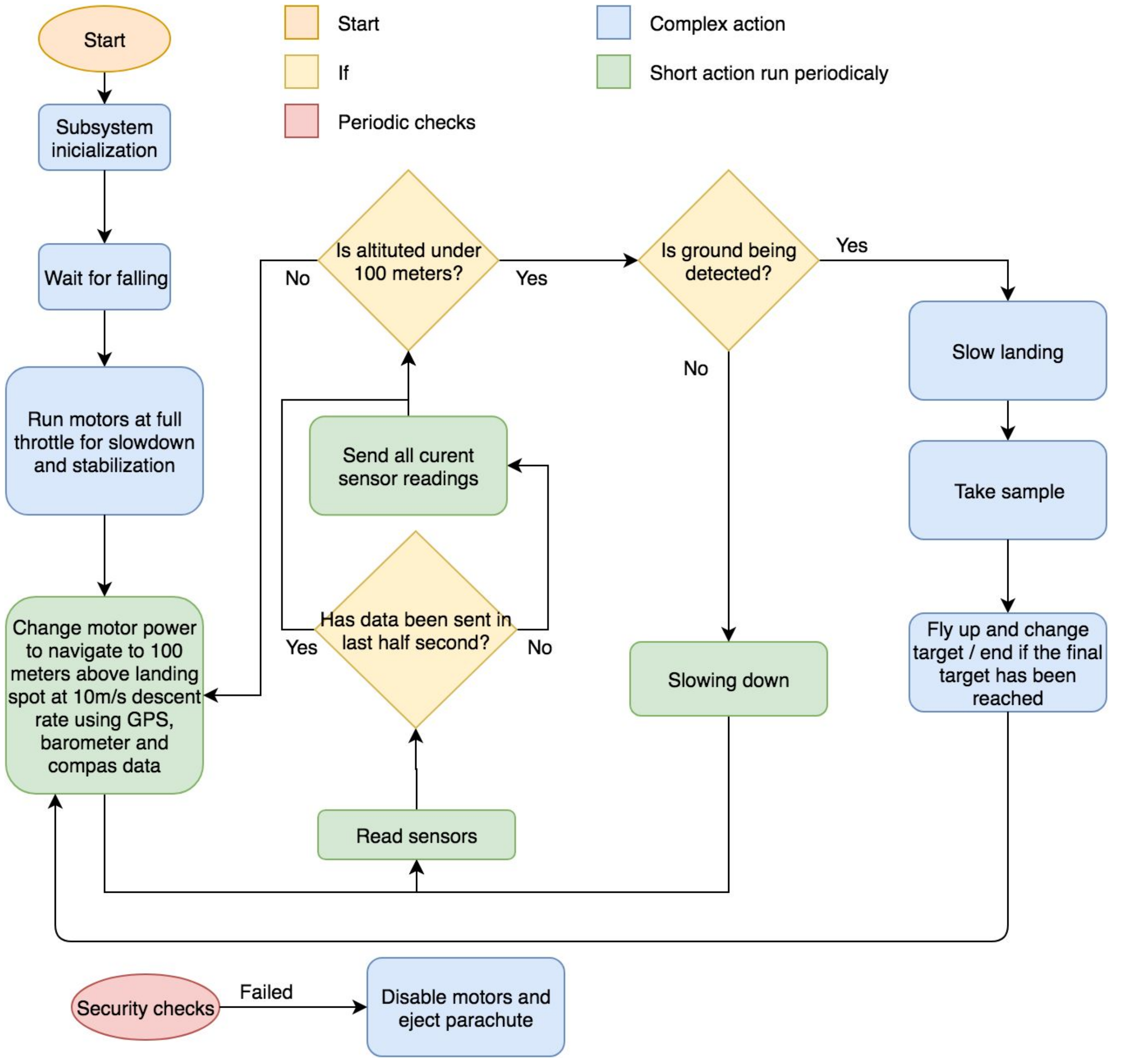
Sixteen 1S LiPo batteries are used in a 2S (7.4V) configuration. Each battery gives 200 mAh at 3.7V and allows 35C discharge. That amounts to 1600mAh at 7.4V and 280C discharge. All logic electronics is expected to draw up to 1A and the motors draw 15A on average. That gives us 5 minutes of flight and 16 more minutes of functioning. Flight downward is expected to last up to 200 second allowing extra half of the time as freedom. In case the batteries are detected to be low the parachute can be ejected.

The PCBs were designed using KiCAD. All schematics are available at github.com/suchanekj/CanSatGOSA/tree/master/CanSat2.0/Schematics/Circuit and a detailed list of parts is located at our website.

- **Software design**

The program initializes and then keeps running in loop where it measures data from sensors and GPS, based on GPS controls motors speed and CanSat's direction and transmits data to ground station.

All CanSat software is written in Arduino code based on C++. We used a huge amount of libraries for which we thank their creators. We used CLion IDE, Atom editor, Arduino IDE and PDE (Processing Development Environment). Every bit of our code or code we used has GNU GPL license and it is available at https://github.com/suchanekj/CanSatGOSA/tree/master/CanSat2.0/Code



- **Recovery system**

The descent will be controlled using 4 electric motors which combined have about 640 g of thrust at max. Arms holding the motors will put themselves from resting position into flight position. After stabilization motors will slow down the descent and start moving in the direction of predetermined landing position. Right above ground, about 5 meters, CanSat will slow down even more for soft touchdown.

In case of failure of stabilization or running out of power a parachute will deploy for safe descent and landing.

○ **Ground support equipment**

The ground station is split up between laptops. One is receiving through an analog antenna the video feed from onboard camera. The video is saved locally on the computer and if internet connection is provided streamed to our YouTube channel.

The second laptop is connected to Arduino Nano via USB connection and runs a processing sketch which listens to arduino's serial. The sketch processes the input data, saves all communication, logs errors and is capable of sending data to our web page where it is stored as a backup and graphed for live inspection. The arduino is running a simple script for receiving data from Yagi antenna which we made ourselves and printing it to the serial.

PROJECT PLANNING

○ Time schedule of the CanSat preparation

Key dates:

31. 10. 2017	CanSat workshop for team leaders/teachers
11. 1. 2018	Successful telecommunication test
31. 1. 2018	Czech CanSat semi-final
22. 2. 2018	First prototyping and testing workshop
29. 3. 2018	First flight test
29 - 20. 4. 2018	Czech CanSat final
26.6. - 1.7. 2018	European final

Short overview of the project month by month:

October:

At the beginning of October, we began to think what to choose as our secondary mission. In that time we thought that our secondary mission will be a directed landing. (The decision that life detection will be the secondary mission was made later.) We had three different options:

- A steerable parachute
- An aeroplane
- A drone or a helicopter

The team was separated into pairs and each pair had to vindicate their option and find problems in others designs. We came to conclusion that the best and most interesting solution will be the drone.

November:

We began to draw design options and we were looking for an optimal solution for construction difficulties such as deploying motors to theirs correct position. We received the first piece of sponsoring from KPGO. All team leaders had a workshop organised by ESERO.

December:

Jakub Suchánek started drawing a PCB and we had to agree on what sensors we want put into the CanSat. We had set up a meeting with Jan Horák a member of

RAJsat team which participated in the European CanSat competition in 2016 and 2017. He helped us with the decision showed us the RAJsat team CanSat. We asked him nearly every question we had and thanks to that we learnt a great amount new knowledge. We were consulting with him even in the following months.

January:

We started January with two tests of telecommunication. The first one was unsuccessful but the second one was a real success. The greatest distance we tested was about 6.7km and the connection was flawless. On 31th January, the czech semi-final was held. It consisted of two parts - test of telecommunication and presentation. In the presentation we introduced ourselves and our project and showed our vision as what it will come if we advance to the final.

February:

After successful semi-final, it was high time to order components so we could start construction as soon as possible. We were designing a piece of equipment which would take a sample of soil and place it in a petri dish with agar. As parts for the PCB arrived Jakub Suchánek started soldering. In the end of the month we had workshop with objective to test parachute for stabilization.

March:

Most of the construction work happened in March and Patrik Novotný build an UV light tube and tested it with agar. On 29th March there was another workshop. Part of our team drove to Liberec for professionally 3D printed hull and the rest tested for the first time the flight capabilities of our CanSat. This test was a success and you can watch it here: https://gosa.cz/surl/yt/ft1/

April:

On 1st April we were finishing construction and tested O_3 generator - the UV tube. We started writing a final report for the Czech final using LaTeX. We had another meeting with KPGO and they agreed to support us in case we advance to the european final. On 19th and 20th April the czech final was held near Pilsen. We had some difficulties but the data we measured and processed was enough to win and send us to the european final.

May:

We had a meeting with Epson, Bison&Rose and the headmaster of our school where we talked about future cooperation. The work was slowed down due to final exams on our school and some personal activities such as visiting CERN. However, even during learning for the exams everyone worked on his own.

June:

We started with a small workshop for construction part of the team. We worked and are still working on a redesigned version of our CanSat - CanSat 2.0. The redesign was important as we gained experience from the national final.

- ### Resource estimation

- ***Budget***

Since we have designed PCBs and 3D printed packages, we have saved a lot of money. Rather, we decided to use this money for precise sensors and flight systems to allow CanSat to fly like a drone.

We have not used any part of any CanSat kit so it is not mentioned in the following table.

Inner electronics	€325,56	
	Sensors	€93,75
	Flight systems	€54,14
	Printed circuit board	€7,23
	Camera and SD card	€54,55
	Other	€115,90
Batteries	€44,05	
Construction	€58,87	
Communication	€13,48	
Total expenses	**€441,97**	

- ***External support***

We have obtained financial and material support from our general partner - Epson, Klub přátel Gymnázia Opatov (KPGO - an association of parents of students at our school), JČMF (The Union of Czech Mathematicians and Physicists), Česká fyzikální společnost (Czech physics society), Rotorama (a company selling drones and drone components), Technical university in Liberec - the nanomaterials faculty, Planetárium Praha and PCBWay.

EPSON

Gymnázium Opatov Praha 1993

TECHNICKÁ UNIVERZITA V LIBERCI
Ústav pro nanomateriály, pokročilé technologie a inovace

PLANETÁRIUM PRAHA
Hvězdárna a planetárium hl.m. Prahy, p.o.

ROTORAMA

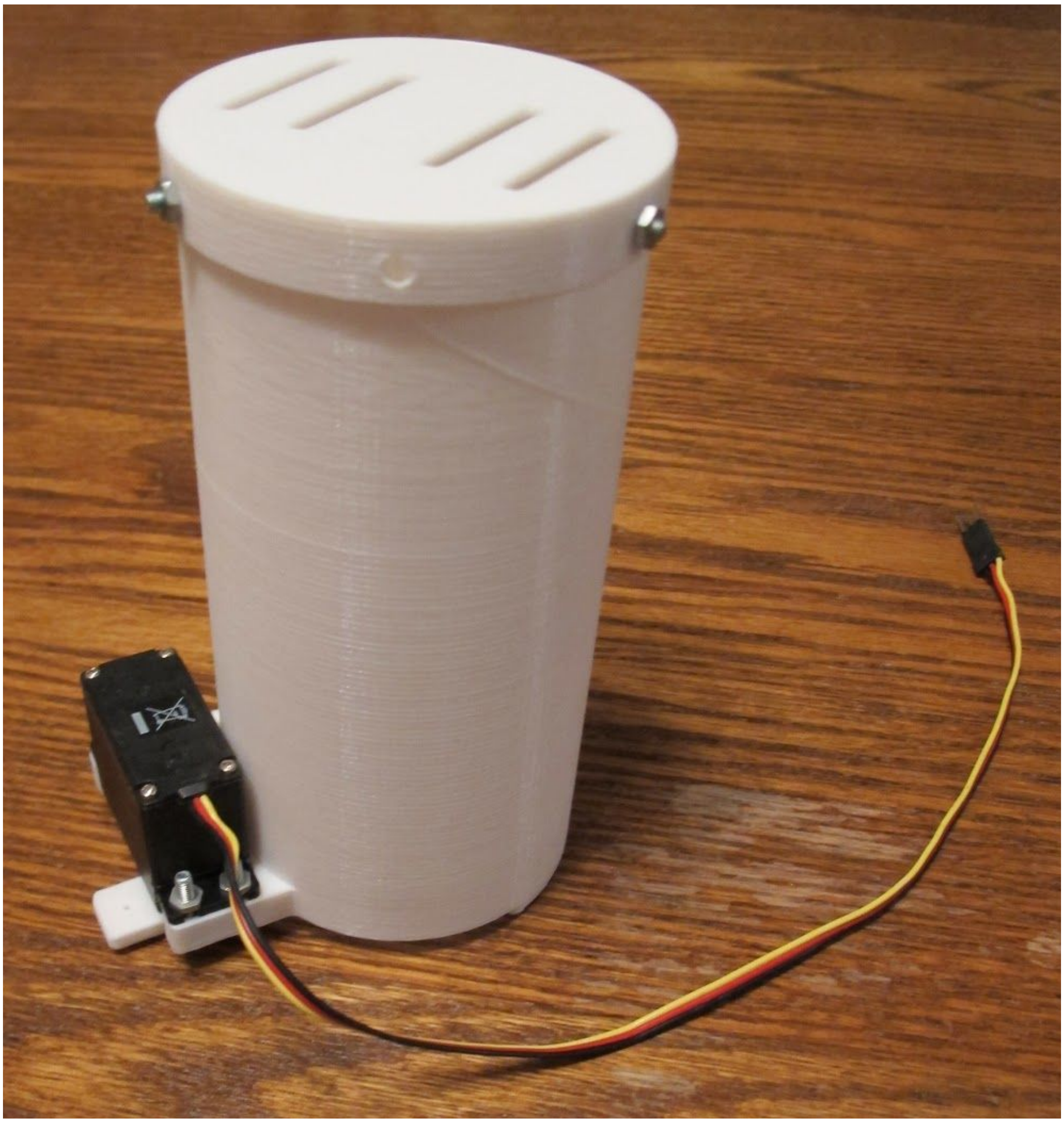
PCBWay

- **Test plan**

All electronic modules are tested on a breadboard first so in later development it is easier to find and eliminate bugs and failures such as bad soldering or wrong connection. Then the components are tested in larger groups which work together. All sensors and GPS are tested working together. The drive system is tested separately by flying it as a drone by radio transmitter. In the end, the whole CanSat is tested together as one piece. For short range transmission test we use our second smaller antenna.

The backup recovery system, parachute, was tested many times by dropping it from heights from 5 to 50 meters. For these tests we utilised our own drone with a releasing contraption and models of our CanSat made out of soda cans, rice, sugar, water and lead. For extra safety we bought 48 m2 sail for covering firewood and we caught the CanSat into it.

You can watch the first test flight on our YouTube channel:
https://www.youtube.com/watch?v=SB2rOg4BJvo



releasing mechanism

LESSONS LEARNT FROM THE NATIONAL LAUNCH CAMPAIGN (ONLY APPLIES TO TEAMS SELECTED VIA NATIONAL COMPETITION)

As it was the first time we participated in this competition we weren't as experienced prepared as our opponents who had participated in this competition for the second or third time. First thing we realised is that testing is crucial.

Due to loss of our drone few days before launch we could not test the ability of autonomous flight. After a discussion on whether to use the untested autonomous landing system or tested landing on parachute we decided to leave the stakes low and go with the safer option. Even without the directed landing we could measure a lot of data which we could present.

On the launch day the weather was sunny and temperatures were above 30°C. This caused our CanSat to overheat and one of the cables burned down. We had to replace the cable and build a makeshift heatsink. The repairs were done well and after some time we were able to launch. At the launch site we had some problems powering up the CanSat but with help of pliers we managed to turn it on.

During the flight one of our antennas winded up tangled into some parachute suspension lines. Hopefully, this didn't cause a lot of problems only the parachute didn't inflate properly so the descent speed was slightly faster than we expected - about 8m/s.

The data analysis went without major problems, yet it could have been speeded up by advance formulas and table preparation. We made an outline of our final presentation in advance, therefore the actual work was way easier. We simply filled all the data and photos in.

The main problem about our presentation was that we didn't have enough time to present our project and the data we measured and processed. We have to work on abbreviation and pointing out the most important pieces of information. Fortunately, there was a QnA segment during which we said additional information. We agreed that the plan to have as many sensor as we could fit into the CanSat was a life-saver because even with some difficulties we were able to process and present a lot.

OUTREACH PROGRAMME

For the CanSat competition we established Gymnázium Opatov Space Agency - GOSA. GOSA doesn’t work just on the CanSat but the main goal is to help enthusiastic students from our school realizing their projects and ideas. We organised a TED talk-like event in December where students give talks to students.

We have our own website: https://www.gosa.cz/Home/ and it’s english equivalent: https://www.gosa.cz/en/Home/ where you can learn more about us and our whole CanSat project. There are articles, photos, documents and link for our GitHub where all our code and technical materials are available.

We have our own facebook page: https://www.gosa.cz/surl/fb where we post photos behind the scenes and communicate with our fans in a less serious manner than on the website.

The outreach programme is focused primarily on people interested in electronics or science in general. That's why the majority of articles are on IT/electronics related webs. We have articles on various web pages and an interview in czech radio. All articles and interviews are available at: https://www.gosa.cz/en/Media/ but most of them are only in Czech. Most of our photos are on our web: https://gosa.cz/Photos/

We are working with a PR agency Bison&Rose which is affiliate of Burson-Marsteller. It pushes articles and press releases to media.

We presented our project to students of our school on a Lecture day which we organised and there was a presentation for parents on a school open day in April where everyone could come and ask what they had on their mind.

A photo from open school day

REQUIREMENTS

Characteristics	Figure (units)
Height of the CanSat	115mm
Mass of the CanSat	340g
Diameter of the CanSat	66mm
Length of the recovery system	690mm
Flight time scheduled	100-200s
Calculated descent rate	10ms^{-1}
Radio frequency used	433,55 MHz 438,60 MHz 866,60 MHz 5828,00 MHz
Power consumption	16A/1A
Total cost	€441,97

On behalf of the team I confirm that our CanSat complies with all the requirements established for the 2018 European CanSat competition in the official Guidelines.

For the whole Hatalom team
In Prague 10.6.2018

Jakub Zeman, safety officer

CANSAT REQUIREMENTS

[1] All the components of the CanSat must fit inside a standard soda can (115 mm height and 66 mm diameter), with the exception of the parachute. Radio antennas and GPS antennas can be mounted externally (on the top or bottom of the can, but not on the sides), depending on the design.

N.B. The rocket payload area usually has 4.5 cm of space per CanSat available, along the can's axial dimension (i.e. height), which must accommodate all external elements including: parachute, parachute attachment hardware, and any antennas.

[2] The antennas, transducers and other elements of the CanSat cannot extend beyond the can's diameter until it has left the launch vehicle.

[3] The mass of the CanSat must be between 300 and 350 grams. CanSats that are lighter must take additional ballast with them to reach the 300 grams minimum mass limit required.

[4] Explosives, detonators, pyrotechnics, and inflammable or dangerous materials are strictly forbidden. All materials used must be safe for the personnel, the equipment, and the environment. In case of doubt, Material Safety Data Sheets (MSDS) will be requested.

[5] The CanSat must be powered by a battery and/or solar panels. It must be possible for the systems to be switched on for four continuous hours.

[6] The battery must be easily accessible in case it has to be replaced/recharged.

[7] The CanSat must have an easily accessible master power switch.

[8] Inclusion of a retrieval system (beeper, radio beacon, GPS, etc.) is recommended.

[9] The CanSat should have a recovery system, such as a parachute, capable of being reused after launch. It is recommended to use bright coloured fabric, which will facilitate recovery of the CanSat after landing.

[10] The parachute connection must be able to withstand up to 1000 N of force. The strength of the parachute must be tested to ensure that the system will operate nominally.

[11] For recovery reasons, a maximum flight time of 120 seconds is recommended. If attempting a directed landing, then a maximum of 170 seconds flight time is recommended.

[12] A descent rate between 8 and 11 m/s is recommended for recovery reasons. In case of a directed landing, a lower descent rate of 6m/s is recommended. However, the airfield might determine additional mandatory restrictions on the velocity. In this case, the information will be provided to the teams well in advance so that they can adapt their secondary missions to these restrictions.

[13] The CanSat must be able to withstand an acceleration of up to 20 g.

[14] The total budget of the final CanSat model should not exceed 500€. Ground Stations (GS) and any related non-flying item will not be considered in the budget. More information regarding the penalties in case the teams exceed the stated budget can be found in the next section.

[15] In the case of sponsorship, all items obtained should be specified in the budget with the actual corresponding costs on the market.

[16] The CanSat must be flight-ready upon arrival at the launch campaign. A final technical inspection of the CanSats will be done by authorised personnel before launch.