CanSat 2024
Critical Design Review (CDR)
Version 1.0

Team 2050

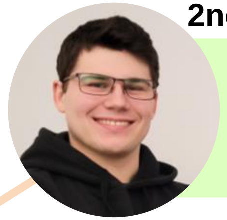
KoNaR Can

Presentation Outline

Number	Section name	Presenter(s)	Slides
1	Introduction	Krzysztof Kowaczek	1-8
2	Systems Overview	Krzysztof Kowaczek	9-27
3	Sensor Subsystem Design	Patryk Peroński	28-39
4	Descent Control Design	Paweł Iwańczyk	40-51
5	Mechanical Subsystem Design	Paweł Iwańczyk	52-72
6	Communication and Data Handling (CDH) Subsystem Design	Krzysztof Kowaczek	73-88
7	Electrical Power Subsystem (EPS) Design	Krzysztof Kowaczek	89-94
8	Flight Software (FSW) Design	Tomasz Lubelski	95-104
9	Ground Control System (GCS) Design	Tomasz Lubelski	105-116
10	CanSat Integration and Test	Krzysztof Kowaczek	117-135
11	Mission Operations & Analysis	Krzysztof Kowaczek	136-142
12	Requirements Compliance	Krzysztof Kowaczek	143-153
13	Management	Krzysztof Kowaczek	154-169

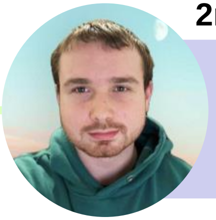
Team Organization

dr inż. Robert Muszyński
- Faculty Advisor



2nd Master

Krzysztof Kowaczek
- Team leader
- Electronics
- Software



2nd Bachelor

Mateusz Wojtaszek
- Electronics
- Software

2nd Bachelor

Mateusz Morawiak
- Finances & support
- Public Relations

3rd Bachelor

Natalia Nienartowicz
- Mechanics

2nd Master

Tomek Lubelski
- Electronics
- Software

3rd Bachelor

Paweł Iwańczyk
- Mechanics

3rd Bachelor

Patryk Peroński
- Electronics
- Software

3rd Bachelor

Kamil Winnicki
- Mechanics

3rd Bachelor

Mateusz Zolisz
- Ground Station

Acronyms (1/4)

Acronym	Definition
A	Analysis
ABS	Acrylonitrile Butadiene Styrene
AC	Alternating Current
AT	Attention
BLDC	Brushless Direct Current
CAD	Computer Aided Design
CDR	Critical Desing Review
CDH	Communication and Data Handling
CSV	Comma-Separated Values
D	Demonstration
DIP	Dual Inline Package

Acronyms (2/4)

Acronym	Definition
EPS	Electrical Power Subsystem
FR4	Fire Retardant class 4
FSW	Flight Software
GCS	Ground Control System
GPS	Global Positioning System
GPIO	General Purpose Input Output
GS	Ground System
LED	Light Emitting Diode
Li-ion	Lithium ion
MCU	Microcontroller Unit
MSM	Main State Machine
NMEA	National Marine Electronics Association

Acronyms (3/4)

Acronym	Definition
Ni-Cd	Nickel-Metal Cadium
Ni-Mh	Nickel-Metal Hydride
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PET-G	Polyethylene Terephthalate Glycol
PFR	Post Flight Review
PWM	Pulse Width Modulation
RTC	Real Time Clock
RTOS	Real-Time Operating System
SDIO	Secure Digital Input Output
SD	Secure Digital
SDHC	Secure Digital High Capacity

Acronyms (4/4)

Acronym	Definition
SO	System Overview
SOIC	Small Outline Integration Circuit
SSD	Sensor Subsystem Design
SPI	Serial Peripherial Interface
T	Test
I	Inspection
I2C	Inter-Integrated Circuit
IMU	Inertial Measurment Unit
XCTU	Configuration Platform for Xbee/RF Solutions
XPS	Extruded Polystyrene

System Overview

Krzysztof Kowaczek

Mission Summary

Main objectives
The mission will simulate a space probe (CanSat) entering a planetary atmosphere. It shall contain a detachable heatshield and a hen's egg, which will simulate a delicate instrument. The integrated electronics shall include sensors for tracking altitude, internal temperature, battery voltage, GPS position and tilt of the CanSat during descent. The main design assumptions and events during the mission are as follows: • The CanSat shall take the place and function of the nose cone during ascent. The CanSat shall measure the speed of the rocket during ascent and of itself during descent. • CanSat shall open an aero-braking heat shield after deployment from the rocket. The descent rate shall be between 10 to 30 meters/sec. The aero-braking CanSat must maintain a stable orientation with the heat shield facing the direction of descent. • At an altitude of 100 meters, the CanSat shall release the aero-braking heat shield and simultaneously deploy a parachute to reduce the descent rate to less than 5 meters/sec. • The CanSat shall land with the egg intact.
Bonus objective
The selectable bonus objective will be attempted. We will include a camera, that will record the moment of CanSat deployment and release of the parachute. The reasoning being that it is easy to integrate into the structure of the CanSat and we would like to analyze the parachute release process. Also, the motto „Dare mighty things" is very closely related to us.

Summary of Changes Since PDR (1/4)

Sensor subsystem design:

Change	Reasons
MPU-6050 IMU was replaced with BMI270.	• The new sensor is cheaper and more available • They have similar performance

Descent Control Design

Change	Reasons
Changed material from carbon fibre to ABS plastic.	• Carbon fibre would block all communications.

Summary of Changes Since PDR (2/4)

Mechanical Subsystem Design

Change	Reasons
The battery has been moved to the bottom of the Payload.	• Shifting the center of gravity and freeing up space in the upper part of the device.
The BLDC motor was replaced with a DC one and a gear set was added.	• Easier control system and greater parts availability.
Added additional space for electronics.	• Insufficient space for electronics with previous design.

Communication and Data Handling

Change	Reasons
Additional FRAM in CDH	• to store flight data even in the event of a power failure.
Additional commands to CDH, for tests and assembly of CanSat	• Command to control Parachute (CHUTE) • Command to control Deployment Mechanism (HTSHLD)

Flight Software Design

Change	Reasons
Added FRAM non-volatile memory for storing the most critical parameters of CanSat.	• This type of memory is more reliable than SD Cards.
The BLDC motor was replaced with a DC motor with encoder.	• Part availability, easier control algorithm.

Electrical Power Subsystem Design

Change	Reasons
Chaged block diagram to accomodate for changes applied in CDH in PDR and calculated new power budget.	• Additon of FRAM memory • Changes from BLDC motor to DC motor

Ground Control System (GCS) Design

Change	Reasons
XBee USB adapter changed to out custom board	• It allows us to make backups on SD card in case of computer malfunction.
Buttons for the new commands "CHUTE" and "HTSHLD"	• Command to control Parachute (CHUTE) • Command to control Deployment Mechanism (HTSHLD)

System Requirement Summary (1/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
C1	The CanSat shall function as a nose cone during the rocket ascent portion of the flight.	X			X
C2	The CanSat shall be deployed from the rocket when the rocket motor ejection charge fires.	X			X
C3	After deployment from the rocket, the CanSat shall deploy its heat shield/aerobraking mechanism.	X			X
C4	A silver or gold mylar streamer of 50 mm width and 1.5 meters length shall be connected to the CanSat and released at deployment. This will be used to locate and identify the CanSat.	X	X		
C5	At 100 meters, the CanSat shall deploy a parachute and release the heat shield.	X	X		X
C6	Upon landing, the CanSat shall stop transmitting data.	X			X
C7	Upon landing, the CanSat shall activate an audio beacon.	X	X		X
C8	The CanSat shall carry a provided large hens egg with a mass range of 51 to 65 grams.	X			X
C9	0 altitude reference shall be at the launch pad.	X			X

System Requirement Summary (2/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
C10	During descent with the heat shield deployed, the descent rate shall be between 10 to 30 m/s.	X			X
C11	At 100 meters, the CanSat shall have a descent rate of less than 5 m/s.	X			X
S1	The CanSat mass shall be 900 grams +/- 10 grams without the egg being installed.		X		X
S3	Nose cone radius shall be exactly 71 mm.		X		X
S4	Nose cone shoulder radius shall be exactly 68 mm.		X		X
S5	Nose cone shoulder length shall be a minimum of 50 mm.		X		X
S6	CanSat structure must survive 15 Gs vibration.			X	
S7	CanSat shall survive 30 G shock.			X	
S8	The CanSat shall perform the function of the nose cone during rocket ascent.	X			X

System Requirement Summary (3/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
S11	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high-performance adhesives.	X	X		
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.	X		X	
M5	The CanSat shall deploy a heat shield after deploying from the rocket.	X			X
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s	X			X
M7	At 100 meters, the CanSat shall release a parachute to reduce the descent rate to less than 5 m/s.	X			X
M8	The CanSat shall protect a hens egg from damage during all portions of the flight.	X	X		X
E2	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polimer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	X	X		
E3	Easily accessible power switch is required.		X		X
E4	Power indicator is required.		X		X

System Requirement Summary (4/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
E5	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	X		X	X
X1	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.		X		
X2	XBEE radios shall have their NETID/PANID set to their team number.		X		
X3	XBEE radios shall not use broadcast mode.		X		
X4	The CanSat shall transmit telemetry once per second.	X	X		X
X5	The CanSat telemetry shall include altitude, air pressure, temperature, battery voltage, CanSat tilt angles, air speed, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	X	X		X
SN1	CanSat shall measure its speed with a pitot tube during ascent and descent.	X			X
SN2	CanSat shall measure its altitude using air pressure.	X			X
SN3	CanSat shall measure its internal temperature.	X			X

System Requirement Summary (5/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
SN4	CanSat shall measure its angle stability with the aerobraking mechanism deployed.	X			X
SN5	CanSat shall measure its rotation rate during descent.	X			X
SN6	CanSat shall measure its battery voltage.	X			X
SN7	The CanSat shall include a video camera pointing horizontally.	X			X
SN8	The video camera shall record the flight of the CanSat from launch to landing.	X			X
SN9	The video camera shall record video in color and with a minimum resolution of 640x480.	X			X
G1	The ground station shall command the CanSat to calibrate the altitude to zero when the CanSat is on the launch pad prior to launch.	X		X	X
G2	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	X	X		X
G3	Telemetry shall include mission time with 1 second or better resolution.	X	X		X
G4	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	X		X	X

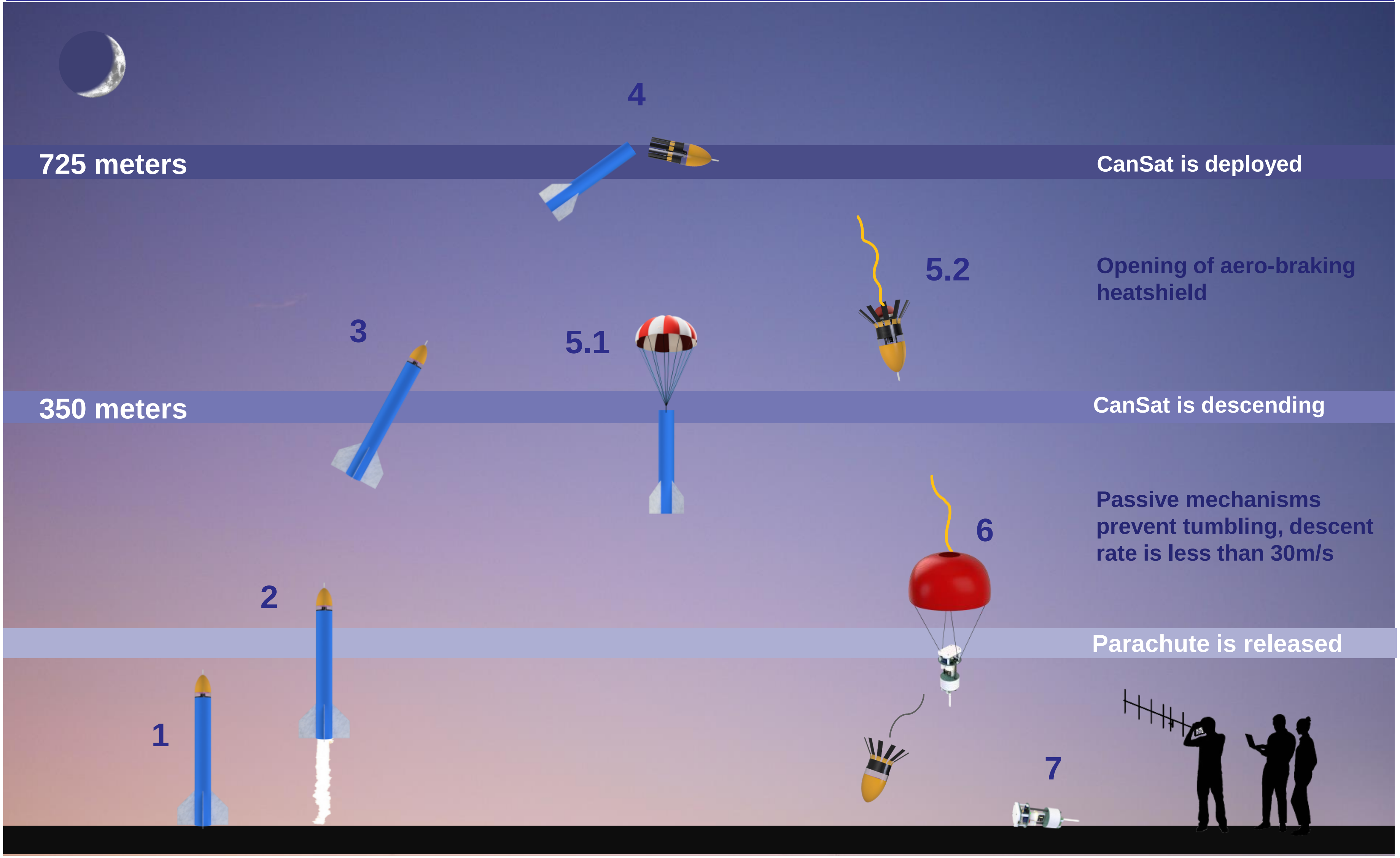
System Requirement Summary (6/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
G6	All telemetry shall be displayed in real time during descent on the ground station.	X	X		X
G7	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.) and the units shall be indicated on the displays.	X	X		X
G8	Teams shall plot each telemetry data field in real time during flight.	X	X		X
G9	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and an antenna.	X			
G10	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	X	X	X	
G11	The ground station software shall be able to command the payload to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	X			X
G12	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the CanSat.	X	X		
G13	The ground station shall use a tabletop or handheld antenna.	X	X		
G15	The ground system shall count the number of received packets. Note that this number is not equivalent to the transmitted packet counter, but it is the count of packets successfully received at the ground station for the duration of the flight.	X	X		X

System Requirement Summary (7/7)

Rqmt Num	Requirement	Verification			
		A	I	T	D
F1	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	X		X	X
F2	The CanSat shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	X		X	X
F3	The CanSat shall have its time set to within one second UTC time prior to launch.	X			X
F4	The flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	X		X	X
F5	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the payload altitude.	X		X	X
F6	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	X		X	X

System Concept of Operations (CONOPS) (1/2)

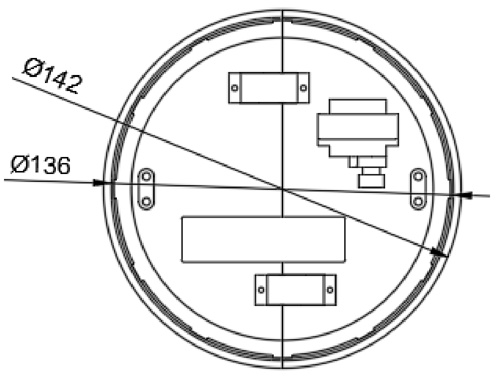


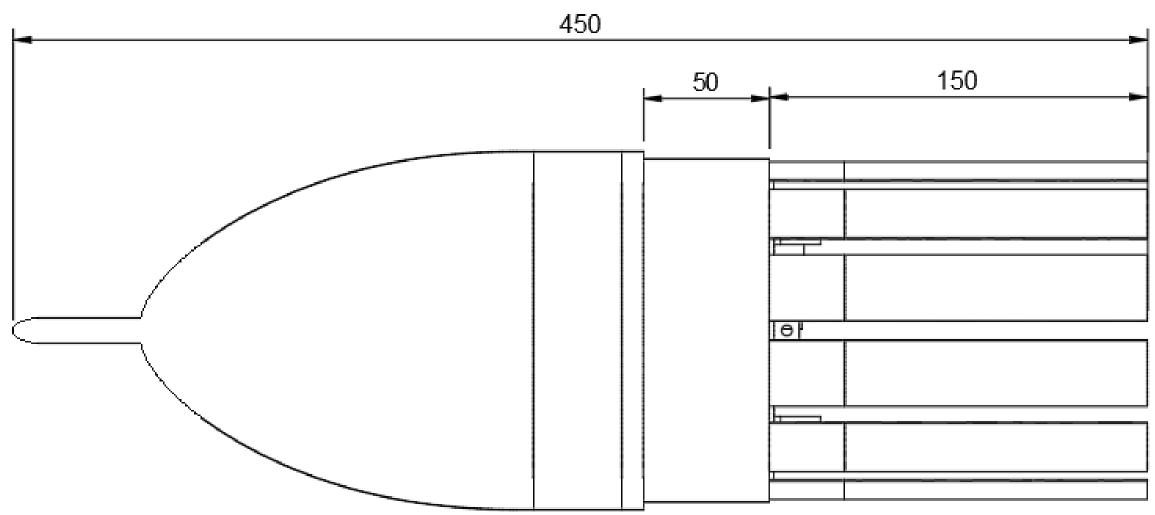
System Concept of Operations (CONOPS) (2/2)

Number of operation	Description
1	CanSat (after integrating with the rocket and placed on the launch pad) is awaiting telemetry start and time synchronization commands, after which telemetry will be sent to the Ground Station with a frequency of 1 Hz.
2	The rocket is launched.
3	Ascent. The CanSat will measure altitude and speed during ascent. Cameras will be turned on.
4	CanSat and rocket separation after the parachute ejection charge fires at an altitude of 670 to 725 meters. CanSat will deploy it's aerobraking heatshield and record on video the moment of deployment. An attached gold mylar streamer will help identify the CanSat from a distance.
5.1	The rocket is descending on its own parachute.
5.2	The CanSat is descending with a speed from 10 to 30 meters per second using the aerobrake. The shape of the CanSat ensures it will not tumble. The BLDC motor rotates the camera according to the rotation of the CanSat.
6	At 100 metres altitude the aerobraking heatshield will be released and a parachute will be deployed. It will slow down the CanSat to 5 m/s or less.
7	After no altitude changes are detected, the CanSat will turn into its landed state. All cameras will be turned off, telemetry will be stopped, and an audio beacon will be activated.

CanSat Physical Layout (1/4)

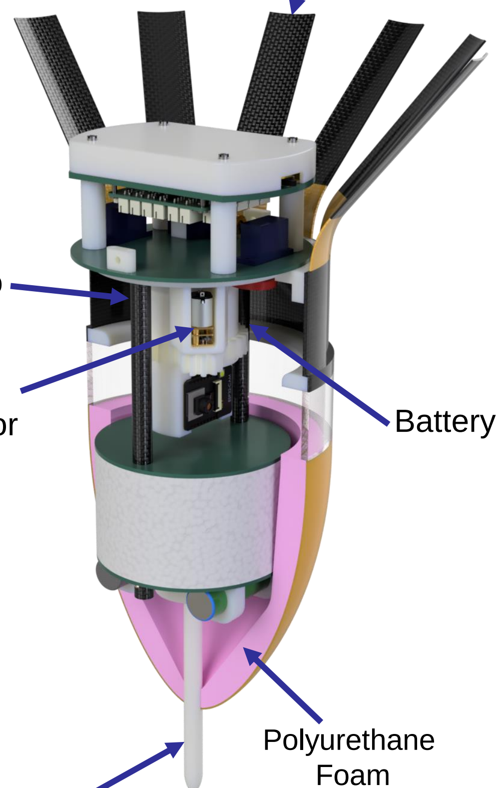
- The radius of the nose cone will be 71 mm (142 mm in diameter).
- The radius of the nose cone shoulder will be 68 mm (136 mm in diameter).
- The length of the nose cone shoulder will be 50 mm.

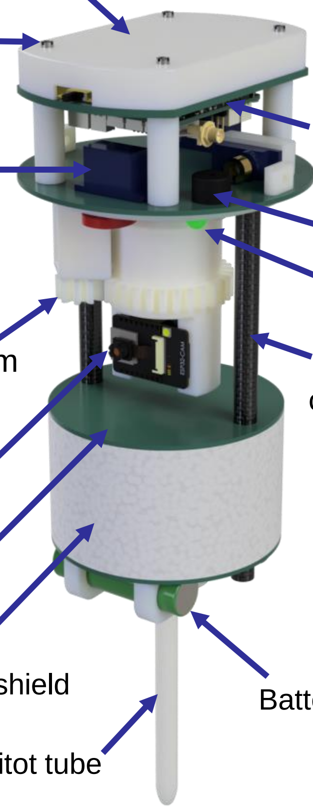


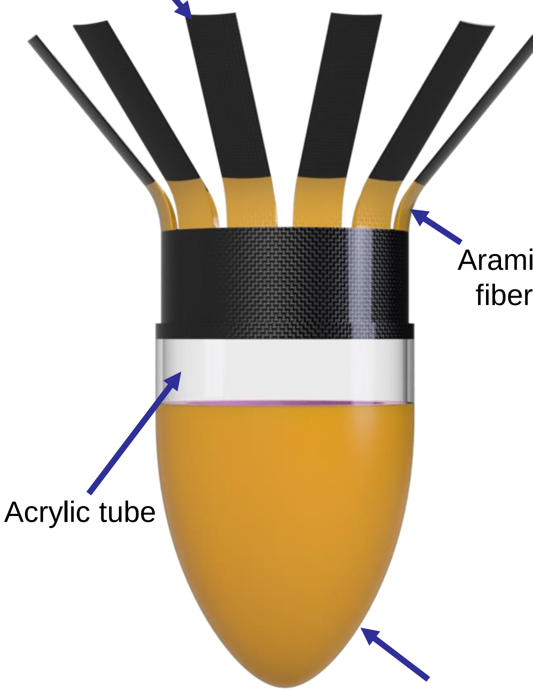


CanSat Physical Layout (2/4)

Whole CanSat	Payload	Aerobraking heat shield

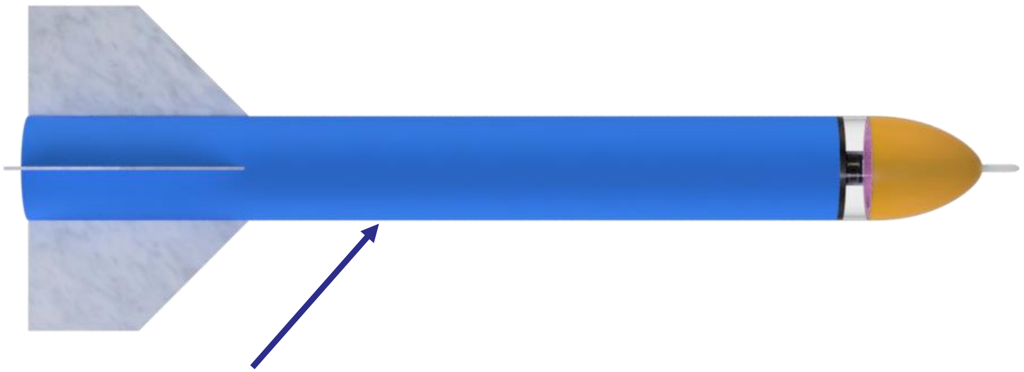


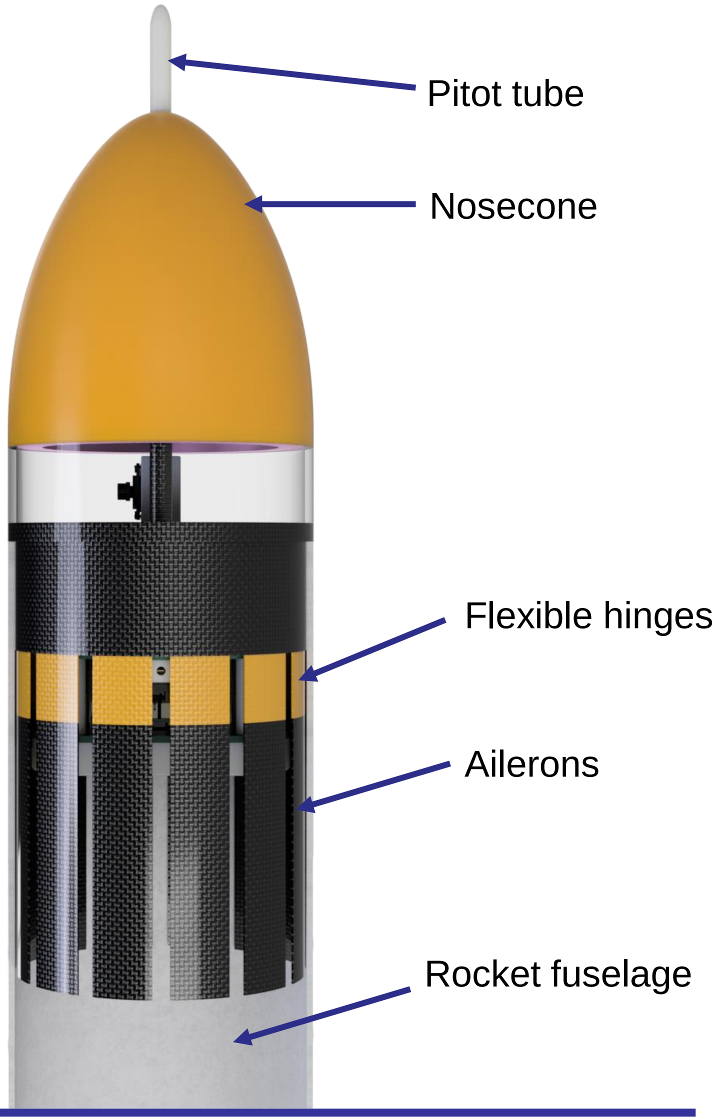




CanSat Physical Layout (3/4)

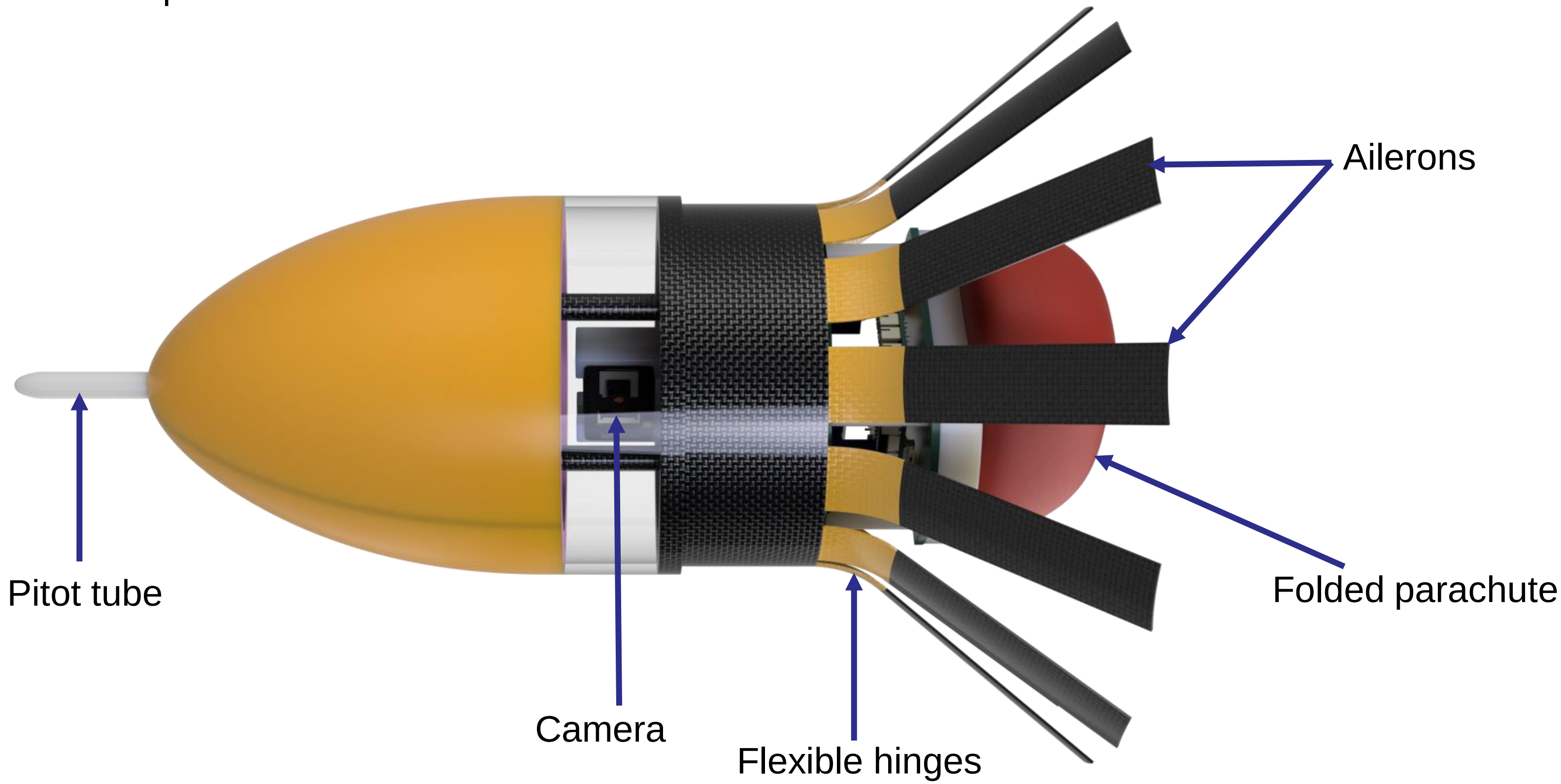
CanSat in launch configuration. Here we can see how the CanSat is placed inside the rocket (in the render on the left, the rocket fuselage is in cross-section). We can see here that the ailerons are in the stowed position, positioned straight parallel to the longitudinal axis of the fuselage. Due to their low-friction coating, sliding in and out will not be difficult. Pitot tube is pointed in direction of airstream.





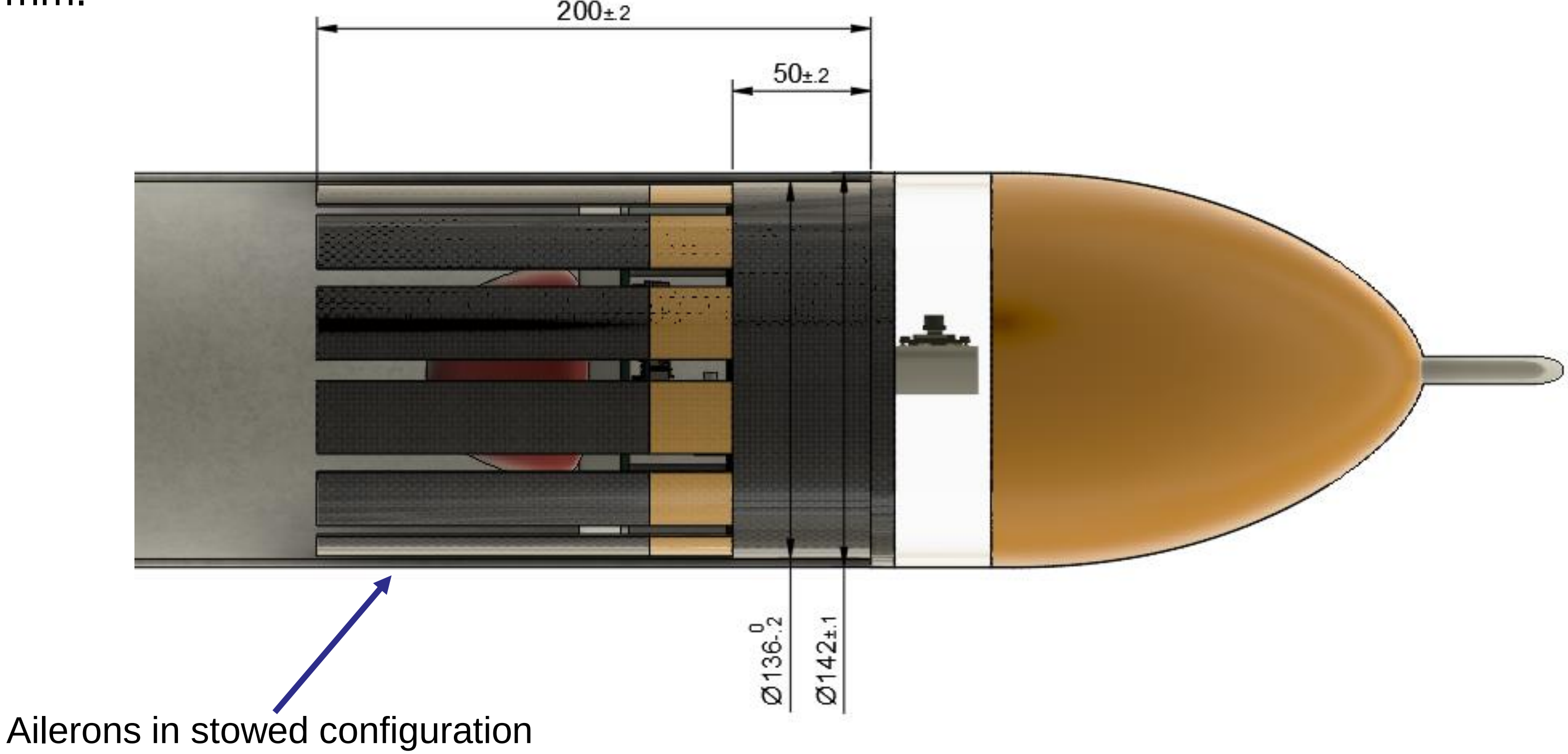
CanSat Physical Layout (4/4)

In the deployed configuration you can see changes in the appearance of the device. The ailerons were bent on flexible hinges, becoming, together with the nosecone, part of the heatshield/aerobraking system. The pitot tube is still directed along the direction of movement of the device, and the camera has been locked to a given azimuth in space.



Launch Vehicle Compatibility

On the left side, CanSat in launch configuration and its dimensions related to the CanSat-Rocket interface are presented. To ensure that the device slides out freely, appropriate dimensional margins are provided, also shown in the figure on the left. The part inside the rocket has no sharp elements in the CanSat, and the tips of the ailerons are properly rounded. The length of CanSat inside the rocket is shorter than 350 mm and is equal to 200 mm.



Sensor Subsystem Design

Patryk Peroński

Sensor Subsystem Overview

Type	Model	Functions	Interface
Rotation sensor	BMI270	Tracking the payload rotation using gyroscope	I2C
Tilt sensor	BMI270	Determining tilt of the CanSat using complementary filter	I2C
Voltage sensor	Divider with MCU ADC	Monitoring the battery condition	ANALOG
GPS	GY-NEO6MV2	Tracking the payload position	UART
Air Pressure and ttemperature sensor	STEMMA QT LPS22	Air temperature and pressure (altitude) measurement	I2C
Pitot pipe Sensor	STEMMA QT LPS22	Velocity measurement during flight.	I2C
Camera (main)	ESP-32-CAM	Capturing the video during descent	GPIO, I2C
Camera (bonus)	ESP-32-CAM	Capturing the probe release	GPIO, I2C

Sensor Changes Since PDR

Part	Change	Reasons
Payload tilt sensor, Payload rotation sensor	MPU-6050 IMU was replaced with BMI270.	• The new sensor is cheaper and more available • They have similar performance

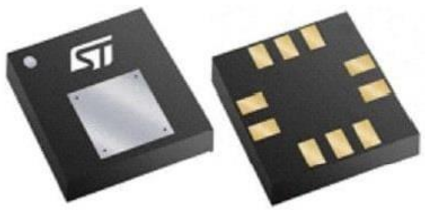
Payload Air Pressure Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [hPa]	Resolution [Pa]	Accuracy [hPa]	Interface	Price [$]
LPS22	2 x 2 x 0.76	0.006	3.3 - 5	0.004	260 - 1260	0.24	0.1	I2C or SPI	4.54

Description:
After enabling the pressure measurement, sensor is periodically storing measured value in its register. Required data is read from three registers and then combined into one value which is then divided by 4096 to get value in hPa.

We use specified formula:

Pressure = (data[0] << 16 | data[1]<<8 | data[2])/ 4096

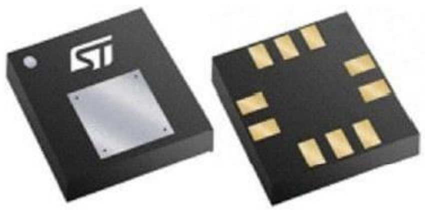


Payload Air Temperature Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [°C]	Resolution [°C]	Accuracy [°C]	Interface	Price [$]
LPS22	2 x 2 x 0.76	0.006	3.3 - 5	0.004	-40 - +85	0.01	0.1	I2C or SPI	4.54

Description:
After enabling the sensor, current temperature value is stored in two data register which are periodically read. Then we can retrieve temperature in Celsius degrees using this formula:

Temperature = (data[0]<<8 | data[1])/100;



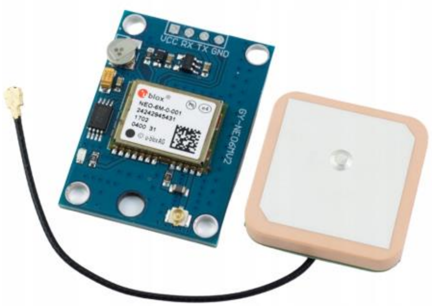
Payload GPS Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Sensitivity [dBm]	Resolution [m]	Update rate [Hz]	Interface	Price [$]
GY-NEO6MV2	36 x 24	15.5	3.3 - 5	-161	< 2	5	UART	9.0

Description:
The GPS uses NMEA commands to communicate (through UART). To read position data the MCU will wait for the $GPGGA command. Each command will be validated and interpreted. Each received frame has specified format:

$GPGGA,002153.000,3342.66188,N,11751.3858,W,1,10,1,2,27.0,M,-34.2,M,,0000*5E

The most crucial information are latitude and longitude which are before letters N and W, those represent geographical directions and can be N,S or W,E.



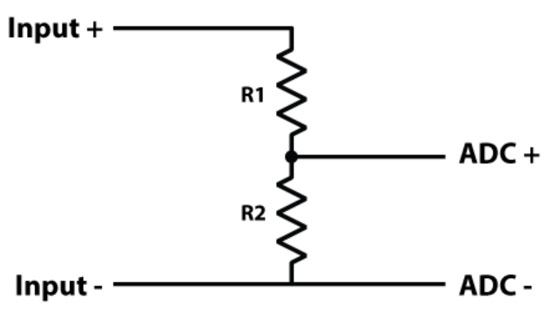
Payload Voltage Sensor Summary

Name	Size [mm]	Mass [g]	Operating current [mA]	Range [V]	Resolution [V]	Interface	Price [$]
STM32 ADC With Voltage Divider	-	-	0.2	0 - 3.3	0.001	Analog	0.02

Description:
In order to measure battery voltage, we need to use specified formula that takes into an account voltage divider.

$$V = \frac{R_1 + R_2}{R_1 \cdot \left(\frac{RAW \cdot 3.3V}{4096}\right)}$$

Where RAW is ADC reading from 0 – 4095.



Speed Sensor Summary

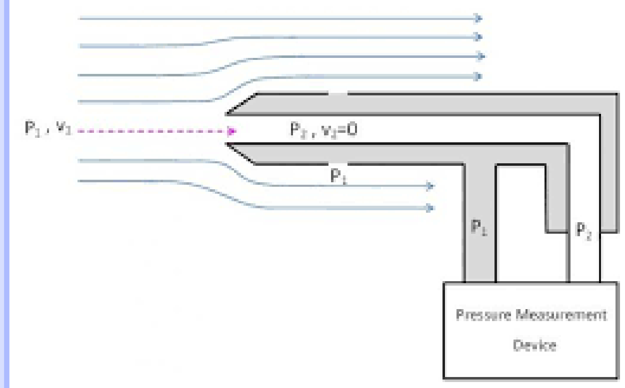
Name	Size [mm]	Mass [g]	Operating current [mA]	Range	Resolution	Interface	Price [$]
Pitot pipe with two LPS22	-	-	0.01	260 – 1260 hPa	0.24 Pa	I2C	4.54

Description:
To measure speed, we use Pitot pipe based on two LPS22 pressure sensors. By measuring pressure difference between pressure acquired on each sensor, in other words difference between static and dynamic pressure, we can calculate speed with formula:

$$v = \sqrt{\frac{2 \cdot P_o - P}{p}}$$

Where:
P_o – static pressure
P – dynamic pressure
p – air density

Two sensors will be used (beside the actual pressure sensor)



Payload Tilt Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [g]	Resolution [g]	Interface	Price [$]
BMI270	2.5 x 3 x 0.83	0.572	1.71 - 3.6	1	±16,±8 ±4,±2	0.00006	I2C or SPI	5.93

Description:
On Gyroscope startup the correction value will be applied to ensure that initial tilt during startup will be (0,0,0).
During the flight, data will be read in equal time intervals from internal registers.

The tilt from the Earth normal (Z) will be calculated using the Pythagorean theorem based on earth gravitational acceleration. In addition, data from gyroscope will also be provided so using sensor fusion with tilt based on accelerometer reading, we can get more accurate tilt estimation.

Payload Rotation Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [°/s]	Resolution [°/s]	Interface	Price [$]
BMI270	2.5 x 3 x 0.83	0.572	1.71 - 3.6	1	±2000,±1000 ±500,±250, ±125	0.004	I2C or SPI	5.93

Description:
Rotation will be calculated based on angular velocity read from IMU in constant timestamps. Then read data will be integrated and gives us angular position. When we notice any unwanted drift in reading, we will use additional filters.

Camera Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Field of View [°]	Resolution [pixels]	Frames per second [Hz]	Price [$]
ESP-32-CAM + OV2640	27 x 40.5 x 4.5	10	3.3	100	65	1600 x 1200 800 x 600 352 x 288	15 30 60	8.19

Description:
Camera module is able to capture picture with acceptable resolution with decent frames. It is compact and draw as little current as possible with reasonable price.

Camera module is going to communicate with main MCU with I2C interface. It allows for configuration changes on the fly and more advance recording control.

Captured frames are compressed with JPEG encoding and then merged into AVI movie files saved into SD card.

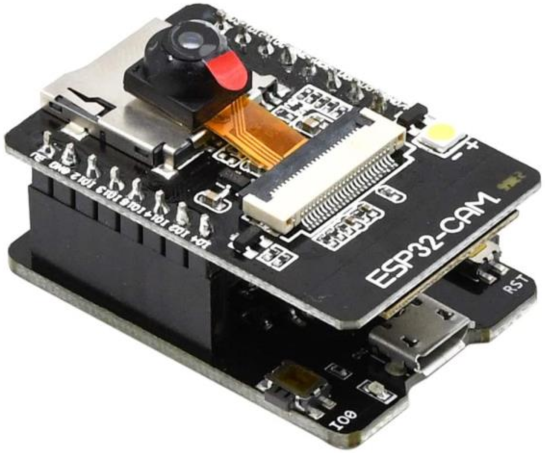
Bonus Camera Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Field of View [°]	Resolution [pixels]	Frames per second [Hz]	Price [$]
ESP-32-CAM + OV2640	27 x 40.5 x 4.5	10	3.3	100	65	1600 x 1200 800 x 600 352 x 288	15 30 60	8.19

Description:
Camera module is able to capture picture with acceptable resolution with decent frames. It is compact and draw as little current as possible with reasonable price.

Camera module is going to communicate with main MCU with I2C interface. It allows for configuration changes on the fly and more advance recording control.

Captured frames are compressed with JPEG encoding and then merged into AVI movie files saved into SD card.

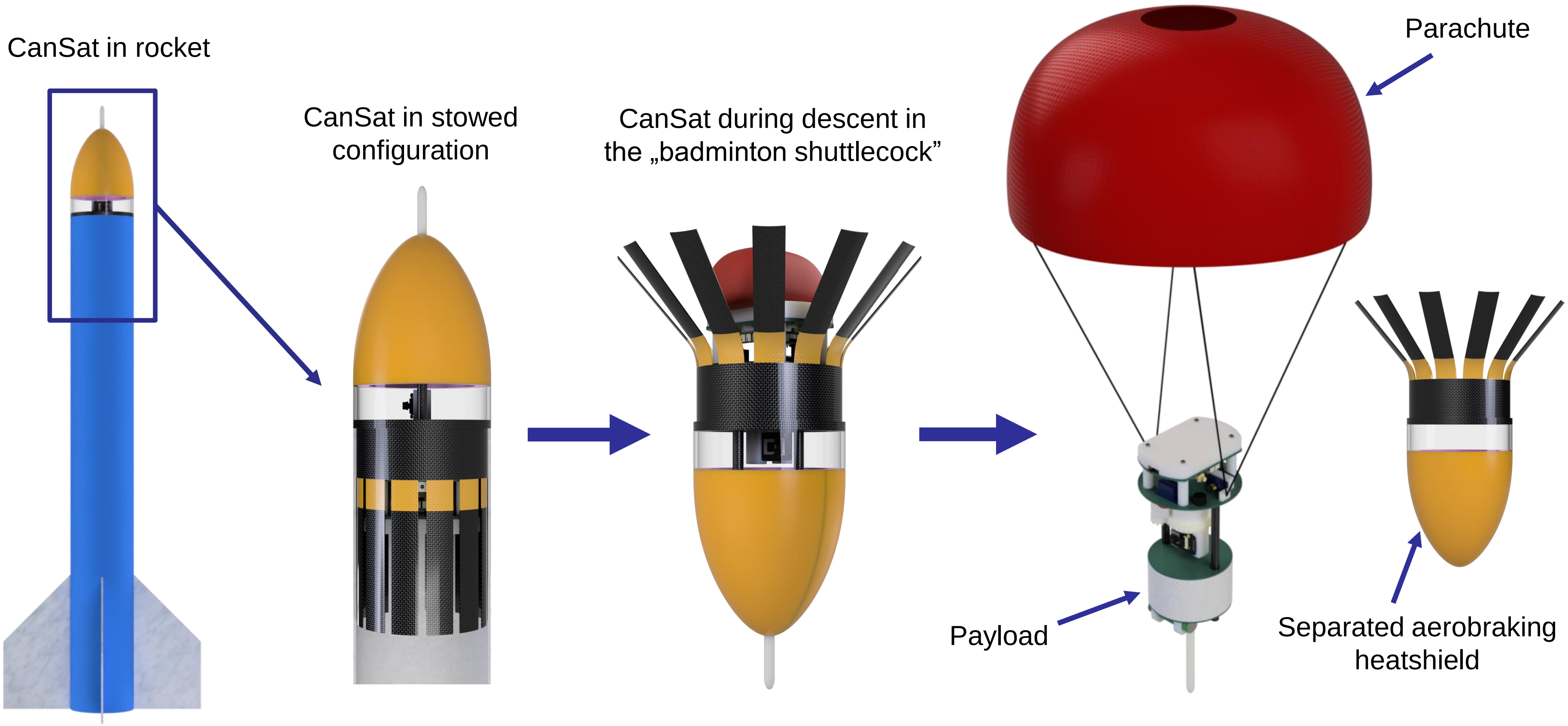


Descent Control Design

Paweł Iwańczyk

Descent Control Overview

In the renders below we can see CanSat in the rocket, then a cross-section showing how it is stowed. Then the device itself is shown descending with the heatshield, and then descending without it on a parachute.



Ascent

Descent from ~700 to 100 metres

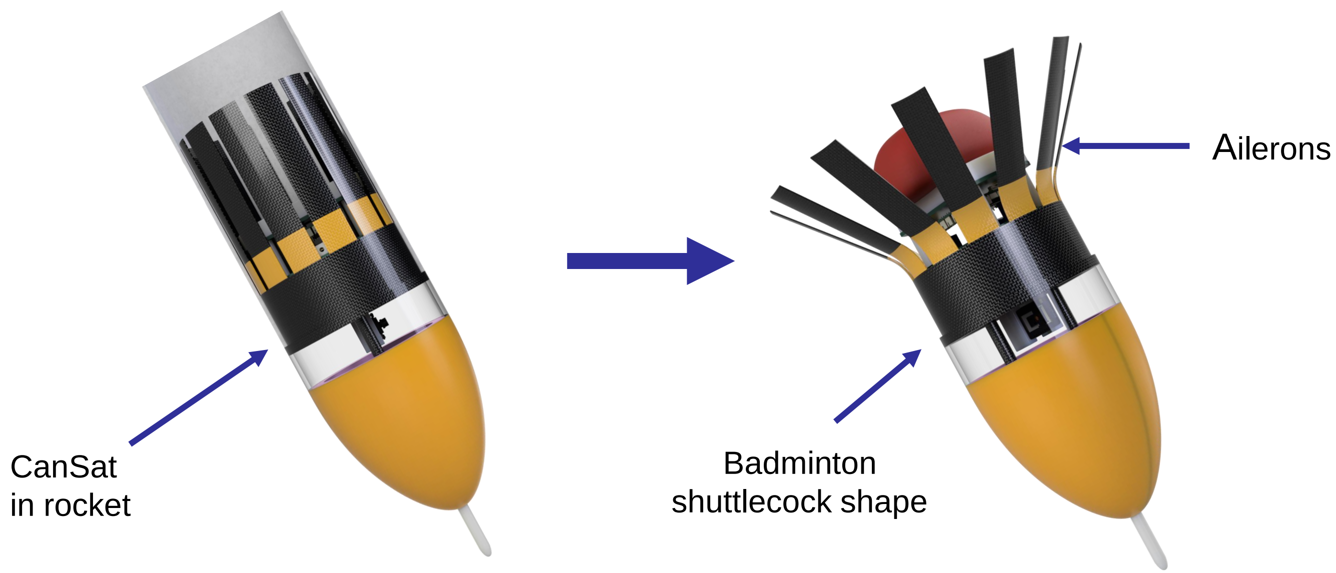
Descent from 100 to ground level

Descent Control Changes Since PDR

Part	Change	Reasons
Aerobraking Heat shield	Changed material from carbon fibre to ABS plastic.	Carbon fibre would block all communications.

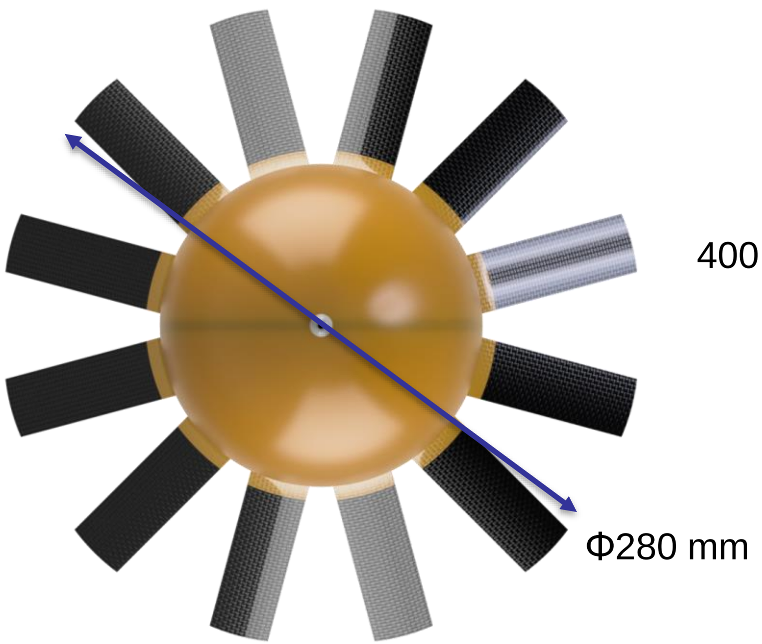
Payload Aerobraking Descent Control Hardware Summary (1/2)

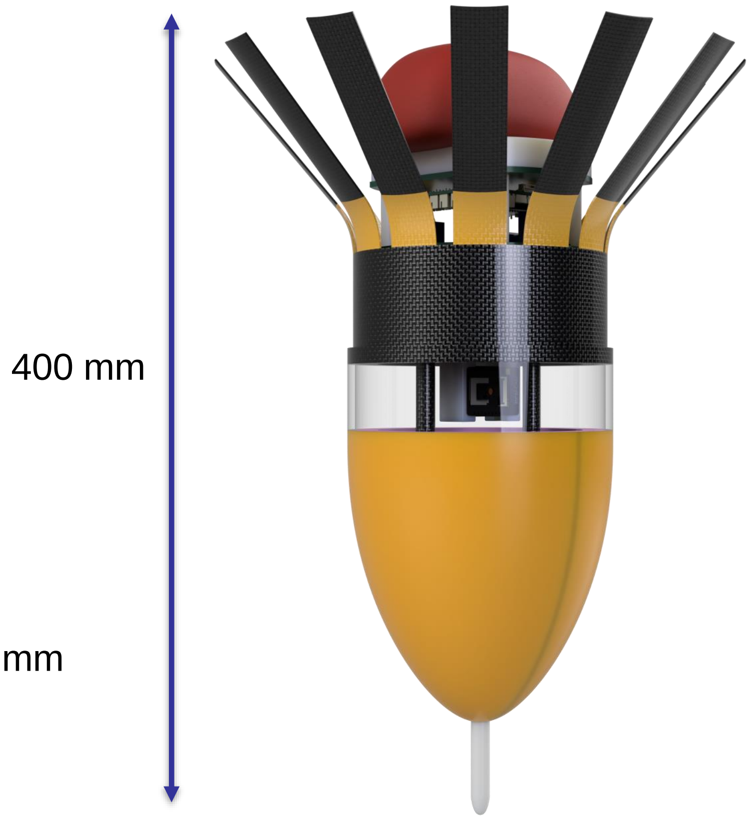
Our system provides a passive aerobraking system. After being removed from the rocket, the 12 ailerons automatically deflect, providing a shape similar to a badminton shuttlecock. This configuration ensures high stability on tumbling, but may cause slight rotation of the device, nevertheless the camera will be placed on gearbox mount, controlled by a motor, that will remove the rotation effect. Nosecone is also part of the heatshield. Its shape is streamlined and was created by using a tangent curve to the tubular part of the CanSat. By locating the center of pressure behind the center of gravity, we ensure proper stability of the device.



Payload Aerobraking Descent Control Hardware Summary (2/2)

We chose bright orange as the color of our cansat. We chose this because it is an easily visible color, which will make it easier to recover the device.





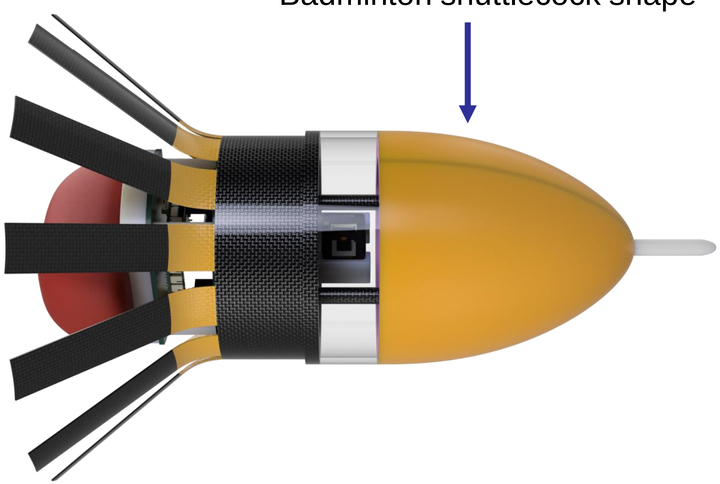
Payload Descent Stability Control Design (1/2)

During aerobraking, our CanSat will use a passive stabilization mechanism. Passive speed control is determined by the terminal velocity, which will cause the device to stabilize at the set speed. By using a shape resembling a badminton shuttlecock, the device will be stable in all axes except the rotation axis, however the camera will be stabilized in this axis. The transition from stowed to deployed state will occur automatically when the device slides out of the rocket fuselage. The nosecone will also be a part of the aerobraking. In order to be sure about the stability of our device, appropriate tests will be carried out using scale models.

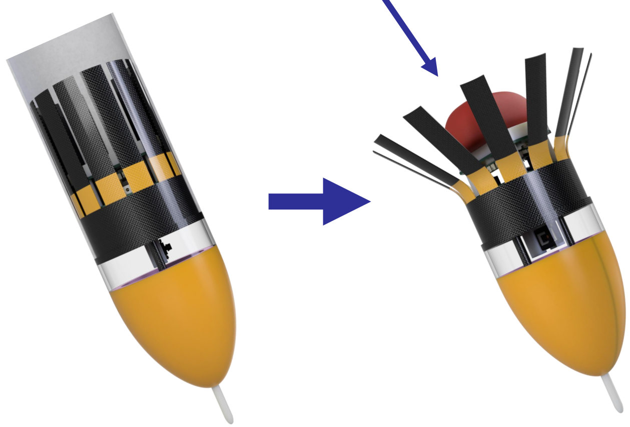
The mechanism will consist of ailerons, which will be hidden inside the rocket, and a nosecone, which will also be used for aerobraking. The ailerons will deflect themselves thanks to the use of elastic material in their construction (aramid fibres) and will remain in this position also thanks to the elastic force.

Ailerons

Badminton shuttlecock shape



Ailerons shaped into shuttlecock

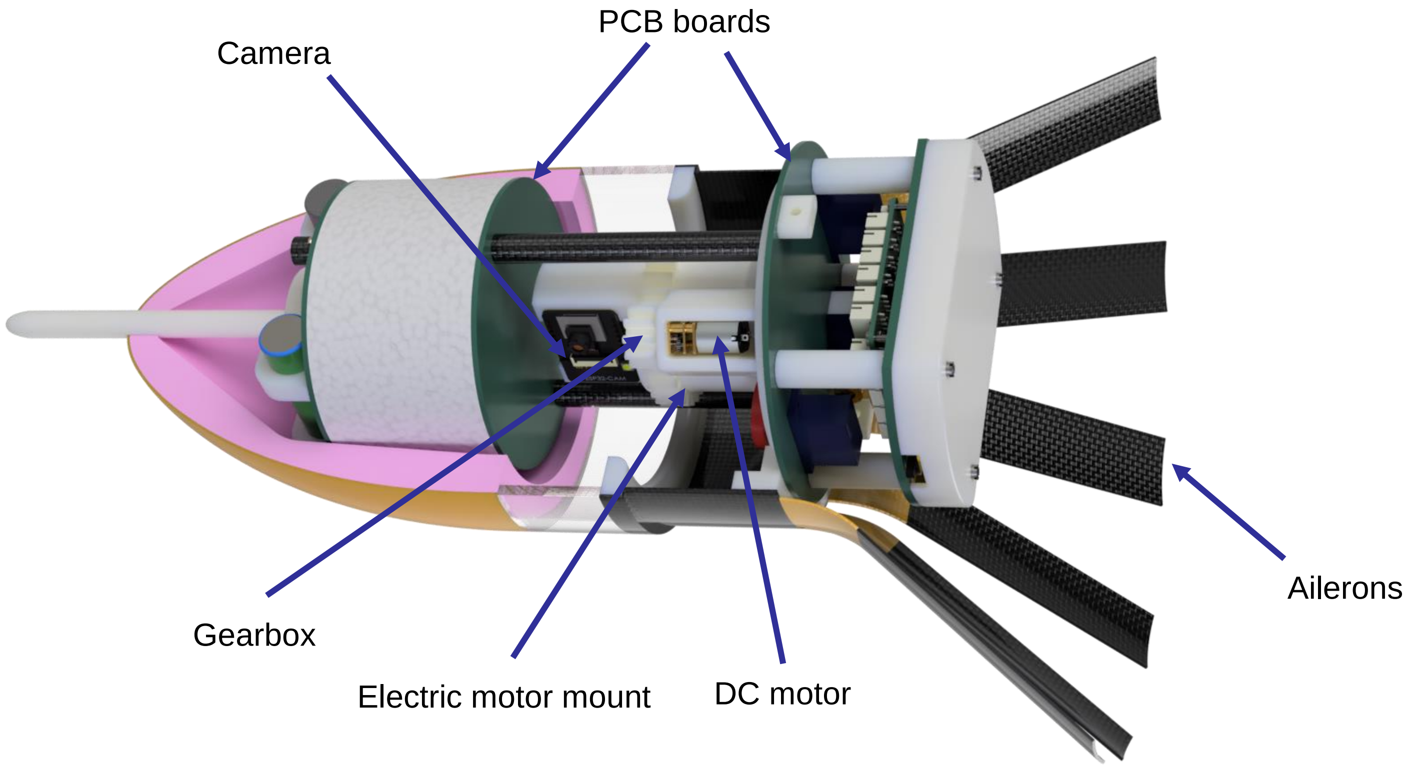


Payload Descent Stability Control Design (2/2)

By using a shape similar to a badminton shuttlecock, CanSat is **passively stabilized** - this means that stability will be achieved in all axes using aerodynamic forces. Additional stabilization in the rotation axis will only apply to the camera itself. The aerodynamic elements responsible for passive stabilization are the ailerons and the appropriately shaped nosecone.

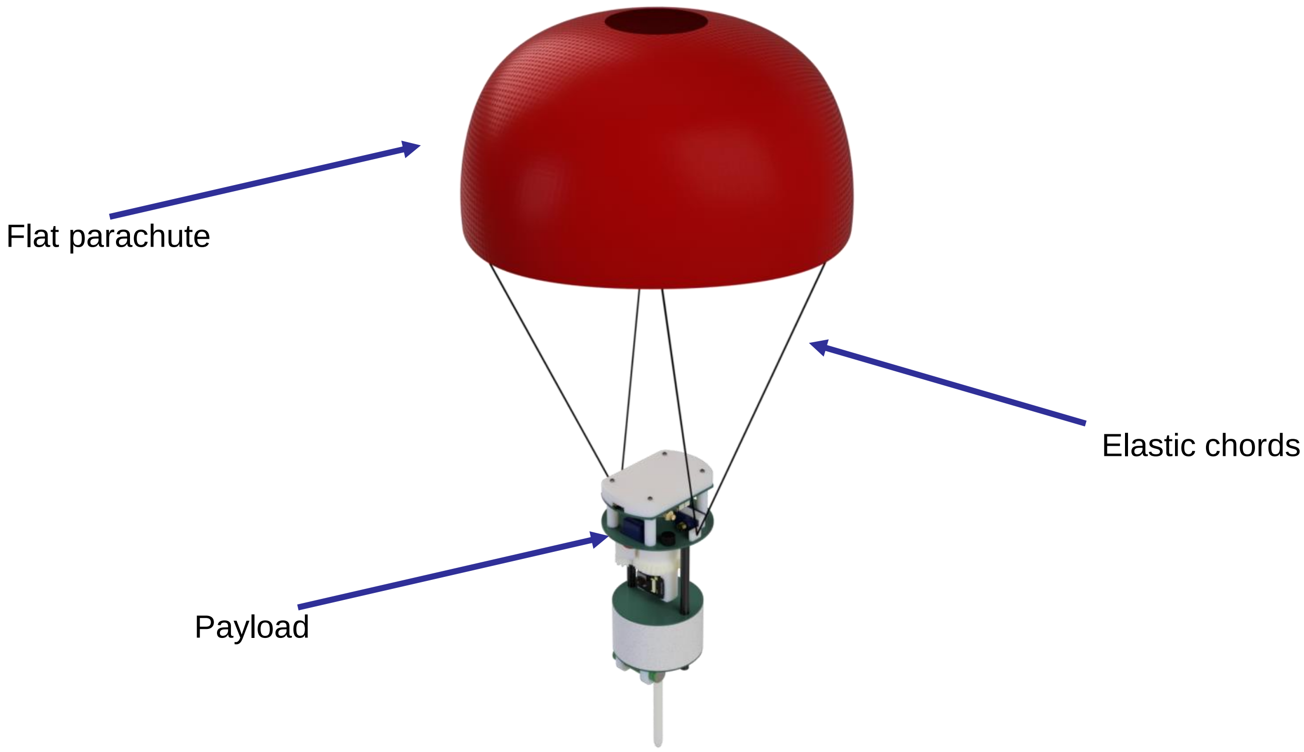
Payload Rotation Control Strategy

During aerobraking, active rotation stabilization will apply only to the camera – rest of Cansat will be passively stabilized. It will be done by placing camera on an electric motor with gearbox and then using software to control stabilization appropriately.
The system will consist of gearbox, electric motor, the camera mount and the camera itself. The Flight Software will be responsible for counting the motor revolutions using an encoder and for monitoring the Payloads rotation, and using this data to control the camera pointing direction.



Payload Parachute Descent Control Hardware Summary

Flat parachute will be attached to the top part of the payload using an elastic chord. This mounting place will ensure stability during descent. Ease of manufacturing of flat parachutes will enable us to make our own one. Many iterations of parachutes can be made to provide optimal descent rates and much needed stability.



Descent Rate Estimates (1/3)

Aerobreaking Descent Rate Estimates

The terminal velocity of any falling object through an atmosphere can be calculated using the following equation:

$$v = \sqrt{\frac{2 \cdot m \cdot g}{C_d \cdot \rho \cdot A}},$$

where:
v – terminal velocity,
m – mass of the object (CanSat),
g – gravitational constant,
C_d - coefficient of drag (estimated),
ρ – air density,
A – aerobrake area.

Parameter	Value
m	0.9 kg
g	9.81 $\frac{m}{s^2}$
C_d	0.561
ρ	1.2 $\frac{kg}{m^3}$
A	0.038 m^2

The calculated terminal velocity is equal to:

$$v = \sqrt{\frac{2 \cdot 0.9 \cdot 9.81}{0.531 \cdot 1.2 \cdot 0.038}} = \mathbf{26.27 \frac{m}{s}}$$

Parachute Descent Rate Estimates

The same equation can be modified to estimate the diameter of the flat parachute to obtain a desired descent speed:

$$d = \sqrt{\frac{8 \cdot m_p \cdot g}{C_d \cdot \rho \cdot \pi \cdot v^2}},$$

where:
d – diameter of the parachute
m_p – mass of the CanSat after heat shield release,
g – gravitational constant,
C_d – coefficient of drag,
ρ – air density,
v – desired speed.

Parameter	Value
m_p	0.598 kg
g	9.81 $\frac{m}{s^2}$
C_d	0.8
ρ	1.2 $\frac{kg}{m^3}$
v	5 $\frac{m}{s}$

The desired speed is less than 5 $\frac{m}{s}$. The calculated parachute diameter should be at least this large:

$$d = \sqrt{\frac{8 \cdot 0.598 \cdot 9.81}{0.8 \cdot 1.2 \cdot \pi \cdot 5^2}} = \mathbf{0.789\ m}$$

The parachute will be made by ourself and it's diameter will be **0.85 m** to ensure low enough descent speeds. Thus the estimated descent rate is: **4.64** $\boldsymbol{\frac{m}{s}}$.

Descent Rate Estimates (3/3)

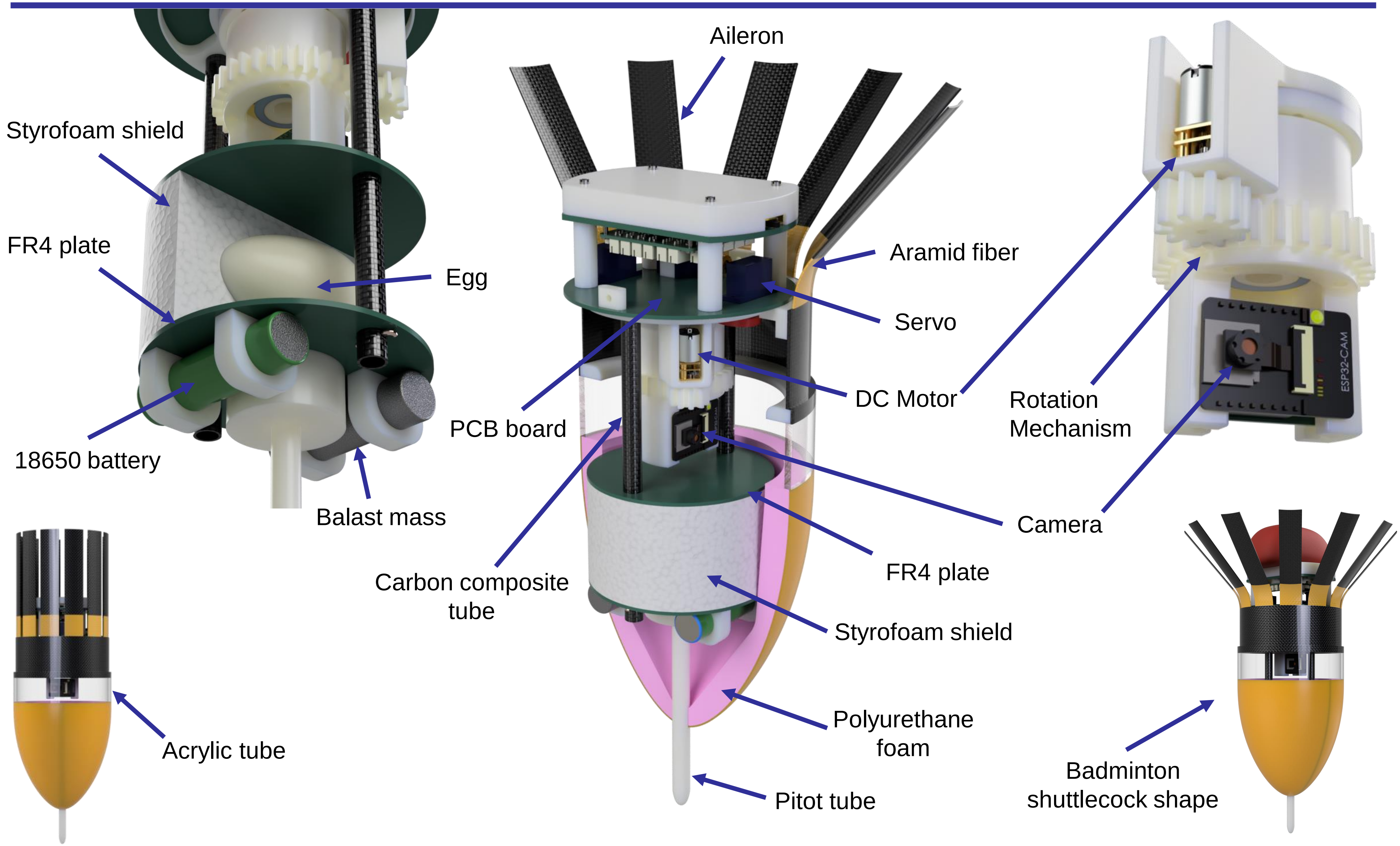
Final descent rates are given in the table below. The exact descent rates will be determined experimentally during device tests.

Descent phase	Descent rate estimate
Aerobraking descent	$26.27\ \frac{m}{s}$
Parachute descent	$4.64\ \frac{m}{s}$

Mechanical Subsystem Design

Paweł Iwańczyk

Mechanical Subsystem Overview



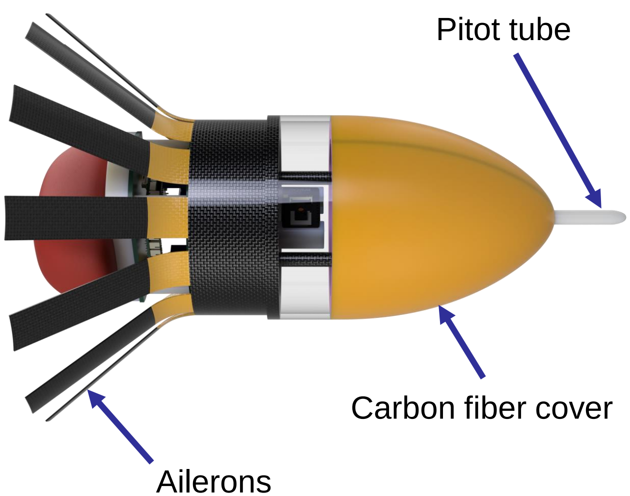
Mechanical Subsystem Changes Since PDR

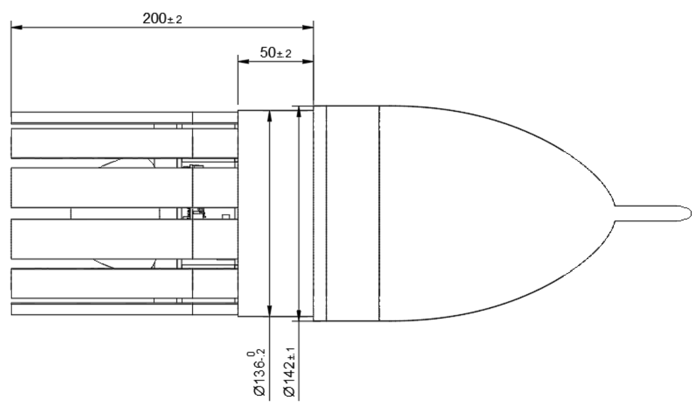
Part	Change	Reasons
Battery placement	The battery has been moved to the bottom of the Payload.	Shifting the center of gravity and freeing up space in the upper part of the device.
Camera rotation controll	The BLDC motor was replaced with a DC one and a gear set was added.	Easier control system and greater parts availability.
New electronic compartment	Added additional space for electronics.	Insufficient space for electronics with previous design.

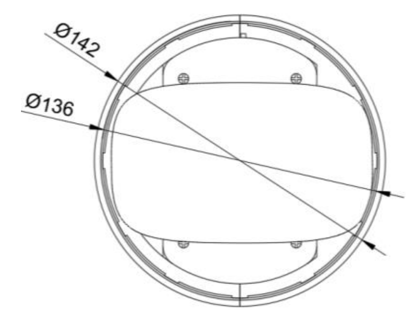
Payload Mechanical Layout of Components (1/4)

CanSat structure and dimensional drawings

- CanSat stabilization is achieved by using optimal aerodynamical shape, similar to badminton shuttlecock, which protects against tumbling.
- Most of the structure is made of composites, to ensure maximum strength, and polyurethane foam.
- Camera rotates around the axis of the device, allowing it to point at a given direction on the horizon, compensating for possible rotation of the device itself.
- The transparent part of the cover is made of an acrylic tube.



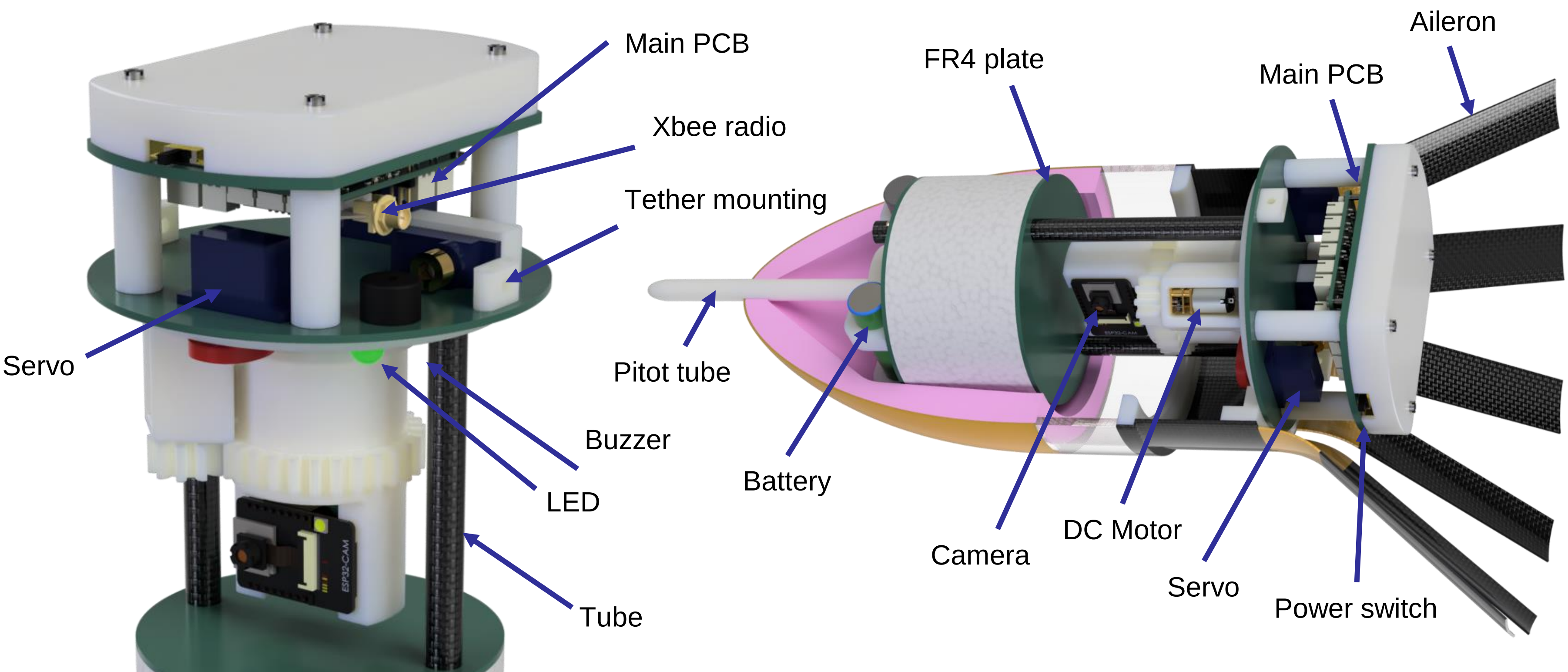




Payload Mechanical Layout of Components (2/4)

Location of electrical components

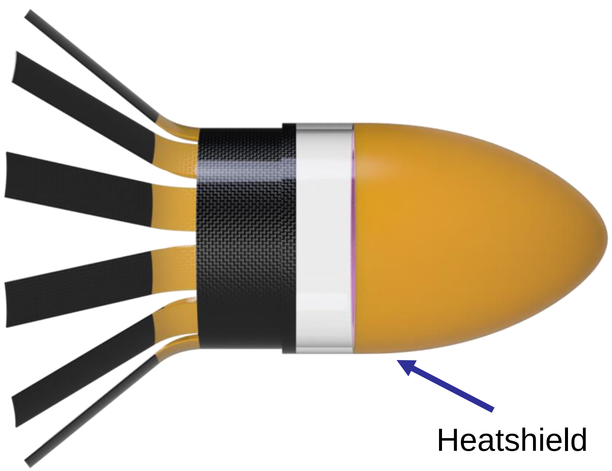
Electronic boards are directly structural elements, which ensures their durable assembly. Additionally, this solution saves weight by taking advantage of the high strength of the PCBs. Larger components (such as servomechanisms) are also mounted directly to PCBs using appropriate holders and clamps. The elements connecting the PCBs to the rest of the structure are 2 tubes made of carbon composite, connected to the PCBs using epoxy glue.

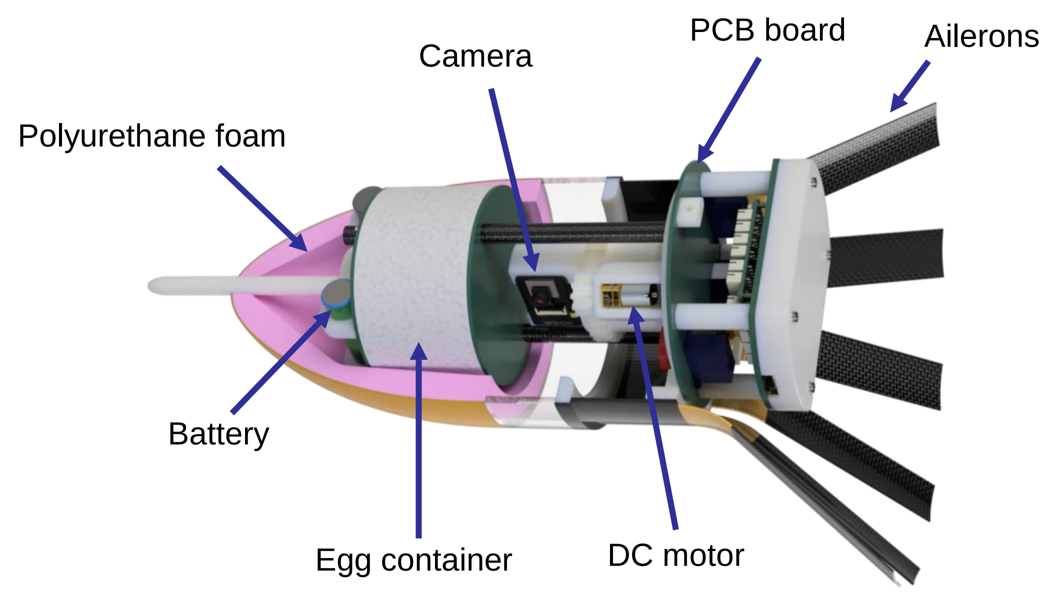


Payload Mechanical Layout of Components (3/4)

The heatshield design is based on the shape of a badminton shuttlecock, which ensures good stability and prevents tumbling. Stabilization of the camera in the rotation axis will be ensured by the DC motor with gearbox to which it will be mounted. Thanks to this, we will have active stabilization of the rotation axis and passive (aerodynamic) stabilization on the other axes.

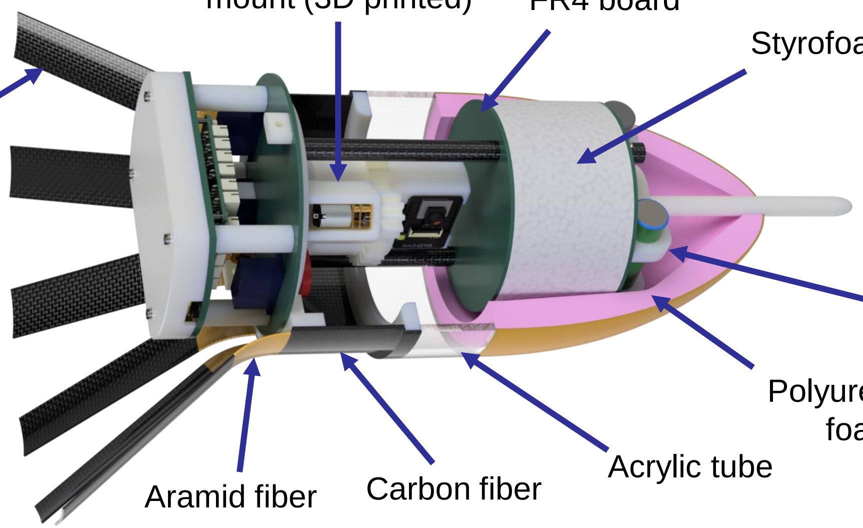
The CanSat structure is made mainly of composites, which allows for significant weight reduction. The outer part of the heatshield is made of carbon composites and aramid fiber, while the internal structure is based on the use of PCB boards as structural elements. In addition, to increase stiffness (and to protect the egg), polyurethane foam was used in some places.





Payload Mechanical Layout of Components (4/4)

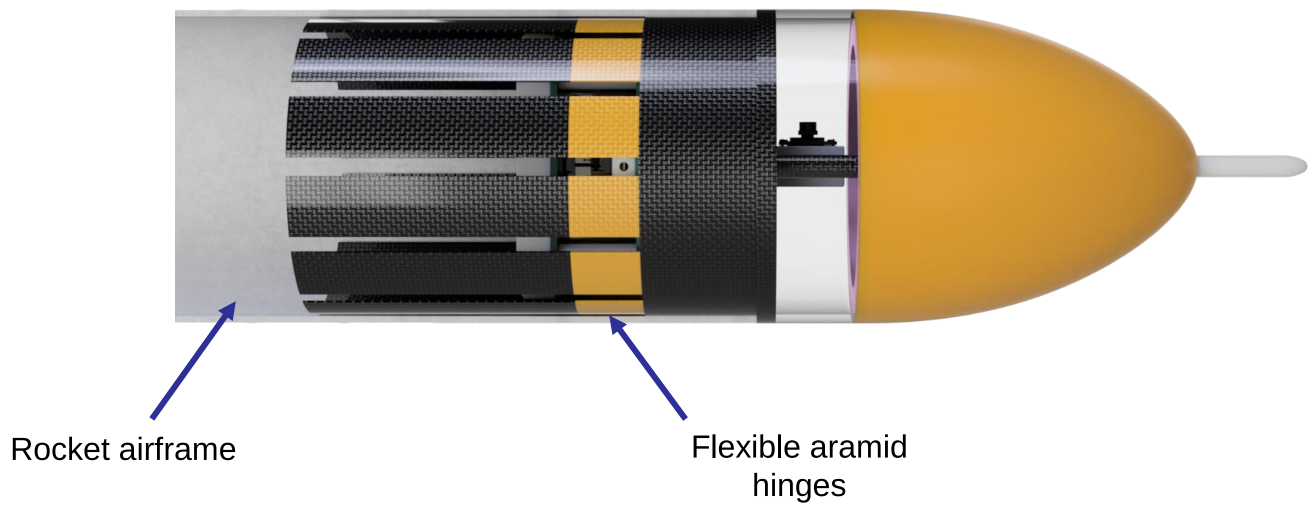
Main body of CanSat is made out of Carbon Fiber composite. To create the nose structure, carbon fiber PET-G composite 3D printed, and then polyurethane foam is applied, which serves to increase the stiffness of the structure. The "hinges" to which the ailerons used to airbrake the device are attached (made of carbon fiber) are made of aramid fiber, which is springier than carbon fiber. The Payload's construction also uses composite materials: FR4 boards (commonly known as PCB) are used as the main mounting points of the elements, and they are connected using carbon fiber tubes. Elements that would be difficult to make from composite fabric will be made of 3D printed materials, including the camera assembly, gearbox assembly and fragments of the pitot tube. To ensure good visibility for the camera, the straight nosecone fragment will be made of an acrylic tube



*Antenna was not moddeled, but will be placed near egg container

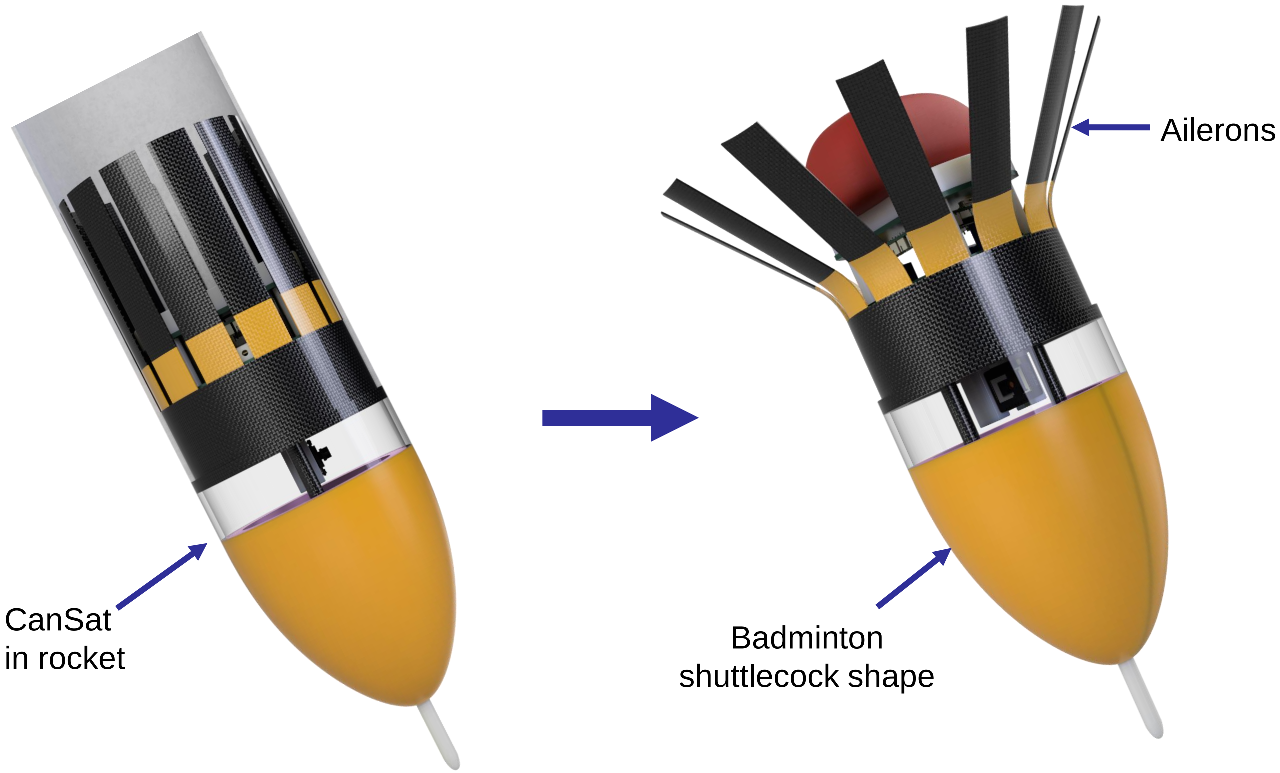
Payload Aerobraking Pre Deployment Configuration

The bases of the shuttlecocks are made of a flexible aramid, the shuttlecocks are held in place by the elastic force while inside the rocket. Since the outer surface of the ailerons will be covered with a layer of material with a low coefficient of friction, they will not hinder the device from sliding out of the rocket.



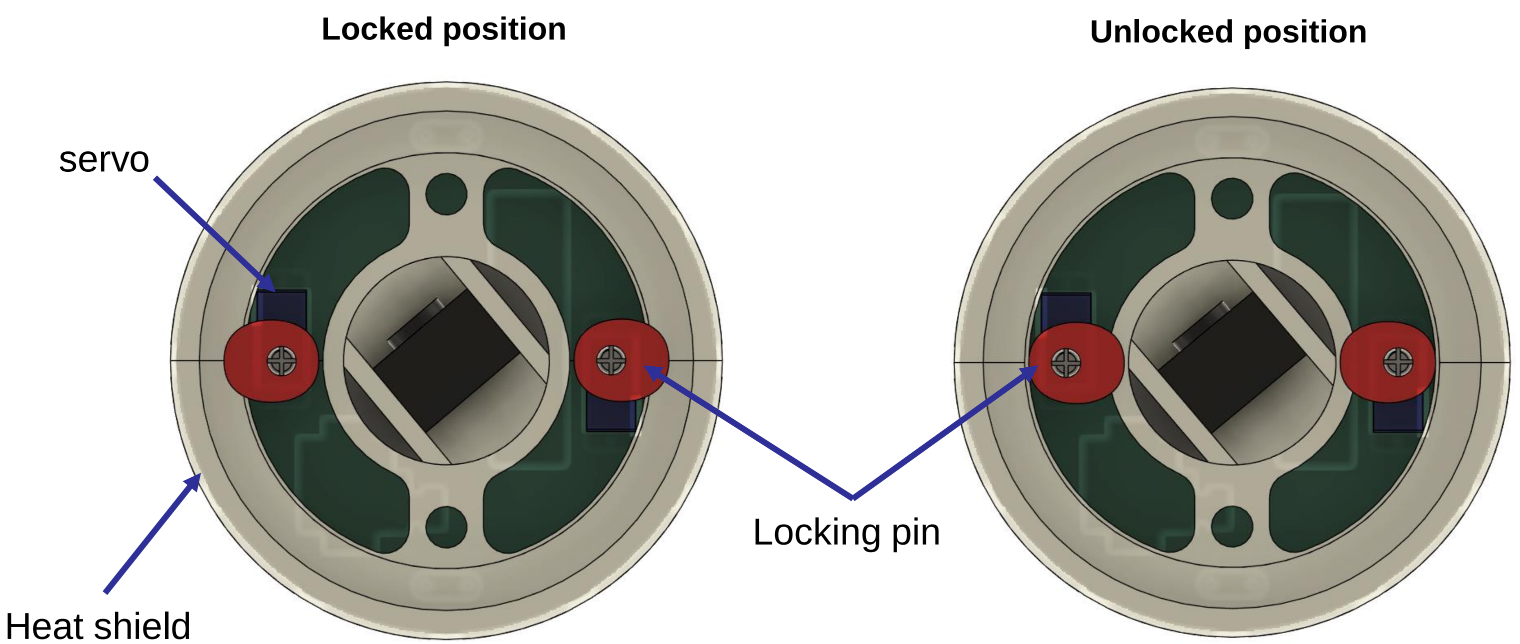
Payload Aerobraking Deployment Configuration (1/2)

The CanSat transition from the stowed position to the deployed configuration takes place through the deflection of 12 ailerons placed around the device's perimeter when the CanSat is released from the rocket. Ailerons are made of elastic material and are pre-tensioned, so as soon as the device leaves the rocket, they are bent and the aerobraking process begins.



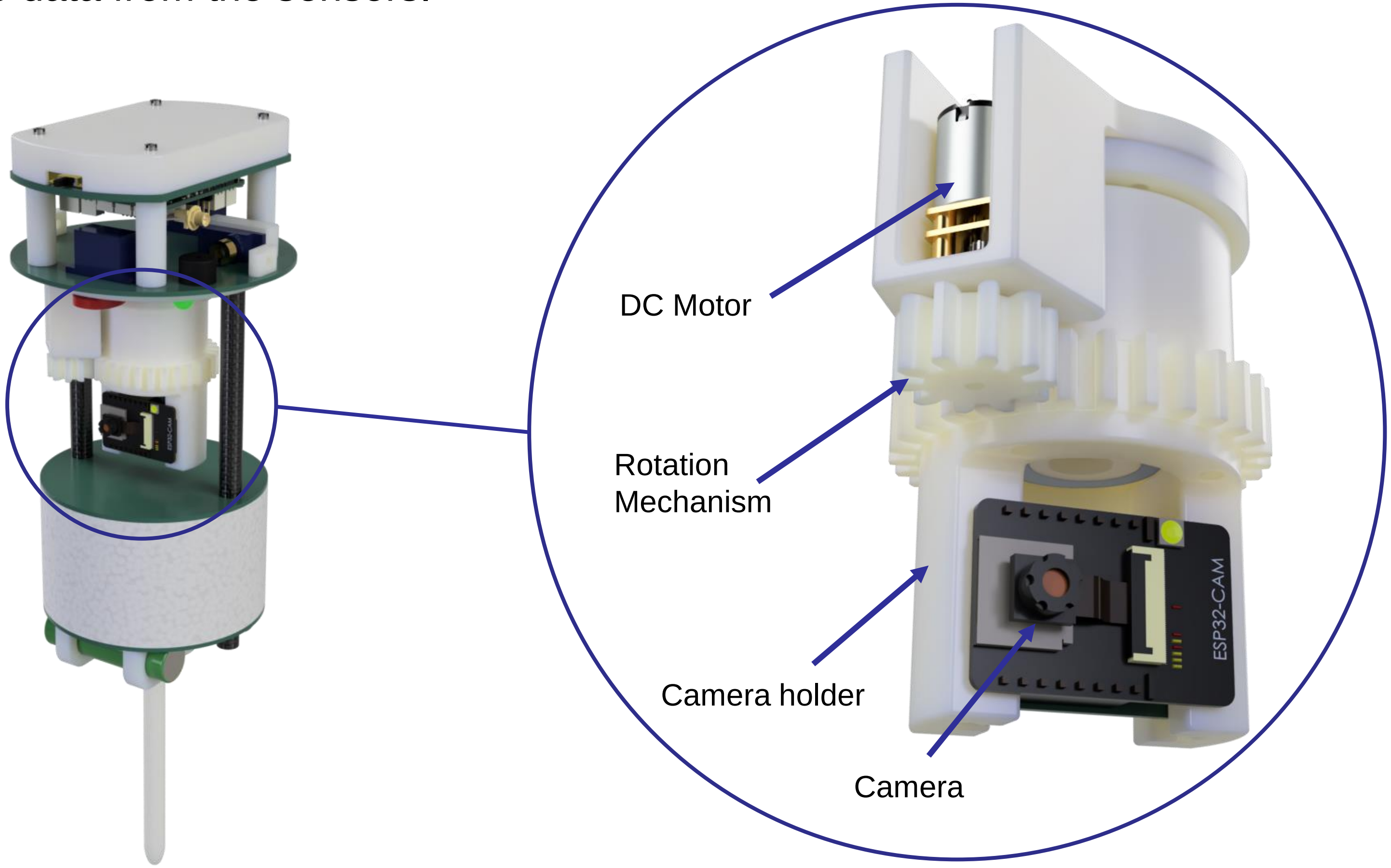
Payload Aerobraking Deployment Configuration (2/2)

The Payload separation system from the aerobraking structure uses a double-lock mechanism, controlled by servomechanisms. When the separation process begins, the servos attached to the Payload rotate and the locks placed on their axes stop standing in the way between the Aerobraking structure and the Payload separation. Mylar golden strip will be mounted atop of parachute and will also help to pull parachute of the CanSat.



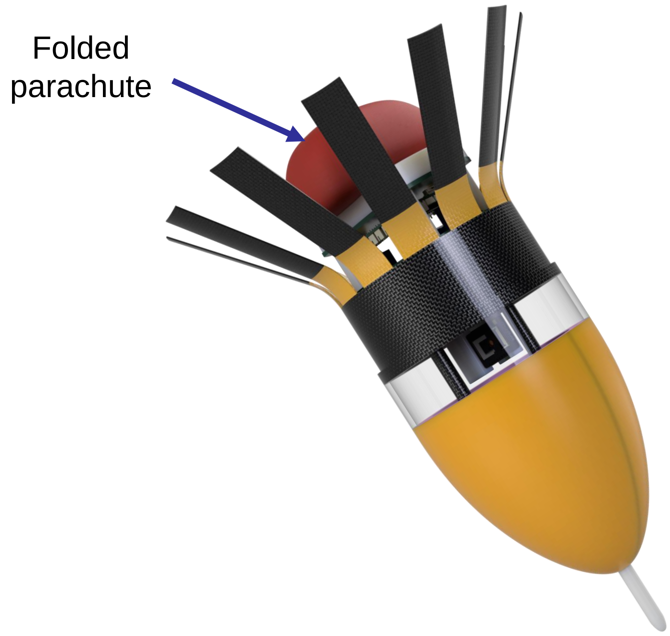
Camera Pointing Control

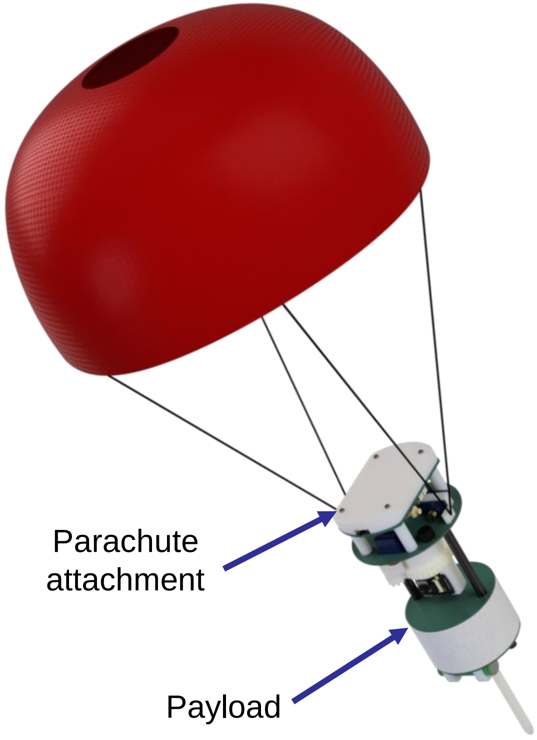
Camera pointing is maintained during descent by using a gear system driven by a DC motor, which is controlled by the main controller of the device, which will appropriately control the motor thanks to data from the sensors.



Payload Parachute Deployment Configuration (1/3)

The parachute is attached to the payload, to its upper plate. Before deployment, it is folded and attached to the structure using a release mechanism. This mechanism consists of a servo mechanism with a mounted latch and an elastic cord that tightly holds the parachute to the payload structure. When the servo rotates through a given angle, the cable is released and so is the parachute.

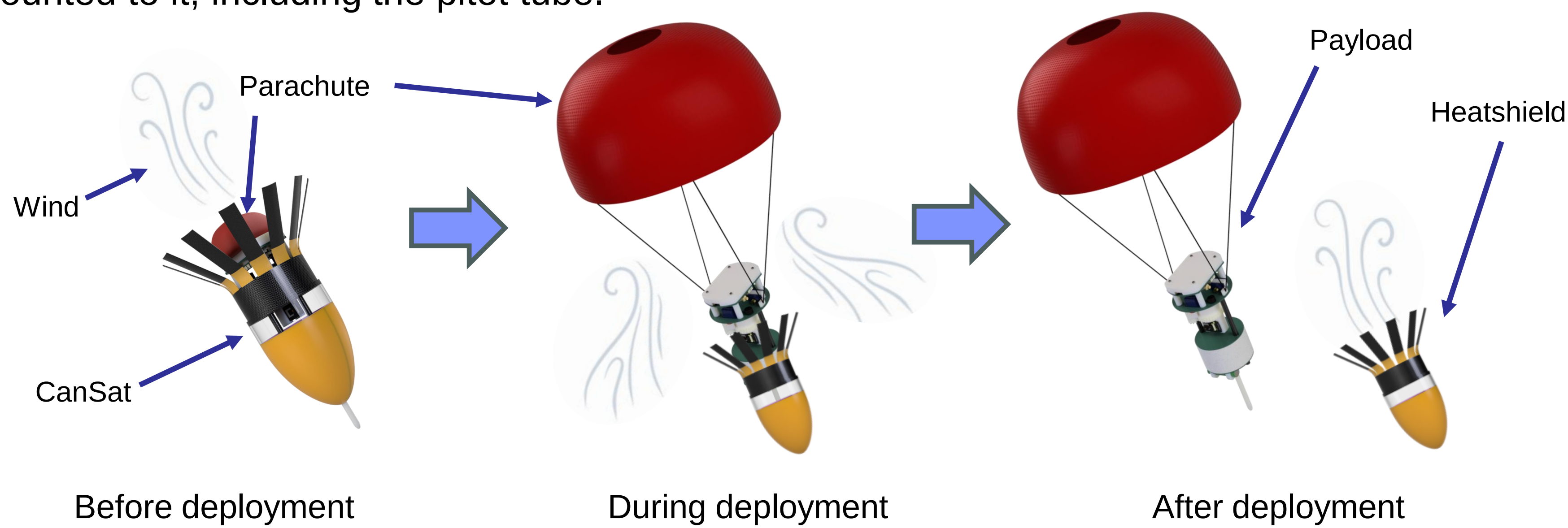




Payload Parachute Deployment Configuration (2/3)

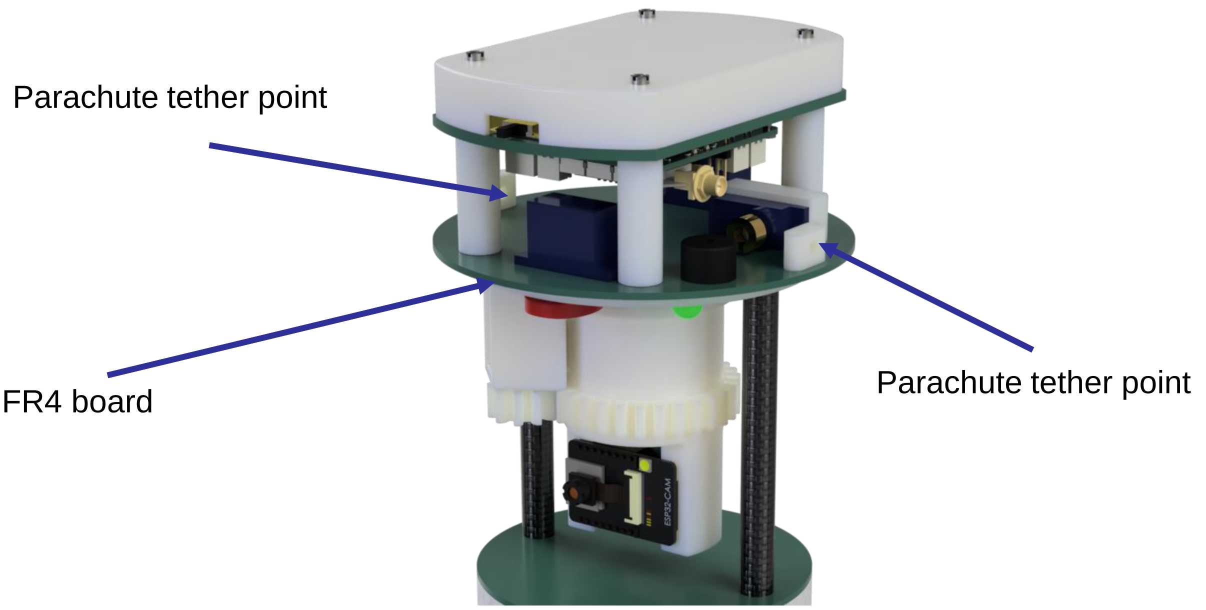
The transition of Payload from the stowed position to the deployed configuration takes place by opening the parachute and then pulling off the Payload through the drag force generated by the parachute, as it is greater than the drag force of the Heatshield being discarded.

In order to deploy the payload, two servomechanisms placed on the upper plate of the payload must rotate through a given angle, which unlocks the movement of the payload in the longitudinal axis of the device, allowing it to slide out thanks to the previously opened parachute. The number of elements is minimal and the use of two servomechanisms results from concern for adequate resistance to high G's and the symmetry of the unlocking mechanism. When the payload is unlocked, it can slide out freely along with all the elements mounted to it, including the pitot tube.



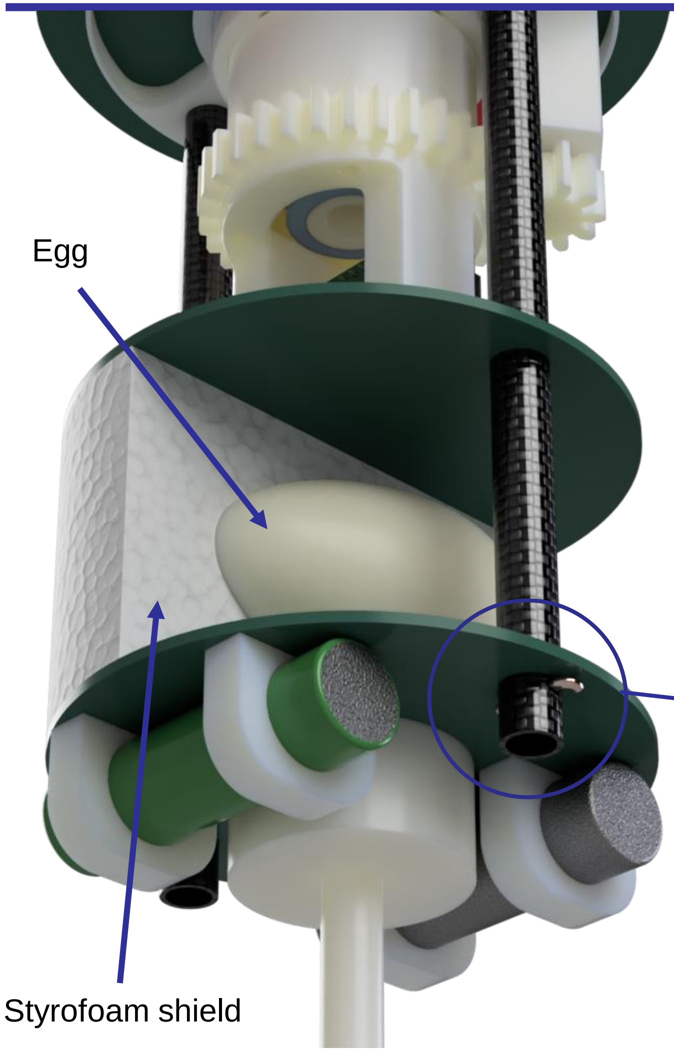
Payload Parachute Deployment Configuration (3/3)

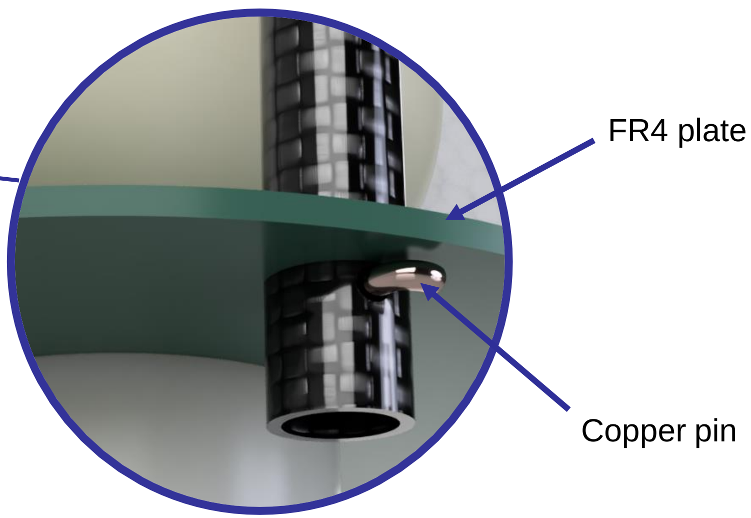
The parachute is attached to the Payload using cables. These lines are pulled through 3D printed eyelets, and then a knot is tied to prevent the parachute from being released.



Payload Egg Containment Configuration (1/3)

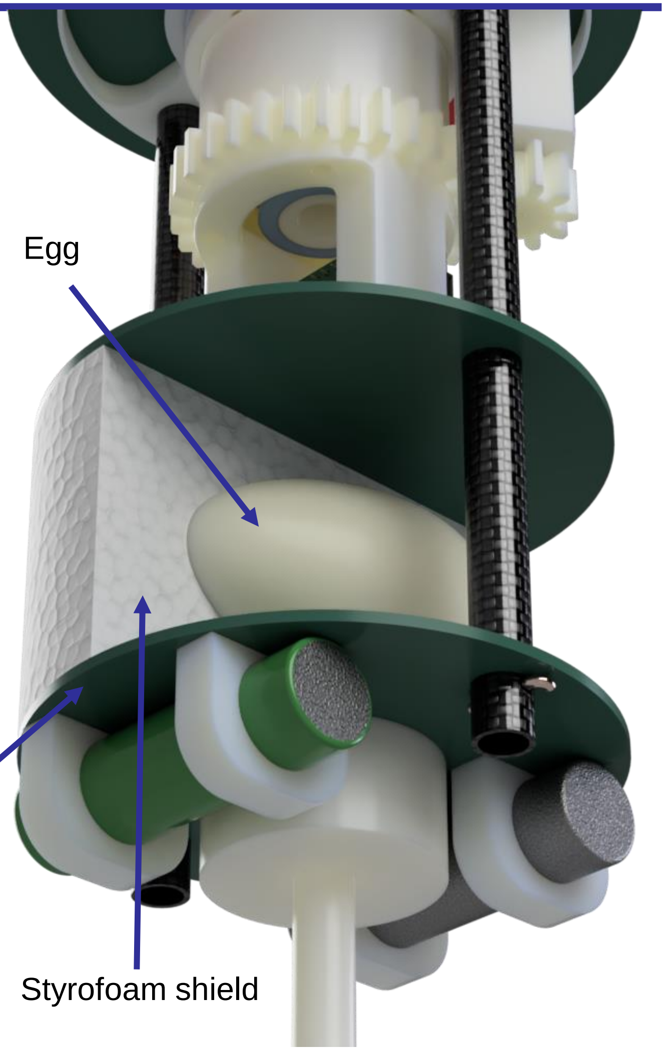
In order to place the egg in CanSat, before attaching the payload to the heatshield, we will place the egg in a Styrofoam shield and then secure it with an FR4 plate and copper pins. Then the payload should be attached to the heatshield (insert it into the heatshield and then rotate the two servos) and CanSat is ready to fly.





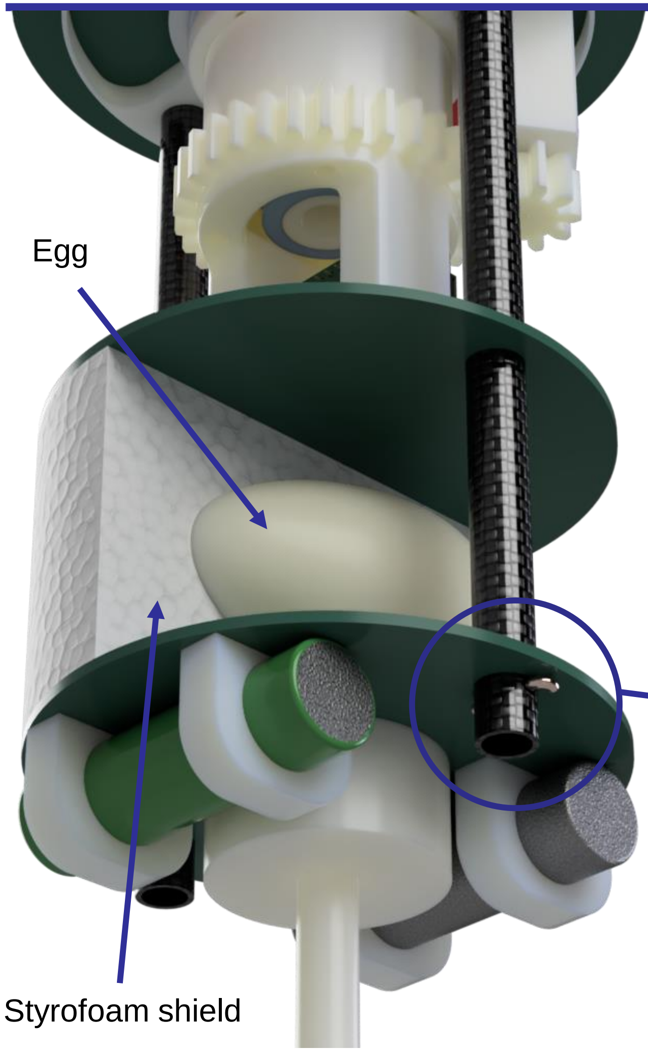
Payload Egg Containment Configuration (2/3)

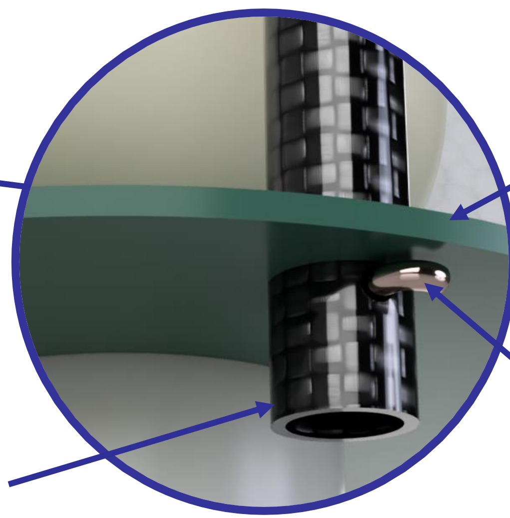
During the mission, the egg is placed in a Styrofoam shield, surrounding it and preventing it from moving. At the same time, due to the method of mounting, the egg does not transfer almost any stress. During flight, the plates located at the bottom and top of the Styrofoam shield compress it slightly, eliminating any possibility of movement.
Additionally, placing the egg inside the Styrofoam protects it against high-frequency vibrations.



Payload Egg Containment Configuration (3/3)

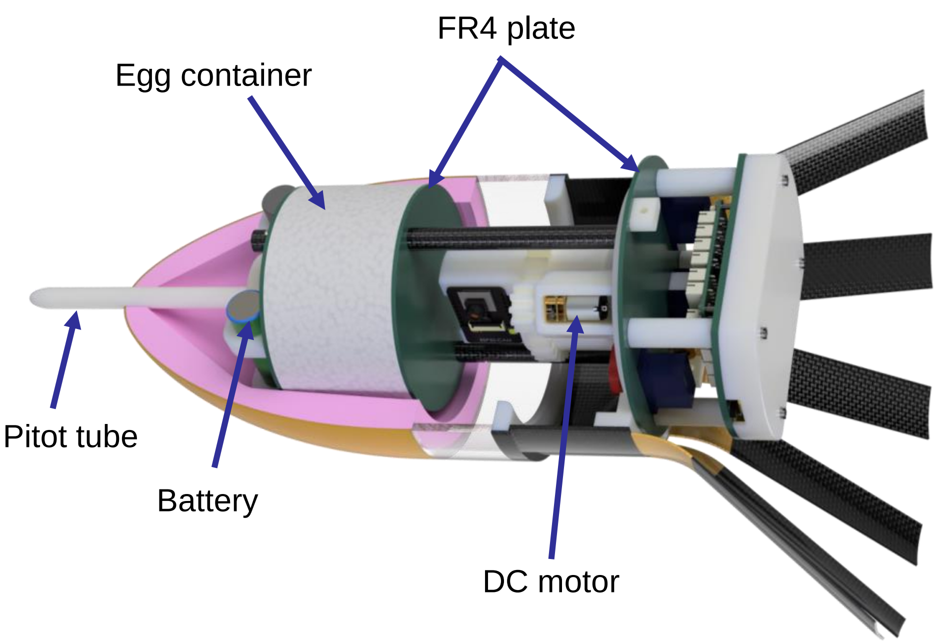
The egg is placed inside a previously hollowed out Styrofoam, which is mounted between two plates made of FR4 material. The upper one is attached with epoxy resin to carbon fiber tubes, while the lower one is attached with copper pins. By taking advantage of the natural elasticity of Styrofoam, the egg is firmly and securely attached, while carrying almost no stress.

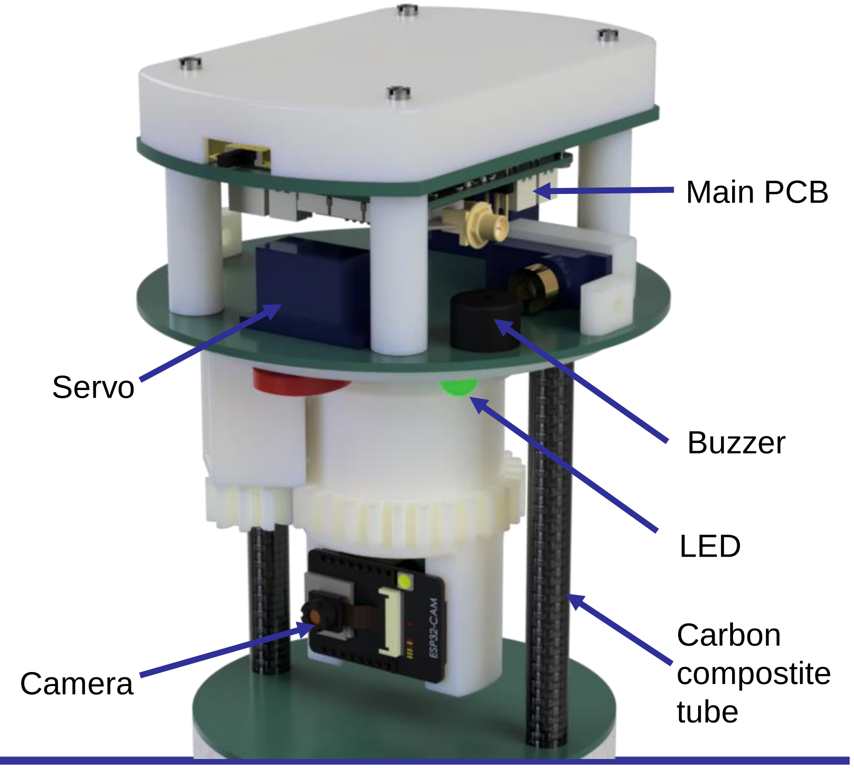




Electronic component mounting methods

Electronic components are placed on PCBs and soldered or attached to the structure using screws. The DC Motor that will be used to control the camera will be mounted to the 3D printed structure using screws, the servomechanisms will also be screwed directly to the FR4 plates. Electrical connections will be secured with glue to prevent unplanned disconnection. In addition, all electronic components that could be exposed to moisture will be covered with a protective layer of acrylic varnish.





Mass Budget (1/3)

Name of component	Quantity [pieces]	Mass per piece [g]	Uncertainty [g]	Source
LPS22 breakout module	2	3.1	0.2	Measured
Custom PCB board	1	20	2	Estimate
GY-NEO6MV2	1	15.5	0.5	Measured
ESP-32-CAM	2	10	0.5	Measured
SANDISK Ultra microSDHC 32GB	3	0.25	0.003	Datasheet
XBP9B-DMST-012	1	6	0.2	Measured
ANTX150P118B09153	1	0.675	0.01	Measured
Samsung INR18650-25R	1	45	1.2	Datasheet
Connectors	1	12	1	Estimate
Electrical wires	1	10	0.5	Estimate
MG90S servo	3	9	0.5	Datasheet
DC motor	1	9.5	0.5	Datasheet

Mass of all electronic components: 172.6±8.9 g

Mass Budget (2/3)

Name of component	Quantity [pieces/amount]	Mass per piece [g]	Uncertainty [g]	Source
Aileron	12	3.5	0.5	CAD estimate
Heat shield	1	310	10	CAD estimate
Parachute mount	2	2	0.1	CAD estimate
Carbon fibre rod	2	13	0.5	CAD estimate
Heatshield lock	1	50	1	CAD estimate
Motor mount	1	25	0.1	CAD estimate
Egg protection shield	1	20	0.5	CAD estimate
Payload lock	1	5	0.5	CAD estimate
Camera mount	1	60	2.5	CAD estimate
Pitot tube	1	60	2.5	CAD estimate
Pins and screws	1	22	2	Estimate
Epoxy resin glue	1	15	3	Estimate
Parachute	1	17	1	Estimate
Acrylic tube	1	18	1	Estimate
Balast mass to equal out weight	1	45	2	Estimate

Mass of all mechanical components and structural materials: 703±30g

Mass Budget (3/3)

Name	Mass [g]	Uncertainty [g]
Electrical components	172.6	8.9
Mechanical components and structural materials	703	30
Total	**875.6**	**38.9**

The required mass of the CanSat is 900 g (without the hens egg).
The approximate mass of the CanSat is 875.6g.

Margin: 900 g – 875.6 g = **24.4 g** (underweight)

Most probably additional weight needs to be added to the CanSats structure. This will be done in the form of steel balls glued with epoxy resin.
If the mass turns out to be too high (due to the high uncertainty), it can be reduced by lowering the thickness of the heatshield.

Communication and Data Handling (CDH) Subsystem Design

Krzysztof Kowaczek

CDH Overview

Type	Model	Function(s)
Processor	STM32F412RGT6	Gathering and handling information from sensors. Interacting with the Ground Station; transmitting information and carrying out instructions.
Memory	MicroSD card	Archiving telemetry data as a safeguard. Backing up software state to ensure resilience in the event of an electronic system reboot
RTC	Internal STM RTC with a backup battery	Measuring mission time.
Antena	ANTX150P118B09153	Amplifying signal range.
Radio	XBee XBP9B-DMST-012	Transmitting data and commands.
FRAM	FM24C64B-G	Memory that retains data without needing power

CDH Changes Since PDR

Part	Change	Reasons
Payload memory	Added FRAM memory.	Is soldered to the main PCB, thus more reliable regarding vibrations.
Payload commands	Added CHUTE and HTSLD commands.	These commands will allow for easier testing and assembly of CanSat.

Payload Processor & Memory Summary (1/2)

Name	Boot time [ms]	CPU speed [MHz]	Operating voltage [V]	Flash memory [kB]	RAM [kB]	I/O Pins	Interfaces	ADC [channel/ resolution]
STM32F412RGT6	~5	100	3.3	1024	256	50xGPIO, of which: -16x PWM out -16x Analog in	4 x I2C, 4 x USART, 5 x SPI/I2S, SD IO, USB	16/12 - bit

Description:

- Sufficient clock speed
- Fast boot time
- All needed interfaces are on-board
- Proper pin count
- Sufficient RAM and Flash memories
- Easy to solder on a custom PCB
- Power consumption is estimated as 363mW
- Data Bus Width: 32 bit

We use specified formula:

- Power consumption = 3.3V * 110mA = 363mW

Resource datasheet

Payload Processor & Memory Summary (2/2)

Name	Memory	Interfaces	Package	Voltage [V]
SANDISK Ultra microSDHC 32GB	32GB	SPI/SDIO	microSD	2.7 ÷ 3.6
FM24CL64B-G	64kb	I2C	8-SOIC	2.7 ÷ 3.6

MicroSD card Description:
- High availability
- Easy to replace
- High capacity
- Easy to use in the software
- Vibration resistant

The task of the SD card is to collect information during the flight.

FRAM Description:
- High availability
- High capacity
- Easy to use in the software
- Low power consumption

The task of FRAM is to record critical state machine and calibration data.

Payload Real-Time Clock

Name	Size [mm]	Mass [g]	Interface	Reset tolerance	Type
Internal STM32 RTC clock	Integrated into STM32	-	Internal bus	Unaffected due to coin battery backup	Hardware

Description:
- Saves weight due to being integrated
- Is reset resistant
- CPU can read directly from RTC
- Has backup battery source
- MCU already chosen

The RTC is online all the time, its backup battery will last for over 6 months.

When on the launch pad command ST will be used to set the proper time in the RTC registers. Theoretical resolution is 30us.

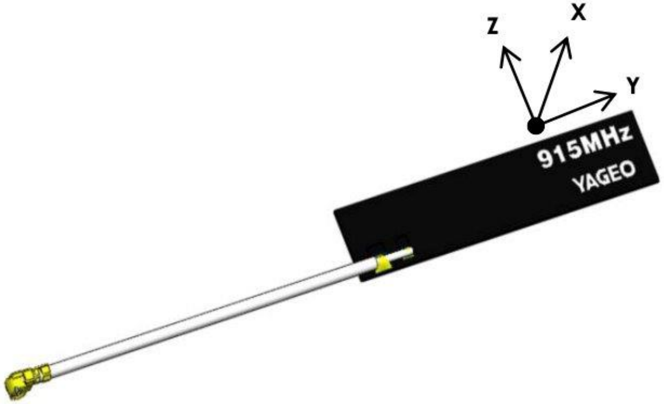
Payload Antenna Selection (1/2)

Name	Connector type	Antenna type	Frequency range(s) [MHz]	Weight [g]	Peak gain [dBi]	Efficiency [%]	Range [km]
ANTX150P118B09153	I-PEX (U.fl compatible)	PCB strip	890 ÷ 925	0.675	1.9	>55	~0.6 (worst case) ~9 (best case)

Description:

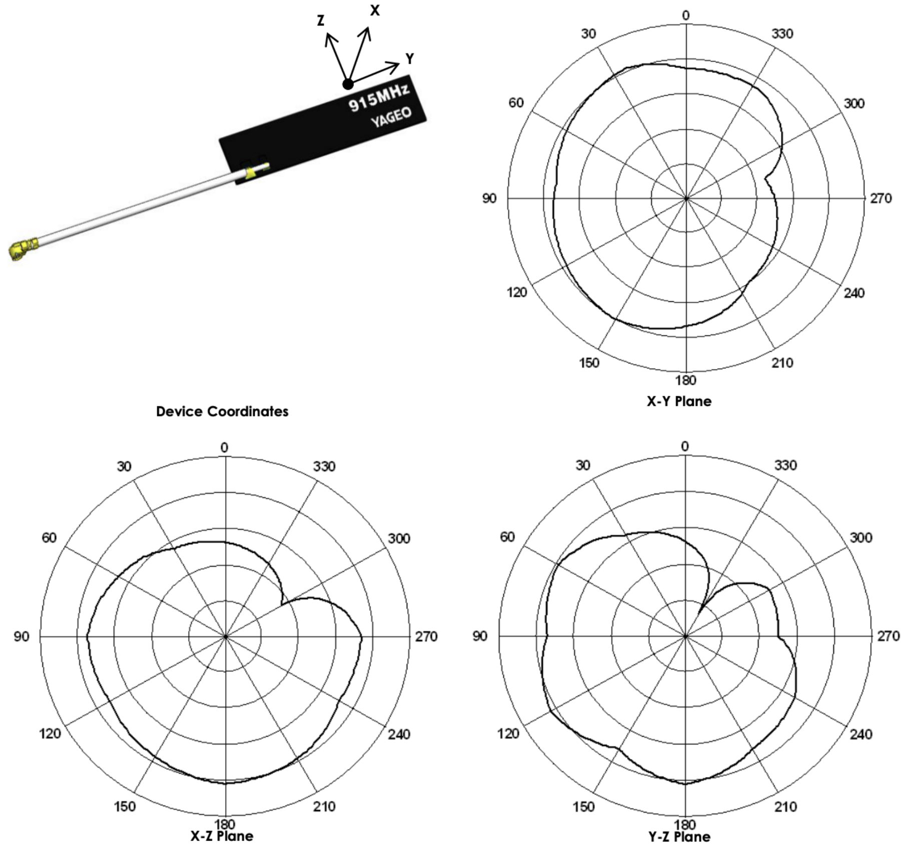
- High gain
- High best case range
- Small mass
- Wider frequency range

Early tests proved usefulness of this antenna, the communication was uninterrupted.



Payload Antenna Selection (2/2)

ANTX150P118B09153



Payload Radio Configuration (1/2)

Name	Operating voltage [V]	Operating current [mA]	Baud rate [kbps]	Sensitivity [dBm]	Operating frequency [MHz]	Transmit power [mW/dBm]	Range [km] (best case)
XBP9B-DMST-012	2.4 ÷ 3.6	TX: 229 RX :44	19.2	-110	900	250/24	~15 (outdoor)

Description:
- Has goot outdoor range
- High enough data speed
- Sufficient baudrate

Payload Radio Configuration (2/2)

XBee Radio selection:
XBP9B-DMST-012 has been chosen for incorporation both in the payload and at the Ground Station.

Xbee Configuration:
XBees will operate in the same network in AT (transparent) mode. The radio will operate in **unicast mode**, and it will communicate with the MCU using UART interface.

Transmission Control
Prior to initiating, the radio will remain idle awaiting setup instructions (ST, CAL, CX).
Following the receipt of the CX command, it will commence transmitting a data packet at a rate of one per second (**1Hz**).
Transmission of packets will cease upon detection of landing.

PANID/NETID is set to 2050

Payload Telemetry Format (1/3)

Field	Description	Resolution
TEAM_ID	the assigned four digit team identification number	-
MISSION_TIME	UTC time in format hh:mm:ss.ss	1 s
PACKET_COUNT	Total count of transmitted packets since turn on, which is to be maintained through processor reset.	1 packet
MODE	'F' for flight mode and 'S' for simulation mode.	-
STATE	The operating state of the software. (e.g., LAUNCH_WAIT, ASCENT, LANDED, etc.)	-
ALTITUDE	Altitude in units of meters. Relative to ground level.	0.1 m
AIR_SPEED	the air speed in meters per second measured with the pitot tube during both ascent and descent	0.1 m/s
HS_DEPLOYED	'P' indicates the heat shield is deployed, 'N' otherwise.	-
PC_DEPLOYED	'C' indicates the parachute is deployed (at 100 m), 'N' otherwise.	-
TEMPERATURE	The temperature in degrees Celsius	0.1 °C
PRESSURE	The air pressure of the sensor used in kPa	0.1 kPa
VOLTAGE	Voltage of the CanSat power bus in volts.	0.1 V
GPS_TIME	Time from the GPS receiver. Reported in UTC.	1 s
GPS_ALTITUDE	Altitude generated by the GPS receiver in meters above mean sea level.	0.1 m
GPS_LATITUDE	Latitude from the GPS receiver in decimal degrees north.	0.0001 °

Payload Telemetry Format (2/3)

Field	Description	Resolution
GPS_LONGITUDE	Longitude from the GPS receiver in decimal degrees west.	0.0001°
GPS_SATS	Number of GPS satellites being tracked by the GPS receiver.	integer
TILT_X	The angle of the CanSat long axis deviation. Perpendicular to the gravity vector and Y axis.	0.01°
TILT_Y	The angle of the CanSat long axis deviation. Perpendicular to the gravity vector and X axis.	0.01°
ROT_Z	The rotation rate of the CanSat in degrees per second	0.1 °/s
CMD_ECHO	The text of the last command received and processed by the CanSat	-
OPTIONAL	No further details will be communicated.	-

Telemetry information will be dispatched using ASCII-encoded fields, delimited by commas and concluded with a carriage return. This telemetry information will be communicated at a **1Hz** rate and a baud rate of 19200 bps.

Payload Telemetry Format (3/3)

Telemetry frame template:

TEAM_ID, MISSION_TIME, PACKET_COUNT, MODE, STATE, ALTITUDE,
AIR_SPEED,HS_DEPLOYED, PC_DEPLOYED, TEMPERATURE, PRESSURE,
VOLTAGE, GPS_TIME, GPS_ALTITUDE, GPS_LATITUDE, GPS_LONGITUDE,
GPS_SATS,
TILT_X, TILT_Y, ROT_Z, CMD_ECHO

Telemetry frame Example:

2050,15:24:09,00015,F,PRE_LAUNCH,0.0,
2.9,N,N,26.5,102.5,
4.30, 15:24:09,110.6,34.2000,-69.0000,
3,
0.12,0.19,0.11,CXON

The telemetry data file will be named: ***Flight_2050.csv***

Payload Command Formats (1/3)

Command name	Format	Description	Example
CX - Payload Telemetry On/Off Command	CMD,<TEAM_ID>,CX, <ON_OFF>	1. CMD and CX are static text. 2. <TEAM_ID>is the assigned team identification. 3. <ON_OFF>is the string 'ON' to activate the payload telemetry transmissions and 'OFF' to turn off the transmissions.	CMD,2050,CX,ON activates payload telemetry transmission
ST - Set Time	CMD,<TEAM_ID>,ST, <UTC_TIME>|GPS	1. CMD and ST are static text. 2. <TEAM_ID>is the assigned team identification. 3. <UTC_TIME>|GPS is UTC time in the format hh:mm:ss or 'GPS' which sets the flight software time to the current time read from the GPS module.	CMD,2050,ST, 13:35:59 Set RTC time to 13:10:12 ------------------------ CMD,2050,ST,GPS Set RTC time to the time from the GPS module
SIM - Simulation Mode Control Command	CMD,<TEAM_ID>,SIM, <MODE>	1. CMD and SIM are static text. 2. <TEAM_ID> is the assigned team identification 3. <MODE> is the string 'ENABLE' to enable the simulation mode, 'ACTIVATE' to activate the simulation mode, or 'DISABLE' which both disables and deactivates the simulation mode	CMD,2050,SIM, ENABLE && CMD,2050,SIM, ACTIVATE

Payload Command Formats (2/3)

Command name	Format	Description	Example
SIMP - Simulated Pressure Data (to be used in Simulation Mode only)	CMD,<TEAM_ID>,SIMP, <PRESSURE>	1. CMD and SIMP are static text. 2.<TEAM_ID> is the assigned team identification. 3.<PRESSURE> is the simulated atmospheric pressure data in units of pascals with a resolution of one Pascal.	CMD,2050,SIMP, 101325 Treat 101325 as a value from the pressure sensor
CAL - Calibrate Altitude to Zero	CMD,<TEAM_ID>,CAL	1. CMD and CAL are static text. 2.<TEAM_ID> is the assigned team identification. 3. Sets the relative altitude is set to 0.	CMD,2050,CAL Sets the transmitted altitude to 0
BCN - Control Audio Beacon	CMD,<TEAM_ID>,BCN, ON|OFF	1. CMD and BCN are static text 2. <TEAM_ID> is the assigned team identification 3. <ON|OF> are static strings "ON" or "OFF" that control the audio beacon	CMD,2050,BCN,ON

Payload Command Formats (3/3)

Command name	Format	Description	Example
CHUTE – Parachute Deployment Mechanism Control	CMD,<TEAM_ID>, CHUTE, LOCK|UNLOCK	1. CMD and SIMP are static text. 2.<TEAM_ID> is the assigned team identification. 3.<LOCK|UNLOCK> are static strings "LOCK" or "UNLOCK" that control parachute deployment	CMD,2050,CHUTE,LOCK
HTSHLD – Heat Shield Deployment Mechanism Control	CMD,<TEAM_ID>, HTSHLD, LOCK|UNLOCK	1. CMD and SIMP are static text. 2.<TEAM_ID> is the assigned team identification. 3.<LOCK|UNLOCK> are static strings "LOCK" or "UNLOCK" that control heat shield deployment	CMD,2050,HTSHLD, LOCK

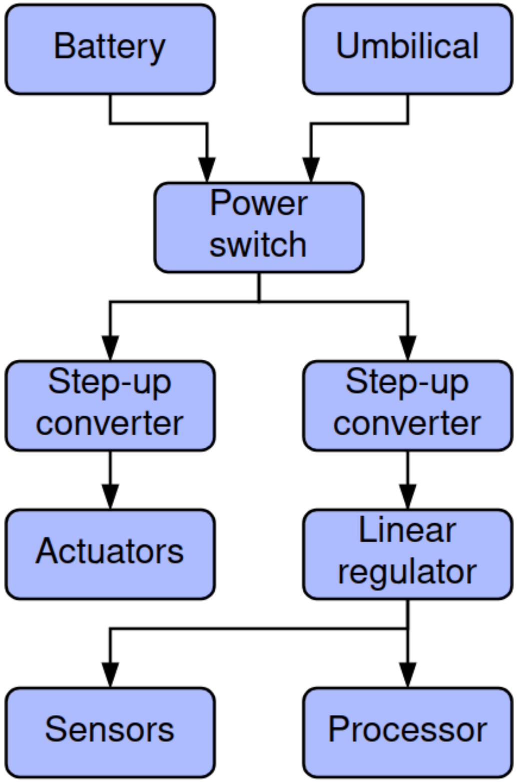
Commands: CHUTE and HTSHLD will only be used for tests and assembly of CanSat.

Electrical Power Subsystem Design

Krzysztof Kowaczek

EPS Overview

Simplified diagram:



Component	Description/Purpose
Battery	Samsung INR18650-25R, main power source for the CanSat
Umbilical	Externally applied power source used for testing and charging the battery
Power switch	Easily accessible switch used to power on the device
Step-up converter	Used to convert the variable battery voltage (3.0-4.2V) to 5V
Linear regulator	Converts 5V down to 3.3V, which is used to supply the processor, sensors and other components

EPS Changes Since PDR

Parts	Change
Block diagram, power budget	BLDC motor (PDR) was substituted with a DC motor (CDR). Chaged block diagram to accomodate for this change and calculated new power budget.
Block diagram, power budget	FRAM memory was added. Chaged block diagram to accomodate for this change and calculated new power budget.

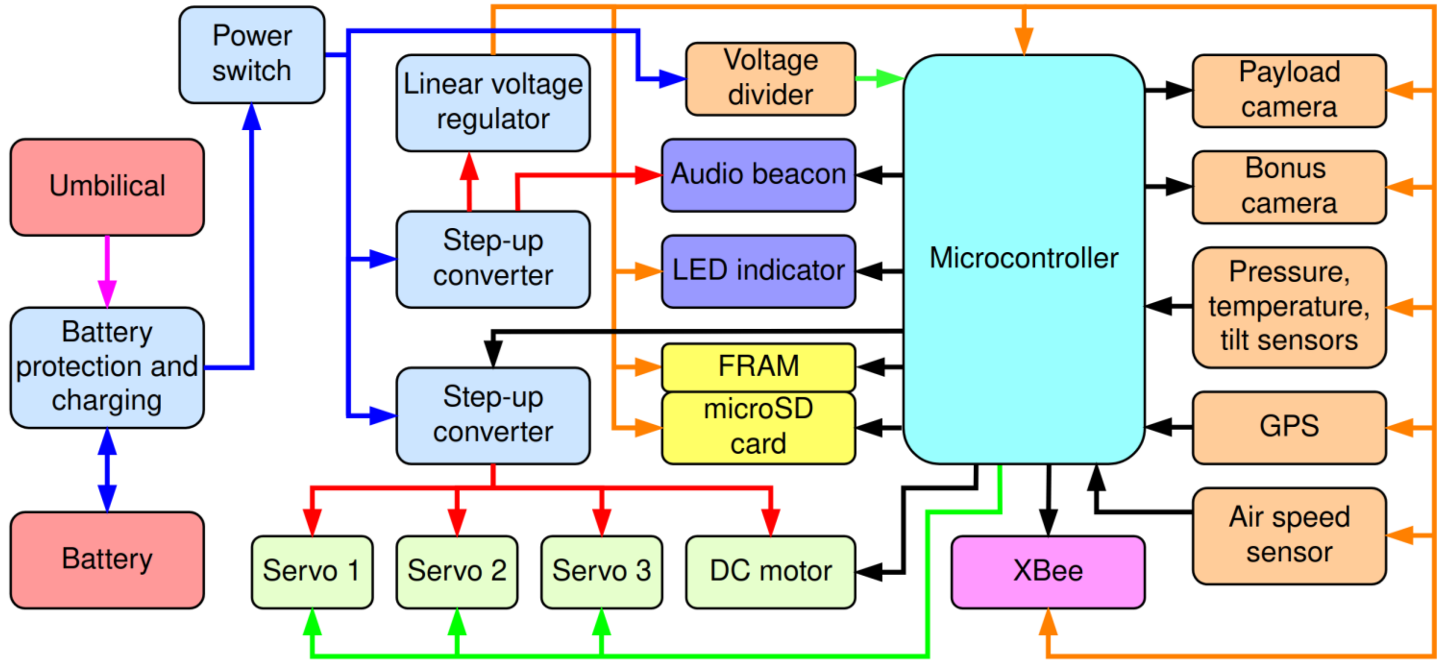
Payload Electrical Block Diagram

Block description:

- Power source
- Power switching and conversion
- Indicators
- Sensors
- Data storage
- Actuators
- Radio

Voltages and signals:

- Battery voltage
- 5V
- 3.3V
- Umbilical (5V)
- Digital signals
- Analog signals



Description:
The main power switch will be located in the aft section of the CanSat, which will allow for easy access. After powering up the LED will start blinking and audio beacon will be used for a short time. When connecting the umbilical power source all electronics will be powered through it and the battery will start charging. Two step-up converters allow for more robustness. The second converter, used for powering actuators, can be shutdown to conserve energy.

Payload Power Source

Parameter	Value
Name	Samsung INR18650-25R
Nominal voltage	3.7V
Continuous current	20A
Instantenuous current	100A
Capacity	2500mAh / 9.25Wh
Internal resistance	13 mOhm
Price	$5.79
Weight	45
Configuration	Single cell

Important notes:
The power source is a durable barrel-type, lithium-ion battery. Tabs will be spot-welded to terminals to ensure good connection. It will be secured using special mountings.

Payload Power Budget

Component	Active power consumption [mW]	Idle power consumption [mW]	Estimated active time [h]	Estimated idle time* [h]	Quantity	Power consumed** [Wh]	Source
BMI270	1.32	1.32	0.2	1.8	1	0.0047	Datasheet
GY-NEO6MV2	82.5	1.65	0.5	1.5	1	0.0779	Datasheet
LPS22	0.0396	0.0396	0.5	1.5	3	0.0003	Datasheet
ESP-32-CAM	346.5	49.5	0.1	1.9	2	0.4588	Measured
Battery voltage divider	0.74	0.74	2	0	1	0.0015	Calculated
MicroSD card	363	0.33	0.5	1.5	3	0.9732	Datasheet
STM32F412RGT6	71.61	0.06105	2	0	1	0.2553	Datasheet
XBP9B-DMST-012	755.7	145.2	0.1	1.9	1	0.6265	Datasheet
Step-up converter	12.95	1.85	2	0	2	0.0518	Datasheet
Servo motor	900	0	0.1	1.9	3	0.3176	Measured
DC motor	1600	0	0.1	1.9	1	0.0647	Measured
FRAM	16.5	16.5	0.1	1.9	1	0.0588	Datasheet
Buzzer	150	0	0.1	1.9	1	0.0176	Datasheet
LED	33	0	1	1	3	0.1765	Calculated

*Calculated as minimal requirement of 2 operating hours minus active time.
**Includes voltage conversion losses and quantity.

The Payload will be able to operate for **more than 2 hours** after integration with the rocket.

Battery capacity [Wh]	9.25
Estimated total power consumption [Wh]	3.209
Power margin [Wh]	6.041
Battery power level after 2 hours [%]	65.31

Flight Software (FSW) Design

Tomasz Lubelski

FSW Overview (1/2)

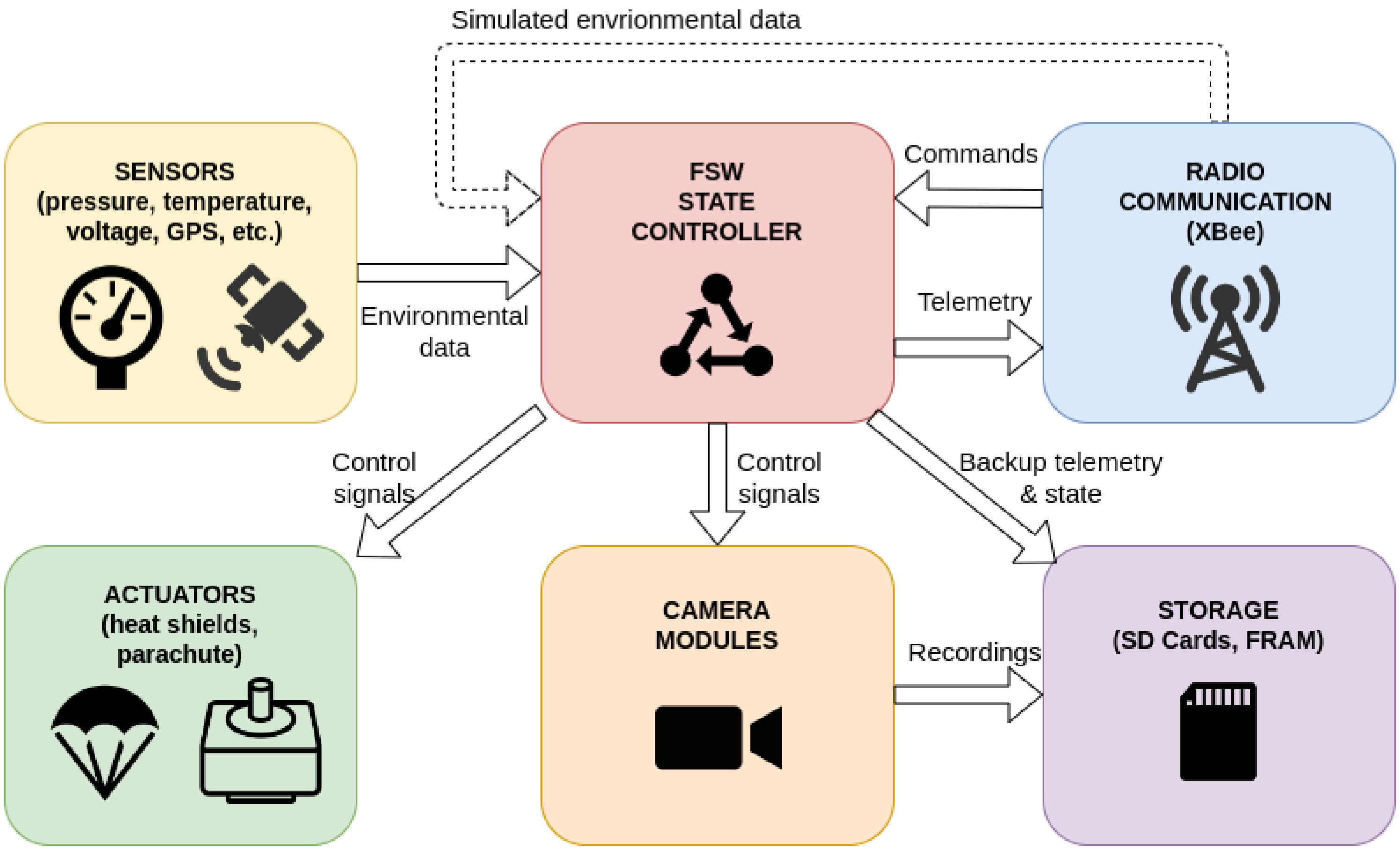
Main FSW tasks:

- State transitions in response to commands and environmental data from sensors
- Acquisition, processing and transmission of telemetry data
- Calibration and supervision of peripheral devices
- Monitoring battery voltage and current
- Control of actuators

Utilized technologies:

- Programming languages: C, C++
- Hardware abstraction library: STM32HAL
- Development environment: STM32CubeMX, PlatformIO
- Real-time operating system: FreeRTOS
- Utility libraries: Embedded Template Library

General flight software flow

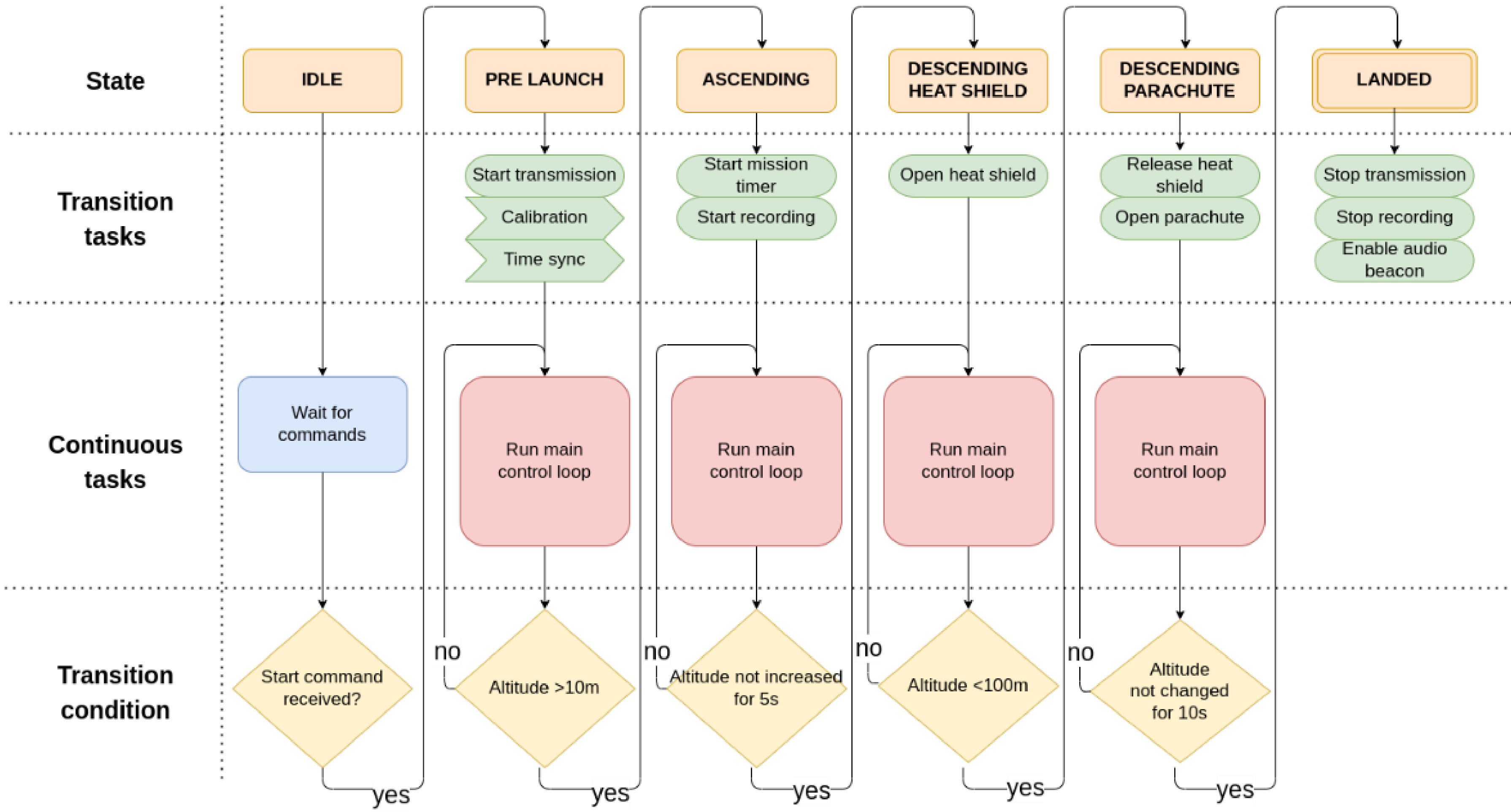


FSW Changes Since PDR

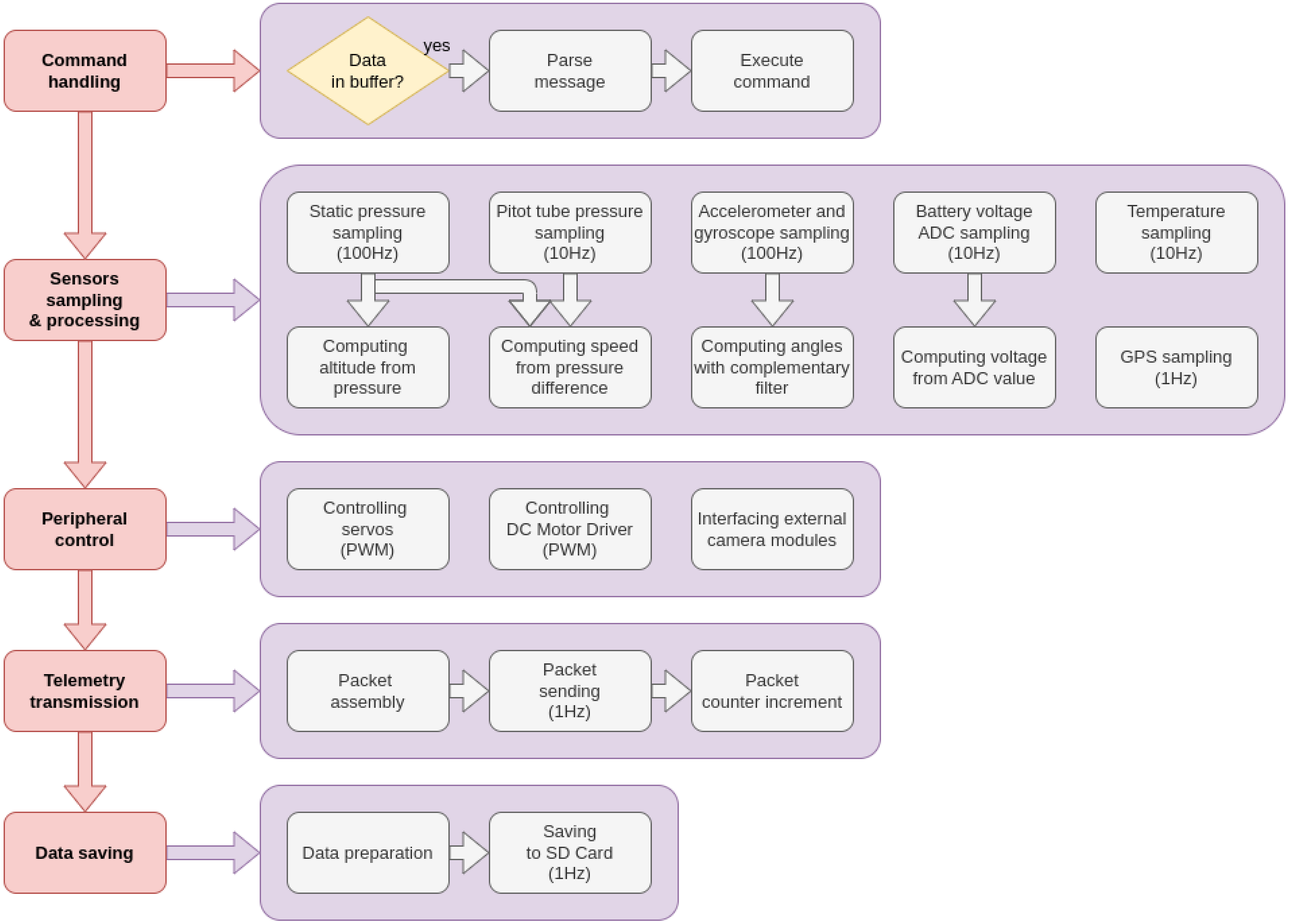
Part	Change	Reasons
Recovery procedure	Added FRAM non-volatile memory for storing the most critical parameters of CanSat.	This type of memory is more reliable than SD Cards.
Camera rotation controll	The BLDC motor was replaced with a DC motor with encoder.	Part availability, easier control algorithm.

Payload CanSat FSW State Diagram (1/3)

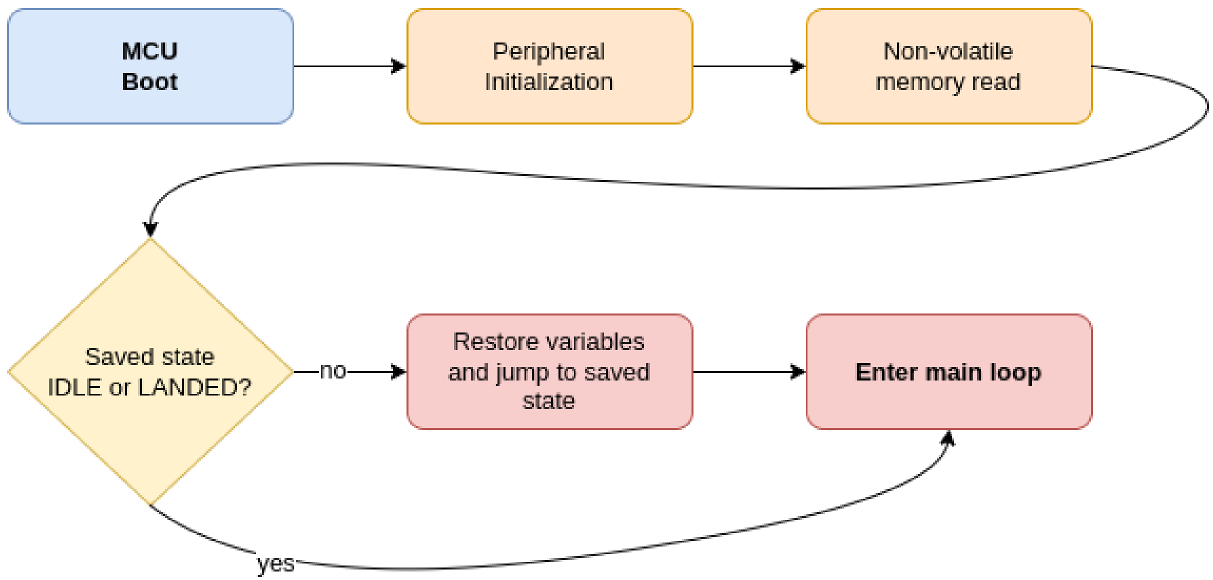
Main decision state machine



Payload CanSat FSW State Diagram (2/3)



Boot and recovery procedure



Possible restart causes:

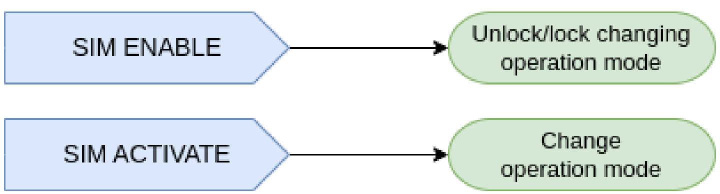
- battery voltage drop,
- contact vibrations,
- watchdog timer firing,
- energetic particle from outer space.

Data stored in non-volatile memory:

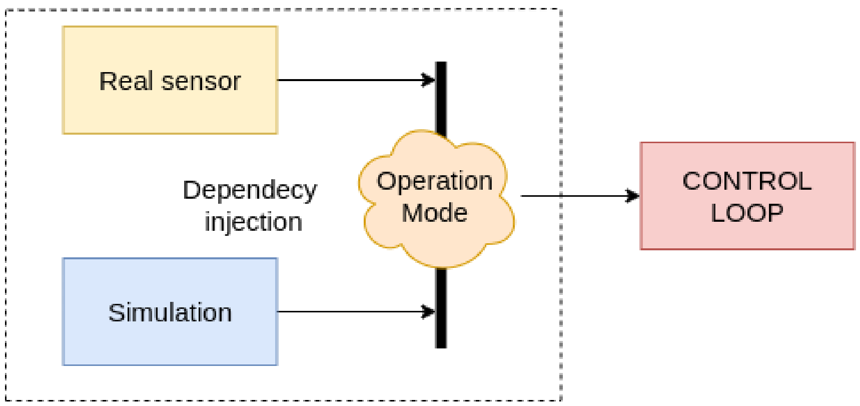
- current state and operational mode,
- mission time,
- radio packet counters,
- calibration values.

Simulation operation mode

Operation mode change procedure



Abstract sensor service



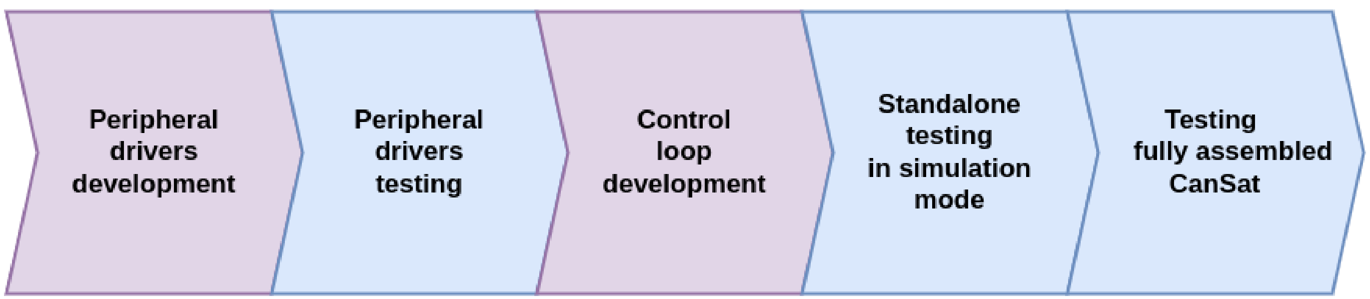
Simulation mode assumptions:

- Operation mode change is initially locked.
- Simulation activation is only possible after unlocking by separate command.
- Real data sampling and simulated data injection is completely transparent to the main control loop.

Software Development Plan (1/2)

Steps to avoid late software development:

- Special team members focused only on software development.
- Writing peripheral libraries with breakout boards before ordering actual PCB.
- Early implementation of simulation mode to test only electronic circuit before final assembly.



Software Development Plan (2/2)

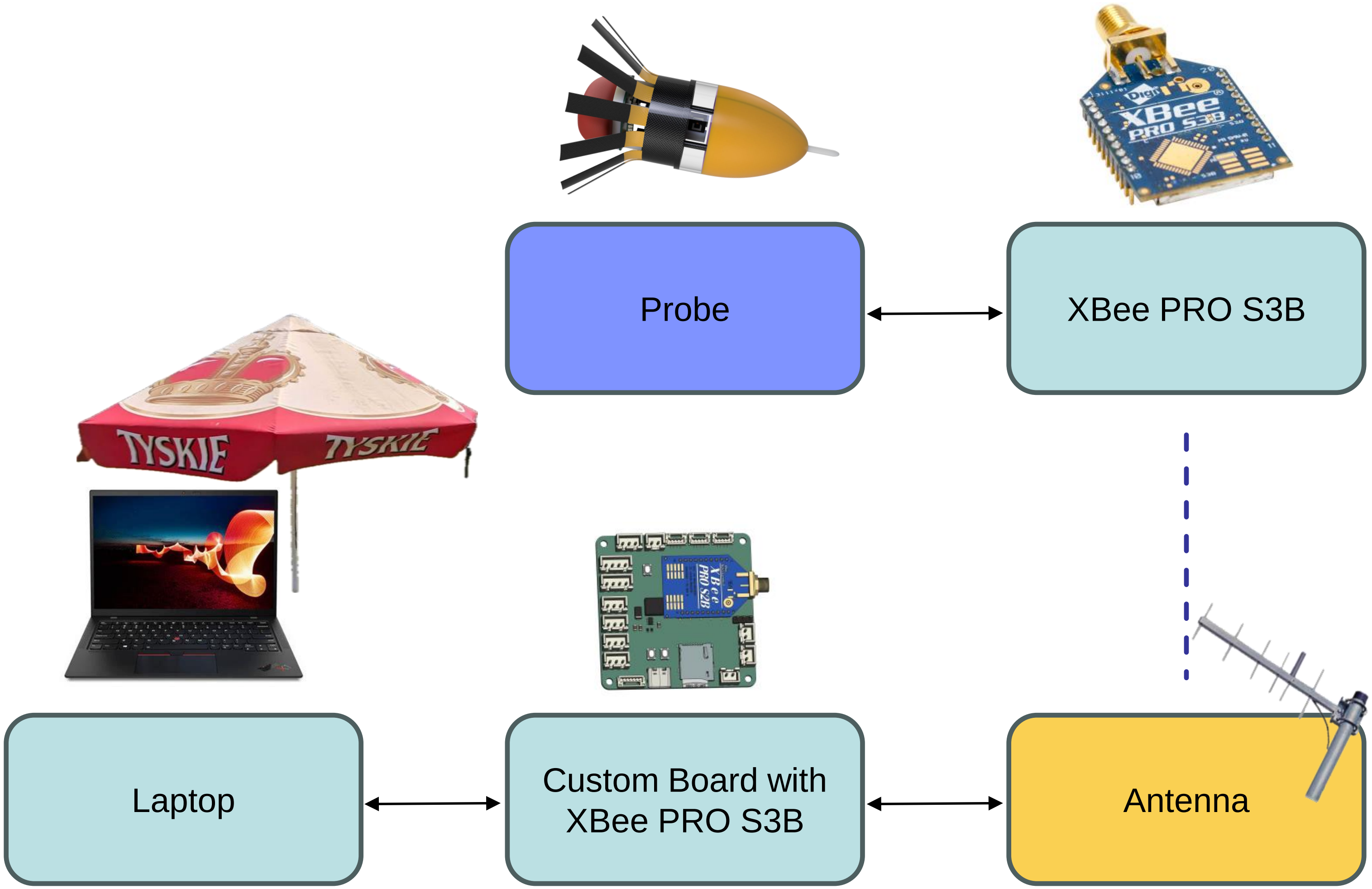
Progress made since PDR:

- Libraries for most peripheral devices has been written and tested using individual breakout boards.
- State machine has been written and is able to perform state changes.
- All pinouts has been consulted and approved with mainboard designer.

Ground Control System (GCS) Design

Tomasz Lubelski

GCS Overview



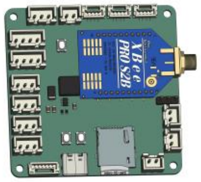
GCS Changes Since PDR

Part	Change
Design	We changed the XBee USB Adapter to our custom board, which allows us to make backups on SD card in case of computer malfunction.
Software	We added buttons for two new commands: “CHUTE” and “HTSHLD”.

GCS Design

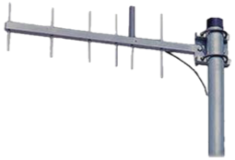
Laptop

USB Serial



Custom Board
with XBee PRO
S3B

RP-SMA - N-Female

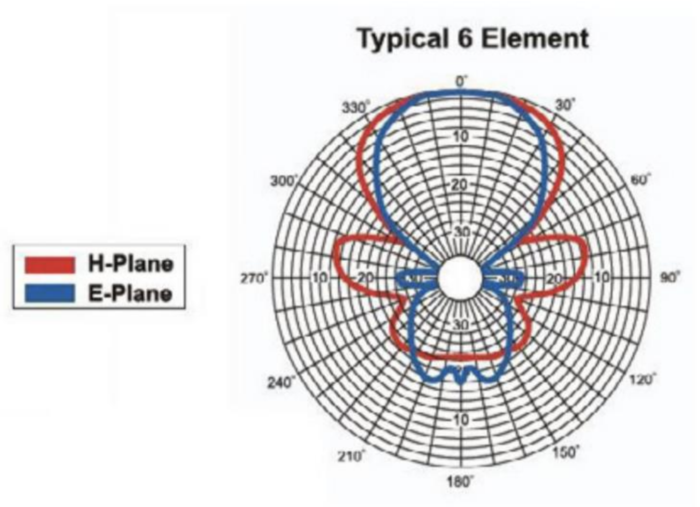


Antenna

Specifications	
Battery	Laptop can operate on battery for a minimum of 2 hours.
Overheating Mitigation	The laptop will be shielded by an umbrella, which not only protects it from the sun but also enhances screen visibility.
Autoupdate Mitigation	The laptop will have a **GNU/Linux** operating system which doesn't force auto-updates.

GCS Antenna (1/3)

Name	Frequency Range [MHz]	Gain (dBd)	Type	Mount	Price [$]
Larid Technologies PC906N	896 - 940	8.5	Yagi	Handheld	65.73

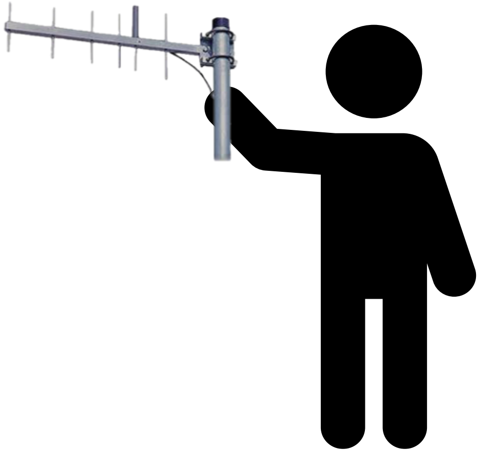


PC906N RADIATION PATTERN

Larid Technologies PC906N
• Good enough gain • Handheld antenna does not require any stand • Portable • Quite cheap

GCS Antenna (2/3)

Antenna mounting design



Antenna will be pointed in direction of CanSat for best signal and minimalize data loss. Its lightweight, portable design allows for easy handling and adjustment.

GCS Antenna (3/3)

Data:

P_{RX} = -42.48 dBm
P_{TX} = 24 dBm
G_{TX} = 1.9 dBi
L_{TX} = 0 dB (negligible)
L_{FS} = 77.03 dBm
G_{RX} = 8.5 dBd = 10.65 dBi
L_{RX} = 2 dB (estimated)
R_S = -101 dBm
d = 800 m
f = 900 MHz

According to our calculations, assuming a distance of 800 metres, the received power is sufficient to maintain a stable connection with a significant power margin.

However, these calculations would need to be verified in real-world conditions.

Free Space Loss Calculation

$$L_{FS} = 20\log_{10}(\mathrm{d}) + 20\log_{10}(\mathrm{f}) + 20\log10(4\pi/c) - G_{TX} - G_{RX}$$

$$L_{FS} = 20log_{10}(800) + 20log_{10}(900 \cdot 10^6) + 20\log10(\frac{4\pi}{3\cdot 10^8}) - 1.9 - 10.65 \approx \mathbf{77.03}\ [dB]$$

Received Power Calculation

$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - L_{TX} - L_{RX} - L_{FS}$$

$$P_{RX} = 24 + 1.9 + 10.65 - 0 - 2 - 77.03 \approx -\mathbf{42.48}\ [dBm]$$

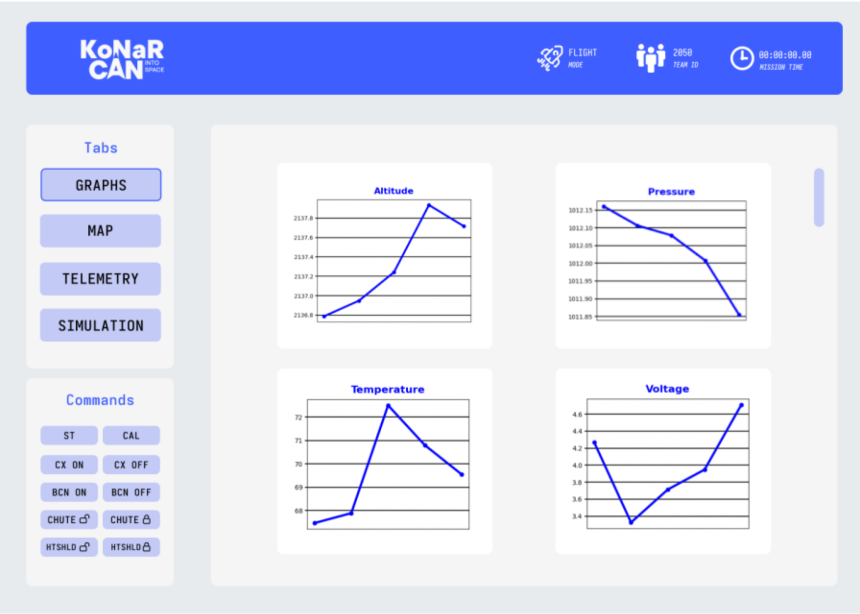
Link Budget

- 42.48 dBm > - 101 dBm

GCS Software (1/5)

Section	Description
Software packages and technologies used	We'll make the GCS software using Python3 and Tkinter to create a user-friendly interface. To ensure we get data on time, we'll use multithreading. This helps the software handle data smoothly while keeping the interface responsive.
Commercial Off The Shelf (COTS) Software Packages Used	XCTU (Configuration Platform for XBee/RF Solutions)
Real-Time Plotting Software Design	The application will feature a „Graphs" tab where users can visualize real-time telemetry parameters. Additionally, there will be a map display showcasing the current GPS location along with telemetry data presented in textual format.
Command Software And Interface	There will be „Commands" widget which allows to send defined commands such as altitude and tilt (row and pitch) calibration command to payload.
Telemetry Data Recording And Media Presentation To Judges For Inspection	Data and media files will be transferred to judges via a USB drive.
Description of .csv Telemetry File Creation For Judges	The received payload telemetry data will be logged into a „Flight_2050.csv" file.
Description of .csv Telemetry File Creation For Judges	In the „Simulation" tab, users can add a read-only .csv file, and simulation mode can be activated by sending the commands 'SIM ENABLE' and 'SIM ACTIVATE.' Once simulation mode is activated, the GCS will transmit lines from the .csv file as pressure data to the payload at a frequency of 1Hz.

GCS Software (2/5)

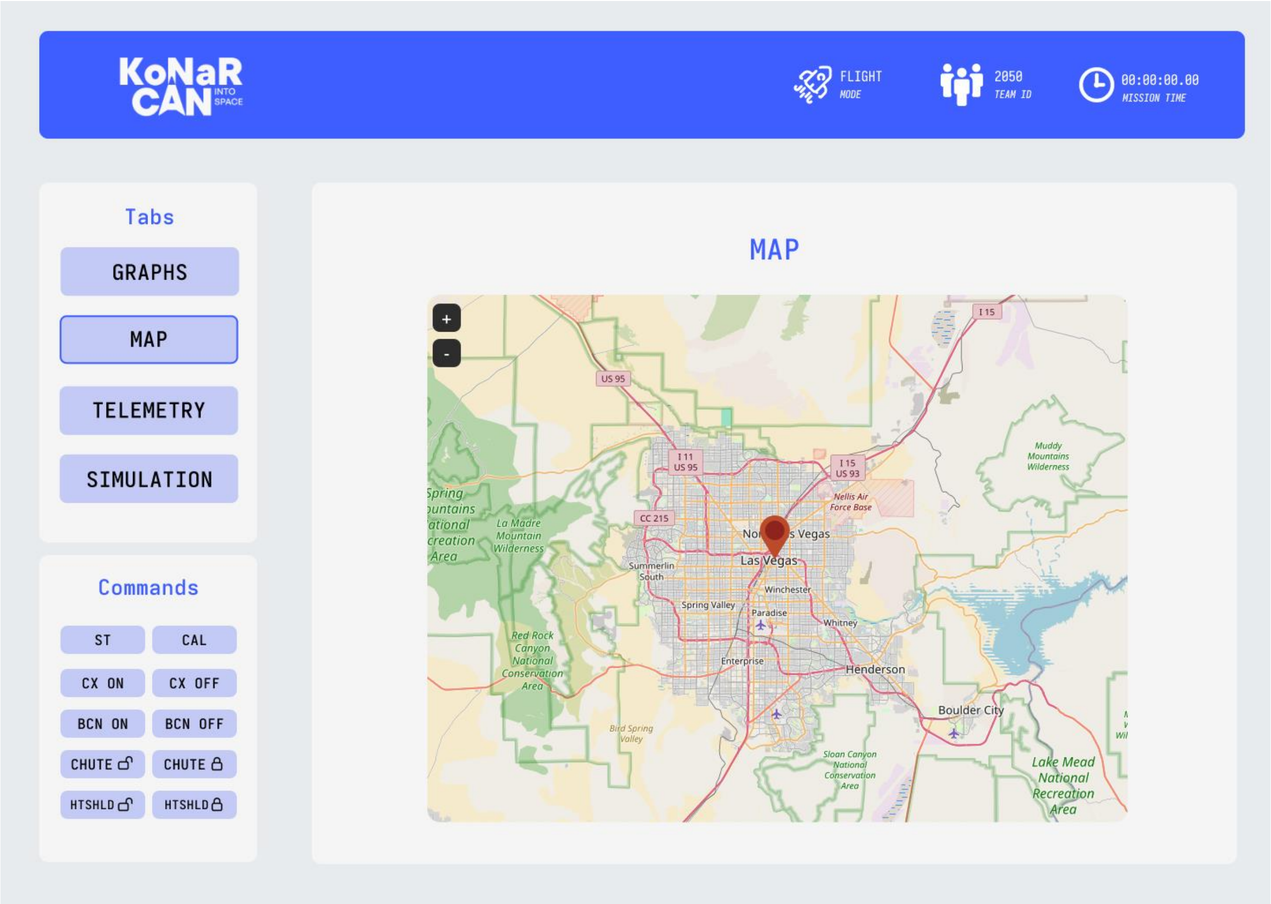


Scroll graphs

Selectable tabs

Commands widget

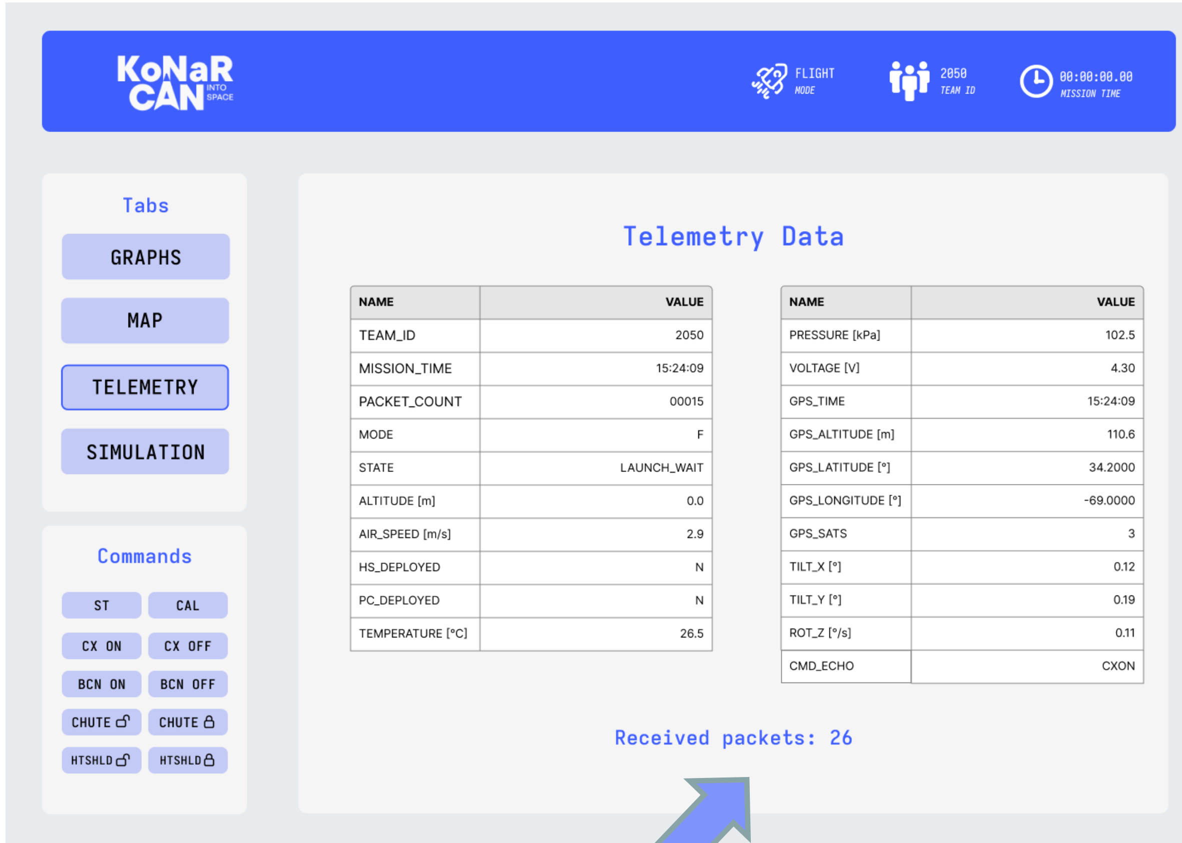
GCS Software (3/5)



Map with actual GPS data

GCS Software (4/5)

Telemetry data display in enginnering units



NAME	VALUE
TEAM_ID	2050
MISSION_TIME	15:24:09
PACKET_COUNT	00015
MODE	F
STATE	LAUNCH_WAIT
ALTITUDE [m]	0.0
AIR_SPEED [m/s]	2.9
HS_DEPLOYED	N
PC_DEPLOYED	N
TEMPERATURE [°C]	26.5

NAME	VALUE
PRESSURE [kPa]	102.5
VOLTAGE [V]	4.30
GPS_TIME	15:24:09
GPS_ALTITUDE [m]	110.6
GPS_LATITUDE [°]	34.2000
GPS_LONGITUDE [°]	-69.0000
GPS_SATS	3
TILT_X [°]	0.12
TILT_Y [°]	0.19
ROT_Z [°/s]	0.11
CMD_ECHO	CXON

Received packets by GCS

GCS Software (5/5)

Simulation mode control tab

CanSat Integration and Test

Krzysztof Kowaczek

CanSat Integration and Test Overview (1/2)

Our CanSat is going to be tested by specified tests:		
Subsystem level	Each subsystem will be tested separately	Sensors, CDH, EPS, Radio Communications, FSW, Mechanical, Descent Control
Integrated level	All subsystems will be put together and tested	Descent Testing, Communications, Mechanisms, Deployment
Simulation level	Flight software logic of Integrated subsystem will be tested in simulation mode	Flight Software Logic, Ground Station Software
Environment level	Our CanSat will be tested in environment similar to specified in the Competition Guide	Drop test, Thermal test, Vibration test, Vacuum test

CanSat Integration and Test Overview (2/2)

Subsystem level	Initially, we will construct preliminary tests on the mechanical structure and perform fitting tests. Concurrently, the electronic circuits will undergo soldering, programming, and troubleshooting.
Integrated level	Once each component is functioning correctly, they will be assembled and evaluated collectively as a single unit.
Simulation level	Following the successful integration test, we will employ a simulation mode to verify the harmonious operation of all mechanisms, communication systems, electronics, and the applied algorithms.
Environment level	Finally, environmental testing will be carried out to confirm the CanSat's operational viability in the designated conditions.

Subsystem Level Testing Plan (1/5)

Subsystem	Test case	Acceptance criteria	Test result
FSW	Microcontroller is correctly initialized	Blinking LED	Not tested
FSW	Debugs logs sending via serial port	Serial interface transmit data	Not tested
FSW	After startup FSW starts in MSM	Debug log that show state switch to MSM	Not tested
FSW	MSM can switch to next mission states	Debug logs indicate that machine is progressing to different states	Not tested
FSW	FSW can survive power cuts	After power cuts, MSM stars from last state and sensors do not loss calibrations settings	Not tested
Mechanical	Payload doesn’t release under shock and vibrations	Payload release mechanism does not release payload	Not tested
Mechanical	Payload is properly separated from Heat shield	Payload is released, mechanism does not get stuck	Not tested
Mechanical	Electronic mounting withstands all shock and vibrations	Electronic is kept in place and do not move arround	Not tested
Mechanical	Parachute opens after release	Parachutes cords don’t tangle	Not tested
Mechanical	Container descents on parachute correctly	The proper speed of descent is maintained	Not tested
Mechanical	Camera rotation mechanism is moving	The DC motor is able to rotate the camera	Tested

Subsystem Level Testing Plan (2/5)

Subsystem	Test case	Acceptance criteria	Test result
Mechanical	Camera rotation mechanism control	Camera is pointing in one direction	Tested
Sensors	Sensors are set up correctly, communication is possible	Sensor's data can be read via debugs logs	Not tested
Sensors	Temperature measurement	Temperature data can be read via debug logs	Tested
Sensors	Pressure measurement	Pressure data can be read via debug logs	Tested
Sensors	Voltage measurement	Voltage value can be read via debug logs	Tested
Sensors	GPS data reading	GPS data can be read via FSW	Tested
Sensors	GPS NEMA frames decoding	GPS time, satellites info, latitude, longitude are available	Tested
Sensors	Altitude measurement	Altitude calculated from test value are similar to value returned by CanSat	Tested
Sensors	Sensors can be calibrated and return zero values when stationary	All values from sensors are zero when CanSat is on the ground	Not tested
Sensors	Camera is recording	Camera records a video with decent quality and framerate	Tested
Sensors	Camera configurations via serial interface	Camera records video with given configuration	Tested
Sensors	Speed measurement in air	Speed can be read via debug logs	Not tested

Subsystem Level Testing Plan (3/5)

Subsystem	Test case	Acceptance criteria	Test result
CDH	File system initialization on SD Card	File system is initialized successfully	Not tested
CDH	SD Card is ready for writing data	File system returns no error when saving files	Tested
CDH	Data can be read from SD Card	Files can be read from filesystem	Tested
CDH	Data are available on FRAM after power loss	Data are always available	Tested
CDH	Real-Time clock measures time	Time of CanSat and Ground Station are synced during the tests	Tested
EPS	Pressure and temperature sensor is powered	Required voltage on necessary pins is measured	Not tested
EPS	GPS sensor is powered	Required voltage on necessary pins is measured	Not tested
EPS	Camera is powered	Required voltage on necessary pins is measured	Not tested
EPS	MCU is powered	Required voltage on necessary pins is measured	Not tested

Subsystem Level Testing Plan (4/5)

Subsystem	Test case	Acceptance criteria	Test result
EPS	microSD card is powered	Required voltage on necessary pins is measured	Not tested
EPS	PCB doesn't have shortcuts	PCB has no shorts to ground or power lines	Not tested
EPS	PCB is properly soldered	No colds joints are presented, and joints are soldered correctly	Not tested
EPS	Battery can withstand high current	Battery can maintain current on high load	Tested
EPS	CanSat can operate for two hours	CanSat battery is not depleted after two hours in idle state	Not tested
EPS	Voltage regulators and DC converters work properly	Proper voltages are maintained on all power lines under load	Not tested
EPS	IMU is powered	Sensor returns proper data	Not tested
EPS	Xbee is powered	Required voltage on necessary pins is measured	Not tested
Descent control	FSW can control deployment mechanisms	The parachute is deployed	Not tested
Descent control	State machine can detect change in flight phases	State is switched when appropriate conditions are met	Not tested
Descent control	Aerobraking heat shield flight keeps correct velocity	CanSat descent with speed of 10 – 30 m/s	Not tested

Subsystem Level Testing Plan (5/5)

Subsystem	Test case	Acceptance criteria	Test result
Descent Control	Parachute flight keeps correct velocity	CanSat descent with speed less than 5 m/s	Not tested
Radio communication	XBee Radio can receive data	Data sent to XBee can be read via debug log	Tested
Radio communication	Xbee Radio can transmit data	Data send from FSW can be read on PC with XBee	Tested
Radio communication	XBee radios NETPID/PANID is set to their team number	NETPID/PANID is set to 2050	Tested
Radio communication	Open air radio range testing	Radio range is enough for at least double of the flight altitude	Not tested
Radio communication	Ground level radio range testing	Radio range is enough for the flight altitude	Not tested
Radio communication	GSC can communicate with the CanSat	The connection is established and stable	Not tested
Radio communication	GCS can transmit and receive data	Data is succesfully transmitted and received	Not tested
Radio communication	GCS data plotting	Data is plotted in real time	Not tested

Integrated Level Functional Test Plan (1/2)

Descent testing
The descent test will cover the whole descent subsystem beginning at separation from the Rocket's airframe. As our design does not include any active deployment mechanism the first passing criteria will be if the CanSat can easily slide out of an airframe mockup. Also the deployment of the ailerons will be verified. Next, the CanSat will be lifted using drone and then released. The stability of flight and camera will be checked. The descent rate shall be in 10 – 30 m/s after separation from the Rocket (drone). Descent rate after heatshield release and parachute opening should drop to 5 m/s or less.
Mechanism testing
The CanSat has to be able to withstand high G's forces acting on the structure and still work as intended afterwards (or even during these conditions). To test if all mechanisms are able to perform as expected, the Environmental Test will be conducted. If all mechanisms survive, the structural integrity is just like before the test and no release mechanism has loosened, the CanSat mechanisms will be declared mission ready. A harder test will be performed, in which all mechanisms will be 'crash-tested'. All mechanisms will be required to move as intended during high-stress situations.
Deployment test
Stationary tests of Aerobraking Heat Shield and parachute opening will be performed first. Later, during Mission Rehearsal, these deployments will be tested in mission-like conditions during the drone test.
Simulation test
SIM ENABLE and SIM ACTIVATE commands will be send to the CanSat from the Ground Station. Then GS is going to send air pressure values in order to override readings from barometer to test FSW behavior without taking it into sky high above.

Integrated Level Functional Test Plan (2/2)

Communications test plan
General test plan: We will perform field tests to check the range communication and bandwidth. The device will be placed on the drone and then we will check the communication between it and the ground station. **Antenna test plan:** Ground station antenna will be tested with varying degrees of precision, aiming it towards the CanSat satellite for evaluation. **Telemetry verification:** We will check the XBee readout to make sure we're getting the packets right, and then we'll confirm if their format is correct for our telemetry data. **Ground station software tests:** We will unit test data reception, command sending, CSV file writing and data plotting modules, followed by integration testing to ensure seamless module interaction. Additionally, we'll perform functional testing to validate software features, user interface testing for usability and readability, and testing for software performance.

Environmental Test Plan

Subsystem	Test case
Drop test	The CanSat would be tied to non-stretching cord and then dropped from height of 61 cm to simulate 30 Gs shock. The mechanical and electronic systems will be checked afterwards. All of them should survive and work as indented.
Thermal test	An isolated chamber made of XPS (extruded polystyrene) will be used. The CanSat placed inside in the chamber, is going to be heated to 60 C with a hair dryer to verify if all systems can work in required temperature range. During the whole test the telemetry is going to be received constantly.
Vibration test	The CanSai is going to be attached to orbital sanders that operate at fixed frequency up to 233 Hz. The system should withstand such vibrations and work properly afterwards. The accelerometer data shall be collected throughout the test.
Vacuum test	The CanSat will be closed in hermetic chamber that is connected to a suction device. The pressure value will decrease and that would affect read altitude which would increase. The test will show how altitude value change when the pressure value change.
Fit check	We are going to prepare a form made with a 3D printer to check if the CanSat would fit and not get stuck in the airframe during separation. The ring is going to have diameter of 141 mm and height of 50 mm.

Test Procedures Descriptions (1/7)

Mechanical			
Test Proc	Test Description	Rqmts	Pass Criteria
1	Payload withstand shocks.	M3	Payload and its components are intact after sudden shock.
2	Payload is properly separated from Rocket.		Payload is released, mechanism does not get stuck
3	Electronic mounting withstands all shock and vibrations.	M3	Electronic is kept in place and do not move around.
4	Electronic withstand environment hazards.		Electonic still working after sudden exposed for shocks or direct sunlight.
5	Battery is easily dismounted from payload.	E3	Battery can be replaced in matter of one minute.
6	Container and payload parachutes open after release.		Parachute cords don't tangle.
7	Container descents on parachute correctly.		The proper speed of descent is maintained.

Test Procedures Descriptions (2/7)

Flight Software			
Test Proc	Test Description	Rqmts	Pass Criteria
1	The microcontroller is correctly initialized		The LED Is blinking
2	Debug logs sending via serial port		Serial interface transmit data
3	After startup FSW starts in MSM		Debug log that show state switch to MSM
4	MSM can switch to next mission slates		Debug logs indicate that machine is progressing to different states
5	FSW can survive power cuts		MSM doesn't loss calibration settings after power cuts.
6	Packet transmission count test	F1	The software maintains and correctly increments a transmission packet count.
7	UTC time synchronization test	F3	The flight software's clock is synchronized to UTC time within one second before launch.
8	Simulation mode and altitude determination test	F4, F5	In simulation mode, the flight software uses radio uplink pressure values to accurately determine the payload's altitude, and the system responds correctly to the SIMULATION ENABLE and SIMULATION ACTIVATE commands.

Test Procedures Descriptions (3/7)

Sensor subsystem			
Test Proc	Test Description	Rqmts	Pass Criteria
1	Temperature measurment	SN3	Temperature data can be read via debug logs
2	Pressure measurment	SN2	Pressure data can be read via debug logs
3	Voltage measurment	SN6	Voltage value can be read via debug logs
4	GPS data reading		GPS data can be read via FSW
5	GPS NEMA frames decoding		Crucial informations from GPS are avaliable
6	Altitude measurment	SN2	Altitude calculated from test value are similar to value returned by CanSat
7	Sensors can be calibrated and return zero values when stationary	G4	All values from sensors are zero when CanSat is on the ground
8	Camera is recording	SN8	Camera records a video with decent quality and framerate
9	Camera configurations via serial interface		Camera records video with given configuration
10	Speed measurement in air	SN1	Speed can be read via debug logs
11	Tilt aproximation and reading		CanSat estimate its tilt correctly and send it to Ground Station

Test Procedures Descriptions (4/7)

Communications and Data Handling			
Test Proc	Test Description	Rqmts	Pass Criteria
1	File system initialization on SD Card		File system is initialized successfully
2	File system initialization on internal Flash		File system is initialized successfully
3	SD Card is ready for writing data		File system returns no error when saving files
4	Data can be read from SD Card		Files can be read from filesystem
5	Data are available on SD Card after power loss		Files are always available
6	Real-Time clock measures time	G6,G8	Time of CanSat and Ground Station are synced during the tests
7	Writing data into Internal Flash		Data can be read from Internal Flash after power cut
8	Transmitting a data packet at a rate of one per second (1Hz)	G3	The data is received with appropriate frequency.
9	Telemetry includes required data	X1, X4, X5	Telemetry system transmits once per second, including all specified data points, and uses the correct XBEE radio settings.
10	Data logging and csv file generation test	G2	The ground station correctly logs sensor data and generates csv files without errors, with the data formatted as specified.

Test Procedures Descriptions (5/7)

Electrical Power System			
Test Proc	Test Description	Rqmts	Pass Criteria
1	Pressure and temperature sensor is powered	X5	Required voltage on necessary pins is measured
2	GPS sensor is powered	X5	Required voltage on necessary pins is measured
3	Camera is powered		Required voltage on necessary pins is measured
4	MCU is powered	X5	Required voltage on necessary pins is measured
5	microSD card is powered		Required voltage on necessary pins is measured
6	PCB doesn't have shortcuts		PCB has no shorts to ground or power lines
7	PCB is properly soldered		No colds joints are presented, and joints are soldered correctly
8	Battery can withstand high current		Battery can maintain current on high load
9	CanSat can operate for two hours		CanSat battery is not depleted after two hours in idle state
10	Voltage regulators and DC converters work properly		Proper voltages are maintained on all power lines under load
11	IMU is powered	X5	Sensor returns proper data
12	Xbee is powered	X5	Required voltage on necessary pins is measured
13	Protection against power surge		Battery is still operational after mayor hardware power malfunction

Test Procedures Descriptions (6/7)

Integrated level testing			
Test Proc	Test Description	Rqmts	Pass Criteria
1	Descent testing: CanSat dropped from a drone will maintain its descent velocity required by mission guide.		Descent velocity read from sensors during each FSW state will be in the required range.
2	Camera stability during descent.		Camera should keep it position and record stable film recording.
3	Communication range test on the field.		CanSat and GS should maintain connection at maximum distance specified in mission guide.
4	Communication bandwidth test.		CanSat and GS should maintain reasonable communication bandwidth during mission.
5	Payload mechanism can release the payload		When released the payload drops out of the container.
6	Parachute release test.	C5	Parachute is released without any distrubance.
7	Heatshield deployment test	C3	Heatshield is deployed properly during test.
8	G-force mechanical stress test	S6,S7	CanSat is able to withstand G-force specified in mission guide.
9	Simulation engagement test.	F6	CanSat enters into simulation mode after reciving SIM ENABLE and SIM ACTIVATE commands from GS.
10	Air pressure data receiving during simulation.	F5	CanSat in simulation mode recive air pressure values from GS and use them instead of values from real sensors.

Test Procedures Descriptions (7/7)

Environmental Test Plan			
Test Proc	Test Description	Rqmts	Pass Criteria
1	Drop test from height of 61 cm to test it against shock resilience		The mechanics and electronics of CanSat should be intact after test.
2	Thermal test: CanSat resistance for high temperature.		CanSat should withstand temperature of 60 degrees Celsius.
3	Telemetry works in high temperature.		In temperature of 60 degrees Celsius CanSat should keep its telemetry working.
4	Vibration test: CanSat mechanical test against vibrations.		CanSat structure should withstand vibration with frequency of 233 Hz and works as intendent after test.
5	Accelerometer working during vibration test.		During vibration test accelerometer shall record data and maintain its working afterwards.
6	CanSat altitude reading based on air pressure.	SN2	Altitude reading should increase when air pressure decreases.
7	Fit check, if the CanSat would fit in the airframe during mission.		CanSat should fit into round contraption with diameter of 141 mm and height of 50 mm and not get stucked.

Simulation Test Plan

Simulation mode is used for easy FSW testing.

This mode replaces readings of from real pressure sensor for values received from ground station. It doesn't interfere with other sensors readings – the rest of values, other than the pressure and altitude will be readings from real sensors.

Sequence of operations:

- The simulation mode is activated by command SIM ENABLE and SIM ACTIVATE sent from Ground Station to the payload.
- Ground Station will start sending air pressure values, from provided flight profile CSV file, using barometric pressure sensor commands.
- FSW will replace received values and use them instead of data from pressure sensor.
- Simulation mode is disabled with SIM DISABLE command send from GS.

Mission Operations & Analysis

Krzysztof Kowaczek

Overview of Mission Sequence of Events (1/2)

Sequence	Event	Tasks to perform
1	Arrival at launch site	• Safely arriving on time at the launch site • Inspection of the CanSat or Ground Station equipment for any damage
2	CanSat preparations	• CanSat assembly • Ground Station assembly • Testing of all mechanisms and telemetry • CanSat check-in
4	Pre-launch	• Setting up the Ground Station in the intended area • Integration of the CanSat into the rocket • Moving the rocket to the launch site • Communication check
5	Launch	• Launch procedures execution • Flight operations
6	Recovery	• Submission of telemetry data received by the Ground Station • Clearing the ground station area • Heading out to recover the CanSat • Presentation of the CanSat to the judges before disassembly and recovery of video data
7	Data analysis	• Telemetry and video data analysis and preparation of PFR

Overview of Mission Sequence of Events (2/2)

Role	Team member(s)	Responsibilities
Mission Control Officer (MCO)	Mateusz Morawiak	• Overview and managing of team operations • Verify that CanSat is ready for launch • Performing countdown
Ground Station Crew (GSC)	Mateusz Zolisz Tomasz Lubelski Mateusz Wojtaszek	• Setting up the Ground Station • Verification of communication • Handling hand-held antenna • Submission of received telemetry data
Recovery Crew (RC)	Natalia Nienartowicz Kamil Winnicki	• Observations of CanSat flight trajectory • Recovery of CanSat and its telemetry data
CanSat Crew (CC)	Paweł Iwańczyk Krzysztof Kowaczek Patryk Peroński	• Final tests and inspection before CanSat check-in • Status verification • Integration of the CanSat into the rocket

Field Safety Rules Compliance

Mission Operations Manual	
Section	**Description**
Ground Station Configuration	Process for setting up the ground station as well as initializing communication between the CanSat and the ground station.
Cansat Preparation	Instructions for assembly and checklist of what needs to be verified to be sure the Cansat is working properly.
Cansat Integration	Instructions for how to turn on the Cansat, verificate status and integration of the Cansat into the Rocket airframe.
Launch Preparation	Instructions for delivery and installation of rocket on launch pad.
Launch Procedure	Event sequence guide for Mission Control Officer. Checklist to verify if Cansat is go for launch.

Development status and plan:

- Mission Operations Manual has been downloaded and general assumption about the Cansat have been written down. The MOM is available to all team members on our Google Drive cloud.
- More detailed instructions will be written at the time of assembly of the Cansat.
- The MOM will be revised at the Environmental Tests to check if everything is well unterstood.

CanSat Location and Recovery

Section	Description
CanSat payload recovery	A gold mylar streamer will be attached to the CanSats parachute, that will help track it visually. The last GPS position will also be used to determine its last known position. The audio beacon will help locate it in proximity. Any structural elements will be painted fluorescent orange.
Detachable heat shield recovery	The heat shield will be painted bright orange. As it will not contain any electronics one member of the Recovery Team will be assigned to specifically observe the descent to locate the heat shield as we don't want to cause unnecessary littering.
Labeling	Both the detachable heat shield and internal electronics (payload) will be labeled with the team contact info by glueing stickers in visible places. An example sticker (fake information provided only for demonstration purposes) is presented below.

CanSat competition 2024

Contact information:
Krzysztof Kowaczek
+01 234 567 890
team2050@example.com

Mission Rehearsal Activities (1/2)

Procedure	Description
Ground System Radio Link Check	The Ground Station will be set up and the CanSat will be powered on. Telemetry data received from the CanSat should be received and data should be plotted on the Ground Station software. Commands will be sent to check two-way communication.
Powering on/off the CanSat	The CanSat will be analyzed for any missing mechanical parts and for any unplugged connector. The CanSat Crew will be responsible for detecting such error, while other members will leave a part not mounted, to ensure that the CanSat Crew is prepared for any possibility. Next the power switch will be turned on and power to all systems will be verified.
Launch Configuration Preparations	The CanSat will be disassembled. The structure is designed in a way that allows access to inner workings. A dummy hen's egg will be placed inside Egg Compartment. The CanSat will be assembled again. The battery will be charged using the umbilical power source to ensure the CanSat has enough operating time left. A static mechanism test will be performer.

Mission Rehearsal Activities (2/2)

Procedure	Description
Loading the CanSat in the Launch Vehicle	A mockup cardboard tube, that simulates the Rockets airframe, will be prepared. All pre-insertion actions will be performer such as: checking for any damage or unplugged connectors, powering up the CanSat and verifying that all systems are operating correctly. At last the ailerons will be bend back and the CanSat will be inserted into the Rockets airframe.
Telemetry Processing, Archiving, and Analysis	Data obtained from test runs will be saved to a csv file. Then the data will be analyzed: altitude and pressure will indicate when the CanSat was lifted or lowered down, tilt readings will show how much the CanSat was off the nadir direction, etc. This way we will familiarize ourselves with the telemetry format.
Recovery	One part of the team will place the CanSat in high grass, while the other part will watch on data plots and GPS position. The audio beacon will be turned on. The Recovery Team will be responsible for searching for the CanSat without visuals.

None of the described rehearsals were performer to the date of March 29, 2024. However we plan on using a cargo quadcopter drone from our science club to perform a mission simulation with lower alitdute to check if every system is performing as intendet. The mission rehearsal is scheduled for May.

Requirements Compliance

Krzysztof Kowaczek

Requirements Compliance Overview

The existing design fulfills almost all specified requirements; however, there is a possibility of incorporating some modifications before the construction phase to enhance the system. Testing is needed.

Some important tests that were required to meet the requirements still need to bee performed. Other tests like environmental and descent will be done in near future.

We defined most tests to seek for any improvement for our design. Although our project should be sufficient for the tasks mentioned in Mission Guide.

Following slides provide information about design compliance to requirements based on Mission Guide.

Requirements Compliance (1/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C1	The CanSat shall function as a nose cone during the rocket ascent portion of the flight.	Comply	25, 41	
C2	The CanSat shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	21	
C3	After deployment from the rocket, the CanSat shall deploy its heat shield/aerobraking mechanism.	Comply	21, 41	
C4	A silver or gold mylar streamer of 50 mm width and 1.5 meters length shall be connected to the CanSat and released at deployment. This will be used to locate and identify the CanSat.	Comply	21	
C5	At 100 meters, the CanSat shall deploy a parachute and release the heat shield.	Comply	21, 41	
C6	Upon landing, the CanSat shall stop transmitting data.	Comply	99	
C7	Upon landing, the CanSat shall activate an audio beacon.	Comply	99	
C8	The CanSat shall carry a provided large hen's egg with a mass range of 51 to 65 grams.	Comply	66-68	
C9	0 altitude reference shall be at the launch pad.	Comply	99	

Requirements Compliance (2/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
C10	During descent with the heat shield deployed, the descent rate shall be between 10 to 30 m/s.	Partial comply	49, 51	Testing needed
C11	At 100 meters, the CanSat shall have a descent rate of less than 5 m/s.	Partial comply	50, 51	Testing needed
C12	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost of the CanSat. Equipment from previous years shall be included in this cost, based on current market value.	Comply	160	
S1	The CanSat mass shall be 900 grams +/- 10 grams without the egg being installed.	Comply	72	Weight will be added
S2	Nose cone shall be symmetrical along the thrust axis.	Comply	23	
S3	Nose cone radius shall be exactly 71 mm.	Comply	23	
S4	Nose cone shoulder radius shall be exactly 68 mm.	Comply	23	
S5	Nose cone shoulder length shall be a minimum of 50 mm.	Comply	23	
S6	CanSat structure must survive 15 Gs vibration.	Partial comply	69	Testing needed
S7	CanSat shall survive 30 G shock.	Partial comply	69	Testing needed
S8	The CanSat shall perform the function of the nose cone during rocket ascent.	Comply	21	

Requirements Compliance (3/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
S9	The rocket airframe can be used to restrain any deployable parts of the CanSat but shall allow the CanSat to slide out of the payload section freely.	Comply	59	
S10	The rocket airframe can be used as part of the CanSat operations.	Comply	60	
S11	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high-performance adhesives.	Comply	56, 58	
M1	No pyrotechnical or chemical actuators are allowed.	Comply	61, 64, 68	
M2	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting the vegetation on fire.	Comply	61, 64, 68	No mechanisms will use heat.
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Partial comply	69	Testing needed
M4	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	93	No spring contacts
M5	The CanSat shall deploy a heat shield after deploying from the rocket.	Comply	21	
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s.	Comply	49	

Requirements Compliance (4/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
M7	At 100 meters, the CanSat shall release a parachute to reduce the descentrate to less than 5 m/s.	Comply	22, 99	
M8	The CanSat shall protect a hen egg from damage during all portions of the flight.	Comply	68	
M9	If the nose cone is to be considered as part of the heat shield, the documentation shall identify the configuration.	Comply	24	
M10	After the CanSat has separated from the rocket and if the nose cone portion of the CanSat is to be separated from the rest of the CanSat, the nose cone portion shall descend at less than 10 meters/second using any type of descent control device.	Comply	24	Heat shield is integral part of the aerobraking mechanism
E1	Lithium polymer batteries are not allowed.	Comply	93	
E2	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	Comply	93	
E3	Easily accessible power switch is required.	Comply	92	
E4	Power indicator is required.	Comply	69, 92	
E5	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	94	

Requirements Compliance (5/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
X1	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	81	
X2	XBEE radios shall have their NETID/PANID set to their team number.	Comply	82	
X3	XBEE radios shall not use broadcast mode.	Comply	82	
X4	The CanSat shall transmit telemetry once per second.	Comply	82	
X5	The CanSat telemetry shall include altitude, air pressure, temperature, battery voltage, CanSat tilt angles, air speed, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	Comply	85	
SN1	CanSat shall measure its speed with a pitot tube during ascent and descent.	Comply	35, 83	
SN2	CanSat shall measure its altitude using air pressure.	Comply	31, 83	
SN3	CanSat shall measure its internal temperature.	Comply	32, 83	
SN4	CanSat shall measure its angle stability with the aerobraking mechanism deployed.	Comply	36	
SN5	CanSat shall measure its rotation rate during descent.	Comply	37, 84	
SN6	CanSat shall measure its battery voltage.	Comply	34, 83	

Requirements Compliance (6/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
SN7	The CanSat shall include a video camera pointing horizontally.	Comply	45	
SN8	The video camera shall record the flight of the CanSat from launch to landing.	Comply	22	
SN9	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	38	
G1	The ground station shall command the CanSat to calibrate the altitude to zero when the CanSat is on the launch pad prior to launch.	Comply	87, 112, 113	
G2	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	87, 116	
G3	Telemetry shall include mission time with 1 second or better resolution.	Comply	84, 112	
G4	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Comply	77, 112	
G5	Each team shall develop their own ground station.	Comply	106	
G6	All telemetry shall be displayed in real time during descent on the groundstation.	Comply	113	

Requirements Compliance (7/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G7	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.) and the units shall be indicated on the displays.	Comply	115	
G8	Teams shall plot each telemetry data field in real time during flight.	Comply	112, 113	
G9	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and an antenna.	Comply	108	
G10	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	Comply	108	
G11	The ground station software shall be able to command the payload to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Comply	116	
G12	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the CanSat.	Comply	112	
G13	The ground station shall use a tabletop or handheld antenna.	Comply	109	

Requirements Compliance (8/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
G14	Because the ground station must be viewed in bright sunlight, the displays shall be designed with that in mind, including using larger fonts (14 point minimum), bold plot traces and axes, and a dark text on light background theme.	Comply	113,114,115	
G15	The ground system shall count the number of received packets. Note that this number is not equivalent to the transmitted packet counter, but it is the count of packets successfully received at the ground station for the duration of the flight.	Comply	115	
F1	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Comply	101	
F2	The CanSat shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	101	
F3	The CanSat shall have its time set to within one second UTC time prior to launch.	Comply	87, 100	
F4	The flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	Comply	102	

Requirements Compliance (9/9)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
F5	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the payload altitude.	Comply	102	
F6	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	102	

Management

Krzysztof Kowaczek

Status of Procurements (1/3)

Electrical components			
Component	Quantity	Date of ordering	Status
ESP-32-CAM	2	December 2024	Received
XBP9B-DMST-012	1	December 2024	Received
ANTX150P118B09153	1	February 2024	Received
Electrical wires	N/A	February 2024	Received
SANDISK Ultra microSDHC 32GB	3	03/19/2024	Received
Samsung INR18650-25R	1	03/19/2024	Received
DC motor	1	03/19/2024	Received
9g Servo	3	03/19/2024	Received
Custom PCB board with sensor assembly	2	03/27/2024	Awaiting (expected arrival 04/09/2024)
Connectors fow manual assembly	N/A	03/28/2024	Awaiting (expected arrival 04/02/2024)
RTC battery	1	03/28/2024	Awaiting (expected arrival 04/02/2024)

Status of Procurements (2/3)

Mechanical components/materials			
Component	Quantity	Date of ordering	Status
Filament for 3d printing	2	03/07/2024	Received
Carbon fibre tube	1	03/07/2024	Received
Poliuretan foam	1	03/07/2024	Received
Acrylic tube	1	03/07/2024	Received
Styrofoam block	1	03/07/2024	Received
FR4 laminate	3	03/07/2024	Received
Brass rod	2	03/07/2024	Received
Pins and screws	N/A	03/07/2024	Received
Glue	2	03/07/2024	Received
Nylon cords for parachute	1	03/23/2024	Received
Nylon fabric for parachute	1	03/23/2024	Received
Carbon fibre fabric plain	1	N/A	To be ordered
Aramid fibre fabric plain	1	N/A	To be ordered
Epoxy resin	1	N/A	To be ordered
Gold mylar	1	N/A	To be ordered

Not ordered materials are to be obtained from a sponsor, we will use 3D printed parts as substitute for prototyping purposes for now.

Status of Procurements (3/3)

Ground Station components			
Component	Quantity	Date of ordering	Status
XBee USB adapter	1	December 2024	Received
Antenna adapter	1	03/28/2024	Awaiting (expected arrival 04/02/2024)
Larid Technologies PC906N	1	03/28/2024	Awaiting (expected arrival 04/02/2024)

*N/A is used in two ways:
- It indicates that some parts are difficult to count (i.e. many component types and quantities are needed or they were ordered bulk)
- Not Available, because it will be ordered soon

CanSat Budget – Hardware (1/3)

Material name	Price per piece	Quantity	In total	Status
Carbon fibre fabric plain	$49.75	1	$49.75	Actual
Aramid fibre fabric plain	$16.83	1	$16.83	Actual
Filament for 3D printing	$11.31	2	$22.62	Actual
Carbon fibre tube	$16.08	2	$32.16	Actual
Poliuretan foam	$30.65	1	$30.65	Actual
Acrylic tube	$34.17	1	$34.17	Actual
Styrofoam block	$10.05	1	$10.05	Actual
Brass rod	$7.04	1	$7.04	Actual
Pins and screws	$10.05	1	$10.05	Actual
Glue	$12.56	1	$12.56	Actual
Nylon fabric for parachute	$18.84	1	$18.84	Actual
Parachute materials	$22.61	1	$22.61	Actual
FR4 laminate	$11.22	3	$33.66	Actual
Epoxy resin	$2.51	1	$2.51	Actual

Cost of all mechanical parts and structural materials: $285.15

CanSat Budget – Hardware (2/3)

Component name	Price per piece	Quantity	In total	Status
Custom PCB board	$42.71	2	$42.71	Actual
SANDISK Ultra microSDHC 32GB	$6.28	3	$18.84	Actual
XBP9B-DMST-012	$56.83	1	$56.83	Actual
ANTX150P118B09153	$1.56	1	$1.56	Actual
Samsung INR18650-25R	$5.50	1	$5.50	Actual
DC motor with gearbox	$24.75	1	$24.75	Actual
9g Servo	$5.03	3	$15.09	Actual
ESP32-CAM	$8.28	2	$16.56	Actual
Electrical wires	$17.59	1	$17.59	Actual
Connectors	$12.31	1	$12.31	Actual
GPS GY-NEO6MV2	$6.78	1	$6.78	Actual
LPS22	$2.85	2	$5.90	Actual

Cost of all electronic components : $224.40

CanSat Budget – Hardware (3/3)

Section	Cost
Mechanical parts and materials	$285.15
Electronics	$224.40
Total CanSat probe cost	**$509.55**

All prices were converted to dollars from Polish zloty. The exchange ratio at the day of calculations was USD/PLN = 3.98.

No part nor material was used previously, so all parts and materials are new.

CanSat Budget – Other Costs (1/2)

Ground Station equipment	Price	Quantity	In total	Status
Antenna - Larid Technologies PC906N	$65.57	1	$65.57	Actual
Antenna adapter	$10.90	1	$10.90	Actual
XBee	$56.83	1	$56.83	Actual
Laptop – we will use our own	$750	0	$0	Estimated

Ground Station expenses: $133.3

Expense	Price	Quantity	In total	Status
Flight tickets	$900	9	$8100	Estimated
Accomodation	$900	9	$8100	Estimated
Car rental and fuel	$1800	1	$1800	Estimated
Meals	$250	9	$2250	Estimated
Competition fee	$200	1	$200	Actual

Travel expenses can change depending on team size changes.

Travel expenes and fee: $20700

CanSat Budget – Other Costs (2/2)

Expense	Price
CanSat probe	$509.55
Ground Station	$133.3
Travel	$20700
Total:	**$21342.85**

Income source	Funds	Status
University funding	$7537.69	Obtained
Active sponsors	$4371.78	Actual
Planned sponsors	$9500	To be obtained

Budget summary:

- Our Students Interest Group „KoNaR” has a lot electronical and material resources available for prototyping, along with a well-equipped workshop. We don’t have to worry about prototyping expenses.
- We still need to obtain a lot of funds to be able to travel to the competition with all team members. We plan to obtain a few crucial sponsors, that were eager on sponsoring us regarding other projects.
- If something regarding sponsors goes wrong, we will still be able to fund the travel expenses by ourselves, dividing the remaining cost equally.

Program Schedule Overview

Event/Activity	Oct.		November				December				January					February				March				April					May				June	
	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10
Team application		■	■																															
Mission requirements analysis			■	■	■	■	■																											
Design overview							■	■	■	■	■																							
PDR preparation									■	■	■	■	■	■	■																			
Winter break									■	■	■																							
Prototype testing														■	■	■	■	■	■	■	■	■	■	■	■									
Exams																■	■	■																
PDR presentation																		■																
Inter-semester break																		■	■															
CDR preparation																				■	■	■	■											
Easter break																							■	■										
CDR presentation																										■								
CanSat assembly and testing																						■	■	■	■	■	■	■	■					
Environmental tests																												■	■	■	■			
FRR																																	■	
Launch date																																	■	
PFR																																	■	

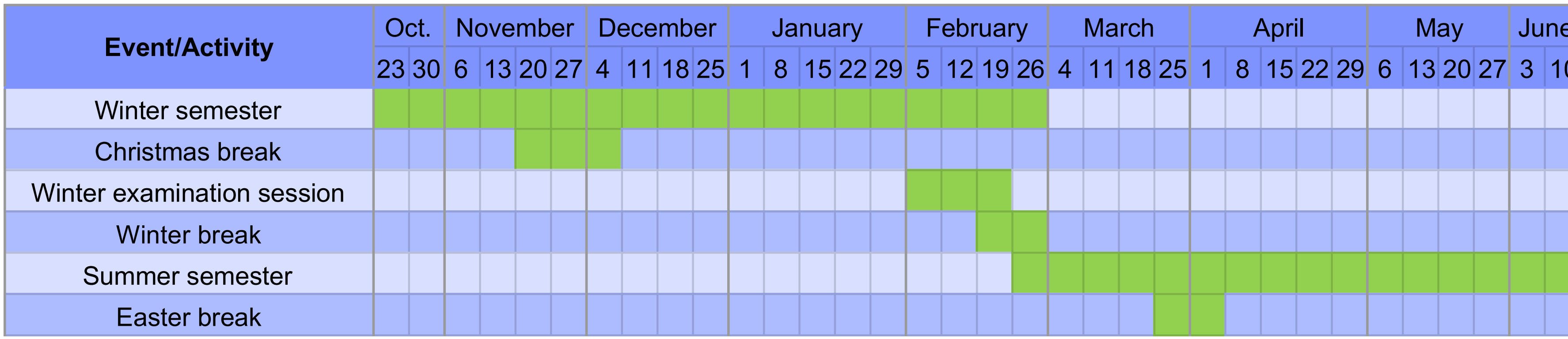
Detailed Program Schedule (1/3)

Event/Activity	Oct.		November				December				January					February				March				April					May				June		Team member(s)
	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	
Checking electronics and software requirements		■	■	■	■																														Electronics and Software teams
Selection of individual elements						■	■	■																											Electronics team
Test of cameras									■	■	■																								Patryk Peroński
Sensor tests									■	■	■	■	■	■	■	■	■																		Krzysztof Kowaczek, Tomasz Lubelski
Preparation of PCB																			■	■	■	■	■	■											Krzysztof Kowaczek
Components ordering																					■	■	■												Krzysztof Kowaczek
Checking the correctness of PCB execution																								■	■	■									Tomasz Lubelski, Mateusz Wojtaszek
Software development																									■	■	■								Software team
Software debugging and testing																										■	■	■							Electronics and Software teams
Integration of elctronic subsystems																												■	■	■					Electronics team
Simulation tests																													■	■	■				Whole team
Software selection for GS							■	■	■	■	■	■	■																						GS team
GUI design selection											■	■	■	■	■																				GS team
Development of backend													■	■	■	■	■	■	■	■	■	■													Mateusz Zolisz
GCS integration																				■	■	■	■	■	■	■	■								GS team
GCS debugging and testing																												■	■	■	■				Software and GS teams

Detailed Program Schedule (2/3)

Event/Activity	Oct.		November				December				January					February				March				April					May				June		Team member(s)
	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	
Checking mechanical requirements		■	■	■																															Mechanics team
Mechanical design concept 1 planning					■	■	■	■	■																										Paweł Iwańczyk, Natalia Nienartowicz
Mechanical design concept 2 planning					■	■	■	■	■																										Kamil Winnicki
Materials research							■	■	■	■																									Mechanics team
3D CAD model design 1									■	■	■	■	■	■																					Paweł Iwańczyk
3D CAD model design 2									■	■	■	■	■	■																					Kamil Winnicki
Advice on the manufacturing process														■	■	■	■																		Natalia Nienartowicz, Paweł Iwańczyk
Improvement to the design																■	■	■	■																Mechanics team
Ordering of materials																				■	■	■	■												Krzysztof Kowaczek
Construction work of critical substructures																				■	■	■													Paweł Iwańczyk
Strength testing																						■	■												Kamil Winnicki
Construction work of whole structure																							■	■	■										Mechanics team
Integration with electronics																									■	■									Natalia Nienartowicz
Mechanical tests																										■	■	■							Mechanics team
Environmental tests																												■	■	■	■				Whole team
Preparation for shipment																																■			Natalia Nienartowicz

Detailed Program Schedule (3/3)



Status of work completeness:
We are currently deep in construction work of the Cansat. Some tasks may require more time than other, but taking in consideration all work that had to be done and what's left, we estimate our work is **about 60% complete.**

As our team has to travel accross the Atlanitc Ocean to come to the competition we had to think hard how to transport everything. After consultations with other people from our science club (which have some experience with travelling abroad) we decided for taking the risk and bringing the Cansat equipment in our luggage.

Preparation for transport → The Cansat will be disassembled and placed into small cushioning packages. Spare parts will also be packed. Every team member will store a part and some tools in their luggage taking limitations into account.

Transport methods → We plan to arrive one week before the competition to New York and wait a few days for eventual missed luggage. We will rent two cars to drive to Blacksburg.

After arrival → All parts and tools will be checked and the Cansat will be assembled for the competition. Spare parts will be used in case something was damaged during transport

Conclusions (1/2)

Major accomplishments
• The camera rotation mechanism has been tested. • Camera has been written and the cameras have been tested. • The circuit board has been designed. • The majority of components are already in our possession. • We have written libraries for all sensors and we are obtaining required data. • The Flight Software integrates all sensor libraries, the state machine is defined and is able to transit between states. The software however is currently developed on a stm32-nucleo board, but can be easily ported to other boards.
Major unfinished work
• Most testing has not yet been conducted • The circuit board is in transit • CanSat has not yet been assembled • Some parts and materials have to be ordered • More funding is to be obtained, but we will be able fund the travel on our own if no more sponsors are to be found.

Conclusions (2/2)

Final conclusion
• All preliminary steps to engineer the CanSat probe have been completed. • We are prepared to proceed with our tasks, maintaining adherence to the timeline. • Our confidence in our design remains steadfast.