CanSat 2023
Critical Design Review (CDR)

1082

PWr Aerospace

Presentation Outline

Team Organization

1st Doctoral

Tobiasz Puślecki
- Team leader
- Electronics and Software Engineering

2nd Master

Katarzyna Ignatowicz
- Finances and support

2nd Bachelor

Jakub Kaszowski
- Leader of Electronics
- Electronics Engineering

1st Bachelor

Tomasz Drewniak
- Leader of Mechanics
- Mechanical Engeineering

3rd Bachelor

Eunika Puślecka
- Finances and support

3rd Bachelor

Hubert Kulik
- Electronics and Software Engineering

1st Bachelor

Konrad Łebek
- Mechanical Engeineering

1st Bachelor

Tymoteusz Puślecki
- Public Relations

Dr hab. Inż. Paweł Kabacik
- Faculty Advisor

Acronyms

A – Analysis
ABS – Acrylonitrile butadiene styrene
API – Application Programming Interface
CAD – Computer Aided Design
CDH – Communication and Data Handling
CDR -Critical Design Review
CONOP- Concept of Operations
CG – Center of Gravity
CP – Center of Pressure
CSV – Comma Separated Value
D – Demonstration
DCS- Descent Control System
EPS – Electrical Power Subsystem
FR-4 – Glass-reinforced epoxy laminate
FRR - Flight Readiness Review
FSW – Flight Software
GCS – Ground Control System
GPS – Global Positioning System
GS – Ground Station
HW - Hardware
I – Inspection
I2C, **IIC** – Inter-Integrated Circuit
IMU – Inertial Measurement Unit
LCO- Launch Control Officer
MCU – Microcontroller Unit
uC – Microcontroller
ADC – Analog to Digital Converter
RTC – Real Time Clock
SDIO – Secure digital input/output interface
NMEA – National Marine Electronics Association protocol
PDR-Preliminary Design Review
PCB – Printed Circuit Board
PETG – Polyethylene terephthalate
PFB – Pre-Flight Briefing
PFR – Post Flight Review
PWM – Pulse Width Modulation
RPM- Rotations Per Minute
RSO- Range Safety Officer
SOE- Sequence of Events
SPI – Serial Peripheral Interface
T – Test
TBD - To Be Determined
TBR - To Be Resolved
TBT – To Be Tested
UART – Universal Asynchronous Receiver-Transmitter
USB – Universal Serial Bus
VM -Verification method

System Overview

Konrad Łebek

Mission Summary

Main objectives
The CanSat shall be launched to an altitude ranging from 670 meters to 725 meters.
Descend using a parachute at a rate of 15 m/s.
At 500 meters CanSat shall release a probe that shall open a heat shield.
When the probe reaches 200 meters, it shall deploy a parachute and slow the descent rate to 5 meters/second
Once the probe has landed, it shall attempt to upright itself and raise a flag 500 mm above the base of the probe
A video camera shall be included and point toward the ground during descent.
CanSat shall collect the required telemetry at a one (1) Hz sample rate and transmit the telemetry data to the Ground Station.
Bonus objective
A video camera shall be integrated into the container and point toward the probe. The camera shall record the event when the probe is released from the container. Video shall be in color with a minimum resolution of 640x480 pixels and a minimum of 30 frames per second. The video shall be recorded and retrieved when the container is retrieved. We decided to perceive a bonus objective, our rationale is that the additional camera is fairly easy to implement and every point counts towards the end goal.
External objective
Create a universal PCB that can be the base for CanSat as well as for other projects.

Summary of Changes Since PDR

We made **no complex** changes since submitting PDR

Small changes are introduced in:
- CDH – a new command was added [80]
- EPS – the battery was replaced, 9V power supply was added [94]
- Mechanical design – some mechanisms were modified [44]

AEROSPACE PWR

System Requirement Summary (1/8)

Rn	Requirement	Verification			
		A	I	T	D
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams.	X	X		
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	X			X
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	X	X		
4	The container shall be a fluorescent color; pink, red or orange.	X	X		
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open.	X	X		X
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	X	X		X
7	The rocket airframe shall not be used as part of the CanSat operations.	X	X		X
8	The container's parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	X	X		X

System Requirement Summary (2/8)

Rn	Requirement	Verification			
		A	I	T	D
9	The Parachutes shall be fluorescent Pink or Orange	X	X		
10	The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	X		X	
11	0 altitude reference shall be at the launch pad.	X			X
12	All structures shall be built to survive 15 Gs of launch acceleration.			X	
13	All structures shall be built to survive 30 Gs of shock.			X	
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	X	X		
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	X		X	
16	Mechanisms shall not use pyrotechnics or chemicals.	X	X		

System Requirement Summary (3/8)

Rn	Requirement	Verification			
		A	I	T	D
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	X	X		
18	Both the container and probe shall be labeled with team contact information including email address.		X		
19	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost. Equipment from previous years shall be included in this cost, based on current market value.	X	X		
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	X			X
21	XBEE radios shall have their NETID/PANID set to their team number.		X		
22	XBEE radios shall not use broadcast mode.		X		
23	The container and probe shall include an easily accessible power switch that can be accessed without disassembling the CanSat and science probes and in the stowed configuration.	X		X	
24	The container and probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the CanSat and in the stowed state.	X		X	

System Requirement Summary (4/8)

Rn	Requirement	Verification			
		A	I	T	D
25	An audio beacon is required for the probe. It shall be powered after landing.	X	X	X	
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	X		X	
27	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.	X	X		
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	X		X	
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	X		X	X
30	The CanSat shall operate during the environmental tests laid out in Section 3.5.	X		X	
31	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	X		X	
32	The probe shall be released from the container when the CanSat reaches 500 meters.	X		X	X

System Requirement Summary (5/8)

Rn	Requirement	Verification			
		A	I	T	D
33	The probe shall deploy a heat shield after leaving the container.		X	X	X
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	X		X	
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/- 1m/sec.	X		X	
36	Once landed, the probe shall upright itself.			X	X
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	X		X	
38	The probe shall transmit telemetry once per second.	X		X	
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	X		X	X
40	The probe shall include a video camera pointing down to the ground.		X		X

System Requirement Summary (6/8)

Rn	Requirement	Verification			
		A	I	T	D
41	The video camera shall record the flight of the probe from release to landing.	X		X	
42	The video camera shall record video in color and with a minimum resolution of 640x480.	X		X	
43	-				
44	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	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	X	X	X	
46	The probe shall have its time set to within one second UTC time prior to launch.	X			X
47	The probe 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
48	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
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	X			X

System Requirement Summary (7/8)

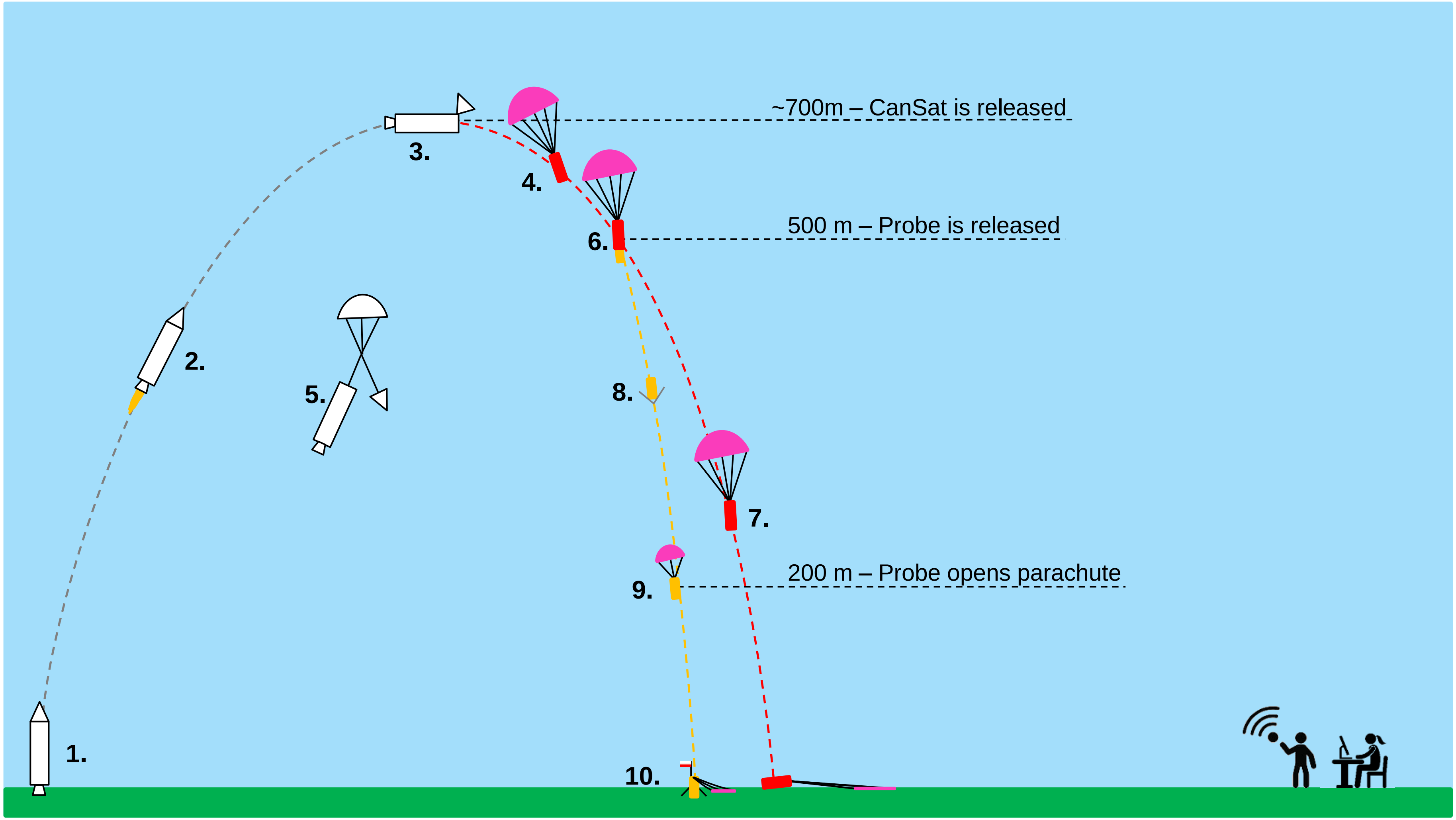
Rn	Requirement	Verification			
		A	I	T	D
50	The ground station shall command the CanSat to start calibrating the altitude to zero when the CanSat is on the launch pad prior to launch.	X			X
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	X	X		X
52	Telemetry shall include mission time with 1 second or better resolution.	X			X
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	X		X	X
54	Each team shall develop their own ground station.		X		
55	All telemetry shall be displayed in real time during descent on the ground station.	X			X
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		X		X
57	Teams shall plot each telemetry data field in real time during flight.		X		X

System Requirement Summary (8/8)

Rn	Requirement	Verification			
		A	I	T	D
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		X		X
59	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
60	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
61	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

*Req 43 was skipped in the mission guide.

System Concept of Operations (1/2)



System Concept of Operations (2/2)

Mission phase:

1. Pre-launch preparation.
2. Launch and ascend to apogee.
3. CanSat release from rocket compartment — at 670 to 725 meters.
4. CanSat descent using the first parachute at a rate of 15 m/s.
5. Rocket descent using a parachute, then landing.
6. At 500 meters CanSat deploys the Probe, with camera recording.
7. Container continues descent with constant speed.
8. Probe opens heatshield and descends at a rate of 20 m/s or less.
9. At 200 meters probe opens the parachute, slows down to 5 m/s.
10. After landing probe uprights itself and rises a flag. End of telemetry and camera recording. Audio beacon activation.

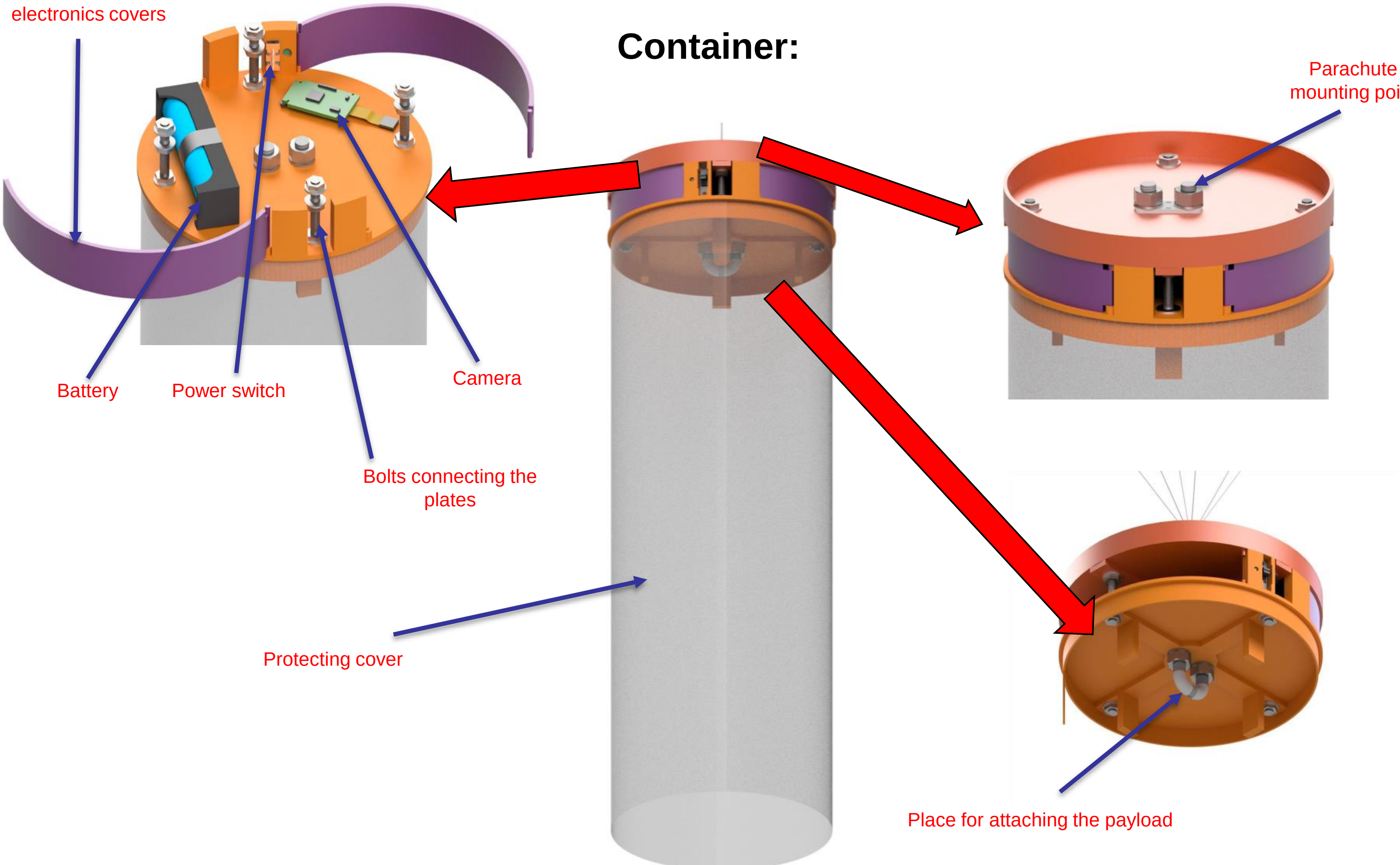
Recovery and Data Reduction:

1. Probe recovery using the latest known GPS position, audio beacon, and fluorescent probe body color.
2. Container recovery using fluorescent body color.
3. Video data recovery from camera internal storage.
4. Sampled data analysis, formatting and data reduction.
5. PFR preparation.
6. PFR presentation.

Role	Person	Responsibilities
Mission Control Officer (MCO)	Tobiasz Puślecki	Communication with judges
Ground Station Crew (G)	Jakub Kaszowski, Katarzyna Ignatowicz	Ground Station preparation, Receiving telemetry, Issuing commands to CanSat
Recovery Crew (R)	Hubert Kulik, Tymoteusz Puślecki	Finding CanSat after mission
CanSat Crew (C)	Tomasz Drewniak, Konrad Łebek, Eunika Puślecka	Ppreparing the CanSat, integrating it into the rocket and verifying its status

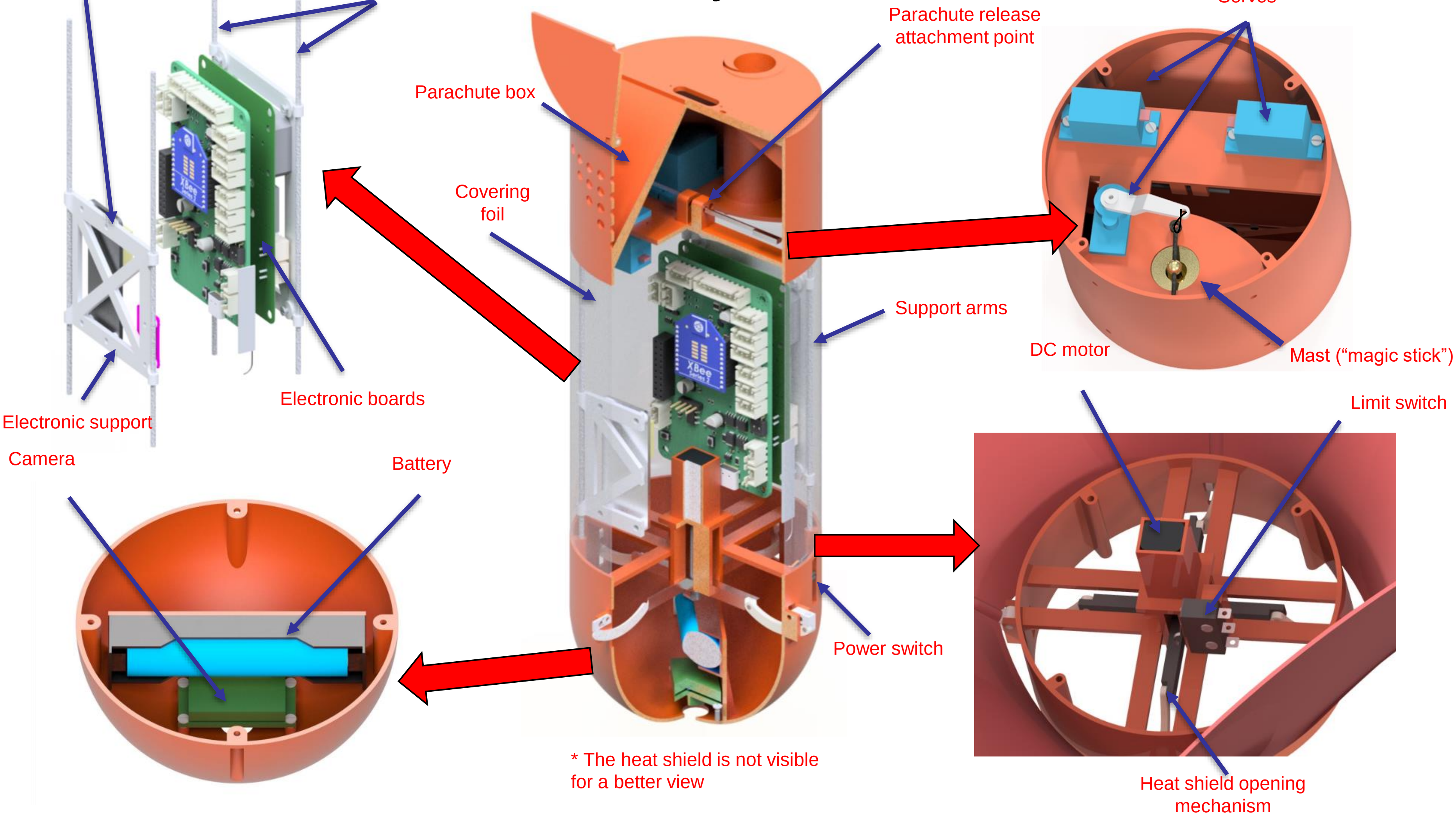
CanSat Physical Layout (1/4)

Container:



CanSat Physical Layout (2/4)

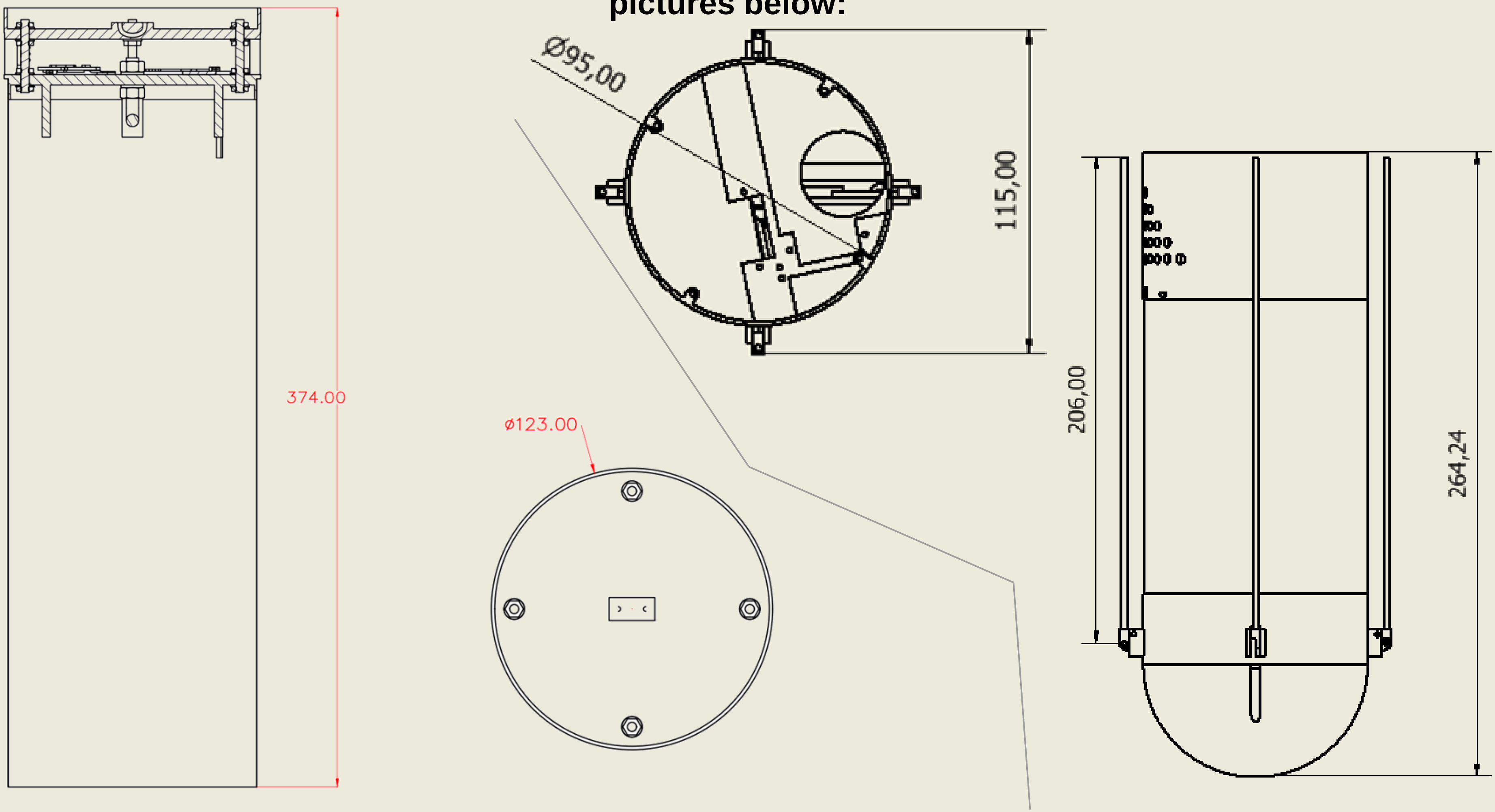
Payload:



* The heat shield is not visible for a better view

CanSat Physical Layout (3/4)

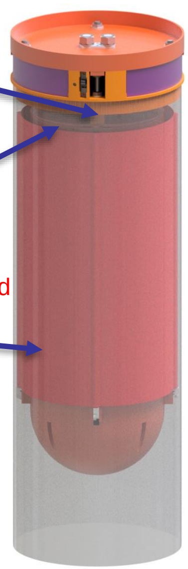
The most important dimensions of the payload and the container are described in the pictures below:

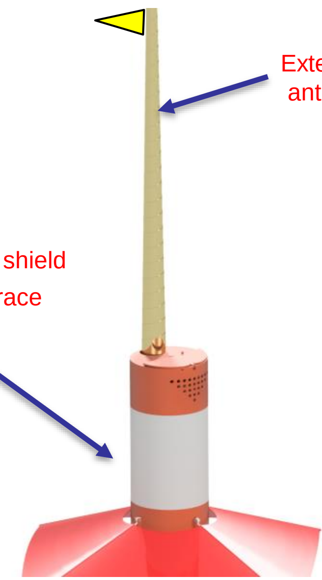


Note: All dimensions are in mm

CanSat Physical Layout (4/4)

Configurations in flight stages		
Stage 1 (pre-deployment payload configuration)	Stage 2 (payload descent configuration)	Stage 3 (landing configuration)
After falling out of the rocket, the CanSat is in the position shown below. The first parachute opens immediately. At the right height, the payload is released by the servo mechanism.	Upon release, the second servo mechanism opens the heat shield and begins to decelerate to the required speed. Then, at the right height, the first servomechanism (its use will be described later) releases the parachute. Payload slows down to landing speed.	When it touches the ground, the heat shield turns into stiffening feet. The parachute descends and the antenna extends.





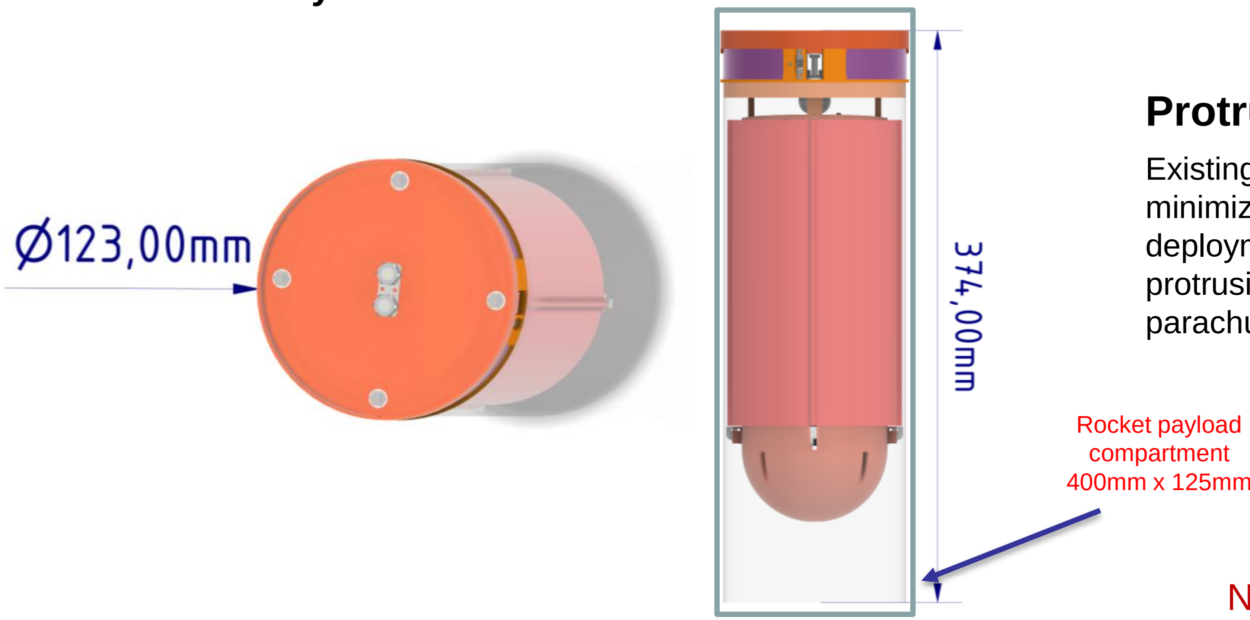
Launch Vehicle Compatibility

Clearances

To allow easy deployment CanSat was designed to be smaller than maximum size allowed by mission guide. Radially and axially there would be margin that allows smooth deployment. **No parts are using the rocket payload section as suport.**

Dimensions	Probe	Rocket	Margin
Diameter	123 mm	125 mm	2 mm
Length	374 mm	400 mm	26 mm

Container + Payload dimensions:



Protrusions

Existing **edges will be rounded up** to minimize risk of failure during deployment. There is no additional protrusion. Parachutes are hidden in the parachute bay.

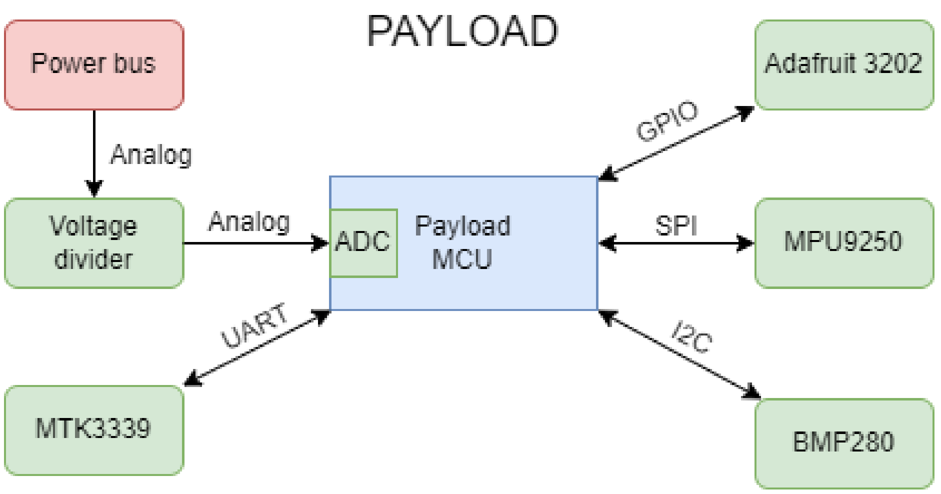
Note: All dimensions are in mm

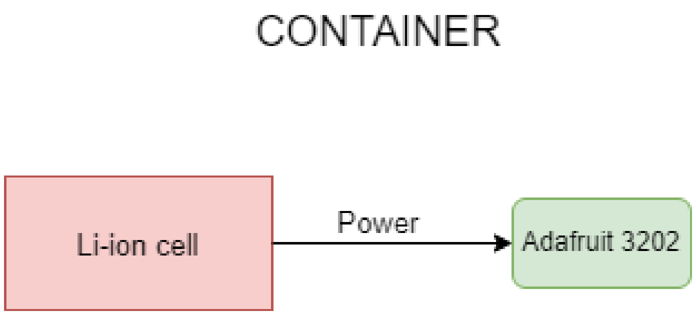
Sensor Subsystem Design

Hubert Kulik

Sensor Subsystem Overview

TYPE	MODEL	FUNCTIONS	INTERFACE
AIR PRESSURE AIR TEMPERATURE	BMP280	Air temperature and pressure (altitude) measurement	I2C
GPS	MTK3339	Tracking the payload position	UART
VOLTAGE	μC ADC + DIVIDER	Monitoring the battery condition	ANALOG
GYROSCOPE	MPU9250	Tracking the payload rotation	SPI
CAMERA (probe)	Adafruit 3202	Capturing the video during descent	GPIO
CAMERA (container)	Adafruit 3202	Capturing the probe release	GPIO





Turned on all the time

Sensor Changes Since PDR

We made **no** changes since submitting PDR in the sensor subsystem design section

Test Report:
Currently we are able to read data from all the sensors and calculate physical values from them using the hardware we manufactured. The cameras are also operational.

Payload Air Pressure Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [hPa]	Resolution [Pa]	Accuracy [hPa]	Interface	Price [$]
BMP280	2 2.5 1	1.2	1.8 ÷ 3.6	0.003	300 ÷ 1100	0.16	±0.12	I2C	3

After enabling the pressure measurement, the pressure registers are periodically read and combined into one variable (*formula 1*).Then, the compensation formula from the datasheet is applied (*formula 2*), and the result is divided by 256 as a floating point (*formula 3*). **It gives the measured pressure in Pa.**

Formula 1:
pressure = data[0] << 12 | data[1] << 4 | data[2] >> 4;
Formula 2:
pressure_compensate = datasheet page 45.
Formula 3:
pressure_Pa = (float)pressure_compensate / 256;

The data is stored in IEEE 754 float.

To convert pressure to altitude we use the formula:
Where p_0 is the air pressure measured at the launch pad.

$$altitude = 44330 * \left(1 - \left(\frac{p}{p_0}\right)^{\frac{1}{5.255}}\right)$$

p – measured pressure value at altitude [Pa]
p_0 – reference pressure value at reference level [Pa]

We expect raw relative altitude accuracy of ±1m, after filtration the accuracy can be as low as ±0.05m.

Payload Air Temperature Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [°C]	Resolution [°C]	Accuracy [°C]	Interface	Price [$]
BMP280	2 2.5 1	1.2	1.8 ÷ 3.6	0.003	-40 ÷ 85	0.1	±0.1	I2C	3

After enabling the temperature measurement, the temperature registers are periodically read and combined into one variable (*formula 1*).Then, the compensation formula from the datasheet is applied (*formula 2*), and the result is divided by a 100 as a floating point (*formula 3*). **It gives the measured temperature in °C.**

Formula 1:

temperature = data[0] << 12 | data[1] << 4 | data[2] >> 4;

Formula 2:

temperature_compensate = datasheet page 45.

Formula 3:

temperature_C = (float) temperature _compensate / 100

The data is stored in IEEE 754 float.

Payload GPS Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Sensitivity [dBm]	Resolution [m]	Update rate [Hz]	Interfaces	Price [$]
MTK3339	35 26 7	20	3.0÷ 5	20	-165	<2.5	1÷10	UART	42

The GPS uses NMEA commands to communicate (through UART). To read position data the MCU will wait for the $GPGGA command (an example is below). Each command will be validated and interpreted. The important for the mission data are collected in the array, indicated by bold font.

No.	Description:
1	UTC of Position
2	**Latitude**
3	**N or S**
4	**Longitude**
5	**E or W**
6	**Valid? (0=No, 1=GPS fix,2=diff fix)**
7	**Number of satelites in use**
8	Horizontal dilution of position
9	Antenna altitude above/below mean sea level (geoid)
10	Meters (Antenna height unit)
11	Geoidal separation
12	Meters (Units of geoidal separation)
13	Age in seconds since last update from diff. reference station
14	Diff. reference station ID#
15	**Checksum**

Latitude/Longitude resolution is 0.0001°.
Number of satellites is integer number.
Estimated accuracy of position is 2.5m.

Frame template:

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh

Payload Voltage Sensor Summary

Name	Size [mm]	Mass [g]	Operating Current [mA]	Range [V]	Resolution [V]	Interfaces	Price [$]
STM32 ADC + Voltage divider	-	-	0.2	0 ÷ 3.3	0.001	Analog	0.1

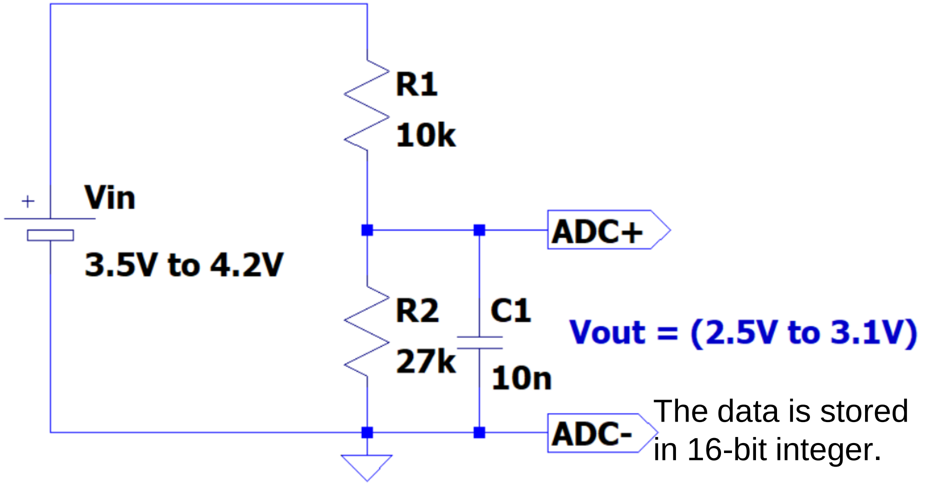
In order to obtain the value of battery voltage with the selected circuit, we have developed the following equation:

$$V_{battery} = \frac{37k\Omega}{10k\Omega}(RawVal * \frac{3.3V}{4096}) = 2.9801mV * RawVal$$

Where RawVal is ADC read. ADC max is 4095.

Expected:

Resolution	~ 3mV
Measure range	0 to 12V
Idle current	0.15mA



The data is stored in 16-bit integer.

Payload Tilt Sensor Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [°/s]	Resolution [°/s]	Interfaces	Price [$]
MPU9250	25 15 3	3	2.4 ÷ 3.6	0.4	250,500, 1000,2000	0.004	I2C	11

When the gyroscope will be initialized on the launchpad, internal compensation will provide the correction factor, a high-time constant filter will be activated, and the initial tilt will be set to (0,0,0).
During the flight, data will be read in equal time intervals from internal registers.

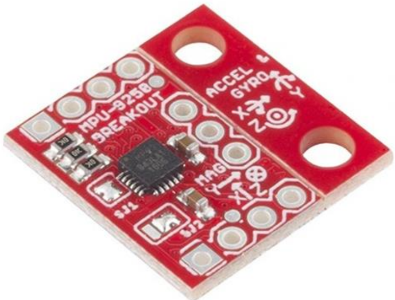
The formula for tilt in an N-axis is: $TiltN(t) = TiltN(0) + \int_0^t RotationN(t) * dt$

The integral can be substituted by a Newton-Cotes formula.
The C constant influence can be suppressed using the Madwick filter.

The internal Signal Processor is set to do the operations, the final value will be directly read from it. **If the read drifts, we will add filtering in the MCU.**

The tilt from the Earth normal (Z) will be calculated using the Pythagorean theorem:

$$TotalTilt(t_{landed}) = \sqrt{(TiltX(t_{landed})^2 + TiltY(t_{landed})^2)}$$



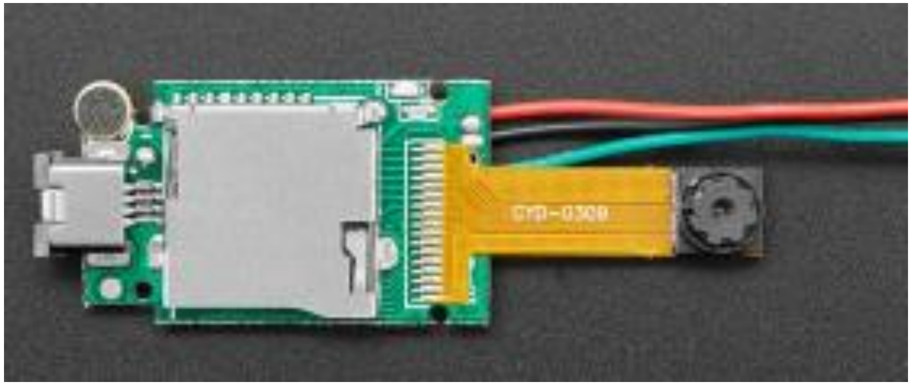
The data is stored in IEEE 754 float.

Camera Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	microSD card	Resolution [pixels]	Field of view [°]	Frames per second	Interfaces	Price [$]
Adafruit 3202	29 17 5	2.8	3.7÷5.0	110	Yes	**640x480**	120	30	GPIO	18

After deployment, GPIO pin connected to camera will be set on high logic state, then camera will start recording video.
Video is stored on the on-board microSD card and its resolution is 640x480, so it meets the competition requirements.

Reasons
• Small dimensions and mass • Built-in microSD • Video recorded in color • Video resolution and fps considering requirements • Records in RGB colors

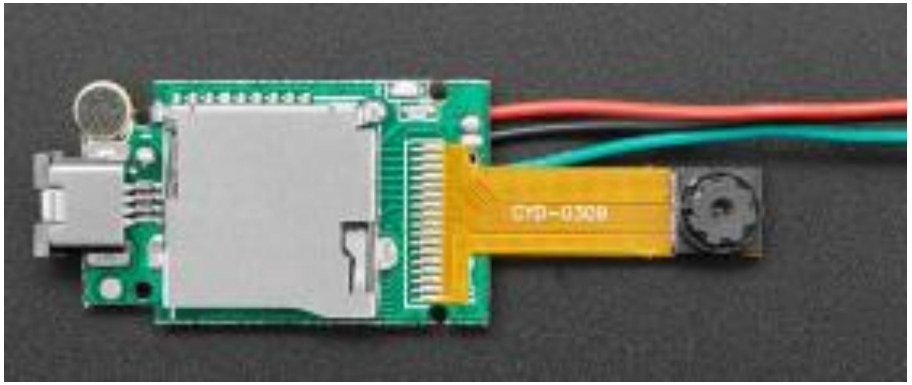


Bonus Camera Summary

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	microSD card	Resolution [pixels]	Field of view [°]	Frames per second	Interfaces	Price [$]
Adafruit 3202	29 17 5	2.8	3.7÷5.0	110	Yes	**640x480**	120	30	GPIO	18

After start the camera will start recording, the memory will last for around 28h, the battery for around 15h.
Video is stored on the on-board microSD card and its resolution is 640x480, so it meets the competition requirements.

Reasons
• Small dimensions and mass • Built-in microSD • Video recorded in color • Video resolution and fps considering requirements • Records in RGB colors



Descent Control Design

Konrad Łebek

Descent Control Overview

CanSat descent is divided into 3 stages:

1. The first stage takes place right after separating from the rocket, at this point the Container with Payload inside descends on the first parachute, **slowing it down to a speed of 15 m/s, payload parachute is stowed in its compartment.**

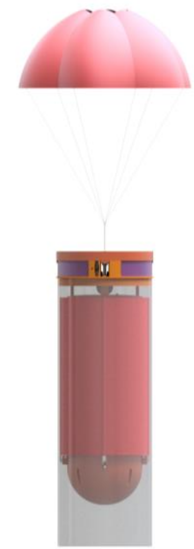
2.1 **At an altitude of 500 m payload releases from the container. The container continues freefall on its parachute.**

2.2 **After separation** payload will deploy heat shield. Descent speed will be limited to **20 m/s**.

3. Then, at the altitude of **200 m**, the third phase will begin. The second parachute will open and the payload will slow down to **5 m/s**. It will land at this speed.

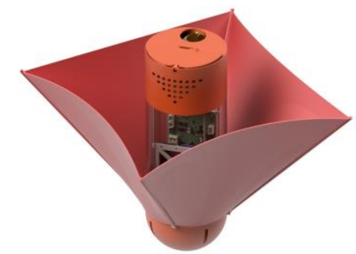
	Flight Configuration	Altitude	Components necessary
1	After Separation	Over 500m	Container parachute
2	Aerobraking	500m - 200m	Heat shield mechanism and DC motor
3	Final descent	200m - ground	Payload parachute

1.



2.1

2.2



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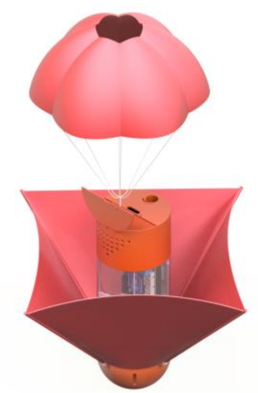


Descent Control Changes Since PDR

We made **no** changes since submitting PDR in the descent control section

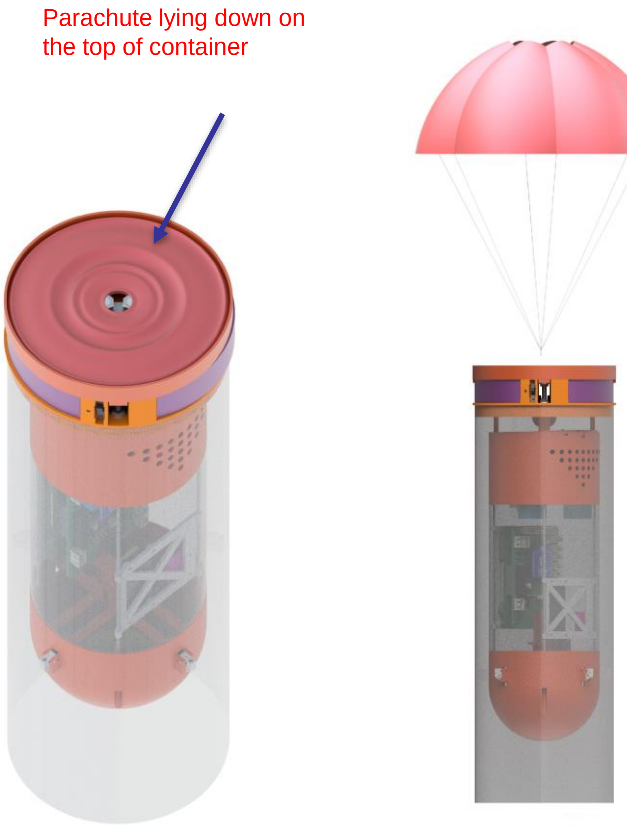
Prototype testing

Full test of the descent control system is yet to be performed. Currently, parachute mounting was tested for shock resistance and raw strength. The heatshield mechanism is jam-free.

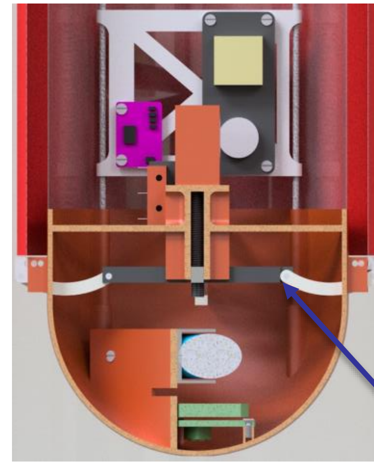
Container Descent Control Hardware Summary

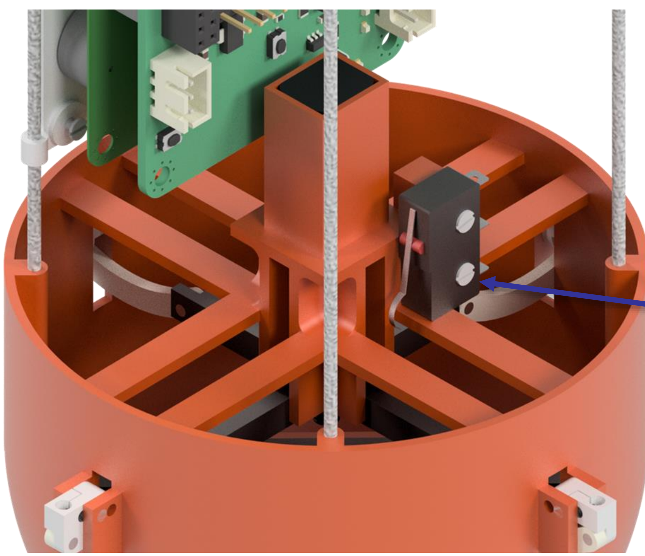
Container parachute

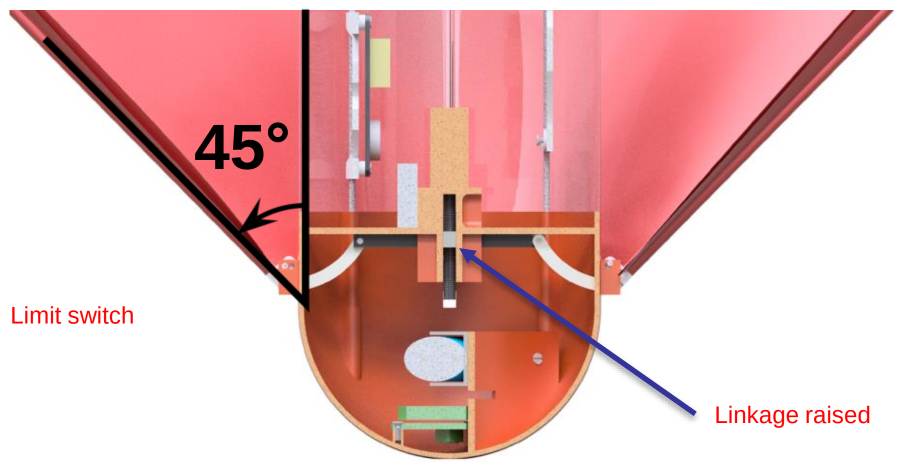
- The first parachute, **lying on top of the container, opens immediately after separation from the rocket.** At a speed of not more than 15 m/s, it will descend to a height of 500 metres.
- The stabilization of the descent will depend on the even distribution of weight and a properly prepared parachute.
- It will be **pink hexagonal parachute** with a **diameter of 0.3 metres.**



- The heat shield is made of a durable **red** material stretched over four spokes. After separating from the container a centrally mounted screw motor unfolds the spokes by engaging a series of linkages. A limit switch is installed to detect when heatshield has reached **45° angle** and achieved the deployed position. The motor is then stopped.
- The heat shield will have an area of ***0.071 m²*** which will provide the desired falling speed (less than 20 m/s)

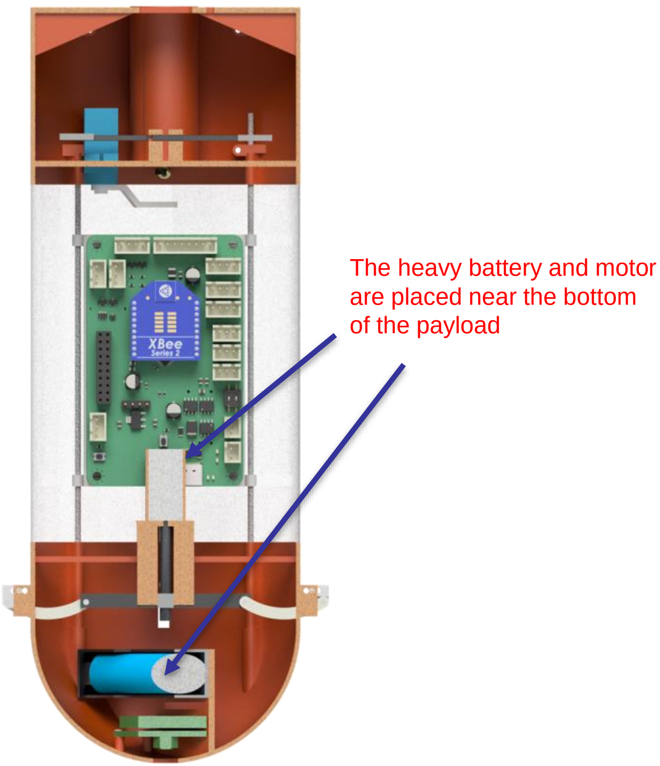


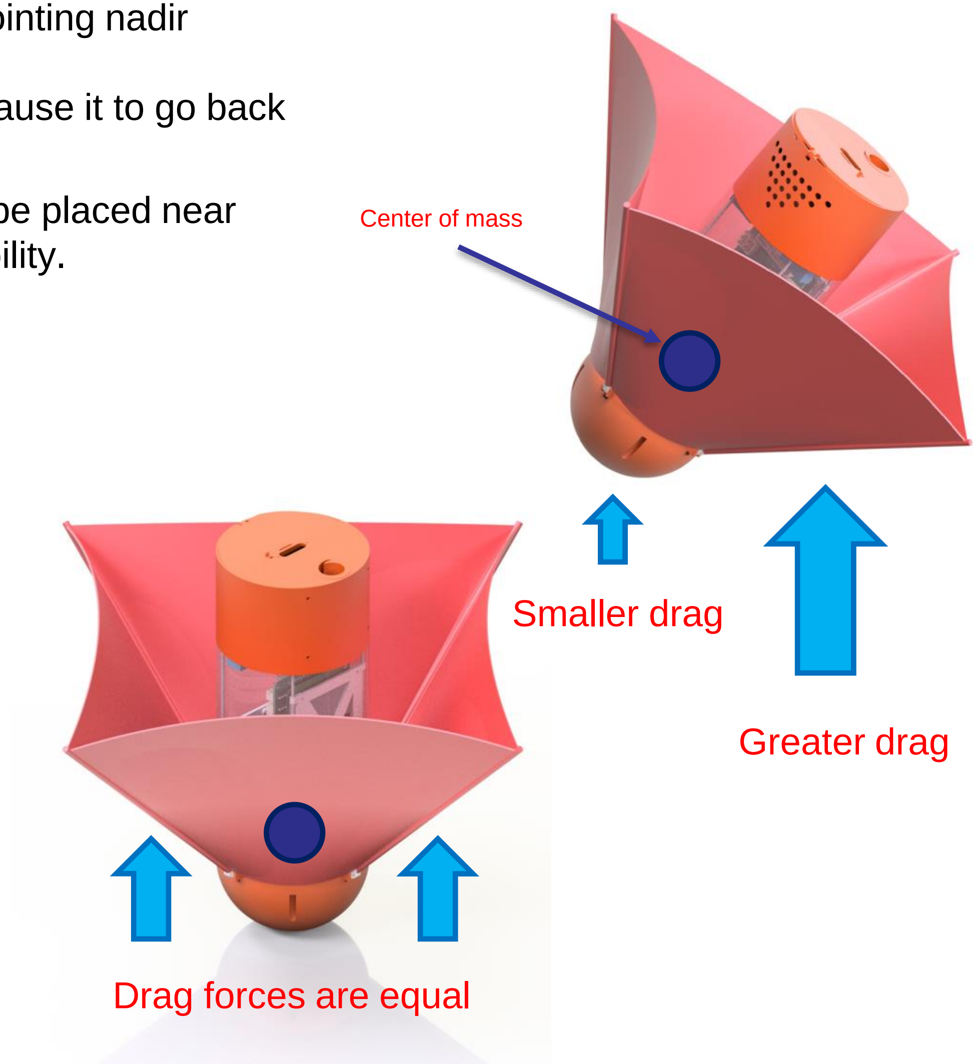




Payload Descent Stability Control Design

- During aerobraking, payload will be kept pointing nadir thanks to the shape of the heat shield.
  When tilting to one side, greater drag will cause it to go back to the vertical position.
- Additionally, the heaviest components will be placed near the bottom of the payload, to help with stability.



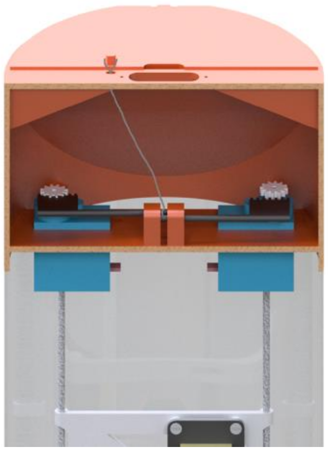


Payload Parachute Descent Control Hardware Summary

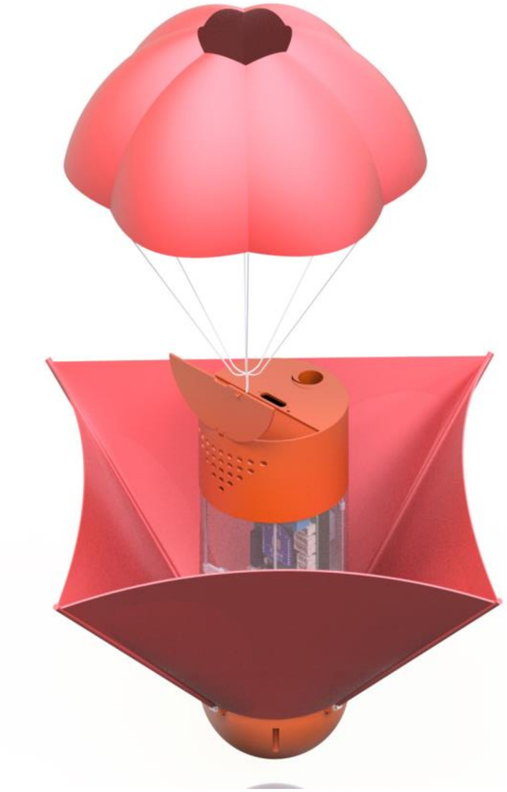
Payload parachute

- The payload parachute is stowed away in a container under a hinged door until it is needed. Upon descending to 200m altitude a servo motor will release the parachute. Then the payload will maintain a speed of 5 m/s until landing.
- It will be **pink hexagonal parachute** with a **diameter of 0.7 metres.**

Parachute in its container



Servo motor release mechanism



Descent Rate Estimates (1/2)

CONTAINER WITH PAYLOAD DESCENT

$$S_p = \frac{2mg}{v^2 \rho C_d}$$

$$d = \sqrt{\frac{2S_p}{\sqrt{3}}}$$

Parameters:

d - parachute diameter for a hexagonal parachute after compensation (diameter of inscribed circle) 0.2897 m

Sp –parachute size for a square parachute

g - gravitational acceleration 9.81 m/s2

m - container with payload mass 0.7 kg (+/-0.01)

Assumptions (all situations):

ρ - air density at standard temperature: 1.12 (kg/m^3)

C_d - drag coefficient for parachute: 0.75

C_D - drag coefficient for heat shield 0.5

Estimated container wit payload descent rate = 14.99 m/s

PAYLOAD AEROBRAKING DESCENT

$$\frac{1}{2}\frac{\rho}{B}v^2 = g + \frac{dv}{dt}$$

$$B = \frac{m}{C_D\, S}$$

Parameters:

m - payload mass 0.5 kg (+/- 0.01)

S - aerobraking area 0.071 m^2

g - gravitational acceleration 9.81 m/s^2

$\frac{dv}{dt}$ - tends to zero

B – balistic coefficient

Estimated payload aerobraking descent rate = 15.01 m/s

PAYLOAD DESCENT WITH PARACHUTE

$$S_p = \frac{2mg}{v^2 \rho C_d}$$

$$d = \sqrt{\frac{2S_p}{\sqrt{3}}}$$

Parameters:

d - parachute diameter (diameter of inscribed circle) 0.7 m

g - gravitational acceleration 9.81 m/s2

m - payload mass 0.5 kg (+/-0.01)

Estimated paylad descent rate with parachute = 5.01 m/s

Descent Rate Estimates (2/2)

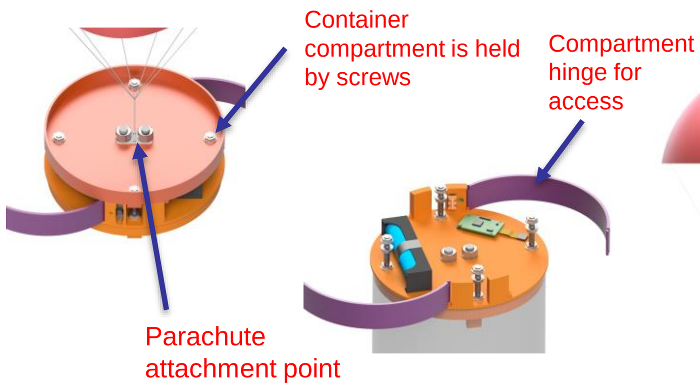
Flight phase	Speed of descent [m/s]
CanSat with payload descent	14.99
Payload descent	15.01
Payload descent with parachute	5.01

Calculated values are within the scope of the competition

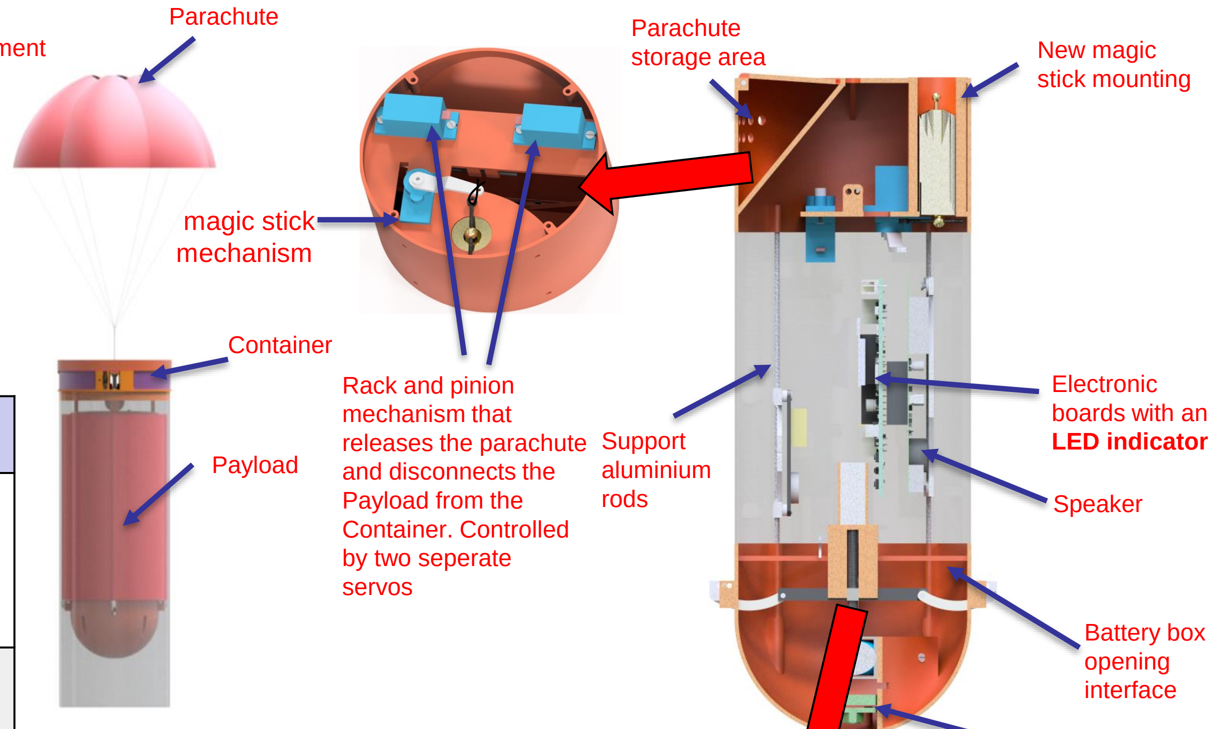
Mechanical Subsystem Design

Konrad Łebek

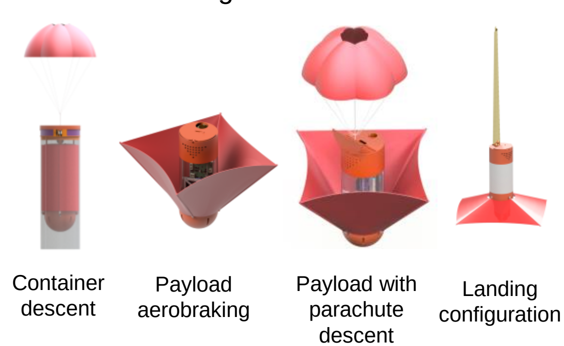
Mechanical Subsystem Overview

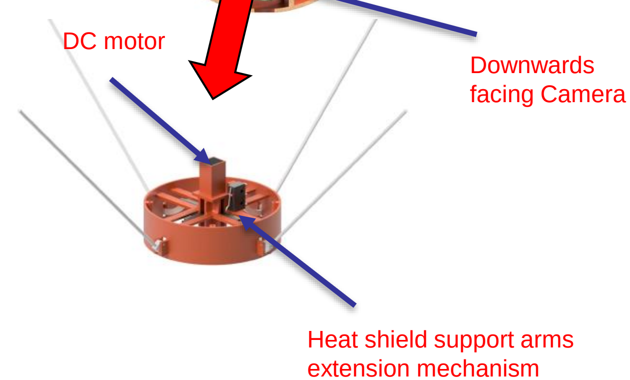


Part	Material
Container	3D printed ABS, metal screws, PET foil side cover with aluminium wire support
Payload structure	3D printed ABS, aluminium rods, PETG side cover
Electronic supports	3D printed ABS
Heat shield and parachute	Nylon
Heat shield opening mechanism	3D printed structure and linkages



Mechanical configurations:

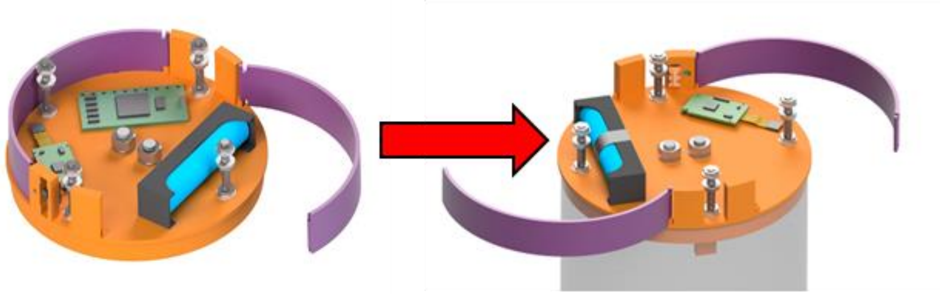




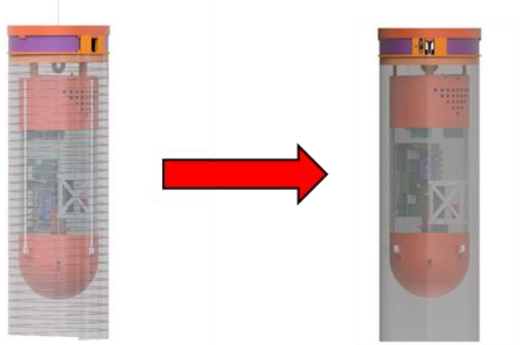
Mechanical Subsystem Changes Since PDR

CONTAINER CHANGES

1. No electronic board in container

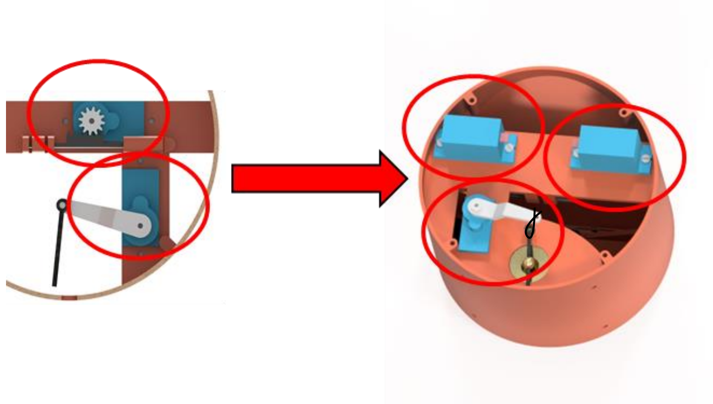


2. New container cover

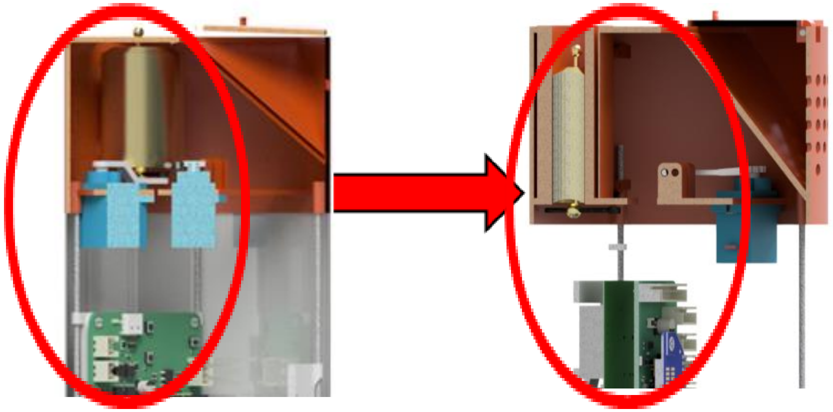


PAYLOAD CHANGES

1. Three servo mechanism instead of two



2. New „magic stick” mast holder and additional electronics board



Container Mechanical Layout of Components (1/5)

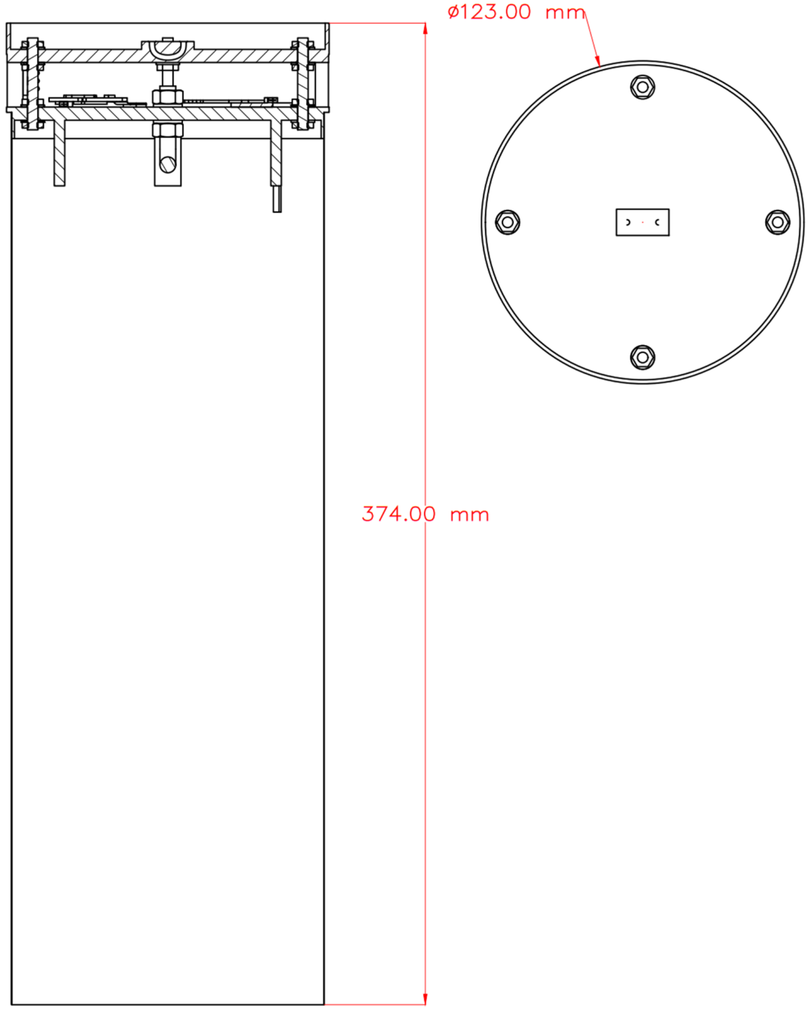
Overall design summary and CAD model

Design 1

- The Camera is activated manually before the CanSat is put into the rocket.
- Construction made out of 3D printed parts and lightweight laminating foil pipe
- Elements are screwed together
- Easily accessible, encapsulated, small electronics bay
- 14650 battery used as a power source
- **Single parachute with no release mechanism is used**
- **There are no mechanisms in the container**
- **The container will be labeled with team contact information**

Container Mechanical Layout of Components (2/5)

Container dimension drawings

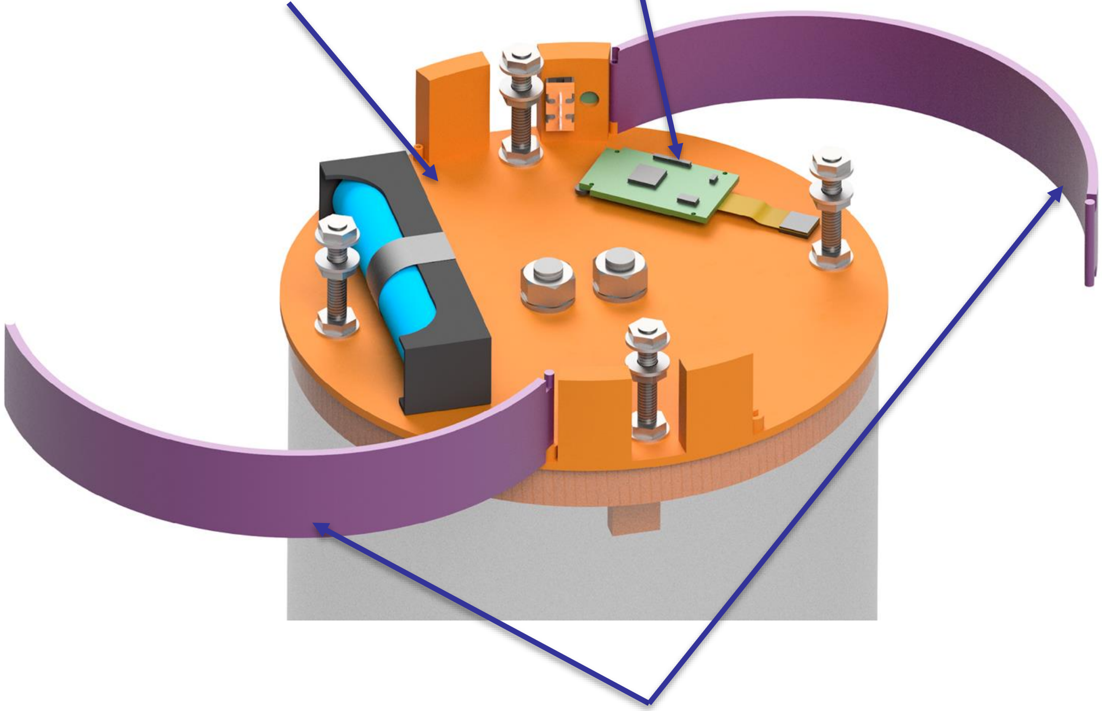


Container Mechanical Layout of Components (3/5)

Location of electrical components

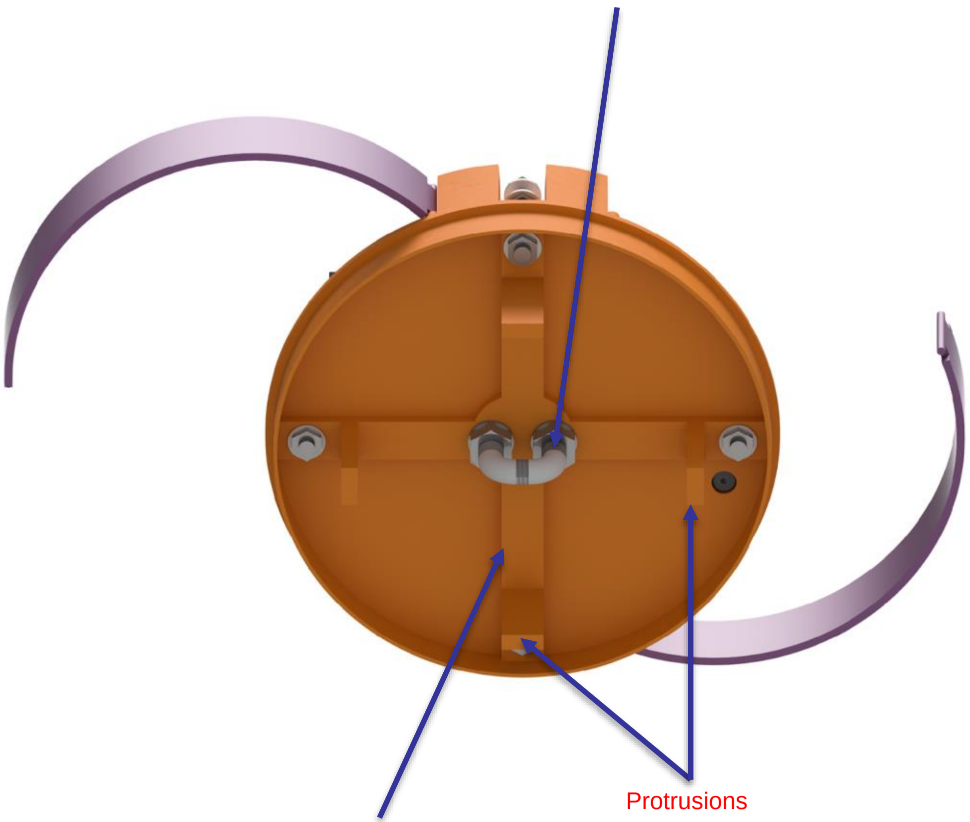
The container houses only a 14650 battery and an Adafruit 3202 Mini Camera together with a switch and an LED to power the camera and to indicate it works.

In the small electronics bay in the upper part of the container. Both the battery and camera are secured in place using fasteners and high-strength adhesives. To ensure the battery doesn't get disconnected it is placed horizontally and additionally secured with tape.



Container to Payload attachment

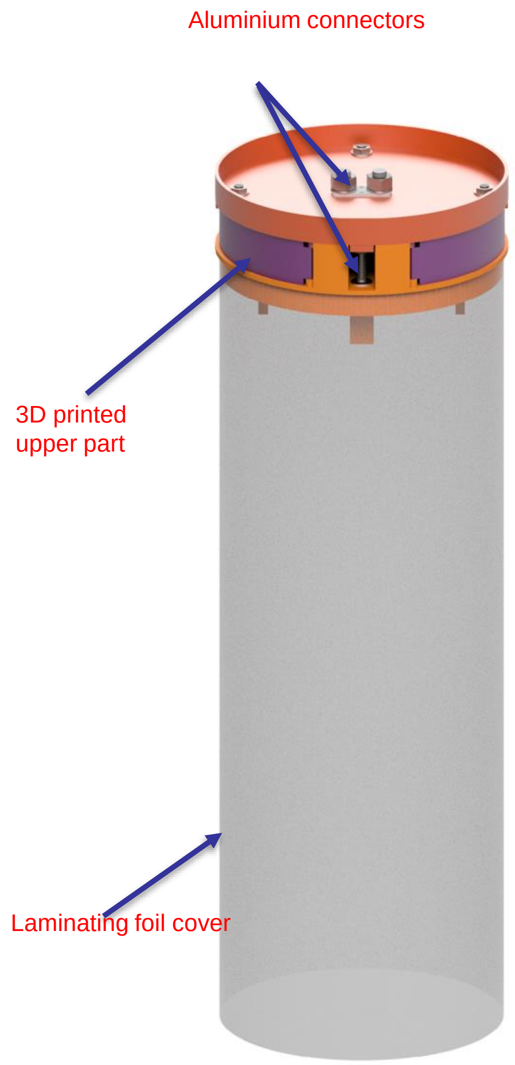
The container will be connected with the payload by a special M6 U-bolt. The bolt is connected to the container bottom plate in a strengthened place. A special tether will be wrapped around this U-bolt and it will holt the payload to the container. In the upside-down position e.g. in a rocket, the payload will lay on special plastic protrusions. We will try to minimize the slack in the tether to minimize the possibility of the payload bumping with the container.



Container Mechanical Layout of Components (5/5)

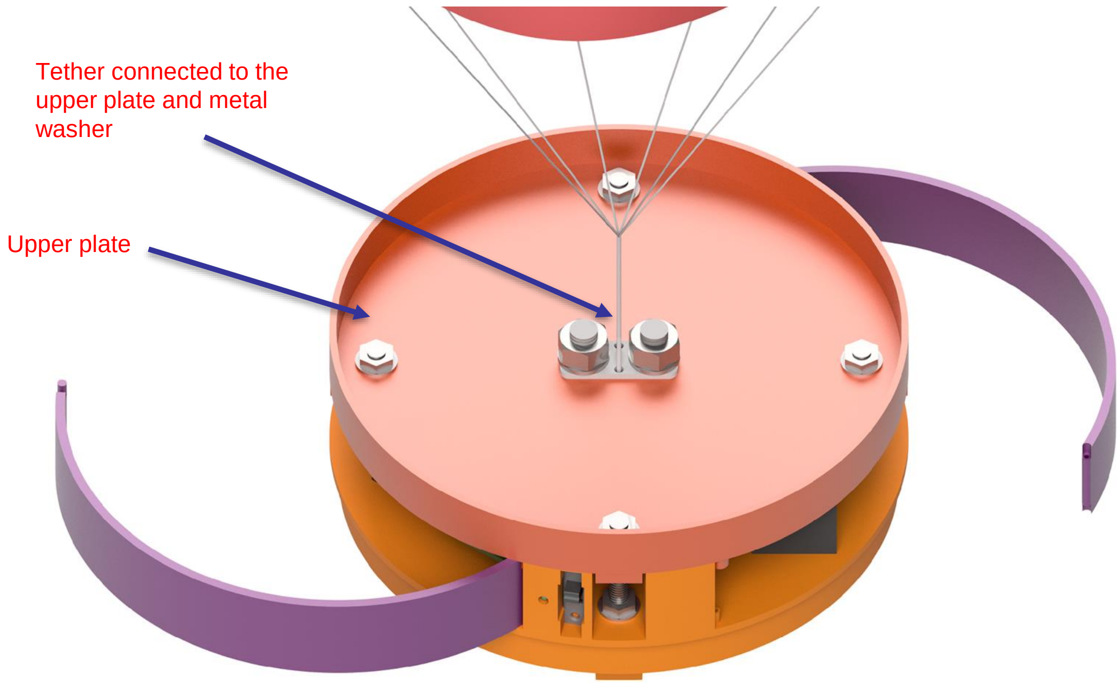
Structural material selection

Part	Materials	Rationale
Pipe	Laminating foil	Container cover made out of laminating foil is cheap, quite easy to manufacture and robust enough for our needs.
Electronics bay	3D printed ABS	3D printed ABS is a light cheap and flexible material that allows us to make intricated shapes needed for the container
Connectors	Aluminium	Aluminium is light, easy to machine.



Container Parachute Attachment Mechanism

The parachute is connected to the Container via a thicker tether threaded through a special hole in the electronics bay upper plate and a special aluminium washer that connects the parachute straight with the payload. The tether is made out of nylon and the plate is made out of ABS. To ensure a good enough strength the upper plate is strengthened and screwed together with the washer.

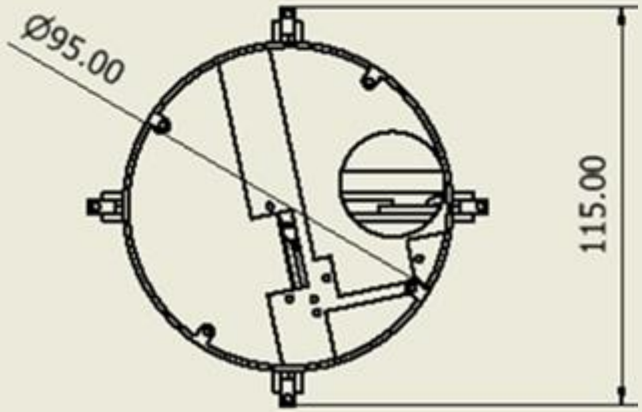


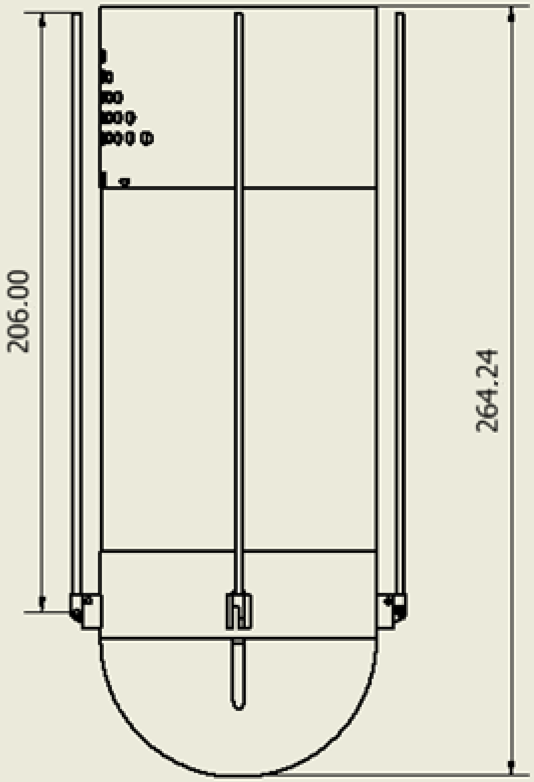
Payload Mechanical Layout of Components (1/9)

Overall design traits and feats:

- DC motor used to open the heatshield
- **No pyrotechnics or chemicals are used in this design.**
- 3D printed structure with aluminium struts
- Camera mounted at the bottom
- Two servos motor used to open the parachute and release the payload
- Servo motor used to release the ”magic stick” mast.
- Custom electronics board
- Bottom-heavy design to increase passive stability
- Antenna glued to the clear cover
- **The payload will be labeled with team contact information**

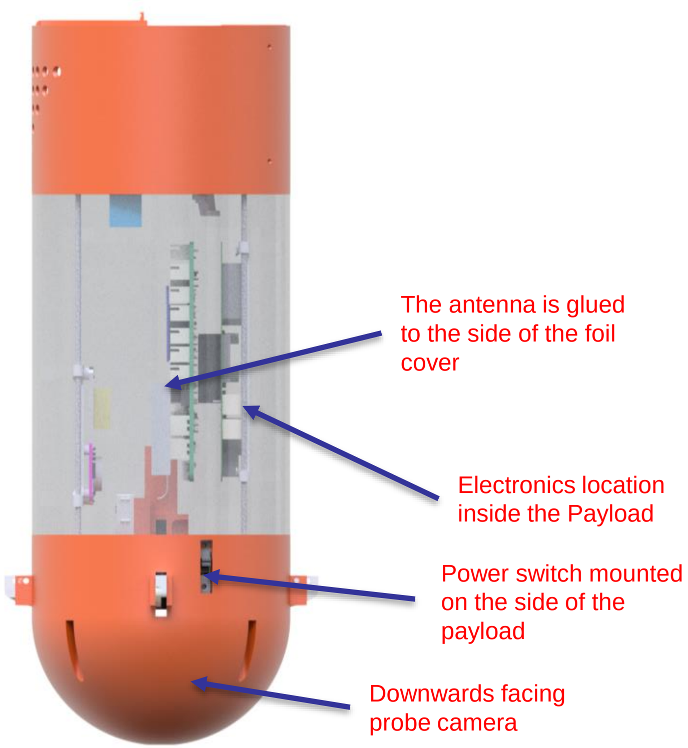
Critical dimensions

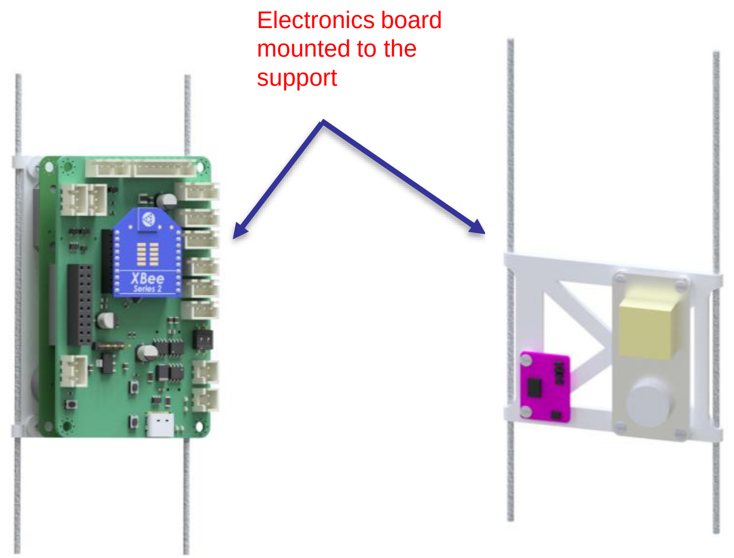




Location of electronics

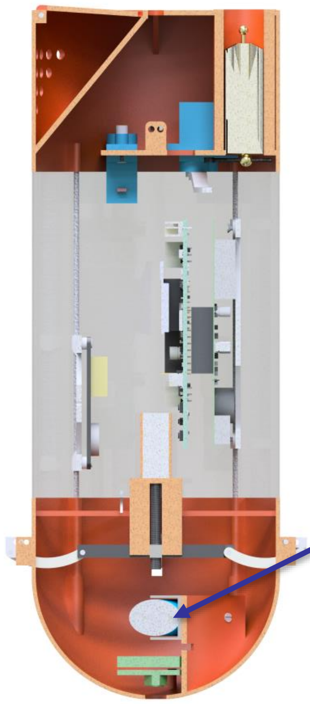
The electronic boards will be housed in the middle part of the payload. The board will be screwed to a 3D-printed custom support. That is mounted to the connecting struts. This ensures safe and reliable attachment. The indicator LED will be found on the electronics board and the power switch is at the lower part of the payload. The antenna will be glued to the payload cover. **The probe camera is mounted at the bottom of the payload and is looking down through a small hole.**





Battery access

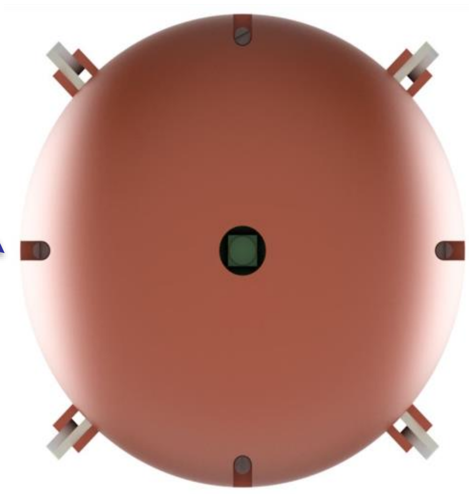
The battery is placed at the bottom of the payload and access to the battery requires the removal of 4 screws, which can be done in less than a minute with the right tools. The basket for a single 14650 battery, is screwed sideways to the payload structure.



Battery placement inside the Payload

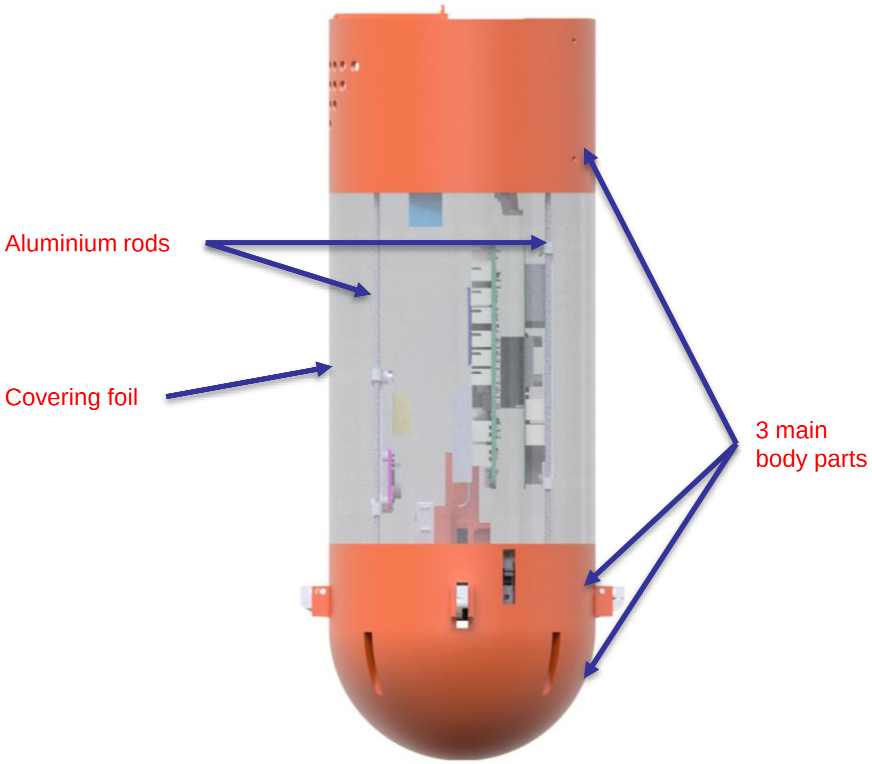
The screws that hold the battery compartment cover

Payload bottom view



Mechanical elements trade and selection

The Payload's body consists of three main 3D-printed elements and a foil cover. **The separated 3D-printed parts will be held together using strong aluminium rods, nuts and washers to ensure structural integrity under the launch and shock forces.** Adjacent parts will be screwed together. The space in the middle will be covered by thick foil mounted in special grooves in the 3D-printed parts.

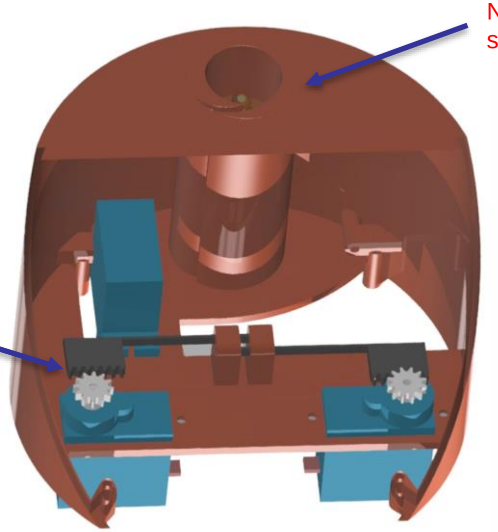


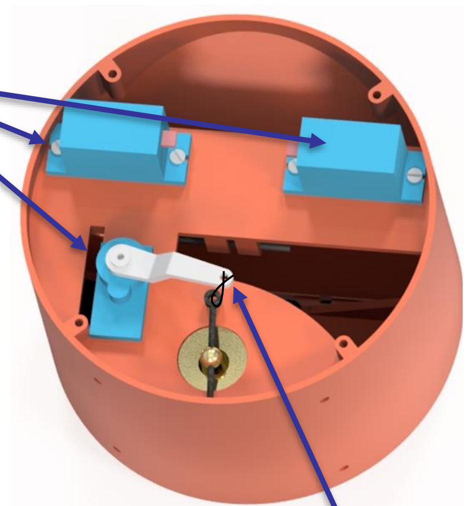
Payload Mechanical Layout of Components (6/9)

Mechanisms description

This design has three important mechanisms, **all of them slightly oversized to ensure reliability under high accelerations**:

- The first mechanism is a rack and pinion design powered by a servo motor. This mechanism has three positions. Closed position is set before the launch. Mechanism is powered by to seperate servo motors, one responsible for releasing payload from container and the other for parachute deployment.
- The second mechanism is a servo using a pitman arm to release a pin to open the spring-loaded, magic stick after landing.

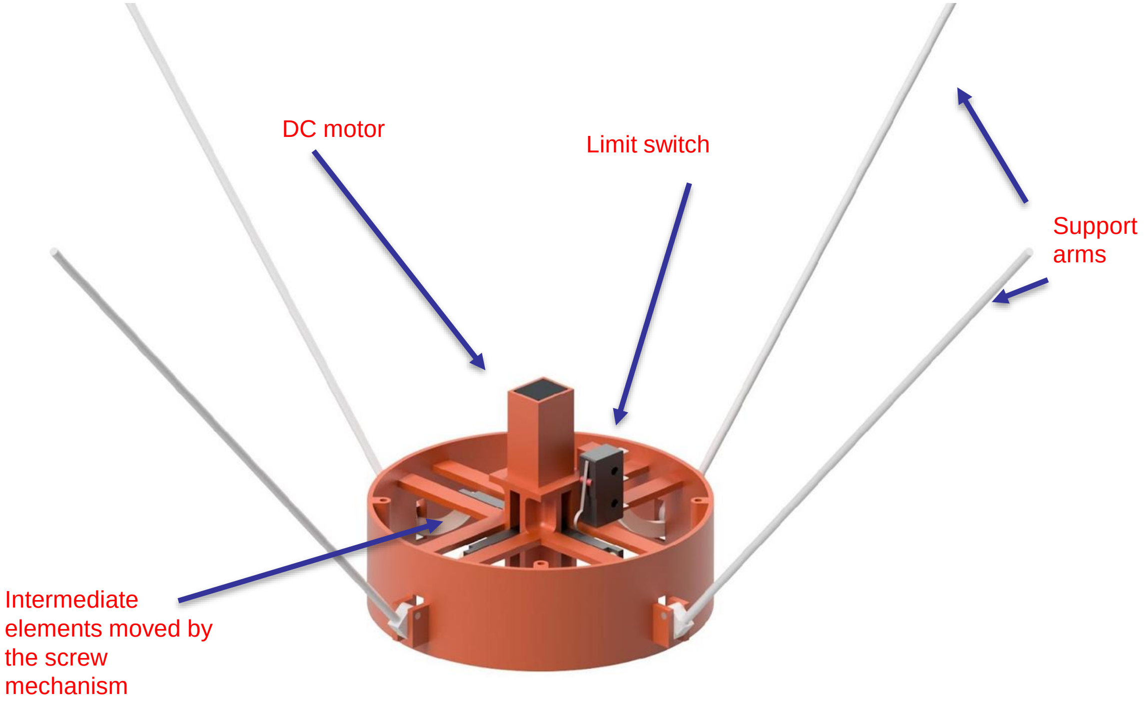




Payload Mechanical Layout of Components (7/9)

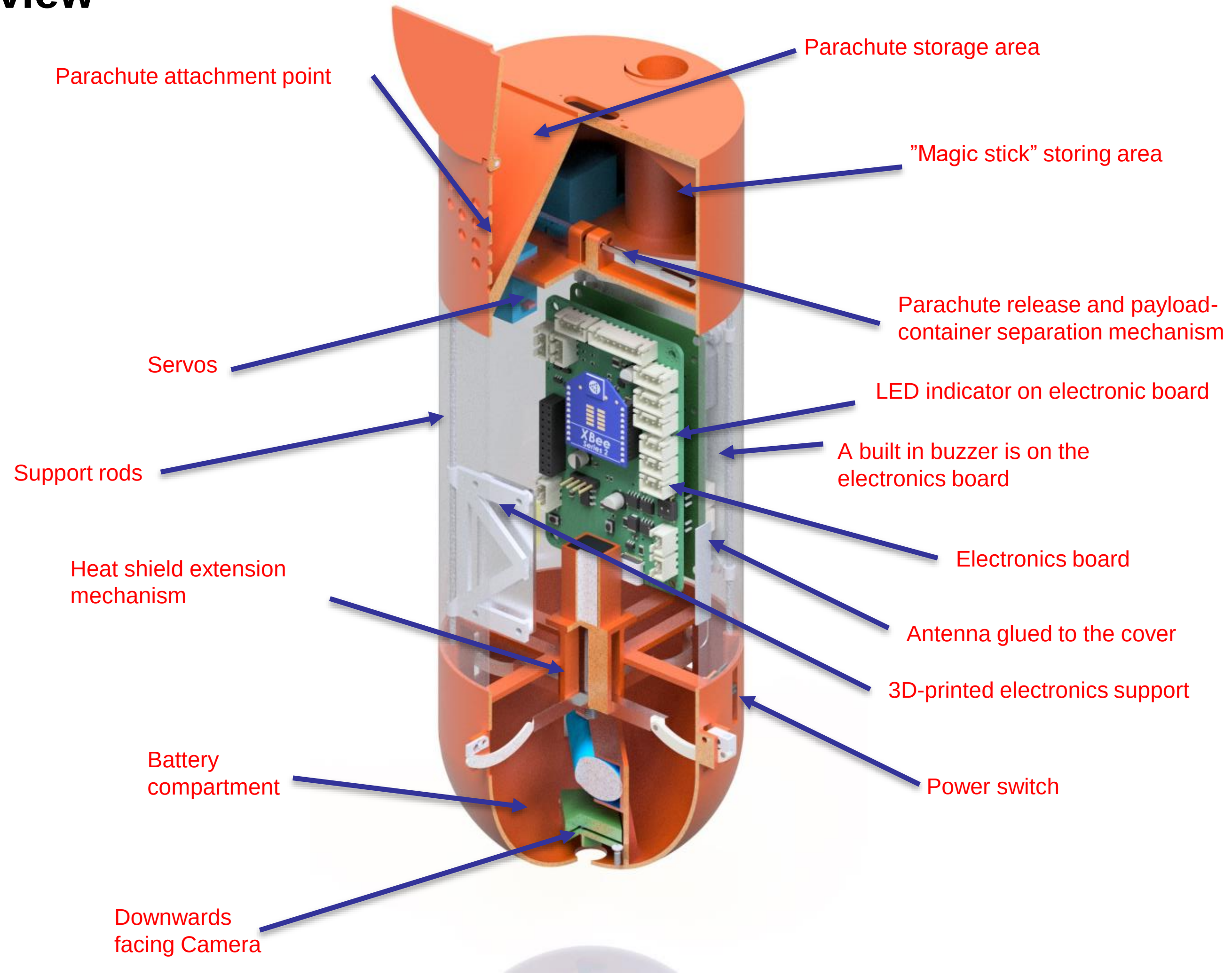
Payload landing mechanisms

The third mechanism is the biggest in this design as it opens the heat shield and uprights the payload after landing. It uses a geared DC motor to power a screw mechanism that pushes out the heatshield support arms. The mechanism also has a limit switch to stop in the right position when opening the heat shield. After landing the support arms will fully extend to upright the payload.



Payload Mechanical Layout of Components (8/9)

Overall overview



Payload Mechanical Layout of Components (9/9)

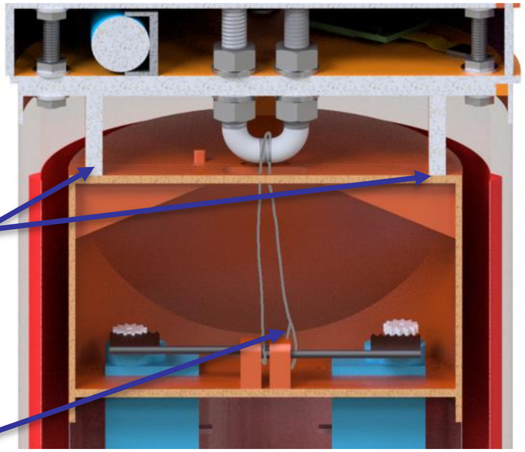
Structural material selection

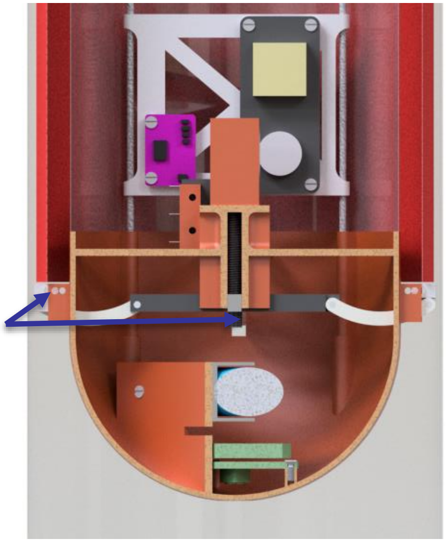
Part	Materials	Selection and reasoning
Cover	Laminating foil	Payload cover made out of laminating foil is cheap, quite easy to manufacture and robust enough for our needs.
Payload body	ABS 3D print	3D printed ABS is a light cheap and flexible material that allows us to make intricate shapes needed for the payload.
Connectors	Aluminium	Aluminium is light, easy to machine.

Payload Pre Deployment Configuration

The payload will be secured to the container by a tether that will be preloaded to ensure no bumping. The preloading will be carried out by using the screws holding the U-bolt in the container. In a normal state the payload will press slightly onto a special stabilising protrusions on the bottom part of one of the container „plates”.

The heatshield will be held in a stowed position until the payload is released. **This position is held securely because the screw mechanism is self locking**. No matter how great the force the screw won’t move until the DC motor starts rotating.





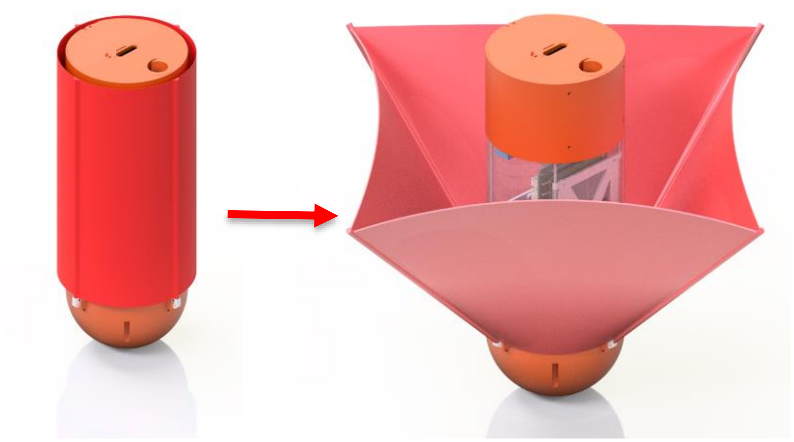
Payload Aerobraking Deployment Configuration

The container contains no mechanism and the release mechanism is entirely inside the payload. The mechanism consists of a tether mounted on one end to a stenghened payload part and on the other end it will be held by a securing pin operated by a servomechanism. The tether will be passed through the U-bolt in the container.

To allow for a safe and smooth payload separation, the container has smooth insides. The payload also has little protrusions.

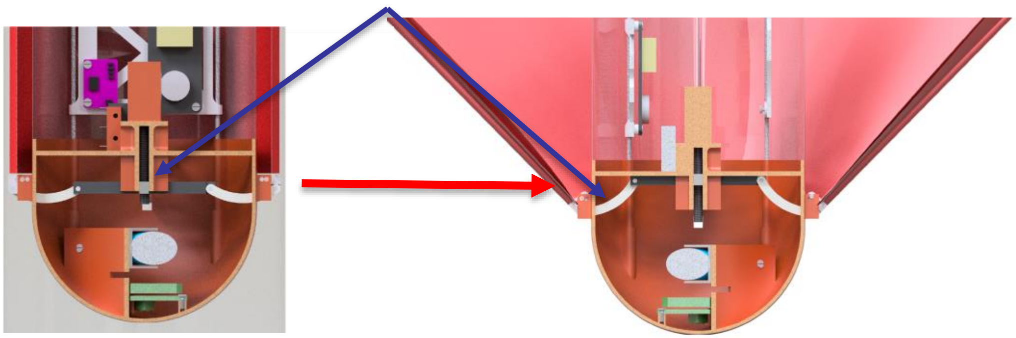
After the deployment from the container, the payload will open it's heatshield to a predetermined angle that will limit the decent rate to about **15 m/s**.

The heatshield is deployed by using a DC motor that creates linear motion by a screw mechanism. This linear motion is then converted by linkages back into rotational motion to deploy the heatshield.



The heatshield opens up immediately after The payload is released from the container.

Linear moton from the DC motor rotates the heatshield spokes. On the right the mechanism has moved upwards

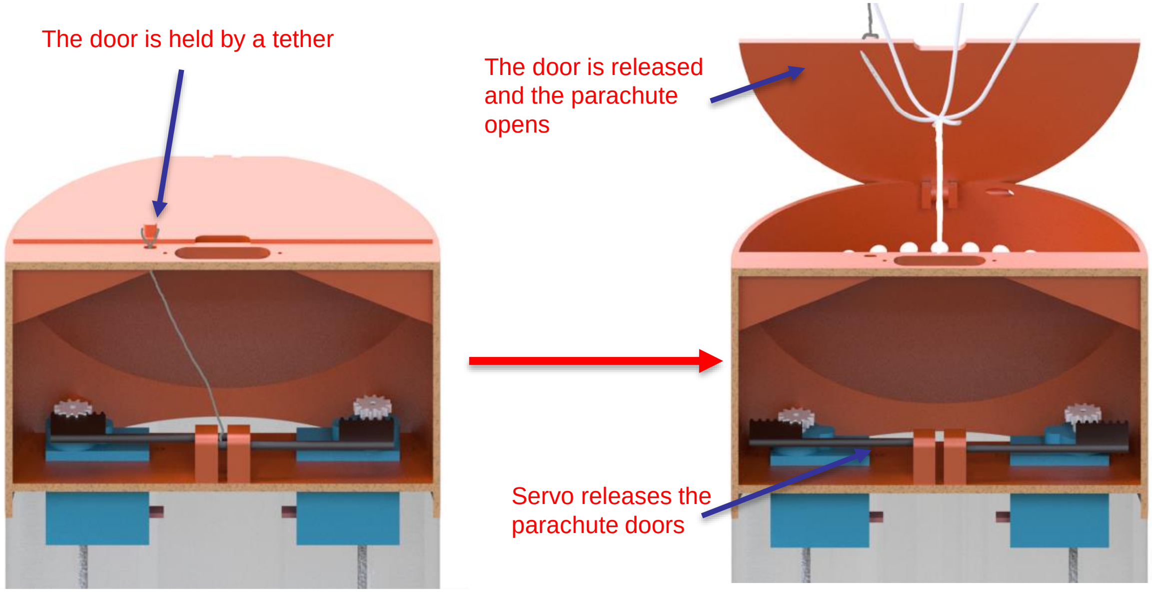


Payload Parachute Deployment Configuration

The parachute will be folded and stored in a special compartment inside the payload. The compartment is closed on top by hinged doors. To release the Parachute the doors are released to open and the movement of air around the payload will force the door open and push out the parachute. Further testing will show if a spring is needed to help the door open or to minimalize the tether slack to minimalize the possibility of a pre-mature parachute opening.

The door release mechanism is realized using a servo that releases a tether via a pin.

The parachute is connected to a strengthened part of the assembly it's stored in. The assembly absorbs shocks quite well and is strong enough for this role.

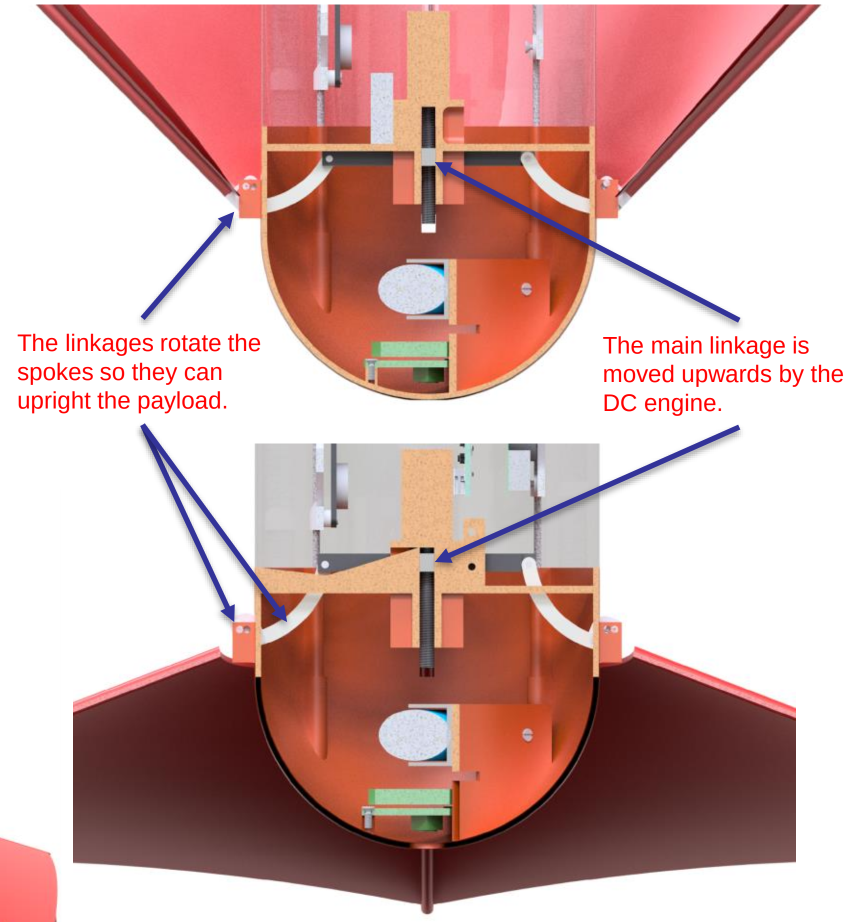


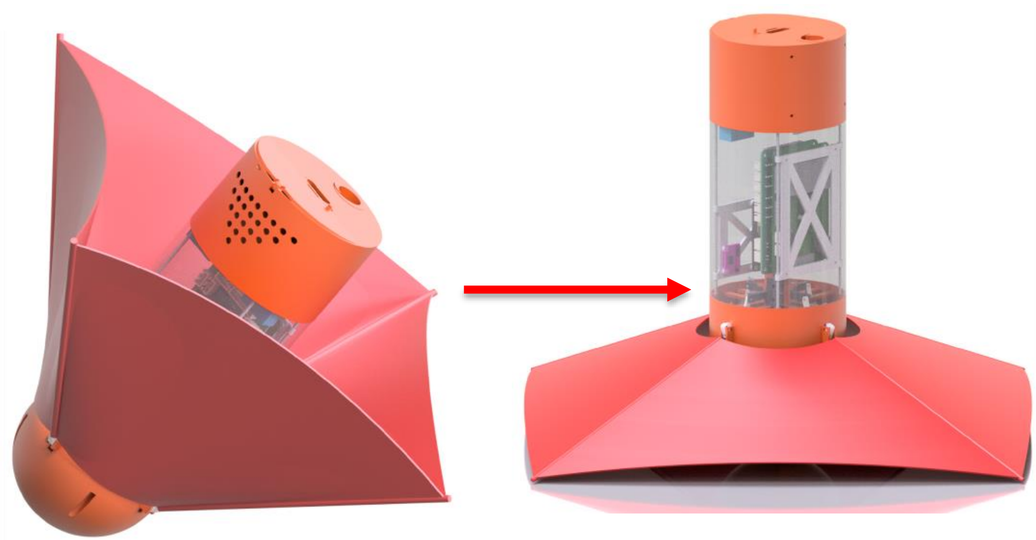
Payload Uprighting Description

After landing is detected the Payload will upright itself.

This will be done by using the same mechanism as for the heatshield opening.

The mechanism uses a DC motor and screw mechanism to create linear motion. By the use of linkages, this motion is then converted into the rotational motion of heatshield spokes that will serve as uprighting legs.





Payload Flag Deployment Configuration

Mast opening mechanism

The flag attached to the mast will be lifted over 500 mm above the base of the probe by means of a "magic stick" placed in the upper part of the payload

Flag selection

We chose nylon for the material for the flag. The flag will be glued to the mast with epoxy glue.

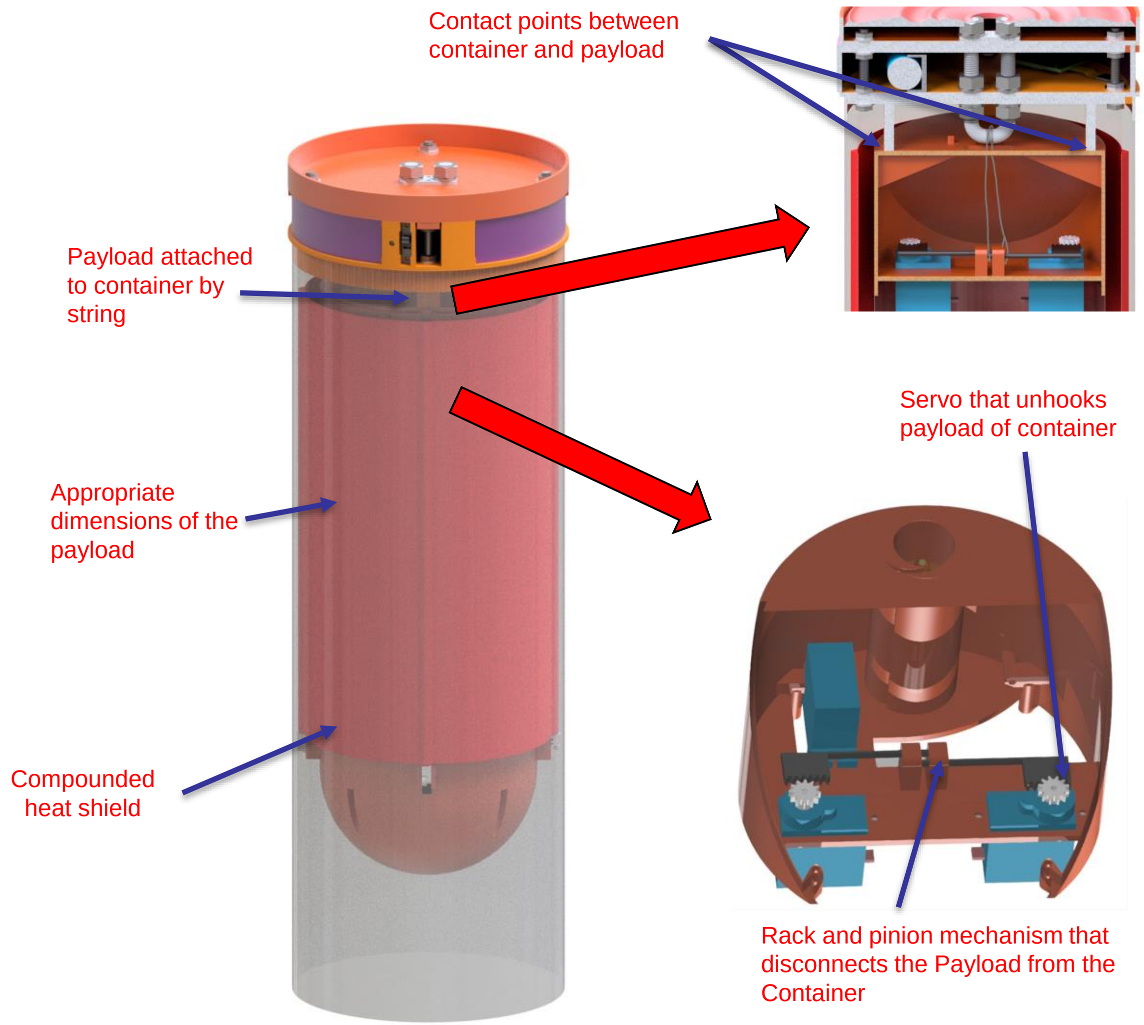
Container Payload Mount

Payload protection

The payload placed in the container has dimensions that ensure rigidity and **resistance to overload** - there is no possibility that it will move and hit the container during the flight. The top of the payload rests on special contact points. However, they **do not prevent the release of the payload** from the container. The heatshield is also permanently stopped by a DC motor which prevents any hooking.

Payload release

Payload will be released using a mechanism with a servo that disconnects it from the container.



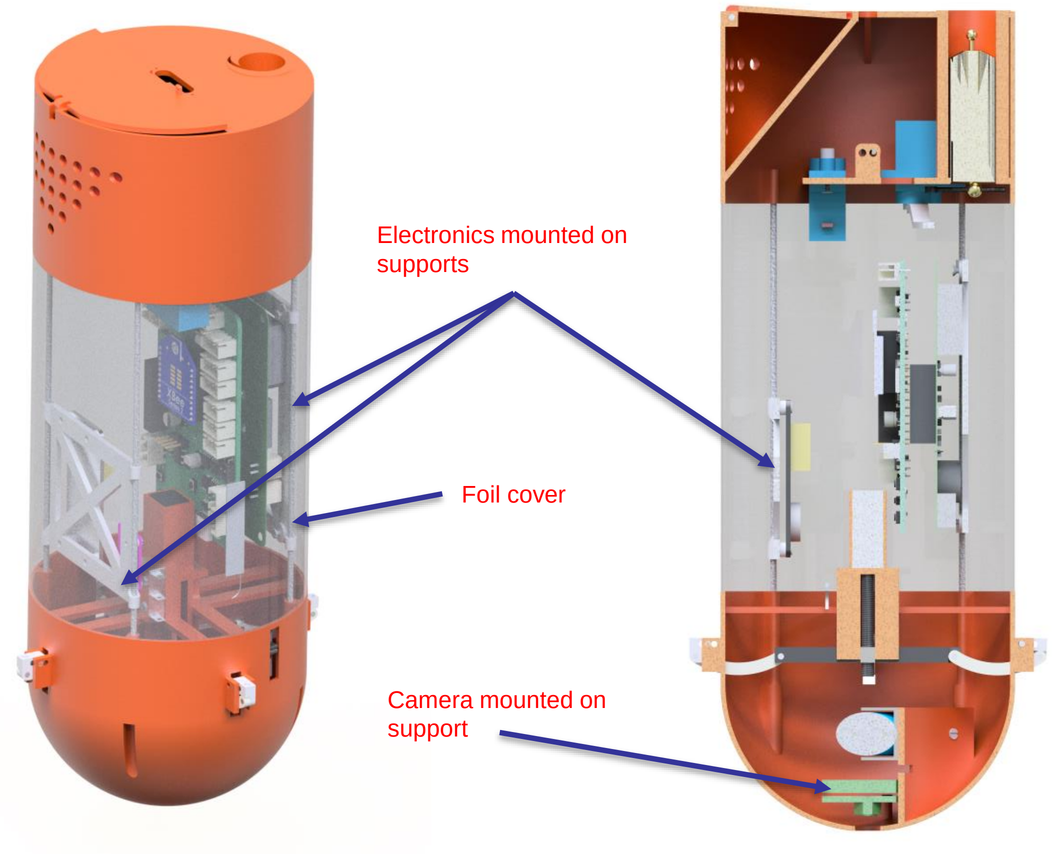
Structure Survivability (1/4)

Electronic components mounting methods – Payload:

Electronic circuit boards will be mounted **with screws** to 3D printed supports which will be **glued** to the metal support rods. All electronic components will be mounted using screws, nuts and washers or will be soldered on the main circuit board. This will provide a stable and safe attachment.

The electronics board of the camera will be mounted to the body of the payload using screws. The camera will be **glued** onto a special support.

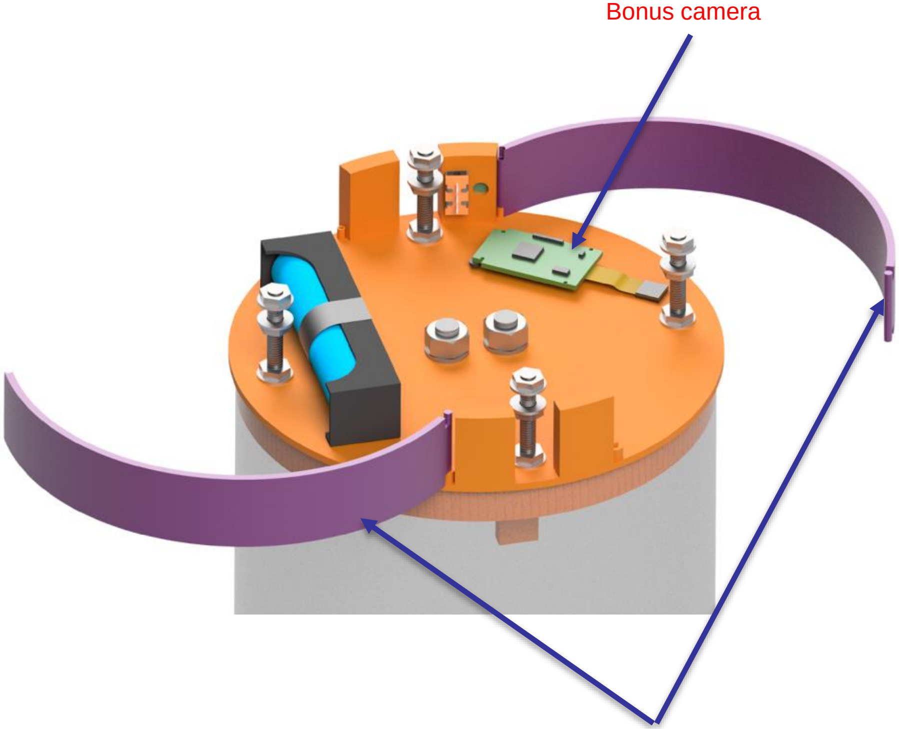
All electronics will be protected by the body of the payload or the foil cover which will protect the components from environmental influence.

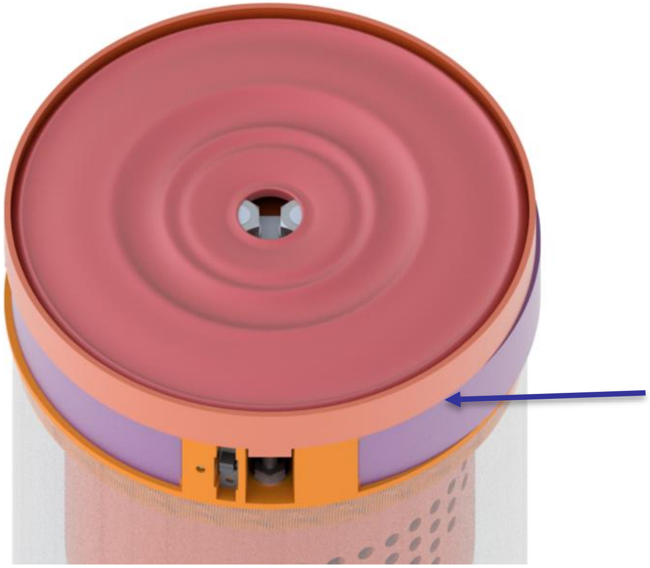


Electronic components mounting methods – Container:

The only electronic components in the container are the bonus camera—which will be **glued** in place—and its electronics board, which will be attached with **screws.**

These components are held in a small electronics bay behind two covers.





Structure Survivability (3/4)

Shock force requirements and testing:

An impact shock test will be conducted to test the strength of the parachute and payload mounting points and electronics shock resistance. The CanSat parachute mounting will be attached with a non-stretchable cord and then dropped from altitude of 61 cm to simulate 30 Gs shock. After the test, we will check if all mechanical and electronics systems work properly

Additionally, we will conduct a vibration test. The CanSat will be attached to an orbit sander. This will allow us to determine if all mechanism and electronics can work properly when influenced by 233 Hz vibrations. During this test, the accelerometer will give us valuable data for subsequent analysis.

To check if the deployment mechanism works properly we will lift the CanSat with an airplane and release it. The stability of flight and tether release parameters will be checked. Both cameras stability will be verified. The descent rate after releasing first parachute shall be 15 ± 5 m/s. Descent rate of payload with heatshield open shall not exceed 20 m/s and 5 ± 1 m/s after opening its parachute.

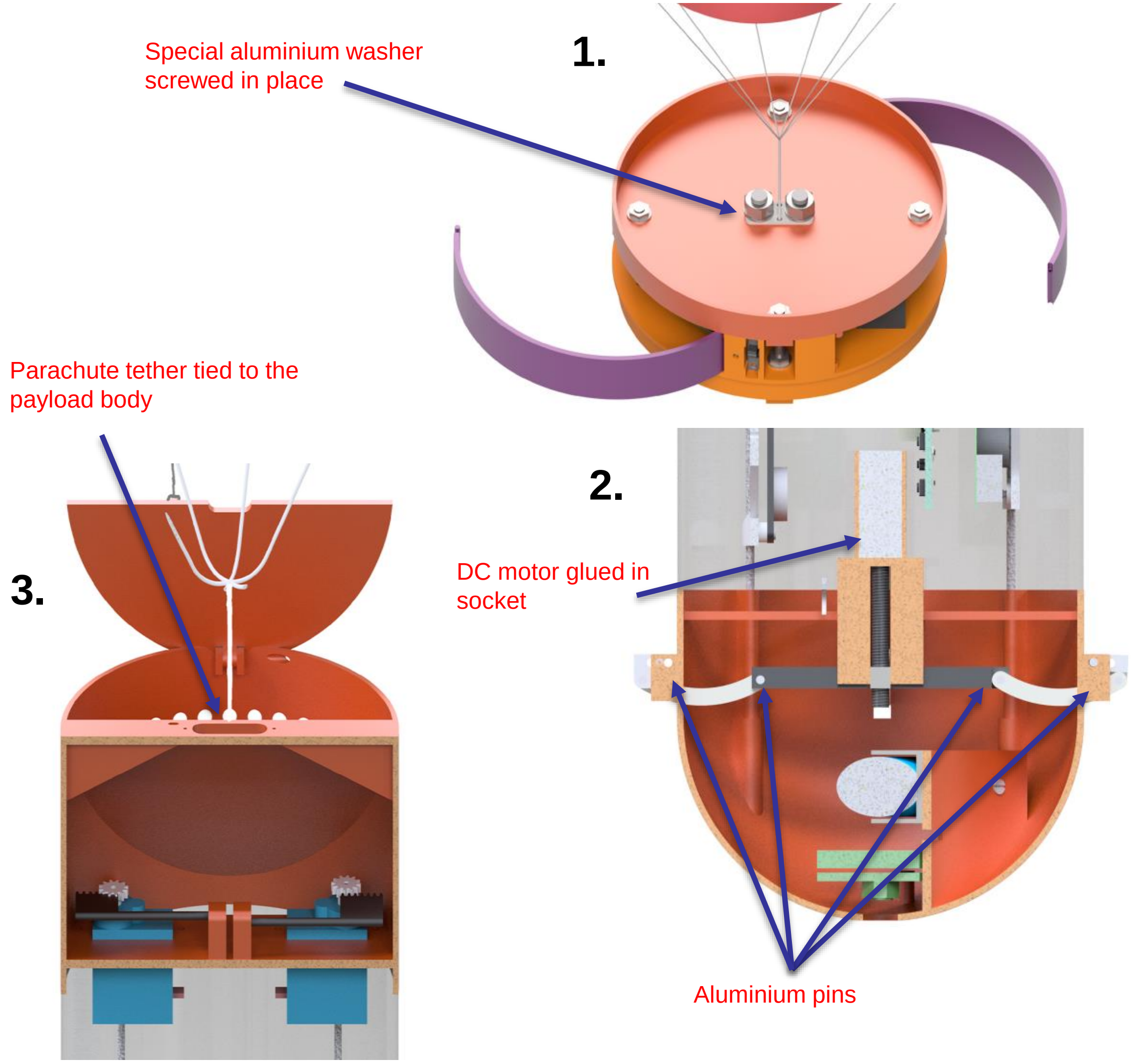
Structure Survivability (4/4)

Descent control attachments:

1. Container parachute:
The nylon parachute tether is threaded through a hole in the electronics bay upper plate. The hole is reinforced with a special aluminium washer which is screwed to the upper plate using the central bolt.

2. Heat shield:
The spokes which open the heatshield and give it structure—as well as all the linkages which are driven by the DC motor—are connected by aluminium pins. The DC motor is glued in a tight fitting socket.

3. Payload parachute:
The nylon parachute tether is connected to a strengthened part of the assembly in which the parachute is stored.



Mass Budget (1/8)

Container

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Structure with Decent Control system	Container parachute	Nylon	1	10.0±0.2	10.0±0.2	Datasheet
	Upper plate integrated with parachute attachment	ABS	1	37.0±0.5	37.0±0.5	Estimated
	Lower plate	ABS	1	42.0±0.5	42.0±0.5	Estimated
	Payload holder	Aluminium	1	21.5±0.2	21.5±0.2	Measured
	Container electronics cover	ABS	2	6.0±0.25	12.0±0.5	Estimated
	Connecting bolts	Aluminium	4	1.5±0.05	6.0±0.2	Estimated
	M6 nut	Steel	4	3.0±0.125	12.0±0.5	Estimated
	M6 washer	Steel	4	1.0±0.05	4.0±0.2	Estimated
	M4 nut	Steel	16	1.25±0.01	20.0±0.2	Measured
	M4 washer	Steel	16	0.3±0.01	4.8±0.2	Measured
	Foil container cover	PET	1	26.0±0.5	26.0±0.5	Estimated

Summary mass = 195.30 ± 3.70 g

Mass Budget (2/8)

Container

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Electronic systems	Camera	Adafruit 3202	1	2.8±0.05	2.8±0.05	Datasheet
	Memory Card	SanDisk microSDHC 16GB	1	0.25±0.05	0.25±0.05	Datasheet
	Battery	XTAR 14500-80PCM	1	20.0±0.1	20.0±0.1	Datasheet
	Battery holder	Keystone Electronics 2460	1	2.0±0.2	2.0±0.2	Datasheet
	Camera holder	ABS	1	5.0±0.2	5.0±0.2	Measured
	Screws	Steel	8	0.75±0.025	6.0±0.2	Datasheet

Summary mass = 36.05 ± 0.80 g

Mass Budget (3/8)

Payload

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Structure	Uprighting mechanism frame	ABS	1	27.0±0.5	27.0±0.5	Estimated
	Battery compartment (bottom) cover	ABS	1	26.0±0.5	26.0±0.5	Estimated
	Parachute bay	ABS	1	40.0±0.5	40.0±0.5	Estimated
	Foil payload cover	PET	1	6.0±0.5	6.0±0.5	Estimated
	Aluminium rods	Aluminium	4	2.0±0.05	8.0±0.2	Estimated
	Electronics support 1	ABS	1	7.0±0.2	7.0±0.2	Estimated
	Electronics support 2	ABS	1	4.0±0.2	4.0±0.2	Estimated
	Screws M2 x 4	Steel	4	0.15±0.01	0.6±0.05	Datasheet

Summary mass = 118.60 ± 2.65 g

Mass Budget (4/8)

Payload

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Electronic systems	Electronic board	BasedBoard	1	27.5±0.05	27.5±0.05	Measurement
	Camera	Adafruit 3202	1	2.8±0.05	2.8±0.05	Datasheet
	Radio	XBP9B-XCST-001	1	28.7±0.1	28.7±0.1	Datasheet
	GPS	MTK3339	1	8.5±0.1	8.5±0.1	Datasheet
	Rotation sensor	MPU9250	1	5.0±0.05	5.0±0.05	Datasheet
	Memory Card	SanDisk microSDHC 16GB	1	0.25±0.05	0.25±0.05	Datasheet
	Battery	Panasonic NCR18650B	1	48.5±0.1	48.5±0.1	Datasheet
	Battery basket	ABS	1	3.8±0.2	3.8±0.2	Estimated
	Antenna	ANTX150P118B09153	1	5.0±0.2	5.0±0.2	Estimated
	Screws	Steel	12	1.0±0.01	12.0±0.2	Datasheet
	Audiobeacon	Speaker 0.2W 12mm	1	5.0±0.2	5.0±0.2	Datasheet
	Connectors	JST 3-4 wires	5	0.3±0.004	1.5±0.02	Measurement
	LED	THT 5mm	1	0.5±0.1	0.5±0.1	Datasheet
	Switch	S22L NINIGI	1	4.64±0.05	4.64±0.05	Datasheet
	BasedBoard Attach	BasedBoard	1	15±0.5	15±0.5	Estimated

Summary mass = 170.19 ± 1.97 g

Mass Budget (5/8)

Payload

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Mast deployment mechanism	Servo	SG90	1	9.0±0.1	9.0±0.1	Datasheet
	Removable mast mount	ABS	1	20.0±0.5	20.0±0.5	Estimated
	Magic stick latch	Steel	1	1.0±0.2	1.0±0.2	Estimated
	Magic stick	Steel	1	23.0±0.5	23.0±0.5	Measured
	Pins 4mm	Aluminium	1	0.035±0.005	0.035±0.005	Estimated
	Screws M2 x 4	Steel	2	0.15±0.02	0.3±0.05	Datasheet
	Screws M5 x 10	Steel	2	1.5±0.05	3.0±0.1	Datasheet

Summary mass = 56.34 ± 1.46 g

Mass Budget (6/8)

Payload

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Payload release and parachute release mechanism	Servo	SG90	2	9.0±0.1	18.0±0.1	Datasheet
	Parachute cover	ABS	1	6.0±0.5	6.0±0.5	Estimated
	Payload parachute	Nylon	1	44.0±0.2	44.0±0.2	Datasheet
	Rack and pinion mechanism	ABS	1	0.6±0.1	0.6±0.1	Estimated
	Screws M2 x 4	Steel	3	0.15±0.01	0.45±0.03	Datasheet
	Tether	Nylon	1.0 m	0.4 g	0.4±0.05	Estimated
	Pins 4mm	Aluminium	2	0.035±0.01	0.07±0.02	Estimated
	Pins 8mm	Aluminium	1	0.07±0.01	0.07±0.01	Estimated

Summary mass = 69.59 ± 1.01 g

Mass Budget (7/8)

Payload

Subsystem	Component	Material / Part number	Quantity	Mass piece [g]	Mass summary [g]	Source
Uprighting and heatshield deployment mechanism	DC Motor	DFRobot DC 6 V 120 RPM	1	16.0±0.5	16.0±0.5	Datasheet
	Threaded cross	ABS/Aluminium	1	3.0±0.1	3.0±0.1	Measured
	Linkages	ABS	4	0.5±0.02	2.0±0.1	Estimated
	Spokes	Aluminium	4	3.0±0.05	12.0±0.2	Measured
	Pins 4mm	Aluminium	8	0.035±0.005	0.28±0.05	Estimated
	Pins 8mm	Aluminium	5	0.07±0.01	0.35±0.05	Estimated
	Limit switch	SS-01GL13-E	1	1.6±0.01	1.6±0.01	Datasheet
	Screws M2 x 6	Steel	2	0.15±0.02	0.3±0.05	Datasheet
	Heatsheat material	Nylon	1	26.0±1.0	26.0±1.0	Estimated

Summary mass = 61.53 ± 2.06 g

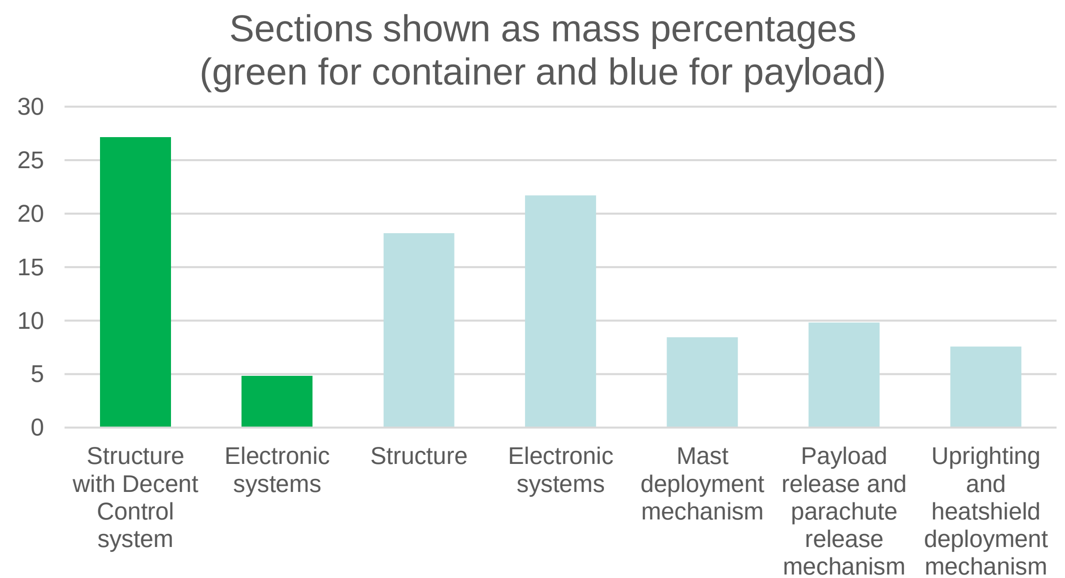
Mass Budget (8/8)

Component	Subsystem	Mass summary [g]
Container	Structure with Decent Control system	195.30 ± 3.70
	Electronic systems	36.05 ± 0.80
Payload	Structure	118.60 ± 2.65
	Electronic systems	170.19 ± 1.97
	Mast deployment mechanism	56.34 ± 1.46
	Payload release and parachute release mechanism	69.59 ± 1.01
	Uprighting and heatshield deployment mechanism	61.53 ± 2.06

Container mass: **231.35 ± 4.50 g**
Payload mass: **476.25 ± 19.15 g**
Summary mass: **707.60 ± 13.65 g**

Margin: 700.00- 707.60 = **7.60 g**

Our CanSat gained some weight since PDR however we are still in the ± 10g margin of error that is allowed by the rules. No changes were made to the filling of 3D printed parts and some screws are still made out of steel so there is room to lighten the CanSat if needed.



Communication and Data Handling (CDH) Subsystem Design

Hubert Kulik

CDH Overview

Type	Component	Function(s)
Processor	STM32F412RET	Collecting and processing data from sensors. Communication with Ground Station; sending data and executing commands.
Memory	MicroSD card	Storing telemetry data as backup. Storing software state as backup in case of the electronics restart.
RTC	Internal STM RTC with a backup battery	Measuring mission time.
Antenna	ANTX150P118B09153	Amplifying signal range.
Radio	Xbee: XBP9B-XCST-001	Transmitting data and commands.

CDH Changes Since PDR

CDH Changes	Rationales
„PC” argument was added to RST command	We missed this functionality during the tests, therefore we added it

Payload Processor & Memory Selection

Name	CPU speed [MHz]	Boot time [ms]	Operating voltage [V]	Flash memory [kB]	RAM [kB]	I/O Pins	Interfaces	ADC [channel/ resolution]
STM32F412RET6	100	~3	3.3	1024	256	40x GPIO, of which: - 32x PWM out - 16x Analog in	5x SPI, 4x I2C 4x UART 1x SDIO 1x USB	1/12-bit

Reasons
• Sufficient clock speed • Fast boot time • All needed interefaces are on-board • Sufficient RAM and Flash memories • Easy to solder on a custom PCB

The STM32 is a 32bit procesor.

Power consumption is estimated as 3.3V * 30mA = 100mW (source:datasheet)

Name	Memory	Interfaces	Package	Voltage [V]
SanDisk microSDHC 16GB	16GB	SPI SDIO	microSD	2.7÷3.6

Reasons
• High availability • Easy to replace • The highest capacity • Easy to use in the software • Vibration resistant

A standard SD card will be used to hold the data.

Payload Real-Time Clock

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

The RTC is online all the time, its backup battery will last for over 6 months.
When on the launch pad command ST will be used to set the proper time in the RTC registers.

Theoretical resolution is 30us.

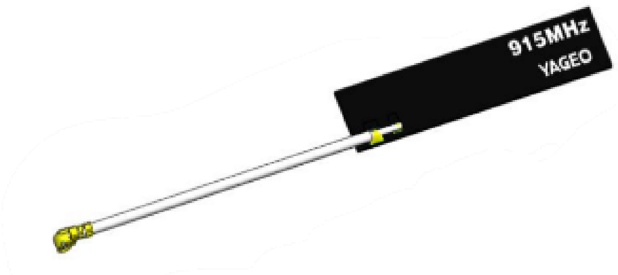
Reasons
• Saves weight due to being integrated • Is reset resistant • CPU can read directly from RTC • Has backup battery source • MCU already chosen

Payload Antenna Selection (1/2)

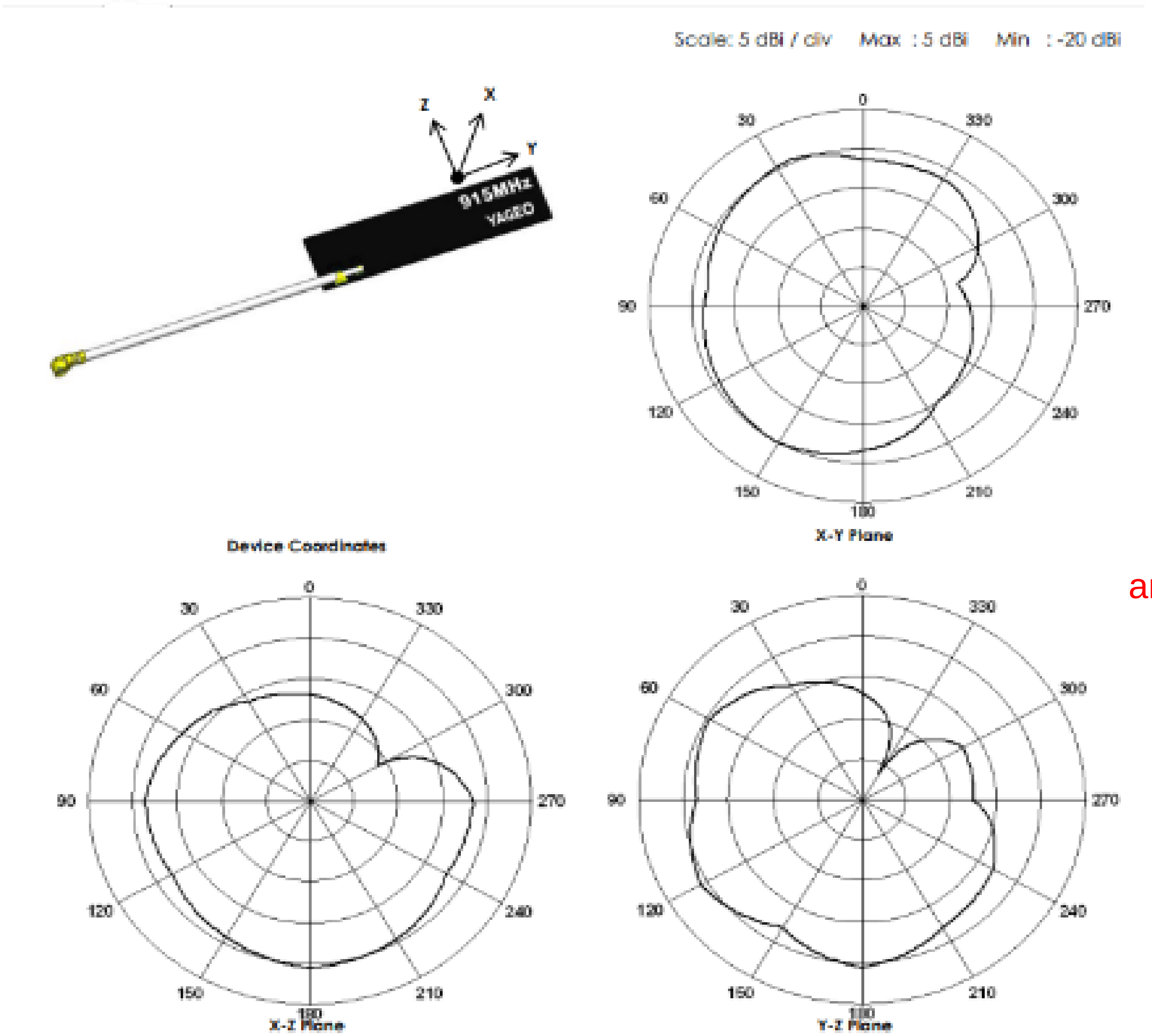
Name	Connector type	Antenna type	Frequency range(s) [MHz]	Weight [g]	Peak gain [dBi]	Efficiency [%]	Range [km]
ANTX150P118B09153	I-PEX (U.fl compatible)	PCB strip	890-925	0.675	1.9	>55	~0.6 (worst case) ~9 (best case)

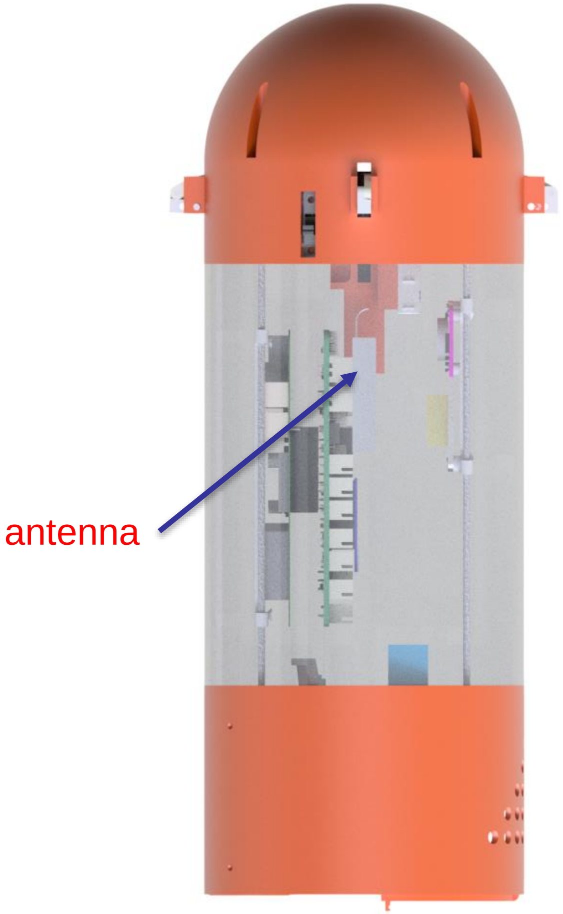
Early tests proved usefulness of this antenna, the communication was uninterrupted
The mass is the smallest possible due to construction based on flexible PCB strips.

Reasons
• High gain • High best case range • Wide frequency range • Small mass



Payload Antenna Selection (2/2)





Payload Radio Configuration (1/2)

Name	Operating voltage [V]	Operating current [mA]	baudrate [kbps]	Sensitivity [dBm]	Operating frequency [MHz]	Transmit power [mW/dBm]	Range [km] (best case)
XBee: XBP9B-XCST-001	2.4÷3.6	TX: 215 RX: 26	20	-109	900	250/24	~15 (outdoor)

*An U.fl connector will be soldered to the XBee to connect the antenna.

Reasons
• Best outdoor range • Has U.fl antenna connector • High transmit power • Sufficient baudrate

Payload Radio Configuration (2/2)

XBee Radio selection:

XBee XBP9B-XCST-001 has been selected and will be used in the payload and in 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.

PANID/NETID is set to **1082** ← Requirement number 21

Transmission Control

Before the start, the radio will be waiting for configuration (ST, CAL, CX).

After receiving the CX command, a data frame will be transmitted every second (**1Hz** frequency).

When landing is detected, the packet transmission is stopped.

Radio prototyping is finished. The selected configuration is suitable for the mission.

Payload Telemetry Format (1/3)

Field	Description	Resolution
TEAM_ID	The assigned team identification.	-
MISSION_TIME	UTC time in format hh:mm:ss.ss.	1s
PACKET_COUNT	Total count of transmitted packets, which is to be maintained through processor reset.	1 packet
MODE	‘F’ for flight (the default mode upon system start) and ‘S’ for simulation.	-
STATE	The operating state of the software. (LAUNCH_WAIT, ASCENT, ROCKET_SEPARATION, DESCENT, HS_RELEASE, LANDED)	-
ALTITUDE	Altitude in units of meters. Relative to ground level.	0.1m
HS_DEPLOYED	‘P’ indicates the Probe with heat shield is deployed, ‘N’ otherwise.	-
PC_DEPLOYED	‘C’ indicates the Probe parachute is deployed (at 200 m), ‘N’ otherwise.	-
MAST_RAISED	‘M’ indicates the flag mast has been raised after landing, ‘N’ otherwise.	-
TEMPERATURE	Temperature in Celsius degrees.	0.1°C
PRESSURE	Absolute pressure in kPa.	0.1kPa
VOLTAGE	Voltage of the CanSat power bus in volts.	0.1V
GPS_TIME	Time from the GPS receiver. Reported in UTC.	1s
GPS_ALTITUDE	Altitude generated by the GPS receiver in meters above mean sea level.	0.1m
GPS_LATITUDE	Latitude from the GPS receiver in decimal degrees north.	0.0001°
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.	1 satelite

Payload Telemetry Format (2/3)

Field	Description	Resolution
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°
CMD_ECHO	The text of the last command received and processed by the CanSat	-
OPTIONAL	No additional informations will be transmitted	-

The telemetry data will be transmitted with ASCII comma separated fields followed by a carriage return. The telemetry data will be sent at **1Hz** frequency, with 115200bps baud rate, in **burst transmission** mode.

Payload Telemetry Format (3/3)

Telemetry frame template:

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

Telemetry frame Example:

1082,13:25:10,00012,F,LAUNCH_WAIT,0.0,
N,N,N,28.1,101.3,
4.18, 13:25:10,122.2,37.5000,-79.0000,5,
0.14,0.27,CXON

The telemetry data file will be named: **Flight_1082.csv**

Competitions Requirements are met!

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 Container telemetry transmissions and 'OFF' to turn off the transmissions	CMD,1082,CX,ON Start transmitting data
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> is UTC in the format hh:mm:ss where hh is hours, mm is the minutes and ss is the seconds. 4. When substituted by GPS, the time is read form the GPS module.	CMD,1082,ST,13:10:12 Set RTC time to 13:10:12 -------------------------------- CMD,1082,ST,GPS Set RTC tome 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,1082,SIM,ENABLE Prepare to work in the Simulation Mode
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,1082,SIMP,101376 Treat 101376 as a value from the pressure sensor

Payload Command Formats (2/2)

Command name	Format	Description	Example
CAL - Calibrate Altitude to Zero	CMD,<TEAM_ID>,CAL	1. CMD and CAL are static text. 2. <TEAM ID> is the assigned team identification. 1. Sets the relativealtitude is set to 0.	CMD,1082,CAL Sets the transmitted altitude to 0
BEEP* – Turn on the speaker	CMD,<TEAM_ID>,BEEP	1. CMD and BEEP are static text. 2. <TEAM ID> is the assigned team identification. 1. Turns on the speaker for a brief time.	CMD,1082,BEEP Turns on the speaker for a second
RST* – Reset parts of the system	CMD,<TEAM_ID>,RST, SOFT | HARD | PC	1. CMD and RST are static text. 2. <TEAM ID> is the assigned team identification. 3. SOFT or HARD or PC is a parameter. 4. HARD simulates lost of power by reseting the MCU. 5. SOFT resets all the parameters to the default state. (packet count, RTC, relative altitude) **6. PC resets only packet count parameter**	CMD,1082,RST,HARD Turns off the MCU for random number of seconds (up to 5s)

* - Commands added by the Team

„CMD,1082,RST,PC" is a new usage of the RST command added after PDR submission. The option to restart the packet counter helped test behavior after an unwanted restart.

Competitions Requirements are met!

Electrical Power Subsystem Design

Hubert Kulik

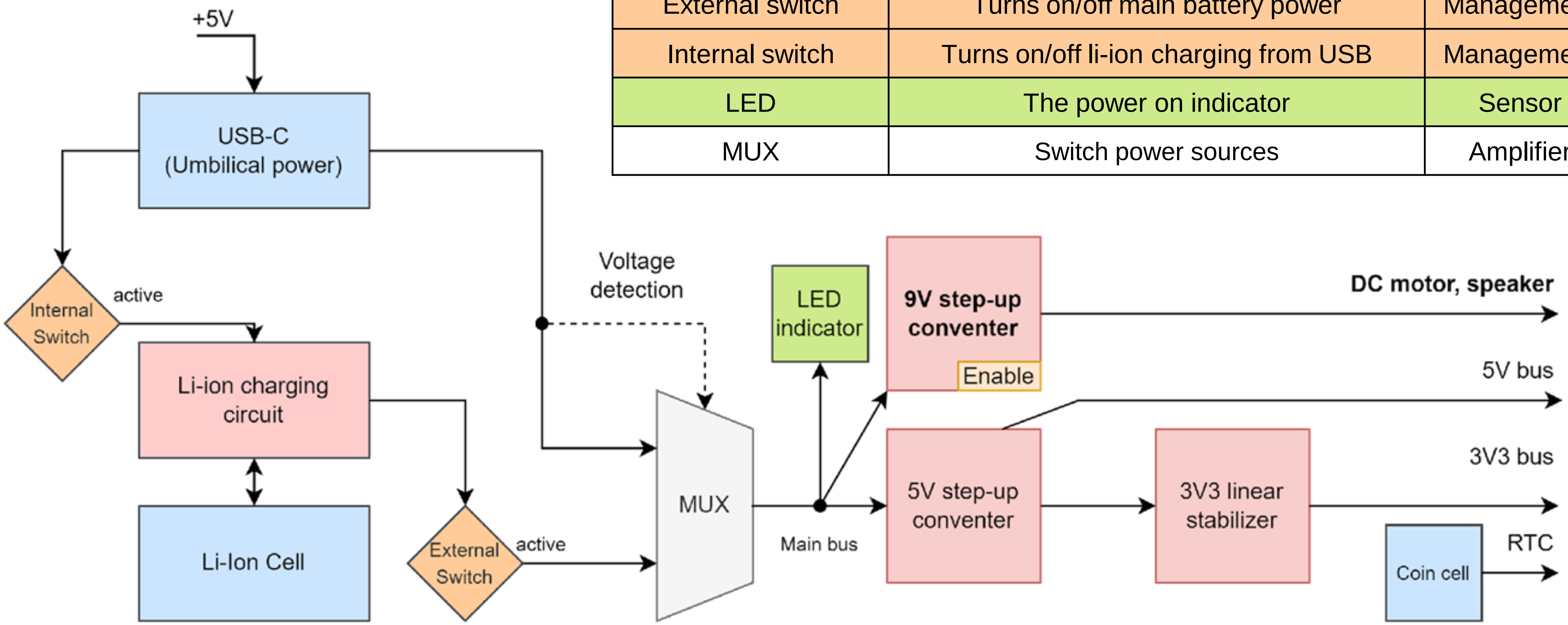
EPS Overview

Multiplexer represents circuit that switches power sources (USB or battery). If USB voltage is present, it has priority to power the board over the battery source.

The board allows us to charge the battery from the same USB port using onboard charging ciruit.

9V conventer was added since PDR. It can be disabled by the MCU if not needed.

Component	Description	Type
USB-C connector	Umbilical power source	Source
3.7V Li-ion cell	Main power source	Source
Coin cell	Prevents RTC from resetting	Source
5V step-up smps	Power supply for sensors and servos	Conventer
3V3 linear stabilizer	Power supply for sensors and MCU	Conventer
9V step-up smps	**Power supply for DC motor and speaker**	**Conventer**
External switch	Turns on/off main battery power	Management
Internal switch	Turns on/off li-ion charging from USB	Management
LED	The power on indicator	Sensor
MUX	Switch power sources	Amplifier



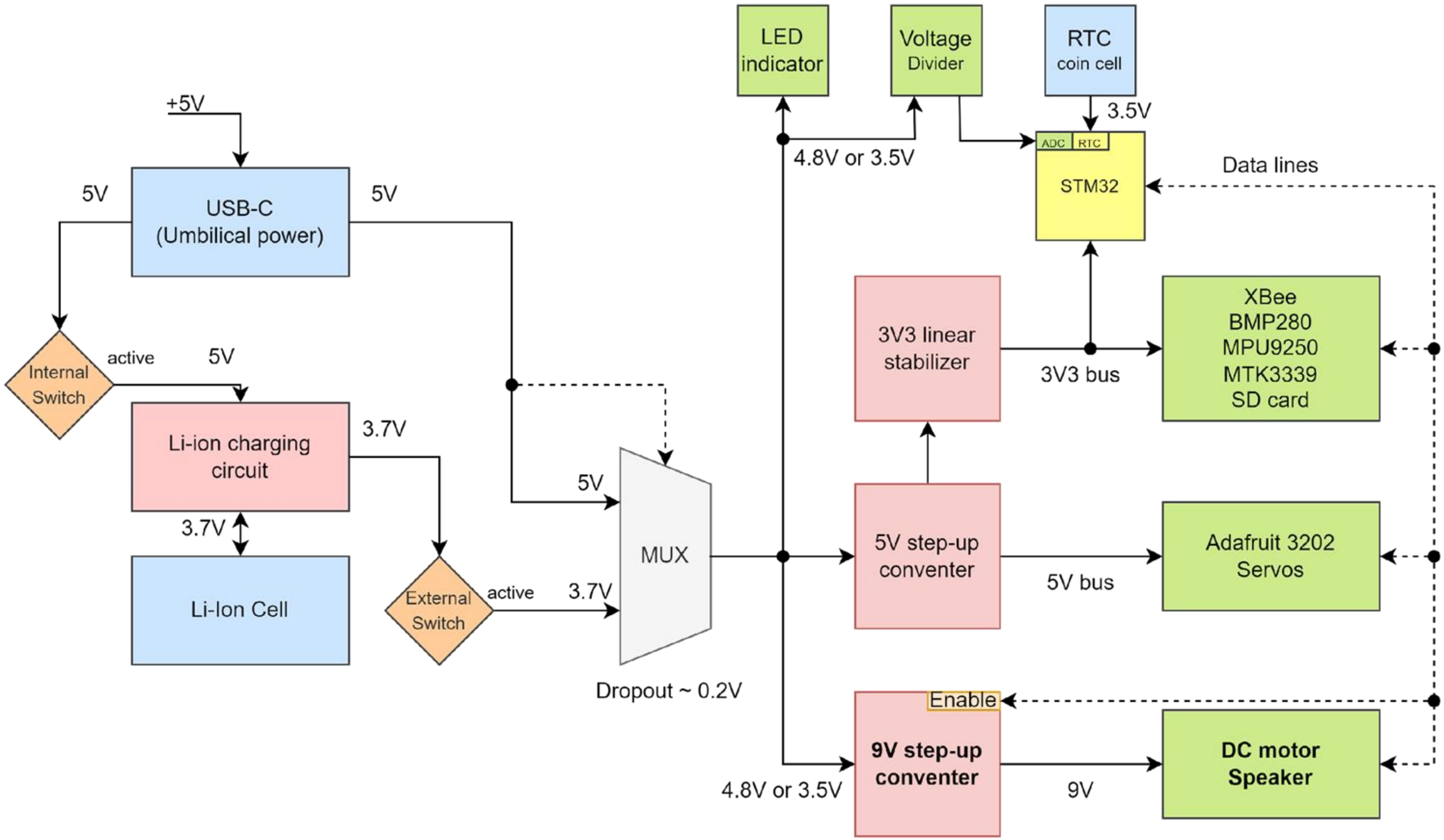
EPS Changes Since PDR

EPS Changes	Rationales
Li-ion cell model is changed to **Samsung INR18650-35E**	The new cell was available in a local distribution center
DC motor is now powered by 9V (previously was 5V)	The test showed the speed of heatshield development is not enough
The budget and diagrams were updated with recently added elements	The 9V power supply was added, the documentation needed to be updated as well

*All changes in the following slides are indicated using bold font.

Payload Electrical Block Diagram

On battery power, the external switch will allow us to switch on the circuit.
LED provides feedback on the power state independent of the MCU.



Payload Power Source

Part	Dimensions [mm]	Weight [g]	Voltage [V]	Capacity [mAh]	Current[mA] const / inst	Type	Charge cycles	Integrated fuses	Cost [$]
Samsung INR18650-35E	⌀18.5 x 65.3	48.5	3.6	3500	8 000 13 000	Li-ion	500	No	7.8

The cell will be placed in an appropriate basket placed vertically, which will prevent it from disconnecting. Because a **single cell** is used, it **does not have a configuration**.
No spring contacts are used.

Payload Power Budget

Component	Model	Voltage [V]	Current [mA]	Power [mW]	Duty cycle [s]	Duty Cycle [%]	Required Energy [Wh]	Source
uC+memory	STM32F412	3.3	30	99	7200	100%	0.1980	Datasheet
Radio (TX)	XBP9B-XCST-001	3.3	215	709.5	1080	15%	0.2129	Datasheet
Radio (RX)	XBP9B-XCST-001	3.3	26	85.8	6120	85%	0.1459	Datasheet
GPS	MTK3339	3.3	20	66	7200	100%	0.1320	Datasheet
Pressure Temperature	BMP280	3.3	25	82.5	7200	100%	0.1650	Datasheet
Gyroscope	MPU9250	3.3	0.4	1.32	7200	100%	0.0026	Datasheet
LED indicators	LED 0603	3.3	10	33	7200	100%	0.0660	Datasheet
SD card	SanDisk 16GB	3.3	(30) 100	(99) 330	(5760) 1440	(80%) 20%	0.1584 + 0.1320	Datasheet
3V3 stabilizer	AZ1117-3V3	5	0.06	0.3	7200	100%	0.0006	Datasheet
5V SMPS	JENOR20200908	3.7	2	7.4	7200	100%	0.0148	Datasheet
9V SMPS	**JENOR20200908**	**3.7**	**2**	**7.4**	**2520**	**35%**	**0.0052**	**Datasheet**
Camera	Adafruit 3202	5	110	550	200	3%	0.0330	Datasheet
Motor	**DFRobot 6V 120RPM**	**9**	**275**	**2475**	**120**	**1.6%**	**0.0788**	**Datasheet**
SERVO 1,2	S9G Micro	5	(6) 40 [*2]	(30) 200 [*2]	(7170) 30	0.5%	0.0597 + 0.0020 [*2]	Datasheet
Speaker	57CS50G-75ND	9	180	1620	30	0.5%	0.0162	Calculated
						Total	1.4854	
						Total (Incl. efficiency)	2.9708	

Note: The value inside brackets () is standby or idle magnitude.

Summary:

Power source:	One Li-ion cell
Total power available:	3.6 V * **3500 mAh** = 12600 mWh = 12.6 Wh
Margin:	12.6 Wh – 2.971 Wh = 9.629 Wh
Percent margin:	2.971 Wh / 12.6 Wh ·100% = 23.6%

With the selected battery, **the Payload can operate for approximately 8 hours** when integrated into the rocket. For safety we assumed that combined efficiency is 50%.

Flight Software (FSW) Design

Hubert Kulik

FSW Overview (1/3)

Overview

Flight software is based on state machine concept. By means of collected data, FSW will evaluate through states, handling events like reaching proper altitude. Besides that, it takes care of sending data to GS via XBee and restoring correct state and time, in case of unwanted restart.

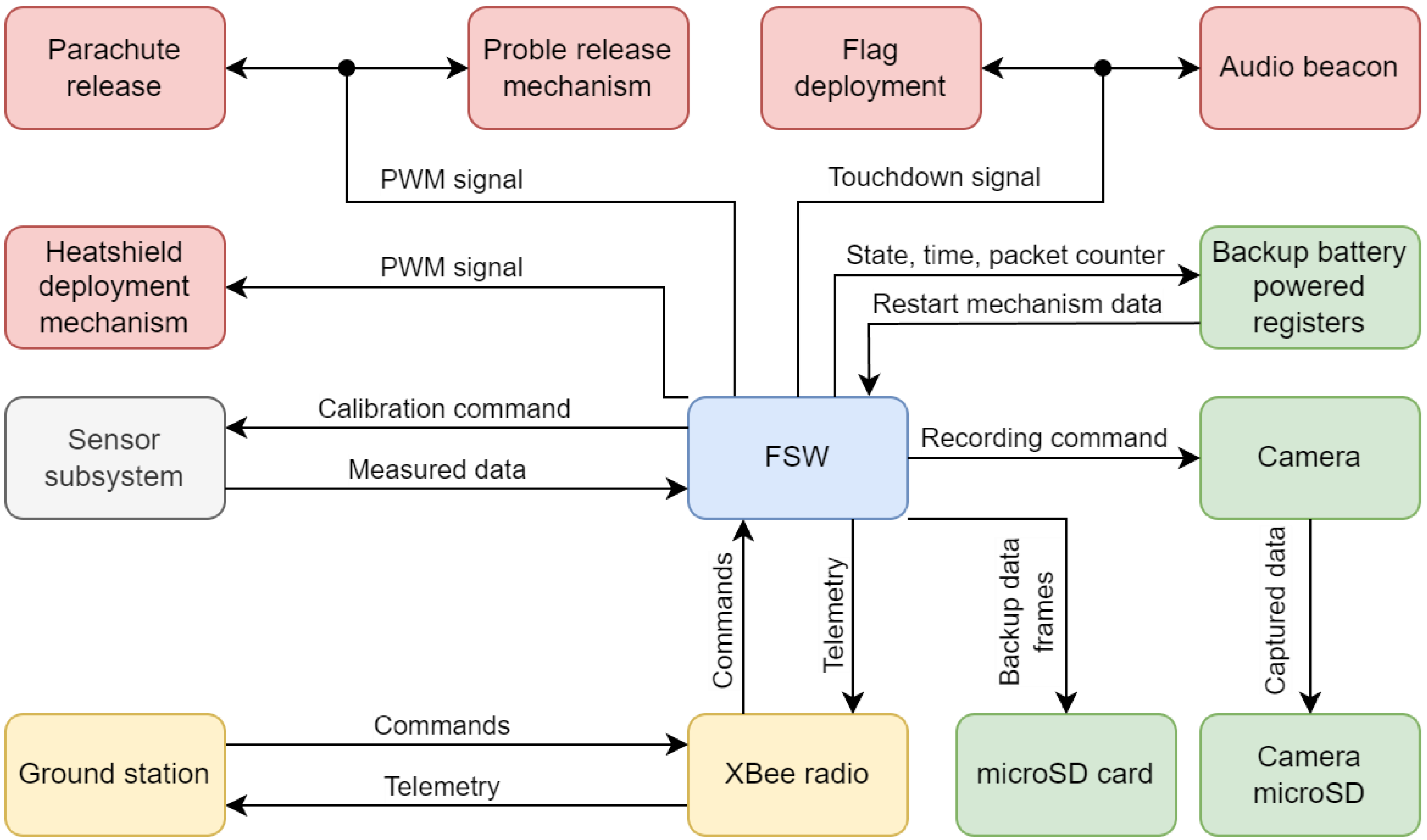
Programming language

Our software is based on C/C++ language.

Developing environment

CLion (IDE), cmake (buildsystem), arm-none-eabi (compiler and debugger)

FSW Overview (2/3)



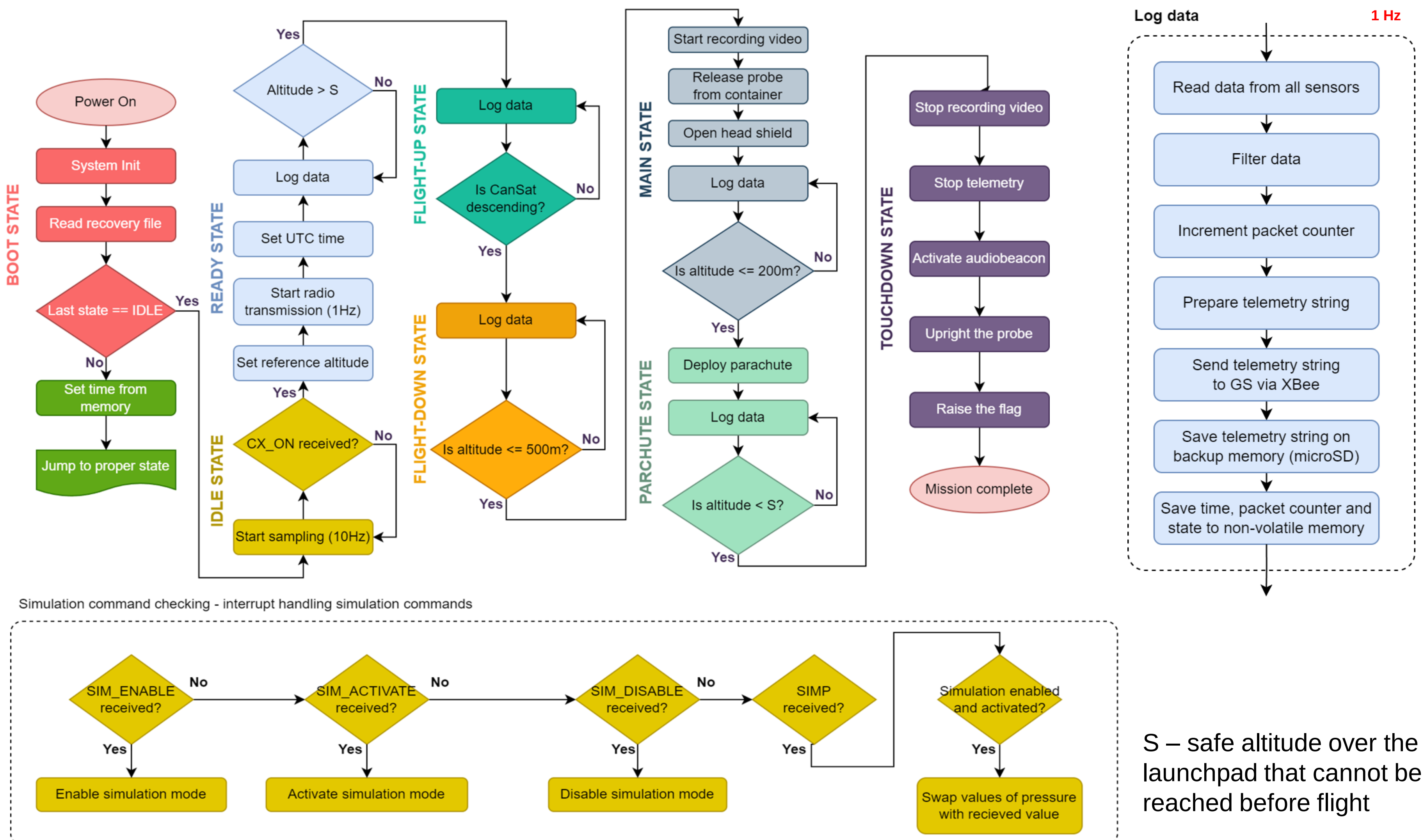
FSW Summary Tasks

- ✓ Sensor calibration
- ✓ Recording raw sensor values and converting them to engineering units
- ✓ Receiving and processing commands from GS (e.g. to start transmission or perform reset)
- ✓ Storing data and video on SD cards
- ✓ Storing recovery data on MCU battery-backuped registers
- ✓ Preparing data packages in required format to transmit
- ✓ Transmitting telemetry packets to Ground Station via Xbee
- ✓ Progressing through FSW States
- ✓ Activating mechanism of probe/parachute deployment in the correct moment
- ✓ Starting recording video in proper time
- ✓ Activating the buzzer and raising the flag after landing
- ✓ Swapping pressure readings for received values in simulation mode

FSW Changes Since PDR

We made **no** changes since submitting PDR in the flight software section

Payload CanSat FSW State Diagram (1/2)



S – safe altitude over the launchpad that cannot be reached before flight

Payload CanSat FSW State Diagram (2/2)

Unwanted restart mechanism

- In case of unwanted restart, proper values are read from non-volatile memory (STM32 backup registers).
  These values are:
  - mission time
  - internal packet counter
  - software state numer
  - altitude of the launchpad

  The values are saved every time they change.

- Reasons for reset are:
  - voltage drop
  - watchdog timer error (it calls software reset of microcontroller)
  - reset command.

- To recover the state after a restart, MCU will check the backup registers.
  If data is present, it will be loaded to variables and the state selector will jump to the proper state.
  In other case, the state selector jumps to state Idle.

Simulation Mode Software

Simulation mode is used for testing and demonstration purposes.

To enter simulation mode Ground Station should send two commands (SIM ENABLE and SIM ACTIVATE) to Payload. Two commands are required to prevent accidental initiation. Then GS will start sending air pressure values at a one second interval as barometric pressure sensor commands (SIMP). FSW will use received values instead of real data from pressure sensor. It will let FSW calculate simulated altitude used by software logic.

This mode doesn't affect other sensors - the values, other than the pressure and altitude will be actual sensor readings.

SIM - Simulation Mode Control Command

- CMD,1082,SIM,ENABLE - enable the simulation mode
- CMD,1082,SIM,ACTIVATE - activate the simulation mode
- CMD,1082,SIM,DISABLE - both disables and deactivates the simulation mode

SIMP - Simulated Pressure Data

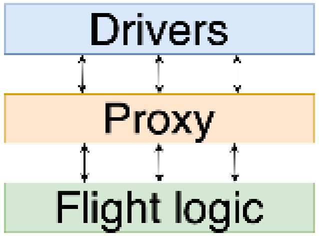
- CMD,1082,SIMP,<PRESSURE> - simulated atmospheric pressure data in Pascals (1 Pa resolution)

Software Development Plan (1/3)

Late software development problem

To reduce the risk, we started the preparations early. We are planning to make three-layer software. First layer contains drivers for sensors and peripherals, second layer (proxy) is connector between 1st and 3rd layers. Third layer contains flight logic only (state machine).

This solution lets us test software independently from hardware. Once we have all of the elements of proxy layer well tested, we can test the flight logic



Prototyping and prototyping environments

To prototype we use breakout modules and breadboards. Each sensor is tested separately. If tests are passed and everything meets requirements, all will be placed on a custom PCB, which allows us to develop whole system.

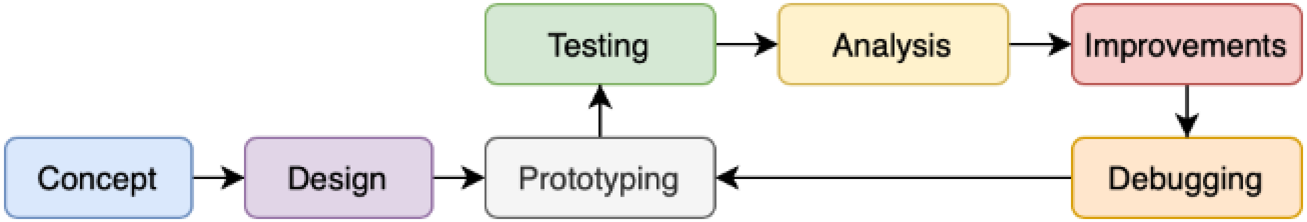
Deployment system, based on servomechanisms, needs to choose coefficients like current, voltage and time empirically, so we do it in our University Lab.

We plan drop test in real environment test using local aeroclub's plane.

Software Development Plan (2/3)

Software developing

We use Git to store and manage our codebase. This tool lets us work in team and track issues as well as make code reviews. To keep continuity of development, we will organize weekly meetings to discuss problems.



Test methodology

Firstly, tests are performed in laboratory, where we can calibrate sensors using specific drivers. Then, during environmental tests, such as free-fall test or drone flight, we can test CanSat in environment similar to the real mission. It allows us to test every sensor as a whole system and the most fault-prone element – radio communication.

Development team: Jakub Kaszowski, Hubert Kulik, Tobiasz Puślecki

Software Development Plan (3/3)

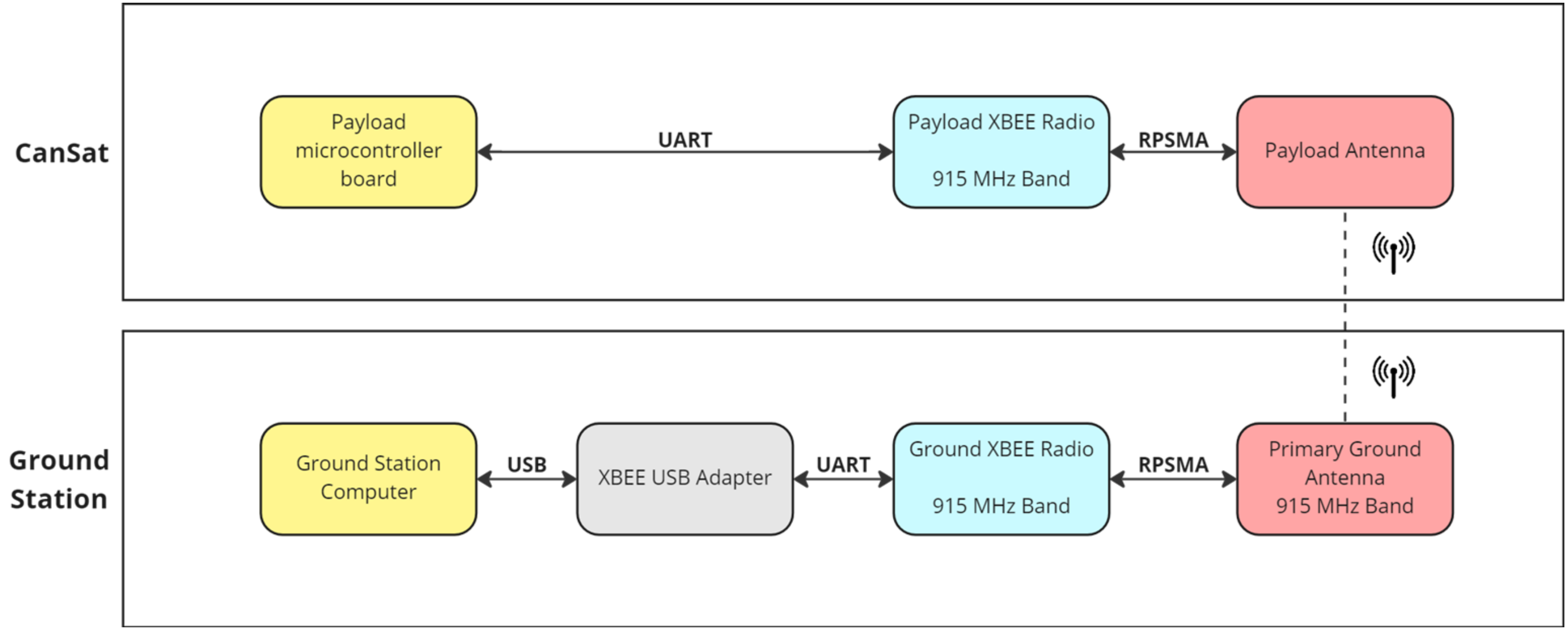
Progress since PDR	
Toolchain preparation	Done
SD card & filesystem preparation	Done
Data filters preparation	Done
Unwanted state mechanism	Done
Communication between payload and GS	Done
Drivers for all sensors	Done
Timer configuration and timing checks	Done
Proxy interfaces	Refactoring in progress
Deployment mechanism support	Done
Integrations of all systems	In progress
Camera support	Done

Ground Control System (GCS) Design

Hubert Kulik

GCS Overview

We will assemble our own Ground Station setup, consisting of the following elements:

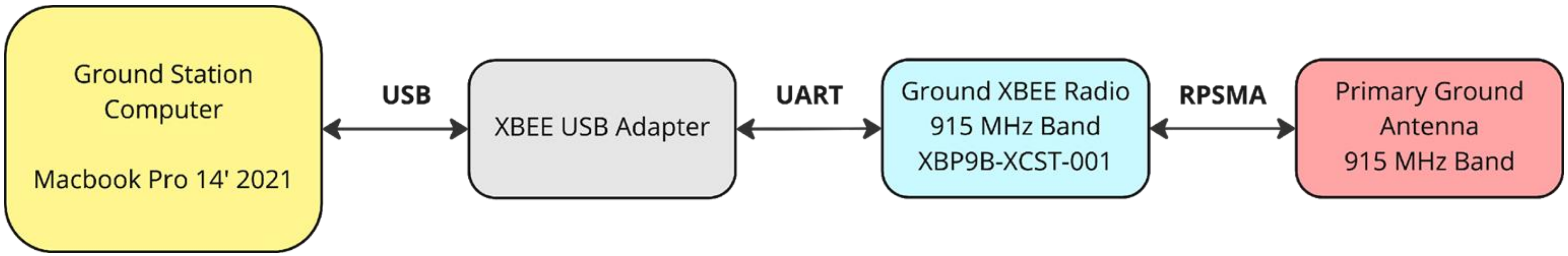


GCS Changes Since PDR

We made **no** changes since submitting PDR in the ground control system section

GCS Design

Specifications	
Operation time	GCS can operate for minimum 2 hours.
Overheating mitigation	Cardboard case with outer surface of silver emergency blanket. We will protect the computer from sunlight with an umbrella.
Autoupdate mitigation	A Macbook Pro is going to be used, and macOS does not enforce auto updates.



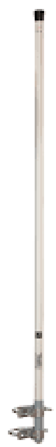
The whole setup is portable, as it is powered by battery is easy to be carried.

GCS Antenna (1/3)

Model	Type	Frequency range [MHz]	Gain [dBi]	VSWR	Direction	Beamwidth	Range [km]
Interline HORIZON 900 8V	Dipole	900÷950	8	>2 @ 902 MHz	Omnidirectional	360° @ -3dB H	~5

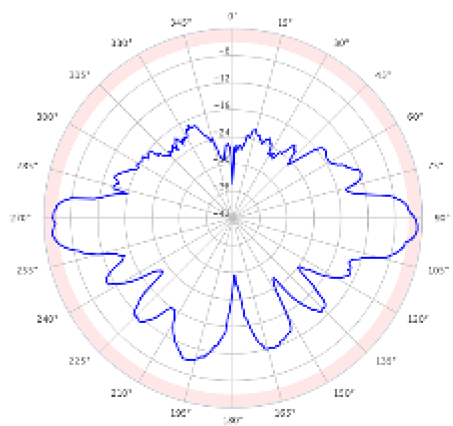
Reasons
• The build of the antenna is preferable for field • The best gain • Better radiation characteristic • Acceptable signal range

The dipole antenna provides good coverage for receiving the signal. Additionally, this model has been tested out in the field during previous CanSat competitions.

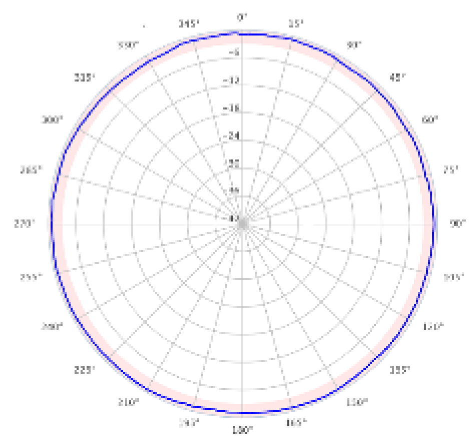


Interline HORIZON 900 8V – 915 MHz Radiation Patterns

VERTICAL



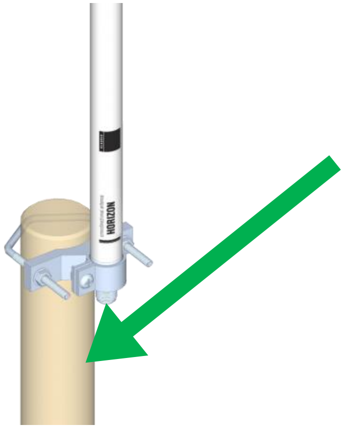
HORIZONTAL



GCS Antenna (2/3)

Antenna mounting design

Interline HORIZON 900 8V is our main antenna. It will be mounted on a **handle** and manually directed to signal transmitted from CanSat. Interline HORIZON 900 8V dipole antenna shall be used with a PCV pipe attached directly to the antenna mount holes. This allows to manipulate the antenna easily by the operator.



Interline HORIZON 900 8V

GCS Antenna (3/3)

Path loss

Predicted distance: $d = 3500m = 3.5\ km$

Center frequency: $f = 915\ MHz$

Center frequency wavelength: $d = 0.327 = 32.7\ cm$

$$L_{FS}[dB] = 20\log_{10}\left(\frac{4\Pi d}{\lambda}\right) = 20\log_{10}\left(\frac{4\Pi \cdot 3500}{0.327\lambda}\right) = 102.7\ [dB]$$

Link Budget

$P_{rx} = ?$

$P_{tx} = 20\ dBm(XBEE)$

$G_{tx} \approx 2\ \text{dBi}$

$P_{rx} = P_{tx} + G_{tx} - L_{fs} - L_{ADD} + G_{rx}$

$G_{rx} = 8\ dBi$

$L_{fx} = 102.8\ dBi$

$P_{rx} = 20 + 2 - 102.7 - 5 + 8 = -77.7\ dBm$

$L_{ADD} = 5\ DBi$

Link Budget (Z)

Receiver sensitivity (min) **=** -106 dBm @ (10kbps)

$-77.7\ dBm \succ -106\ dBm$

Receiver satisfies requirements

P_{rx} - Power @ receiver input

P_{tx} - *Transmitter power*

G_{tx} - Gain of transmit antenna

G_{rx} - Gain of receiver antenna

L_{fs} - Free space loses

L_{ADD} - Additional loses (cable etc.)

GCS Software (1/2)

- Software packages

  GCS software will be built with the Tauri framework using Rust and React JS. React JS will be used for the frontend in order to achieve **real-time plotting**. The Rust backend will process data received on serial port from XBEE radio. **We are not using commercially licensed software.**

React JS

- Telemetry

  Telemetry will be live plotted during flight. All data will be displayed using engineering units. After the flight, **telemetry data from all sensors will be saved to a Flight_1082.csv.** In the end, CSV files are going to be handed over to judges on **USB stick**. Accurate information can be found in CDH section of this presentation.

- Simulation mode description

  The Ground Station operator can enable the simulation mode by sending two commands: SIMULATION ENABLE and SIMULATION ACTIVATE. A file with simulation data will be loaded. After broadcasting a packet that enables simulation mode, the operator will send an activation command, after which the Ground Station will start sending successive values from the CSV file at a frequency of 1 Hz as SIMP command. The simulation mode disabling command – SIM DISABLE – is also sent from the GCS.

- Commands

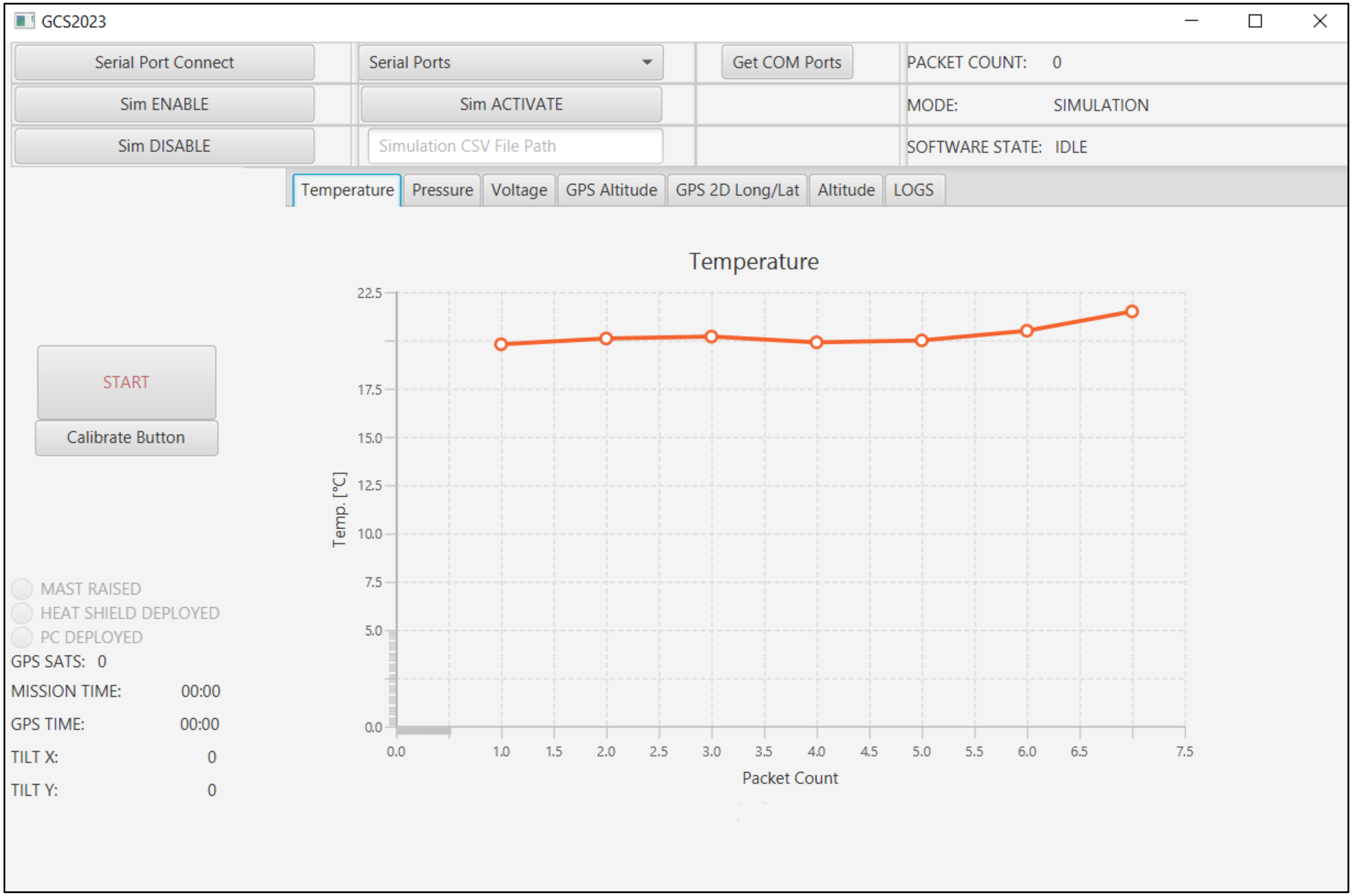
  The Ground Station operator can send a calibration command for the launchpad altitude calibration and the tilt sensor (**row** and **pitch**). The results of calibration can be verified it in the GCS interface. The command for the time set can be sent also by the operator (by clicking proper button in GUI).

- Progress since PDR

  Real-time data plotting and the user interface are implemented. Our Ground Station can receive data and display it from the XBee coming to the serial port, and it can broadcast its own messages to the serial port using the appropriate buttons. It does write this data to the appropriate CSV files.

GCS Software (2/2)

- GCS Graphical User Interface



CanSat Integration and Test

Hubert Kulik

CanSat Integration and Test Overview

Our CanSat will be tested by four level testing		
Subsystem level	Each subsystem will be tested separately	Sensors, CDH, EPS, Radio Communications, FSW, Mechanical, Descent Control
Integrated level	All subsystems will be integrated together and tested	Descent Testing, Communications, Mechanisms, Deployment
Simulation level	Integrated subsystems will be tested in simulation mode to test flight level software logic	Flight Software Logic
Environment level	CanSat will be tested using the Competition Guide directions	Drop test, Thermal test, Vibration test, Fit Check, Vacuum test

Subsystem level → Integrated level → Simulation level → Environmental level

1. Firstly, the payload, container body and mechanism will be built and initially tested. Independently, the electronics circuits will be soldered, programmed and debugged.
2. When all of the components are working properly, they will be put together and tested as a whole device.
3. After completing the integration test, we will use simulation mode to ensure that all mechanism, communication, electronics and implemented algorithms work together properly.
4. At the end, we will conduct environmental tests to make sure that our CanSat can work within specified environment.

Subsystem Level Testing Plan (1/4)

Subsystem	Test case	Acceptance criteria	Test result
FSW	Microcontroller is correctly initialized	Blinking LED	Success
	Debug logs can be sent via serial interface	Serial interface transmits data	Success
	After initialization FSW jumps to MSM	Debug log indicates FSW entered MSM	TBT
	MSM can progress through mission states	Each state sends signed debug log	TBT
	FSW Can survive power cuts	MSM starts with last state, sensors are still calibrated	TBT
Mechanical	Payload doesn't release under shock and vibrations	Payload release mechanism does not release payload unintentionally	Success
	Payload is properly separated from Container	Payload is released, mechanism does not get stuck	TBT
	Electronic mounting withstands all shock and vibrations	Electronics and all peripherals survives vibrations and accelerations without damage	Success
	Battery is easily dismounted from payload	Battery can be replaced in less than one minute	TBT
	The flag mechanism raises the flag	The flag is fully raised	Success
	Electronic bay is isolated from vibrations	Electronic bay mounting isolates high frequency vibrations	TBT
	Container and payload parachutes open after release	Parachutes cords don't tangle	TBT
	Container descents on parachute correctly	The proper speed of descent is maintained	TBT

*TBT – to be tested

Subsystem Level Testing Plan (2/4)

Subsystem	Test case	Acceptance criteria	Test result
Sensors	Sensors and devices are initialized, communication is possible	Sensor/device data can be read via debug logs	Success
	Altitude can be properly calculated	Altitude calculated from test values corresponds to expected altitude	Success
	Temperature measuring	Temperature is correctly measured	Success
	Pressure measuring	Pressure is correctly measured	Success
	Voltage measuring	Voltage is correctly measured	Success
	GPS data is available	GPS data can be read by FSW	Success
	GPS NMEA frame is correctly decoded	GPS time, latitude, longitude, altitude and sats are available	Success
	Sensors can be calibrated and return zero values when stationary on ground	Values read from sensors are zeroed	Success
CDH	File System is properly initialized on SD Card	File system initialization success	Success
	SD Card is ready for writing data	File system returns success when saving files	Success
	SD Card is accessible, data can be read	File system allows fore reading files, data in files are correct	Success
	Data saved in backup registers survives resets and power downs	Data is consistently available	Success
	Real-Time Clock measures time	Time of CanSat and GS are in-sync during the tests	Success

Subsystem Level Testing Plan (3/4)

Subsystem	Test case	Acceptance criteria	Test result
EPS	Pressure sensor is powered	Proper voltage on necessary pins is measured	Success
	Temperature sensor is powered	Proper voltage on necessary pins is measured	Success
	GPS sensor is powered	Proper voltage on necessary pins is measured	Success
	Voltage sensor is powered	Proper voltage on necessary pins is measured	Success
	Camera is powered	Proper voltage on necessary pins is measured	Success
	Processor is powered	Proper voltage on necessary pins is measured	Success
	microSD card is powered	Proper voltage on necessary pins is measured	Success
	PCB doesn't have shortcuts	PCB has no shorts to ground or power lines	Success
	PCB is properly soldered	Joints are properly soldered, there are no cold joints	Success
	Battery withstands high current	Battery works correctly under high current	TBT
	CanSat can operate for two hours	CanSat does not turn off when left in IDLE state for two hours	Success
	Voltage regulators and DC converters work properly	Proper voltage on all power lines under load	Success
	IMU is powered	Proper readings from the sensor given the positioning	Success
	Xbee is powered	Proper voltage on necessary pins is measured	Success

Subsystem Level Testing Plan (4/4)

Subsystem	Test case	Acceptance criteria	Test result
Descent control	FSW can control deployment mechanisms	The servo releases the parachute	TBT
	State machine detects change in flight phases	State is changed when appropriate conditions are met	TBT
	First parachute flight maintain correct descent velocity	CanSat descents at rate between 10 to 20 m/s	TBT
	Second parachute flight maintain correct descent velocity	CanSat descents at rate between 4 to 6 m/s	TBT
Radio communication	XBee Radio can receive data	Data sent to XBee can be read via debug logs	Success
	XBee Radio can transmit data	Data sent from FSW can be read on PC with XBee	Success
	XBee radios NETID/PANID is set to their team number	NETID/PANID is read as 1082	Success
	Open air radio range testing	Radio range is sufficient for double of the flight altitude	TBT
	Ground level radio range testing	Radio range is sufficient for the flight altitude	Success
	GCS can connect with the CanSat	The connection is reached and stable	Success
	GCS can transmit and receive data	Data is successfully transmitted and received	TBT
	GCS plotting data	Data is plotted in real time	TBT

Integrated Level Functional Test Plan

System	Test overview
Descent testing	The CanSat will be **lifted using an airplane and then released**. The stability of flight and tether release parameters will be checked. Both cameras stability will be verified. The descent rate after releasing first parachute shall be 15 ± 5 m/s. Descent rate of payload with heatshield open shall not exceed 20 m/s and 5 ± 1 m/s after opening its parachute
Communications	We will conduct field tests to check the range of radio communication and bandwidth. We will place the device on the plane and check the status of radio communication from the Ground Station
Mechanisms	Tests of Mechanical and Descent Control Subsystem, such as release mechanism of payload, heat shield and parachutes and G-force test, will be performed with the CanSat at Integrated Level. The mechanisms operationality will be tested using the simulation mode. Then, during the airplane test the elements strength will be checked
Deployment	To make sure that each deployment subsystem works according to our assumptions, tests of the parachutes release mechanism and the Payload drop test will be performed. Additionally, stationary tests of the parachute opening, flag raising, and self-uprising/heatshield systems will be carried out
Simulation	After sending two commands SIMULATION ENABLE and SIMULATION ACTIVE pressure data will be sent to the container. Recorded data frames will be checked and compared with our prepared mission state diagram

Environmental Test Plan

Test	Test overview
Drop test	The CanSat parachute mounting would be tied to non-stretching cord and then dropped from altitude of 61 cm to simulate 30 Gs shock. After the test, the mechanical and electronic systems will be checked. All of them shall survive and work properly
Thermal test	A thermal chamber from styrodur will be used. Next, the CanSat will be placed inside. The construction will be heated to 60°C with a dryer to verify if all systems work in required temperature range. During the whole test telemetry shall be received constantly
Vibration test	The CanSat will be attached to an orbit sander. Vibrations (up to 233 Hz) must not affect the operation of all systems and all mechanical components must avoid damage. The accelerometer data shall be collected throughout the test
Fit Check	A cylindrical envelope of 125 mm diameter x 400 mm length will be built. The test will verify, if the CanSat fits inside and can be easily deployed during the flight (it mustn't get stuck)
Vacuum test	The CanSat will be placed in hermetic chamber connected to suction device. The pressure value will decrease and the altitude value will increase. The test will show how the altitude value change when the pressure value change

All tests will be conducted using the Competition Guide directions

Test Procedures Descriptions (1/9)

FSW:

Test No.	Test Description	RN	Pass Criteria
1	The microcontroller is correctly initialized	-	The LED is blinking
2	Debug logs can be sent via serial interface	-	The serial interface transmits data
3	After initialization FSW jumps to MSM	-	Debug log indicates FSW entered MSM
4	MSM can progress through mission states	-	Each state sends signed debug log
5	FSW Can survive power cuts	45	MSM starts with last state, sensors are still calibrated

Mechanics:

Test No.	Test Description	RN	Pass Criteria
6	Payload doesn't release under shock and vibrations from orbit grinder	12, 13	Container descents on parachute correctly
7	Payload can separate from container and the line gets fully unwind	8	Payload is released, mechanism does not get stuck
8	Electronic mounting withstands all shock and vibrations	14	Electronics and all peripherals survives vibrations and accelerations without damage
9	The battery is easily dismounted from the payload	28	Batteries should be changed under a minute
10	The flag mechanism raises the flag	37	The flag is fully raised
11	Electronic bay is isolated from vibrations	13	Piezo crystal taped to PCBs doesn't have high voltage
12	Container and payload parachutes open after release	8	Parachutes cords don't tangle
13	Container descents on parachute correctly	10	The sensor transmits proper descent velocity

Test Procedures Descriptions (2/9)

SSD:

Test No.	Test Description	RN	Pass Criteria
14	Sensors are initialized, communication is possible	38	Sensor/device data can be read via debug logs
15	Altitude can be properly calculated	39	Altitude calculated from measured values corresponds to the introduced change in altitude
16	Temperature measuring	39	Temperature is correctly measured
17	Pressure measuring	39	Pressure is correctly measured
18	Voltage measuring	39	Voltage is correctly measured
19	GPS data is available	39	GPS data can be read by FSW
20	GPS NMEA frame is correctly decoded	39	GPS time, latitude, longitude, altitude and sats are available (frame is injected by UART)
21	Sensors can be calibrated and return zero values when stationary on ground	11	Values read from sensors are zeroed, no static bias is present

CDH:

Test No.	Test Description	RN	Pass Criteria
22	File System is properly initialized on SD Card	-	File system initialization success
23	SD Card is ready for writing data	-	File system returns success when saving files
24	SD Card is accessible, data can be read	-	File system allows for reading files, data in files are correct
25	Data saved in backup registers survives resets and power downs	53	Variables are consistently available, data is not lost
26	Real-Time Clock measures time	46	Time of CanSat and GS are in-sync during the tests

Test Procedures Descriptions (3/9)

EPS:

Test No.	Test Description	RN	Pass Criteria
27	Pressure sensor is powered	-	Proper voltage on necessary pins is measured
28	Temperature sensor is powered	-	Proper voltage on necessary pins is measured
29	GPS sensor is powered	-	Proper voltage on necessary pins is measured
30	Voltage sensor is powered	-	Proper voltage on necessary pins is measured
31	Camera is powered	-	Proper voltage on necessary pins is measured
32	Processor is powered	-	Proper voltage on necessary pins is measured
33	MicroSD card is powered	-	Proper voltage on necessary pins is measured
34	PCB doesn't have shortcuts	-	PCB has no shorts to ground or power lines
35	PCB is properly soldered	-	There are no cold joints and no shortcuts
36	Battery withstands high current	-	Battery works correctly under high current
37	CanSat can operate for two hours	31	CanSat does not turn off, when left in IDLE state, for two hours
38	Voltage regulators and DC converters work properly	-	Proper voltage on all power lines under load
39	Xbee is powered	-	Proper voltage on necessary pins is measured

Test Procedures Descriptions (4/9)

Descent control:

Test No.	Test Description	RN	Pass Criteria
40	FSW Can control deployment mechanisms	-	The servo releases the probe 10 times in a row
41	State machine detects change in flight phases	-	State is changed when appropriate conditions are met
42	First parachute flight keeps correct descent velocity	10	CanSat descents at rate between 10 to 20 m/s
43	Second parachute flight keeps correct descent velocity	35	CanSat descents at rate between 4 to 6 m/s

Radio communication:

Test No.	Test Description	RN	Pass Criteria
44	XBee Radio can receive data	-	Data sent to XBee can be read via debug logs
45	XBee Radio can transmit data	-	Data sent from FSW can be read on PC with Xbee
46	XBee radios NETID/PANID is set to their team numer	21	Payload NETID/PANID is read as 1082
47	Open air radio range testing	-	Radio range is sufficient for double of the flight altitude
48	Ground level radio range testing	-	Radio range is sufficient for the flight altitude
49	GCS can connect with the CanSat	-	The connection is reached and stable
50	GCS can transmit and receive data	-	Data is successfully transmitted and received
51	GCS plotting data	55, 57	Data is plotted in real time, no freezing occurs

Test Procedures Descriptions (5/9)

Tests at integrated level:

Test No.	Test Description	RN	Pass Criteria
52	Descent testing: CanSat droped from a plane will descent with velocity required by mission guide	10, 34, 35	Descent velocities read from sensors classified against an FSW state will be in the required range
53	Communication: Maximum radio range will be found. Test data will be send to GS	-	Minimum radio range must exceed 1.5 km. Format of data frame will be compared to mission guide
54	Mechanism 1: servo can release the payload	-	When released the payload drops out of the container. During this test, the container will be held by hand
55	Mechanism 2: servo can release the parachute	-	Parachute is developed, its cords are not tangled
56	Mechanism 3: DC motor can deploy the heatshield	33	The heatshield is deployed in below 5s, external force cannot interrupt this proces
57	Mechanism 4: DC motor can upright the probe	6	The probe can upright itself from multiple positions
58	Mechanism 5: servo can release the flag	37	The flag height is 500mm ± 25mm
59	Deployment: all stages of deployment will be tested during trial mission	57	The trial mission goes along the mission guide. All requirements are meet
60	Simulation: obtained data will be compared to mission state diagram	47, 48, 60, 61	Obtain results must be received in correct format. States should change in accordance of mission state diagram. Frequency of send data will be checked.
61	Electrical 1: Audio beacon test	25, 26	The speaker produces 92dB of sound pressure when integrated into the body of CanSat. Measured from 0.5m

Test Procedures Descriptions (6/9)

Environmental tests:

Test No.	Test Description	RN	Pass Criteria
62	Drop test: CanSat will be connected to the cord and dropped from 61 cm	12,13, 30	Probe must be fully intact and must still transmit data after drop test
63	Thermal test: CanSat will be placed in oven for two hours in 60 Celsius degree	15,30	Probe must be fully intact and transmit data without loses during test
64	Vibration test: CanSat will be held on orbital sander	14,15, 30	Probe must be fully intact and transmit data without loses during test
65	Fit Check: CanSat will be placed in tube with diameter of 125mm, total lenght not exceed 400mm	2,3, 30	Probe must fit in tube without any problems, the length must not exceed 400mm
66	Vacuum test: CanSat will be placed in vacuum chamber	30	Probe must be fully intact and transmit data without loses during test

Test Procedures Descriptions (7/9)

Remaining requirements:

RN	Description	Evidence of compilance [Page]
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams	77
4	The container shall be a fluorescent color; pink, red or orange	141
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open	45
7	The rocket airframe shall not be used as part of the CanSat operations	22
9	The Parachute shall be fluorescent Pink or Orange	36
16	Mechanisms shall not use pyrotechnics or chemicals	51
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire	62
18	Both the container and probe shall be labeled with team contact information including email address	45,51
19	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost	158
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed	85
22	XBEE radios shall not use broadcast mode	86
23	The container (if needed) and probe shall include an easily accessible power switch that can be accessed without disassembling the CanSat and science probes and in the stowed configuration	18,53

Test Procedures Descriptions (8/9)

Remaining requirements:

RN	Description	Evidence of compilance [Page]
24	The probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the CanSat and in the stowed state	43,47
27	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.	96
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	96
32	The probe shall be released from the container when the CanSat reaches 500 meters.	16,17
36	Once landed, the probe shall upright itself	57,103
40	The probe shall include a video camera pointing down to the ground	53
41	The video camera shall record the flight of the probe from release to landing	17,103
42	The video camera shall record video in color and with a minimum resolution of 640x480	31
44	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	103,104

Test Procedures Descriptions (9/9)

Remaining requirements:

RN	Description	Evidence of compilance [Page]
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands	105
50	The ground station shall command the CanSat to start calibrating the altitude to zero when the CanSat is on the launch pad prior to launch.	105
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section	105
52	Telemetry shall include mission time with 1 second or better resolution	87
54	Each team shall develop their own ground station	110
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	87,105
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna	112
59	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	112

Simulation Test Plan

Simulation mode is used for testing FSW easily. This will test corner cases.

This mode swaps actual readings of **pressure sensor** for those received from ground station.

It doesn't affect other sensors readings - the values, other than the pressure and altitude will be actual sensor readings.

Simulation sequence:

- To enter simulation mode Ground Station should send two commands (SIM ENABLE and SIM ACTIVATE) to the payload.
- GS will start sending air pressure values at a one second interval as barometric pressure sensor commands (using a provided flight profile CSV file).
- FSW will use received values in place of real data from pressure sensor.
- To disable simulation mode, GS should send SIM DISABLE command.

The simulation mode tests: FSW (state progression), data handling and GCS (commands & real-time plot)

Mission Operations & Analysis

Hubert Kulik

Overview of Mission Sequence of Events (1/3)

Our team acquired experience thanks to participation in the previous competition editions. For this reason, we expanded our team with new members to share our knowledge and make the design better.

Role	Person
Mission Control Officer (MCO)	Tobiasz Puślecki
Ground Station Crew (G)	Jakub Kaszowski, Katarzyna Ignatowicz
Recovery Crew (R)	Hubert Kulik, Tymoteusz Puślecki
CanSat Crew (C)	Tomasz Drewniak, Konrad Łebek, Eunika Puślecka

The responsibilities of each role will be attached in the remaining two slides of this section.

- **Ground Station assembly:**

After obtaining the place, the laptop and sun-protection equipment will be set up. The connections Laptop-Xbee-Antenna will be made. Ground station and communication tests will be run afterward.

- **Cansat assembly and test:**

Payload, Parachutes will be assembled to container and payload. All final tests for connection with Ground Station, sensors check and microSD card writing check will be performed at launch site and right before the start.

Overview of Mission Sequence of Events (2/3)

Arrival

- Arriving at launch site (whole team)
- Check for any damages that could appear during the travel (C)

Setting up Ground Station

- Ground control station assembly (G)
- Antenna preparation (G)

Preparations

- CanSat assembly and test (C)
- CanSat communication and sensors test (C/G)
- Separation test (C)
- Cable singeing mechanism test (C)
- Battery charge control (C)
- Mounting payload in the container (C)
- Weight and size final check (MCO)
- Turning in the CanSat for inspection (MCO/C)

Pre-launch

- Moving GCS to dedicated position (G)
- Mounting CanSat in the rocket (MCO/G)
- Communication check (G)
- Sensors calibration (G)
- Safety check (whole team)

Overview of Mission Sequence of Events (3/3)

Launch → **Recovery** → **Post-launch**

Launch

- Executing launch procedures (MCO/C)
- Performing flight operations (G)
- CanSat landing (MCO/R)
- Delivering USB stick with data to the judge (G)

Recovery

- Heading out to recover the probe (R)
- MicroSD card recovery (R)
- Backing up flight data after probe recovery (G)

Post-launch

- Return to the check-in for final judging (R)
- Clearing Ground Station area (G)
- Data analysis (whole team)

Field Safety Rules Compliance

Development	Content
The Mission Operations Manual will be developed using our experience from previous years and based on tests that are yet to be carried. The final version of the operations manual will be ready after completion of Critical Design Review.	Knowing the overview of the Mission Sequence of Events, some of the crucial points of the Mission Operation Manual can be indicated. The diagram depicting them is presented in the next slide [142].

Execution
Final version of the Mission Operation Manual will include not only Mission Sequence, but also team members' roles and safety instructions. Mission Operation Manual will be assembled into a three-ring binder. The launch preparation, launch and removal procedures will be provided by the organizers.

CanSat Location and Recovery

Container Recovery
• Container color will be fluorescent red so that it can be easily detected. • An attached parachute will be in fluorescent pink color. • Landing zone will be determined by observing the descent.
Payload Recovery
• Payload will be made of ABS in fluorescent orange color. • Landing zone will be determined by: observing the descent, GPS location data. • Buzzer (92dB) will be activated after touchdown. • Mast with flag will be raised after landing and uprighting.
Labeling
Payload and container will be labeled with the team email address, contact informations and phone number.

Mission Rehearsal Activities

Configuring the Ground Station

- Ground station assembly
- Antenna preparation
- System initialization
- Communication test

Powering on/off the CanSat

- Battery check
- CanSat is powered on by turning on two power switches

Preparing the CanSat

- Sensors test
- Separation mechanism test
- Probe assembly

Integrating the CanSat into the rocket

- Folding and securing payload parachute
- Mounting payload inside the container
  and securing it
- Folding and securing container parachute
- Mounting CanSat inside the rocket
- Communication check
- Sensors calibration

CanSat recovery

- Backing up data from GS
- Finding the CanSat
- Damage check
- Securing microSD card

Requirements Compliance

Hubert Kulik

Requirements Compliance Overview

Current state of design meets all requirements although some changes may appear during construction in order to improve already working systems.

Most of the tests needed to meet the requirements have already been carried. Environmental and descent test are yet to be done.

Further test are prepared in order to check if there is anything to improve before final design, even though constructing the probe as it is, should suffice to all the tasks mentioned in Mission Guide.

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

Requirements Compliance (1/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams.	Comply	77	
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Comply	20	
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Comply	22	
4	The container shall be a fluorescent color; pink, red or orange.	Comply	141	
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open.	Comply	45	
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	22	
7	The rocket airframe shall not be used as part of the CanSat operations.	Comply	22	
8	The container's parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Comply	50	
9	The Parachutes shall be fluorescent Pink or Orange	Comply	141	

Requirements Compliance (2/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
10	The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	Comply	41	
11	0 altitude reference shall be at the launch pad.	Comply	103,116	
12	All structures shall be built to survive 15 Gs of launch acceleration.	Comply	48,55	
13	All structures shall be built to survive 30 Gs of shock.	Comply	48,55	
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	47,48	
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	56	
16	Mechanisms shall not use pyrotechnics or chemicals.	Comply	51	
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	Comply	62	
18	Both the container and probe shall be labeled with team contact information including email address.	Comply	45,51	

Requirements Compliance (3/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
19	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost. Equipment from previous years shall be included in this cost, based on current market value.	Comply	158	
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	85	
21	XBEE radios shall have their NETID/PANID set to their team number.	Comply	85	
22	XBEE radios shall not use broadcast mode.	Comply	95	
23	The container and probe shall include an easily accessible power switch that can be accessed without disassembling the CanSat and science probes and in the stowed configuration.	Comply	18,53	
24	The container and probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the CanSat and in the stowed state.	Comply	43,58	
25	An audio beacon is required for the probe. It shall be powered after landing.	Comply	43,141,103	
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	Comply	141	
27	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	96	

Requirements Compliance (4/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Comply	18,19	
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	96	
30	The CanSat shall operate during the environmental tests laid out in Section 3.5.	Comply	125	
31	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	97	
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Comply	16,17	
33	The probe shall deploy a heat shield after leaving the container.	Comply	17,103	
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	Comply	17	
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/- 1m/sec.	Comply	16,17,41	
36	Once landed, the probe shall upright itself.	Comply	103	

Requirements Compliance (5/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	Comply	103	
38	The probe shall transmit telemetry once per second.	Comply	103	
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	Comply	89	
40	The probe shall include a video camera pointing down to the ground.	Comply	58,53	
41	The video camera shall record the flight of the probe from release to landing.	Comply	103	
42	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	31,32	
44	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	104	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	104	
46	The probe shall have its time set to within one second UTC time prior to launch.	Comply	103	

Requirements Compliance (6/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
47	The probe 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	105	
48	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude	Comply	105	
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	105	
50	The ground station shall command the CanSat to start calibrating the altitude to zero when the CanSat is on the launch pad prior to launch.	Comply	105	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	105	
52	Telemetry shall include mission time with 1 second or better resolution.	Comply	87	
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Comply	104	
54	Each team shall develop their own ground station.	Comply	110	
55	All telemetry shall be displayed in real time during descent on the ground station.	Comply	116	

Requirements Compliance (7/7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Slide	Notes
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	105	
57	Teams shall plot each telemetry data field in real time during flight.	Comply	117	
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	Comply	112	
59	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	112	
60	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Comply	105	
61	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	105	

*Req 43 was skipped in the mission guide.

Management

Hubert Kulik

Status of Procurements

We don't expect **any** problem with missing components

Mechanics:
All mechanical elements are obtained. The container and the probe prototype exist.
3D printer material is prepared for eventual changes

Electronics:
All sensors, actuators, electronic components and PCBs are already procurement, shipped and assembled

Ground Station:
Almost all Ground Station components are prepared for the tests.
The antenna is yet to be delivered

Software:
No procurements are required

CanSat Budget – Hardware (1/5)

Construction – components and electronics					
Container					
Component	**Model/Material**	**Quantity**	**Price [USD]**	**Total**	**Status**
Container parachute	Nylon	1	19.17	19.17	Actual
Camera	Adafruit 3202	1	18.00	18.00	Actual
Memory Card	SanDisk microSDHC 16GB	1	5.80	5.80	Actual
Battery	XTAR 14500-80PCM	1	4.40	4.40	Actual
Battery holder	Keystone Electronics 2460	1	1.31	1.31	Actual
Camera holder	ABS	1	0.10	0.10	Estimated
Screws	Steel	4	2.20	8.80	Actual
LED	THT 5mm	1	0.21	0.21	Actual
Switch	S22L NINIGI	1	0.35	0.35	Actual
Upper plate integrated with parachute attachment	ABS	1	0.80	0.80	Estimated
Lower plate	ABS	1	0.92	0.92	Estimated
Payload holder	Aluminium	1	0.35	0.35	Estimated
Container electronics cover	ABS	2	0.25	0.50	Estimated
Connecting bolts	Aluminium	4	0.92	3.68	Estimated
M6 nut	Steel	4	0.20	0.80	Estimated
M6 washers	Steel	4	0.12	0.48	Estmated

CanSat Budget – Hardware (2/5)

Component	Model/Material	Quantity	Price [USD]	Total	Status
M4 nut	Steel	16	0,05	0.80	Estimated
M4 washer	Steel	16	0.03	0.48	Estimated
Foil conteinter cover	PET	1	0.55	0.55	Estimated
Payload					
Servo	SG90	3	1.23	3.69	Actual
Pitman arm	ABS	1	0.01	0.01	Estimated
Magic stick latch	Steel	1	0.01	0.01	Estimated
Magic stick	Steel	1	7.98	7.98	Actual
Pins 4mm	Aluminium	1	0.15	0.15	Estimated
Screws M2 x 4	Steel	2	0,35	0.70	Estimated
Screws M5 x 10	Steel	2	0.55	1.10	Estimated
Parachute cover	ABS	1	0.28	0.28	Estimated
Payload parachute	Nylon	1	4.89	4.89	Actual
Rack and pinion mechanism	ABS	1	0.01	0.01	Estimated
Screws M2 x 4	Steel	3	0.35	1.05	Estimated
Tether	Nylon	1	0.30	0.30	Estimated
Pins 4mm	Aluminium	2	0.15	0.30	Estimated
Pins 8mm	Aluminium	1	0.30	0.30	Estimated
DC Motor	DFRobot DC 6 V 120 RPM	1	13.51	13.51	Actual
Threaded cross	ABS/Aluminium	1	0.18	0.18	Estimated

CanSat Budget – Hardware (3/5)

Component	Model/Material	Quantity	Price [USD]	Total	Status
Linkages	ABS	4	0.04	0.16	Estimated
Spokes	ABS	4	0.08	0.32	Estimated
Pins 4mm	Aluminium	8	1.20	9.60	Estimated
Pins 8mm	Aluminium	5	1.50	7.50	Estimated
Limit switch	SS-01GL13-E	1	1.09	1.09	Actual
Screws M2 x 6	Steel	2	0.70	1.40	Estimated
Heatsheat material	Nylon	1	2.66	2.66	Estimated
Uprighting mechanism frame	ABS	1	0.57	0.57	Estimated
Battery compoartment (bottom) cover	ABS	1	0.55	0.55	Estimated
Parachute bay	ABS	1	1.05	1.05	Estimated
Foil payload cover	PET	1	0.13	0.13	Estimated
Aluminium rods	Aluminium	4	0.92	3.68	Estimated
Electronics support 1	ABS	1	0.15	0.15	Estimated
Electronics support 2	ABS	1	0.08	0.08	Estimated
Screws M2 x 4	Steel	4	1.40	5.60	Estimated
Electronic board	BasedBoard	1	40.70	40.70	Actual
Camera	Adafruit 3202	1	18.00	18.00	Actual
Radio	XBP9B-XCST-001	1	65.50	65.50	Actual
GPS	MTK3339	1	42.00	42.00	Actual
Rotation sensor	MPU9250	1	7.00	7.00	Actual

CanSat Budget – Hardware (4/5)

Component	Model/Material	Quantity	Price [USD]	Total	Status
Memory Card	SanDisk microSDHC 16GB	1	5.80	5.80	Actual
Battery	Samsung INR18650-35E	1	7.80	7.80	Actual
Battery basket	ABS	1	0.08	0.08	Estimated
Antenna	ANTX150P118B09153	1	1.53	1.53	Actual
Screws	Steel	12	0.55	6.60	Actual
Audiobeacon	Speaker 0.2W 12mm	1	0.80	0.80	Estimated
Connectors	JST 3-4 wires	5	0.20	1.00	Actual
LED	THT 5mm	1	0.21	0.21	Actual
Switch	S22L NINIGI	1	0.35	0.35	Actual
PCB + passive elements	BasedBoardAttach	1	1.00	1.00	Estimated
Amplifier/H-drive	TB6612	1	4.00	4.00	Actual

CanSat Budget – Hardware (5/5)

Total cost [USD]	
Container	126.43
Payload	211.88
Total	338.31

Prices were converted from Polish złoty to dollars using current exchange rate, which was USD/PLN = 4.35 at the time.

None of the above parts have been used before, so no component is re-used in this construction

All costs fit in requirements and don't exceed presupposed cost

CanSat Budget – Other Costs (1/2)

Ground Control Station					
Component	**Model/Material**	**Quantity**	**Price [PLN/USD]**	**Total [PLN/USD]**	**Status**
XBee USB Adapter	XBee Adapter USB v2.2 - DFRobot DFR0174	2	105.00 / 24.42	210.00 / 48.84	Actual
XBee Radio	XBP9B-XCST-001	2	140.93 / 32.77	281.86 / 65.54	Estimated
RPSMA XBee	DELTACO SMA-FM500	1	100.00 / 23.26	100.00 / 23.26	Actual
Antenna	Interline HORIZON 900 8V	1	400.00 / 93.02	400.00 / 93.02	Actual
RPSMA Antenna	DELTACO SMA-FM500	1	100.00 / 23.26	100.00 / 23.26	Actual

Total [PLN/USD]	1 091.86 / 253.92

Computer for Ground Station is not included, as we are going to use one of our own.

Prototyping	
3D printer filament	
Total [PLN/USD]	300.0 / 69.45

CanSat Budget – Other Costs (2/2)

Attending cost	Quantity	Price [PLN/USD]	Total [PLN/USD]
Travel	10	4 200/ 1 000	42 000/ 10 000
Accommodation	10	4 100/ 976	41 000/ 9 760
Meals	10	1 100/ 261	11 000/ 2 610
Car rent + fuel	2	6 850/ 1 630	13 700/ 3 260
Fee	1	840/ 200	840/ 200
Total cost			108 540/25 830

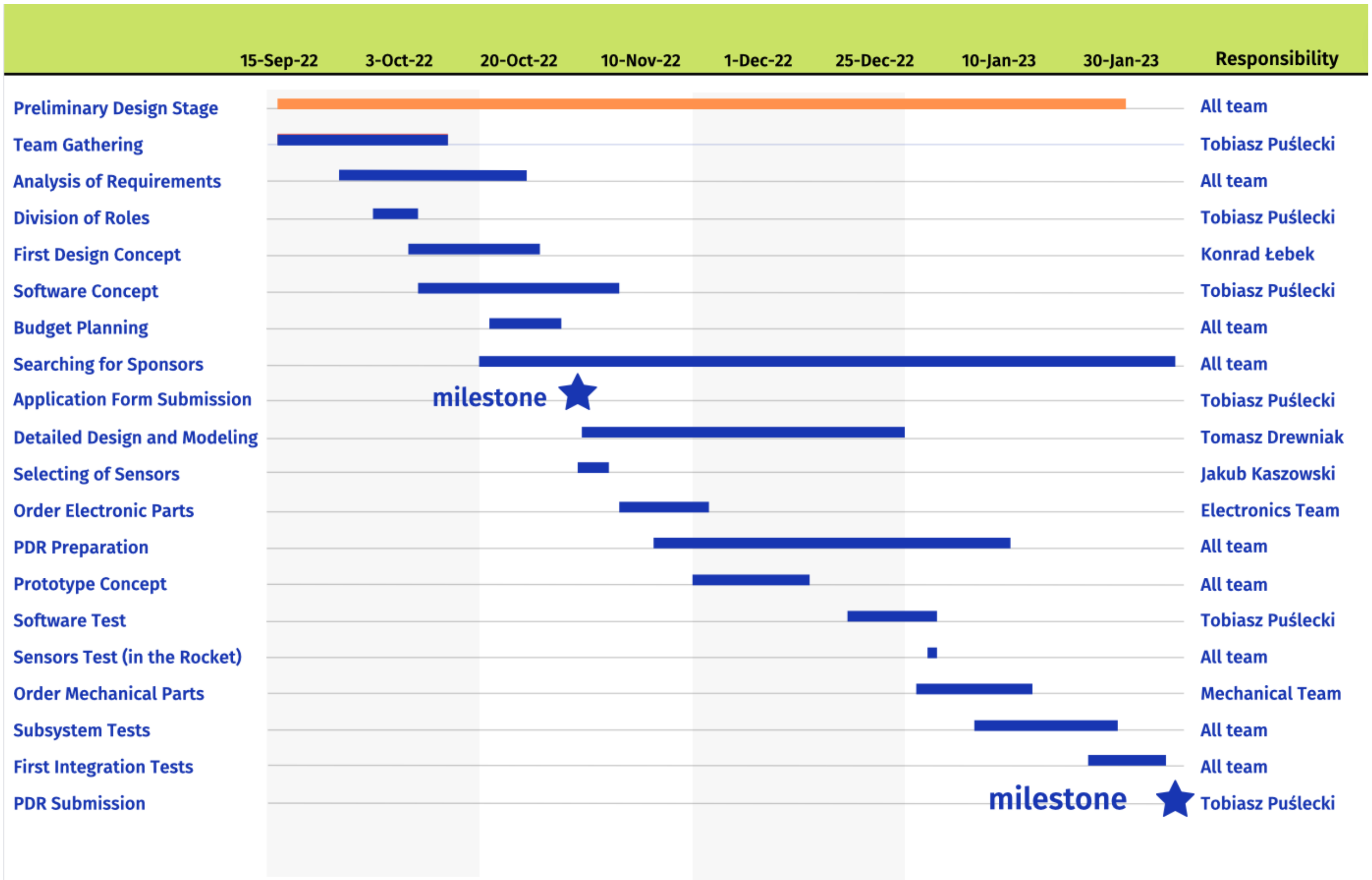
We allow the possibility that the number of team members may change.

Overall mission cost [USD]	26 491.68

Sources of income [PLN/USD]	
University	unknown
Sponsors	25 000 / 5 952.38

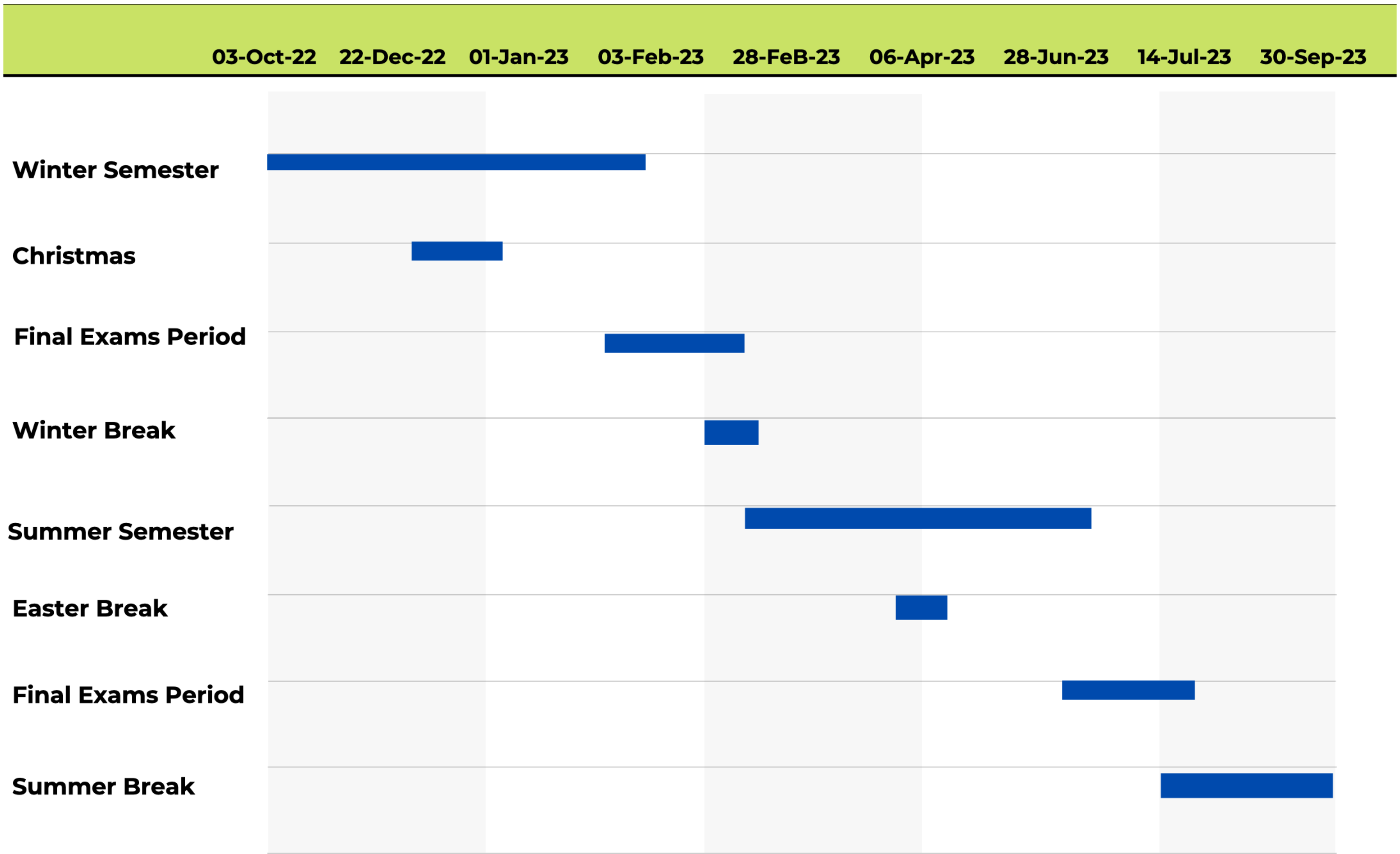
Program Schedule Overview

Detailed Program Schedule (1/4)



Detailed Program Schedule (2/4)

Detailed Program Schedule (3/4)



Detailed Program Schedule (4/4)

In order to estimate our total progress we split the whole mission into 5 parts:
Electronics, Mechanics, Software & Ground Station, Integration & Test, Management
The progress in a part was estimated by members who were working on the given part

Part	Estimated progress
Electronics	95%
Mechanics	70%
Software & Ground Station	95% , 90%
Integration & Test	55%
Management	70%

The overall progress is estimated as the average

Total progress: 76%

Shipping and Transportation

We are planning to take CanSat hardware as parts of our hand luggage in order to make sure nothing gets lost on the way.

The same holds true for any necessary equipment.

Non-essential subsystems and tools will be shipped in checked baggage, as they could be easily replaced in case the luggage went missing.

Conclusions

Major accomplishments

- Teamwork has been organized and conducted according to principles of Scrum methodologies including weekly meetings in our laboratory.
- Most of the tasks are finished on schedule.
- Construction and tests are carried out.
- Electronical systems are finished, tested and integrated.
- Development of GCS software and firmware is already finished.
- The probe mechanical model is ready.

Major unfinished work

- Some mechanical systems need final tests, but no changes are expected.
- Funding is yet to be obtained.

Testing to complete

- All tests including XBee communication, Ground Station interface and the antenna range will be carried out.
- Environmental tests need to be done.
- Antenna range needs to be tested.

Flight software status

- FSW system will be tested soon in April.
- State machine logic implementation and drivers for sensors has been completed.
- Camera, memory card logging and deployment mechanism support are implemented.