CanSat 2024
Preliminary Design Review (PDR)
Version 1.0

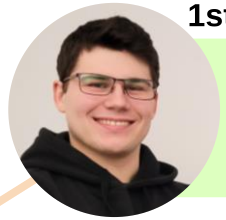
Team 2050

KoNaR Can

Presentation Outline

Team Organization

dr inż. Robert Muszyński
- Faculty Advisor



1st Master

Krzysztof Kowaczek
- Team leader
- Electronics
- Software

2nd Bachelor

Mateusz Wojtaszek
- Electronics
- Software

2nd Bachelor

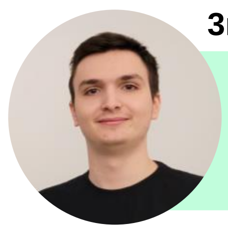
Mateusz Morawiak
- Finances & support
- Public Relations

3rd Bachelor

Natalia Nienartowicz
- Mechanics

1st 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

Systems Overview

Krzysztof Kowaczek,
Paweł Iwańczyk

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.

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

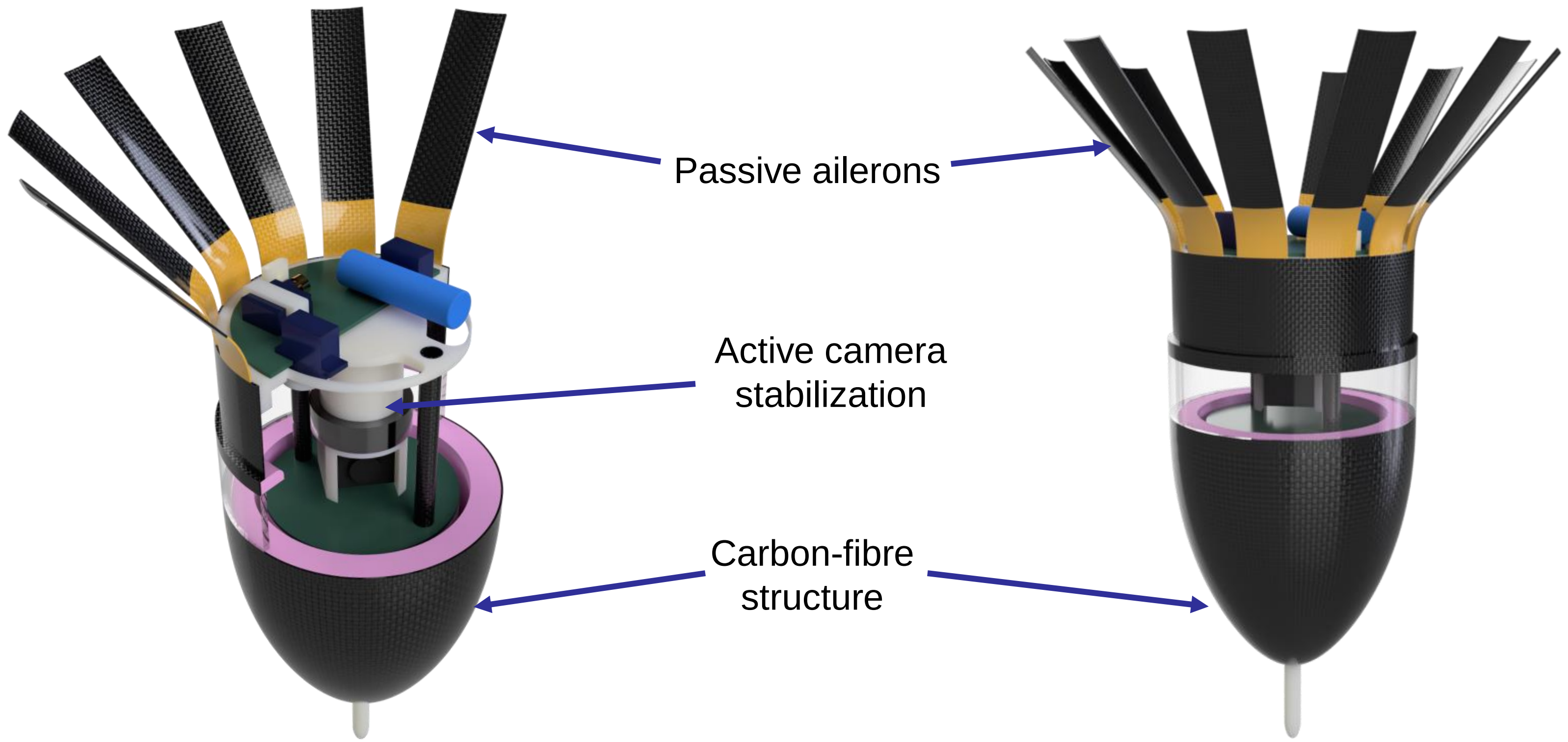
System Requirement Summary (7/7)

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 Level CanSat Configuration Trade & Selection (1/2)

Design 1

CanSat using as many passive systems as possible, offering maximum weight reduction. Using technologies known to us and having as few elements as possible. As a team from a country other than the USA that will have to travel by plane, we care about reliability, simplicity and ease of assembly.

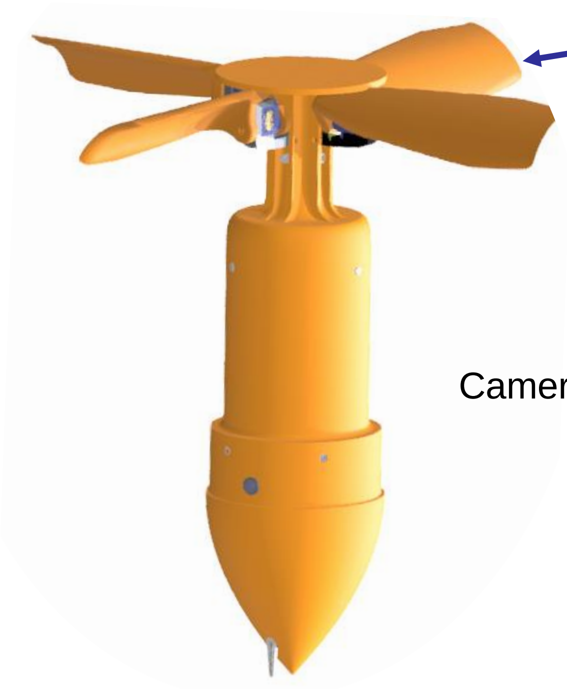


System Level CanSat Configuration Trade & Selection (2/2)

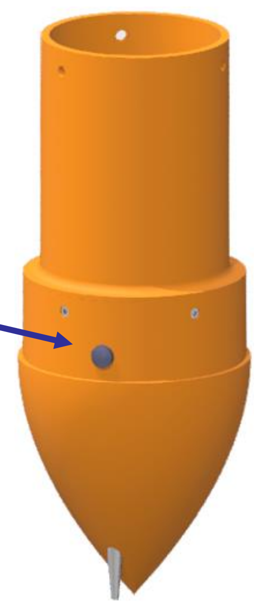
Design 2

CanSat is based mainly on an active stabilization system using variable angle ailerons that also serve as an air brake. Properly setting them allows to prevent rotation around own axis. This approach allows to keep the camera recording in one direction. The structure is mainly based on 3D printing technology, which makes it very easy to build.

CanSat in a rocket



Unfolded configuration



Payload

Rejected ailerons

System Level Configuration Selection

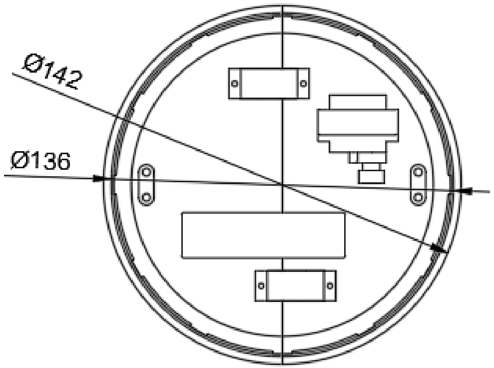
Design 1

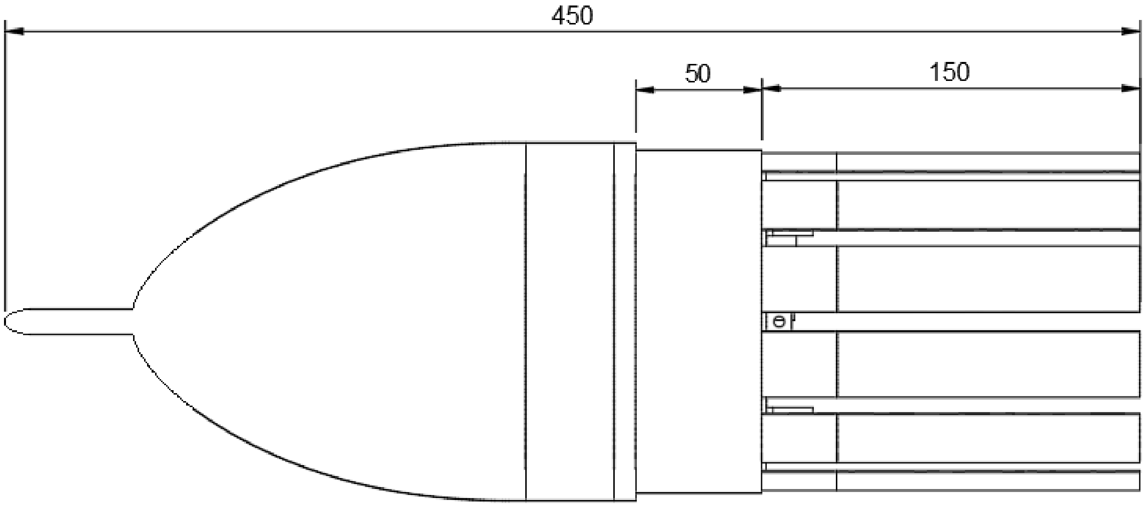
After considering both configurations, we selected the system level configuration presented in Design 1.
We made this choice because:

- **Lower part count**
- **Most mass reduction potential**
- **Lots of passive systems will ensure high reliability**
- **Ease of assembly in field**
- **Use of accessible components will make prototyping simpler**

Physical Layout (1/4)

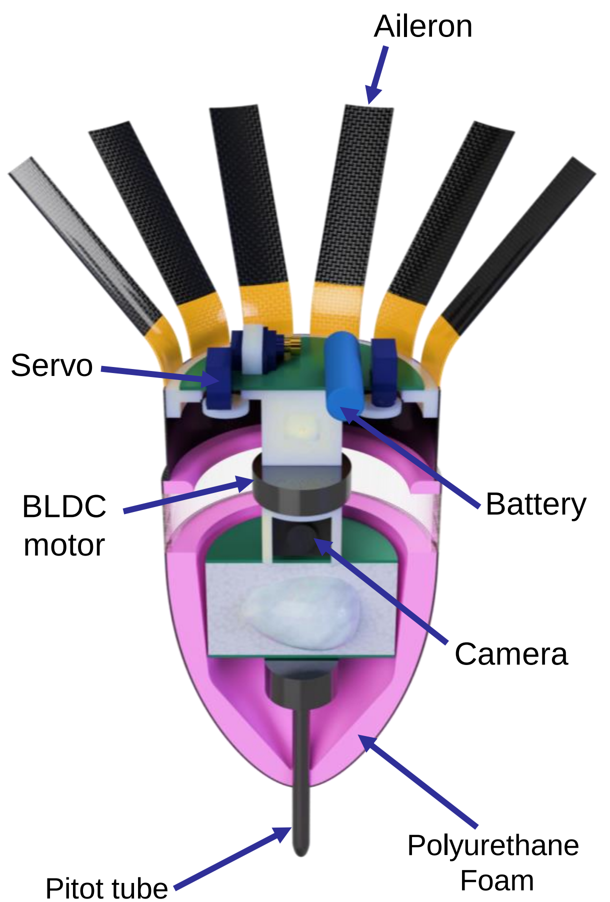
- The radius of the nose cone will be 71 mm (142 mm in diameter).
- The radius of the nose cone shoulder will be 68 mm (136 mm in diameter).
- The length of the nose cone shoulder will be 50 mm.

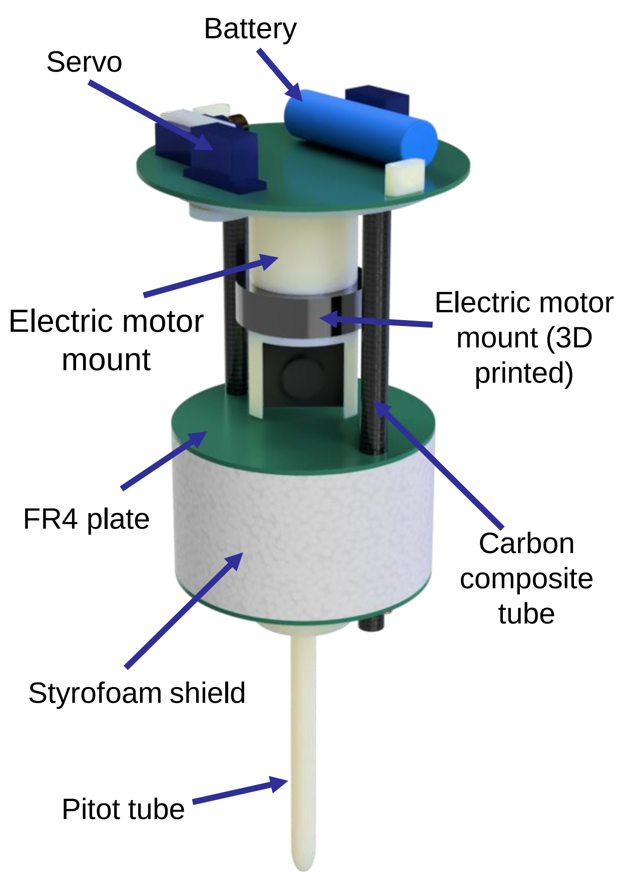


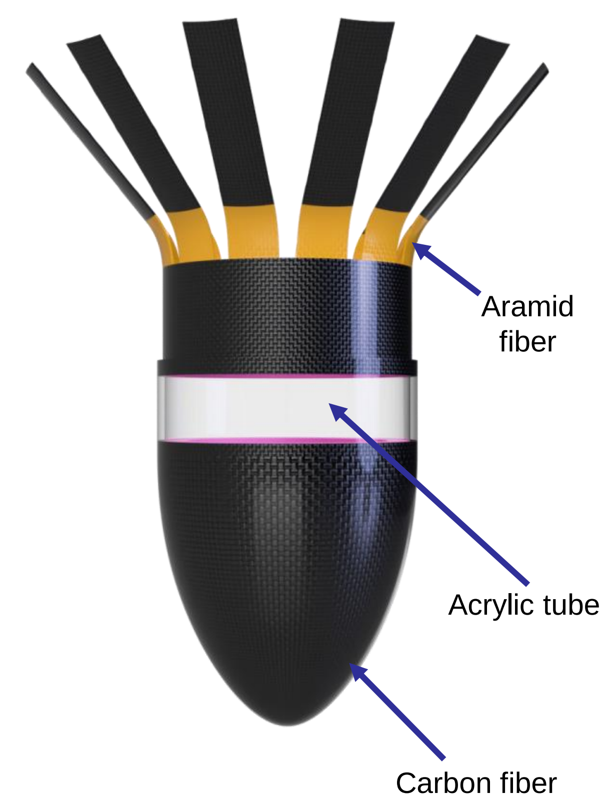


Physical Layout (2/4)

Whole CanSat	Payload	Heat shield



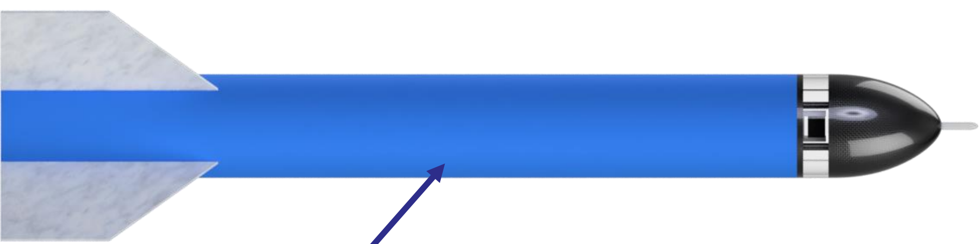


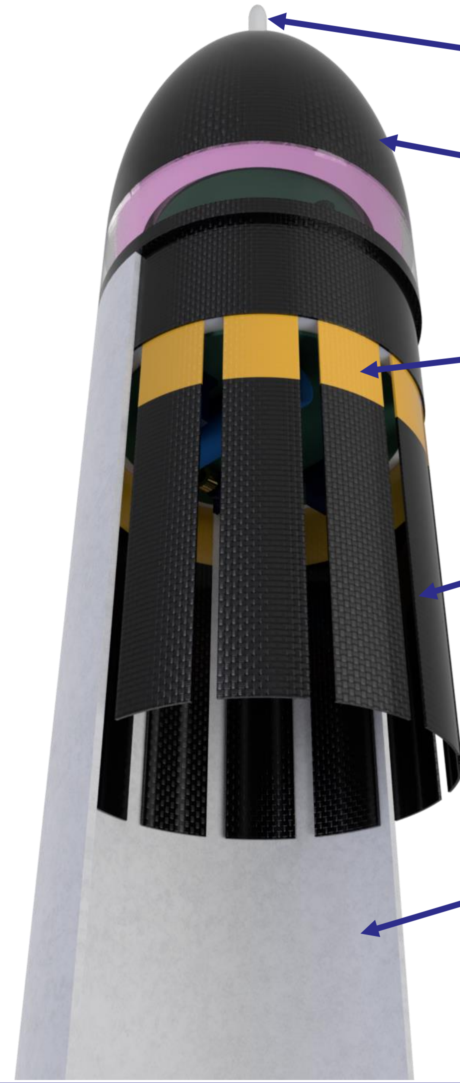


Physical Layout (3/4)

Design 1

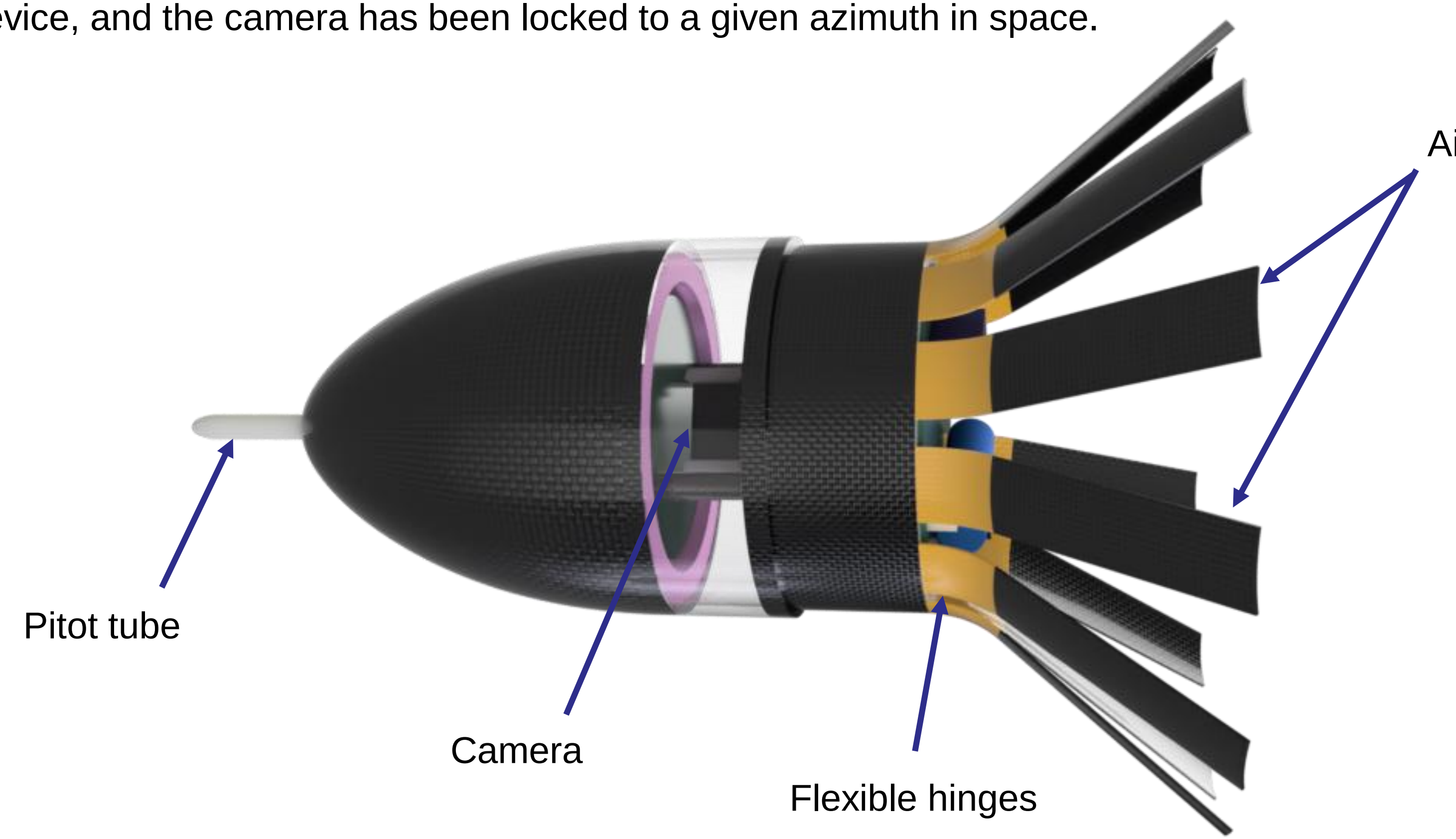
CanSat in launch configuration. Here we can see how the CanSat is placed inside the rocket (in the render on the left, the rocket fuselage is in cross-section). We can see here that the ailerons are in the stowed position, positioned straight parallel to the longitudinal axis of the fuselage. Due to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



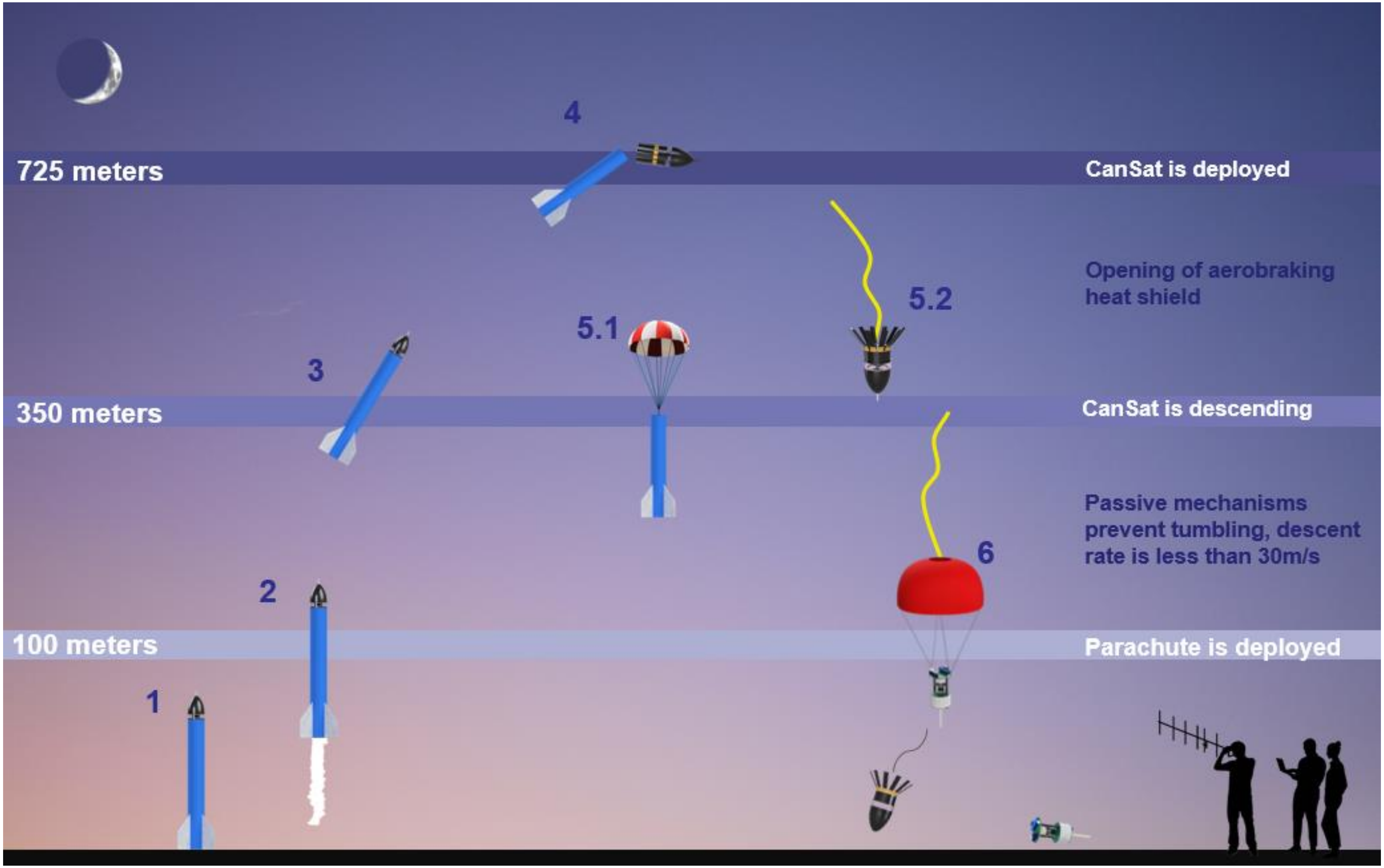


Design 1

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.



System Concept of Operations (1/2)



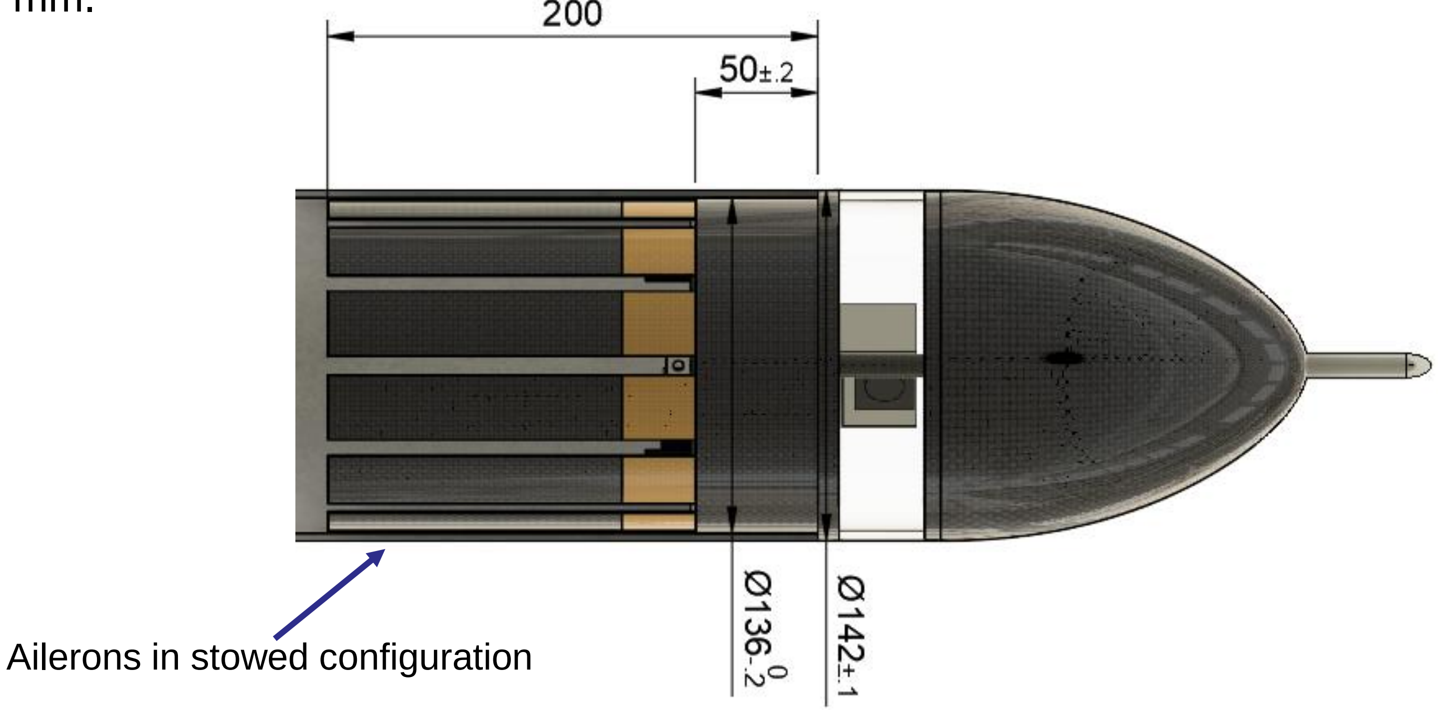
System Concept of Operations (2/2)

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.

Launch Vehicle Compatibility

Design 1

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

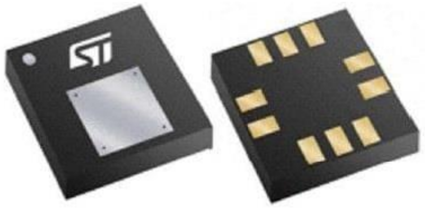
Sensor Subsystem Overview

Type	Model	Functions	Interface
Rotation sensor	MPU-6050	Tracking the payload rotation using gyroscope	I2C
Tilt sensor	MPU-6050	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
Camera (main)	ESP-32-CAM	Capturing the video during descent	GPIO, I2C
Camera (bonus)	ESP-32-CAM	Capturing the probe release	GPIO, I2C

Payload Air Pressure Sensor Trade & Selection

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
BMP280	2 x 2.5 x 0.95	0.048	1.8 - 3.6	0.003	300 - 1100	0.16	0.12	I2C or SPI	9.9
BMP384	2 x 2 x 0.95	0.048	1.65 - 3.6	0.003	300 - 1250	0.016	0.05	I2C or SPI	4.4

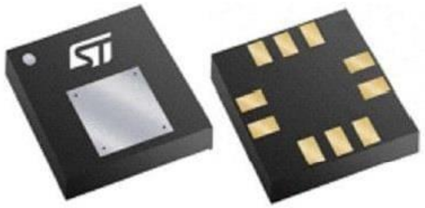
Selected option	Reasons
LPS22	• Temperature measurement • Wide measurement range • Good price-performance ratio • Top production quality • Smallest package



Payload Air Temperature Sensor Trade & Selection

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
STS21	3x 3 x 1.1	0.057	2.1 - 3.6	0.0003	-40 - +125	0.01	0.2	I2C	2.26
DS18B20	2 x 2 x 0.95	0.218	3 – 5.5	0.004	-40 - +80	0.02	0.5	1-Wire	4.05

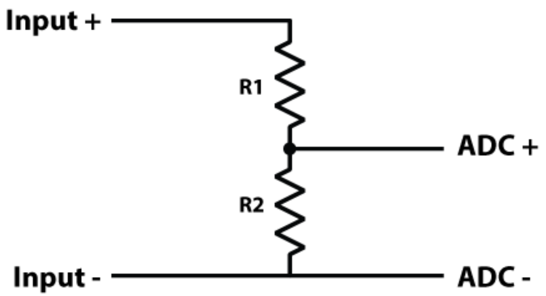
Selected option	Reasons
LPS22	• Air pressure measurement • Good price-performance ratio • Top production quality • Smallest package



Payload Battery Voltage Sensor Trade & Selection

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	4.54
ADS1015	2 x 1.5 x 0.4	0.05	0.15	0 - 3.3	0.001	I2C	1.78

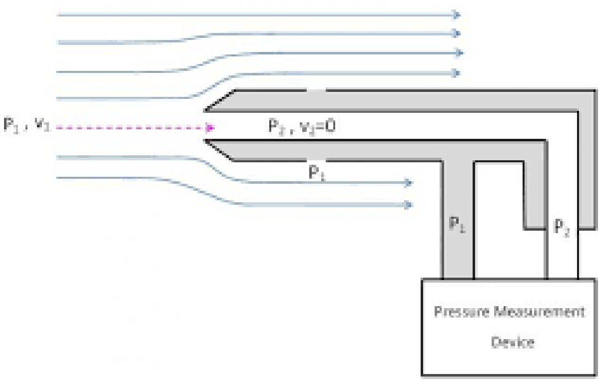
Selected option	Reasons
STM32 ADC With Voltage Divider	• Sufficient resolution • Small amount of external components • Easy to use • Takes no additional space on PCB



Payload Speed Sensor Trade & Selection

Name	Size [mm]	Mass [g]	Operating current [mA]	Range	Resolution	Interface	Price [$]
Pitot pipe with LPS22	-	-	0.01	260 – 1260 hPa	0.24 Pa	I2C	4.54
CUAV MS5525	21 x 20 x 10	17	0.0014	0 - 1379 hPa	0.84 Pa	I2C and SPI	89.00

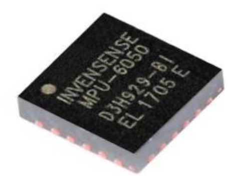
Selected option	Reasons
Pitot pipe with LPS22	• Good measurement accuracy • Easy to use • Reasonable cost



Payload Tilt Sensor Trade & Selection

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [g]	Resolution [g]	Interface	Price [$]
MPU-6050	4 x 4 x 0.9	0.13	2.375 - 3.46	0.4	±16,±8 ±4,±2	0.00006	I2C	8.66
MPU-9250	3 x 3 x 1	0.11	1.8 - 3.6	0.4	±16,±8 ±4,±2	0.00006	I2C or SPI	9.92
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

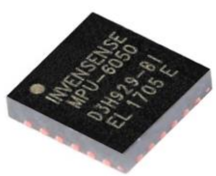
Selected option	Reasons
MPU-6050	• Durable • High resolution • Wide range of configuration options • Good measurement accuracy • Incorporate DMP • High availability



Rotation Sensor Trade & Selection

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [°/s]	Resolution [°/s]	Interface	Price [$]
MPU-6050	4 x 4 x 0.9	0.13	2.375 - 3.46	0.4	±2000,±1000 ±500,±250	0.008	I2C	8.66
MPU-9250	3 x 3 x 1	0.11	1.8 - 3.6	0.4	±2000,±1000 ±500,±250	0.008	I2C or SPI	9.92
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

Selected option	Reasons
MPU-6050	• Durable • High resolution • Wide range of configuration options • Good measurement accuracy • Incorporate DMP • High availability



Payload GPS Sensor Trade & Selection

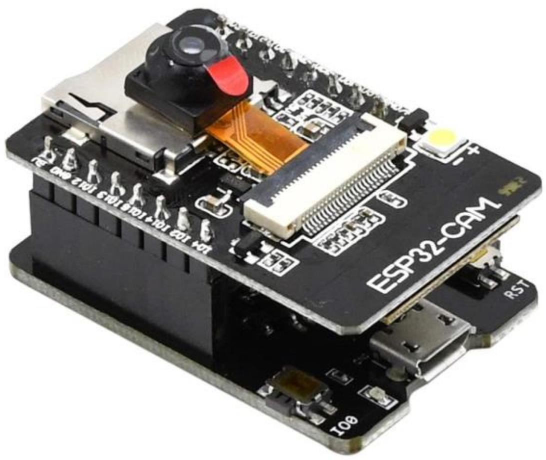
Name	Size [mm]	Mass [g]	Operating voltage [V]	Sensitivity [dBm]	Resolution [m]	Update rate [Hz]	Interface	Price [$]
GY-NEO6MV2	36 x 24	15.5	3.3 - 5	-161	< 2	5	UART	9.0
NEO-M8N M5Stack	54 x 54 x 13	43	2.7 - 3.6	-167	2.5	10	UART	36.9
Sparkfun GPS ZOE-M8Q	25 x 25 x 4	40	3.3	-167	2	18	SPI or I2C or UART	49.95

Selected option	Reasons
GY-NEO6MV2	• Good price-performance ratio • More accurate resolution • Fast cold start < 28 s • Sufficient sensitivity

Payload Camera Trade & Selection

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
Raspberry Pi Zero 2 W + OV5647	65 x 30 x 25	15	5	300	60.6	2592 x 1944 1920 x 1080 640 x 480 320 x 240	15 30 90 120	24.0

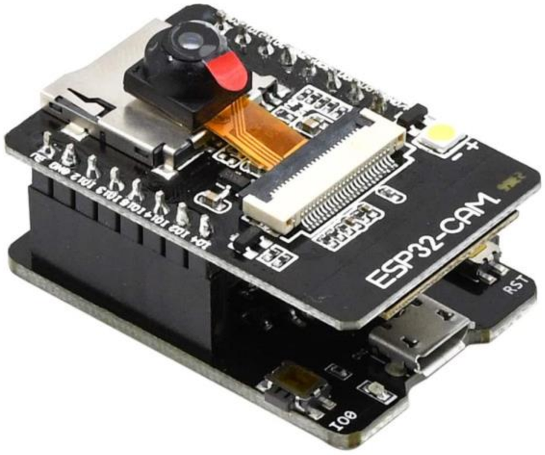
Selected option	Reasons
ESP-32-CAM + OV2640	• Good performance-price ratio • Sufficient resolution and frame per second • Small operating current • MicroSD card for video storage • Compact size • Hardware JPEG encoding



Bonus Camera Trade and Selection

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
Raspberry Pi Zero 2 W + OV5647	65 x 30 x 25	15	5	300	60.6	2592 x 1944 1920 x 1080 640 x 480 320 x 240	15 30 90 120	24.0

Selected option	Reasons
ESP-32-CAM + OV2640	• Good performance-price ratio • Sufficient resolution and frame per second • Small operating current • MicroSD card for video storage • Compact size • Hardware JPEG encoding

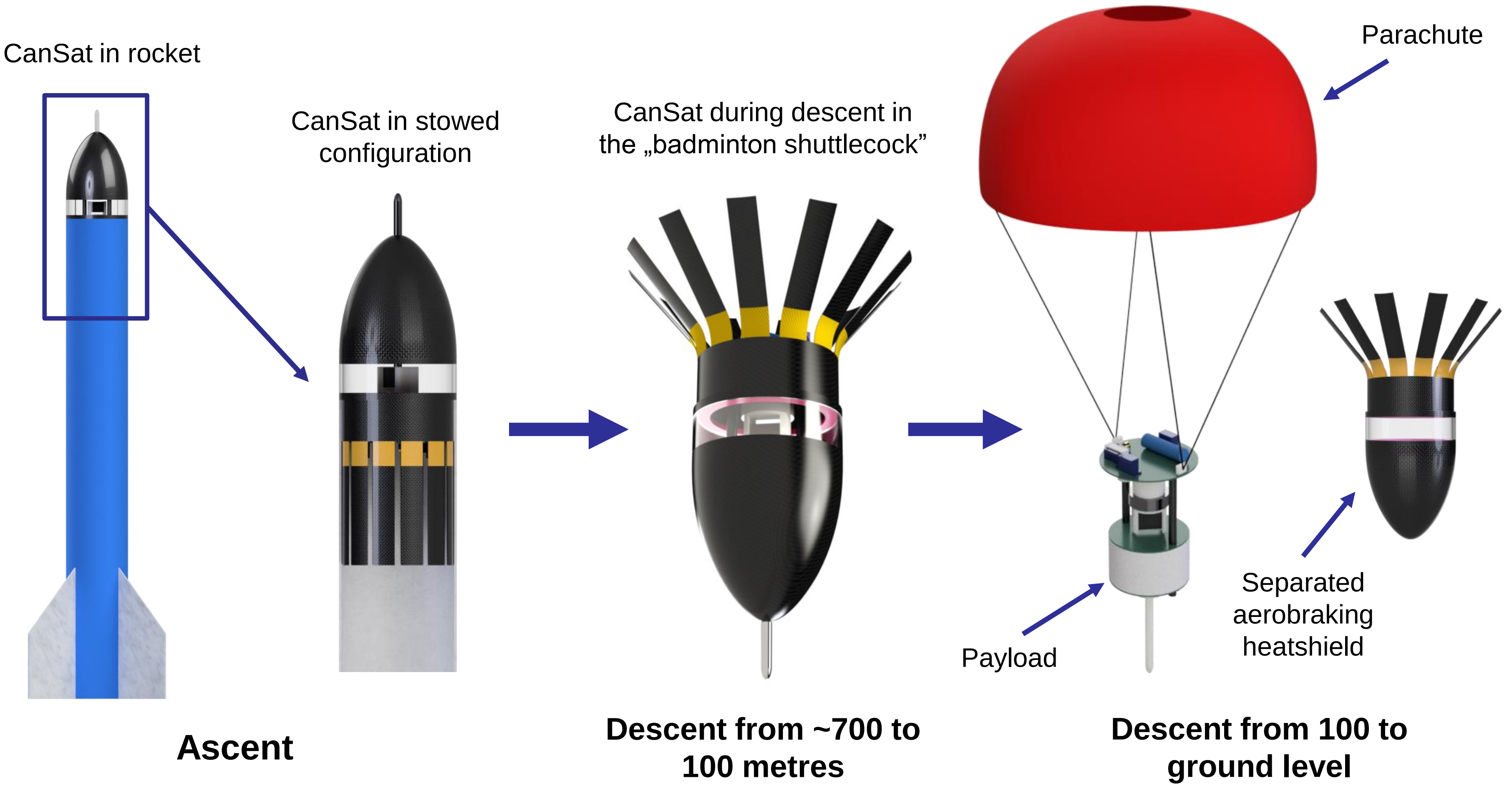


Descent Control Design

Paweł Iwańczyk

Descent Control Overview

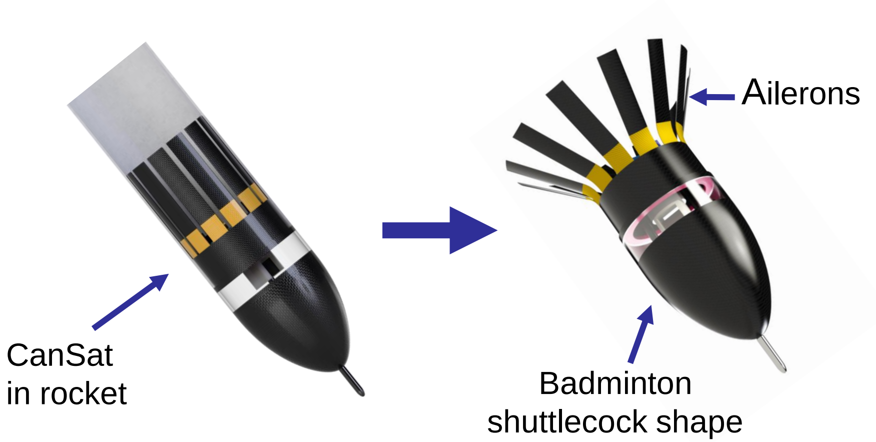
In the renderings below we can see CanSat in the rocket, then a cross-section showing how it is stowed. Then the device itself is shown descending with the heatshield, and then descending without it on a parachute.



Payload Aerobraking Descent Control Strategy Selection and Trade (1/2)

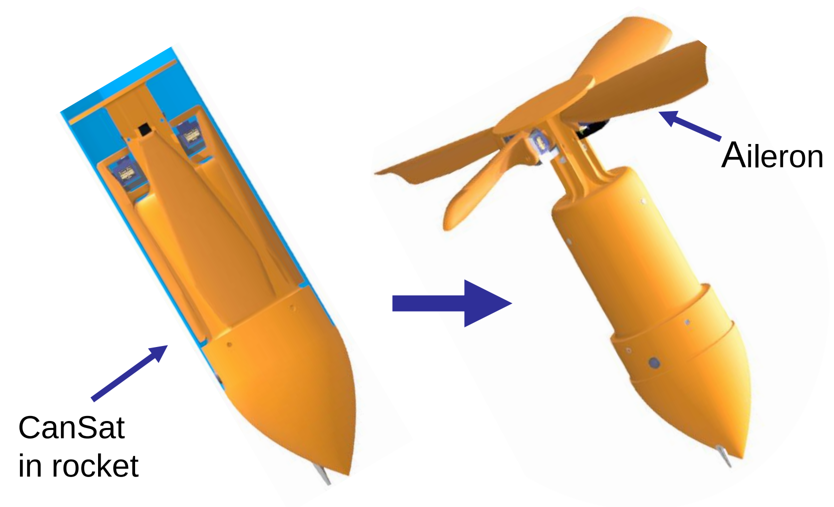
Design 1

Our system provides a passive aerobraking system. After being removed from the racket, 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, but the camera will be placed on 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.



Design 2

The aerobraking system is based on 4 controllable C-shaped ailerons. This shape and the independent control of each aileron allows us to axially stabilize the CanSat. Unfortunately, in order to ensure sufficiently high aerodynamic resistance, the ailerons must have a large surface area, which translates directly into the size and weight of the entire CanSat.



Payload Aerobraking Descent Control Strategy Selection and Trade (2/2)

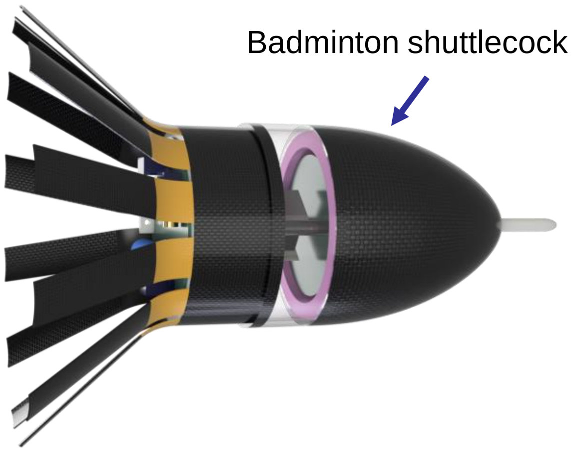
Design	Description	Advantages	Disadvantages
1	„Badminton Shuttlecock”	• Simple and reliable • Small number of elements • Low weight	• No active control possible • Hard to manufacture
2	Ailerons	• Great possibilities of controlling the CanSat • Axial stabilization of the entire CanSat	• Very large mass and size of the structure • Complicated structure containing a lots of moving elements

Selected aerobraking mechanism	Reasons
Design 1: „Badminton Shuttlecock”	• It offers the highest reliability • Our team members have experience with composite materials. • Very low weight is also important for us.

Payload Aerobraking Descent Stability Control Strategy Selection and Trade (1/3)

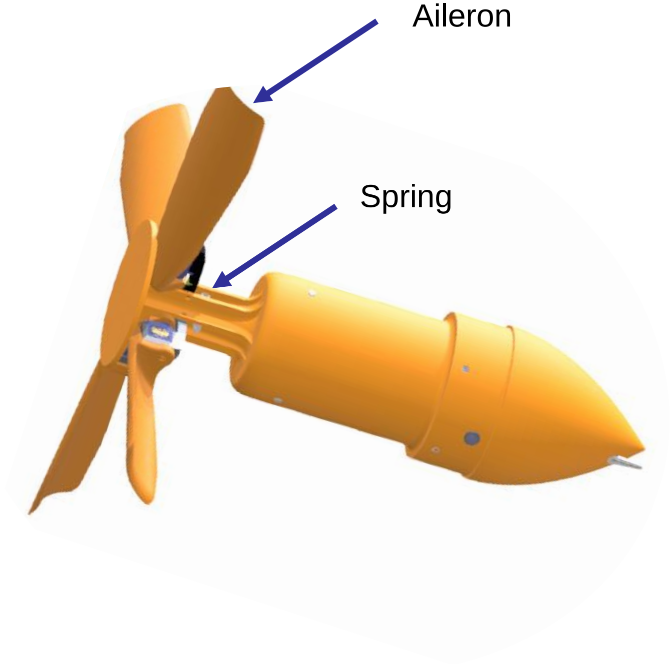
Design1

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. Only 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. the nosecone will also form part of the aerobraking. In order to be sure about the stability of our device, appropriate tests will be carried out using models.



Design2

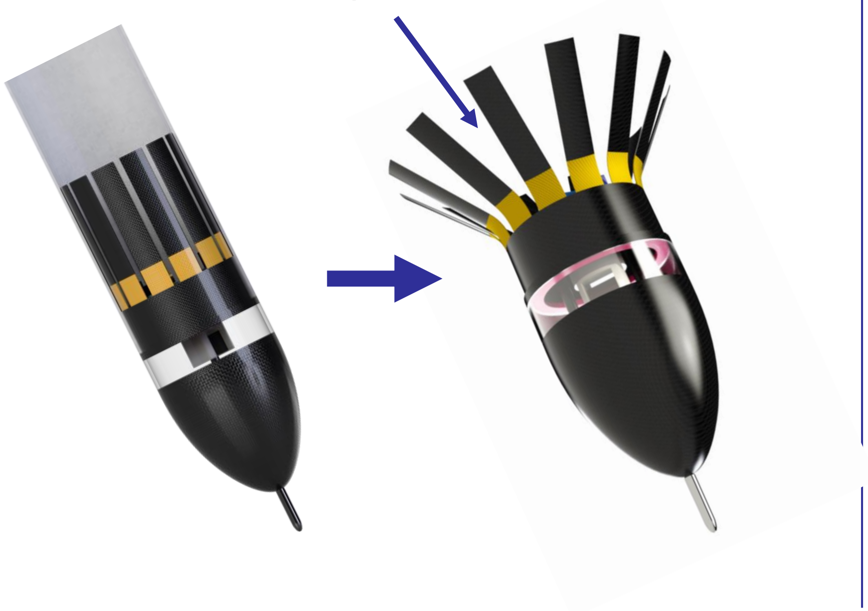
In this design CanSat have active type of stabilization based on 4 C-shaped ailerons. At first when the CanSat is in the rocket the ailerons are stowed. When the CanSat is separated from the rocket, spring push the aileron outside and next air hits the aileron from the bottom causing full aileron deployment.



Design1

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 and will remain in this position also thanks to the elastic force.

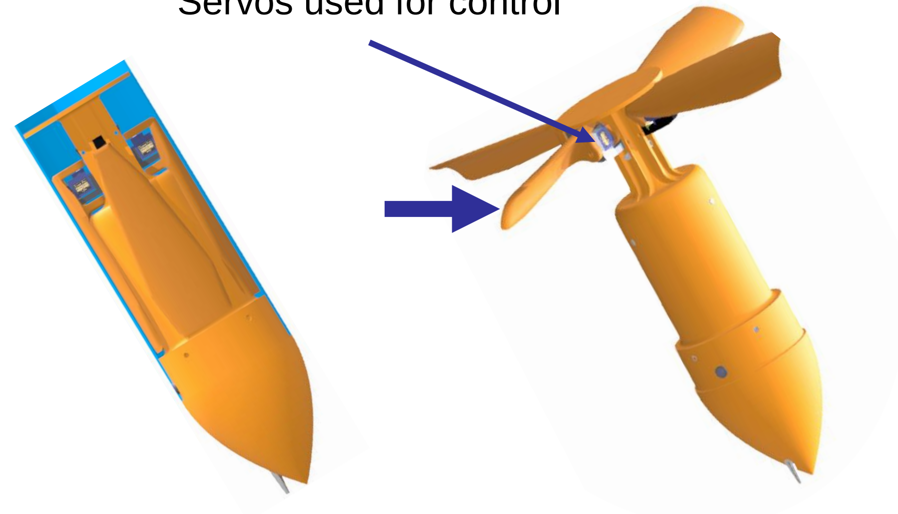
Ailerons shaped into buttlecock



Design2

When CanSat is in full deployment configuration. The position of ailerons can be controlled by a servo. In the zero position C-shaped aileron works like a sail catching the air and makes a lot of aerodynamic resistance. The shape of the aileron and its rotation causes the resultant force vector to be directed sideways. Due to the fact that the ailerons are placed axially symmetrically, the combination of all four resultant forces causes rotation around the axis.

Servos used for control



Payload Aerobraking Descent Stability Control Strategy Selection and Trade (3/3)

Design	Description	Advantages	Disadvantages
1	Passive ailerons	• High reliability • Low mass • Almost no moving parts	• No control over descent parameters
2	Active ailerons	• High control of descent	• Higher mass • Lower reliability • Complex design

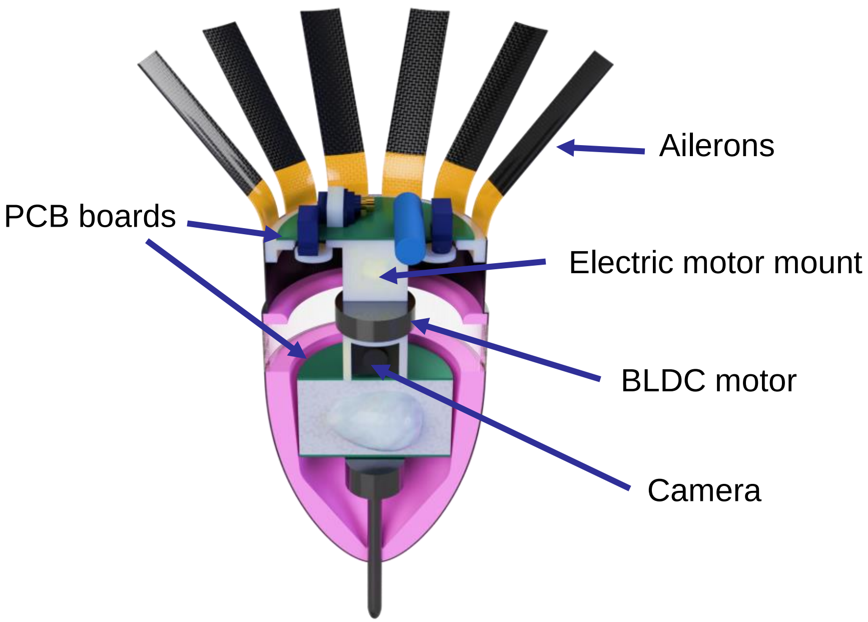
Selected stability control strategy	Reasons
Design 1: Passive ailerons	It provides the lowest mass and is sufficient for our pourpose. No moving parts ensures nothing will jam or break during deployment.

Payload Rotation Control Strategy Selection and Trade (1/2)

Design 1

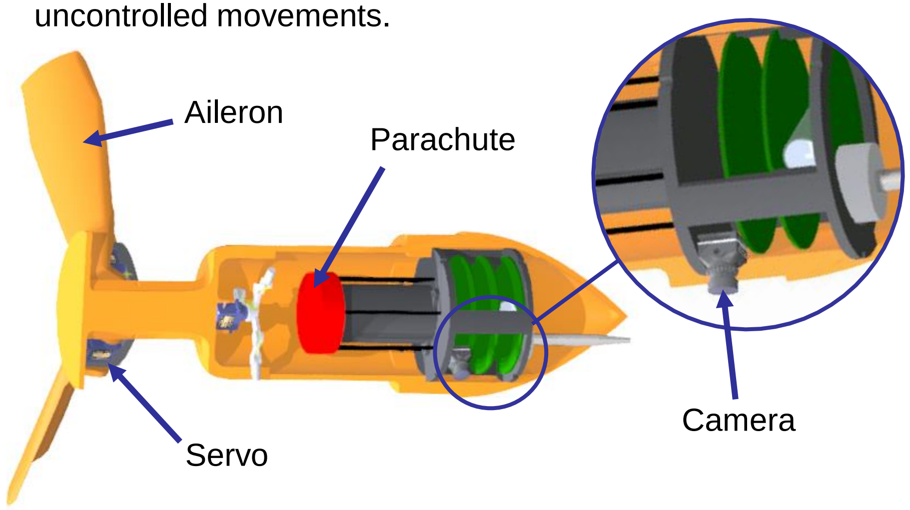
During aerobraking, rotation stabilization will apply only to the camera. It will be done by placing it on an electric motor and then using software to control it appropriately.

The system will consist of assembling the electric motor, then the electric motor itself, assembling the camera and the camera itself.



Design 2

Active rotation control during aerodynamic braking is achieved thanks to four ailerons with a controllable pitch angle. This allows you to precisely adjust the angle of the aileron, which in turn affects the amount of air captured and the aerodynamic drag generated. The shape of the letter C and the appropriate positioning of the aileron cause the resultant force vector to be directed sideways. Due to the fact that the ailerons are placed axially symmetrically and due to the combination of all four net forces, the uncontrolled rotation of the CanSat can be stopped. This system allows the CanSat's rotation to be effectively manipulated during descent, which is crucial to achieving the intended landing trajectory and avoiding uncontrolled movements.



Payload Rotation Control Strategy Selection and Trade (2/2)

Design	Description	Advantages	Disadvantages
1	Electric motor	• Simplicity • Reliable • Ease of control	• Relatively high mass • Lack of roll control of other components
2	Ailerons with a controllable pitch angle	• Active stabilization system • Direct impact of CanSat positions	• Lots of moving elements • Considerable complexity of the structure • Ailerons large size affects mass and dimensions of the CanSat • Aileron rotation can cause tumbling

Selected rotation control strategy	Reasons
Design 1: Electric motor	• Mechanically simple solution • Mass savings on other parts • Reliable

Payload Parachute Descent Control Strategy Selection and Trade (1/2)

Desing 1

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 will enable us to make our own. Many iterations of parachutes can be made to provide optimal descent rates and much needed stability.

Desing 2

Parafoil would provide great stability to Payload, because it initiates movement into one direction. It would be mounted similarly to the flat parachute, but additional mounting points will be needed.

Payload Parachute Descent Control Strategy Selection and Trade (2/2)

Design	Description	Advantages	Disadvantages
1	Flat parachute	• Stable • Reliable • Low price	• No resistance to strong winds • Inevitable fluctuation of the device
2	Parafoil	• Very Stable • Resistance to strong winds	• High price • Lack of team experience with this type of parachute

Selected rotation control strategy	Reasons
Design 1: Flat parachute	• Easy to buy • Adequate stability • Low weight • Our team is familiar with this type of parachute

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	0.5
ρ	1.2 $\frac{kg}{m^3}$
A	0.038 m^2

The calculated terminal velocity is equal to:

$$v = \sqrt{\frac{2 \cdot 0.9 \cdot 9.81}{0.5 \cdot 1.2 \cdot 0.038}} = \mathbf{27.83 \frac{m}{s}}$$

Descent Rate Estimates (2/3)

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.

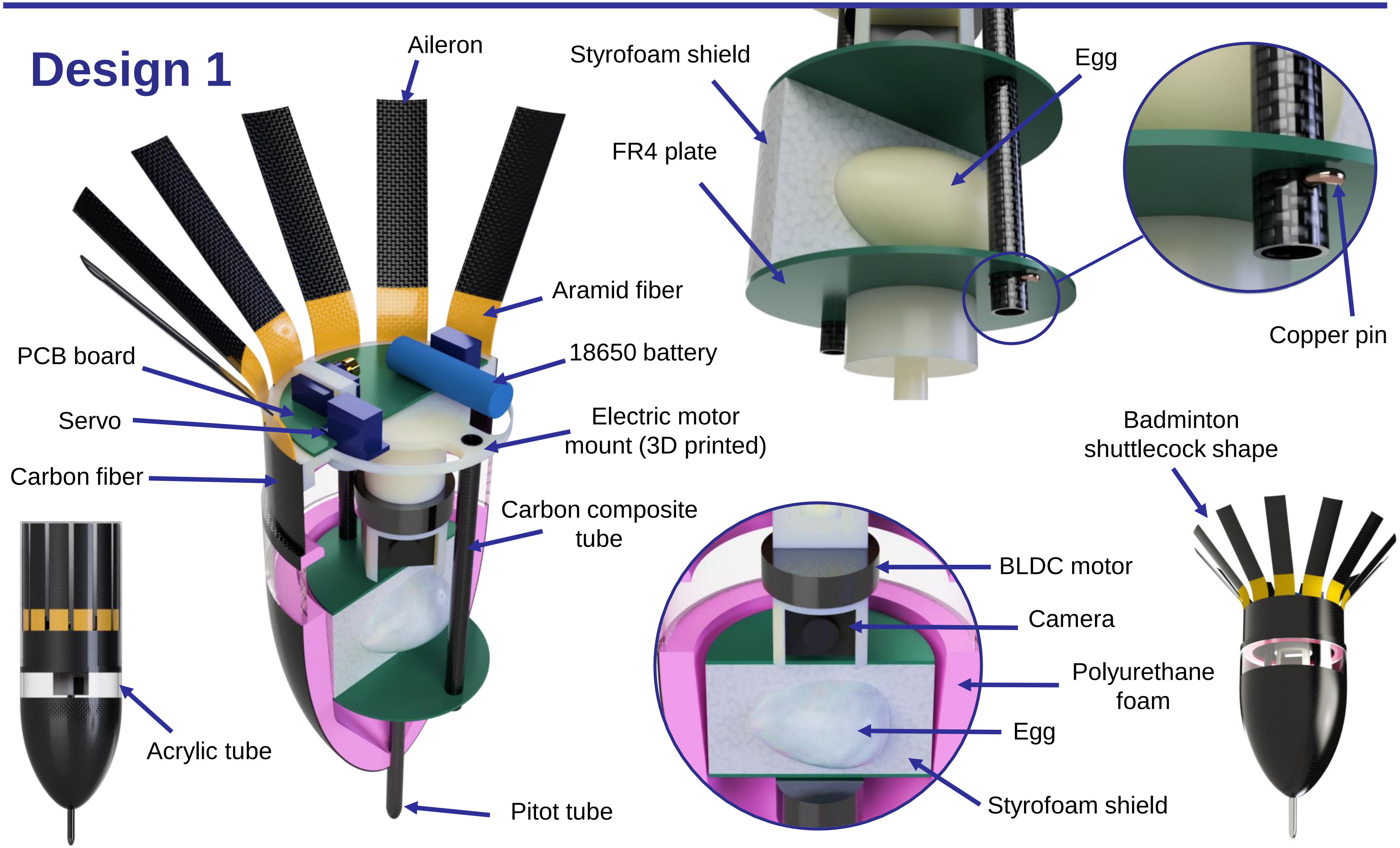
Descent phase	Descent rate estimate
Aerobraking descent	$27.83\ \frac{m}{s}$
Parachute descent	$4.64\ \frac{m}{s}$

Mechanical Subsystem Design

Paweł Iwańczyk

Mechanical Subsystem Overview

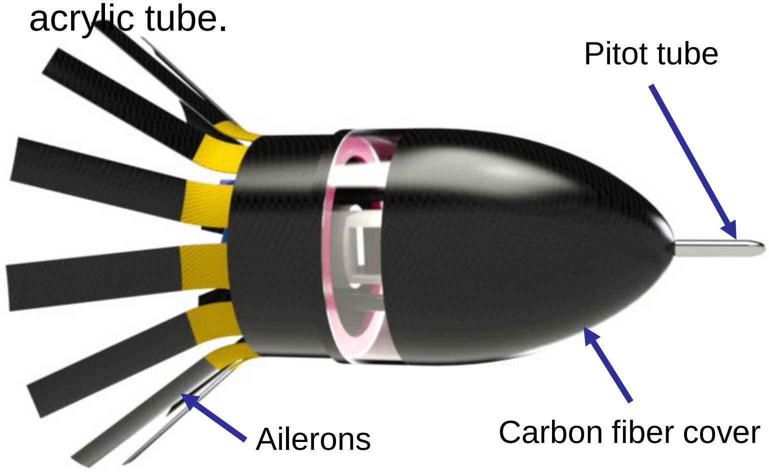
Design 1



Payload Mechanical Layout of Components Trade & Selection (1/7)

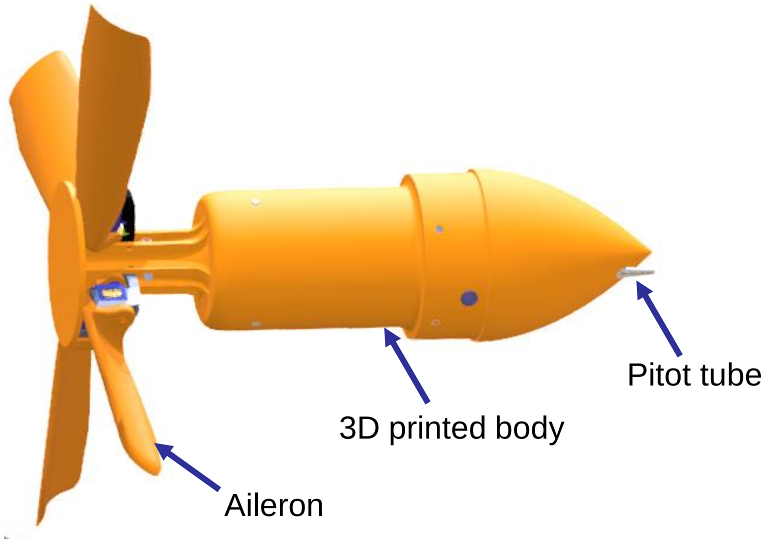
Design1

- CanSat stabilization is achieved by using optimal aerodynamical shape, simillar 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.



Design2

- CanSat is stabilized by its aerodynamic shape.
- Axial stabilization is carried out using movable, foldable ailerons that also function as an air brake.
- The camera is permanently placed and is stabilized by ailerons, which allows the camera to maintain one direction.
- The structure can be fully printed on a 3D printer.

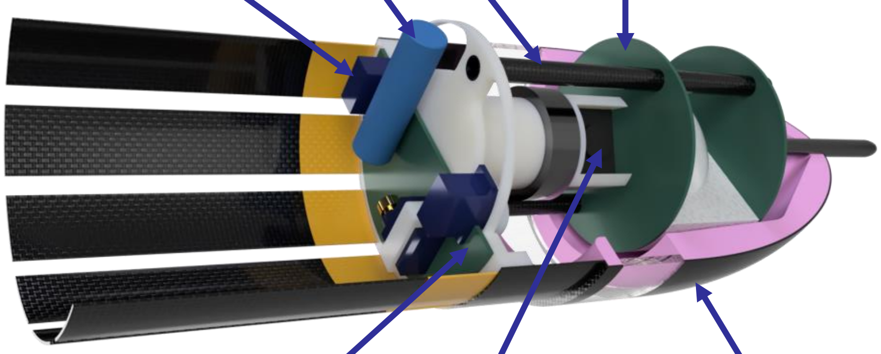


Payload Mechanical Layout of Components Trade & Selection (2/7)

Location of electrical components

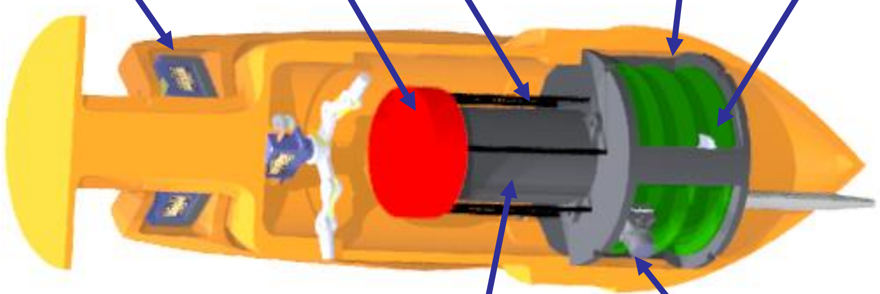
Design1

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.



Design2

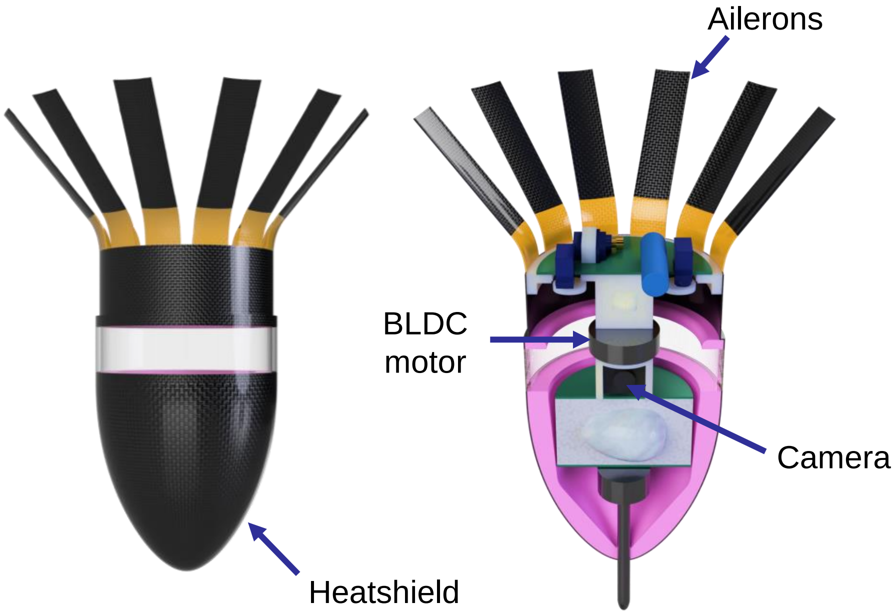
All electronic boards were placed in a container inserted into the nose. This container is attached to the nose using special grooves and attached to the structure by pressing the upper part of the CanSat.



Payload Mechanical Layout of Components Trade & Selection (3/7)

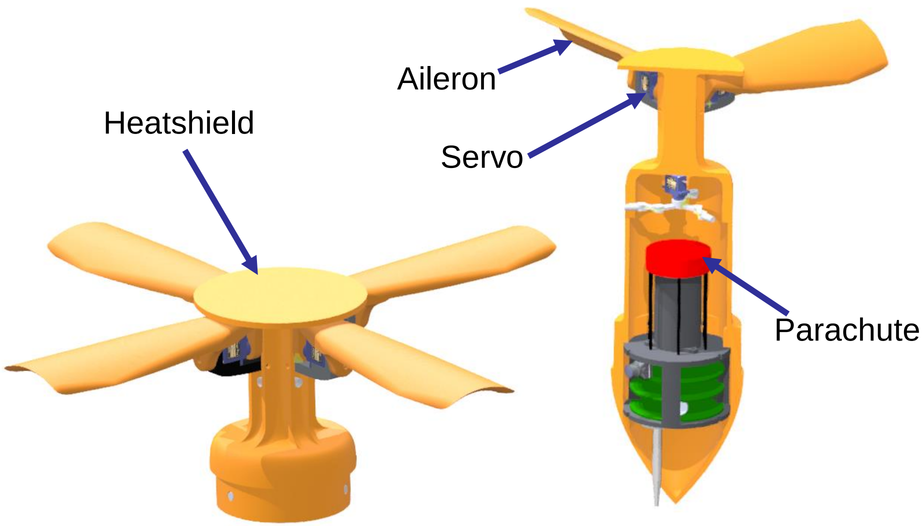
Design1

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 stepper motor 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.



Design 2

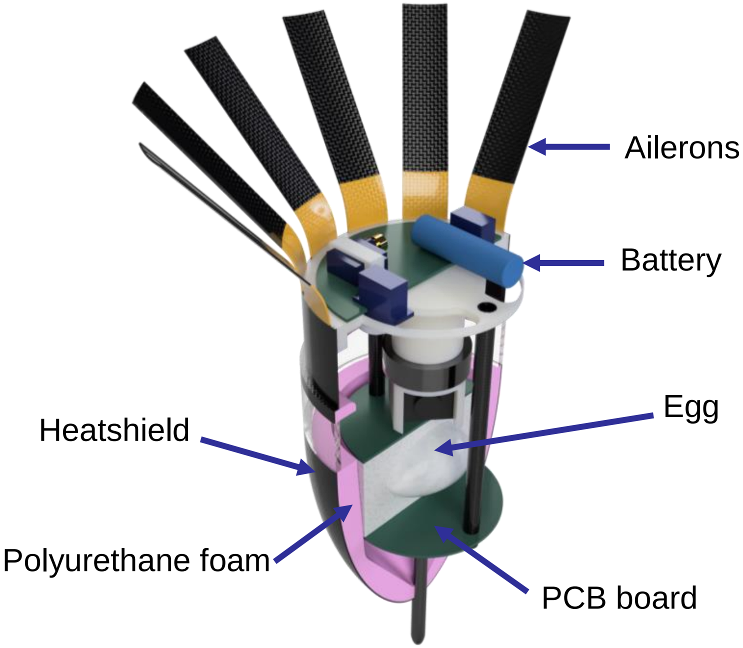
The heatshield is the 4 ailerons on the top of the CanSat. When the CanSat is placed in the rocket, the ailerons are folded. When the CanSat is thrown from the rocket, it is automatically deployed, first using springs and then by air flowing between the CanSat structure and the bottom of the ailerons. They have a shape similar to the letter 'C', which causes aerodynamic roughness. Each aileron is controlled by a servo, which allows for axial stabilization of the CanSat by appropriately positioning each aileron.



Payload Mechanical Layout of Components Trade & Selection (4/7)

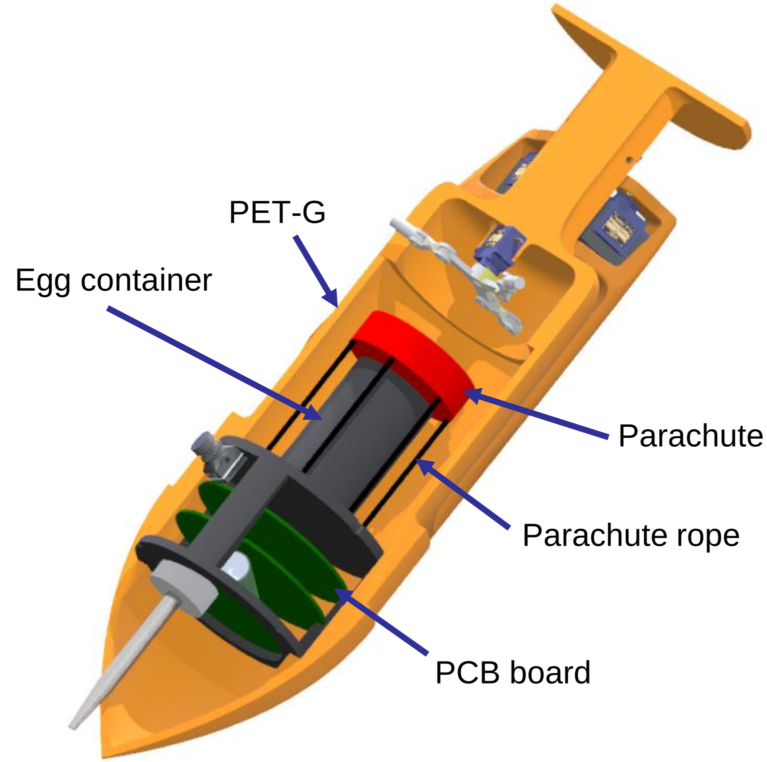
Design1

The CanSat structure is made mainly of composites, which allows for significant weight reduction. The outer part of the heatshield is made of carbon 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.



Design 2

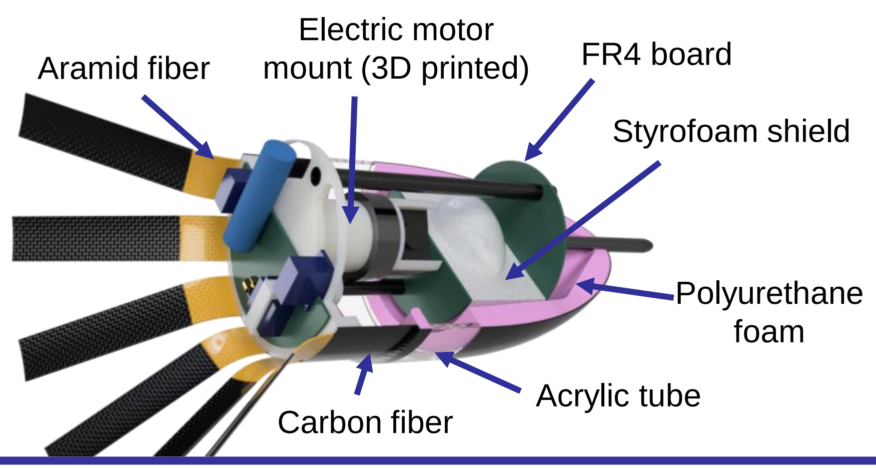
All structural elements of the CanSat are made of 3D printing using PET-G material, this approach makes the CanSat very easy to produce. The egg container is filled with polyurethane foam to dampen vibrations and protect the egg.



Payload Mechanical Layout of Components Trade & Selection (5/7)

Design 1

Main body of CanSat is made out of Carbon Fiber composite. To create the nose structure, carbon fiber composite is applied to polyurethane foam, which serves to increase the stiffness of the structure. The "hinges" to which the ailerons used to airbrake the device are attached (also made of carbon fiber) are made of aramid fiber, which is more springy 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 materials will be made of 3D printed nylon, including the camera assembly, engine assembly and fragments of the pitot tube. To ensure good visibility for the camera, the nosecone fragment will be made of an acrylic tube.

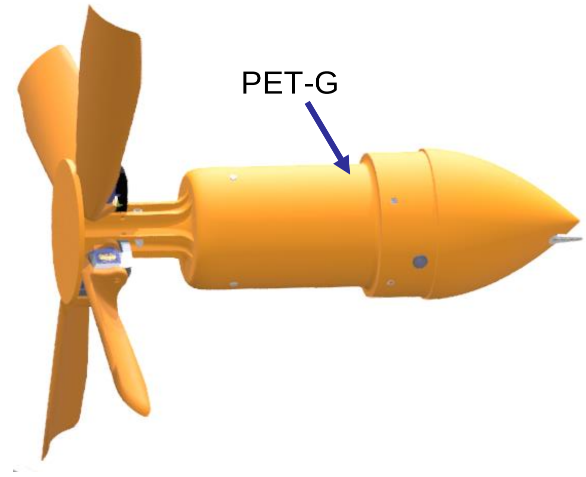


Design 2

The CanSat's construction is based on PET-G (Polyethylene Terephthalate Glycol-modified) material. This material was chosen because the entire housing can be printed on a 3D printer. Unlike PLA material, PET-G has much higher temperature resistance and greater durability. Compared to ABS material, which is also very resistant to high temperatures, printing from PET-G is much easier.

The use of 3D printing technology ensures relatively quick and easy fabrication of CanSat.

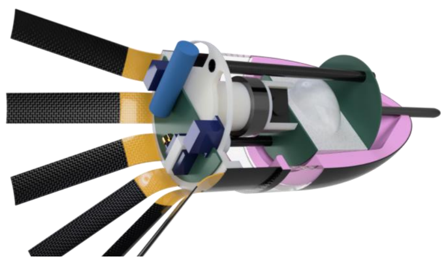
The disadvantages of this solution are the high weight resulting from the need for the structure to have thick walls that will ensure high strength of such a structure.



Payload Mechanical Layout of Components Trade & Selection (6/7)

Design	Description	Advantages	Disadvantages
1	Exposed electronical components	• Ease of reprogramming of electronics • Good acces to electronic parts • Helps with cooling of components	• Exposure to environment • Center of mass is higher
2	Hidden electronical components	• Low center of mass will provides better stability • No exposure to environment	• Servos are ditched alongside the heatshield • Electronic components are heating up more • Difficult access to components

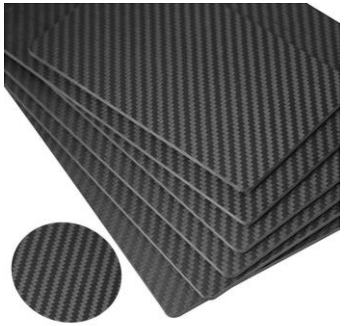
Selected mechanical layout	Reasons
Design 1: Exposed electronical components	We choose Design 1 because we want to be able to acces electronic components easily, also we want to provide adequate cooling of electronical components.



Payload Mechanical Layout of Components Trade & Selection (7/7)

Material	Advantages	Disadvantages
Carbon fiber	• Superb durability-to-mass ratio • High rigidity • Lightweight	• Hard to create complicated shapes
ABS plastic	• Cheap • Easy to manufacture different shapes • Light	• Not as temperature resistant as other materials • Anisotropic
Plywood	• Compress-, stretch- and bend-resiliant • High durability-to-weight ratio	• No water resistance • Can catch fire

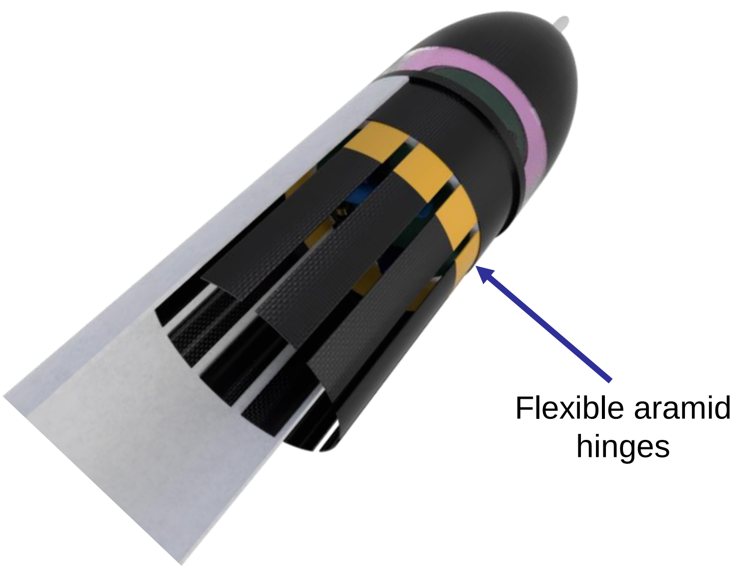
Selected material	Reasons
Carbon fiber	• Carbon fiber provides the best mechanical properties, making it an excellent choice despite its difficulty in manufacturing. • The CanSats body can be thinner and lighter.



Payload Aerobraking Pre Deployment Configuration Trade & Selection (1/2)

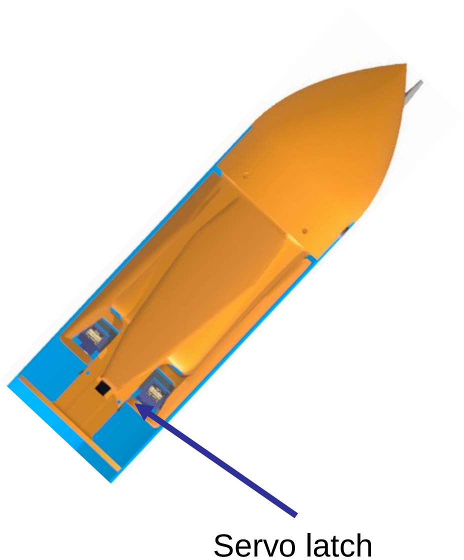
Design 1

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. Due to the fact that 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.



Design 2

The ailerons of the aerobraking mechanism are made out of ABS material. They will be 3D-printed and will have a lot of grooves that increase friction. To mitigate this issue a servo latch will be used, that will ensure the ailerons won’t open inside the rocket, and in consequence get stuck.



Payload Aerobraking Pre Deployment Configuration Trade & Selection (2/2)

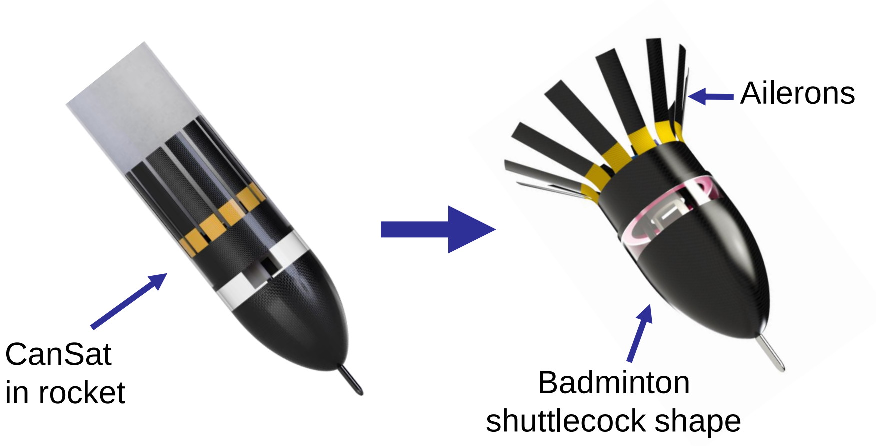
Design	Description	Advantages	Disadvantages
1	Flexible hinges	• Fully automatic and maintenance-free • Low mass • Few elements	• Lack of control
2	Servo latches	• Fully automatic and maintenance-free	• Big mechanical stresses putted on small parts • Large number of parts

Selected pre deployment configuration	Reasons
Design 1: Servo latches	A simple and lightweight construction will help us to stay within mass limits, also high reliability is very important to us and will help us perform many tests without disassembly.

Payload Aerobraking Deployment Configuration Trade & Selection (1/2)

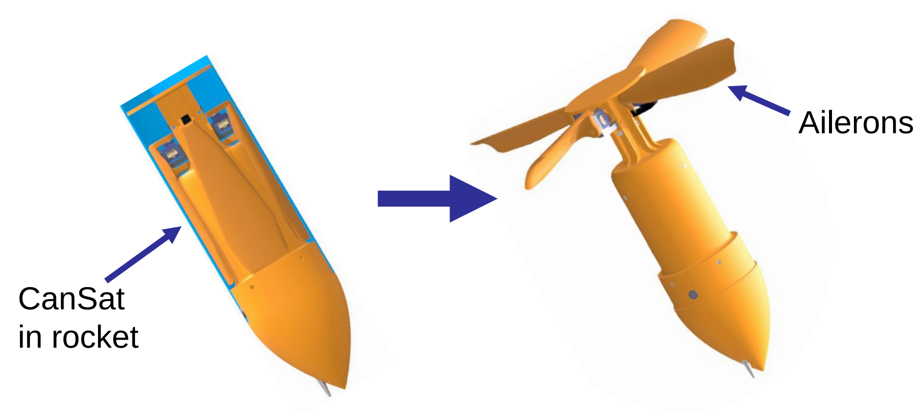
Design 1

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.



Design 2

When the CanSat leaves the rocket, the mechanism holding the ailerons is released by turning the servo. At the very beginning of the transition to the unfolded position, the ailerons are pushed outwards by the springs. This creates a gap between the structure and the shuttle. Then, when the CanSat falls nose down, the air movement is directed along the CanSat's axis. This air enters the gap between the aileron and the CanSat, causing the ailerons to expand further until they are fully deployed and locked in their maximum position.



Payload Aerobraking Deployment Configuration Trade & Selection (2/2)

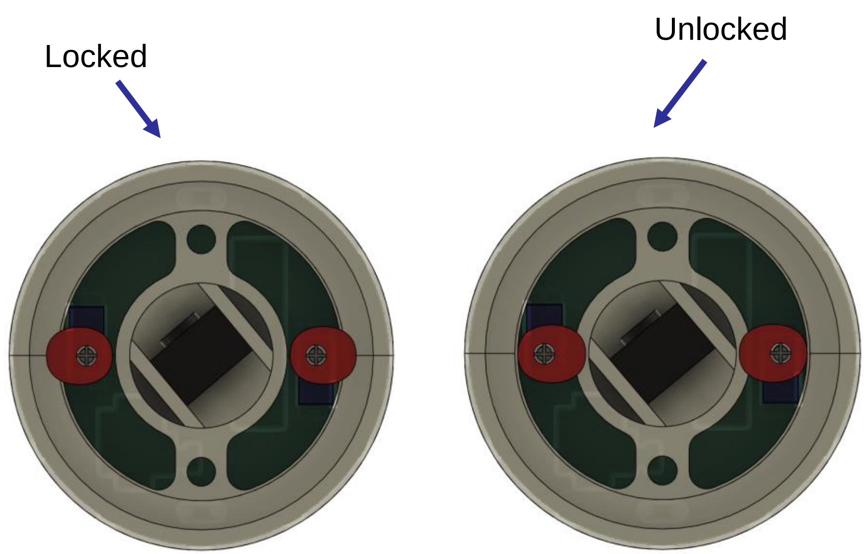
Design	Description	Advantages	Disadvantages
1	Flexible hinges	• Reliability • Low shock stress • Low mass	• Lack of release control
2	Servo latches	• Precise control of release	• High mass • High shock stresses • Possibility of jam

Selected deployment configuration	Reasons
Design 1:	Due to the low shock stresses and low weight, we decided to choose Design 1. These parameters will allow us to test the device multiple times without the risk of damaging it.

Payload Aerobraking Release Trade & Selection (1/2)

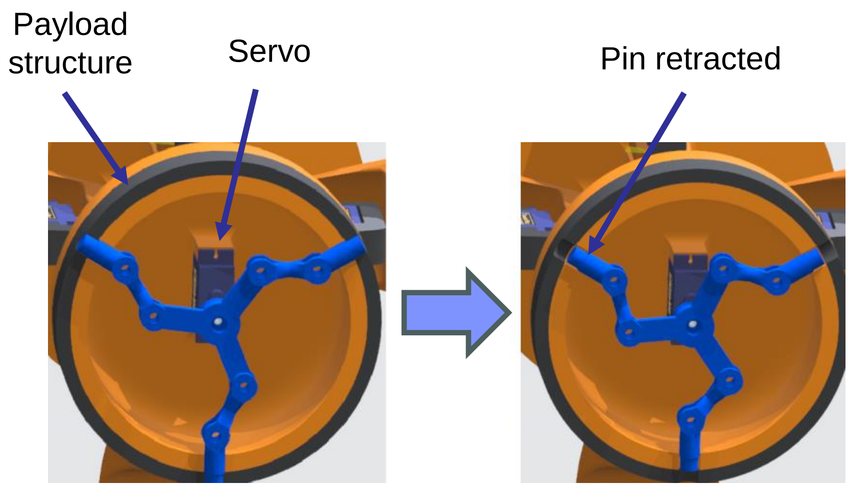
Design 1

The Payload separation system from the aerobraking structure uses a two-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.



Design 2

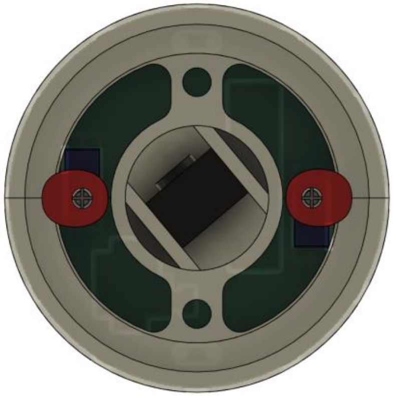
The payload rejection method used is based on three pins that are pulled out using a servo. These pins in the initial configuration hold the payload and heatshield together. When moving to the next stage of the mission, the servo mechanism performs a rotational movement, which thanks to the use of a tendon-like mechanism, is transformed into linear movement, which then causes the pins to slide out and the heatshield to be disconnected from the CanSat. Mylar golden strip would be mounted to the top of Payload and will be paralel to the parachute.



Payload Aerobraking Release Trade & Selection (2/2)

Design	Description	Advantages	Disadvantages
1	Redundant double lock	• High reliability • Redundancy • Simplicity	• Loads are affecting servo
2	3-pins mechanism	• The loads do not directly affect the servo	• A large number of moving parts • Complicated assembly process • Requires difficult electrical disengaging connections due to ditching of servos

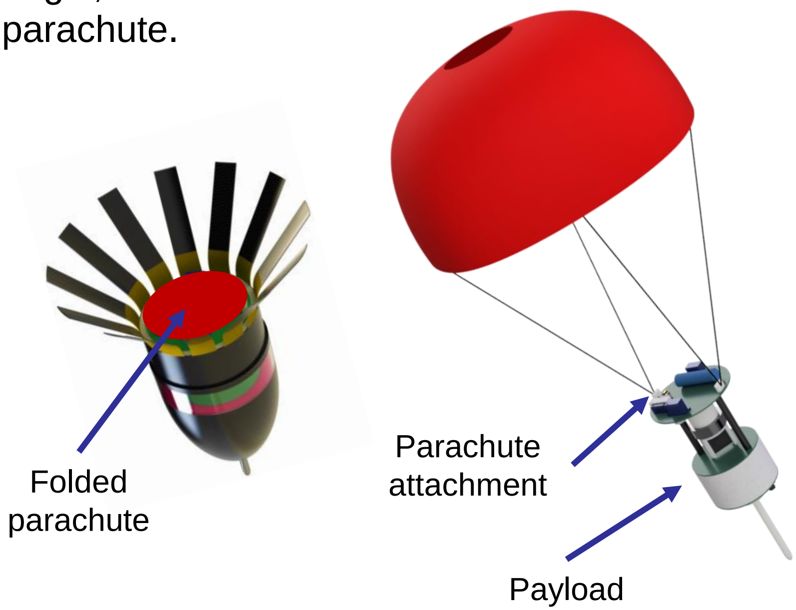
Selected release mechanism	Reasons
Design 1: Redundant Double Lock	We choose Design 1, because we want to have simplest possible solution, also high reliability is paramount to us.



Payload Parachute Deployment Configuration Trade & Selection (1/3)

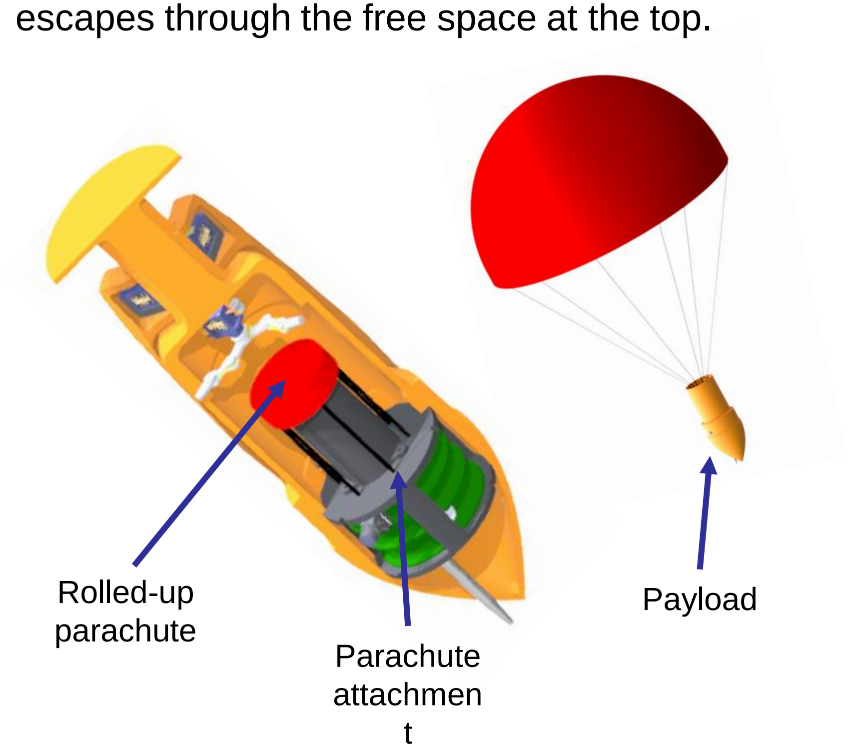
Design 1

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.



Design 2

The parachute is attached to the top of the electronics case. The rolled-up parachute is held in the space between the egg container and the aileron rejection mechanism. When the mission moves to the next stage and the airbrake is released, the parachute unfolds and escapes through the free space at the top.

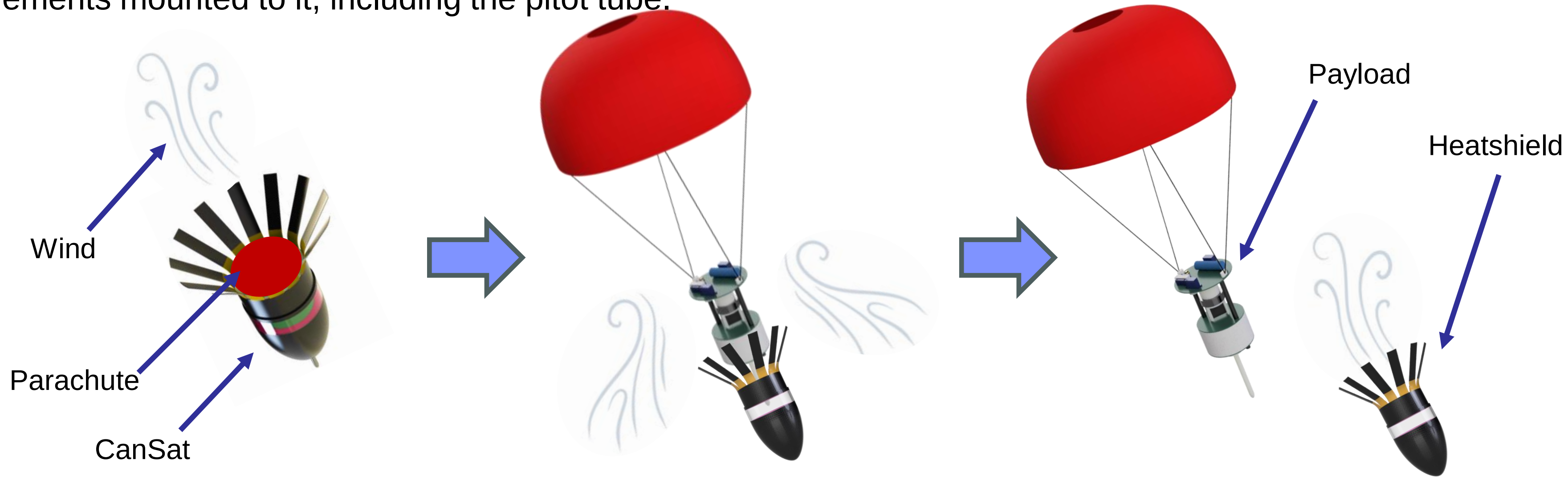


Payload Parachute Deployment Configuration Trade & Selection (2/3)

Design 1

The transition of Payload from the stowed position to the deployed configuration takes place by opening the parachute and then extending 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.



Before deployment During deployment After deployment

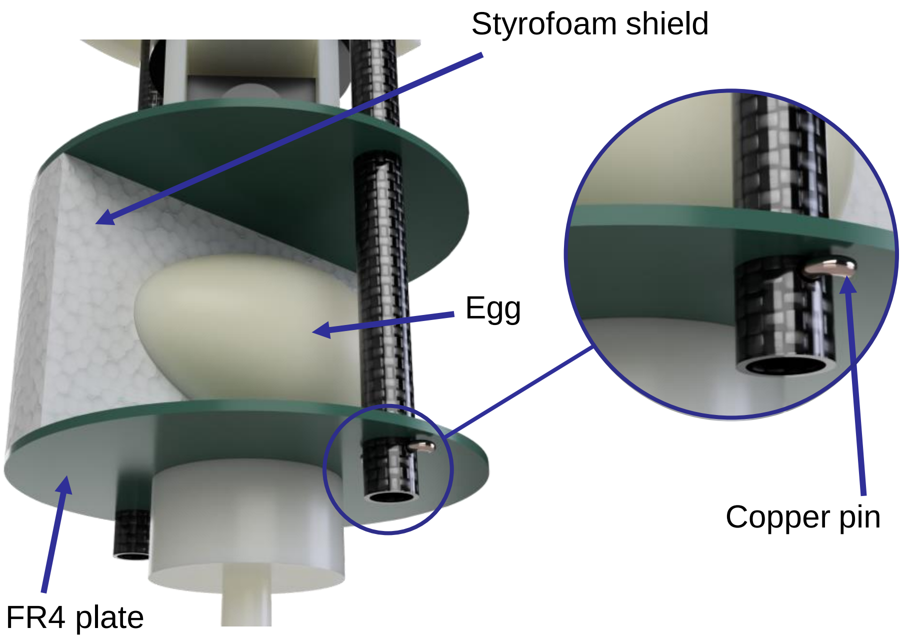
Payload Parachute Deployment Configuration Trade & Selection (3/3)

Design	Description	Advantages	Disadvantages
1	Exposed parachute	• High accessability • Reliable • Ease of packing	• Exposure to external conditions
2	Incased parachute	• Secure	• Low accessability • Possibility of parachute jam

Selected egg containment	Reasons
Design 1: Exposed parachute	We decided to use an external parachute solution due to good access to the parachute, which will be folded again many times during tests. This solution also ensures a low risk of parachute blockage.

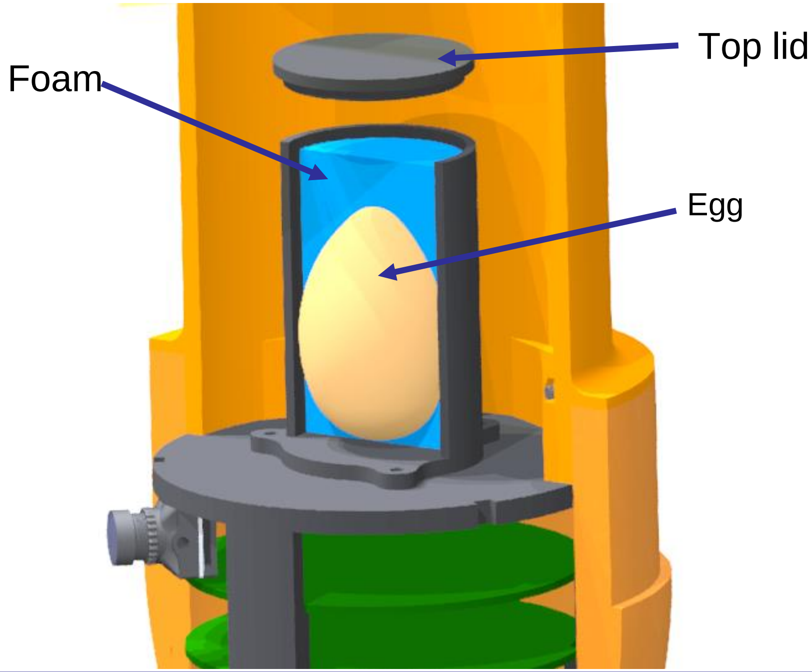
Design 1

In order to place the egg in CanSat, before attaching the payload to the heatshield, 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.



Design 2

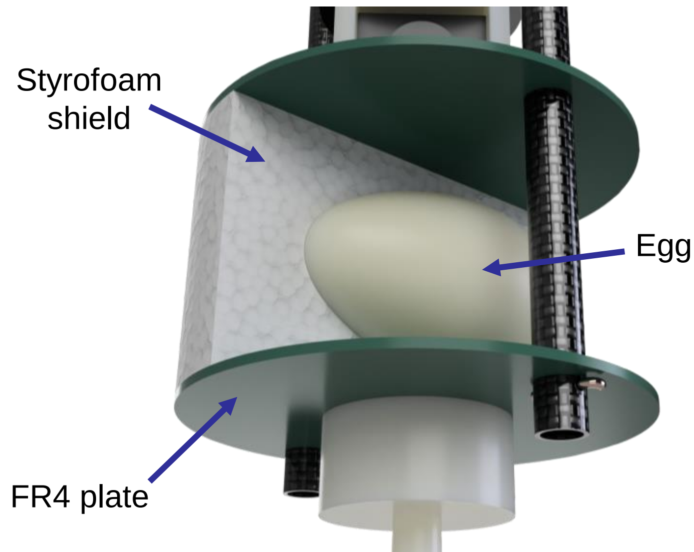
In order to place the egg inside the CanSat before the mission, remove the upper part of the structure attached with five screws. Then remove the top lid of the container and place the egg in a specially pre-cut hole in the XPS (extruded polystyrene) foam.



Payload Egg Containment Configuration Trade & Selection (2/4)

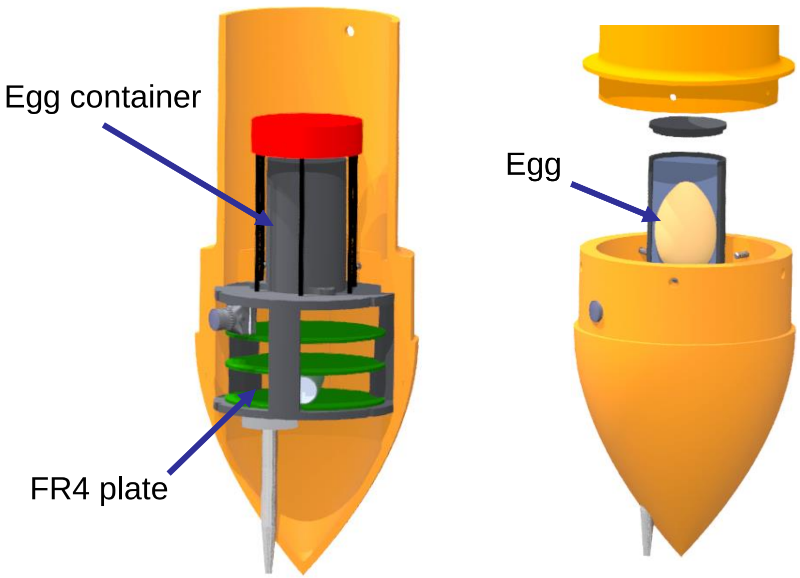
Design 1

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.



Design2

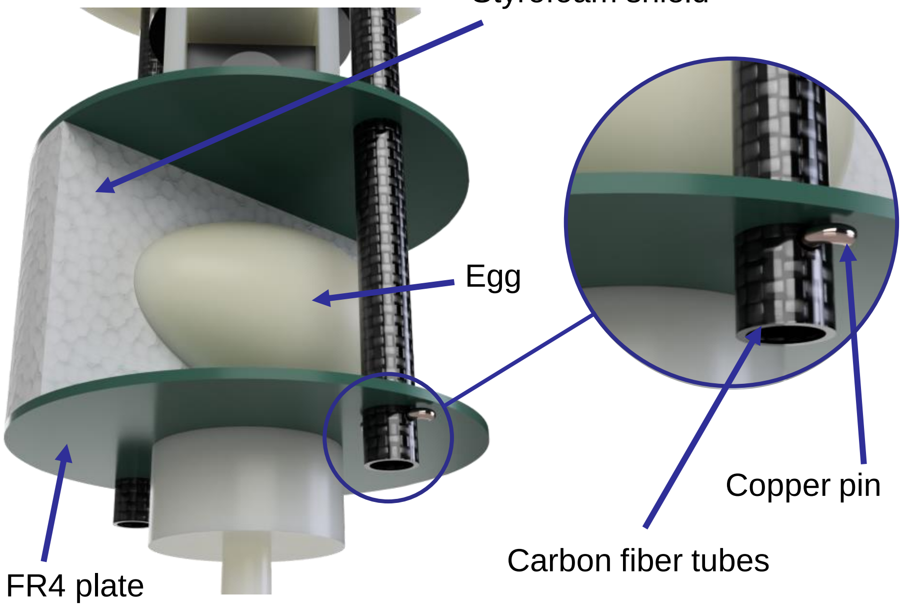
During the mission, the egg is placed in a special 3D printed container with a cap which is attached to the upper part of the electronic case. It is filled with XPS (extruded polystyrene) foam. This positioning means that the container is not a direct structural part that could transfer large forces and loads.



Payload Egg Containment Configuration Trade & Selection (3/4)

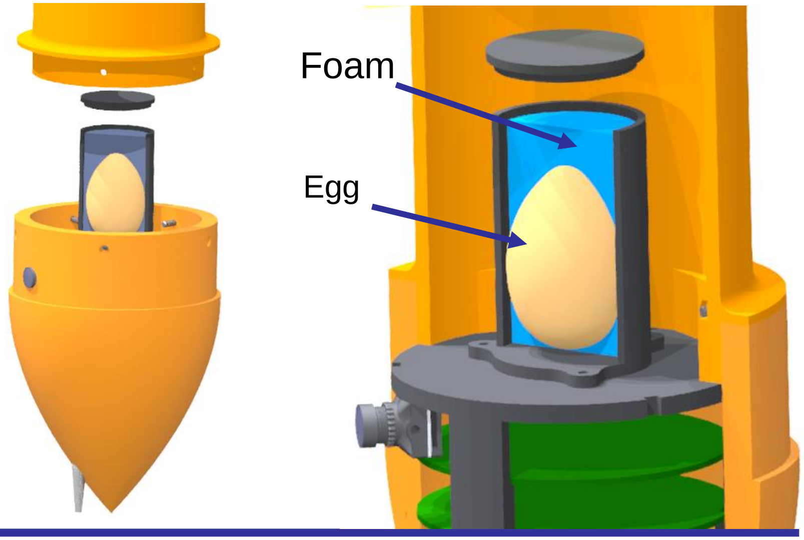
Design 1

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.



Design 2

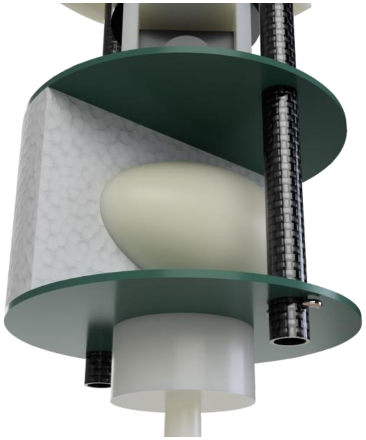
The container is filled with XPS (extruded polystyrene) foam, which has been precisely formed, creating a special cavity for the egg. This foam not only perfectly stabilizes the egg, but also effectively dampens any vibrations, protecting it against possible damage. Thanks to the use of XPS foam, the egg is not only solidly immobilized, but also protected against potential damage resulting from loads or external forces.



Payload Egg Containment Configuration Trade & Selection (4/4)

Design	Description	Advantages	Disadvantages
1	Integral compartment	• Minimal number of parts • High durability	• Not ideal access to egg
2	Separated compartment	• Ease of access to egg • Ease of integration	• High mass • More parts • Need for low strength materials

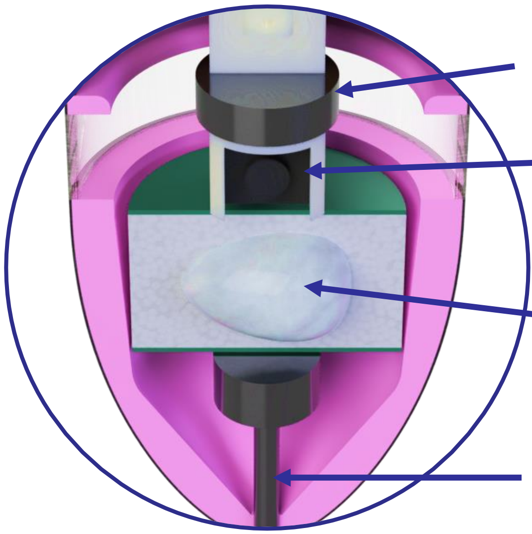
Selected egg containment	Reasons
Design 1: Integral compartment	We decided on a design with an integral compartment, it is easy to make using very durable materials, such as carbon fiber tubes, which will allow the CanSat to withstand landing and all deployment forces.

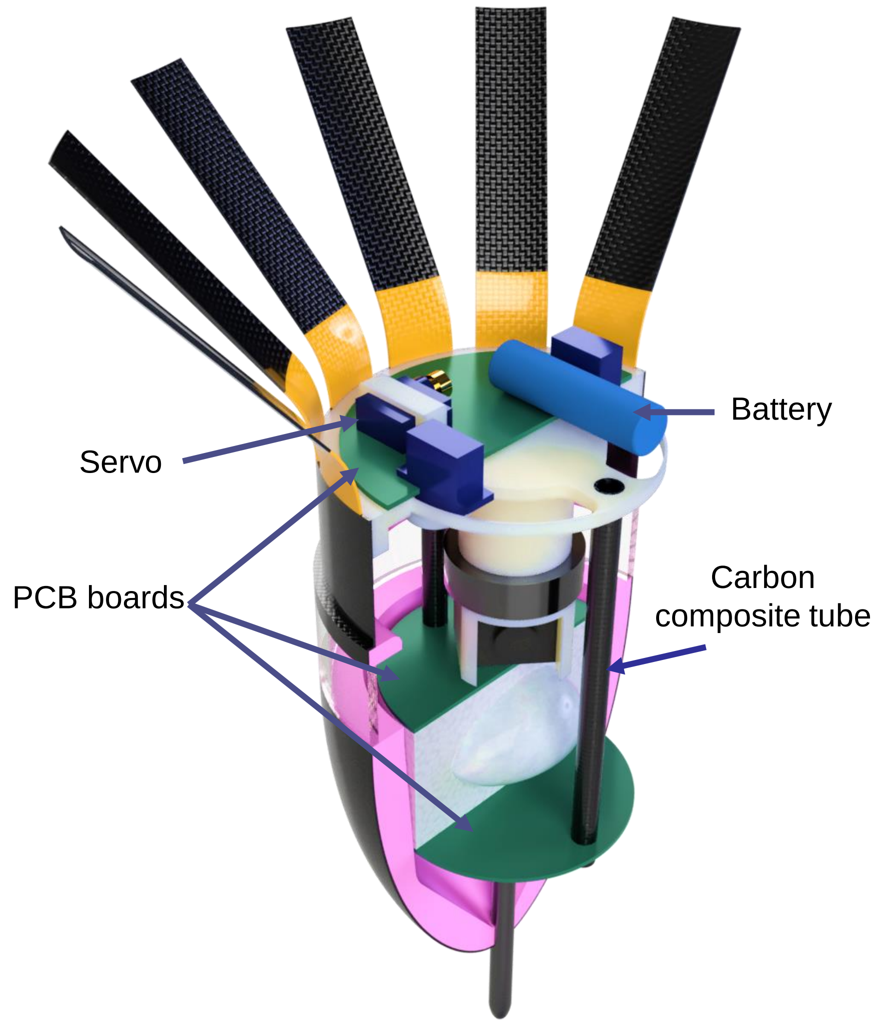


Electronics Structural Integrity

Electronic component mounting methods

Electronic components are placed on PCBs and soldered or attached to the structure using screws. The BLDC 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 PCB boards. 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	1	0.006	0.001	Estimate
MPU-6050	1	0.13	0.001	Estimate
GY-NEO6MV2	1	15.5	0.5	Datasheet
ESP-32-CAM	2	10	0.5	Datasheet
SANDISK Ultra microSDHC 32GB	3	0.25	0.003	Datasheet
STM32F412RGT6	1	0.05	0.001	Estimate
XBP9B-DMST-012	1	8	0.2	Estimate
ANTX150P118B09153	1	0.675	0.01	Measured
Samsung INR18650-25R	1	45	1.2	Datasheet
Small PCB with misc. components	2	30	3	Estimate
Big PCB with misc. components	1	40	4	Estimate
Electrical wires	1	10	0.5	Estimate
9gr servo	3	9	0.1	Datasheet
BLDC motor	1	97	1.5	Datasheet

Mass of all electronic components: 324.1±15.3 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	260	20	CAD estimate
Parachute mount	2	1	0.1	CAD estimate
Carbon fibre rod	2	5	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	2	0.5	CAD estimate
Camera mount	1	10	0.5	CAD estimate
Pitot tube	1	60	3.5	CAD estimate
Pins and screws	1	22	2	Estimate
Epoxy resin glue	1	15	3	Estimate
Parachute	1	12	1	Estimate
Acrylic tube	1	18	1	Estimate

Mass of all mechanical components and structural materials: 556±50 g

Mass Budget (3/3)

Name	Mass [g]	Uncertainty [g]
Electrical components	324.1	15.3
Mechanical components and structural materials	556	50
Total	**880.1**	**65.3**

The required mass of the CanSat is 900 g (without the hens egg).
The approximate mass of the CanSat is 862.1 g.

Margin: 900 g – 862.1 g = **19.9 g**

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 structural supports.

Communication and Data Handling (CDH) Subsystem Design

Krzysztof Kowaczek

Payload Command Data Handler (CDH) Overview

Type	Component	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.

Payload Processor & Memory Trade & Selection (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, SDIO, USB	16/12 - bit
STM32F103RG	~5	72	3.3	1024	96	51xGPIO, of which: -16x PWM out -16x Analog in	2 x I2C, 5 x UART, 3 x SPI, USB, SDIO	16/12 - bit
ATmega328P	~65	20	1.8 ÷ 5.5	32	2	14xGPIO, of which: -6x PWM out -6x Analog in	1x I2C, 1x USART, 1 x SPI	6/10 - bit

Selected processor	Reasons
STM32F412RGT6	• 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

Payload Processor & Memory Trade & Selection (2/2)

Name	Memory	Interfaces	Package	Voltage [V]
SANDISK Ultra microSDHC 32GB	32GB	SPI/SDIO	microSD	2.7 ÷ 3.6
Winbond W25Q128	16MB	SPI	8-SOIC	2.7 ÷ 3.6
EEPROM 24LC01	1KB	I2C	DIP-8	2.7 ÷ 3.6

Selected memory	Reasons
SANDISK Ultra microSDHC 32GB	• High availability • Easy to replace • The highest capacity • Easy to use in the software • Vibration resistant

Payload Real-Time Clock

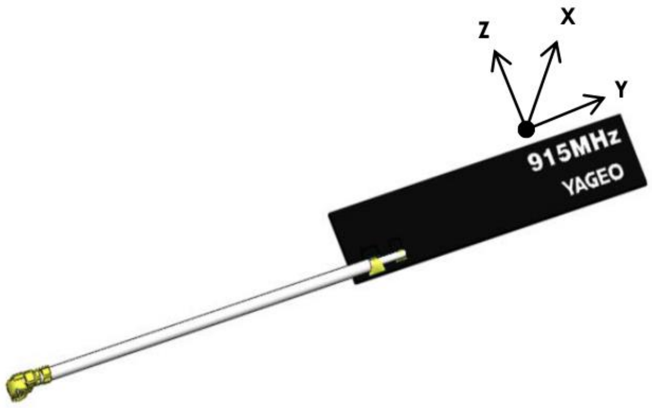
Name	Size [mm]	Mass [g]	Interface	Reset tolerance	Type
Internal STM32 RTC clock	Integrated into STM32	-	Internal bus	Unaffected due to coin battery backup	Hardware
PCF85063AT/AY	3.0 x 4.4	Few milligrams	I2C	Unaffected due to coin battery backup	Hardware
DS1302S RTC	3.9 x 4.9	Few milligrams	I2C	Unaffected due to coin battery backup	Hardware

Selected RTC	Reasons
Internal STM32 RTC clock	• Saves weight due to being integrated • Is reset resistant • CPU can read directly from RTC • Has backup battery source • MCU already chosen

Payload Antenna Trade & Selection (1/2)

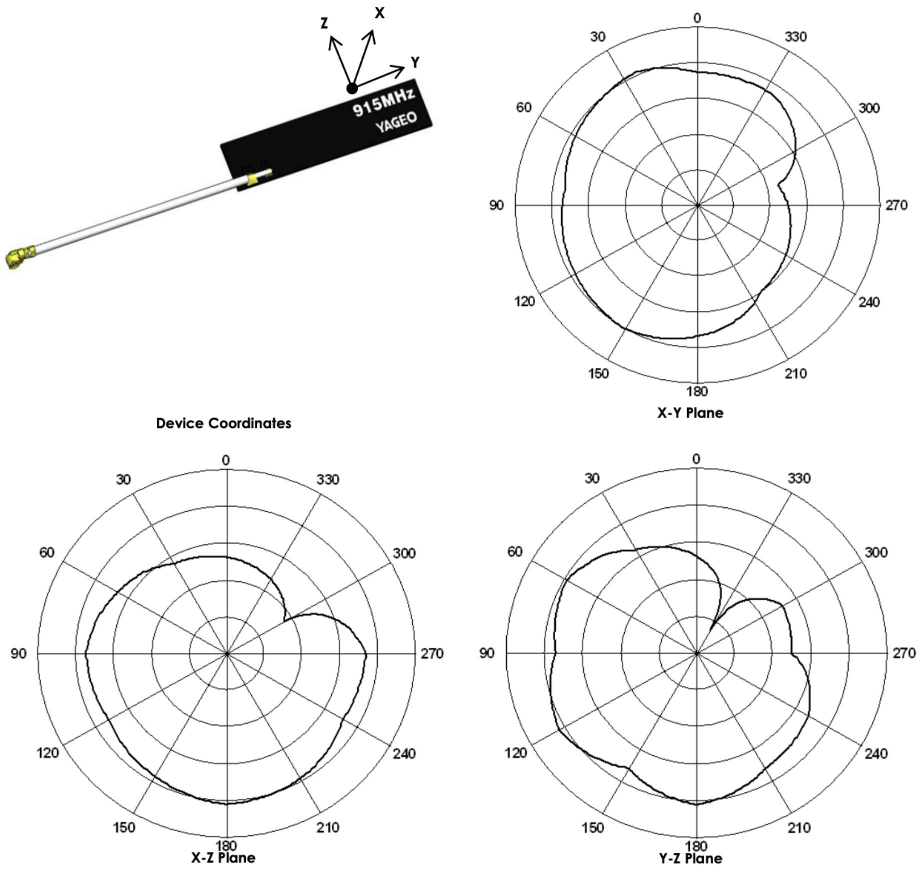
Name	Connector type	Antenna type	Frequency range(s) [MHz]	Weight [g]	Peak gain [dBi]	Efficiency [%]	Range [km]
ANTX150P118B09153	I-PEX (U.fl compatible)	PCB strip	890 ÷ 925	0.675	1.9	>55	~0.6 (worst case) ~9 (best case)
MOLEX 2111400100	U.fl	PCB strip	868 ÷ 870, 902 ÷ 928	0.48	1	>60	~0.4 (worst case) ~7 (best case)

Selected antenna	Reasons
ANTX150P118B09153	• Higher gain • Higher best case range • Slightly better worst case range • Wider frequency range

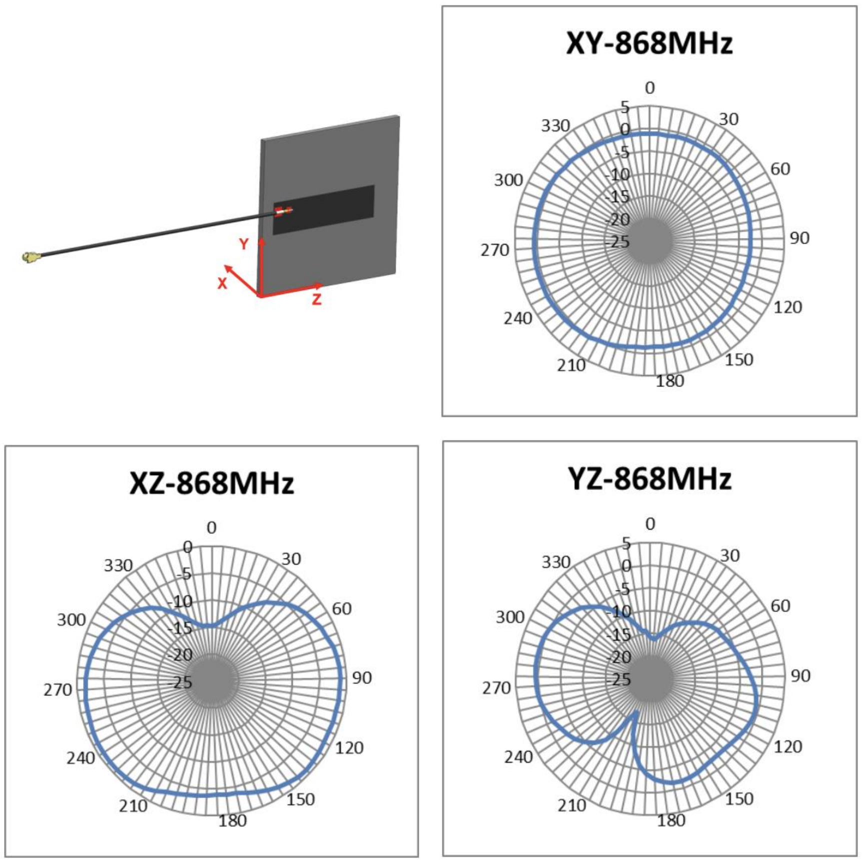


Payload Antenna Trade & Selection (2/2)

ANTX150P118B09153



MOLEX 2111400100



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)
XB24CDMWIT-001	2.7 ÷ 3.6	TX: 45 RX:31	250	-102	2400	63/18	~1.2 (outdoor)

Selected antenna	Reasons
XBee: XBP9B-DMST-012	• Extended outdoor range • High enough data speed

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 (1/2)

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 (2/2)

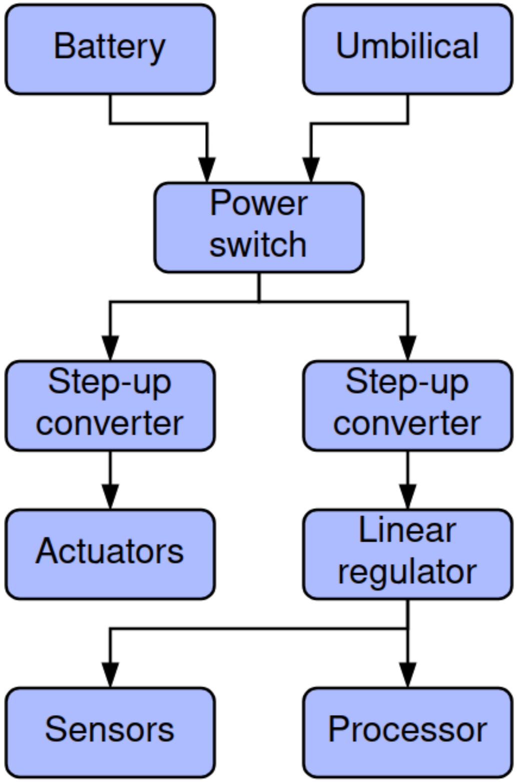
Command name	Format	Description	Example
SIMP - Simulated Pressure Data (to be used in Simulation Mode only)	CMD,<TEAM_ID>, SIMP, <PRESSURE>	1. CMD and SIMP are static text. 2.<TEAM_ID> is the assigned team identification. 3.<PRESSURE> is the simulated atmospheric pressure data in units of pascals with 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

Electrical Power Subsystem (EPS) Design

Krzysztof Kowaczek

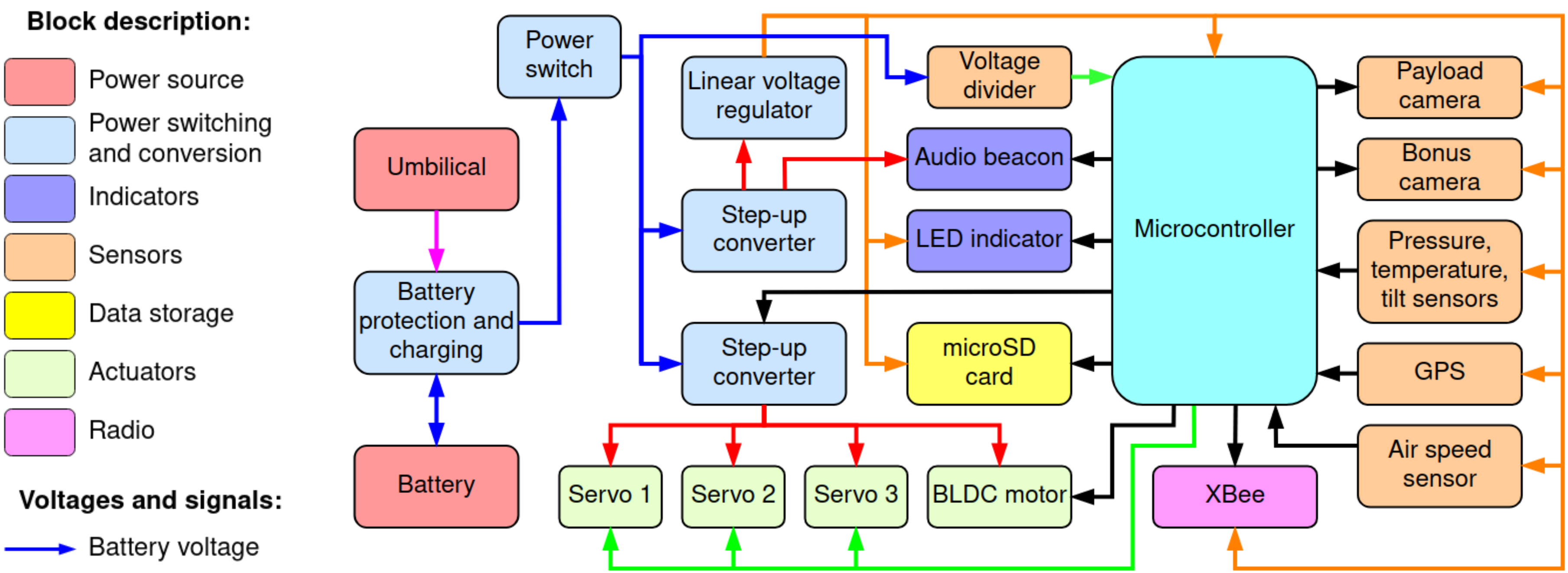
EPS Overview

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

Payload Electrical Block Diagram



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 Trade & Selection

Name	Nominal voltage [V]	Capacity [Wh]	Configuration	Price [$]	Weight [g]
Samsung INR18650-25R	3.7	9.25	Single cell	5.79	45
Duracell Plus MN1604	9	4.95	Internal 6-cell, series	4.59	45
Varta Longlife 4112	4.5	11.25	Internal 3-cell, series	4.89	90

Selected option	Reasons
Samsung INR18650-25R	• High energy density • High current output • Is rechargeable

Important notes:
The selected 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 heavy duty zip ties and kapton tape.

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
MPU-6050	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	2	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
BLDC motor	550	0	0.1	1.9	1	0.0647	Measured
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]	3.027
Power margin [Wh]	6.223
Battery power level after 2 hours [%]	67.28

Flight Software (FSW) Design

Tomasz Lubelski

FSW Overview (1/2)

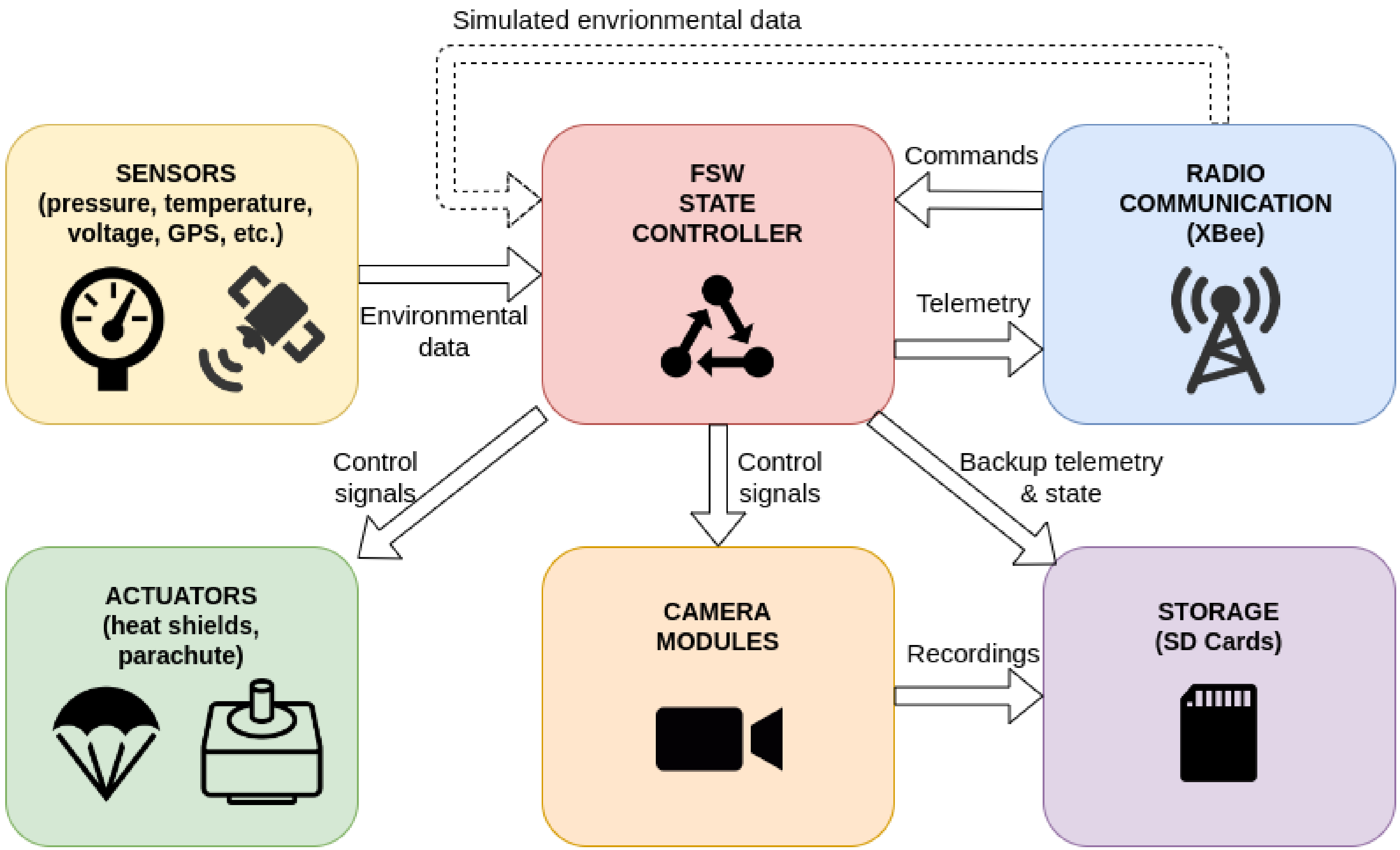
Main FSW tasks:

- 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:

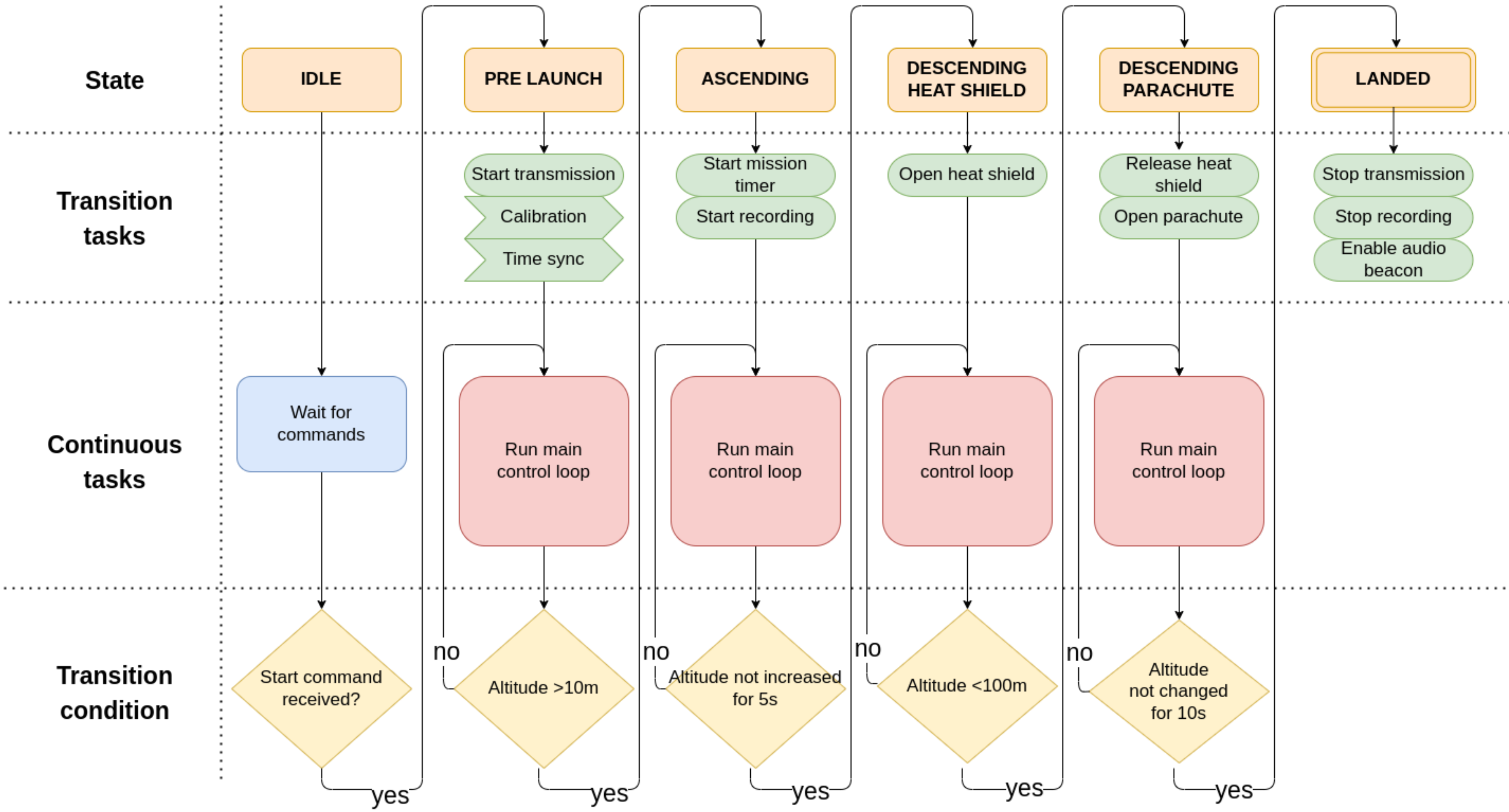
- Programming languages: C, C++
- Hardware abstraction library: STM32HAL
- Development environment: STM32CubeMX, PlatformIO
- Real-time operating system: FreeRTOS
- Utility libraries: Embedded Template Library

General flight software flow

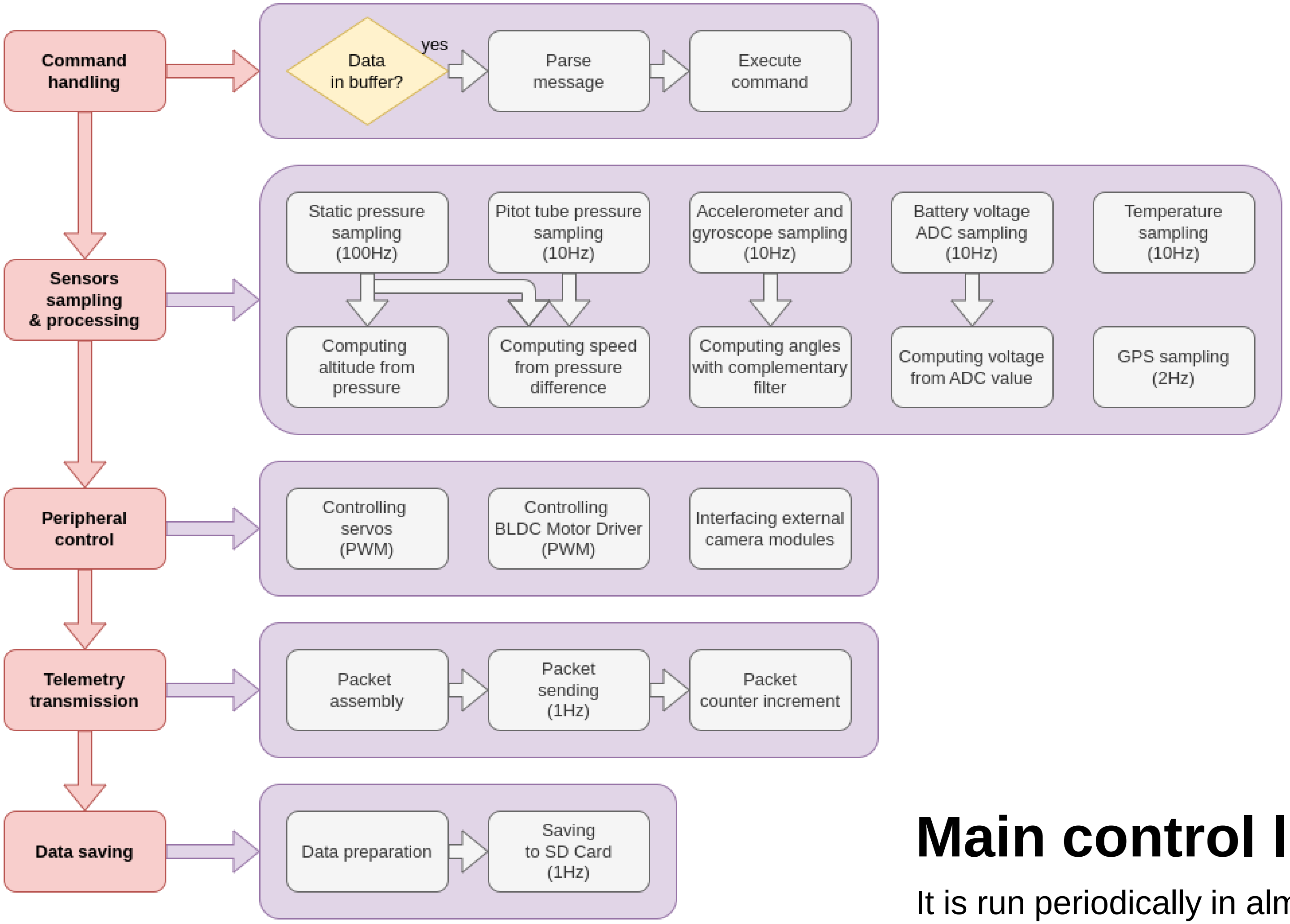


Payload FSW State Diagram (1/3)

Main decision state machine



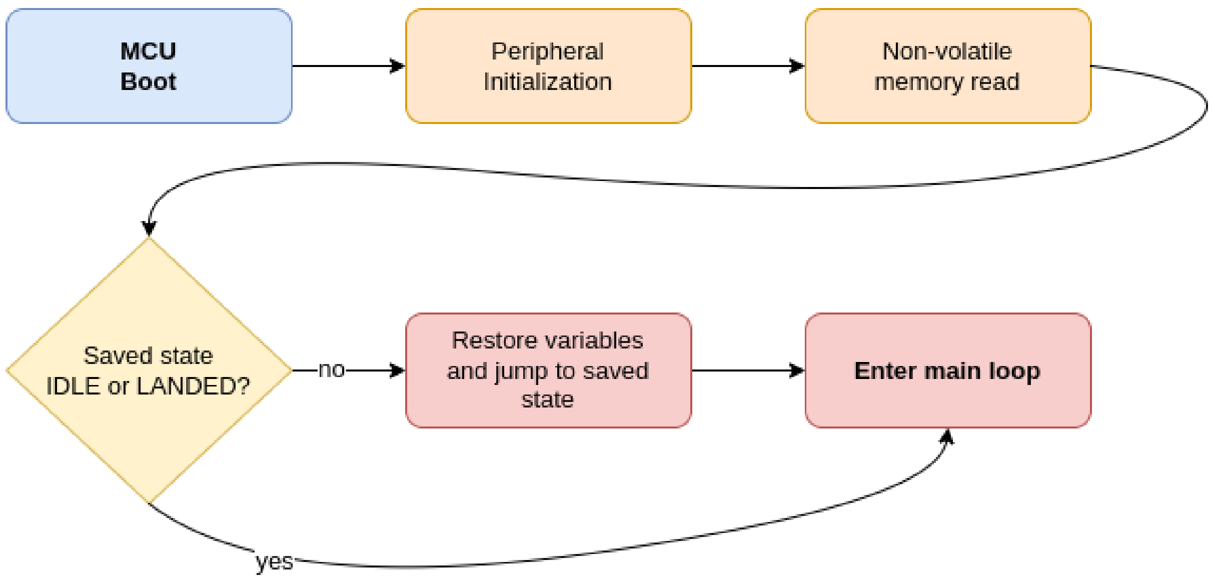
Payload FSW State Diagram (2/3)



Main control loop

It is run periodically in almost every state

Boot and recovery procedure



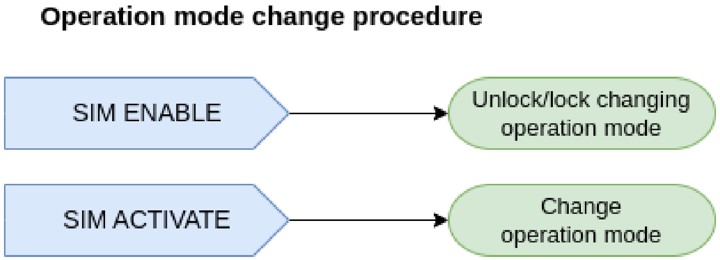
Possible restart causes:

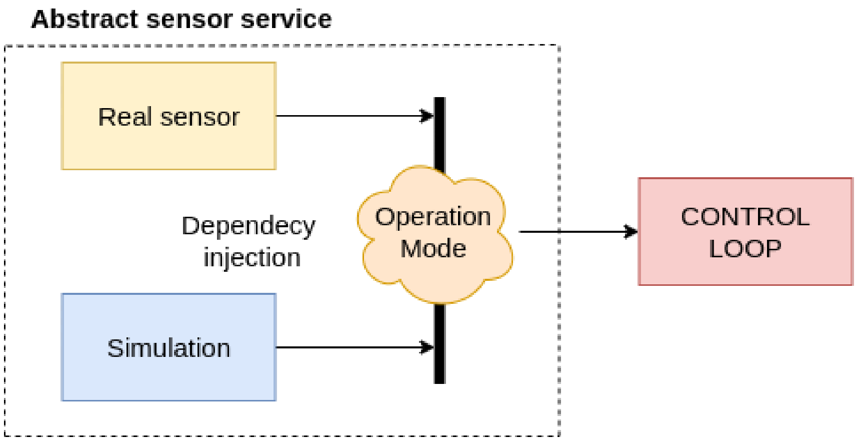
- battery voltage drop,
- contact vibrations,
- watchdog timer firing,
- energetic particle from outer space.

Data stored in non-volatile memory:

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

Simulation operation mode





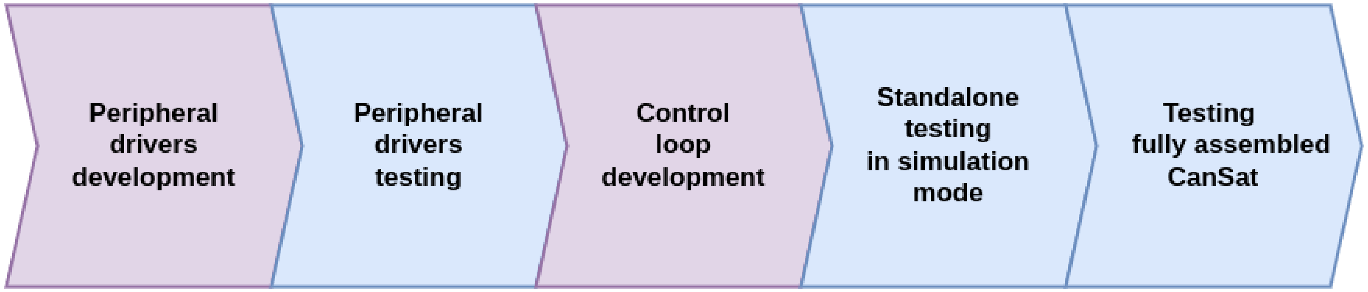
Simulation mode assumptions:

- 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

Steps to avoid late software development:

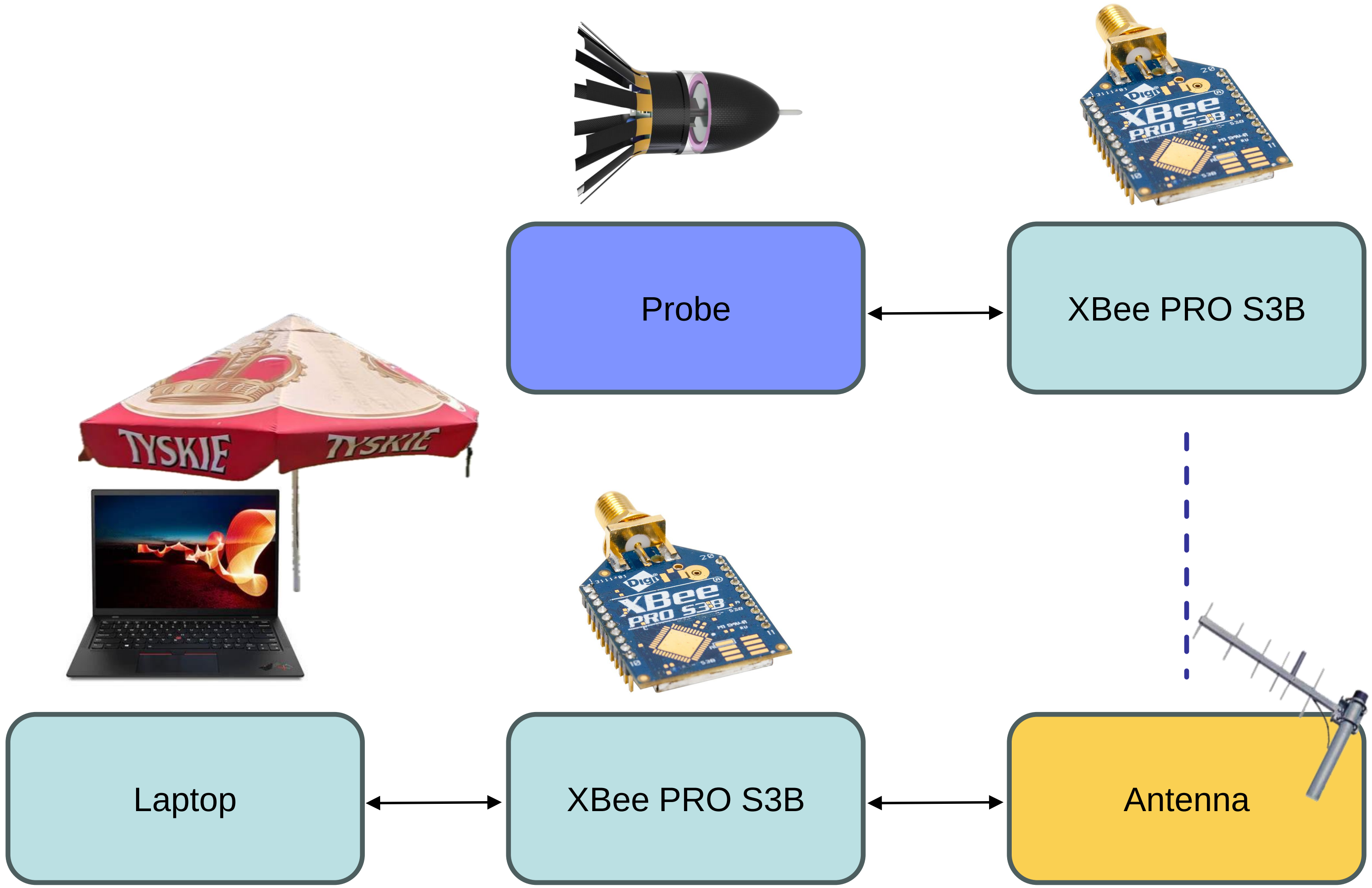
- Special team members focused only on software development.
- Writing peripheral libraries with breakout boards before ordering actual PCB.
- Early implementation of simulation mode to test only electronic circuit before final assembly.



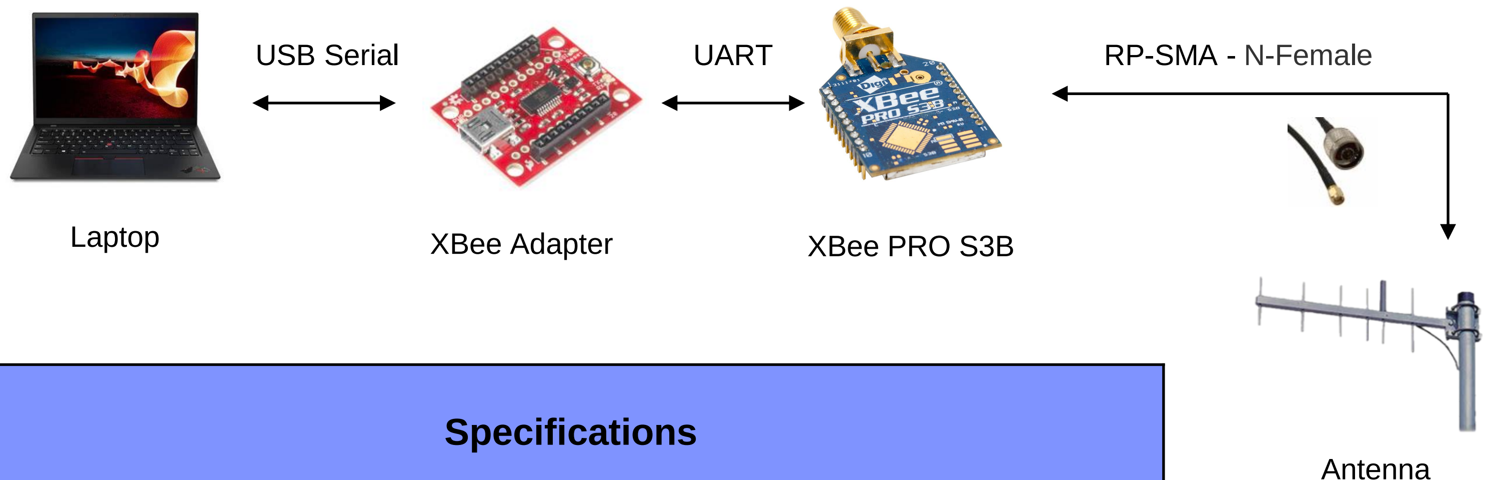
Ground Control System (GCS) Design

Tomasz Lubelski

GCS Overview



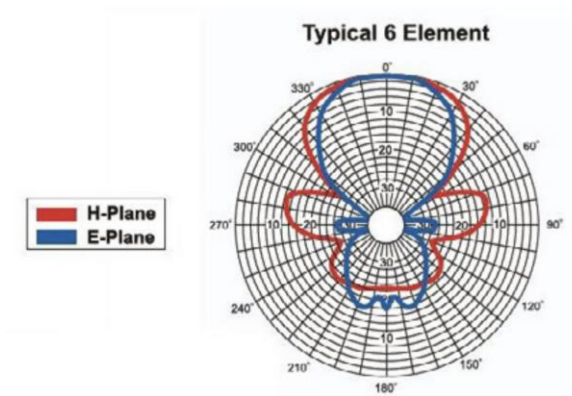
GCS Design



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 Trade & Selection

Name	Frequency Rate [MHz]	Gain (dBi)	Type	Mount	Price [$]
Larid Technologies PC906N	896 - 940	8.5	Yagi	Handheld	65.73
PCTEL MFB9157NF	902 - 928	7	Omnidirectional	Table top	138.46



PC906N RADIATION PATTERN

Selected antenna	Reasons
Larid Technologies PC906N	• Better gain • Cheaper • Handheld antenna does not require any stand

Antenna will be pointed in direction of CanSat for best signal and minimalize data loss.

GCS Software (1/5)

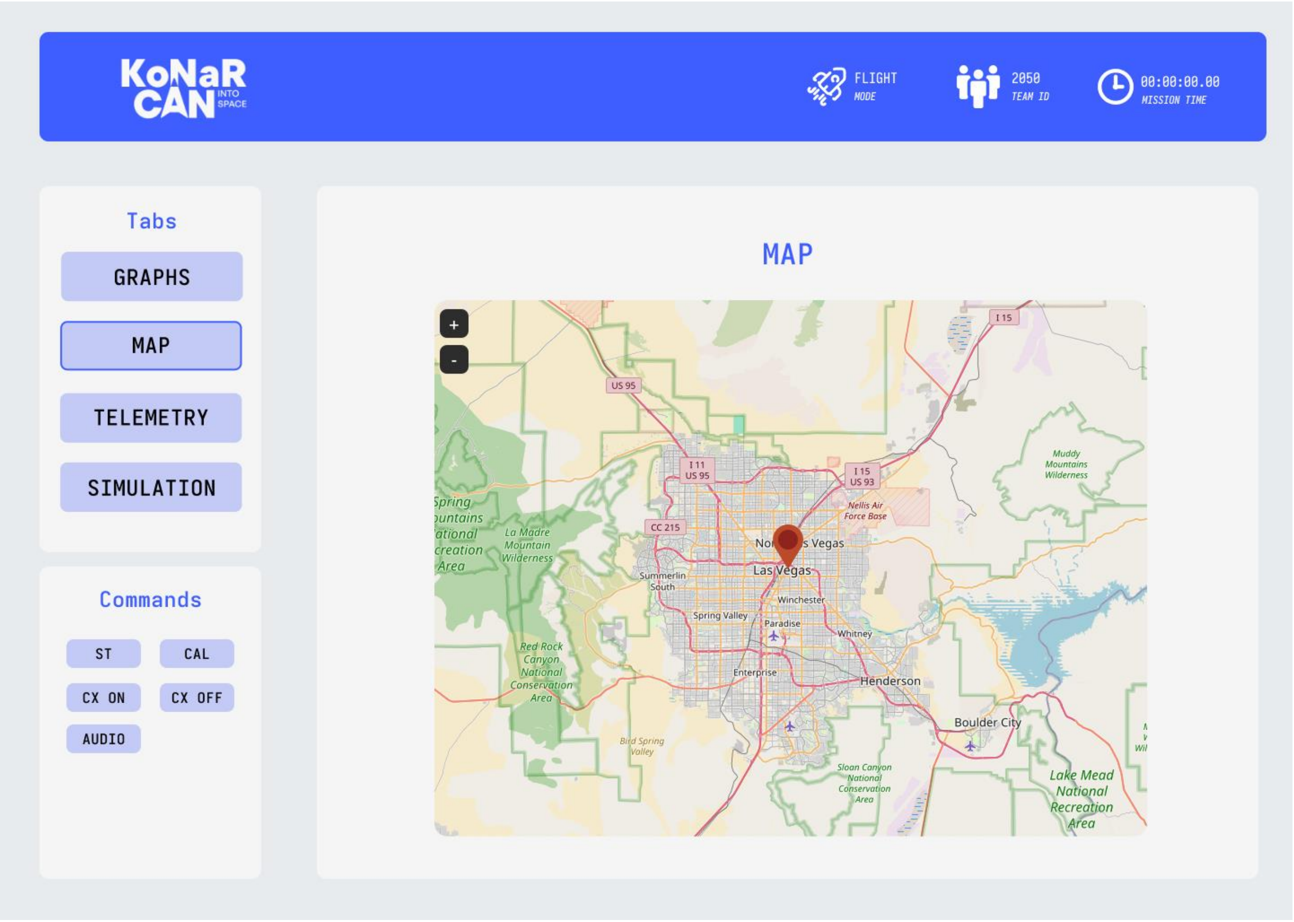
Section	Description
Software packages and technologies used	We'll make the GCS software using Python3 and Tkinter to create a user-friendly interface. To ensure we get data on time, we'll use multithreading. This helps the software handle data smoothly while keeping the interface responsive.
Commercial 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)

Selectable tabs

Commands widget

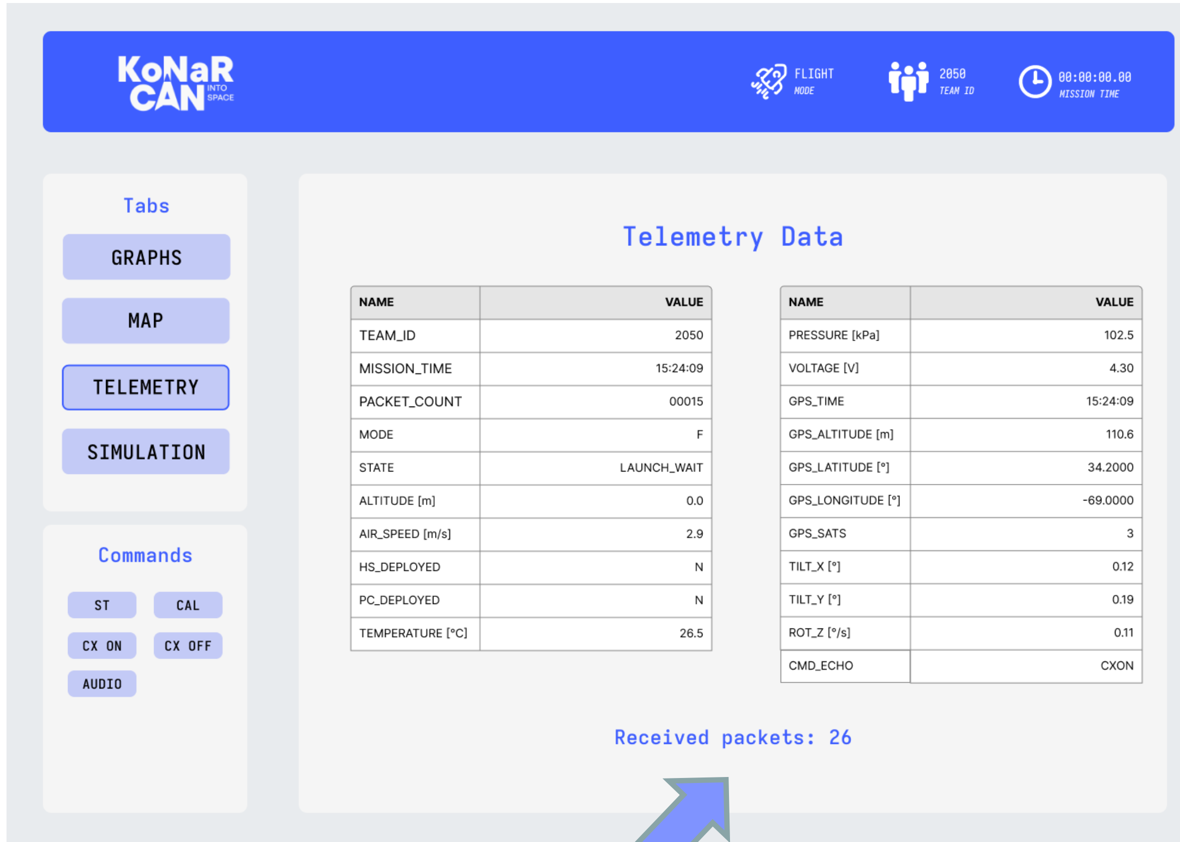
* *Preview graphs with random values*



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
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 Container	Payload is released, mechanism does not get stuck	Not tested
Mechanical	Electronic mounting withstands all shock and vibrations	Payload is released, mechanism does not get stuck	Not tested
Mechanical	The mechanical mechanism raises the flag	The flag is fully raised	Not tested
Mechanical	Battery is easily dismounted from payload	Battery can be replaced in less than one minute	Not tested
Mechanical	Container and payload parachutes open after release	Parachutes cords don't tangle	Not tested

Subsystem Level Testing Plan (2/5)

Subsystem	Test case	Acceptance criteria	Test result
Mechanical	Container descents on parachute correctly	The proper speed of descent is maintained	Not tested
Sensors	Sensors are settled 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	Not tested
Sensors	Pressure measurement	Pressure data can be read via debug logs	Tested
Sensors	Voltage measurement	Voltage value can be read via debug logs	Not 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	Not 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	File system initialization on internal Flash	File system is initialized successfully	Not tested
CDH	SD Card is ready for writing data	File system returns no error when saving files	Not tested
CDH	Writing data into Internal Flash	Data can be read from Internal Flash after power cut	Not tested
CDH	Data can be read from SD Card	Files can be read from filesystem	Not tested
CDH	Data are available on SD Card after power loss	Files are always available	Not tested
CDH	Real-Time clock measures time	Time of CanSat and Ground Station are synced during the tests	Not 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	First parachute 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	Second 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

Subsystem	Test case
Decent testing	The CanSat will be lifted using drone and then released. The stability of flight and camera will be checked. The descent rate after releasing the first parachute shall be in 10 – 30 m/s. Descent rate after heatshield released should drop to 5 m/s or less.
Communications	We will perform filed 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.
Mechanisms	Mechanical and Descent Control Subsystem, such as release mechanism of payload, heat shield and parachute and G-force test are going to be executed with the CanSat at Integrated Level.
Deployment	Tests of the parachute release mechanism and the payload drop are going to be performed. Stationary tests of parachute opening, the parachute ejection and the flag raising system will be performed.

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.

Simulation Test Plan

Simulation mode is used for easy FSW testing.

This mode replace 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)

Team Member Launch Operations Crew Assignments:

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

Mission Operations Manual Development Plan

Section	Development plan
Ground Station Configuration	The Ground Station Crew will be tasked with repetitive assembly and disassembly of the ground station. Based on these actions all steps of assembly will be identified and a check list will be prepared.
CanSat Preparation	The mechanics team will point out which mechanism have to be attended. The electronics and software teams will describe how mechanisms can be remotely controlled and to check if the CanSat is turned on.
CanSat Integration	Various methods of CanSat integration (how to reconfigure the CanSat into its stowed configuration) will be proposed and tested out using a rocket mockup. The best method will be included in the manual alongside the instruction how to turn on the probe and check if everything is flight ready.
Launch Preparation	Instructions what each team member should be doing. Instructions for delivery and installation of rocket on the launch pad (including taking a picture).
Launch Procedure	Basing on the mission guide a step by step procedure for launching the CanSat will be prepared. This will include the instructions for Mission Control Officer and the Ground Station Crew.

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 pink. 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

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 have been performed. Other tests like environmental and descent will be done in near future.

We are preparing another set of tests to seek for any improvement for our design. Although our project should be sufficient for 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	24	
C2	The CanSat shall be deployed from the rocket when the rocket motor ejection charge fires.	Comply	24	
C3	After deployment from the rocket, the CanSat shall deploy its heat shield/aerobraking mechanism.	Comply	24,42,56	
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	24	
C5	At 100 meters, the CanSat shall deploy a parachute and release the heat shield.	Comply	24,65,67	
C6	Upon landing, the CanSat shall stop transmitting data.	Comply	100	
C7	Upon landing, the CanSat shall activate an audio beacon.	Comply	100	
C8	The CanSat shall carry a provided large hen's egg with a mass range of 51 to 65 grams.	Comply	70	
C9	0 altitude reference shall be at the launch pad.	Comply	100	

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	9	Testing needed
C11	At 100 meters, the CanSat shall have a descent rate of less than 5 m/s.	Partial Comply	9	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	144	
S1	The CanSat mass shall be 900 grams +/- 10 grams without the egg being installed.	Partial comply	77	Weight must be added
S2	Nose cone shall be symmetrical along the thrust axis.	Comply	26	
S3	Nose cone radius shall be exactly 71 mm.	Comply	20	
S4	Nose cone shoulder radius shall be exactly 68 mm.	Comply	20	
S5	Nose cone shoulder length shall be a minimum of 50 mm.	Comply	20	
S6	CanSat structure must survive 15 Gs vibration.	Partial Comply	60	
S7	CanSat shall survive 30 G shock.	Partial Comply	60	
S8	The CanSat shall perform the function of the nose cone during rocket ascent.	Comply	24	

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	61	
S10	The rocket airframe can be used as part of the CanSat operations.	Comply	61	
S11	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high-performance adhesives.	Comply	55	
M1	No pyrotechnical or chemical actuators are allowed.	Comply	63, 65	
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	63, 65	No mechanisms will use heat.
M3	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Partial comply	63	Testing needed
M4	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Partial comply	74	Testing needed
M5	The CanSat shall deploy a heat shield after deploying from the rocket.	Comply	63	
M6	The heat shield shall be used as an aerobrake and limit the descent rate to 10 to 30 m/s.	Partial comply	9	Additional testing needed

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	25,	
M8	The CanSat shall protect a hens egg from damage during all portions of the flight.	Comply	57	
M9	If the nose cone is to be considered as part of the heat shield, the documentation shall identify the configuration.	Comply	21	
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	122	Heat shield is integral part of the aerobraking mechanism
E1	Lithium polymer batteries are not allowed.	Comply	95	
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	95	
E3	Easily accessible power switch is required.	Comply	93	
E4	Power indicator is required.	Comply	93	
E5	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	96	

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	93	
X2	XBEE radios shall have their NETID/PANID set to their team number.	Comply	94	
X3	XBEE radios shall not use broadcast mode.	Comply	94	
X4	The CanSat shall transmit telemetry once per second.	Comply	94	
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	103	
SN1	CanSat shall measure its speed with a pitot tube during ascent and descent.	Comply	32	
SN2	CanSat shall measure its altitude using air pressure.	Comply	29	
SN3	CanSat shall measure its internal temperature.	Comply	30	
SN4	CanSat shall measure its angle stability with the aerobraking mechanism deployed.	Comply	33, 34, 101	
SN5	CanSat shall measure its rotation rate during descent.	Comply	34	
SN6	CanSat shall measure its battery voltage.	Comply	31, 101	

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	36,25	
SN8	The video camera shall record the flight of the CanSat from launch to landing.	Comply	36,25	
SN9	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	36	
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	109, 110	
G2	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	109	
G3	Telemetry shall include mission time with 1 second or better resolution.	Comply	112	
G4	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Comply	102	
G5	Each team shall develop their own ground station.	Comply	107	
G6	All telemetry shall be displayed in real time during descent on the groundstation.	Comply	111	

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	112, 87,88	
G8	Teams shall plot each telemetry data field in real time during flight.	Comply	109, 110	
G9	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and an antenna.	Comply	107	
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	106, 107	
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	109, 113	
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	109	
G13	The ground station shall use a tabletop or handheld antenna.	Comply	108	

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	110 - 113	
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	112	
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, 102	
F2	The CanSat shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	101, 102	
F3	The CanSat shall have its time set to within one second UTC time prior to launch.	Comply	90, 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	103, 124	

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	103, 124	
F6	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	103,124	

Management

Krzysztof Kowaczek

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
Nylon filament for 3d printing	$11.31	2	$22.62	Estimated
Carbon fibre tube	$16.08	2	$32.16	Estimated
Poliuretan Foam block	$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	$0.25	25	$6.25	Estimated
Glue	$12.56	1	$12.56	Actual
Nylon fabric for parachute	$18.84	1	$18.84	Actual
Epoxy resin	$22.61	1	$22.61	Actual

Cost of all mechanical parts and structural materials: $263.55

CanSat Budget – Hardware (2/3)

Component name	Price per piece	Quantity	In total	Status
LPS22	$0.95	2	$1.90	Actual
MPU-6050	$3.51	1	$3.51	Actual
GY-NEO6MV2	$6.78	1	$6.78	Actual
ESP-32-CAM	$8.27	2	$16.58	Actual
SANDISK Ultra microSDHC 32GB	$6.28	3	$18.84	Actual
STM32F412RGT6	$4.56	1	$4.56	Actual
XBP9B-DMST-012	$56.83	1	$56.83	Actual
ANTX150P118B09153	$1.56	2	$3.12	Actual
Samsung INR18650-25R	$5.50	1	$5.50	Actual
BLDC motor	$50.25	1	$50.25	Estimated
9g Servo	$5.03	3	$15.09	Actual

Cost of all electronic components : $182.95

CanSat Budget – Hardware (3/3)

Section	Cost
Mechanical parts and materials	$263.55
Electronics	$182.95
Total CanSat probe cost	$503.33

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 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 per person	Quantity	In total	Status
Flight tickets	$900	9	$8100	Estimated
Accomodation	$900	9	$8100	Estimated
Car rental and fuel	$250	9	$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)

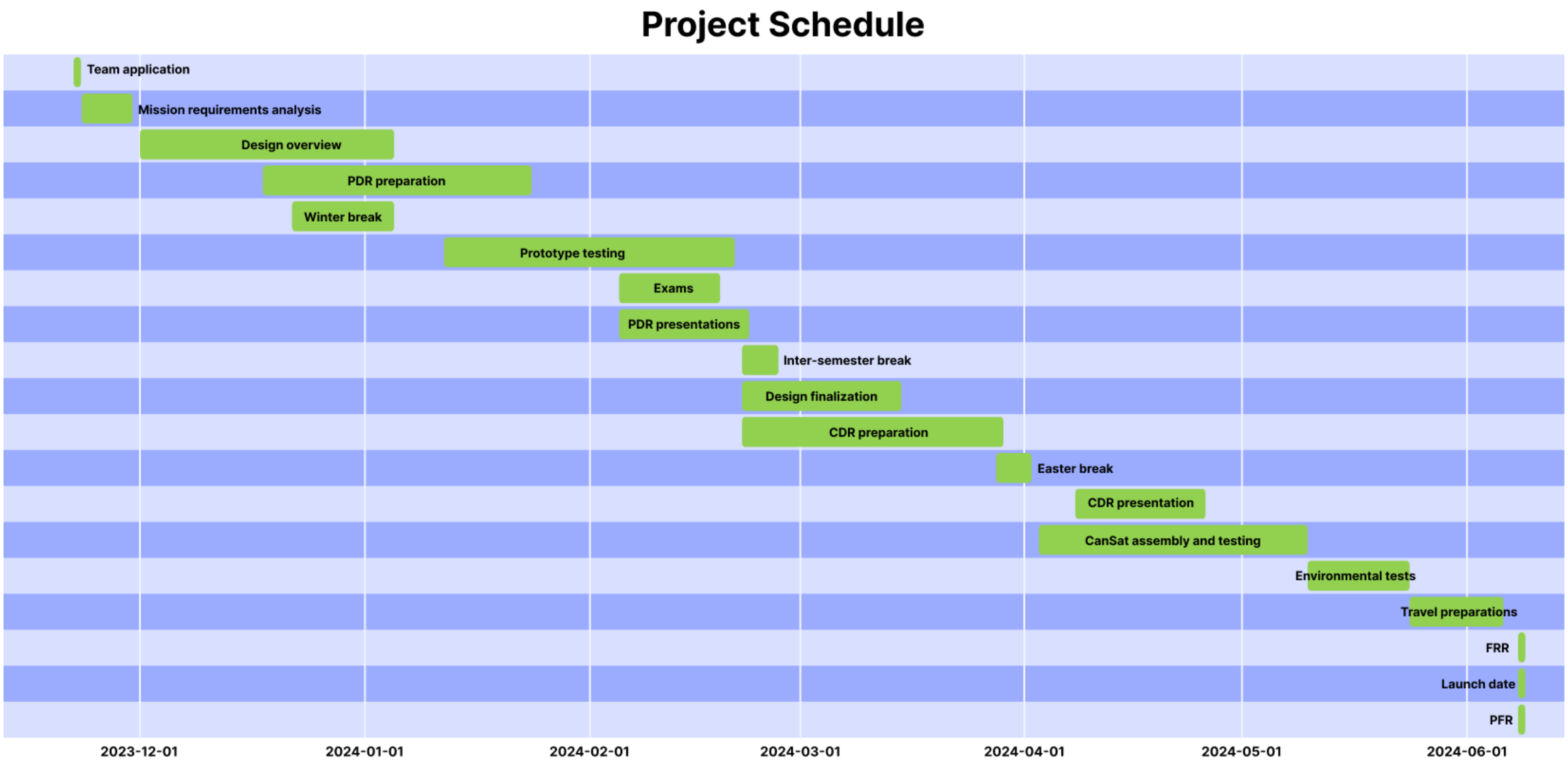
Expense	Price
CanSat probe	$503.33
Ground Station	$133.3
Travel	$20700
Total:	**$21336.63**

Income source	Funds	Status
University funding	$7537.69	Obtained
Active sponsors	$1884.42	Actual
Planned sponsors	$12000	To be obtained

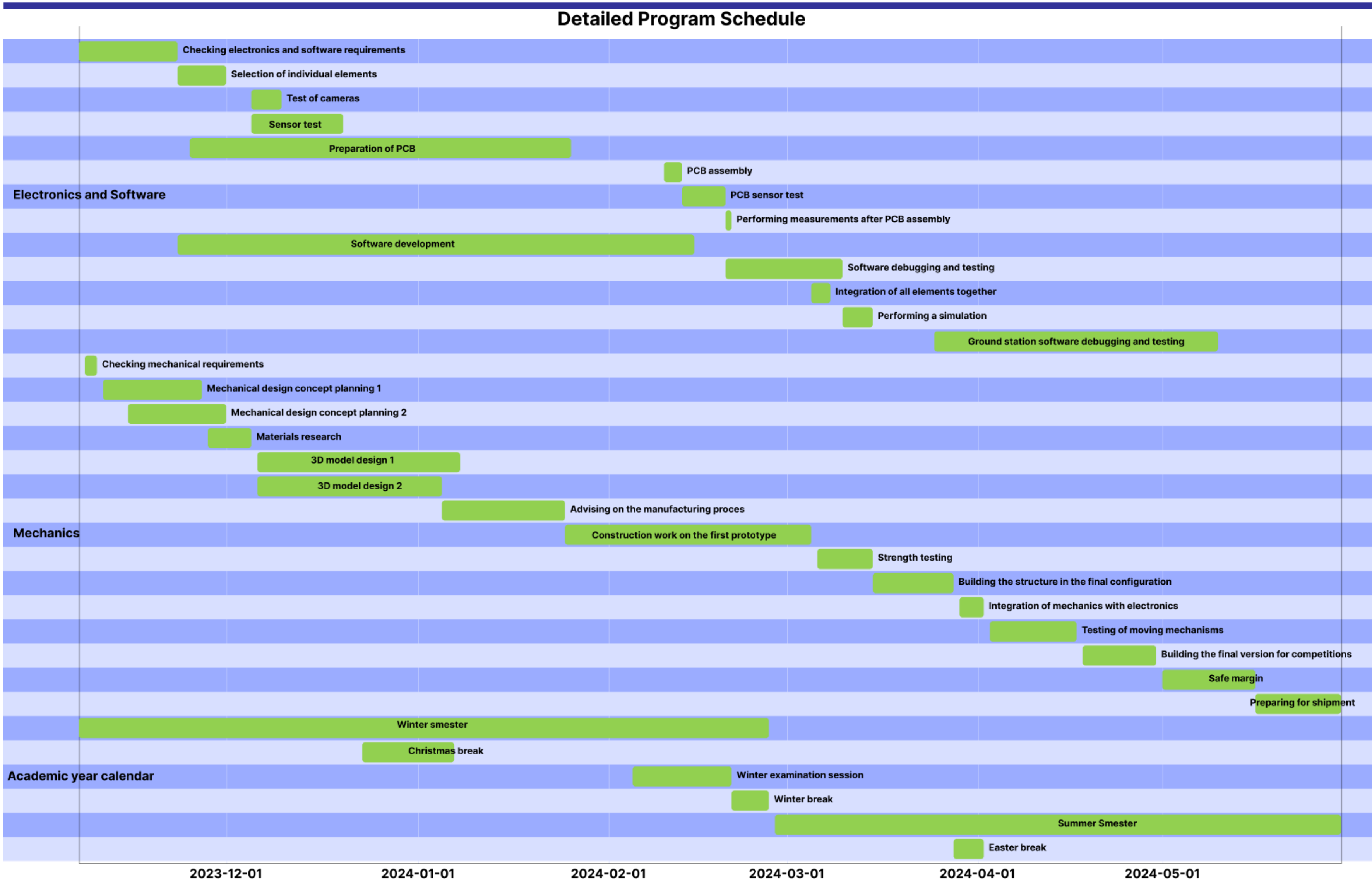
Budget summary:

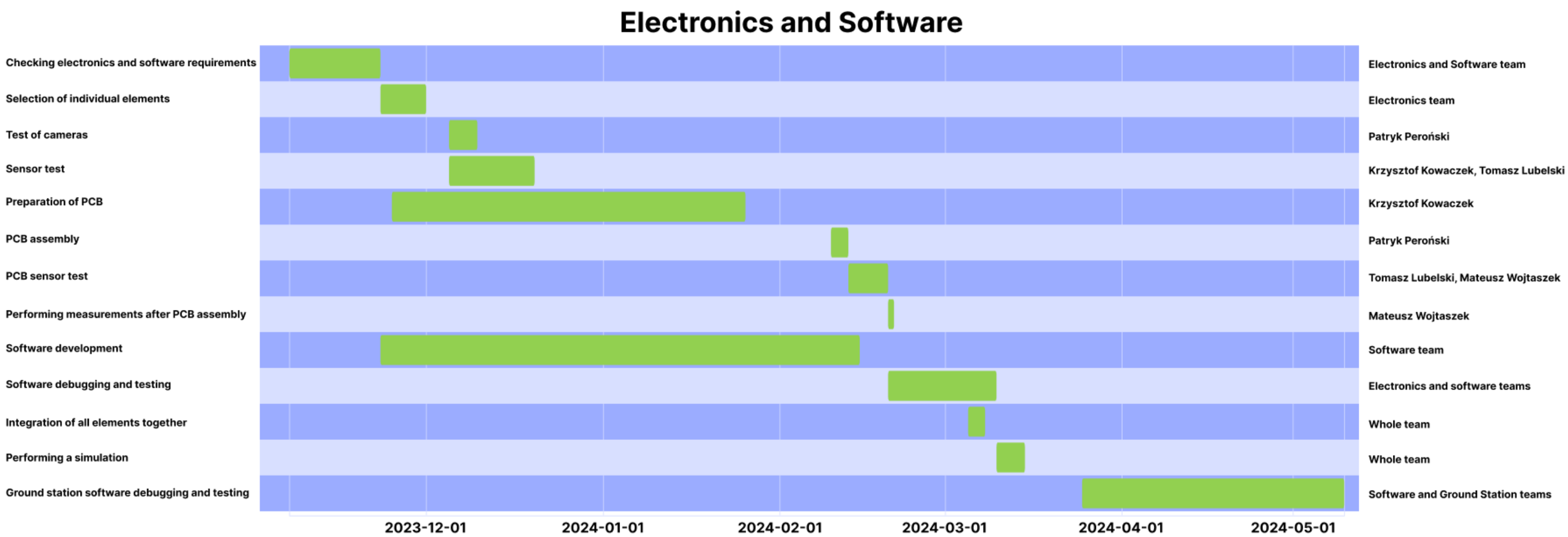
- Our Students Interest Group „KoNaR” has a lot electronical and material resources available for prototyping, along with a well-equipped workshop. We don’t have to worry about prototyping expenses.
- We still need to obtain a lot of funds to be able to travel to the competition with all team members. 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

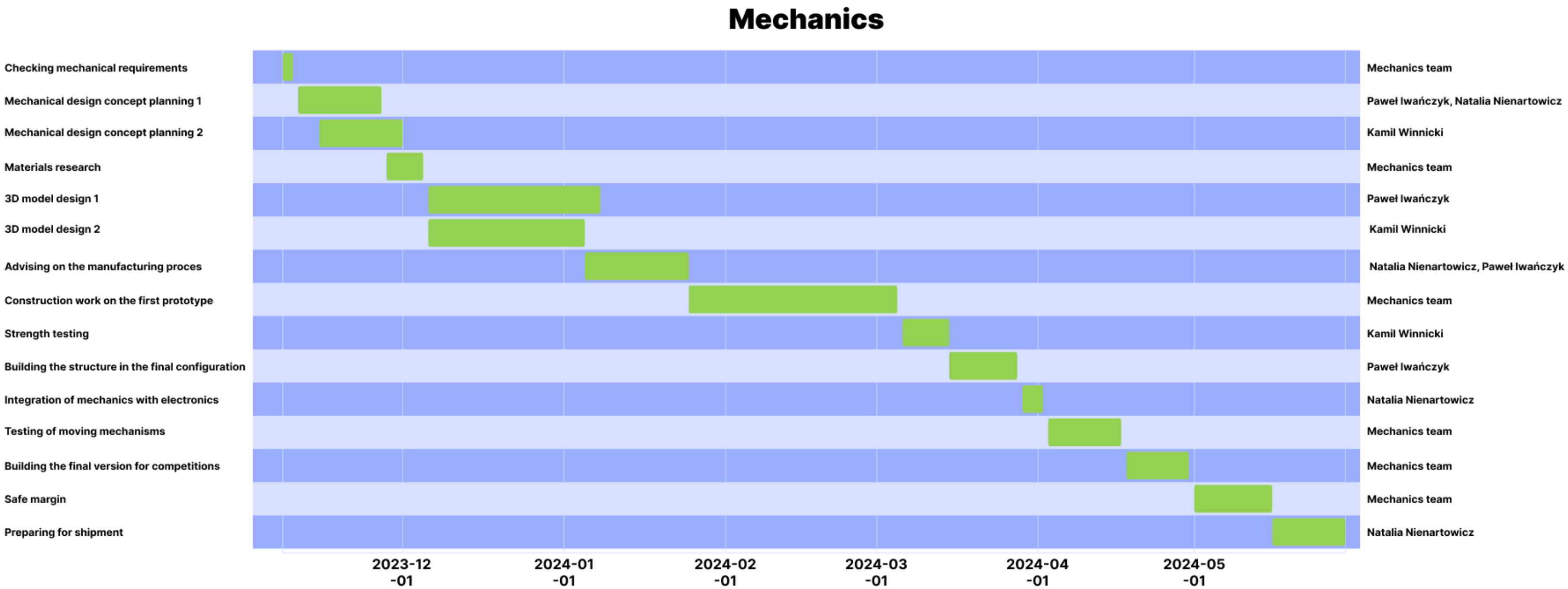


Detailed Program Schedule (1/4)

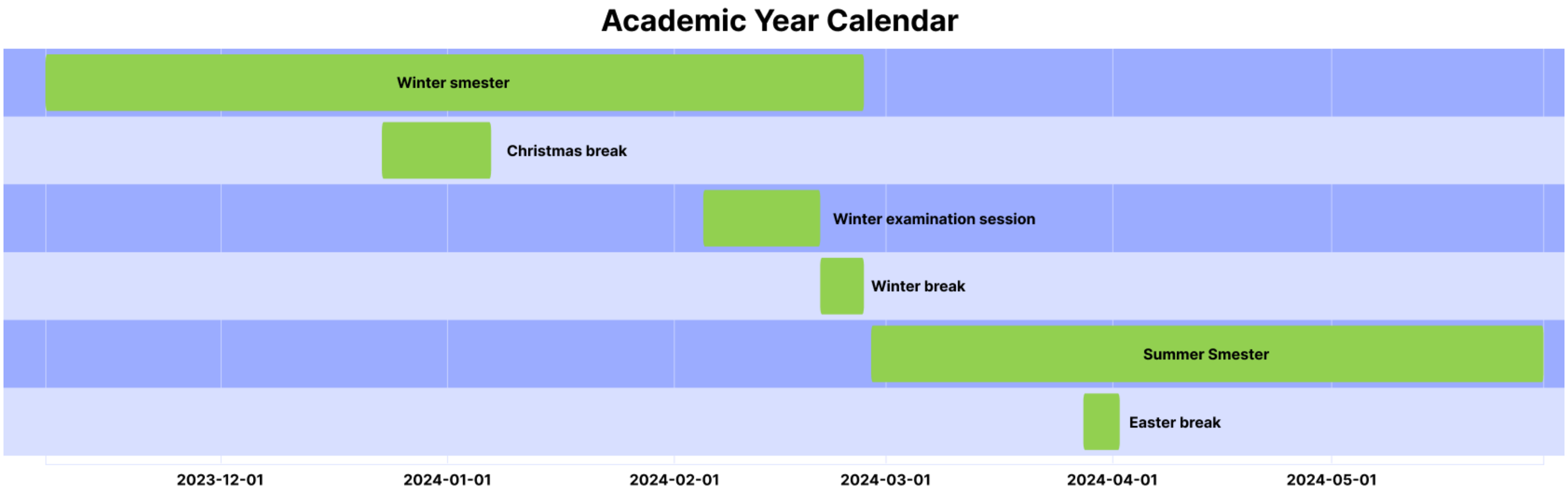



Electronics and Software
Checking electronics and software requirements
Electronics and Software team
Selection of individual elements
Electronics team
Test of cameras
Patryk Peroński
Sensor test
Krzysztof Kowaczek, Tomasz Lubelski
Preparation of PCB
Krzysztof Kowaczek
PCB assembly
Patryk Peroński
PCB sensor test
Tomasz Lubelski, Mateusz Wojtaszek
Performing measurements after PCB assembly
Mateusz Wojtaszek
Software development
Software team
Software debugging and testing
Electronics and software teams
Integration of all elements together
Whole team
Performing a simulation
Whole team
Ground station software debugging and testing
Software and Ground Station teams
2023-12-01
2024-01-01
2024-02-01
2024-03-01
2024-04-01
2024-05-01

Detailed Program Schedule (3/4)



Detailed Program Schedule (4/4)



Conclusions

Major accomplishments
• We succesfully developed software drivers for most sensors and we have defined all software requirements for the mission. • We developed custom cameras firmware. • Mechanical design is ready for prototyping.
Major unfinished work
• Only partial funding was obtained. • Subsystems are still to be finished and integrated. Then tests need to be caried out • The GCS software is presently in the initial phase of development. It incorporates a real-time graph generation feature, where data is retrieved from a separate thread to facilitate concurrent processing.
Final conclusion
• We have already done all preliminary steps to develop the CanSat probe. • We are ready to continue our work, as we are good on schedule. • We are confident on our design.