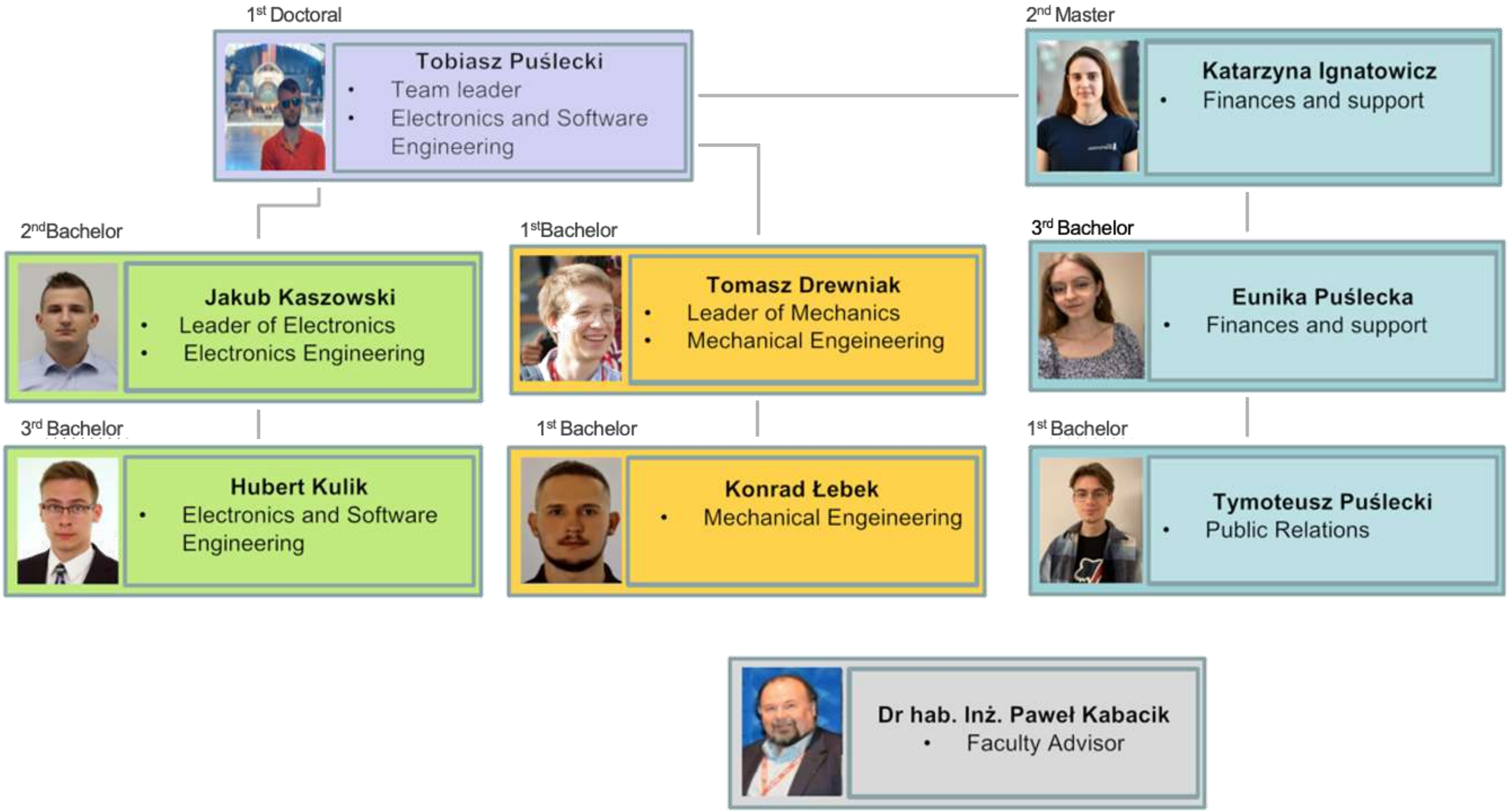
CanSat 2023
Preliminary Design Review (PDR)

1082

PWr Aerospace

Presentation Outline

Team Organization



1st Doctoral

Tobiasz Puślecki
- Team leader
- Electronics and Software Engineering

2nd Master

Katarzyna Ignatowicz
- Finances and support

2ndBachelor

Jakub Kaszowski
- Leader of Electronics
- Electronics Engineering

1stBachelor

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

Systems 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.

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

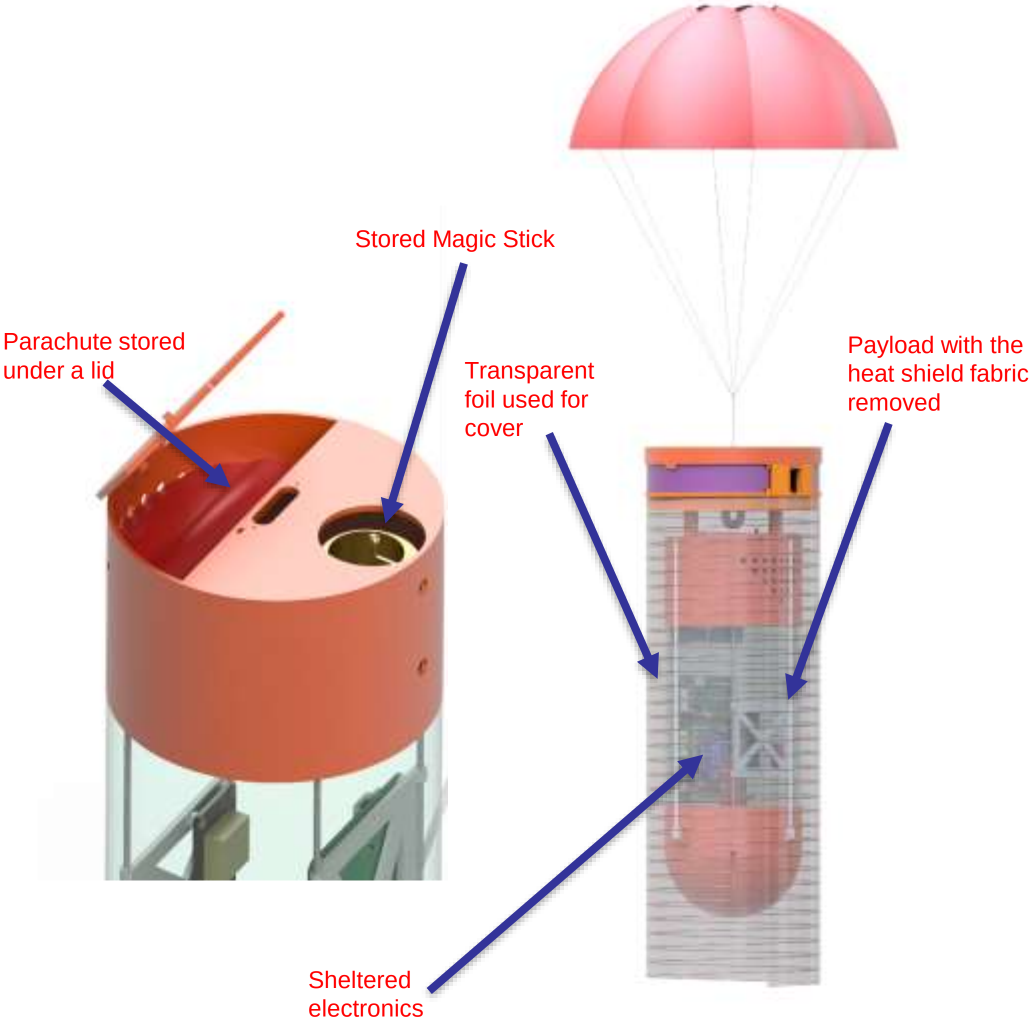
*Req 43 was skipped in the mission guide.

System Level CanSat Configuration Trade & Selection (1/5)

Design 1

Overall system configuration

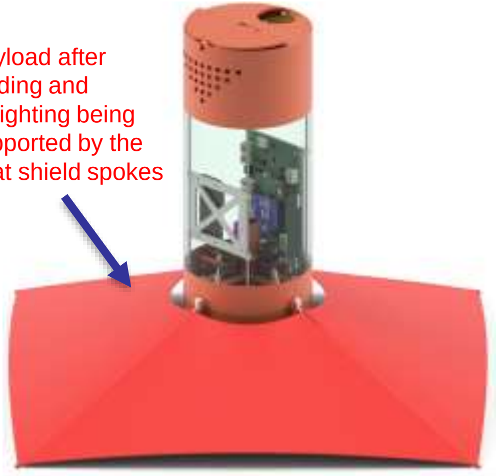
The first design uses one DC motor with a screw to combine two functions into one mechanism. The first function of the mechanism is to open and control the size of the square-shaped heat shield. The second function is to upright the Payload after landing. To offset the mechanism’s heavy weight, structural 3D printed parts with aluminium rods and transparent foil cover are used for both, container and payload. For the flag mast, this concept uses a spring-loaded metal sheet that extends itself. The payload parachute will be stored under a lid and released by a servo at 200 m. Electronics are held securely by custom brackets and stored inside the construction behind a cover.



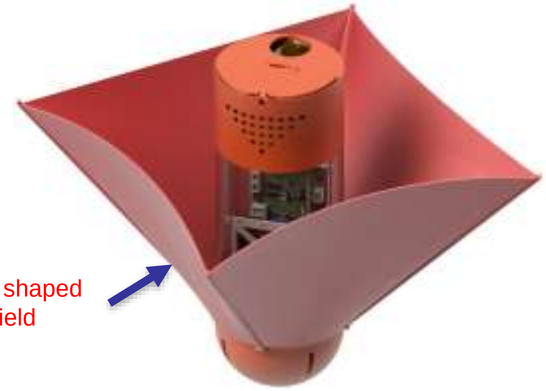
System Level CanSat Configuration Trade & Selection (2/5)

Design 1

Main features
DC motor used to open the heat shield and upright the payload after landing.
Square-shaped heat shield.
Servos used to release the parachute, extend the mast and seperate the payload from the container.
Payload parachute stored under a lid. At 200 meters servo will release a line that holds the lid and the spring will open the parachute cover.
”Magic stick” is a wrapped metal sheet that wants to extend itself, is used as a mast for the flag.
Payload and Container made out of 3D – prints, aluminium rods and transparent foil to reduce mass.
Electronics covered from the environment.

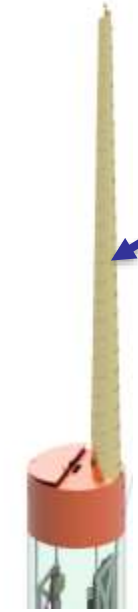


Payload after landing and uprighting being supported by the heat shield spokes



Square shaped heat shield

Main features of CONOPS
Rocket powered ascent and CanSat release at apogee
Decent with the container parachute
Payload release at 500m and immediate heat shield opening
Payload parachute release at 200m
Landing
Payload uprighting
Flag raising



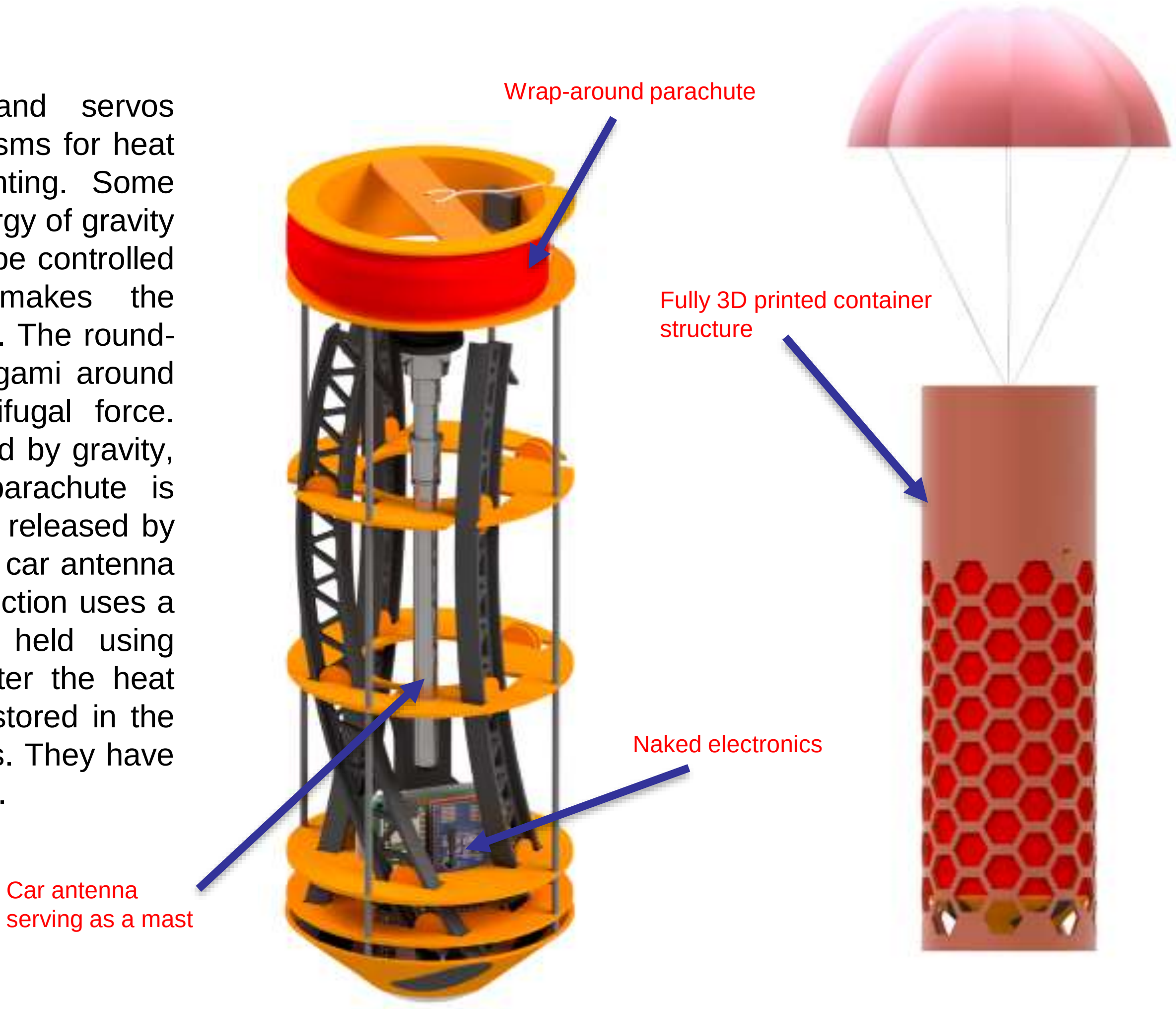
Extended Magic Stick

System Level CanSat Configuration Trade & Selection (3/5)

Design 2

Overall system configuration

This design uses burn wires and servos extensively. It has separate mechanisms for heat shield opening and payload uprighting. Some mechanisms rely on the potential energy of gravity and centrifugal force, and thus can’t be controlled after initiating. This approach makes the mechanisms lighter but less compact. The round-shaped heat shield is folded like origami around the payload and opened by centrifugal force. Landing legs will be released, lowered by gravity, and locked before landing. The parachute is stored in a wrap-around position and released by a burn wire. An automatic, telescopic car antenna is used as the flag mast. The construction uses a 3D-printed reel, dome and plates held using aluminium rods. It has no cover after the heat shield opening. The electronics are stored in the center and they slide into special rails. They have little to no cover from the environment.



Wrap-around parachute

Fully 3D printed container structure

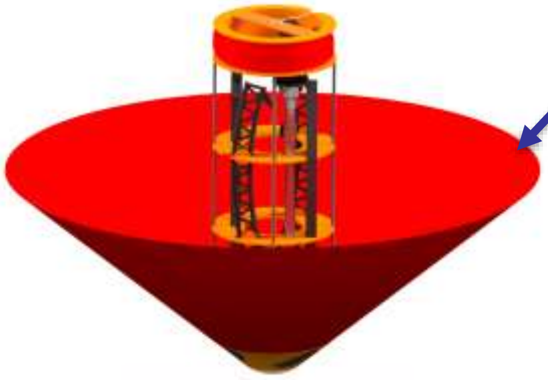
Naked electronics

Car antenna serving as a mast

System Level CanSat Configuration Trade & Selection (4/5)

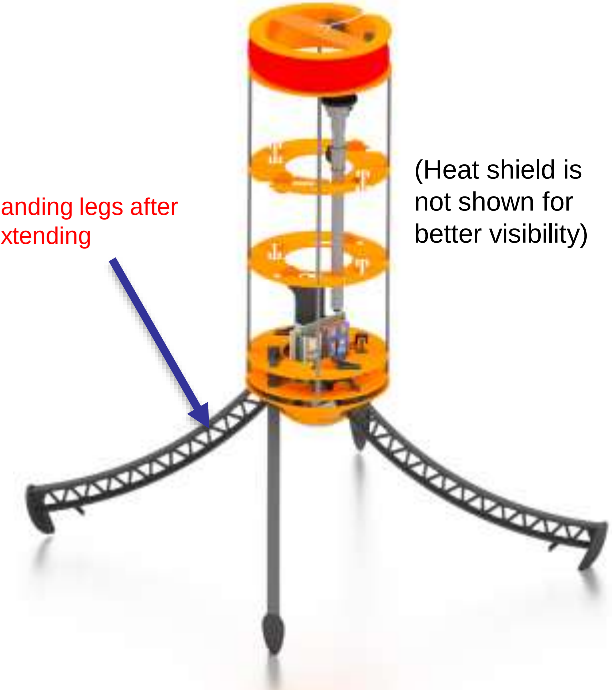
Design 2

Main features
Servos used to release and lock the legs.
Round heat shield.
Heat shield held closed, by Container walls.
Burn wires used to release the parachute and separate the payload from the container.
Wrap-around parachute design to allow for more space for the mechanisms inside the payload
Automatic telescopic antenna used as a mast for the flag.
Payload made out of 3D – prints and aluminium rods
Fully 3D-printed Container with honeycomb grid design.
Electronics exposed to the environment.



Round heat shield

Main features of CONOPS
Rocket powered ascent and CanSat release at apogee
Decent with the container parachute
Payload release at 500m and immediate heat shield opening
Payload parachute release at 200m
Landing legs lowered and locked in place
Landing with the Payload immediately upright
Flag raising



Landing legs after extending

(Heat shield is not shown for better visibility)

System Level CanSat Configuration Trade & Selection (5/5)

Design 1

Design 2

Criteria	Design 1	Design 2
Parachute storage	Pros: Less prone to malfunction, familiar design Cons: Larger weight	Pros: Reduced weight Cons: Possibility of tangling
Heat shield shape	Pros: Easier to create, a simpler opening mechanism is required Cons: Harder to store	Pros: Easier to store Cons: It's difficult to make a cone out of material
Heat shield opening mechanism	Pros: More control over the opening, the opening process is smooth, reliable Cons: Needs electrical power, heavy	Pros: Lightweight, mechanism needs no energy Cons: The opening process is violent, the payload may get stuck inside the container
Uprighting mechanism	Pros: Can really upright the payload Cons: Needs some time and power	Pros: Simpler mechanism Cons: Relies on the landing terrain to be level, uses lots of space
Mast type	Pros: Lighter, can overcome the parachute if it lands on the mast hole Cons: Non-controllable release and very violent process	Pros: Smooth opening process Cons: May get tangled with the parachute, heavy
Materials	Pros: Lighter weight, High degree of freedom of design Cons: Less rigid	Pros: More rigid, less material types used Cons: Need to create thicker walls, increase mass, difficult access to the electronic part

Conclusion:

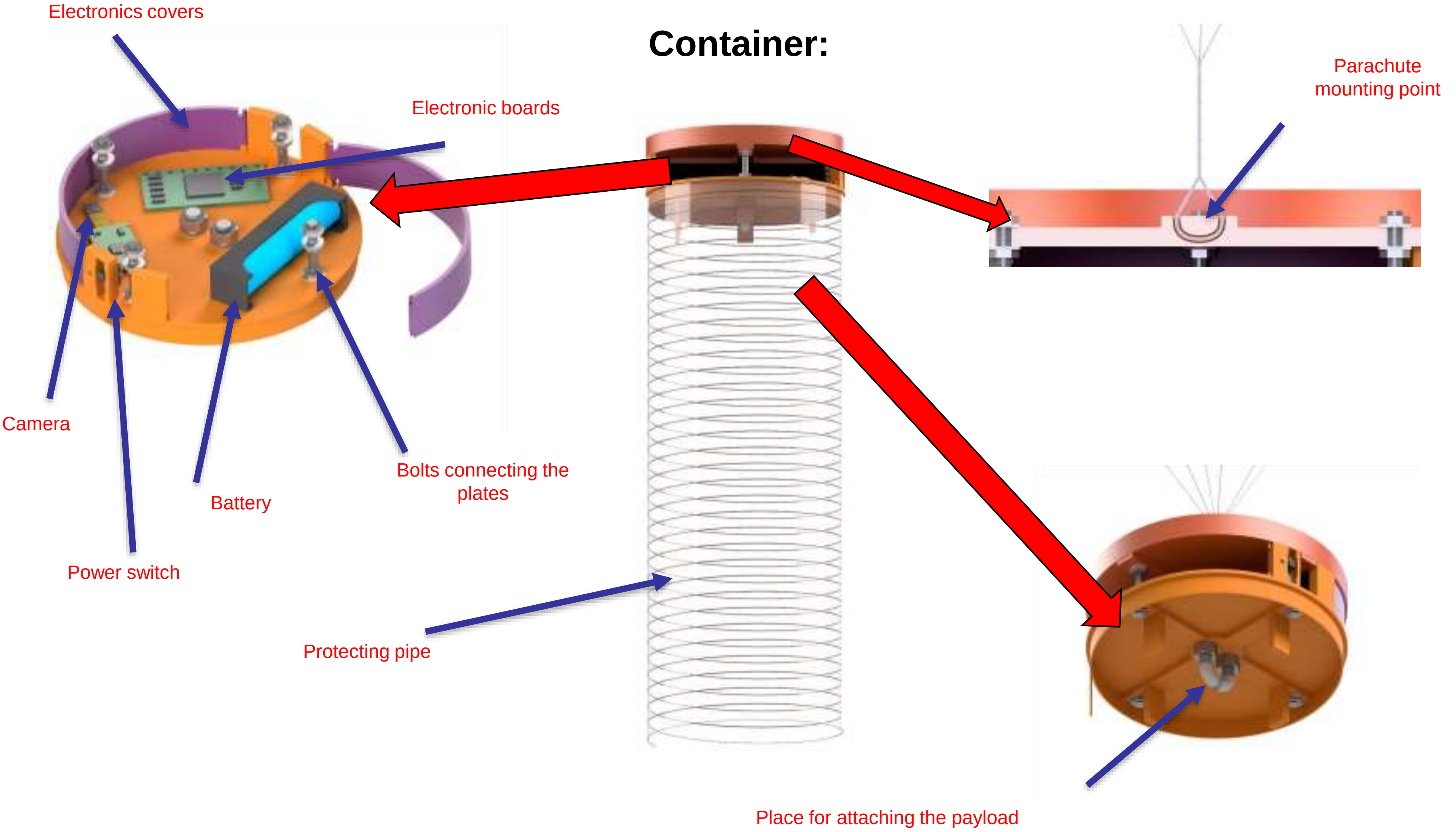
Design 1 has been chosen as it is more reliable and gives more control over the descent, which is most important for us. This design also uses familiar mechanisms and materials. Smaller dimensions allow for more changes in the future if necessary. We also had some concerns with the second design regarding the weight requirements. Overall the first design gives more flexibility and can yield similar or better effects than the second design with significantly less risk.

System Level Configuration Selection

Configuration	Selection options	Selection and reasoning
Structure of container	Foil pipe	**Foil pipe** Honeycomb is too heavy, pipe ensure enough protection
	Honeycomb	
Payload aerobraking	Classic heat shield	**Classic heat shield** Classic heat shield is more reliable and simpler.
	Origami heat shield	
Payload descent stability control	Evenly distributed weight	**Evenly distributed weight** Rejected option required using origami heat shield(hard to make).
	Payload rotation speed	
Payload landing stability	Bottom-heavy design (passive stability)	**Bottom-heavy design** (passive stability) Selected choice are lighter and easier to make.
	strong stiff legs	
Payload parachute release	Servo motor used to open parachute	**Servo motor used to open parachute** More reliable solution.
	Parachute stored in a wrap-around position	
Payload parachute	Flat-hexagonal parachute	**Flat-hexagonal parachute** Similar choices, selected are simpler to make.
	Cruciform parachute	
Container parachute	Flat-hexagonal parachute	**Flat-hexagonal parachute** This choice will ensure us reliability and efficiency.
	Parafoil	
Mast	Magic stick released by servo motor	**Magic stick released by servo motor** Lighter, can overcome the parachute if it lands on the mast hole.
	Automatic telescopic antenna	

Physical Layout (1/4)

Container:



Electronics covers

Electronic boards

Parachute mounting point

Camera

Battery

Bolts connecting the plates

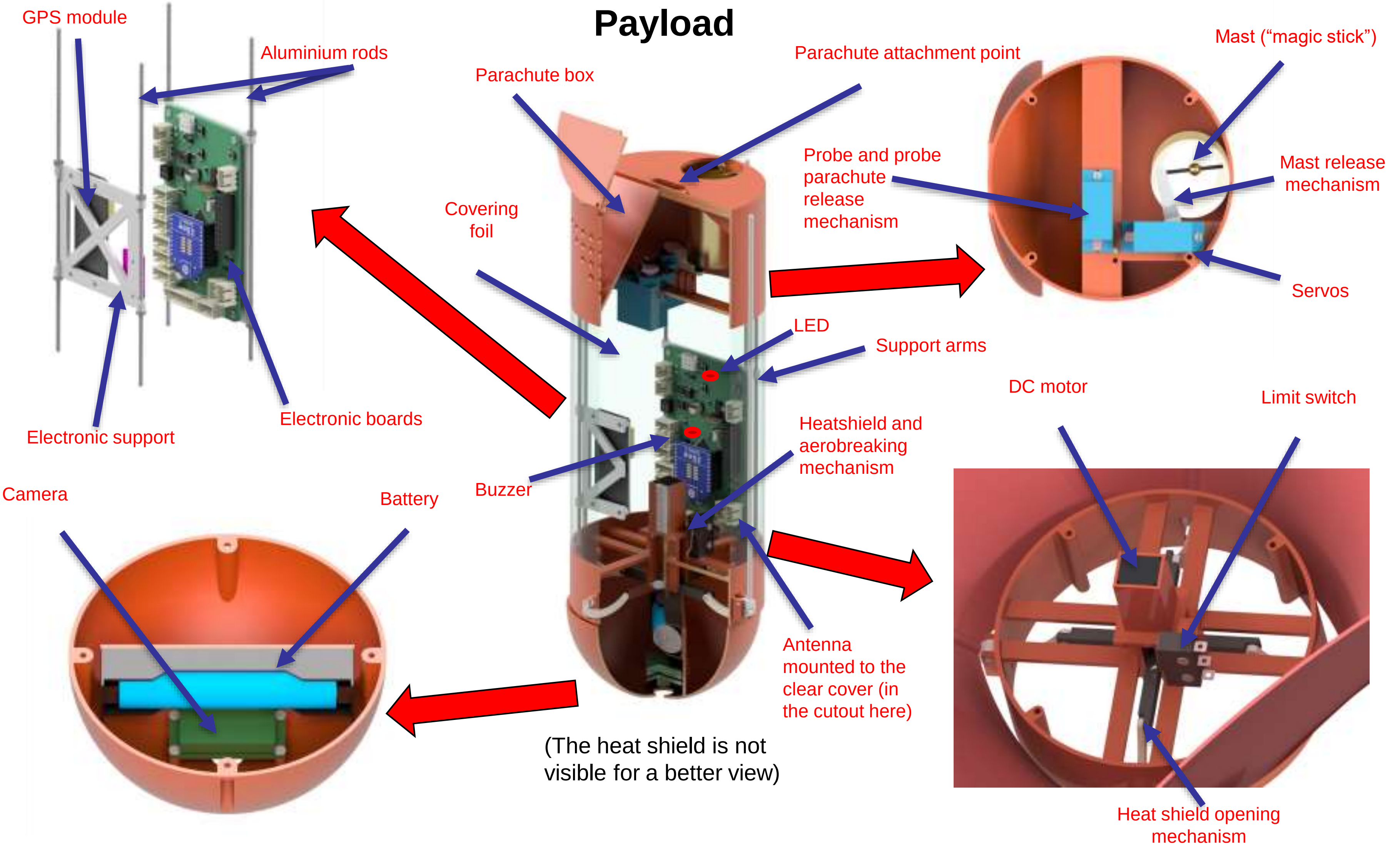
Power switch

Protecting pipe

Place for attaching the payload

Physical Layout (2/4)

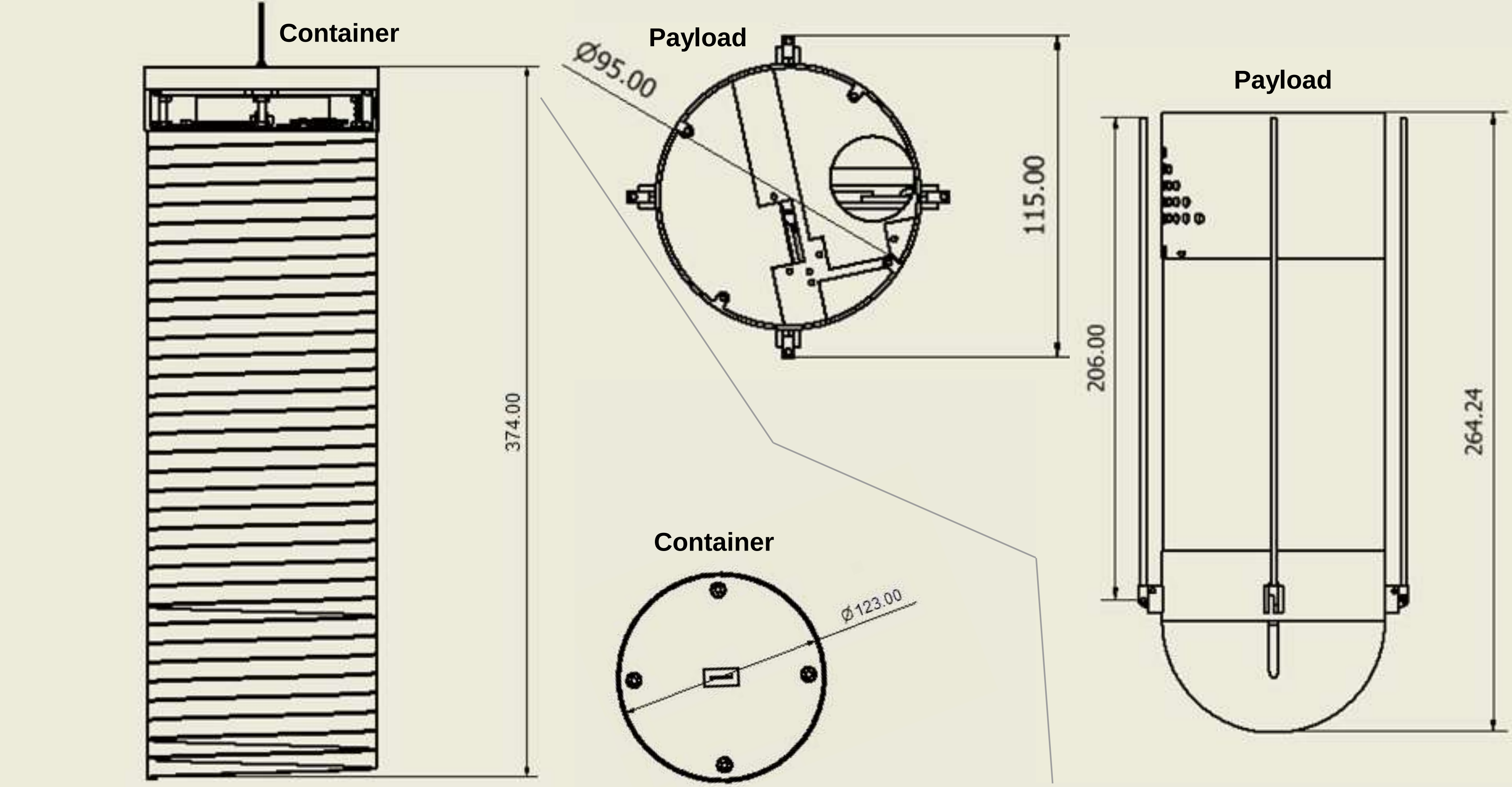
Payload



(The heat shield is not visible for a better view)

Physical Layout (3/4)

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


Container

Payload

Payload

Container

Note: All dimensions are in mm

Physical Layout (4/4)

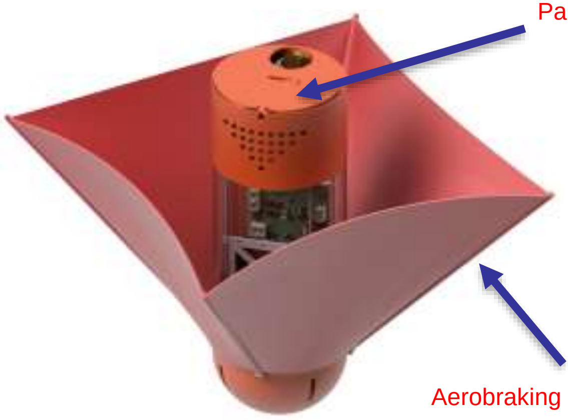
Configurations in flight stages		
Stage 1 (pre-deployment payload configuration)	Stage 2 (payload descent configuration)	Stage 3 (landing configuration)
After falling out of the rocket, the cansat is in the position shown below. The first parachute opens immediately. At the right height, the payload 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 mast extends.

Payload attached to container with line

Payload parachute stowed inside

Aerobraking shield closed

Stoved configuration



Parachute box opens at 200 meters

Aerobraking shield open

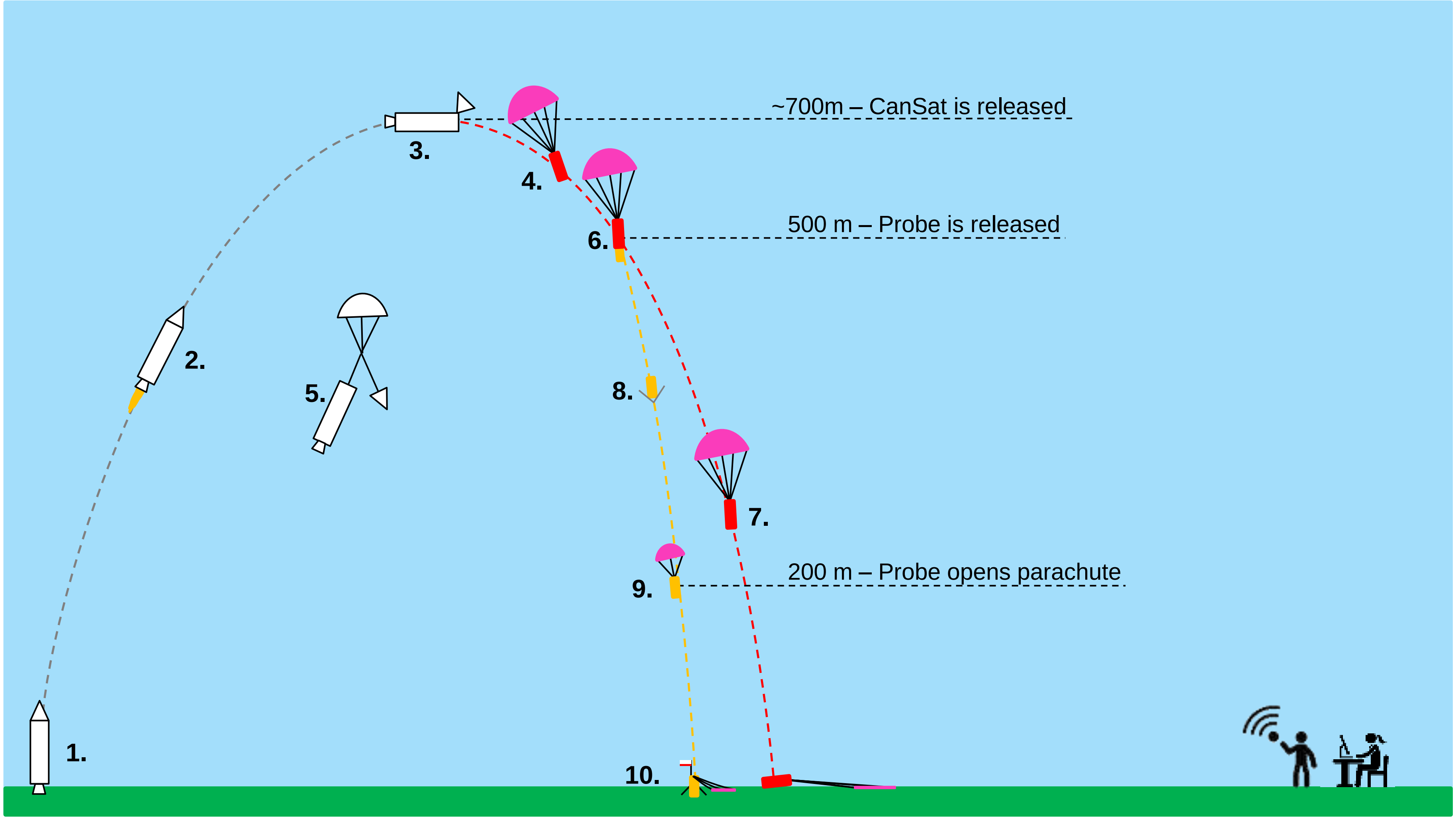
Deployed configuration

Landing configuration

Extended mast

Aerobraking shield as a leg brace

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 — between 670 and 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 its camera recording.
7. Container continues descent with constant speed.
8. Probe opens the heatshield and descends at a rate of 20 m/s or less.
9. At 200 meters probe opens the parachute and 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.

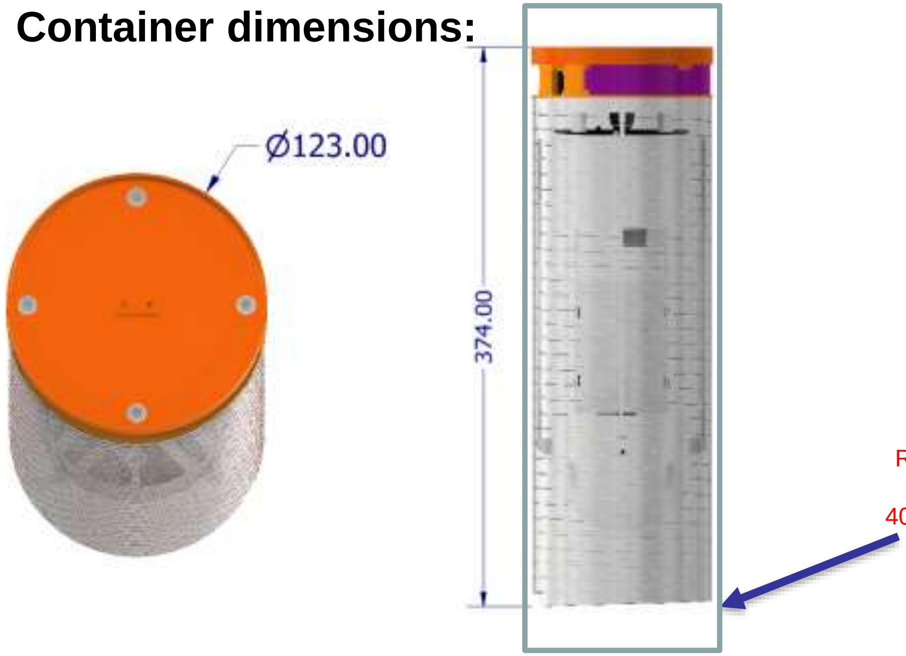
Launch Vehicle Compatibility

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 dimensions:



Rocket payload compartment 400mm x 125mm

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.

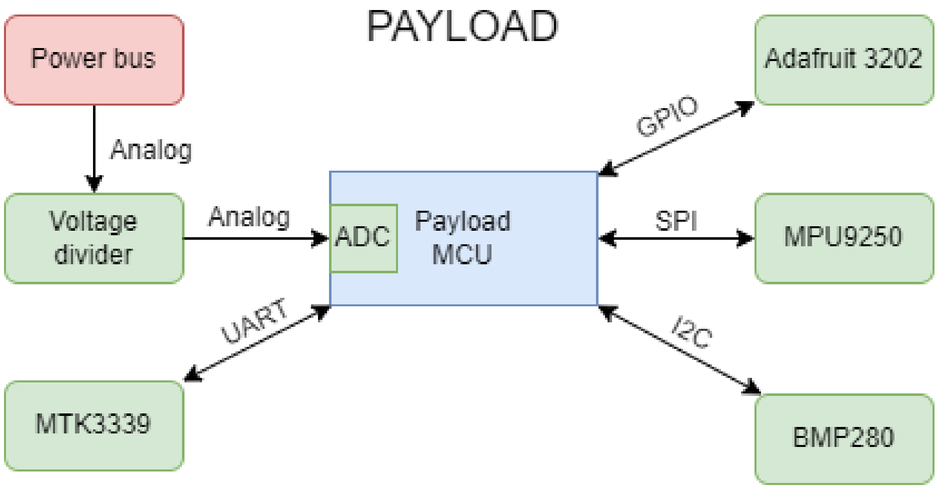
Note: All dimensions are in mm

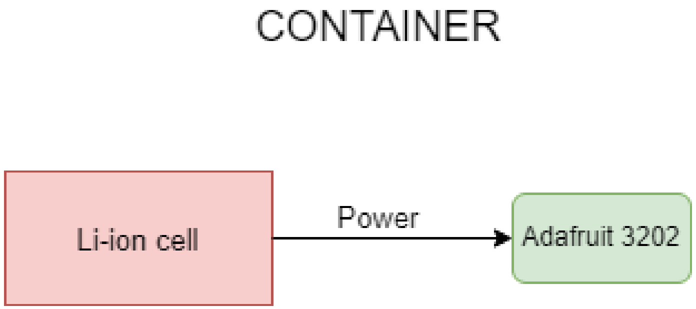
Sensor Subsystem Design

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

Payload Air Pressure Sensor Trade & Selection

Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [hPa]	Resolution [Pa]	Accuracy [hPa]	Interface	Price [$]
BMP280	2 2.5 1	1.2	1.8 ÷ 3.6	0.003	300 ÷ 1100	0.16	±0.12	I2C UART	3
BMP180	16 16 2.5	3	1.8 ÷ 3.6	0.005	200 ÷ 1100	0.02	±0.2	I2C UART	10
MPL3115A2	5 3 1.1	1.6	1.95 ÷ 3.6	0.040	500 ÷ 1100	1.5	±0.1	I2C	6

Selected sensor	Reasons
BMP280	• Proper voltage and good operating current • Best relative accuracy, internal filtering • Temperature measurement • We have experience in working with this sensor from previous editions

Payload Air Temperature Sensor Trade & Selection

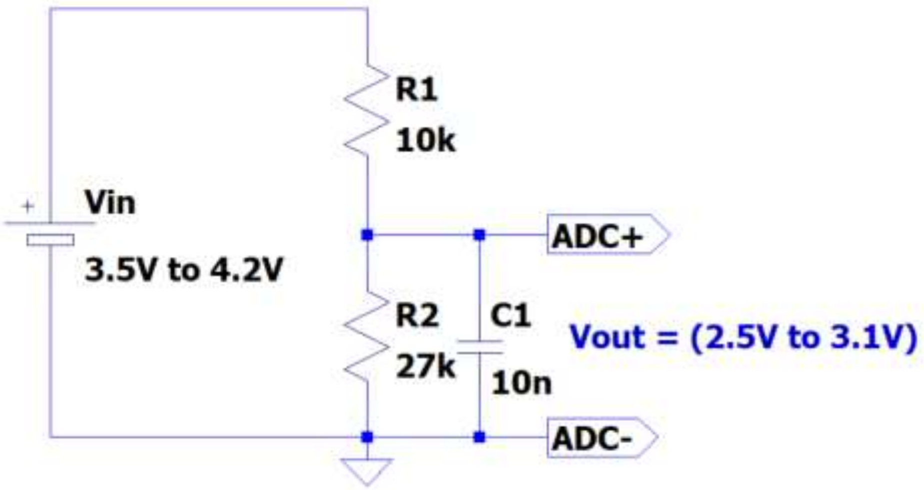
Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Range [°C]	Resolution [°C]	Accuracy [hPa]	Interface	Price [$]
BMP280	2 2.5 1	1.2	1.8 ÷ 3.6	0.25	-40 ÷ 85	0.1	0.1	I2C, SPI	15
DTH22	27 59 14	2.4	3.3 ÷ 6	0.2	-40 ÷ 80	0.5	0.5	1-Wire	6.5
MS5611	19 13 2	1.5	1.8 ÷ 3.6	0.015	-40 ÷ 85	0.1	0.8	I2C	6

Selected sensor	Reasons
BMP280	• Also measures the pressure • Good range and resolution • Low noise and internal filtration • Small dimensions and the mass

Payload Battery Voltage Sensor Trade & Selection

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
INA 219	1.5 3	0.3	1	0 ÷ 26	0.125	I2C	5

Selected sensor	Reasons
STM32 ADC + Voltage divider Battery cell is: Li-ion 18650	• High resolution of reading • Save of space • Easy to use • Requires only 2 external components



Payload Tilt Sensor Trade & Selection

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 SPI	11
MPU-6050	20 16 3	3	2.9 ÷ 3.6	0.4	250,500, 1000,2500	0.016	I2C	2
OKY3231	15 12 3	4.2	2.7 ÷ 5.0	4	250,500, 1000	0.100	I2C SPI	12

Selected sensor	Reasons
MPU9250	• Low power consumption • Includes also magnetometer and accelerometer • Small dimensions • High accuracy • Easily available

Payload GPS Sensor Trade & Selection

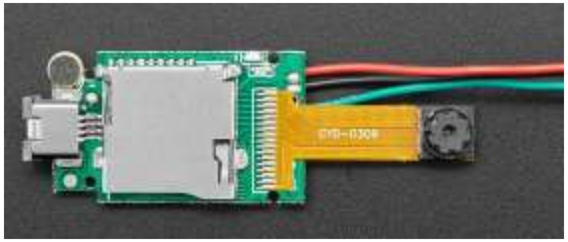
Name	Size [mm]	Mass [g]	Operating voltage [V]	Operating current [mA]	Sensitivity [dBm]	Resolution [m]	Update rate [Hz]	Interfaces	Price [$]
MTK3339	35 26 7	20	3.0÷ 5	20	-165	<2.5	1÷10	UART	42
NEO-6M	36 26 4	17	3.5÷5.5	45	-161	3	1÷5	UART	17
BN-880	28 28 10	10	2.8 ÷ 6	50	-167	2	1÷10	UART	19

Selected sensor	Reasons
MTK3339	• Uses NMEA 0183 • Lowest operating current • Good sensitivity • High availability • Onboard antenna • Onboard RTC

Payload Camera Trade & Selection

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
Eachine 2503	8 8 13	6	3.8÷5.0	200	Yes	1920x1080 1280x720	120	30 60	Analog	30
RunCam Split 3 Micro	19 19 20	14	5÷20	650	Yes	1920x1080	165	60	UART	70

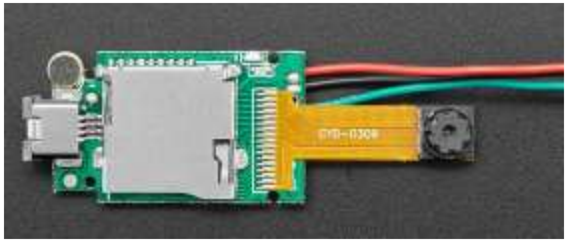
Selected camera	Reasons
Adafruit 3202	• Small dimensions and mass • Built-in microSD • Video recorded in color • Video resolution and fps considering requirements • Records in RGB colors



Bonus Camera Trade and Selection

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
Eachine 2503	8 8 13	6	3.8÷5.0	200	Yes	1920x1080 1280x720	120	30 60	Analog	30
RunCam Split 3 Micro	19 19 20	14	5÷20	650	Yes	1920x1080	165	60	UART	70

Selected camera	Reasons
Adafruit 3202	• 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**.

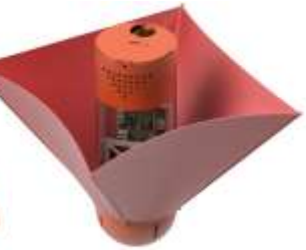
3. Then, at the altitude of **200 m**, the third phase will begin. The second parachute will open and the payload will slow down to **5 m/s**. It will land at this speed.

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

1.

2.1

2.2



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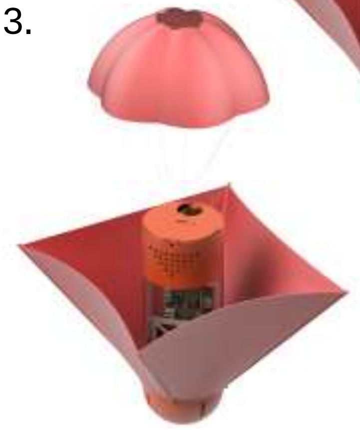


Container Descent Control Strategy Selection and Trade

Container descent overview

The parachute lies on the upper lid of the container. It is attached to the appropriate handle inside the container. Opens immediately after falling out of the rocket.

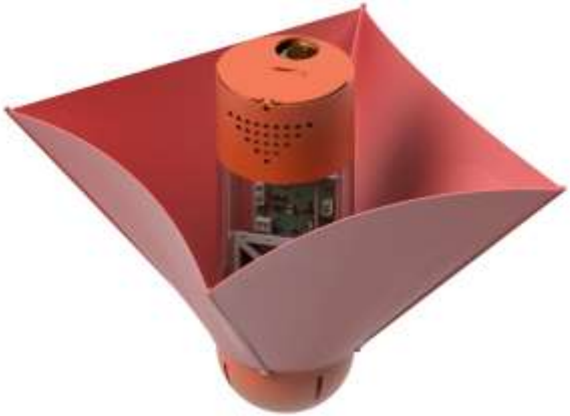
We chose the parachute from two options: a hexagonal parachute or a parafoil.

Section	Option	Pros	Cons	Selection
Comparison of parachute designs	Design 1 **Hexagonal Parachute**	+ stable flight + reliability + simplicity of sewing + simple mechanism open immediately + low price	- problems with strong gusts of wind	**HEXAGONAL PARACHUTE** This choice will ensure us reliability and efficiency. At the same time, it is simple and easily accessible.
	Design 2 **Parafoil**	+ provides very stable downwind flight + reliability + simple mechanism - open immediately after descent	- availability problem - difficult to calculate and measure	

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

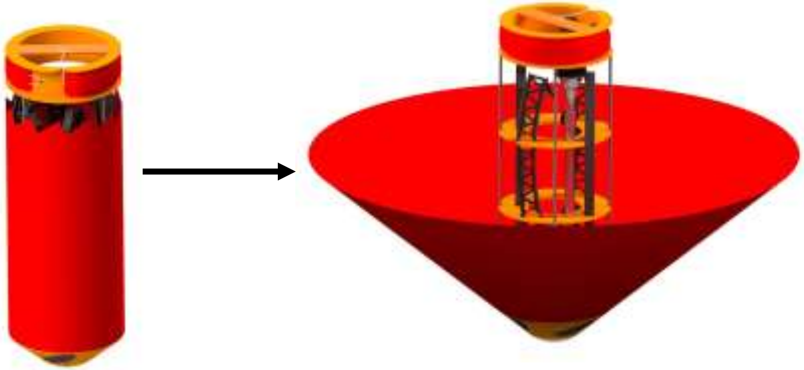
Design 1 (classic)

Heat shield is made of a durable material stretched over four spokes. It will be unfolded by a mechanism based on a threaded shaft motor. Movement in the vertical axis will allow the spokes to unfold. **It unfolds to a designated, calculated angle that will provide the desired speed** (less than 20 m/s).



Design 2 (origami)

Heat shield is made of a stiff fabric folded in an origami style, from a cone into a cylinder (to fit in a container). The cover is deployed by rotating the payload while falling. The rotational speed needed to unwind the sheath is obtained by autorotation caused by the spiral shape of the sheath. The spiral shape of the rolled-up heatshield spins the payload, which unfolds the heatshield (this effect decreases with greater expansion). **The rate of descent depends on the size and angle of the material.**



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

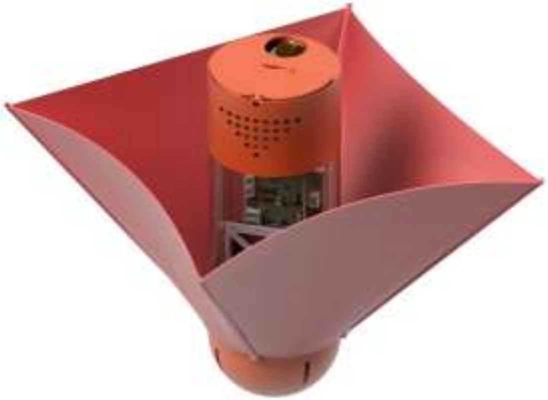
Aerobraking design comparison

Section	Solution	Rationale	Selection
Aero Braking Design	Design 1	+ simple and reliable mechanism + invulnerable to gusts of wind + easier to calculate - heavier construction - needs power, to run the motor	**Design 1** Reliability was the most important thing for us, this idea also ensures accuracy and simplicity.
	Design 2	+ work by itself + lighter, without any mechanisms - the material may bend in flight - it may not work - hard to make	

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

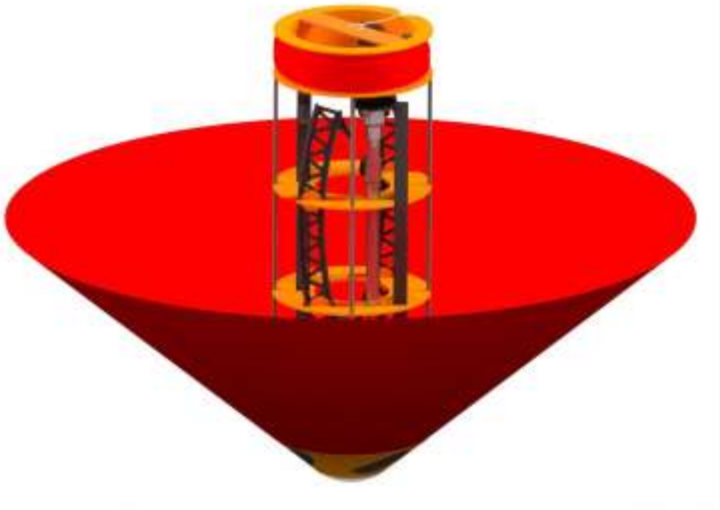
Design 1 - passive stabilization

The stabilization of the Payload is based on distribution of the center of mass in relation to the resultant point of the drag forces of heat shield, which allows the **passive stabilization** and keeps Payload from swaying. In addition to the weight, the shape of heat shield during descend is similar to inverted pyramid which can act as a crude form of stabilising fins. Most of the weight is placed on the bottom of the Payload - combined with the acting forces of gravity, it will ensure less susceptibility to wind and wobbles.



Design 2 - passive stabilization

The stabilization of the Payload is based on the principle of operation of the heat shield itself. From the beginning, rotational movement, then size of the heat shield and speed will add balance to the whole. Here, too, the structure is symmetrical. **All these features give the design passive stability.**



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

Section	Solution	Rationale	Selection
Comparison of stabilization systems	Design 1 **Passive stabilization**	+ High reliability due to mass distribution + Low mass thanks to the use of a passive system. + no complications -if the wind is very strong, it may not be enough	**Design 1** We prefer rely on an already proven to work approach that is simple and sufficient, rather than a new, less reliable system.
	Design 2 **Passive stabilization**	.+ High reliability due to certain rotational speed ensuring stability + Low mass thanks to the use of a passive system -questionable reliability of deploying the heat shield	

Payload Parachute Descent Control Strategy Selection and Trade

Payload descent overview
The parachute lies in a container opened by a servo. After opening, it is tied to mounting holes in center of payload. The parachute will be made of nylon. Symmetrical design balances forces in every direction to maintain nadir direction. We chose the parachute from two options: a hexagonal parachute or a cruciform parachute.

Section	Option	Pros	Cons	Selection
Comparison of parachute designs	Design 1 **Hexagonal Parachute**	+ stable flight + reliability + simplicity of sewing + low price	- problems with strong gusts of wind	**HEXAGONAL PARACHUTE** Both choices are similar, but the second one brings more complications than advantages.
	Design 2 **Cruciform Parachute**	+ provides softer landing + reliability + stable flight	- availability problem - hard to make	

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)

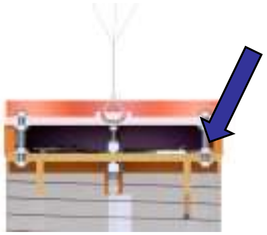
Flight phase	**Speed of descent [m/s]**
Cansat with payload descent	14.99
Payload descent	15.01
Payload descent with parachute	5.01

Calculated values are within the scope of the competition

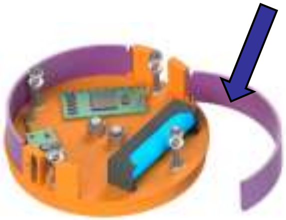
Mechanical Subsystem Design

Konrad Łebek

Mechanical Subsystem Design

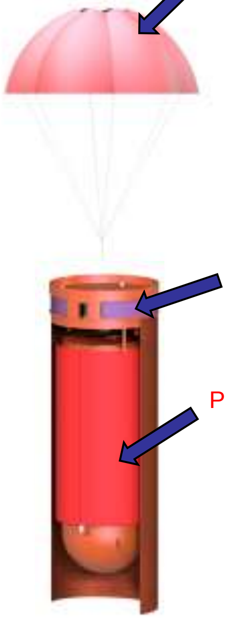


Container compartment is held by screws



Compartment hinge for access

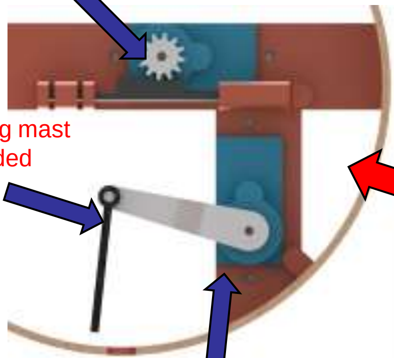
Part	Material
Container	3D printed ABS, metal screws, PET foil side cover with aluminium wire support
Payload structure	3D printed ABS, aluminium rods, PETG side cover
Electronic supports	3D printed ABS
Heat shield and parachute	Nylon
Heat shield opening mechanism	Aluminium support rods, 3D printed linkages



Parachute

Container

Payload



Servo with rack and pinion used to release payload from container and to release payload parachute

Pin holding mast compounded

Servo used to release mast

"magic stick" mast

Line holding parachute compartment shut

Hinge

Parachute compartment

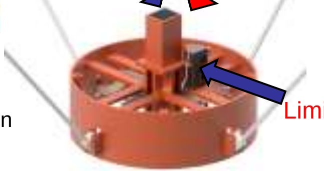
Structural aluminium rod

Series of linkages pulling on heat shield support rods

Battery box opening interface

Battery

Camera assembly



Screw motor

Limit switch

Mechanical configurations:

Container descent

Payload aerobraking

Payload with parachute descent

Landing configuration

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

Overall design trade and selection

Design 1

- No mechanism for camera activation
- Construction made out of 3D printed parts and lightweight 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
- **The container will be labeled with team contact information**

Design 2

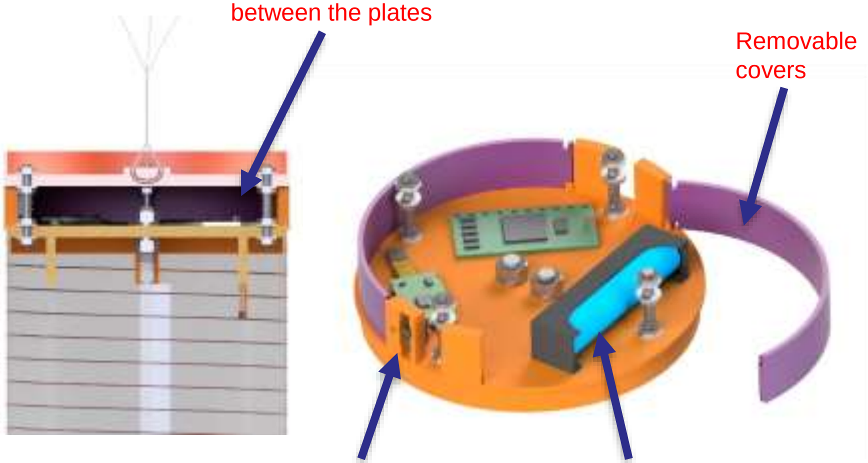
- Light gate used to activate the camera
- Fully 3D printed structure
- Elements are screwed and glued together
- Hard to access but simple in design, small electronics bay
- 18650 battery used as a power source
- Single parachute is used
- **The container will be labeled with team contact information**

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

Location of electronic components

Design 1

The compartment that houses container electronics, will be found between two structural plates made out of ABS. The battery basket will be placed horizontally on it's side to ensure no disconnection when vertical G-forces are applied. The electronics compartment will be closed by removable covers that allow an easy battery change. The main power switch and LED will be found on the side wall of the container.


Small electronic bay between the plates

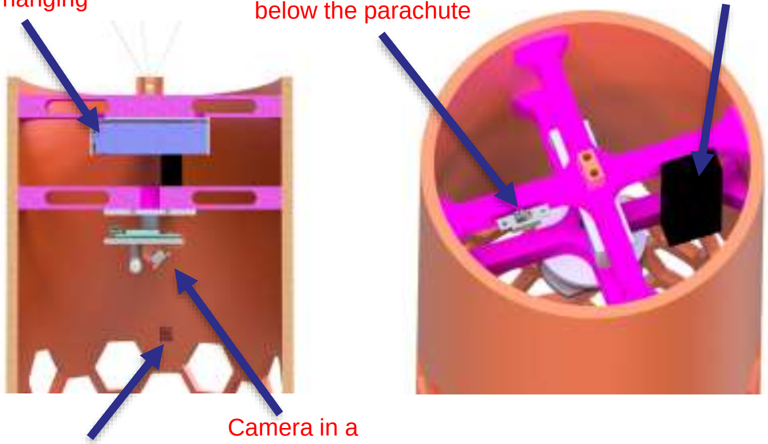
Removable covers

Accessible switch and LED

Battery basket laying on it's side

Design 2

The electronics compartment on this container is found in the upper container part, inside the tube, between two cross like supporting elements. Electronic boards are housed in a box that is glued to the supporting elements. The camera is found in a special basket, found below the supporting elements. The battery in this design, is suspended underneath a supporting cross, however this makes the battery replacement procedure very lengthy as it requires the parachute to be taken off. This battery position can cause a disconnection if high G-forces are applied. The LED and power switch are located below the parachute.


The battery is hanging

Switch and LED mounted below the parachute

Electronics inside a box

Light gate sensor

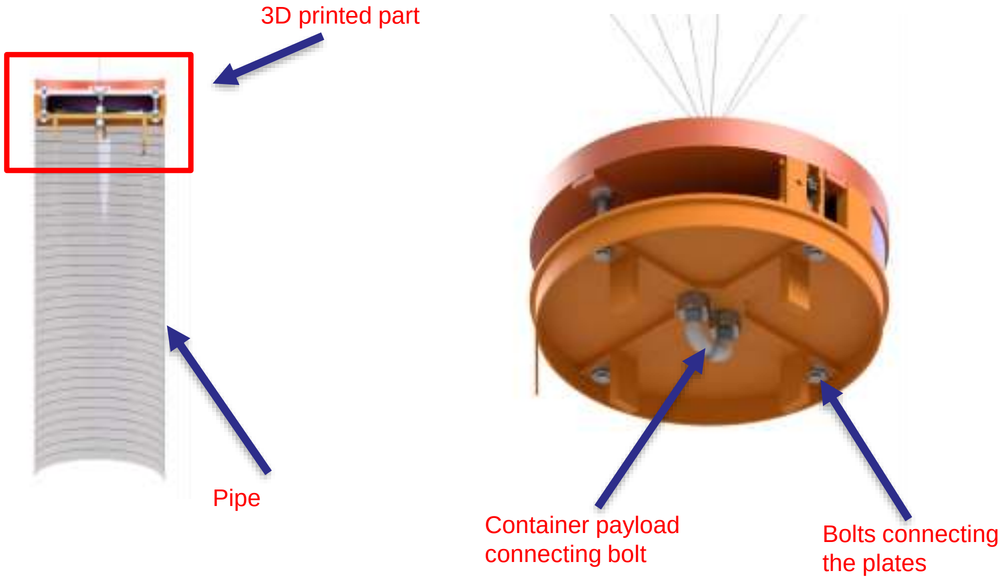
Camera in a special mount

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

Mechanical elements trade and selection

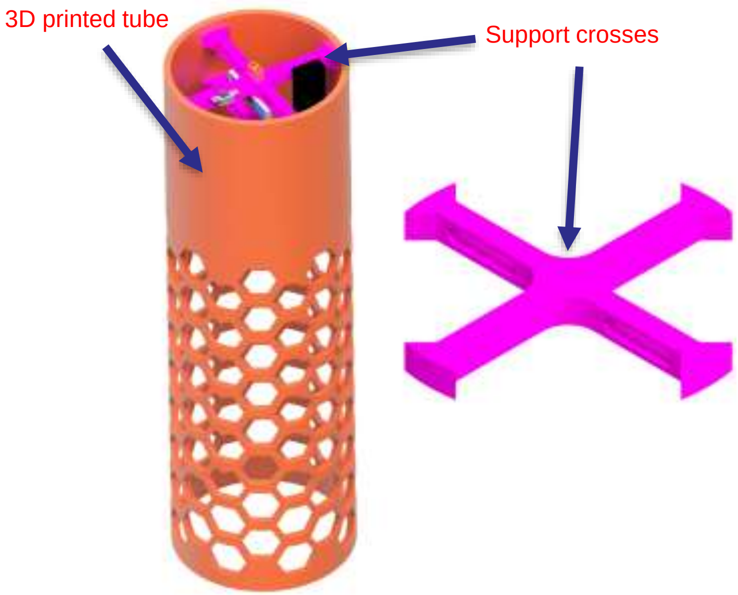
Design 1

This container has an upper 3D printed structural part that houses electronics and a second lower part that only covers the payload before release. The upper part consists of two plates that are quite strong and two side covers that only cover the electronics. The plates are screwed together using M4 aluminium bolts, nuts and washers. This connection type is quite lightweight and very secure. The covers will be held in place by material elasticity and special geometry. The payload-container connection will consist of a metal M6 u-shaped bolt. **The bottom part that houses the payload is made out of a full lightweight pipe**, attached to the bottom plate.



Design 2

This design has a completely 3D printed structure. The upper part consists of a full wall tube and two support crosses. The support crosses are melted to the pipe, yet this connection type has a quite high failure chance. The lower part housing the payload is a gridded continuation of the pipe. This cover type has a higher rigidity but is quite heavy.

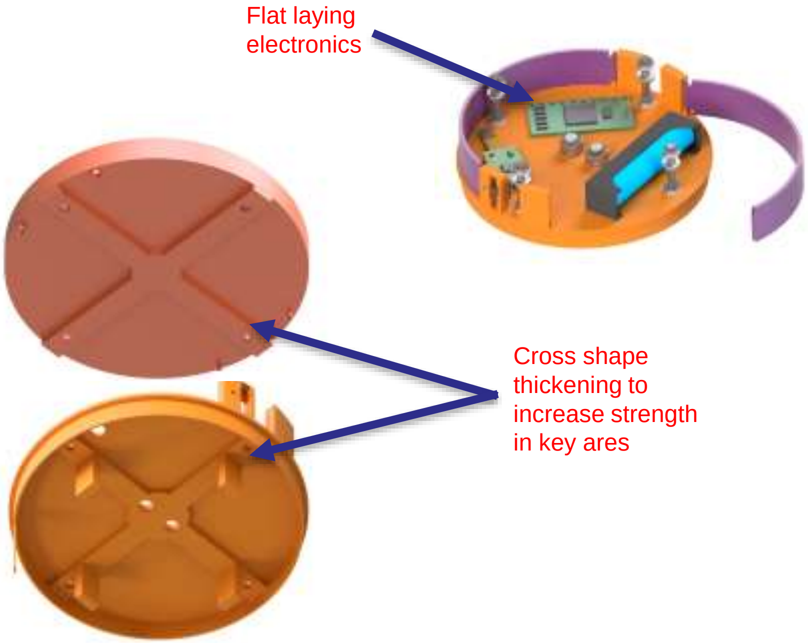


Container Mechanical Layout of Components Trade & Selection (4/7)

Mechanical elements trade and selection

Design 1

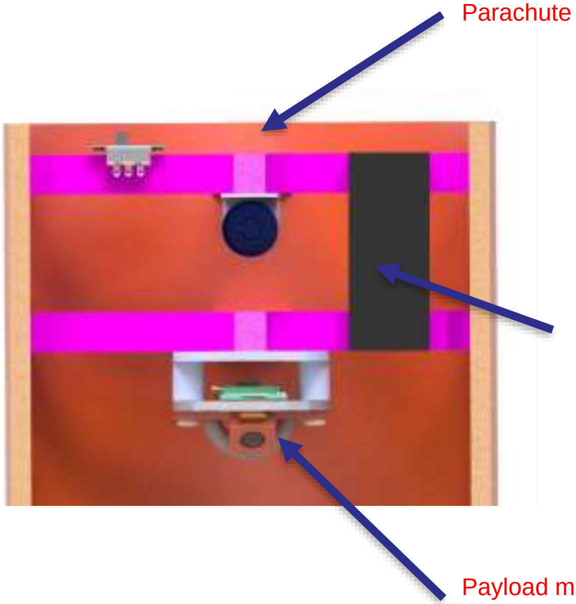
All electronics will be placed horizontally to maximize space allocated to payload. The plates have high strength and simple shapes that are easy to manufacture. Also all elements are connected in a way that allows the plates to bend a little and reduce the shock that is caused by parachute release. **This allows the structure to survive a 30 G shock and 15 G launch.**


Flat laying electronics

Cross shape thickening to increase strength in key ares

Design 2

Here some electronics are placed vertically taking up more space that could be used for the payload. The parachute and payload mountings are found on the supporting crosses. The support crosses may be too weak to handle the force of a chute deployment thus breaking. This design may require lots of testing in the future.


Parachute mounting

Vertically placed electronics

Payload mounting behind the camera

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

Overall view

Parachute mounting spot (3D printed)

Upper plate (3D printed)

Battery basket (3D printed)

LED and switch

Camera

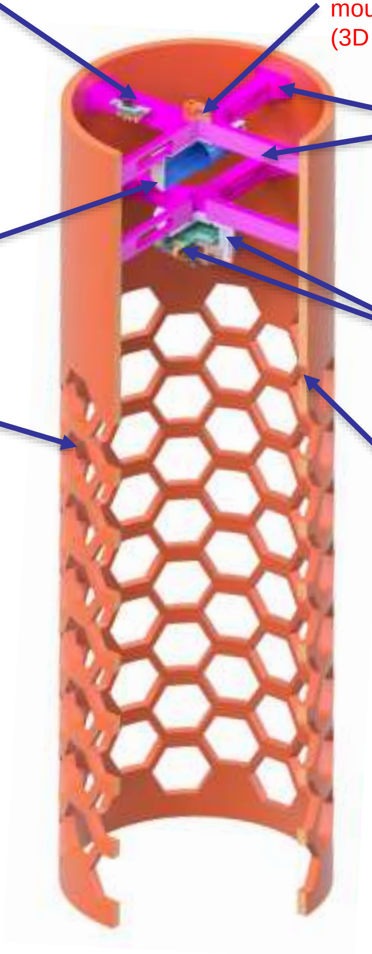
Electronics compartment cover (3D printed)

Lower plate (3D printed)

M6 u-shaped bolt (Aluminium)

M4 connector bolts (Aluminium)

Pipe used as the payload cover (made out of plastic)



LED and switch

Parachute mounting spot (3D printed)

Support crosses (3D printed)

Battery basket (3D printed)

Camera with camera basket (3D printed)

Honeycomb tube design (3D printed)

Light gate mounting place

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

Structural material selection

Design 1

Part	Materials	Selection and reasoning
Pipe	3D print Laminating foil	**Laminating foil** Payload cover made out of laminating foil will be cheaper easier to construct and more robust to damage.
Electronics bay	3D print Plywood	**3D print** 3D printing allows us to make more complicated shapes and has a better strength to weight ratio when compared to plywood.
Connectors	Steel Aluminium	**Aluminium** Although less available and more expensive aluminium is lighter.

Design 2

Part	Materials	Selection and reasoning
Tube	3D print Cardboard	**3D print** The honeycomb design is easier to achieve by 3D printing and connecting other elements to the tube is more secure.
Support crosses	3D print Plywood	**3D print** 3D printing allows us to make more complicated shapes and has a better strength to weight ratio when compared to plywood.

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

Container design comparison

Section	Solution	Rationale	Selection
Container Design	Design 1	+ Easy to assembly and produce + Has more space dedicated to payload + Battery, power switch and LED are easily accesable + Lighter construction - Less rigid construction, may require strengthening	**Design 1** This design has been chosen as it allows us to house a bigger payload, it has less failure points and is more reliable. The screwed construction allows for easier assembling and prototyping.
	Design 2	+ Stiffer construction due to 3D printed body - Heavier construction - The battery placement may cause it to fall out - The battery, LED and switch are harder to access - Connecting the Container to the payload is difficult	

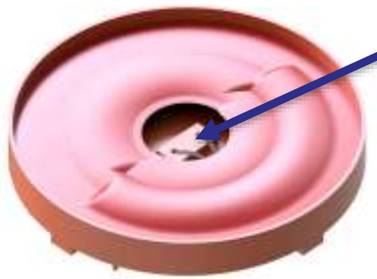
Container Parachute Attachment Mechanism

Design 1

Release method

In this design the parachute just sits on top of container in a special basket with **no release mechanism**. The parachute will open immediately upon nose cone separation to help with rocket separation and to slow down CanSat to 15 m/s.

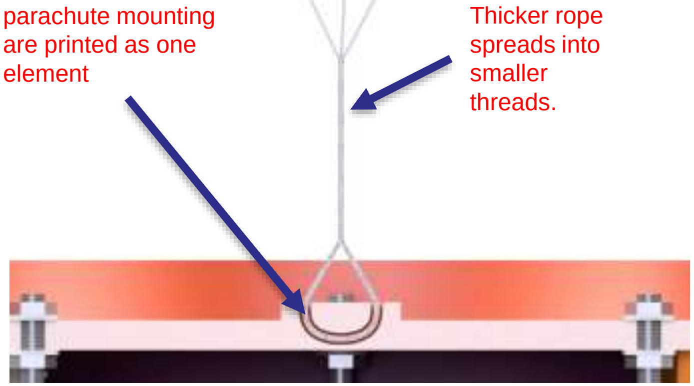
The parachute will rest on this plate



The attachment point

Attachment to container

The parachute is connected to the container via a single thick rope threaded through a special hole in one of the container plates. Then smaller threads connect the parachute dome with this single connection point.



The upper plate and parachute mounting are printed as one element

Thicker rope spreads into smaller threads.

Payload Mechanical Layout of Components Trade & Selection (1/10)

Overall design trade and selection

Design 1

- DC motor used to open the heatshield
- **No pyrotechnics or chamicals are used in this design.**
- 3D printed structure with aluminium struts
- Camera mounted at the bottom
- Servo 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**

Design 2

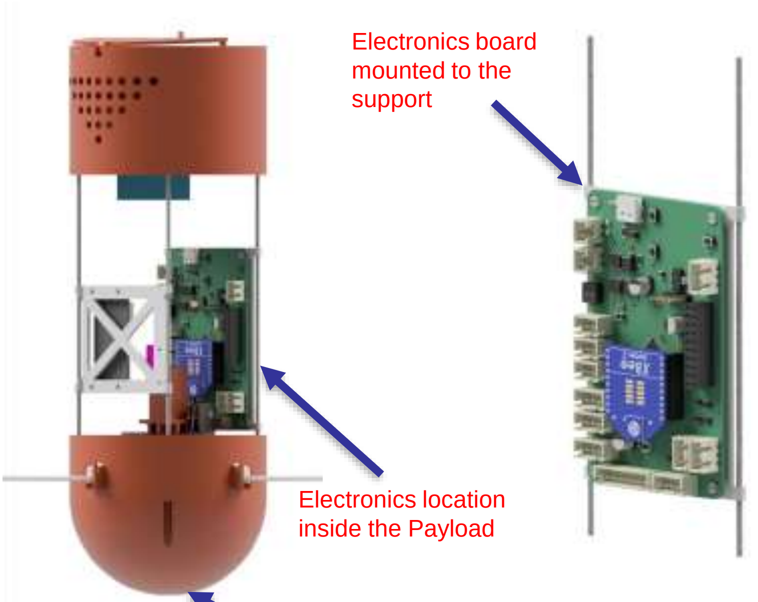
- Centrifugally opened heat shield
- **No pyrotechnics or chamicals are used in this design.**
- 3D printed structure with aluminium struts
- Camera mounted at the bottom
- Parachute stored in a wrap-around position
- Extensive burn wire mechanism use
- Electronics board based on our 2022 design
- DC motor used to open the landing legs
- Automatic telescopic antenna used as a mast
- Antenna mounted on the electronics board
- **The payload will be labeled with team contact information**

Payload Mechanical Layout of Components Trade & Selection (2/10)

Location of electronics

Design 1

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 main power switch and indicator LED will be found on the electronics board. **The probe camera is mounted at the bottom of the payload and is looking down through a small hole.**



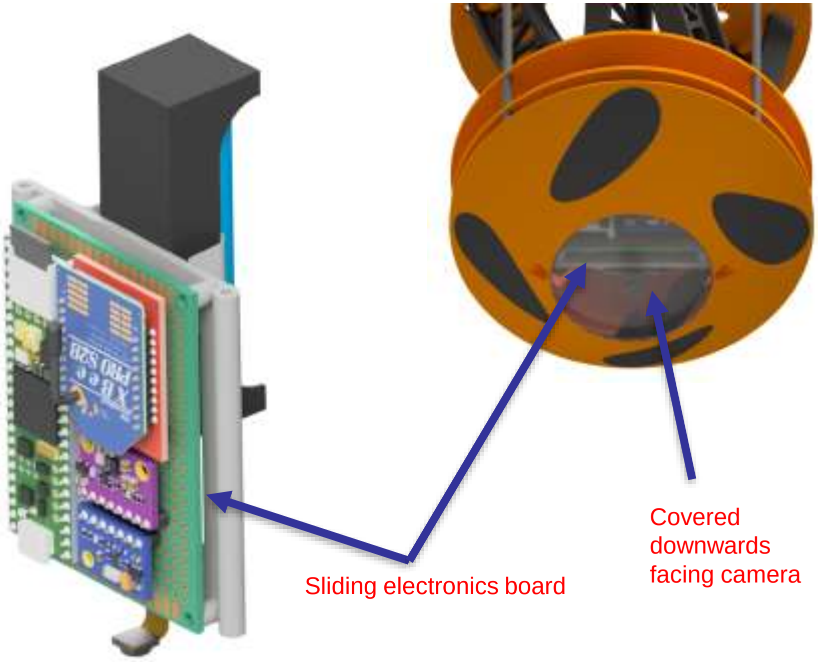
Electronics board mounted to the support

Electronics location inside the Payload

Downwards facing probe camera

Design 2

In this design, the electronic circuit will be mounted in the center of the payload. The whole circuit will be slid in and secured using a latch-in mechanism and screws. Just like in the first design the camera is mounted at the bottom and it looks down through a plastic covered hole.



Sliding electronics board

Covered downwards facing camera

Payload Mechanical Layout of Components Trade & Selection (3/10)

Battery access

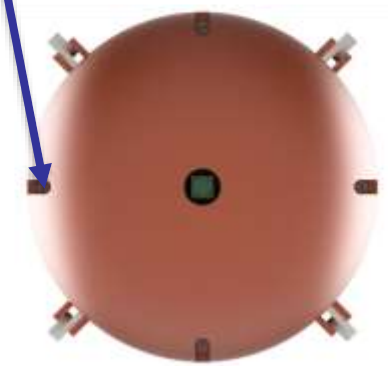
Design 1

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



Design 2

This design also has the battery placed at the bottom but it uses a bigger 18650 battery. Battery access requires pulling out the electronic circuit. This allows for quick access but may compromise the electronics mountings reliability.

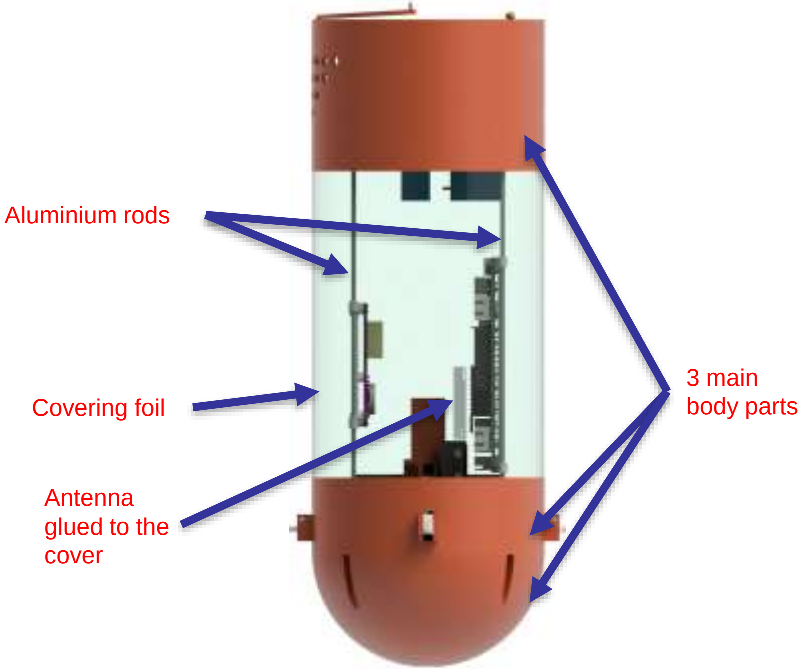
Battery connected to the electronics board and inside the payload

Payload Mechanical Layout of Components Trade & Selection (4/10)

Mechanical elements trade and selection

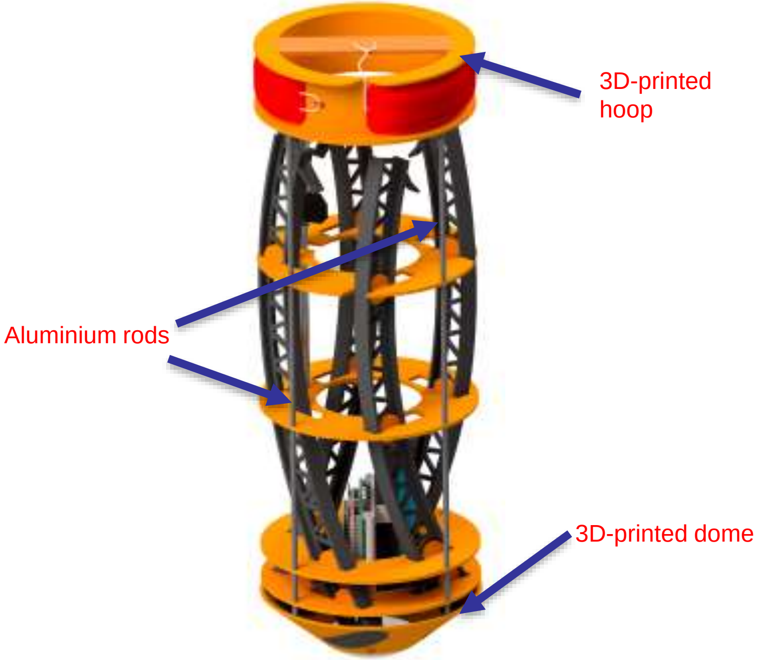
Design 1

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.



Design 2

The Payload consists of four round 3D-printed platforms with holes and round slides for the legs. The battery basket and electronics board will be mounted to these platforms. A cone-shaped cover is mounted on the bottom and a hoop at the top stores the parachute. The whole construction is held in place by four threaded rods with nuts and washers. The top and bottom parts will be additionally secured with adhesives.



Payload Mechanical Layout of Components Trade & Selection (5/10)

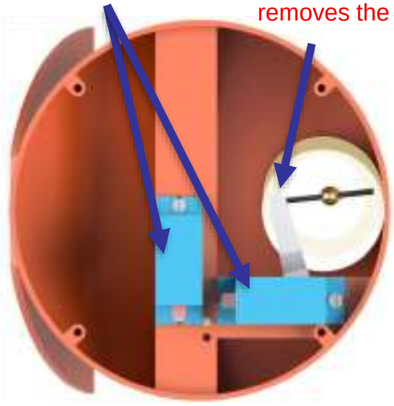
Mechanisms description

Design 1

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 selected before the launch. The intermediate position releases a rope that holds the payload to the container. Open position releases the payload parachute at 200 m by opening a hinged door.
- The second mechanism is a servo using a pitman arm to release a pin to open the spring-loaded, magic stick after landing.

Rack and pinion mechanism that releases the parachute and disconnects the Payload from the Container



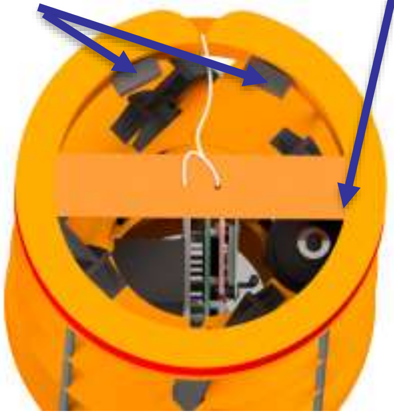
Two servos

Pitman arm that removes the pin

Design 2

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

- The first mechanism uses a burn wire to separate the payload from the container.
- The second mechanism is a copy of the first mechanism and it uses a burn wire to release the parachute.
- The third mechanism uses a retractable, telescopic antenna as a mast.



Burn wire mechanisms

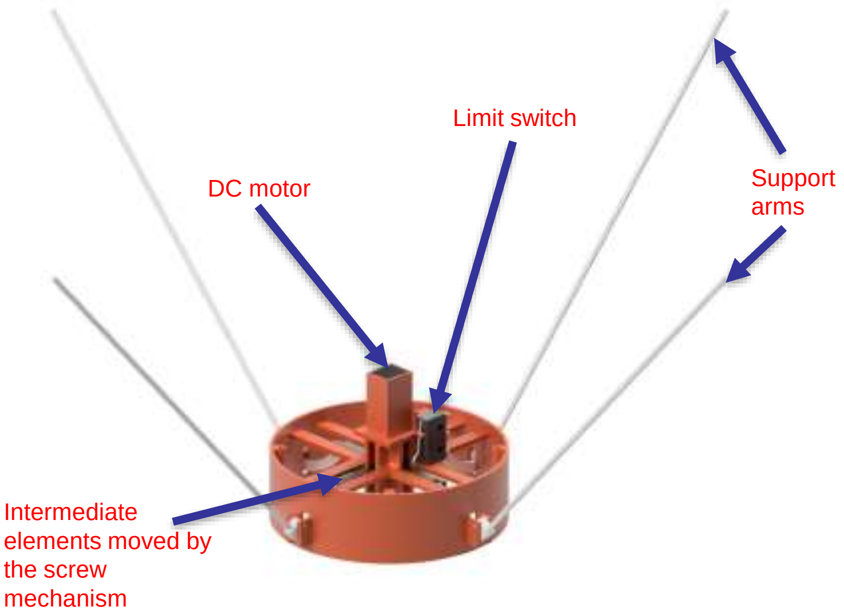
Automatic antenna

Payload Mechanical Layout of Components Trade & Selection (6/10)

Payload landing mechanisms

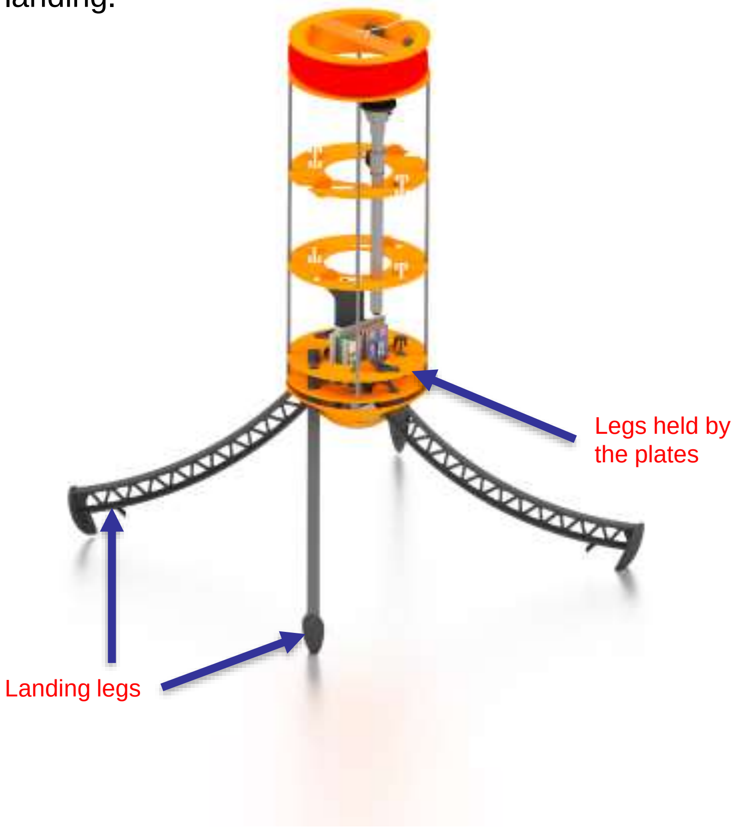
Design 1

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.



Design 2

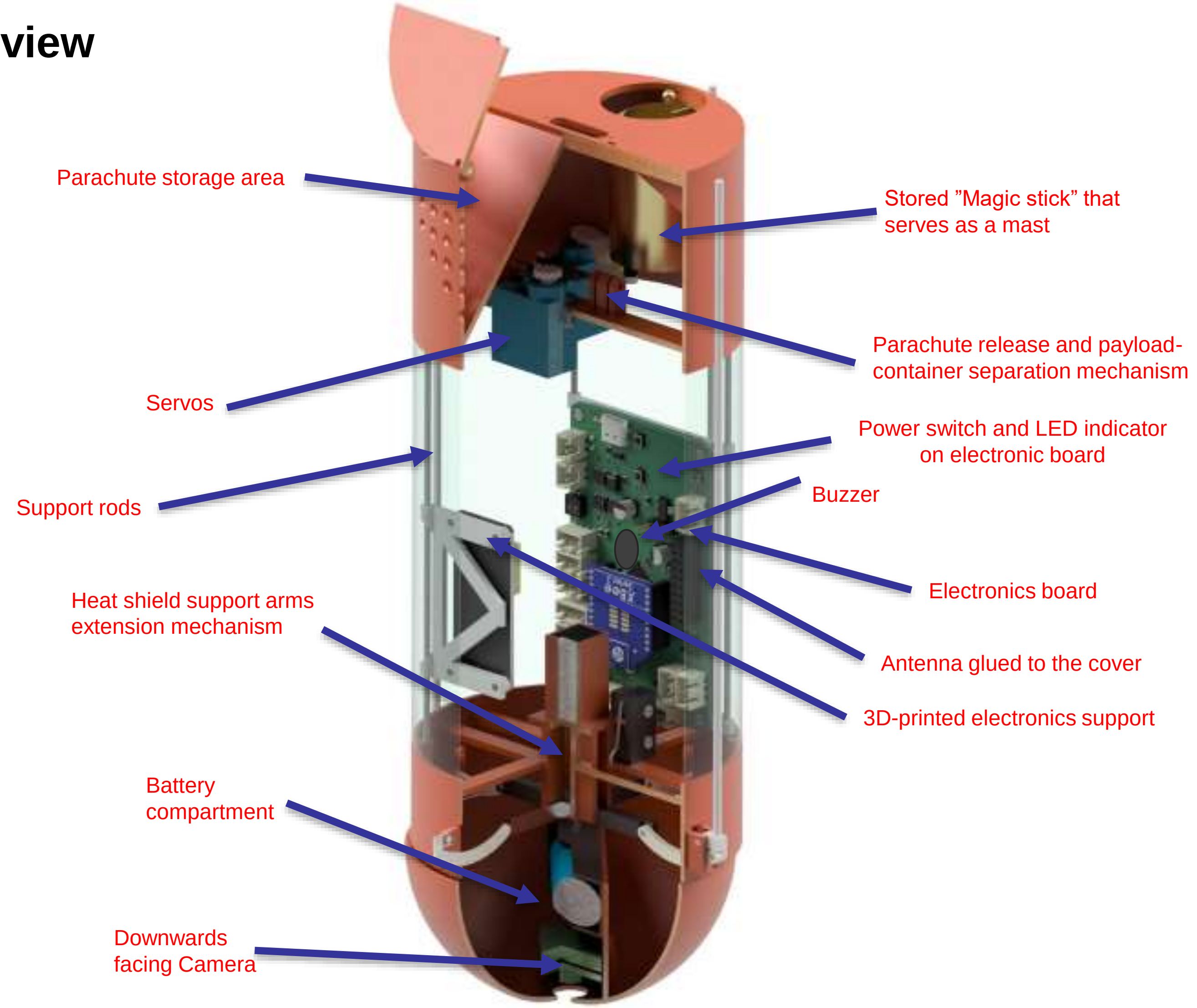
In this design, after the payload parachute opens the landing legs will be released using servo motors. Under the force of gravity, they will slide out and be locked in the release position before landing.



Payload Mechanical Layout of Components Trade & Selection (7/10)

Overall overview

Design 1


Parachute storage area

Stored ”Magic stick” that serves as a mast

Parachute release and payload-container separation mechanism

Servos

Power switch and LED indicator on electronic board

Buzzer

Support rods

Electronics board

Heat shield support arms extension mechanism

Antenna glued to the cover

3D-printed electronics support

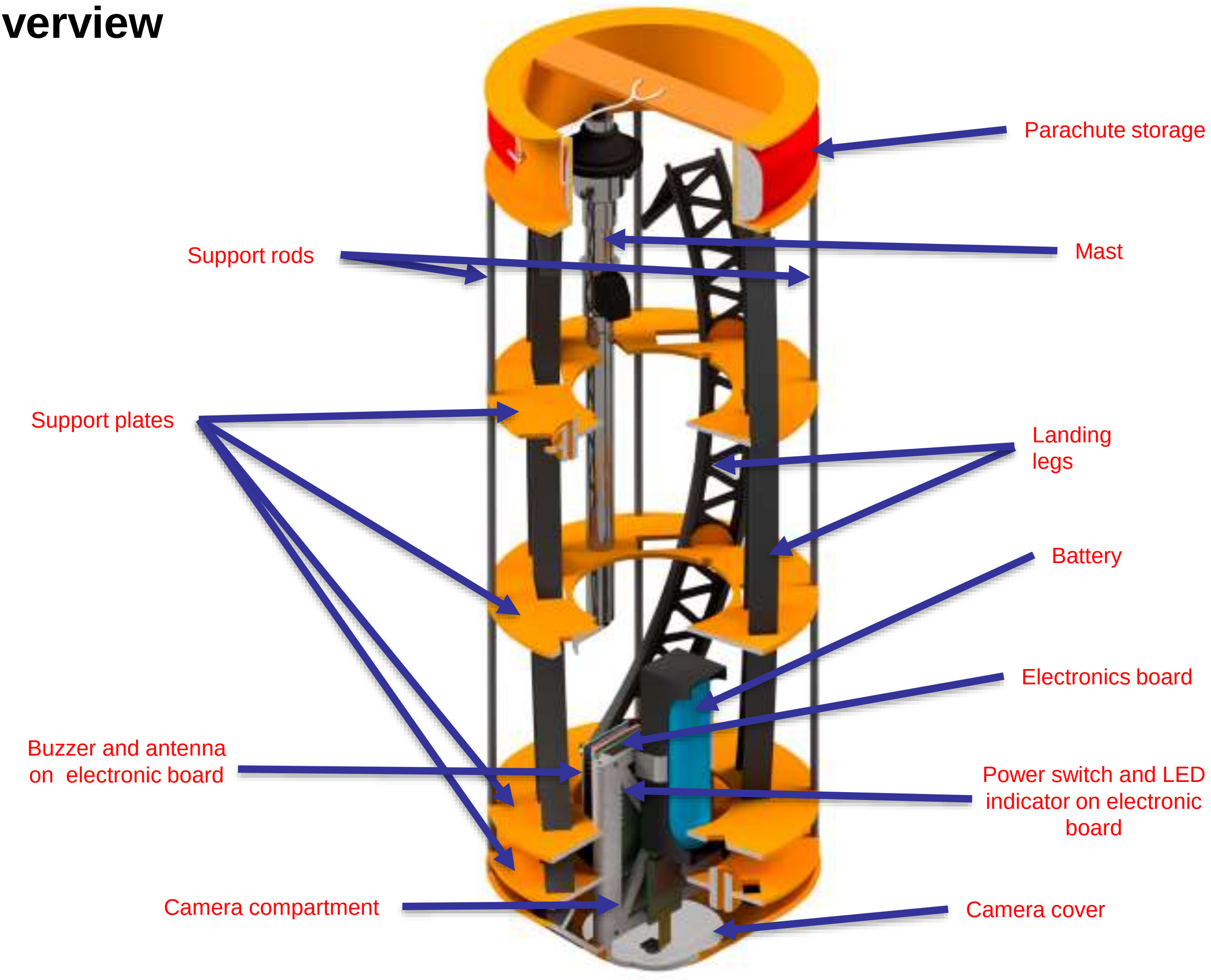
Battery compartment

Downwards facing Camera

Payload Mechanical Layout of Components Trade & Selection (8/10)

Overall overview

Design 2



Payload Mechanical Layout of Components Trade & Selection (9/10)

Structural material selection

Part	Materials	Selection and reasoning
Cover	3D print Laminating foil	**Laminating foil** A payload cover made out of laminating foil will be cheaper, easier to construct and much lighter than the 3D print.
Payload body	3D print Plywood	**3D print** 3D printing allows us to make more complicated shapes. This technique allows for faster and repetitive manufacturing. The material is cheap and we have experience using it.
Connectors	Steel Aluminium	**Aluminium** Although less available and more expensive aluminium is lighter and easier to machine. Aluminium, unlike steel, doesn't affect the magnetic sensors inside the payload.

Payload Mechanical Layout of Components Trade & Selection (10/10)

Payload design comparison

Section	Solution	Rationale	Selection
Payload Design	Design 1	+ Familiar mechanisms and materials. + Reliable heat shield opening mechanism + Heatshield support arms double as landing legs + Lighter mechanisms - Fragile landing (uprighting) legs - The heat shield doesn't open immediately	**Design 1** This design is simpler, more reliable, and requires less energy. It allows for repeatable and controllable heat shield openings during testing and launch. Avoiding unproven and unknown designs makes prototyping easier and faster.
	Design 2	+ Strong landing legs + More stable extendable mast - More power-hungry mechanisms - Complicated battery access - Cramped interior	

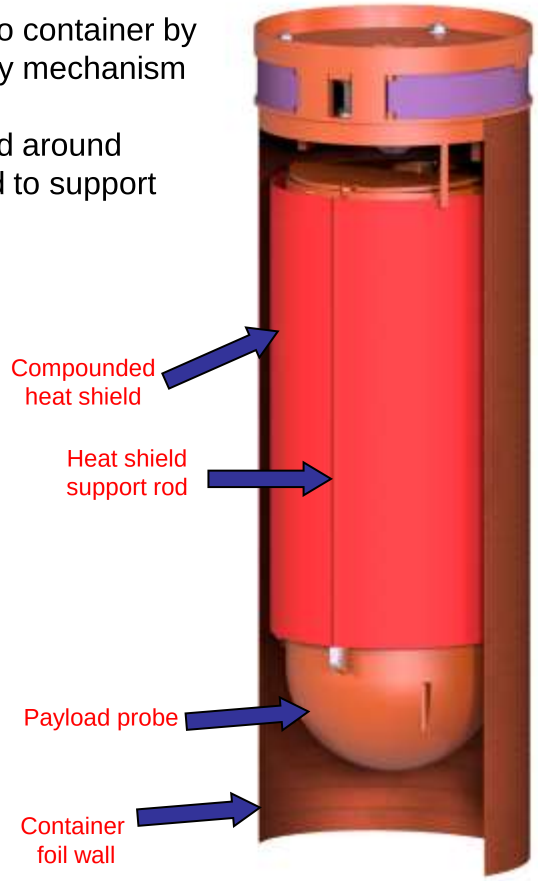
Payload Aerobraking Pre Deployment Configuration Trade & Selection (1/2)

Aerobraking Pre deployment

Design 1

Payload is attached to container by string and released by mechanism inside payload.

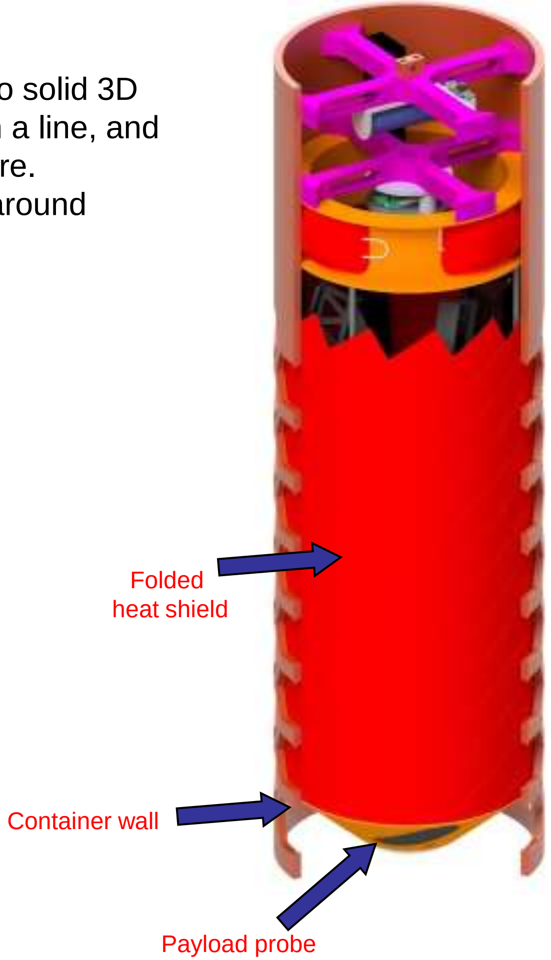
Heatshield is wrapped around payload and attached to support rods.



Design 2

Payload is attached to solid 3D printed container with a line, and released with burn wire.

Heatshield is folded around payload like origami.



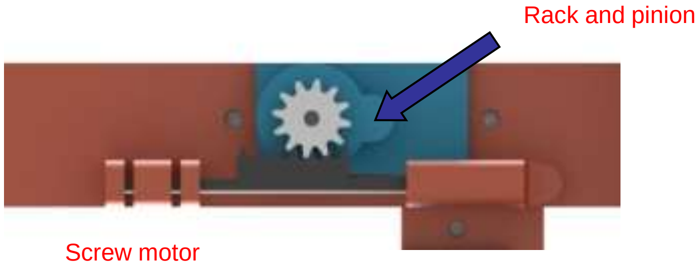
Payload Aerobraking Pre Deployment Configuration Trade & Selection (2/2)

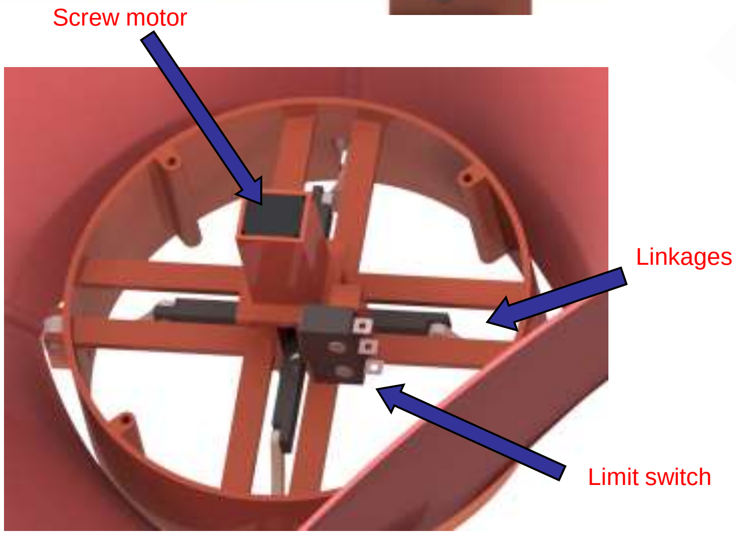
Section	Solution	Rationale	Selection
Aerobraking Pre Deployment	Design 1	+ not very complicated + compatible with the rest of chosen design - might be hard to assemble	**Design 1** This design is chosen to be compatible with the rest of chosen designs.
	Design 2	+ compatible with the rest of the CanSat second design - requires precise folding of heat shield to assemble - heat shield may get damaged when G-forces are applied	

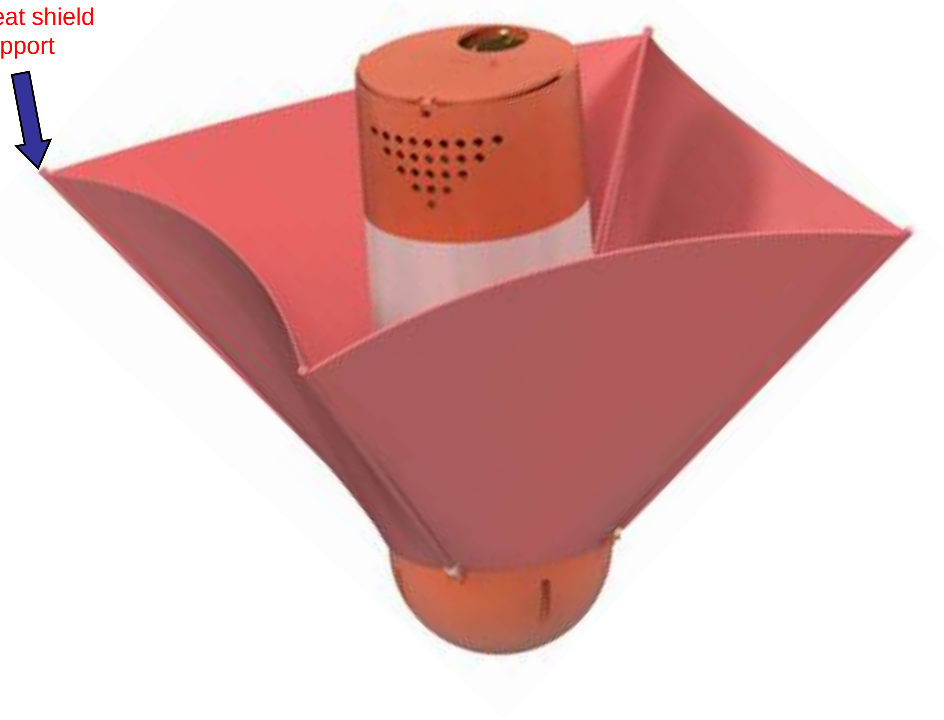
Payload Aerobraking Deployment Configuration Trade & Selection (1/3)

Design 1

Servo actuate rack and pinion mechanism to release string holding payload to container.
As payload starts freefall centrally mounted screw motor pulls on heathild support through series of linkages.
Limit switch is installed to check when heat shield is in deployed position and stop the motor.



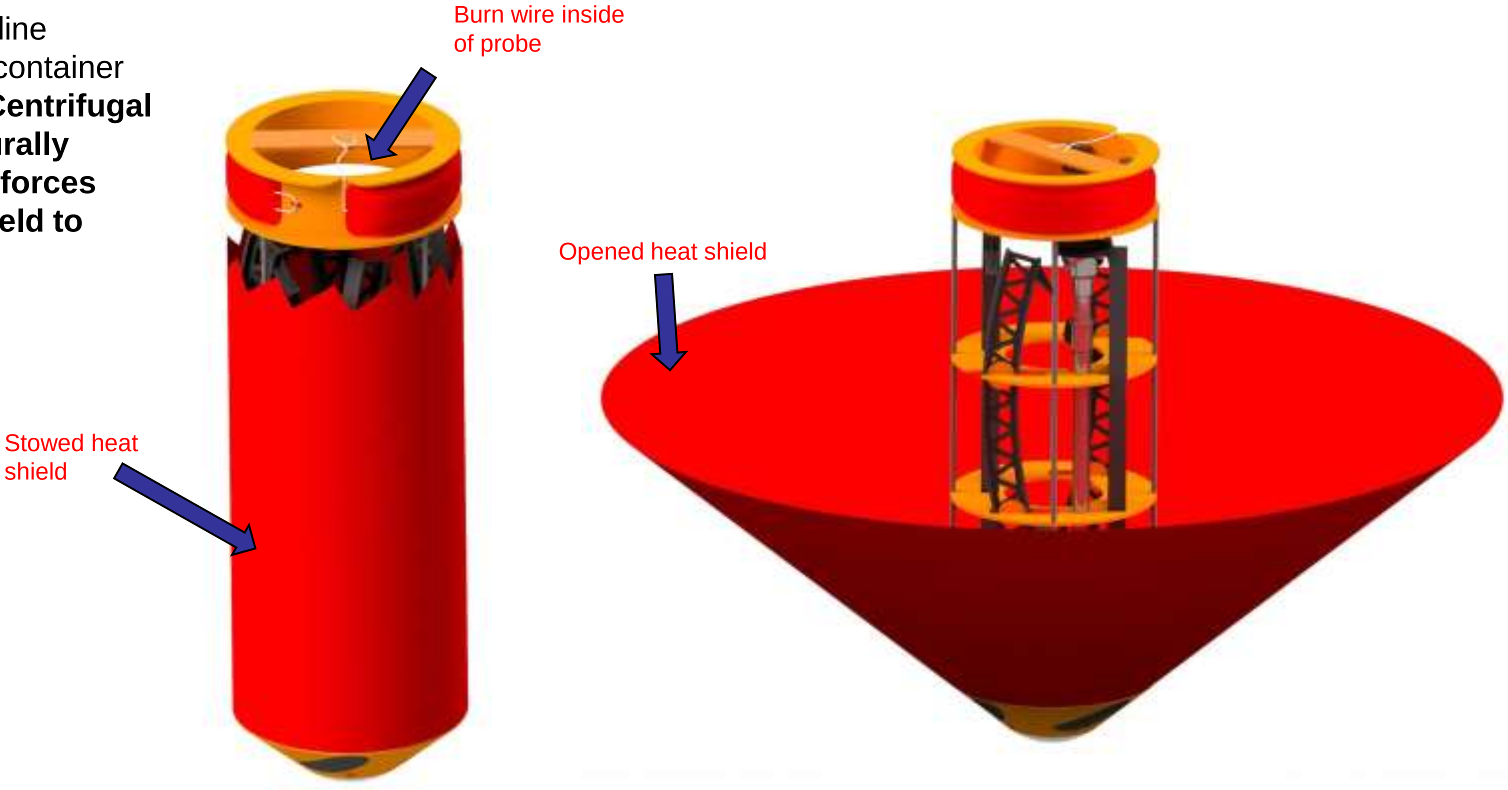




Payload Aerobraking Deployment Configuration Trade & Selection (2/3)

Design 2

Payload breaks line connecting it to container with burn wire. **Centrifugal force from naturally occurring spin forces causes heatshield to open.**



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

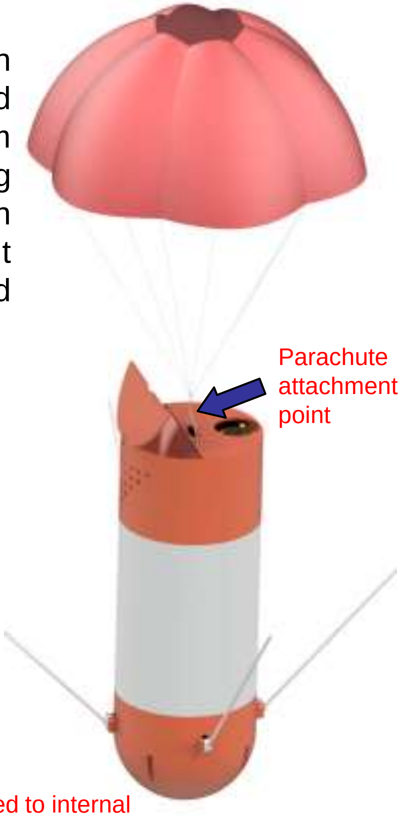
Section	Solution	Rationale	Selection
Aerobraking Deployment	Design 1	+ Reliable heat shield opening + Ability to control heat shield position precisely + Payload deployment mechanism can be reset without replacing any parts - Heavier - Complex mechanism is a potential failure point	**Design 1** This design is chosen for its precision and reliability. It's also easier to test.
	Design 2	+ Lighter + Simple construction - Requires new burnwire after every test and flight - Heatshield opening is not predictable and hard to control	

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

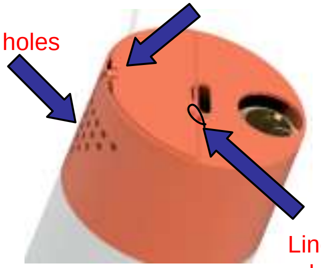
Parachute deployment

Design 1

Parachute is stored in compartment behind a hinged trap door. After servomechanism inside releases string holding trap door shut air will rush through side holes to push out parachute to the deployed position.



Parachute attachment point



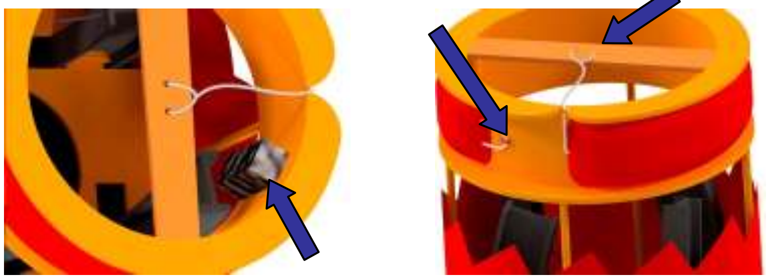
Hinge of a trap door

Side holes

Line connected to internal release mechanism

Design 2

Parachute is tied around a spool with one end of it secured to burn wire mechanism.
Additional box is needed to hide burn wire and prevent it from being cooled by air and not working properly.
After burn wire releases parachute it will be unwinded by the air current to its deployed position.



Burn wire line holding parachute in place

Parachute attachment point

Burn wire box placed securely inside the payload to reduce the fire hazard

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

Section	Solution	Rationale	Selection
Parachute Deployment	Design 1	+ Reusable + Uses existing mechanism for payload release with slight modification - More complex - Heavier	**Design 1** Even though heavier and slightly more complex. It will allow much easier prototyping and testing.
	Design 2	+ Lighter + Less complex - Requires new burn wire mechanism - Non-reusable (Burn wire has to be taken apart and replace after every flight and test)	

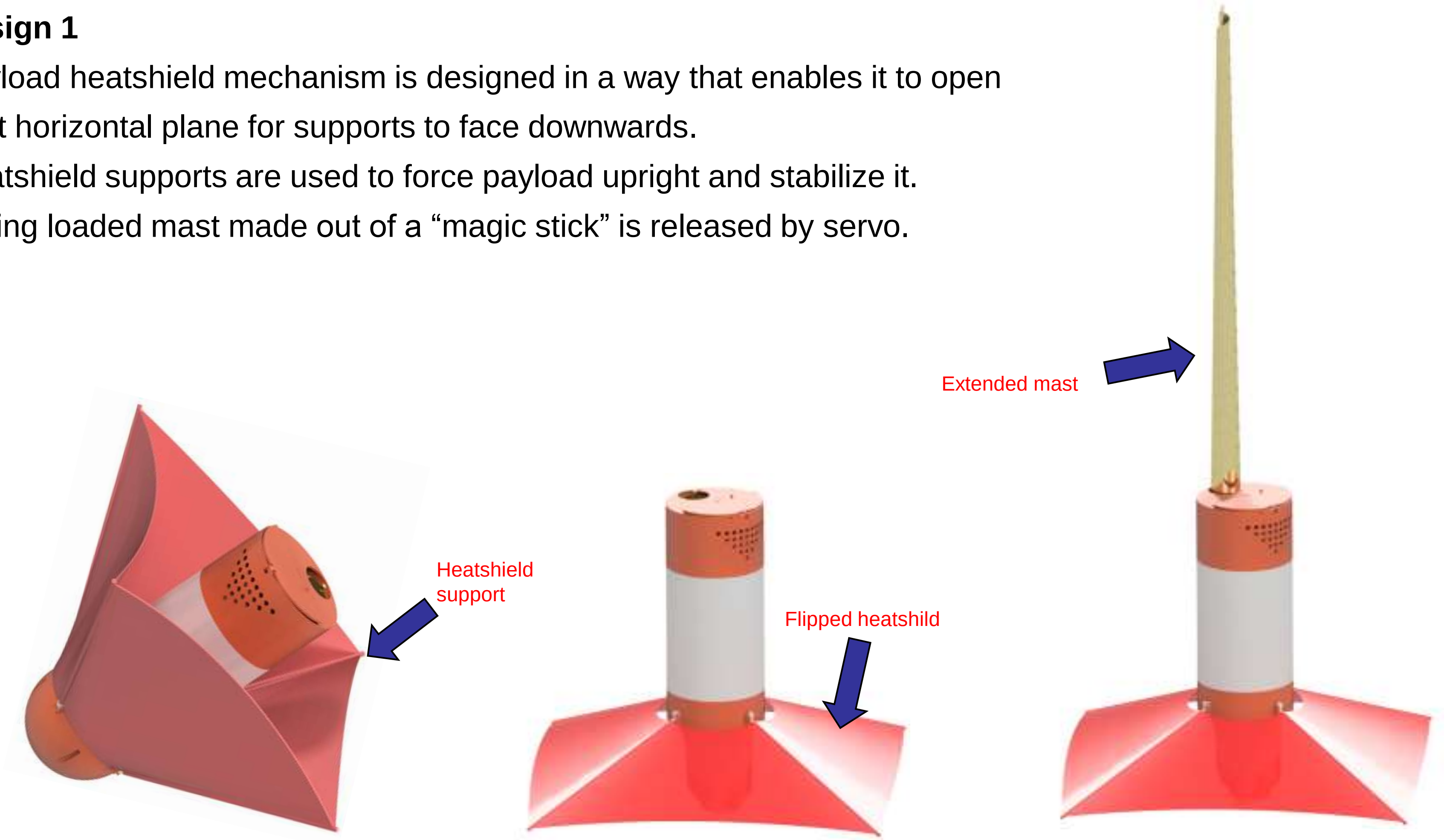
Payload Uprighting Configuration Trade & Selection (1/3)

Design 1

Payload heatshield mechanism is designed in a way that enables it to open past horizontal plane for supports to face downwards.

Heatshield supports are used to force payload upright and stabilize it.

Spring loaded mast made out of a “magic stick” is released by servo.

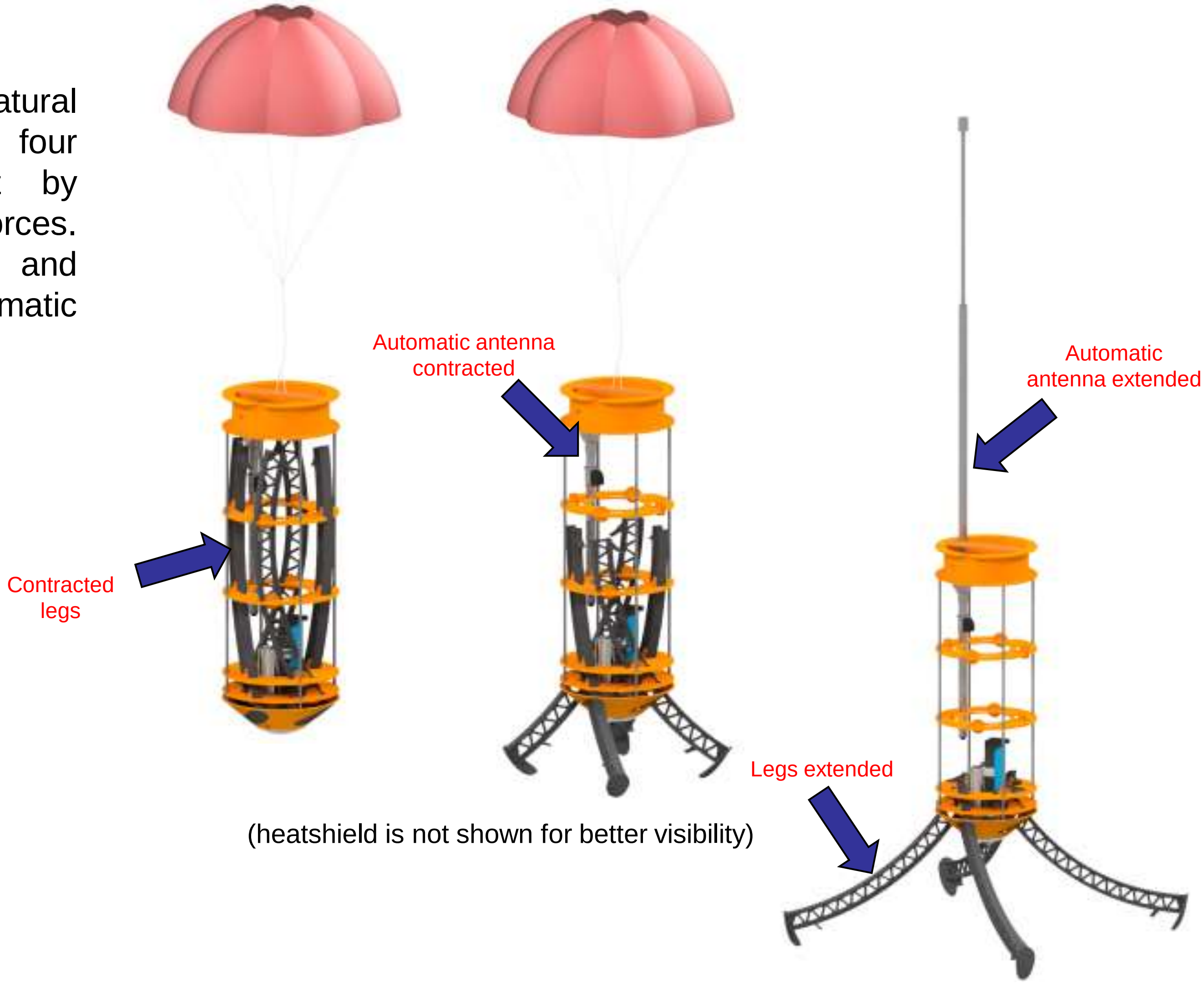


(parachute is not shown for better visibility)

Payload Uprighting Configuration Trade & Selection (2/3)

Design 2

During descend some natural spin of payload occurs, four legs are pushed out by centrifugal and gravity forces. Payload lands straight and proceeds to extend automatic car antenna.



(heatshield is not shown for better visibility)

Payload Uprighting Configuration Trade & Selection (3/3)

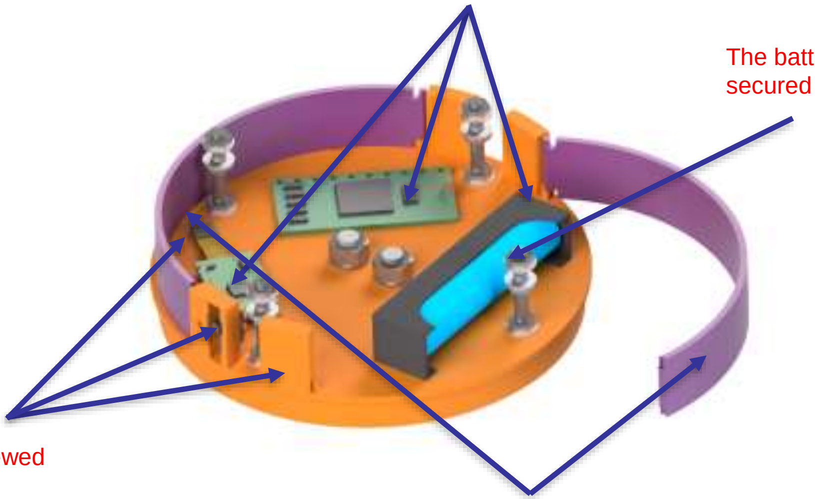
Section	Solution	Rationale	Selection
Payload Uprighting	Design 1	+ High level of control of uprighting + Does not depend on payload landing straight + More stable - Electric motor uses a lot of electricity - Complex mechanism is a potential failure point	**Design 1** This design has been chosen for its high level of control during uprighting sequence. Added stability is also very desired.
	Design 2	+ Ligher + Makes use of naturally occurring spin - Depends on payload landing straight - Legs extension depends on payload spin and is not predictable	

Electronics Structural Integrity (1/2)

Electronic component mounting methods

Container

Electronic elements inside the container will be connected to the lower plate securely. The electronic boards will be screwed to the plate. The camera will be glued in its intended place. The battery basket will be glued sideways to the plate and the battery will be held by springs and secured with insulating tape. The slide switch will be screwed to the protruding element of the plate. The LED will be glued to the same protruding element.



Those elements are glued to the structure

The battery will be additionally secured with some insulating tape

Those elements are screwed to the structure

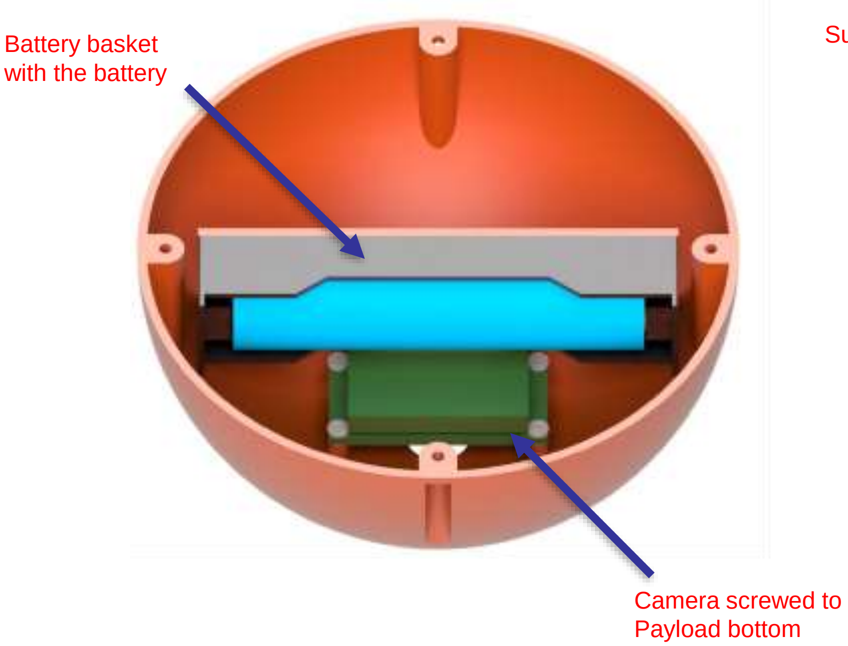
Electronic component enclosures

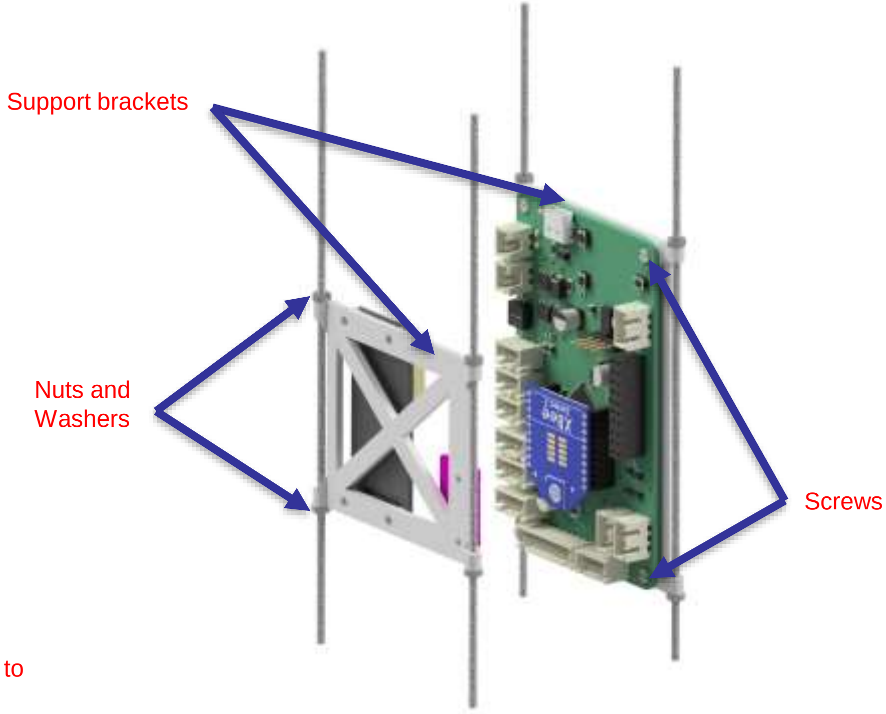
Electronics Structural Integrity (2/2)

Electronic component mounting methods

Payload

All electronic boards will be mounted to custom 3D-printed brackets using screws. Those brackets will be mounted with nuts and washers to aluminium rods. This ensures an easy and secure connection to the payload. The antenna will be glued to the clear cover of the payload by high strength adhesives. The battery basket will be screwed inside the battery compartment, low in the Payload. Like in the Container, the battery is mounted sideways and secured with insulating tape to ensure no disconnection when acceleration is applied. The camera is housed below the battery basket, it is mounted to the body using screws and adhesives.





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	38.0±1.0	38.0±1.0	Estimated
	Lower plate	ABS	1	44.0±1.0	44.0±1.0	Estimated
	Payload holder	Aluminium	1	16.2±0.5	16.2±0.5	Estimated
	Container electronics cover	ABS	2	6.0±0.25	12.0±0.5	Estimated
	Connecting bolts	Aluminium	4	1.5±0.125	6.0±0.5	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	1.2±0.05	19.2±0.5	Estimated
	M4 washer	Steel	16	0.3±0.01	4.8±0.2	Estimated
	Foil container cover	PET	1	26.0±1.0	26.0±1.0	Estimated

Summary mass = 192.20 ± 6.10 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±0.5	5.0±0.5	Datasheet
	Screws	Steel	8	0.75±0.025	6.0±0.2	Datasheet

Summary mass = 36.05 ± 1.10 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±1.0	27.0±1.0	Estimated
	Battery compartment (bottom) cover	ABS	1	26.0±1.0	26.0±1.0	Estimated
	Parachute bay	ABS	1	50.0±1.0	50.0±1.0	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 = 128.60 ± 4.15 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±0.5	3.8±0.5	Estimated
	Antenna	ANTX150P118B09153	1	5.0±0.2	5.0±0.2	Estimated
	Screws	Steel	12	1.0±0.01	12.0±0.12	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

Summary mass = 153.69 ± 1.69 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
	Pitman arm	ABS	1	0.35±0.05	0.35±0.05	Estimated
	Magic stick latch	Steel	1	1.0±0.2	1.0±0.2	Estimated
	Magic stick	Steel	1	46.0±0.5	46.0±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 = 59.69 ± 1.06 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	1	9.0±0.1	9.0±0.1	Datasheet
	Parachute cover	ABS	1	6.0±0.5	6.0±0.5	Estimated
	Payload parachute	Nylon	1	53.0±0.2	53.0±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±0.2	3.0±0.2	Estimated
	Linkages	ABS	4	0.5±0.05	2.0±0.2	Estimated
	Spokes	ABS	4	1.0±0.05	4.0±0.2	Estimated
	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 = 53.53 ± 2.26 g

Mass Budget (8/8)

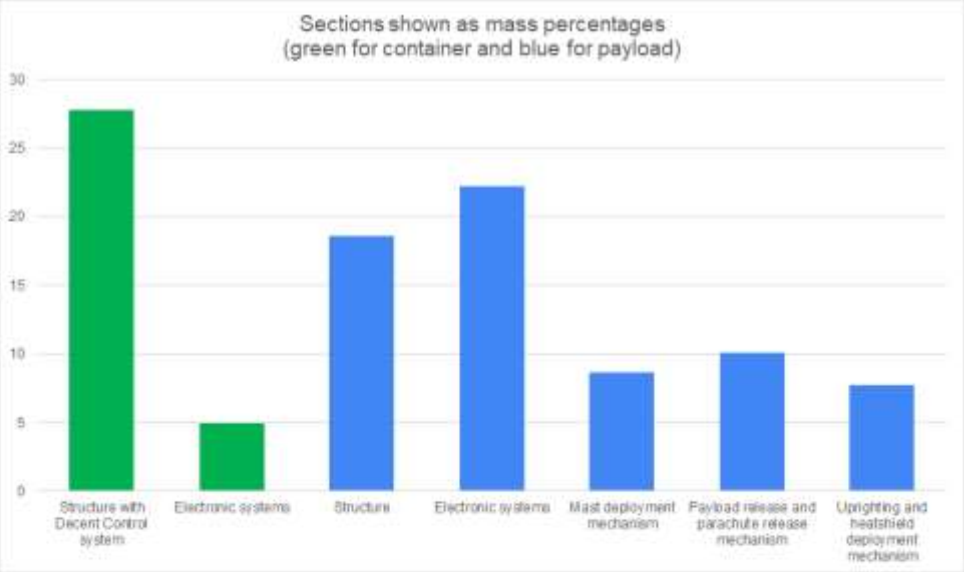
Component	Subsystem	Mass summary [g]
Container	Structure with Decent Control system	192.20 ± 6.10
	Electronic systems	36.05 ± 1.10
Payload	Structure	128.60 ± 4.15
	Electronic systems	153.69 ± 1.69
	Mast deployment mechanism	59.69 ± 1.06
	Payload release and parachute release mechanism	69.59 ± 1.01
	Uprighting and heatshield deployment mechanism	53.53 ± 2.26

Container mass: **228.25 ± 7.20 g**
Payload mass: **465.10 ± 10.17 g**
Summary mass: **693.35 ± 17.37 g**

Margin: 693.35 - 700.00 = **-6.66 g**

In case of CanSat being too heavy, some nuts and bolts can be changed from steel to aluminium, we can also change the 3D printed parts infill.

In case the CanSat is too light we can add some balast at the bottom of the payload.


Sections shown as mass percentages
(green for container and blue for payload)

Communication and Data Handling (CDH) Subsystem Design

Hubert Kulik

Payload Command Data Handler (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: XB24CAPIT-001	Transmitting data and commands.

Payload Processor & Memory Trade & Selection (1/2)

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
iMXRT1062	600	~5	3.3	8092	1024	42x GPIO, of which: - 35x PWM out - 18x Analog in	3x SPI, 2x I2C 8x UART 1x SDIO 2x USB	2/12-bit
STM32F103C8T6	72	~5	3.3	64	20	32x GPIO, of which: - 20x PWM out - 10x Analog in	2x SPI, 2x I2C 3x UART 1x SDIO 1x USB	2/12-bit

Selected processor	Reasons
STM32F412RETx	• Sufficient clock speed • Fast boot time • All needed interefaces are on-board • Proper pin count • Sufficient RAM and Flash memories • Easy to solder on a custom PCB

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

Name	Memory	Interfaces	Package	Voltage [V]
SanDisk microSDHC 16GB	16GB	SPI SDIO	microSD	2.7÷3.6
Winbond W25Q128	16MB	SPI	8-SOIC	2.7÷3.6
EEPROM 24LC01B	1KB	I2C	DIP-8	2.5÷5

Selected memory	Reasons
SanDisk microSDHC 16GB	• High availability • Easy to replace • The highest capacity • Easy to use in the software • Vibration resistant

Payload Real-Time Clock

Name	Size [mm]	Mass [g]	Interface	Reset tolerance	Type
Internal STM32 RTC clock	Integrated into STM32	-	Internal bus	Unaffected due to coin battery backup	Hardware
Teensy V4.1 on-board RTC	Integrated into Teensy V4.1	-	Internal bus	Unaffected due to coin battery backup	Hardware
Adafruit 3295 – RTC PCF8523	26 x 22 x 5	2.3 (+0.9 battery)	I2C	Unaffected due to coin battery backup	Hardware

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

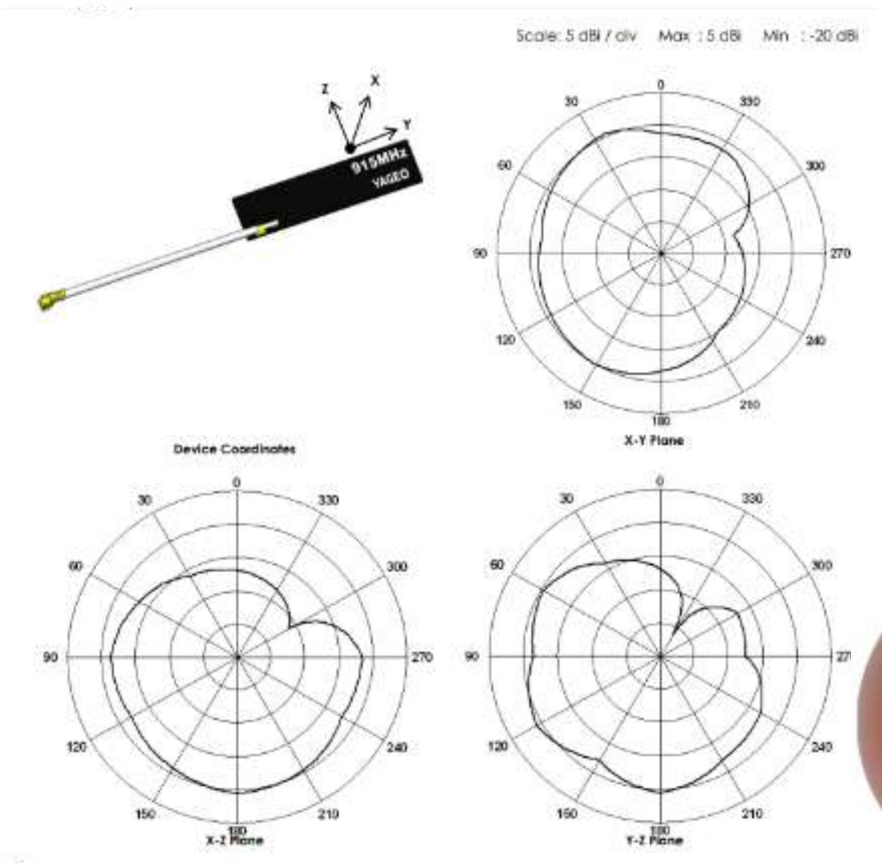
Payload Antenna Trade & Selection (1/2)

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

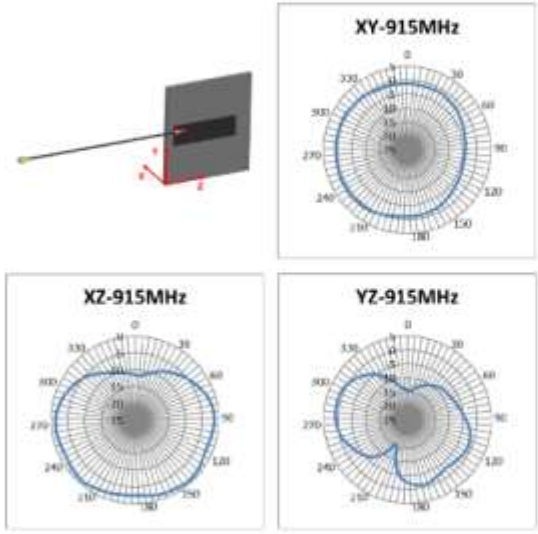
Selected antenna	Reasons
ANTX150P118B09153	- Higher gain - Higher best case range - Slightly better worst case range - Wider frequency range

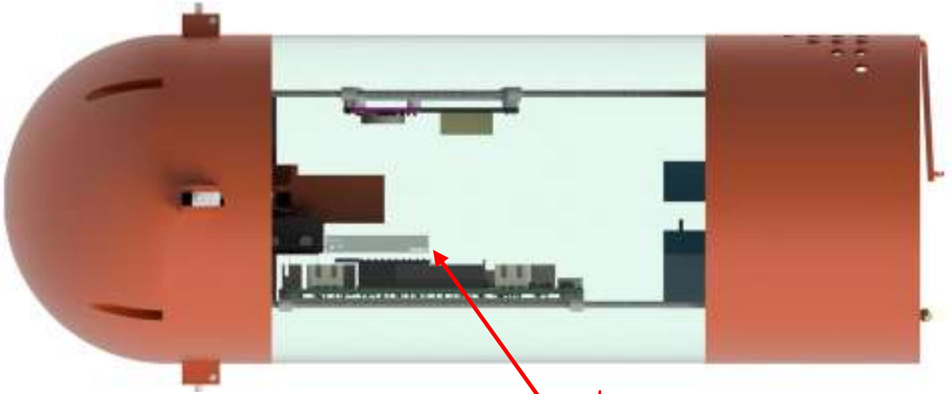
Payload Antenna Trade & Selection (2/2)

ANTX150P118B09153



MOLEX 2111400100





antenna

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)
XBee: XBP24CAUIT-001	2.4÷3.6	TX: 120 RX: 31	250	-101	2400	63/18	~3.2 (outdoor)

Selected Radio	Reasons
XBee: XBP9B-XCST-001	• Better outdoor range • Has U.fl antenna connector, which is smaller than RPSMA • Higher 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.

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 addational 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	1. CMD and RST are static text. 2. <TEAM ID> is the assigned team identification. 3. SOFT or HARD 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)	CMD,1082,RST,HARD Turns off the MCU for random number of seconds (up to 5s)

* - Commands added by the Team

Competitions Requirements are met!

Electrical Power Subsystem (EPS) Design

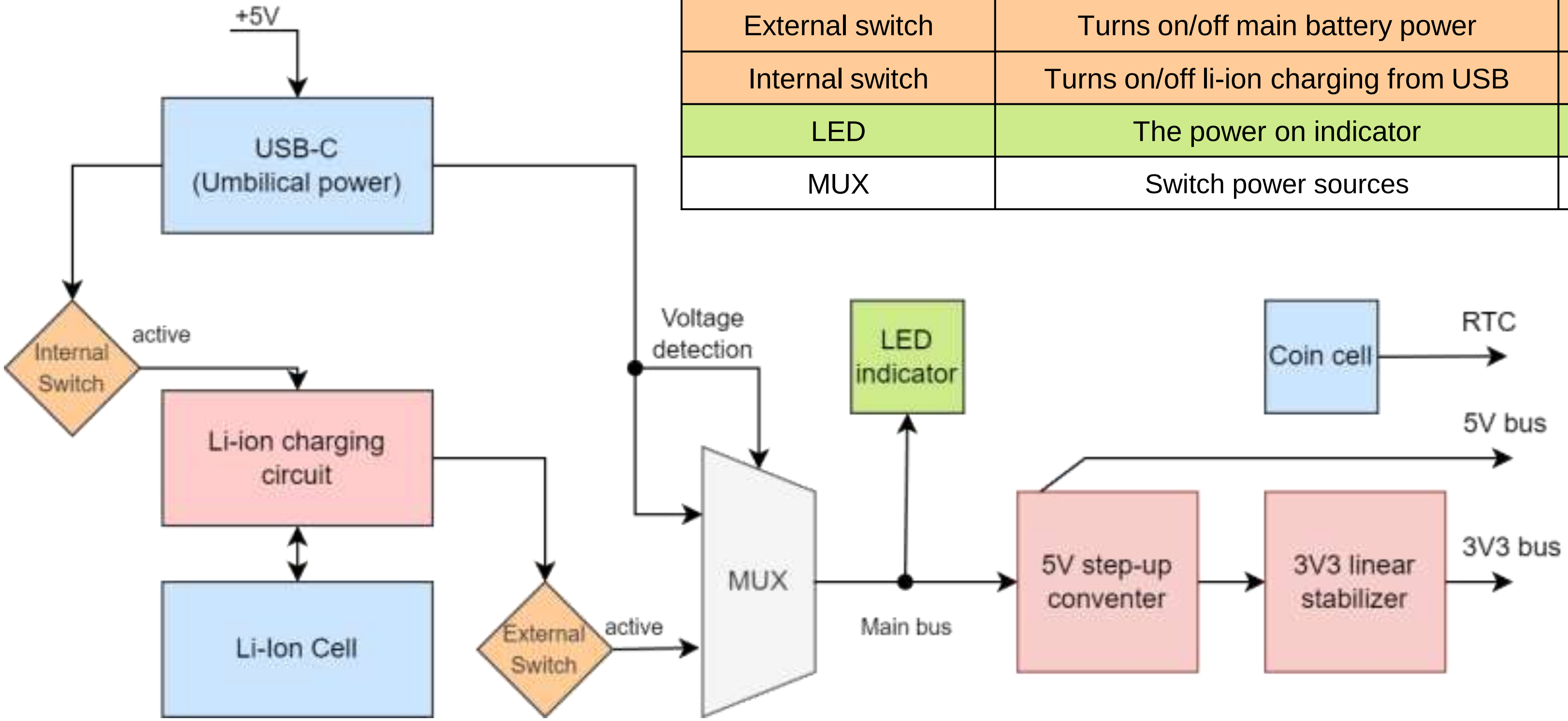
Hubert Kulik

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.

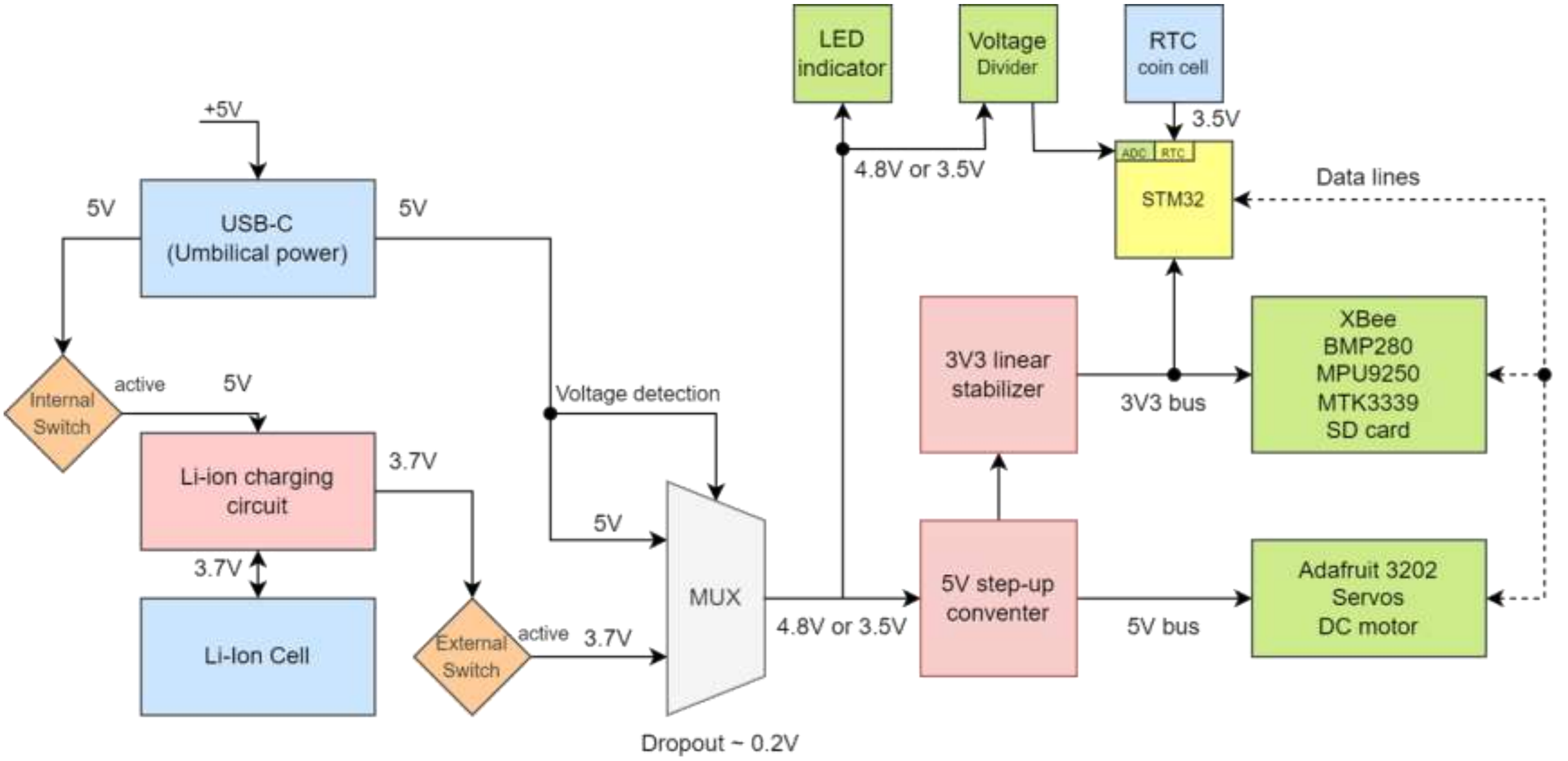
The board allows us to charge the battery from the same USB port using onboard charging ciruit.

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
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



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 Trade & Selection

Part	Dimensions [mm]	Weight [g]	Voltage [V]	Capacity [mAh]	Current max [mA]	Type	Charge cycles	Integrated fuses	Cost [$]
Panasonic NCR18650B	⌀18.5 x 65.3	48.5	3.6	3200	6400	Li-ion	500	No	7.39
Energizer L522	46.50 x 26.50 x 17.50	33.9	9	~750	1000	Lithium	0	No	8.8

Selected battery:	Reasons:
Panasonic NCR18650B	• High capacity • Small dimensions • High energy density • Low internal resistance • Easy to replace • Rechargeable

The battery will be placed in an appropriate basket placed vertically, which will prevent it from disconnecting. Because it is a single cell, **doesn't 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	BMP280	3.3	25	82.5	7200	100%	0.1650	Datasheet
Temperature								
Magnetometer	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
Camera	Adafruit 3202	5	110	550	200	3%	0.0330	Datasheet
Motor	DFRobot 6V 120RPM	5	160	800	120	1.6%	0.0267	Datasheet
SERVO 1	S9G Micro	5	(6) 40	(30) 200	(7170) 30	0.5%	0.0597 + 0.0020	Datasheet
SERVO 2	S9G Micro	5	(6) 40	(30) 200	(7170) 30	0.5%	0.0597 + 0.0020	Datasheet
						Total	1.4113	
						Total (Incl. efficiency)	2.8226	

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

Summary:

Power source:	One Li-ion cell
Total power available:	3.6 V * 3200 mAh = 11520 mWh = 11.52 Wh
Margin:	11.52 Wh - 2.83 Wh = 8.69 Wh
Percent margin:	2.83 Wh / 11.52Wh ·100% = 24.6%

With the selected battery, **the Payload can operate for approximately 4 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.

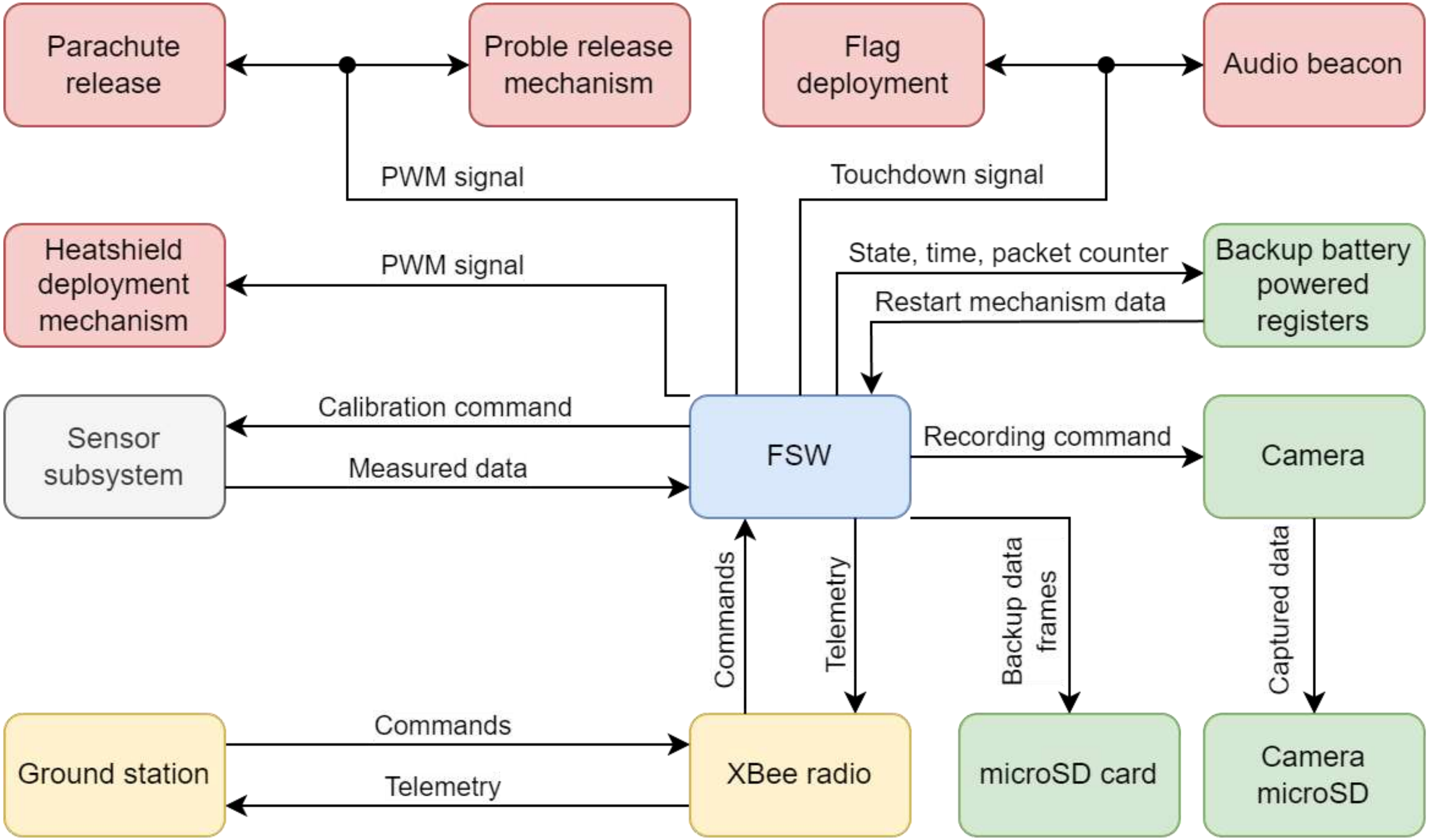
Programming language

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

Developing environment

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

FSW Overview (2/3)

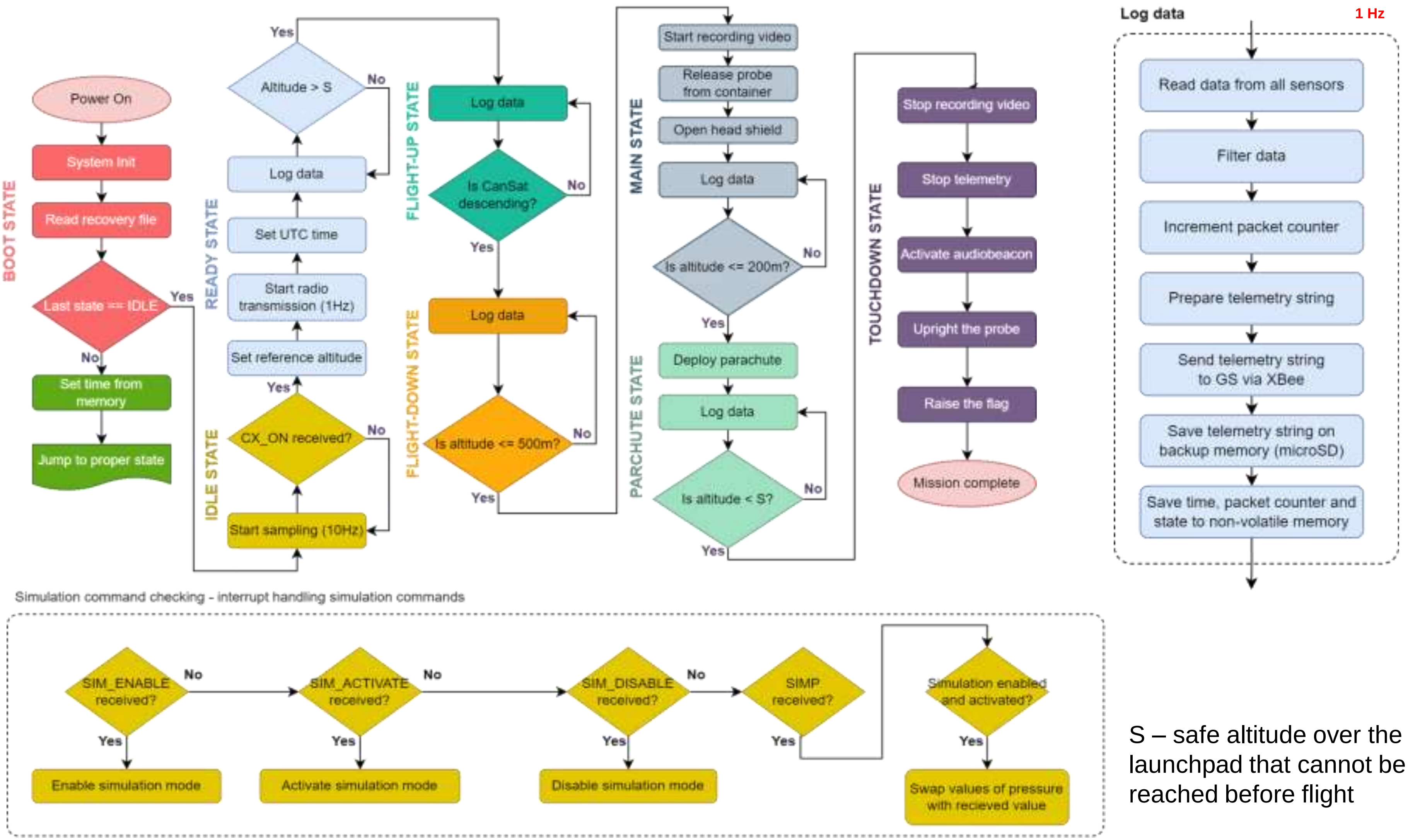


FSW Overview (3/3)

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

Payload FSW State Diagram (1/2)



BOOT STATE

Power On

System Init

Read recovery file

Last state == IDLE

Yes

No

Set time from memory

Jump to proper state

IDLE STATE

Start sampling (10Hz)

CX_ON received?

No

Yes

READY STATE

Set reference altitude

Start radio transmission (1Hz)

Set UTC time

Log data

Altitude > S

No

Yes

FLIGHT-UP STATE

Log data

Is CanSat descending?

No

Yes

FLIGHT-DOWN STATE

Log data

Is altitude <= 500m?

No

Yes

MAIN STATE

Start recording video

Release probe from container

Open head shield

Log data

Is altitude <= 200m?

No

Yes

PARCHUTE STATE

Deploy parachute

Log data

Is altitude < S?

No

Yes

TOUCHDOWN STATE

Stop recording video

Stop telemetry

Activate audiobeacon

Upright the probe

Raise the flag

Mission complete

Log data

1 Hz

Read data from all sensors

Filter data

Increment packet counter

Prepare telemetry string

Send telemetry string to GS via XBee

Save telemetry string on backup memory (microSD)

Save time, packet counter and state to non-volatile memory

Simulation command checking - interrupt handling simulation commands

SIM_ENABLE received?

No

Yes

Enable simulation mode

SIM_ACTIVATE received?

No

Yes

Activate simulation mode

SIM_DISABLE received?

No

Yes

Disable simulation mode

SIMP received?

Yes

Simulation enabled and activated?

Yes

Swap values of pressure with recieved value

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

Payload 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 number, altitude of the launchpad. They are saved every 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

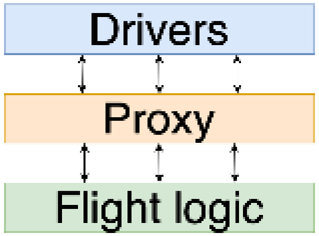
- CMD,1082,SIMP,<PRESSURE> - simulated atmospheric pressure data in Pascals (1 Pa resolution)

Software Development Plan (1/2)

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



Drivers

Proxy

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.

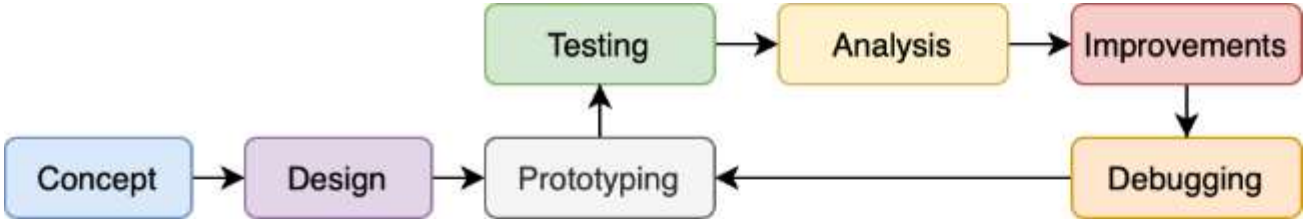
Deployment system, based on servomechanisms, needs to choose coefficients like current, voltage and time empirically, so we do it in our University Lab.

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

Software Development Plan (2/2)

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.

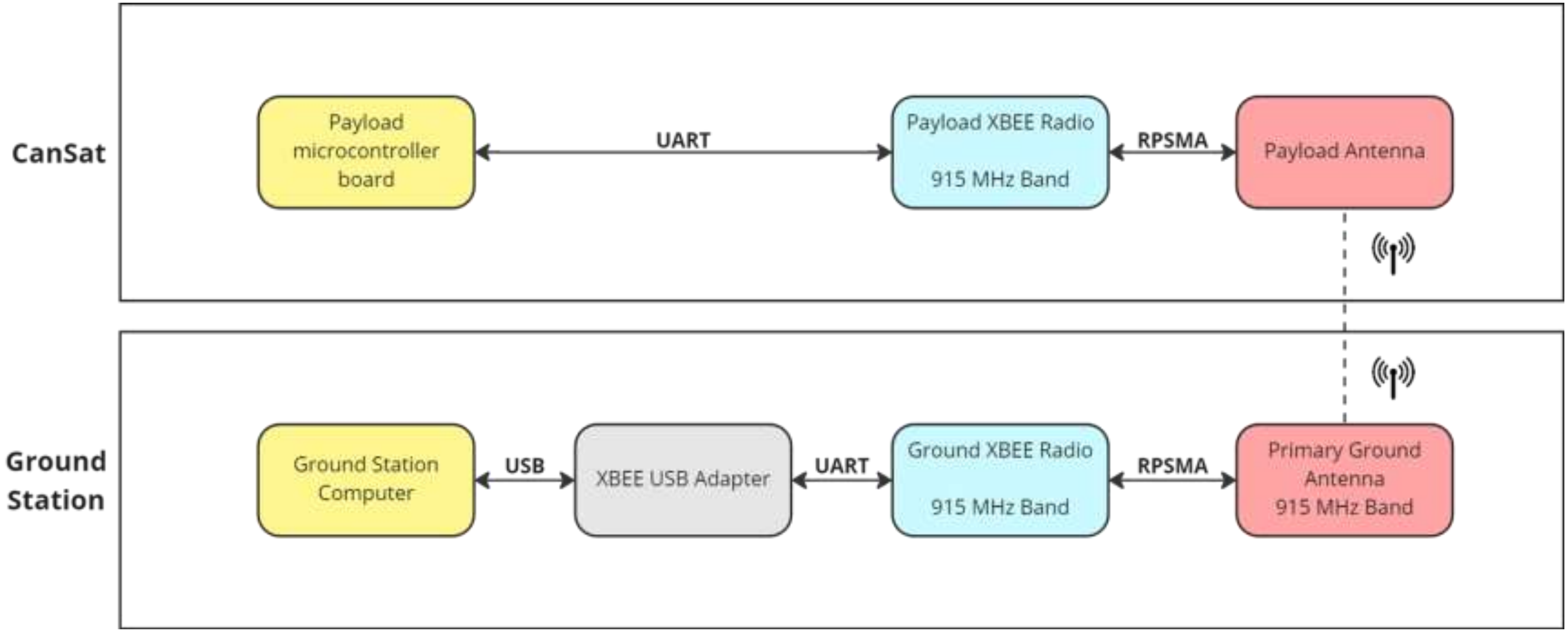
Development team: Jakub Kaszowski, Hubert Kulik, Tobiasz Puślecki

Ground Control System (GCS) Design

Hubert Kulik

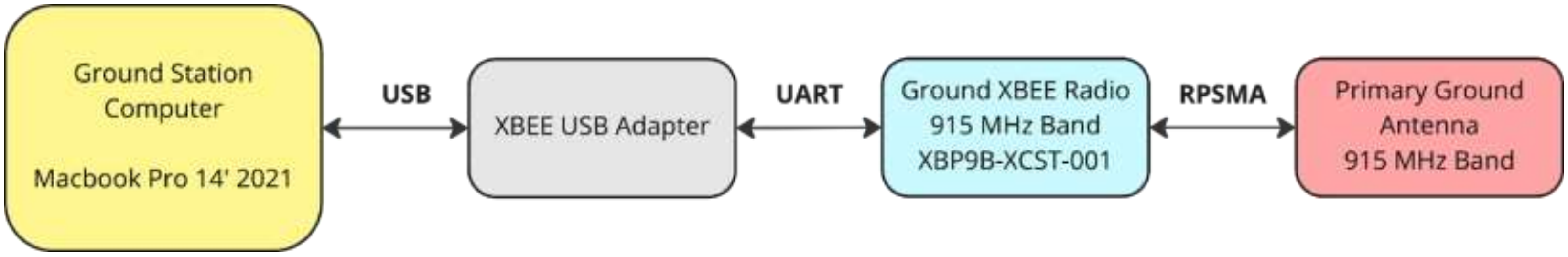
GCS Overview

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



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.


Ground Station Computer

Macbook Pro 14' 2021

USB

XBEE USB Adapter

UART

Ground XBEE Radio
915 MHz Band
XBP9B-XCST-001

RPSMA

Primary Ground Antenna
915 MHz Band

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

GCS Antenna Trade & Selection (1/4)

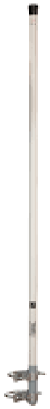
Model	Type	Frequency range [MHz]	Gain [dBi]	VSWR	Direction	Beamwidth	Range [km]
Interline HORIZON 900 8V	Dipole	900÷950	8	>2 @ 902 MHz	Omnidirectional	360° @ -3dB H	~5
2867801	Yagi	898÷902	5	>1.1 @ 900 MHz	Directional	168° H / 78° V	~10

Selected	Reasons
Interline HORIZON 900 8V	• The build of the antenna is preferable for field • The best gain • Better radiation characteristic • Acceptable signal range

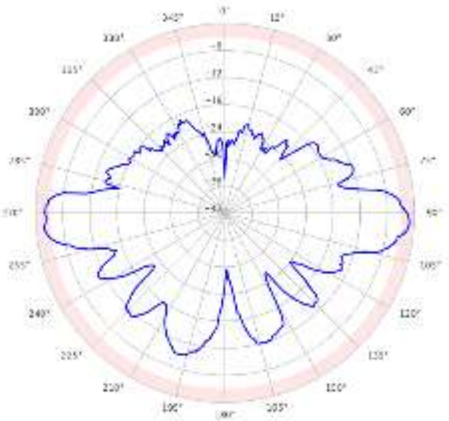
The dipole antenna provides good coverage for receiving the signal. Additionally, this model has been tested out in the field during previous CanSat competitions.

GCS Antenna Trade & Selection (2/4)

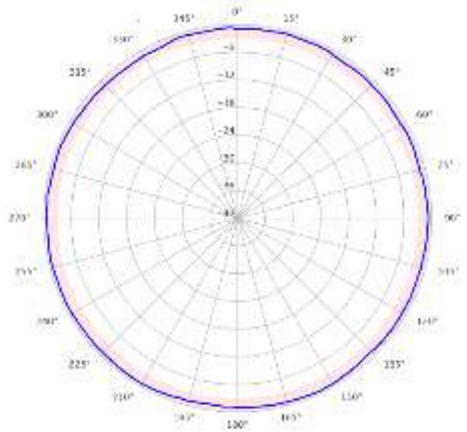
Interline HORIZON 900 8V – 915 MHz Radiation Patterns



VERTICAL

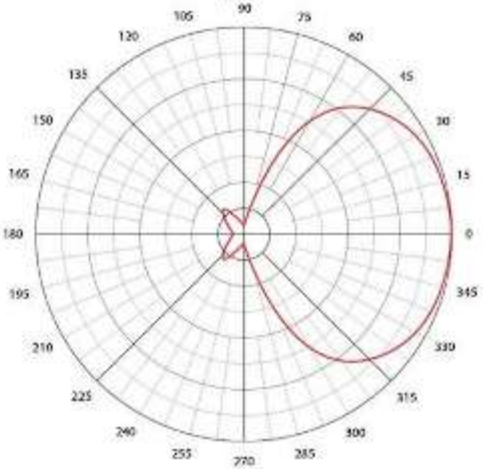


HORIZONTAL

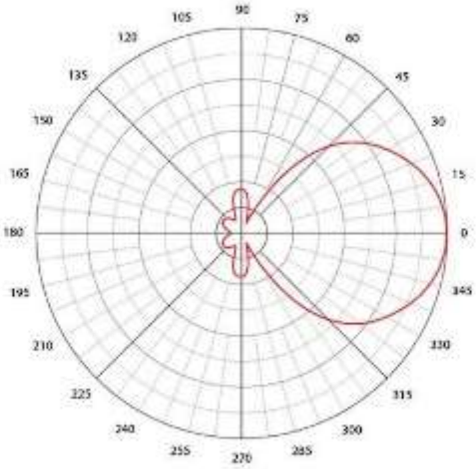


2867801– 902 MHz Radiation Patterns

VERTICAL



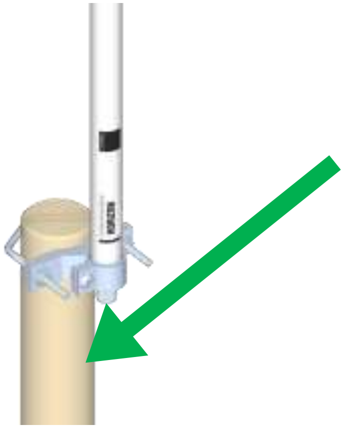
HORIZONTAL



GCS Antenna Trade & Selection (3/4)

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’s mount holes. This allows to manipulate the antenna easily by the operator.



Interline HORIZON 900 8V

GCS Antenna Trade & Selection (4/4)

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

$P_{rx}\ = ?$
$P_{tx}\ = 20\ dBm(XBEE)$
$G_{tx}\ \approx 2$ 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.**

- 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.

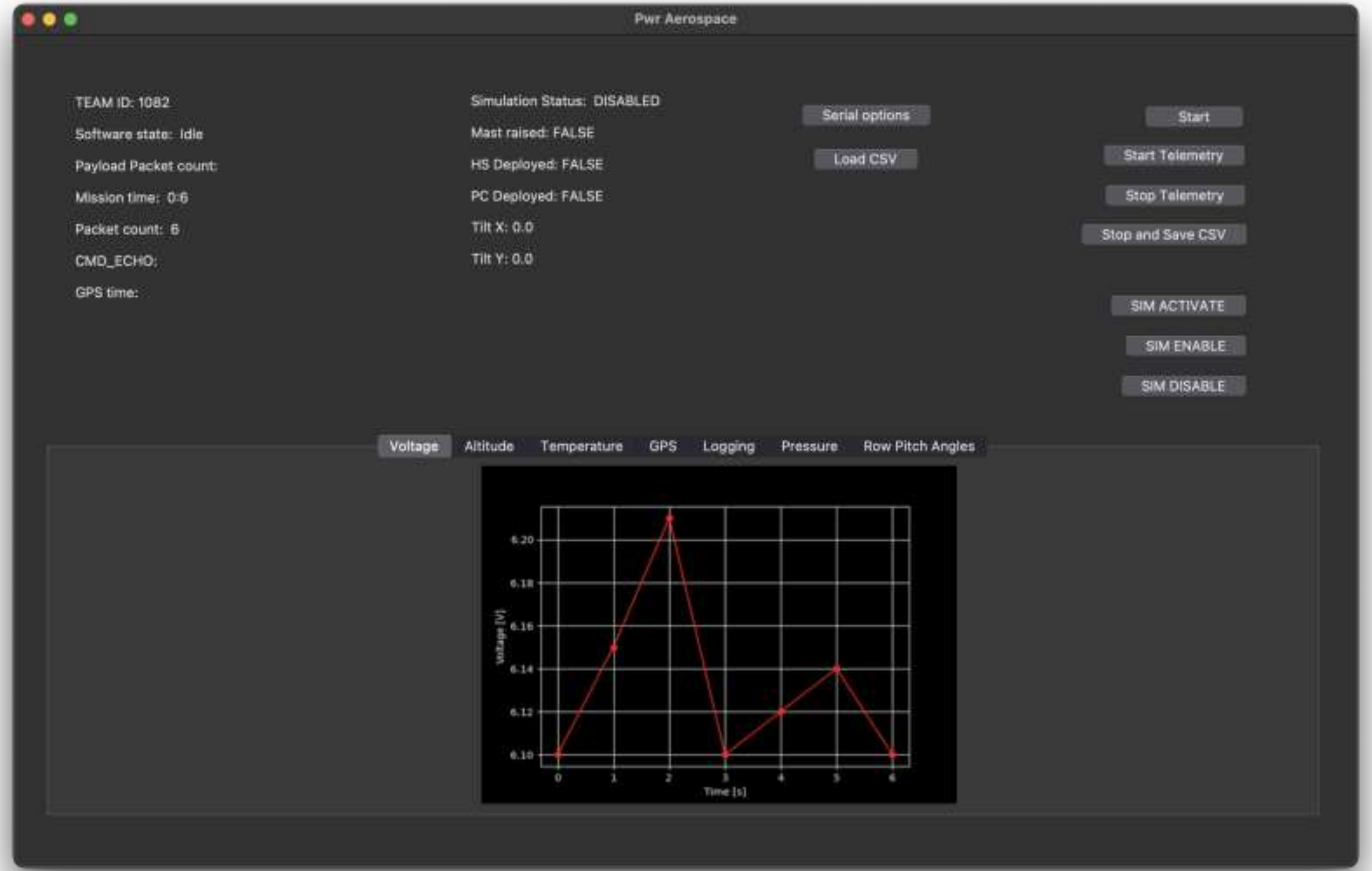
- Commands

  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 verifiedit in the GCS interface.

  The command for the time set can be sent by the operator also.

GCS Software (2/2)

- GCS Graphical User Interface



TEAM ID: 1082
Software state: Idle
Payload Packet count:
Mission time: 0:6
Packet count: 6
CMD_ECHO:
GPS time:

Simulation Status: DISABLED
Mast raised: FALSE
HS Deployed: FALSE
PC Deployed: FALSE
Tilt X: 0.0
Tilt Y: 0.0

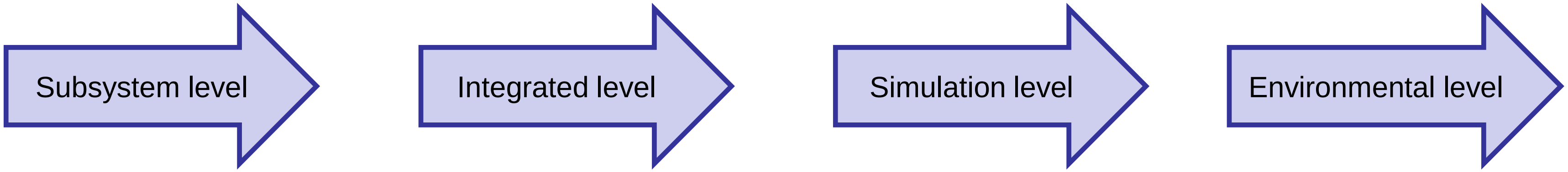
** prototype*

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	To be tested
	Debug logs can be sent via serial interface	Serial interface transmits data	TBT
	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	TBT
	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	TBT
	Battery is easily dismounted from payload	Battery can be replaced in less than one minute	TBT
	The mechanical mechanism raises the flag	The flag is fully raised	TBT
	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

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	To be tested
	Altitude can be properly calculated	Altitude calculated from test values corresponds to expected altitude	TBT
	Temperature measuring	Temperature is correctly measured	TBT
	Pressure measuring	Pressure is correctly measured	TBT
	Voltage measuring	Voltage is correctly measured	TBT
	GPS data is available	GPS data can be read by FSW	TBT
	GPS NMEA frame is correctly decoded	GPS time, latitude, longitude, altitude and sats are available	TBT
	Sensors can be calibrated and return zero values when stationary on ground	Values read from sensors are zeroed	TBT
CDH	File System is properly initialized on SD Card	File system initialization success	TBT
	SD Card is ready for writing data	File system returns success when saving files	TBT
	SD Card is accessible, data can be read	File system allows fore reading files, data in files are correct	TBT
	Data saved on SD Card survives resets and power downs	Files are consistently available	TBT
	Real-Time Clock measures time	Times of CanSat and GS are in-sync during the tests	TBT

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	TBT
	Temperature sensor is powered	Proper voltage on necessary pins is measured	TBT
	GPS sensor is powered	Proper voltage on necessary pins is measured	TBT
	Voltage sensor is powered	Proper voltage on necessary pins is measured	TBT
	Camera is powered	Proper voltage on necessary pins is measured	TBT
	Processor is powered	Proper voltage on necessary pins is measured	TBT
	microSD card is powered	Proper voltage on necessary pins is measured	TBT
	PCB doesn't have shortcuts	PCB has no shorts to ground or power lines	TBT
	PCB is properly soldered	Joints are properly soldered, there are no cold joints	TBT
	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	TBT
	Voltage regulators and DC converters work properly	Proper voltage on all power lines under load	TBT
	IMU is powered	Proper readings from the sensor given the positioning	TBT
	Xbee is powered	Proper voltage on necessary pins is measured	TBT

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	TBT
	XBee Radio can transmit data	Data sent from FSW can be read on PC with XBee	TBT
	XBee radios NETID/PANID is set to their team number	NETID/PANID is set to 1082	TBT
	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	TBT
	GCS can connect with the CanSat	The connection is reached and stable	TBT
	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.
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 parachutes opening, the parachutes ejection system and the flag raising system will be carried out.

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 are conducted using the Competition Guide directions

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.

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

Each role's responsibilities will be attached in the remaining two slides of this section.

- **Ground station assembly:**

We want to make our design simple to be fast executed during launch day. The laptop will be properly connected to XBee Radio via a USB adapter and connected to the dipole antenna Cansat will communicate with ground station via antennas . The payload will communicate with the radio through antennas connected by a splitter.

- **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 assembly (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

- 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)

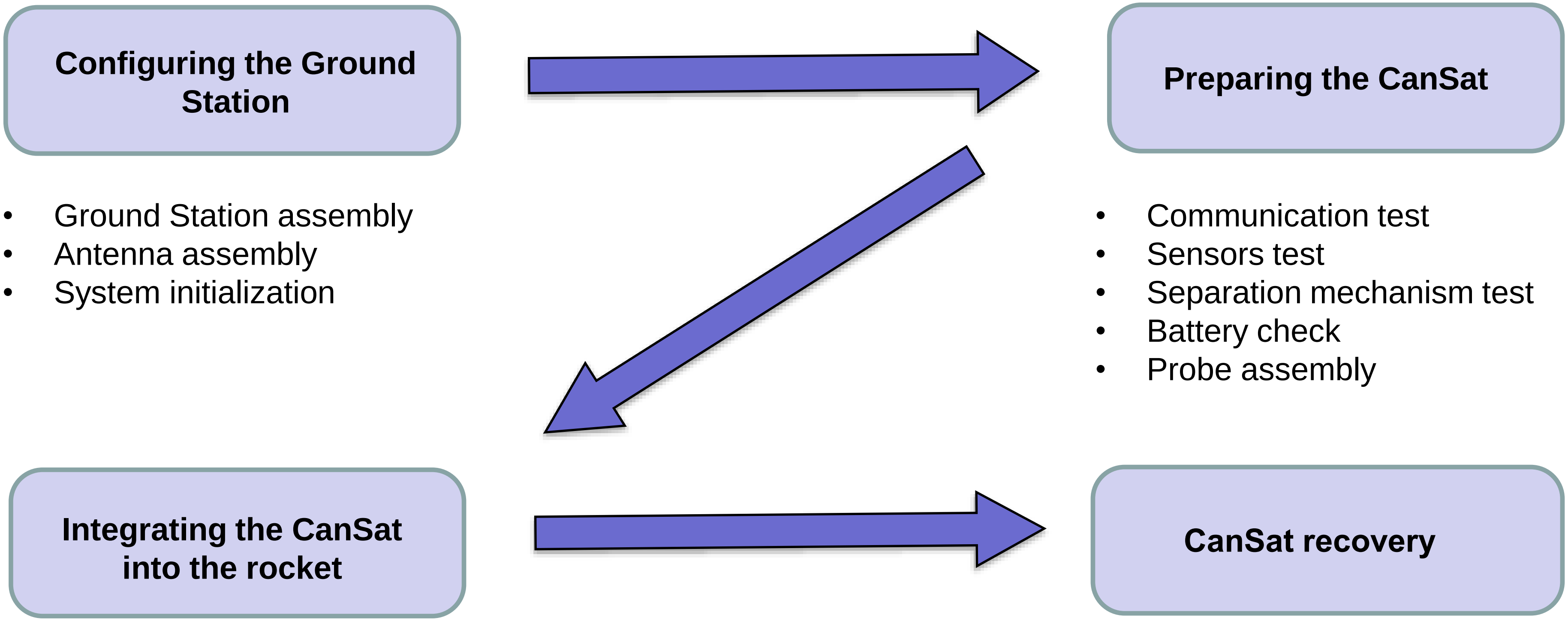
Post-launch

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

Mission Operations Manual Development Plan (1/2)

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. The Mission Operation Manual will be assembled into a three-ring binder and include not only Mission Sequence but team members' roles and safety instructions as well.	However, 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 on the next slide.

Mission Operations Manual Development Plan (2/2)



Configuring the Ground Station

- Ground Station assembly
- Antenna assembly
- System initialization

Preparing the CanSat

- Communication test
- Sensors test
- Separation mechanism test
- Battery check
- 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

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 orange 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 loud) will be activated after touchdown. • Mast with flag will be raised after landing.
Labeling
Payload and container will be labeled with the team email address, contact informations and phone number.

Requirements Compliance

Hubert Kulik

Requirements Compliance Overview

Current state of design meets all requirements although some changes may appear before 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	86	
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	23	
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	27	
4	The container shall be a fluorescent color; pink, red or orange.	Comply	139	
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	51	
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	27	
7	The rocket airframe shall not be used as part of the CanSat operations.	Comply	27	
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	56, 57	
9	The Parachutes shall be fluorescent Pink or Orange	Comply	139	

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	46	
11	0 altitude reference shall be at the launch pad.	Comply	110, 122	
12	All structures shall be built to survive 15 Gs of launch acceleration.	Comply	52, 60	
13	All structures shall be built to survive 30 Gs of shock.	Comply	52, 60	
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	77, 78	
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	61	
16	Mechanisms shall not use pyrotechnics or chemicals.	Comply	57	
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	72	
18	Both the container and probe shall be labeled with team contact information including email address.	Comply	49, 57	

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	153	
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	94	
21	XBEE radios shall have their NETID/PANID set to their team number.	Comply	95	
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	55, 21, 63	
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	22, 53	
25	An audio beacon is required for the probe. It shall be powered after landing.	Comply	22, 139, 110	
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	Comply	139	
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	104	

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	21, 22	
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	104	
30	The Cansat shall operate during the environmental tests laid out in Section 3.5.	Comply	131	
31	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Comply	105	
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Comply	25, 26	
33	The probe shall deploy a heat shield after leaving the container.	Comply	26, 110	
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	Comply	26	
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/- 1m/sec.	Comply	46, 25, 26	
36	Once landed, the probe shall upright itself.	Comply	110	

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	110	
38	The probe shall transmit telemetry once per second.	Comply	110	
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	98	
40	The probe shall include a video camera pointing down to the ground.	Comply	63, 58	
41	The video camera shall record the flight of the probe from release to landing.	Comply	110	
42	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	35, 36	
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	111	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	111	
46	The probe shall have its time set to within one second UTC time prior to launch.	Comply	110	

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	112	
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	112	
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	112	
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	122	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	122	
52	Telemetry shall include mission time with 1 second or better resolution.	Comply	96	
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Comply	111	
54	Each team shall develop their own ground station.	Comply	116	
55	All telemetry shall be displayed in real time during descent on the ground station.	Comply	122	

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	122	
57	Teams shall plot each telemetry data field in real time during flight.	Comply	123	
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	117	
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	117	
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	122	
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	122	

*Req 43 was skipped in the mission guide.

Management

Hubert Kulik

CanSat Budget – Hardware (1/4)

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
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 (2/4)

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
Servo	SG90	1	1.84	1.84	Actual
Pitman arm	ABS	1	0.01	0.01	Estimated
Magic stick latch	Steel	1	0.02	0.02	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
Servo	SG90	1	1.84	1.84	Actual
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 (3/4)

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
Payload					
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 (4/4)

Component	Model/Material	Quantity	Price [USD]	Total	Status
Memory Card	SanDisk microSDHC 16GB	1	5.80	5.80	Actual
Battery	Panasonic NCR18650B	1	7.40	7.40	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

Total cost [USD]	
Container	56.37
Payload	242.20
Total	298.57

Prices were converted from Polish złoty to dollars using current exchange rate, which was USD/PLN = 4.30 at the time.

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

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	
Printed material,	
Total [PLN/USD]	300.0 / 69.45

CanSat Budget – Other Costs (2/2)

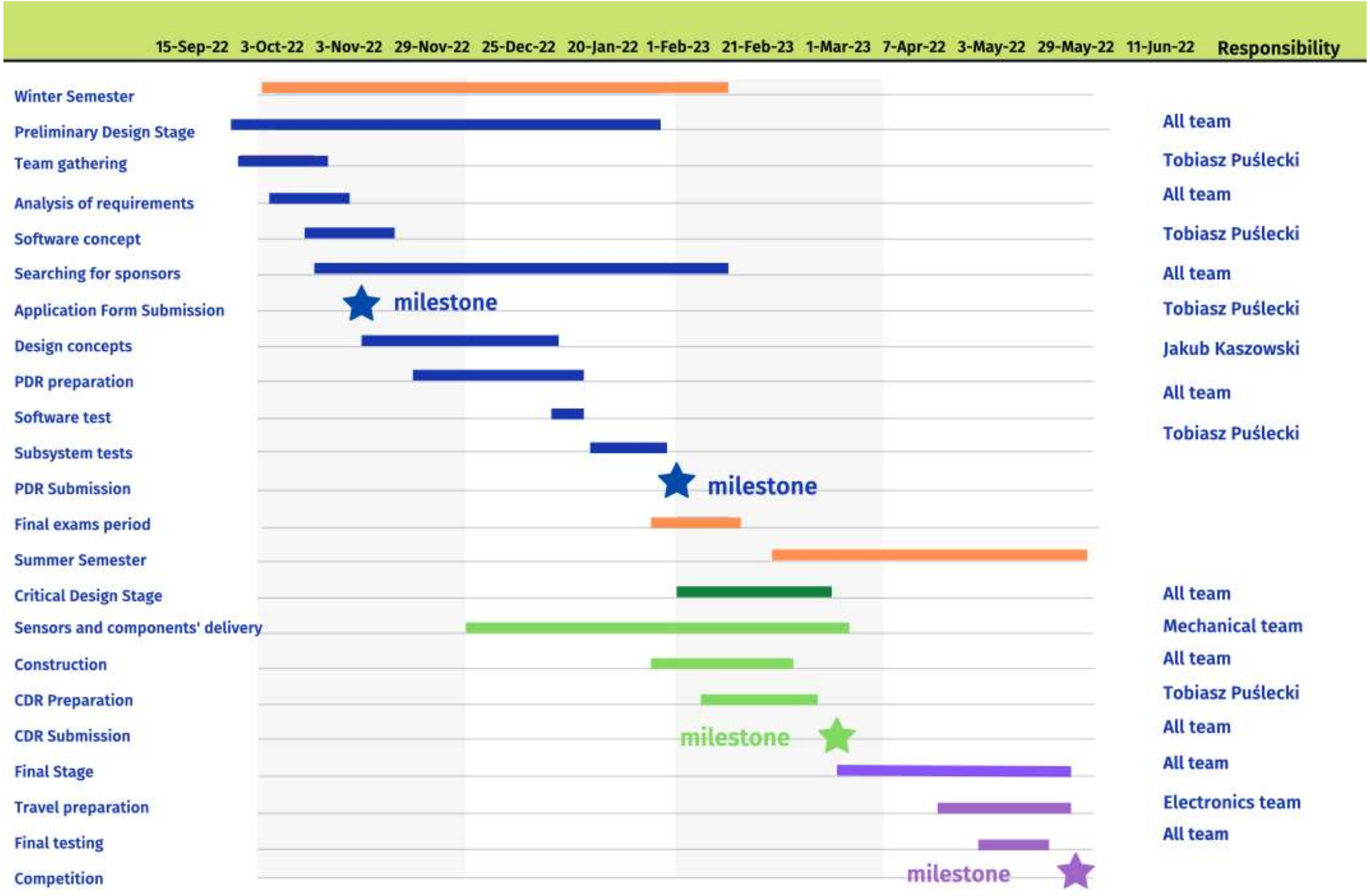
Attending cost	Quantity	Price [PLN/USD]	Total [PLN/USD]
Travel	10	4 200/ 1 000	42 000/ 10 000
Accommodation	10	4 100/ 976	41 000/ 9 760
Meals	10	1 100/ 261	11 000/ 2 610
Car rent + fuel	2	6 850/ 1 630	13 700/ 3 260
Fee	1	840/ 200	840/ 200
Total cost			108 540/25 830

However, we allow the possibility that the number of team members may change.

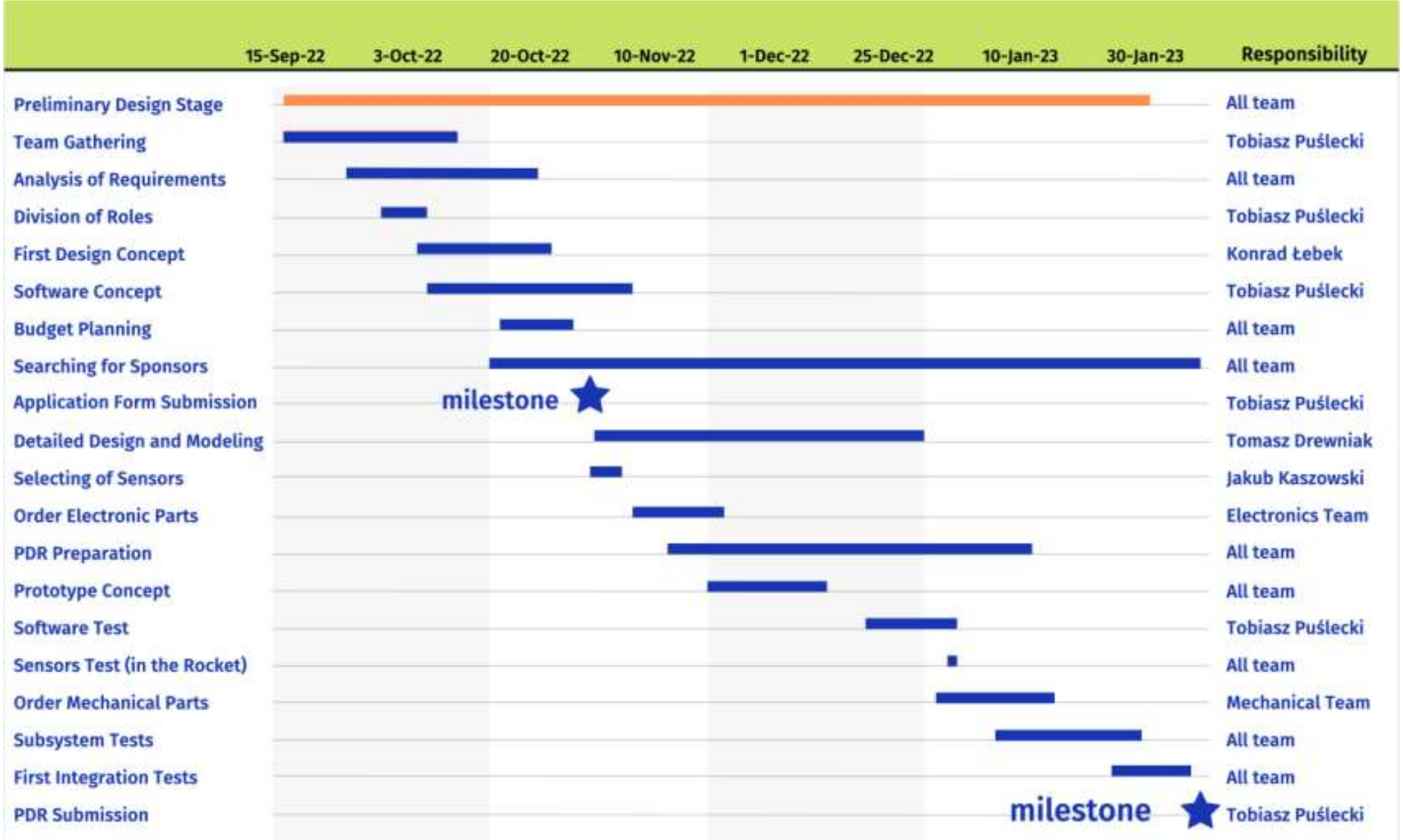
Overall mission cost [USD]	26 451.94

Sources of income [PLN/USD]	
University	97 950/ 23 321
Sponsors	25 000 / 5 952.38

Program Schedule Overview

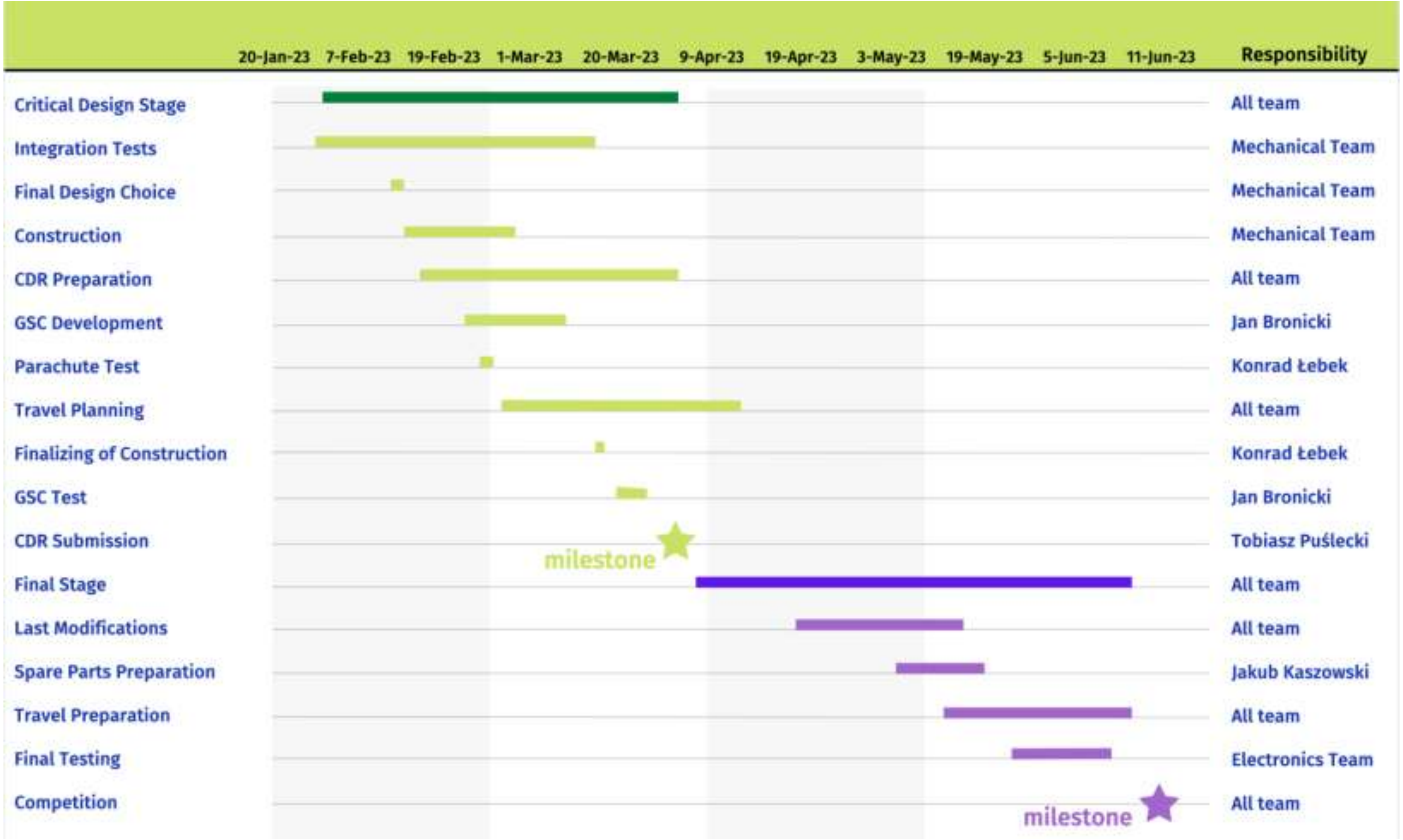


Detailed Program Schedule 1/3



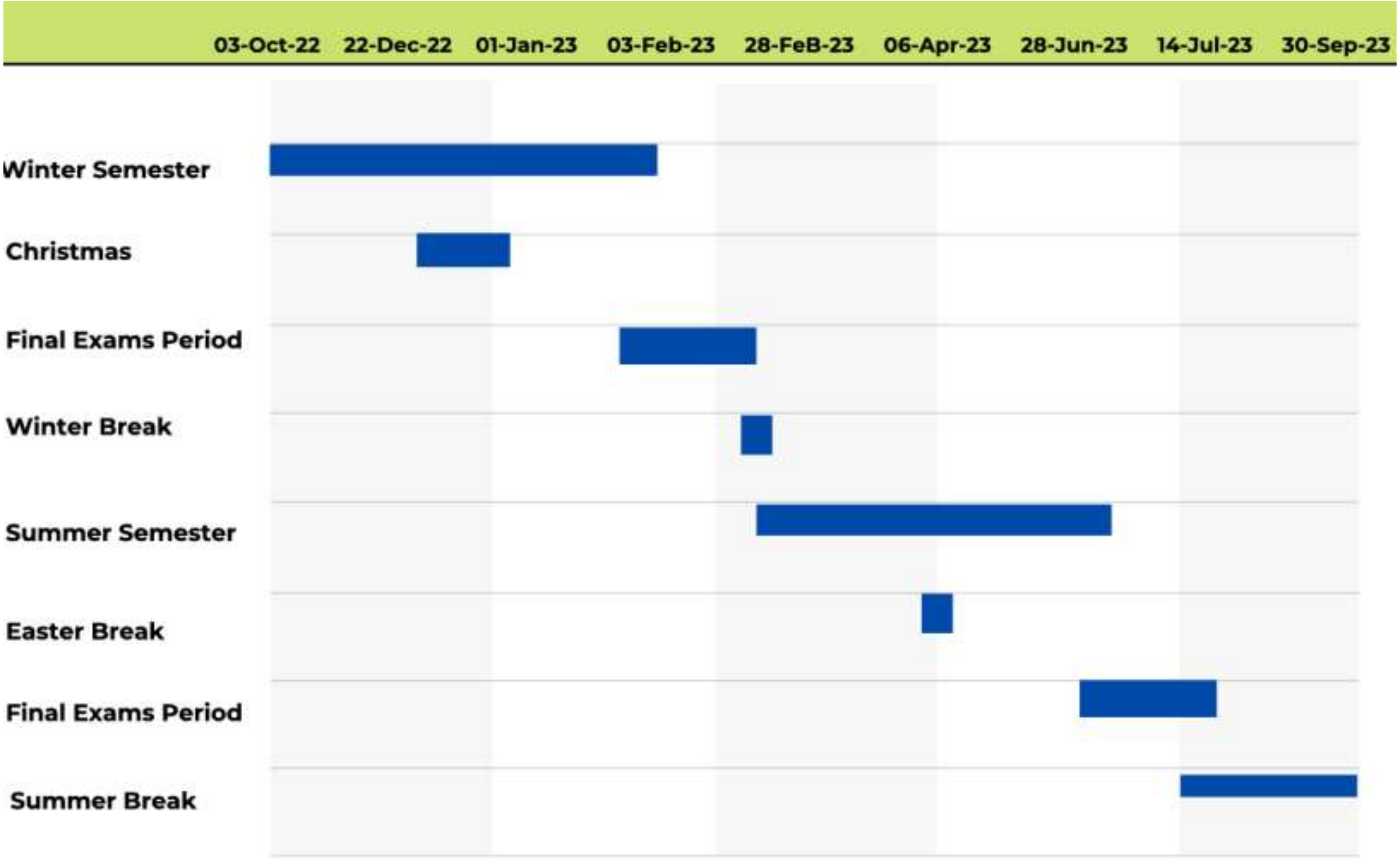
Task	Responsibility
Preliminary Design Stage	All team
Team Gathering	Tobiasz Puślecki
Analysis of Requirements	All team
Division of Roles	Tobiasz Puślecki
First Design Concept	Konrad Łebek
Software Concept	Tobiasz Puślecki
Budget Planning	All team
Searching for Sponsors	All team
Application Form Submission	Tobiasz Puślecki
Detailed Design and Modeling	Tomasz Drewniak
Selecting of Sensors	Jakub Kaszowski
Order Electronic Parts	Electronics Team
PDR Preparation	All team
Prototype Concept	All team
Software Test	Tobiasz Puślecki
Sensors Test (in the Rocket)	All team
Order Mechanical Parts	Mechanical Team
Subsystem Tests	All team
First Integration Tests	All team
PDR Submission	Tobiasz Puślecki

Detailed Program Schedule 2/3



	Responsibility
Critical Design Stage	All team
Integration Tests	Mechanical Team
Final Design Choice	Mechanical Team
Construction	Mechanical Team
CDR Preparation	All team
GSC Development	Jan Bronicki
Parachute Test	Konrad Łebek
Travel Planning	All team
Finalizing of Construction	Konrad Łebek
GSC Test	Jan Bronicki
CDR Submission	Tobiasz Puślecki
Final Stage	All team
Last Modifications	All team
Spare Parts Preparation	Jakub Kaszowski
Travel Preparation	All team
Final Testing	Electronics Team
Competition	All team

Detailed Program Schedule 3/3



Conclusions

Accomplishments

- A team of competent people was formed. Tasks and responsibilities were assigned.
- Teamwork has been organized and conducted according to principles of Scrum methodologies including weekly online meetings.
- Mechanical and electronic systems have been designed.

Unfinished work

- Funding is yet to be obtained.
- All systems need to be developed and tested, after then all changes which will come up, have to be implemented in the existing design.
- Development and test stages will be planned in detail.

Readiness for the Critical Design Stage

- Most of electronic and mechanical parts are to be delivered or funds for them are secured.
- Interviews with sponsors are underway.
- The developed software will be completed and tested on an electronic system that will be constructed.