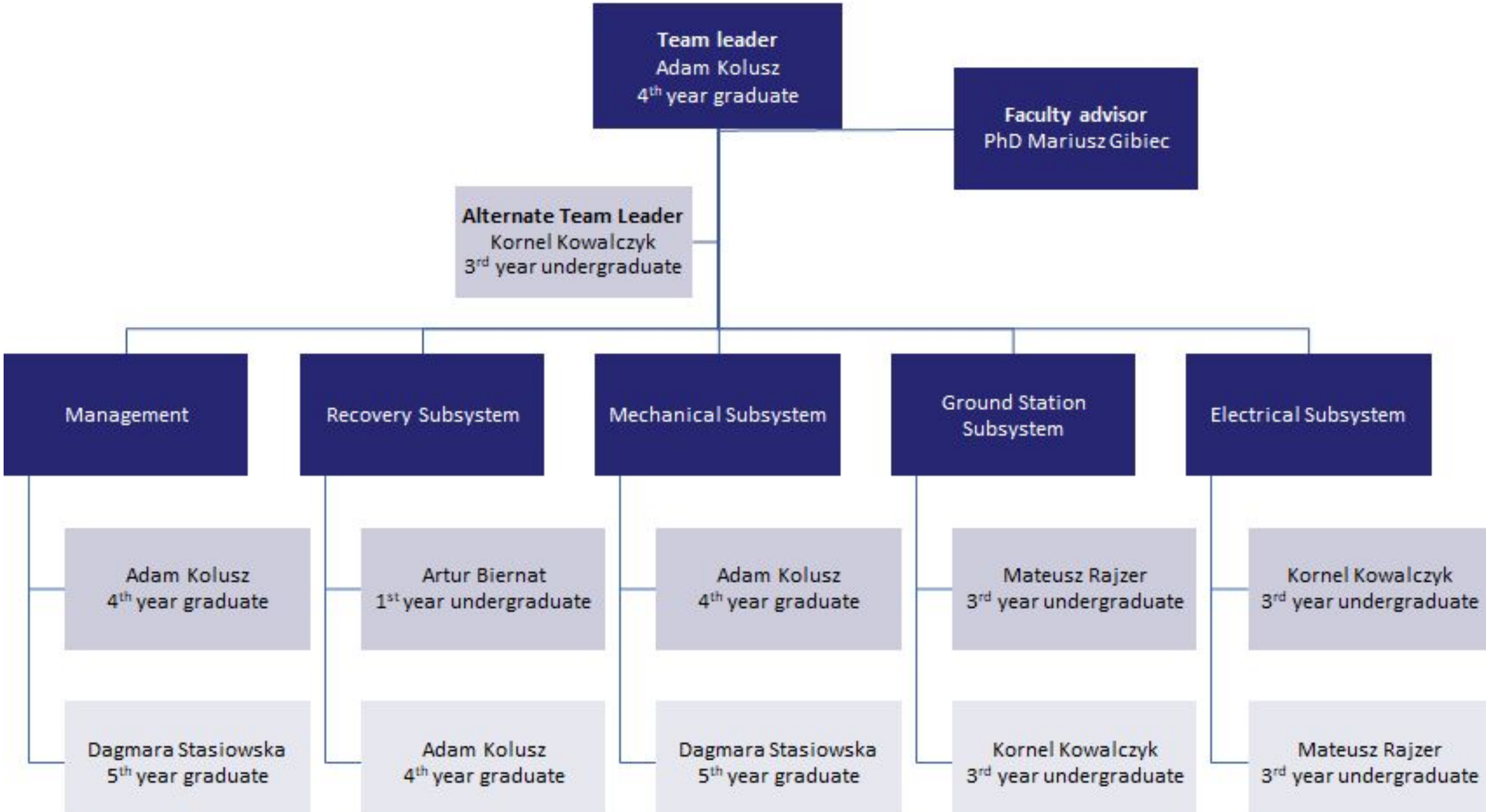
CanSat 2019
Critical Design Review (CDR)
Outline
Version 1.1

#3193

AGH Space Systems

Presentation Outline

Team Organization



Acronyms

Acronym	Explication
3D	Three dimensional
A	Analysis
ABS	Acrylonitrile butadiene styrene
AC	Alternating current
ADC	Analog to digital converter
AT	Advanced Technology
AUX	Auxiliary
CDH	Communication and Data Handling
CDR	Critical Design Review
CGS	Centimetre–gram–second system of units
COTS	Commercial off-the-shelf
CPU	Central processing unit
CSV	Comma-separated values
D	Demonstration
dB	Decibel
DB	D-subminiature electrical connector
DIP	Dual In-line Package
EPS	Electrical Power Subsystem
FPS	Frames per second
FSW	Flight Software
GCS	Ground Control System
GGA	NMEA data format
GMT	Greenwich Mean Time
GPIO	General-purpose input/output

Acronym	Explication
GPS	Global Positioning System
GS	Ground Station
GUI	Graphical user interface
Hz	Hertz
I	Inspection
I2C	Inter-Integrated Circuit
IC	Integrated Circuits
IMU	Inertial measurement unit
JSON	JavaScript Object Notation
LED	Light-emitting diode
MPU	Microprocessing Unit
NETID	Network Identifier
Ni-Cad	Nickel–cadmium battery
Ni-MH	Nickel–metal hydride battery
NMEA	National Marine Electronics Association's communication specification
Pa12+CF	Polyamide (nylon) + Carbon Fiber Filament
PANID	Previous Access Network Identifier
PC	Personal Computer
PCB	Process Control Block
PDR	Preliminary Design Review
PET	Polyethylene terephthalate
PID	Proportional–integral–derivative controller
PFR	Post Flight Review
PIFA	Planar inverted-F antenna

Acronym	Explication
PLA	Polylactic acid
PLN	Polish Zloty New - Polish currency
PMMA	Poly(methyl methacrylate)
Proc	Procedures
PVC	Polyvinyl chloride
PWM	Pulse Width Modulation
RP-SMA	Reverse Polarity SubMiniature version A
Rqmts	Requirements
RTC	Real-Time Clock
SD	Secure Digital
SH	Bourne shell
SL	Scientific Linux
SP	Science Payload
SPI	Serial Peripheral Interface
STM	Short-Term Memory
SW	Software
T	Test
TTL	Transistor-transistor logic
UART	Universal Asynchronous Receiver-Transmitter
USB	Universal Serial Bus
UART	Universal Synchronous/Asynchronous Receiver-Transmitter
USD	United States Dollar
UV	Ultraviolet
VM	Verification Method

System Overview

Kornel Kowalczyk

Mission Summary

Mission Objectives
Deploy CanSat at an altitude of 670 meters to 725 meters above the launch site ground level.
Release SP at 450 meters and keep descent rate at 10 to 15 meters/sec using auto-gyro mechanism.
Collect telemetry data after deployment from a rocket and transmit it to the GS in real time.
Proceed safely to recovery mode after touchdown.
Bonus objectives
Include a video camera to capture release of SP and final 450 meters of descent.
SP shall be spin stabilized.
Rationale of choosing this bonus objective is to obtain flight video which is good feedback material
External Objectives
Our personal objective is to implement adaptive control system in order to provide spin stabilized descent. Mastering this technology will bring us closer to implementing this type of control in our next CanSat and rocket projects.

Summary of Changes Since PDR

Subsystem	Changes
Sensor	No changes
Descent Control	Increased parachute diameter
	Different nylon fabric
	Different shroud lines
Mechanical	Removal of few glass fibre layers of container
	Bearing mount system improvement
	Variation of rotor hub size
	Addition of rubber band tensioner
Communication and Data Handling	No changes
Electrical Power	No changes
Flight Software	No changes
Ground Control	Ground station antenna has been changed

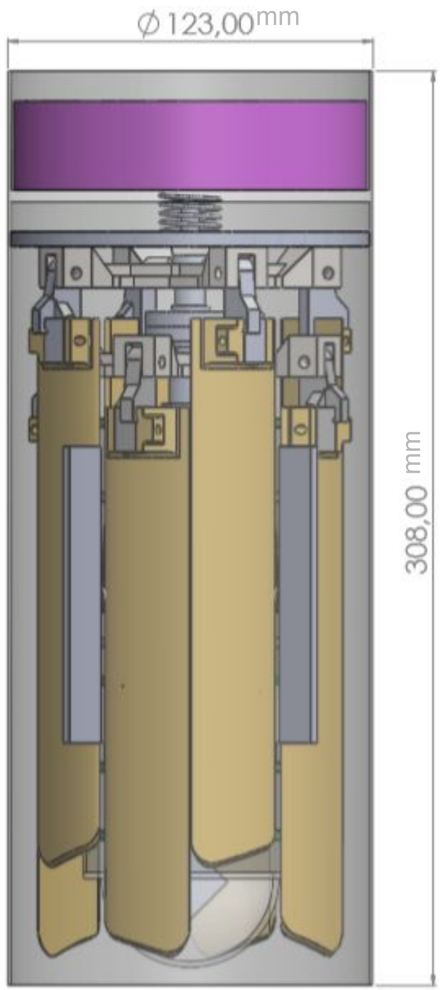
System Requirement Summary 1/2

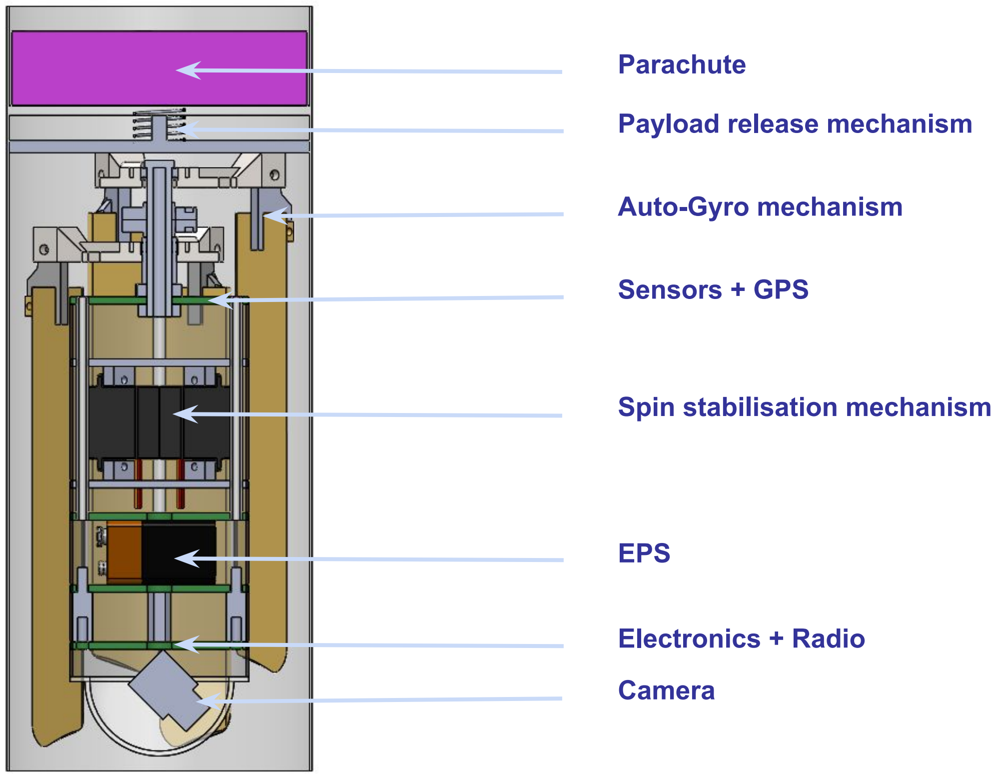
ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
1	Total mass of the CanSat (probe) shall be 500 grams +/- 10 grams	Competition requirement	Total mass of CanSat is not exceeding imposed tolerances	High	x		x	
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Competition requirement.	The CanSat is designed with appropriate dimensions	High		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.	Blockage in rocket compartment would cause failure of whole mission.	All sharp edges will be chamfered	High	x	x		
4	The container shall be a fluorescent color; pink, red or orange.	Competition requirement.	CanSat is pink.	Medium		x		
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Competition requirement. To lower the risk of CanSat getting stuck in rocket.	Airframe of the rocket is not used by CanSat	High		x		
6	The rocket airframe shall not be used as part of the CanSat operations.	Competition requirement. CanSat should be separate autonomous system.	Airframe of the rocket is not used by CanSat.	High		x		
7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	Competition requirement. CanSat has to descent separately from rocket	CanSat will be released from rocket after separation.	High		x		
9	The container shall release the payload at 450 meters +/- 10 meters.	Competition requirement. To let aero-gyro mechanism work.	Payload will be released from the container at 300m.	High		x		
10	The science payload shall descend using an auto-gyro descent control system.	Competition requirement.	Science payload is designed to use auto-gyro descent control system.	High			x	
18	Mechanisms shall not use pyrotechnics or chemicals.	Competition requirement. To assure safety during competition.	No pyrotechnics or chemicals are used.	High		x		

System Requirement Summary 2/2

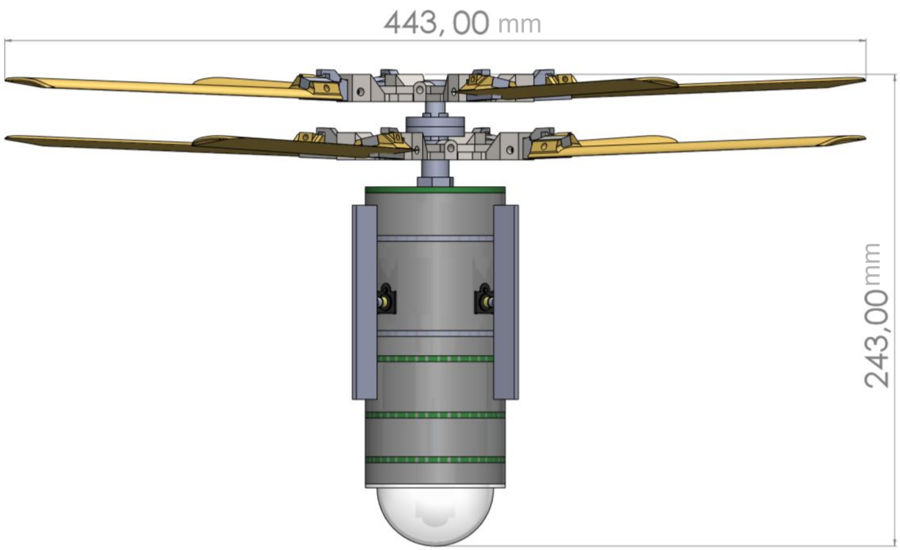
ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
19	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	Competition requirement. To assure safety during competition.	Nichrome wire mechanism will be properly covered.	High		x		
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Competition requirement.	Early assessment of budget shows that cost is under $1000.	Medium	x			
35	Each team shall develop their own ground station.	Competition requirement. Enables communications with CanSat.	GS will be developed.	High		x		x
44	No lasers allowed.	Competition requirement. To assure safety during competition.	CanSat does not contain lasers	High		x		
45	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	Competition requirement.	Probe will include easily accessible power switch.	Medium		x		
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Competition requirement. To make search of the CanSat easier.	CanSat has an audio beacon.	Medium		x		
50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Competition requirement.	Probe will include easily accessible battery compartment.	Medium	x			
54	The CANSAT must operate during the environmental tests laid out in Section 3.5.	Competition requirement	Necessary test will be conducted	High	x	x	x	
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Competition requirement.	Probe will be designed to be able to operate for more than two hours.	Medium	x			

Payload Physical Layout
Launch Configuration

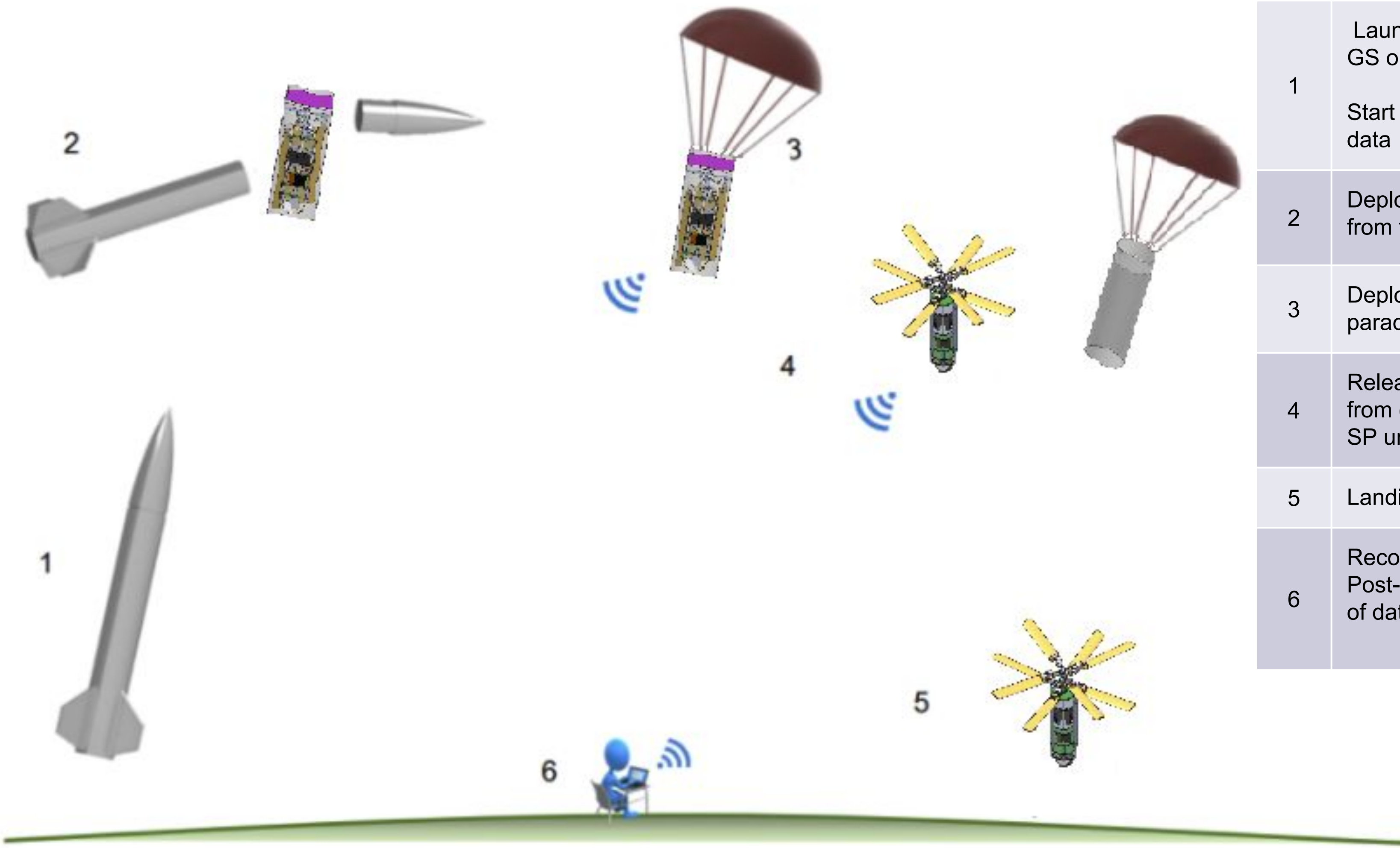




Payload Physical Layout Deployed Configuration



System Concept of Operations 1/3



Operations	
1	Launch and start GS operation Start sending data
2	Deploy Cansat from the rocket
3	Deploy parachute
4	Release the SP from container, SP unfolds rotors
5	Landing
6	Recovery and Post-processing of data in the GS

System Concept of Operations 2/3

CanSat operations	Recovery
Turn on the CanSat, test radio communication, and place it in rocket payload section.	Track the probe (using GPS, buzzer, fluorescent color).
Deploy from the rocket and open the parachute.	Turn off the power.
Make measurements and transmit data packets.	Return to the GS.
Release SP and unfold rotors	Retrieve and extract data from the probe.
Descent maintaining spin stable orientation.	Analyse the data correctness.
Record a video from the flight.	Filter data if needed.
	Create the report for the PFR

System Concept of Operations 3/3

Task	Team member assigned
CanSat assembly	Adam Kolusz, Dagmara Stasiowska
Operating ground station	Mateusz Rajzer, Kornel Kowalczyk
Electronics check	Mateusz Rajzer
Communication check	Mateusz Rajzer, Kornel Kowalczyk
CanSat loading to the rocket	Adam Kolusz
CanSat recovery	Artur Biernat, Dagmara Stasiowska

Launch Vehicle Compatibility

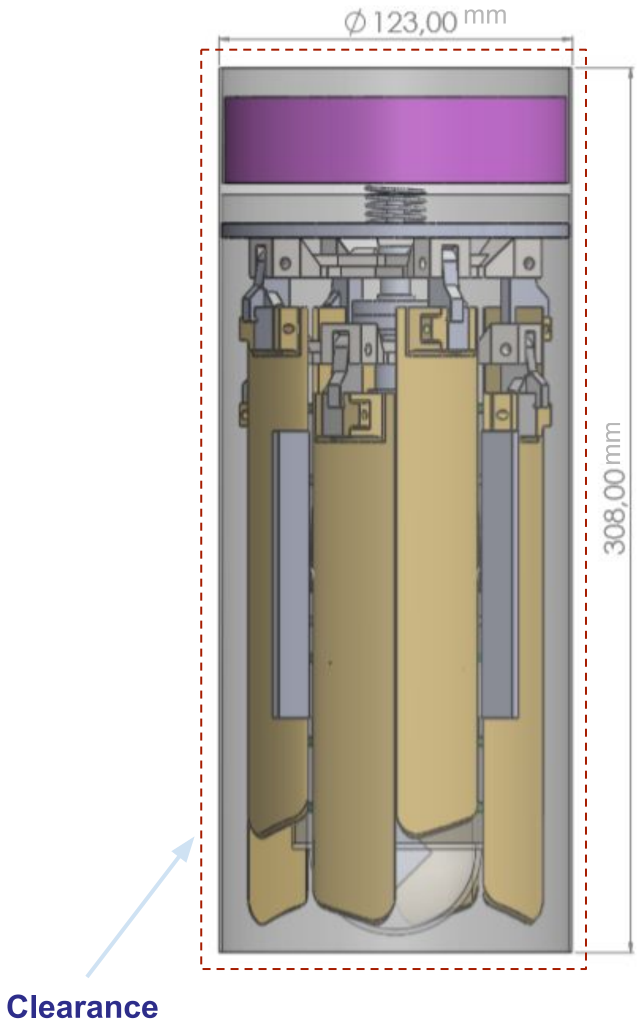
Element	Height [mm]	Diameter [mm]
Rocket payload section	310	125
Probe	308	123

Proper sizing of probe makes direct impact on the mission execution and success. Therefore the structure was designed with safe tolerances:

- 2 mm for height
- 2 mm for diameter

These guarantee that the probe will fit into the rocket payload section. Also, there are no sharp edges on the outside structure of CanSat.

The compatibility with the rocket was verified with a pre-built rocket payload section of our testing rocket during rocket tests.



Sensor Subsystem Design

Mateusz Rajzer

Sensor Subsystem Overview

Sensor type	Model	Sensor's role in subsystem
Tilt sensor	MPU - 9250	Measurement: - Tiilt values on X, Y, Z axes
Air pressure sensor & Air temperature sensor	MS5607	Measurement: - Pressure (altitude) - Air temperature outside the probe
Voltage measurement	Voltage divider, CPU's ADC converter	Measurement: - Current battery voltage
Camera	SQ9	Video recording
GPS	UBLOX NEO-M8	Measurement: - Latitude - Longitude - Altitude - Time - Satellites number
Hall sensor	SS411P	Measurement: -blade rotation frequency

Sensor Changes Since PDR

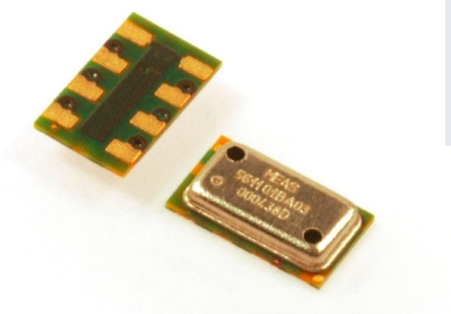
There are no changes since PDR.

Sensor Subsystem Requirements

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Electronics must be protected from the environment.	Electronics is enclosed in the fiber glass SP tube.	High	x	x		
20	The science payload shall measure altitude using an air pressure sensor.	Competition requirement. Altitude must be known for mission objectives fulfillment.	Air pressure is measured.	High	x			
21	The science payload shall provide position using GPS.	Competition requirement. GPS lets us track probe.	GPS position will be provided.	High	x		x	
22	The science payload shall measure its battery voltage.	Competition requirement. Battery voltage lets us predict how long SP can operate.	Battery voltage will be measured.	High	x		x	
23	The science payload shall measure outside temperature.	Competition requirement.	Outside temperature is measured.	High	x			x
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	Competition requirement.	Spin rate of the auto-gyro will be measured as relative to the SP as the Hall sensor is fixed.	High	x			
25	The science payload shall measure pitch and roll.	Competition requirement. Pitch and roll ensures us about SP stability.	Pitch and roll will be measured by MPU.	High	x			
53	The GPS receiver must use the NMEA 0183 GGA message format.	Competition requirement	Chosen GPS uses desired format	High	x	x		

Payload Air Pressure Sensor Summary

Sensor	Measurement range [hPa]	Resolution [hPa]	Accuracy [hPa]	Communication interface	Operating voltage [V]	Power consumption [uA]	Cost [$]	Dimension [mm]	Mass [g]
MS5607	10 - 1200	0.024	1.5	I2C, SPI	1.8 - 3.6	12.5	2.68	5.0 x 3.0. x 1.0	1



Data format and equations

Chosen sensor transmits its data as 24bit ADC readings of a piezo - resistive sensor. This means, that 3 bytes are transmitted to CPU during every measurement cycle.

Altitude will be calculated from pressure with following formula:

$$Altitude = 44330 \cdot \left(1 - \left(\frac{P}{P_0}\right)^{0.190264}\right)$$

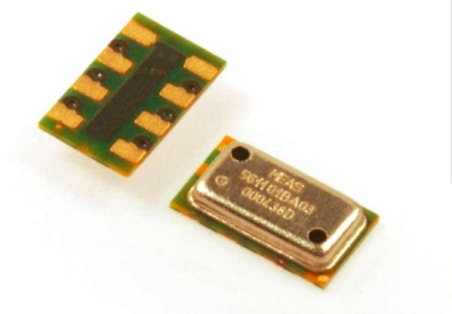
where:

P - current pressure

P_0 - reference pressure

Payload Air Temperature Sensor Summary

Sensor	Measurement range [hPa]	Resolution [hPa]	Accuracy [hPa]	Communication interface	Operating voltage [V]	Power consumption [uA]	Cost [$]	Dimension [mm]	Mass [g]
MS5607	10 - 1200	0.024	1.5	I2C, SPI	1.8 - 3.6	12.5	2.68	5.0 x 3.0. x 1.0	1



Data format and equations

Chosen sensor transmits its data as 24bit ADC readings of a semiconductor temperature sensorsensor. This means, that 3 bytes are transmitted to CPU during every measurement cycle.

Temperature shall be calculated from raw data using formula:

$$Temp = 2000 + \frac{PROM1 * (RAW - PROM2 * 2^{8})}{2^{23}}$$

where:
PROM1, PROM2 – preprogrammed values in sensor's memory,
RAW – bit value read from sensor's register.

GPS Sensor Summary

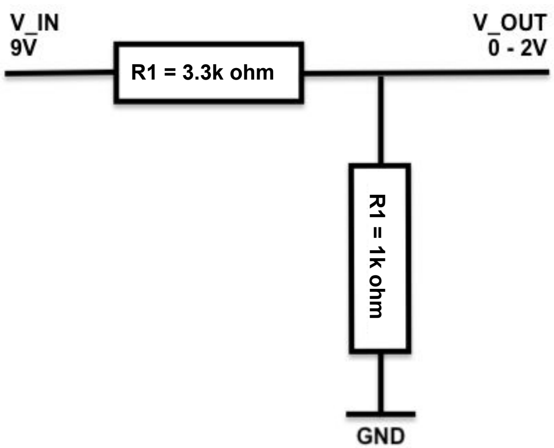
Sensor	Accuracy [m]	Update rate [Hz]	Communication interface	Operating voltage [V]	Current Consumption [mA]	Cost [$]	Dimension [mm]	Weight [g]
UBLOX NEO-M8	2.5	10	UART / SPI	1.65 - 3.60	26	7.7	9.6 x 14.0 x 1.95	0.5

Data format and equations

GPS module is communicated with CPU with UART bus. Every measurement cycle two 32bits floats will be read from the sensor - latitude and longitude.
No additional calculation is needed. Module allows to use NMEA 0183 GGA format.

Payload Voltage Sensor Summary

Sensor	Accuracy [mV]	Resolution [mV]	interface	Current consumption [mA]	Cost [$]	Dimension [mm]	Weight [g]
Voltage divider + CPU's ADC	0.1	8.0	Analog	2	0.1	3.0 x 3.0 x 0.6	0.004



Data format and equations

STM32F103 is equipped with 12bit ADC converter. Battery voltage will be divided on 3.3k and 1k resistors. This way, maximum voltage which can appear on ADC input is 2.15V. Following calculations will be performed with ADC measurement:

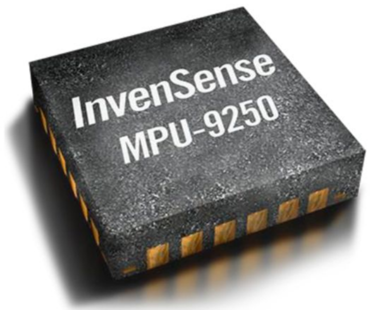
12bits = 4096 steps (4095 max. value)

ADC reading in mV = (ref_voltage / 4095) * adc_result

Above outcome needs to be multiplied by 4.3 to get actual battery voltage

Pitch/Roll Sensor Summary

Sensor	Accuracy [mG]	Resolution [bits]	Communication interface	Supply voltage [V]	Current Consumption [mA]	Cost [$]	Dimension [mm]	Weight [g]
MPU9250	60	16	SPI, I2C	2.4-3.6	0.28	7.90	3.00 x 3.00 x 1.00	< 1



Data format and equations

As MPU9250 is 16 bits sensor, it returns two bytes of acceleration value for every measurement loop cycle, either for accelerometer and gyroscope readings.
Raw values needs to be converted for usable units

For gyroscope calculations are as follows:

Gyro_Rate = Gyro_Raw * Gain
Gyro_Angle += Gyro_Rate * dt, where “dt” is time between loops

And for accelerometer:

Accel_Angle = Arcus_Tangent(Accel_Raw_X, Accel_Raw_Y + PI)
Calculated value, needs to be now converted from radians to degrees (i.e. multiply by 57.29578).

Both readings are then combined in complementary filter to avoid gyro bias and filter linear acceleration noises of accelerometer:

Current_Angle = 98% * (Current_Angle + Gyro_Rate) + (2% * Accel_Angle)

Auto-Gyro Blade Spin Rate Sensor Summary

Sensor	interface	Supply voltage [V]	Package	Cost [$]
SS411P	TTL	2.7 – 7.0	TO92	0.53

Data format and equations

Hall sensor shall generate pulse everytime blades do a full rotation, triggered by a magnet attached to one of blades. This in tern will generate series of pulses which duration can be measured by microcontroller's internal timer. Using this data we can calculate blade's spin rate using formula:

$$F_{RPM} = 60 * \frac{1}{t}$$

Where *t* is time between pulses

Bonus Objective Camera Summary

Sensor	FPS	Resolution [px]	Communication interface	Current Consumption [mA]	Cost [$]	Dimension [mm]	Weight [g]
SQ9	30	1280 x 720	Buttons emulation	150	10	22.0 x 16.0 x 22.0	20

Reasons for choosing SQ9:

Chosen camera has been stripped of its metal casing to save weight and equipped with small PCB board which emulates action of pressing the power and play/pause button. This board automatically turns the camera on and starts recording when connected to power supply and turns off after saving the video. This solution not only offloads the microprocessor, but also ensures that no recording is lost after unanticipated power-down of the main board. Video from the camera has been verified to fulfill CanSat requirements.

Container Air Pressure Sensor Summary

There are no electronics in the container.

Descent Control Design

Artur Biernat

Descent Control Overview

Descent Control System is composed of a parachute for the Container and the foldable auto-gyro mechanism for SP.

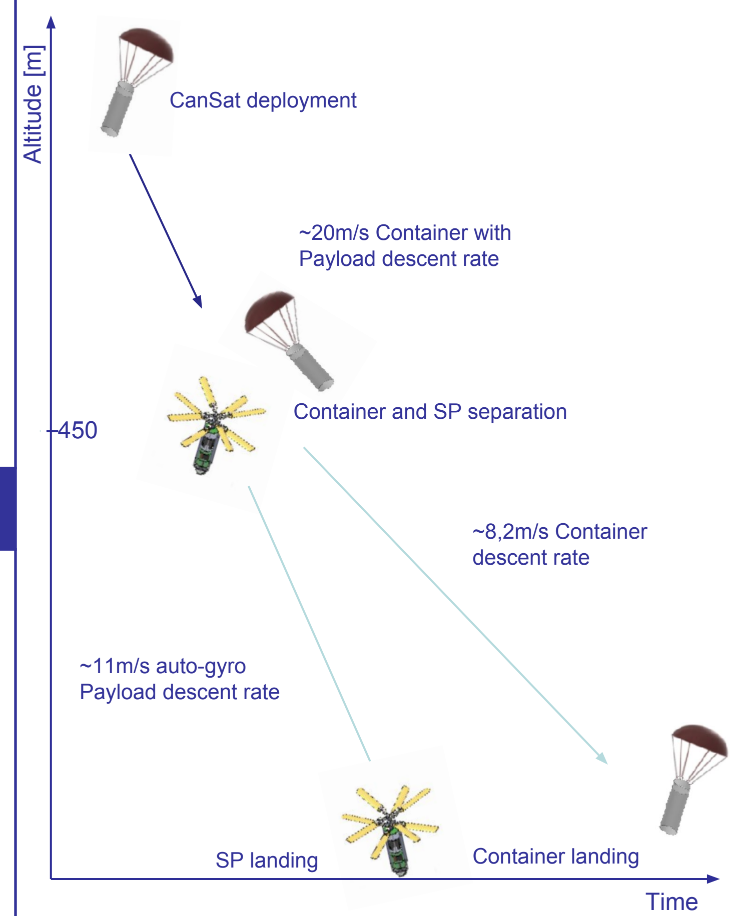
Container and Payload descent control system overview

- Container parachute is being deployed immediately after rocket separates at apogee,
- Semi ellipsoid canopy parachute with diameter of 18.5cm keeps CanSat's descent rate on ~20m/s,
- 4cm in diameter spill hole is cut in the parachute to ensure continuous air flow, avoid unwanted swaying, and slightly increases descent rate,
- Swivel with bearing prevents shroud lines from tangling during entire descent,
- Dacron line absorbs shock and joins parachute with container
- Container's parachute is fluorescent colour.

SP descent control system overview

- SP is deployed from the Container by cutting a nylon string, which connects them, with resistance wire under high current (hotwire mechanism),
- SP deployment mechanism is triggered when the altitude drops below 450m.
- SP is being deployed with use of spring that will push out the piston and the payload of the container

Descent control strategy



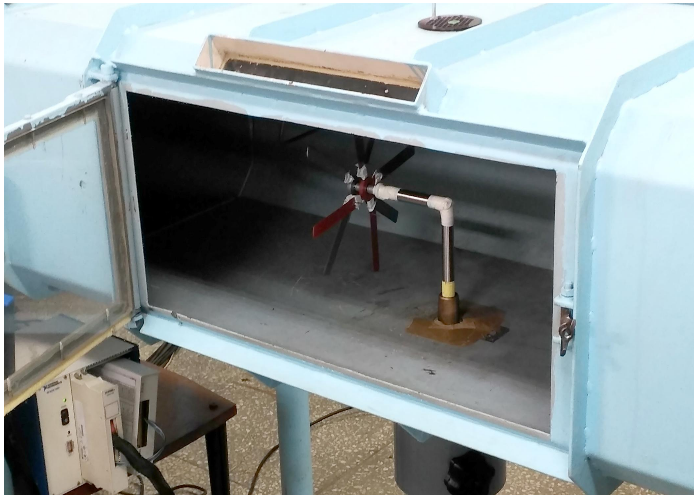
Descent Control Changes Since PDR

Change	Rationale
Increased parachute diameter	Due to bigger permeability factor of new fabric, parachute diameter was increased by 2cm, to keep steady descent at 20m/s rate.
Different nylon fabric	Parachute fabric changed for lighter and more durable nylon fabric, which will provide better overall performance.
Different shroud lines	Previously used thick paracord lines are changed for lighter, thinner and more durable dacron lines.

Prototype testing

Several drop tests were carried out to check if all mission requirements are fulfilled. During those test, every part of descent control system thoroughly verified and optimized to obtain effective performance.

We also had opportunity to run some tests in wind tunnel. That was extremely important as we could test propellers and make few shape corrections that could help us get proper descent rate.



Descent Control Requirements

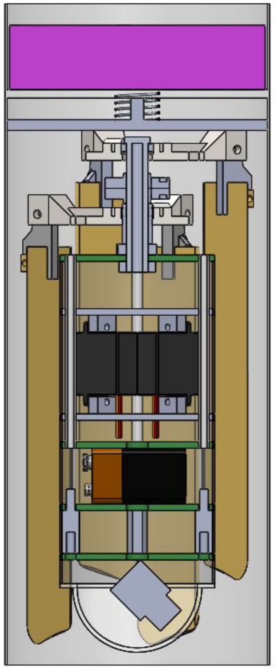
ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	Competition requirement	Parachute is mounted on top of container which allows to open easily when deployed.	High	x	x	x	
8	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	Competition requirement	Parachute calculated and designed to keep descent rate at ~20m/s.	Medium	x		x	
10	The science payload shall descend using an auto-gyro descent control system.	Competition requirement.	Science Payload descends with use of auto-gyro descent control system.	High		x		
11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	Competition requirement Such speed provides safe touchdown	Used propellers provide ~12m\s of descent rate	High	x	x	x	
12	All descent control device attachment components shall survive 30 Gs of shock.	Competition requirement. Designed Probe needs to be reusable.	All used are chosen due to high durability. All materials are tested to resist shock.	High	x		x	
27	The Parachute shall be fluorescent Pink or Orange	Competition requirement. Easier to find.	Parachute is made of fluorescent color fabric.	Medium		x		

Payload Descent Control Hardware Summary 1/3

Payload descent control hardware description

Our payload descent control hardware consists of 2 contra rotating rotors with 4 propellers each, and four ailerons mounted on 4 separate servos.

After being deployed from container, scientific payload unfolds rotors and auto-gyro mechanism activates. Rotors start to spin which creates enough lift force to decrease descent rate to ~ 11m/s. During descent, 4 ailerons can change their angle with use of servos, which will stabilise scientific payload and keep it in nadir position.



Deployment method

After reaching 450m altitude, resistance wire under high current cuts off nylon string attached to container, and SP is being released. Spring mounted between container and SP pushes out piston and will ease deployment. Right after release, propeller are unfolded with use of rubber bands, mounted directly to rotors.

Approach to an altitude of 450 meters

Hotwire cuts nylon strings in enclosed tube that hold piston and SP

Piston pushes SP down

SP is released

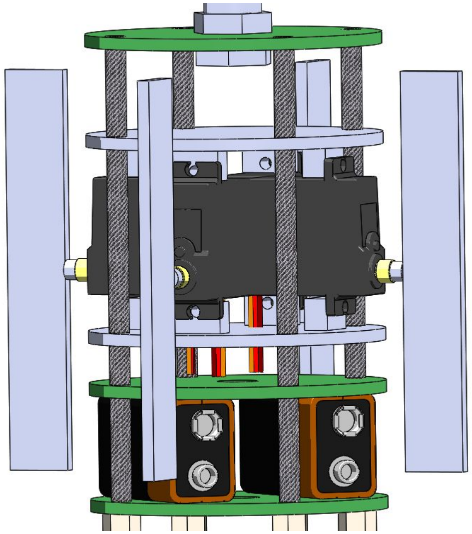
Payload Descent Control Hardware Summary 2/3

Component sizing / Key design considerations / Color selection

All subsystems, and parts were designed to fit into the container, and to provide safe deployment. Parts placement is crucial as it also helps SP to keep nadir position during mission. Parts layout is strictly related to their weight - heavier parts are placed at the bottom of SP to stabilise it during flight.

When designing out CanSat, we tried to make integration as easy as possible, and we wanted to discard complex solutions that could have been problematic.

To increase visibility, outer parts will be painted in bright orange color.



Active components

To provide proper active stabilisation, accurate sensor are necessary, to fulfill this requirement we are using MPU9250 which gives us both gyroscope and accelerometer readings with 60mG accuracy. We calculate needed values as follow:

Gyro_Rate = Gyro_Raw * Gain

Gyro_Angle += Gyro_Rate * dt, where "dt" is time between loops

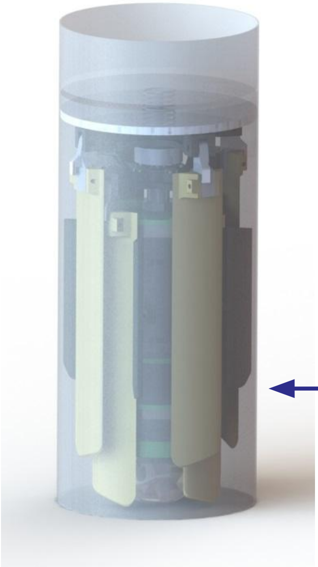
Accel_Angle = Arcus_Tangent(Accel_Raw_X, Accel_Raw_Y + PI)

Current_Angle = 98% * (Current_Angle + Gyro_Rate) + (2% * Accel_Angle)

Then we calculate aileron angle using PID formula:

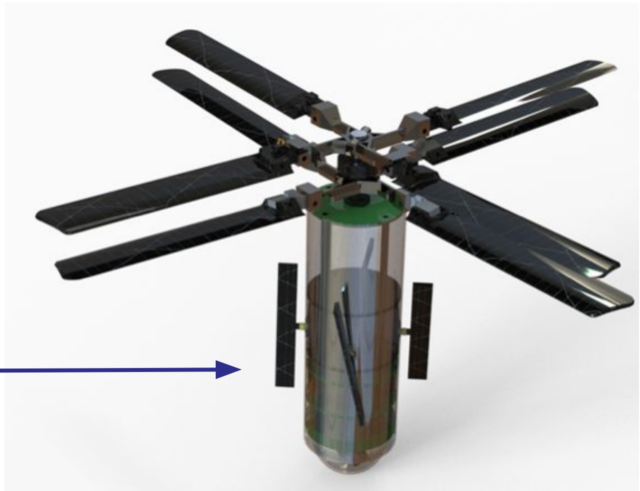
$$C(t) = K_p E(t) + K_I \int_{-\inf}^{t} E(s)ds + K_d \frac{dE}{dt}(t)$$

Payload Descent Control Hardware Summary 3/3



Payload before deployment

Payload after deployment



Payload Descent Control Hardware Summary
● Payload descent control hardware consists of two contra-rotating rotors with foldable propellers and ailerons attached to 4 separate servos, ● Container with SP keeps descending on attached parachute at 20m/s rate until it reaches 450m altitude. At that stage, resistance wire under high current cuts off nylon string attached to container, and SP is being released ● Propellers unfolds immediately after SP deployment, when CanSat reaches 450m altitude, ● Auto-gyro mechanism activates automatically due to air flow and provides steady descent rate of ~10-12m/s,

Descent Stability Control Design Summary

	Chosen configuration
SP descent control	Contra rotating rotors
Spin stabilisation system	4 separate ailerons attached to 4 servos
Stabilisation type	Active

Design description

Doubled rotating propellers prevent from spinning due to generation of two reaction torques that cancel each other out.

Stabilisation is obtained with use of 4 separate ailerons attached to 4 servos. This configuration is easy to construct, implement and integrate. As ailerons are attached directly to servos , whole subsystem is mounted tight, and it is able to calibrate precisely.

SP is being kept in nadir direction, by proper mass distribution. Heavier subsystems like electronics, camera, servos and batteries are mounted at lower section of SP pushing the center of mass as low as possible, whilst the aerodynamic force is at top. To ensure even better stability the rotors have 2° cone angle greatly improving the aerodynamic airflows.

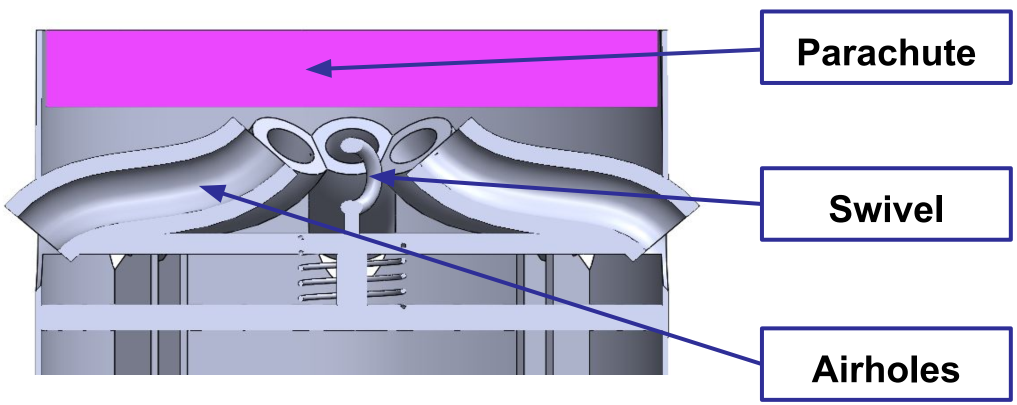
Container Descent Control Hardware Summary

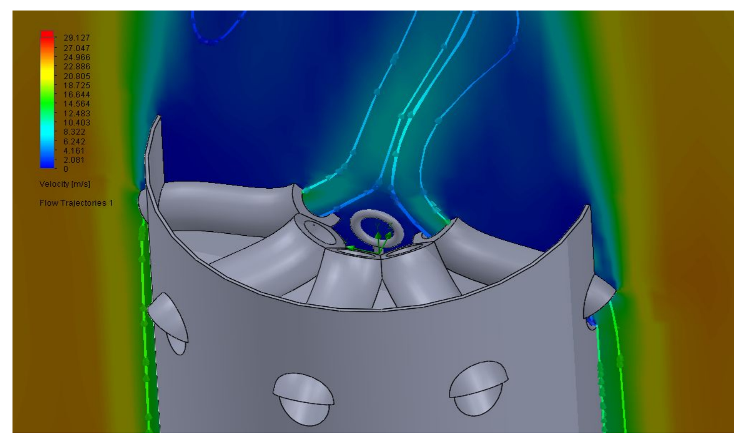
Container Hardware Summary

Our container descent control system is made of of fiberglass body, 3d printed airholes, release piston, parachute with lines and fixed swivel. We only use passive components for descent.

Parachute is deployed right after rocket separation at apogee with use of 3D printed airholes providing sufficient airflow which will help inflate the canopy.
When inflated, parachute provides steady descent rate of 20m/s until reaching 450m. We managed to use swivel and spill hole to stabilise descent and prevent from tumbling and twisting during mission.

After reaching altitude 450m, SP is deployed, container slows down to ~8,2m/s and lands after approximately 55-60 seconds.





Descent Rate Estimates 1/3

CanSat Competition 2019 - Parachute Calc

Payload mass [kg]	0,5	Apogee	700 m
Parachute diameter [m]	0,165	Windspeed	5 m/s
Descent Velocity	**19,90** m/s		
Descent time	35 s		
Maximum distance	176 m		

First stage: Container + SP

- Parachute opens right after reaching apogee,
- Parachute ensures stable descent velocity ~20 m/s
- Container with SP descends for ~15s until it reaches altitude 450m.

CanSat Competition 2019 - Parachute Calc

Payload mass [kg]	0,085	Apogee	450 m
Parachute diameter [m]	0,165	Windspeed	5 m/s
Descent Velocity	**8,21** m/s		
Descent time	55 s		
Maximum distance	274 m		

Second stage: SP deployment - Container recovery

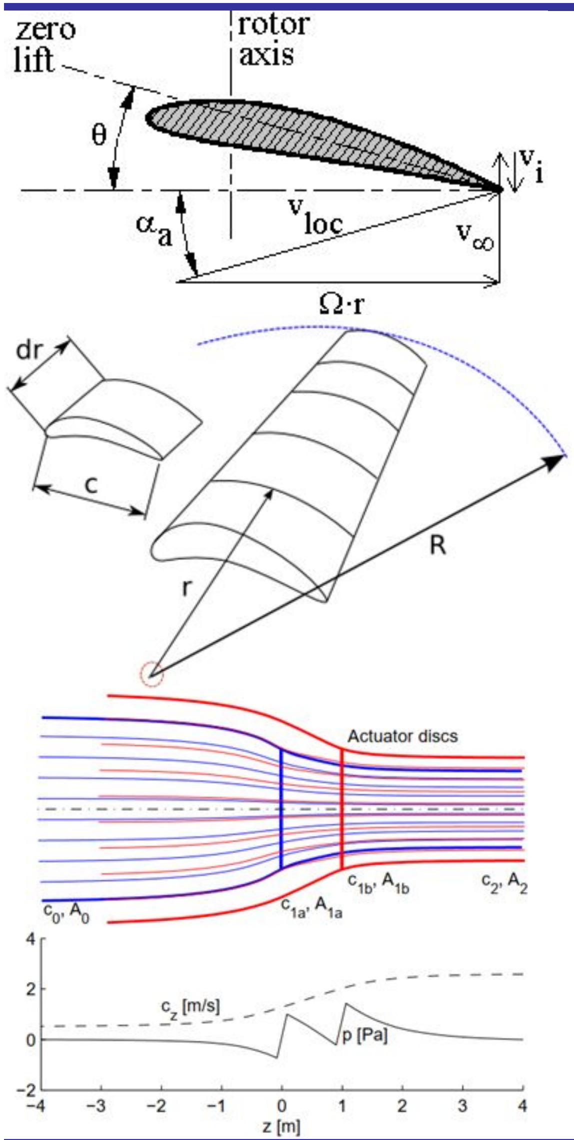
- After reaching 450m altitude SP deploys,
- Descent velocity of container decreases due to significant weight loss,
- Parachute ensures stable descent velocity ~8,2m/s,
- Container lands after approximately 55 seconds

Descent rate estimated using the following formulas and assumptions:

$$v = \sqrt{\frac{2W}{Cd \cdot \rho \cdot A}}$$

W – mass,
Cd – drag coefficient (0.95 assumed for Semi elipsoid canopy)
ρ - air density ($1.168 \frac{kg}{m^3}$)
A – parachute area

Descent Rate Estimates 2/3



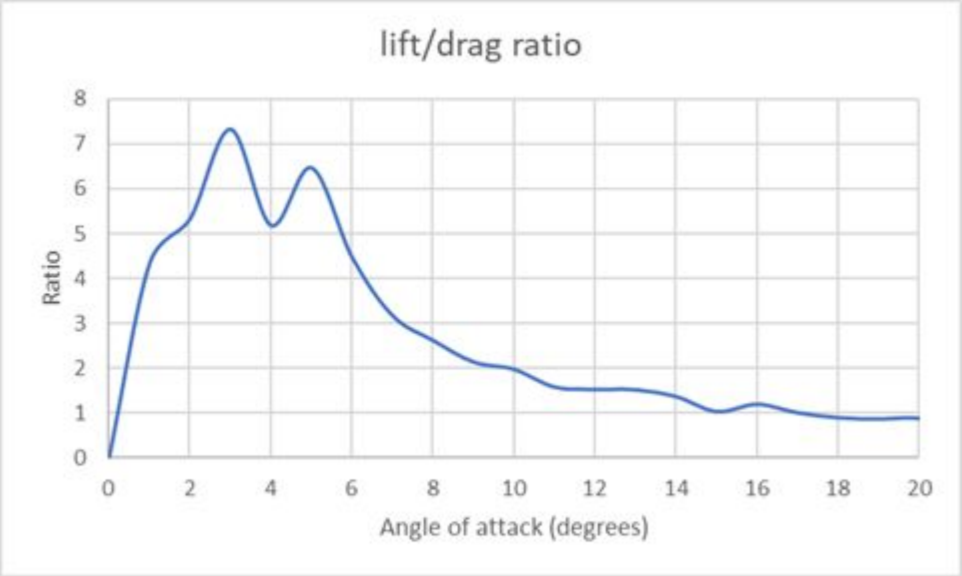
Third Stage: SP recovery

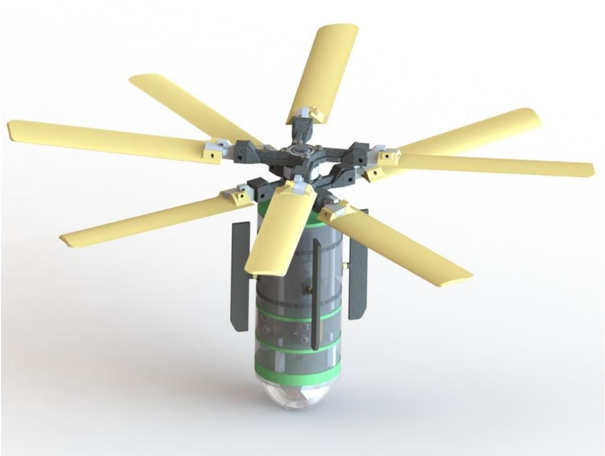
- SP deploys at altitude of 450m,
- SP unfolds its rotors (propellers) and begins to stabilize with use of auto-gyro contra rotating rotor system,
- SP keeps its descent at rate ~10-12/m/s
- SP lands safely after approximately 35-40s.

Descent rate of SP was estimated using Blade Element Momentum theory. We aimed at lower limit to ensure safe recovery. Rotor blades were divided into finite number of sections, to perform calculations and then integrate using known airfoil lift and drag coefficients. Actuator disk theory allowed for finding the relationship between SRP and CRP system basing on thrust and power coefficients which would be obtained if the rotors were powered. It allowed determination how much better performance a system can have, whilst having same diameter of all rotors. At last Gauert theory was used to determine final descent rate and compared with energy method used by Peter D. Talbot and Laurel G. Schroe. For which some data have been used from previous calculations. Considering all cases of the unknown coefficients the descent rate becomes 10.21 - 12.44 [m/s].

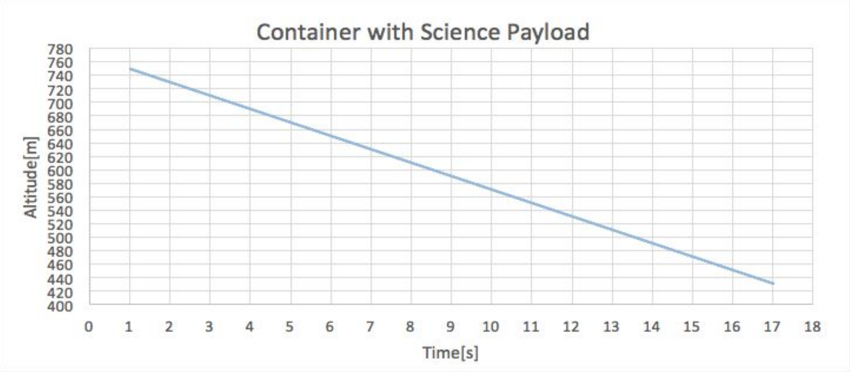
Descent Rate Estimates 3/3

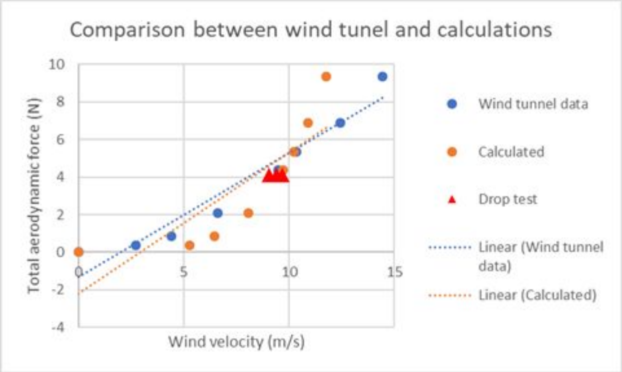
As the calculations are rather complicated and plenty of simplifications were used, the need for using aerodynamic tunnel with scaled model and full scale drop tests aroused. They were performed and the results are plotted on the graph below. The method of design of system exploiting vertical autorotation principle showed near perfect compliance with experimental measurements and even with such complex system as Contra Rotating configuration the estimates were quite accurate. Another tests were performed considering new type of composite - a 3D printed airfoil laminated around by carbon fiber in the matrix of epoxy resin. Whilst adding close to none weight the stiffness of blade was increased greatly, reducing possibility of blade flutter occurrence. This was tested in aerodynamic tunnel as well and a rather good lift and drag coefficients were obtained, but with higher wind velocities the blade started deflecting. See picture on the right.

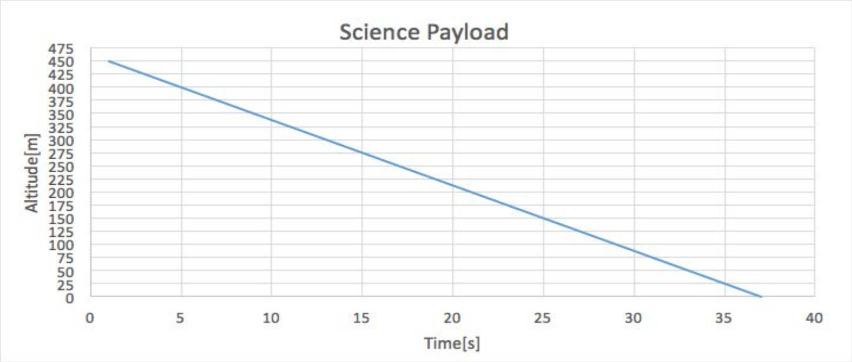




Descent Rate Estimates & Conclusion







CONCLUSIONS

- All materials used to build descent control systems were calculated to survive 30Gs of shock this was ensured by using innovative laminate structures.
- Parachute canopy was designed to ensure stable descent rate of ~20m/s,
- Auto-gyro mechanism was designed to ensure stable descent rate of approximately ~10-12m/s,
- 4 separate ailerons on 4 servos are use to prevent tumbling during descent,
- Mass distribution and cone angle of rotors in SP was set to provide descent in stable vertical position,
- Descent stability control system is designed so the camera is stabilised during whole flight after deployment.

Mechanical Subsystem Design

Adam Kolusz

Mechanical Subsystem Overview

CanSat

Composed of two major components:

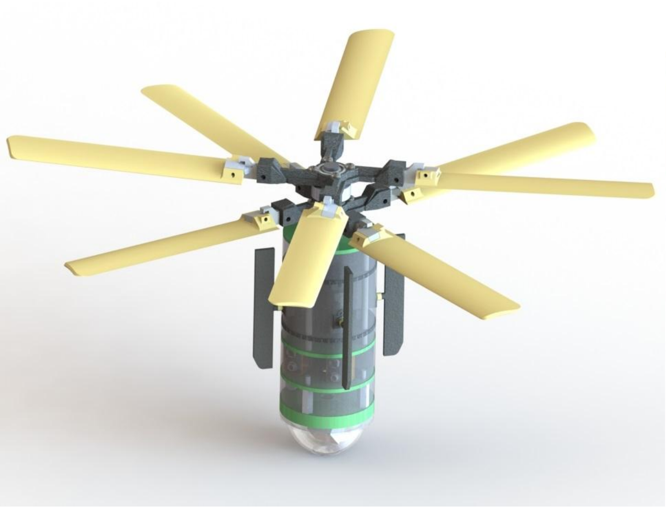
- Container
- SP

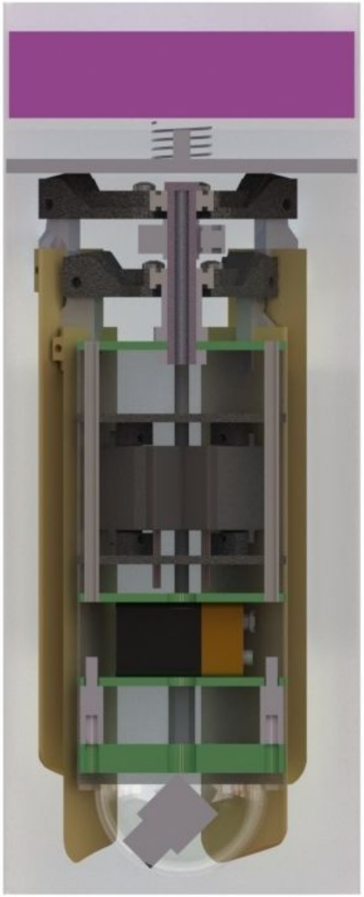
Container

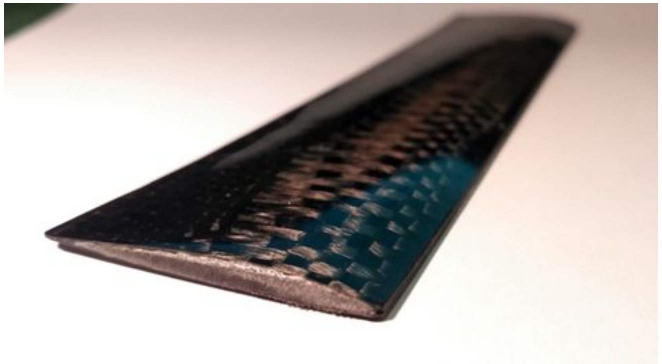
- Protects the stowed science payload during launch
- Equipped with a parachute to ensure proper descent rate in the first phase of descent
- It's built from glass fibre composites with fluorescent dust, carbon fiber composites, Pa12+CF 3D printed parts and PMMA lid (for camera to video through).

SP

- Uses contra rotating propellers that ensure stability made from Pa12+CF printed parts with laminated carbon fiber around it for descent using autorotation
- Main structural part covered with glass fiber laminate cover for better protection.
- Provides integrated deployment mechanism
- Real life transmits all telemetry
- Integrated active stabilization by four ailerons to ensure stable descent
- Low center of mass for high stability







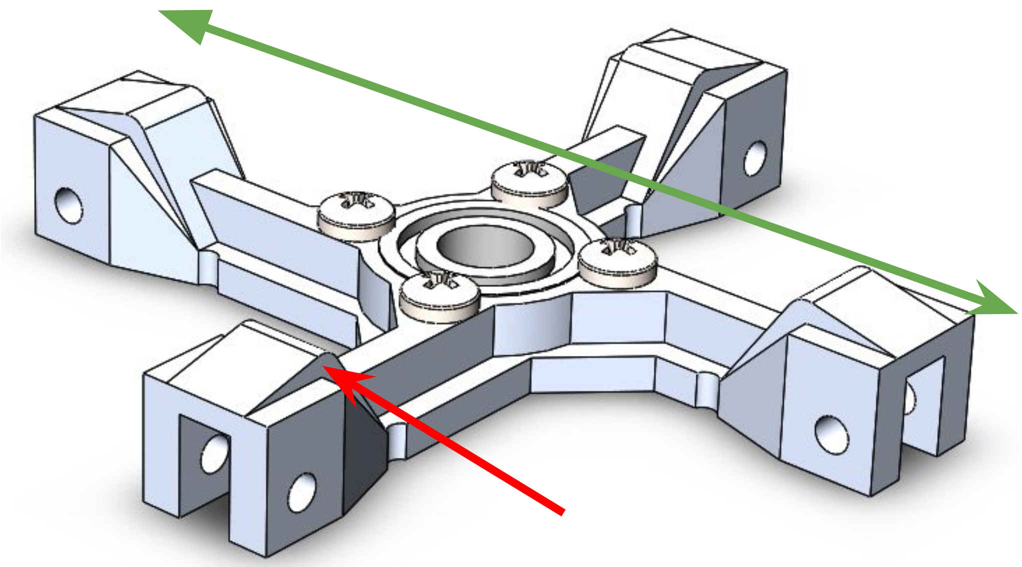
Mechanical Subsystem Changes Since PDR 1/3

	Change	Rationale
SP	Bearing mount improvement	During rocket test the bearing slid off after 10s of stable flight and required
	Added extra tensioners for bands	Increases the force that keeps the rotors opened, making it more resistant.
	Stowed rotor hubs now have varying dimensions	Assures no blockage possibility between rotors during opening and ejection
Container	Container glass layers removed	Weight of the container turned out to be higher than calculated.

Mechanical Subsystem Changes Since PDR 2/3

SP - Rotor hub with bearing mount

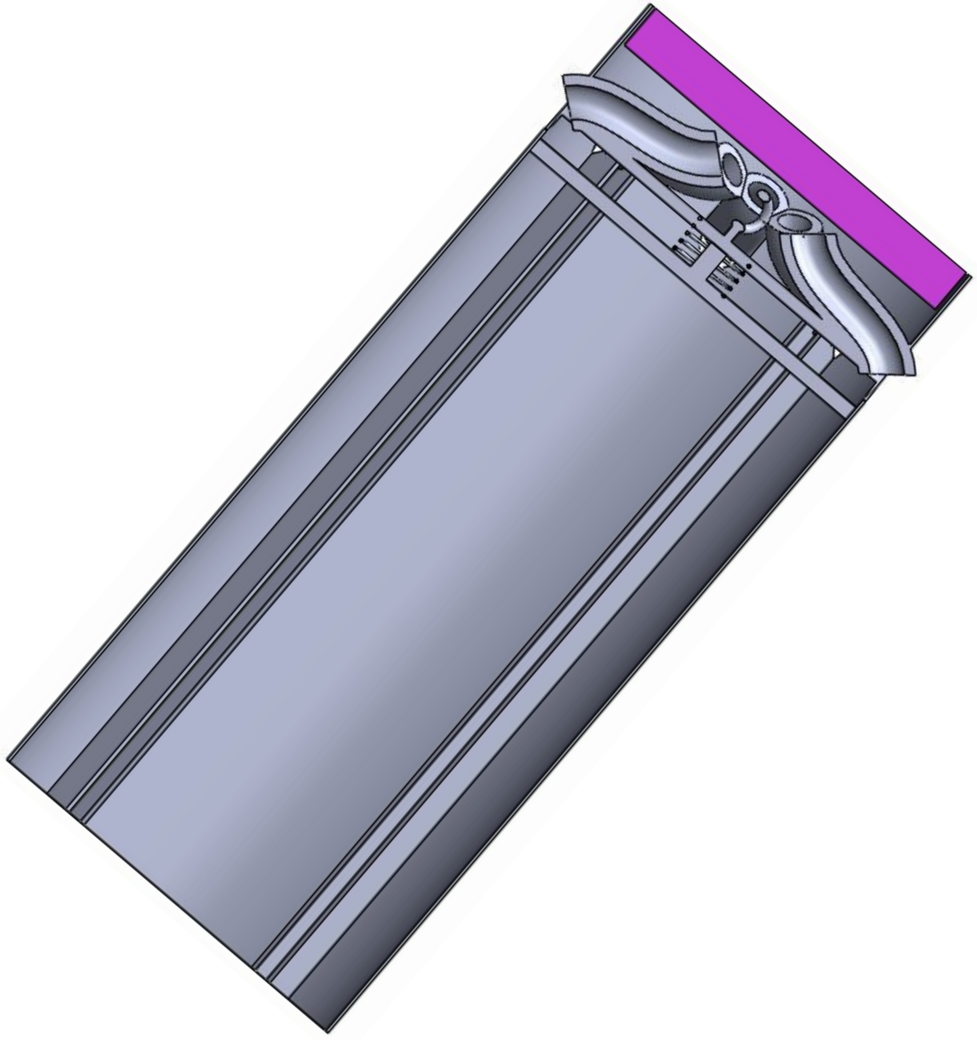
Rocket tests pointed few minor flaws which have been corrected. One major one was that the hub holding bearings released them mid air after 10s of stable flight. This could be caused by 3D print imperfections or vibrations. The design was improved and prototype material upgraded to PET-g as it is slightly more ductile and this allows for tighter fits. Also now the secure position of bearing is provided by four screws. Extra rubber band tensioners marked with red arrow was also added to improve band tensioning force. Additionally rotors now don’t overlap each other when stowed - their size varies (dimension marked with green arrow).



Mechanical Subsystem Changes Since PDR 3/3

Container glass layers removed

Another issue was that container weighted more than expected. This could be cause by too large amount of epoxy resin cured. Due to this fact two out of six layers of glass fiber have been removed and therefore mass was reduced, whilst maintaining appropriate strength as the previous version was an overkill strength-wise.



Mechanical Sub-System Requirements 1/3

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.	Mass of CanSat can not be higher as its descent could be dangerous and influence rocket's trajectory.	Total mass of CanSat is not exceeding imposed tolerances	High	x	x	x	x
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Rockets have compartments with fixed dimensions and in order to reassure proper ejection adequate tolerances must be met.	The CanSat is designed and manufactured with appropriate dimensions.	High	x	x	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.	Blockage in rocket compartment would cause failure of whole mission.	All sharp edges will be chamfered	High	x	x		
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Competition requirement. To lower the risk of CanSat getting stuck in rocket.	Airframe of the rocket is not used by CanSat	High		x		
6	The rocket airframe shall not be used as part of the CanSat operations.	Competition requirement. CanSat should be separate autonomous system.	Airframe of the rocket is not used by CanSat.	High		x		
10	The science payload shall descend using an auto-gyro/passive helicopter recovery descent control system.	Competition requirement.	Science payload is designed to use auto-gyro descent control system.	High	x	x	x	x
12	All descent control device attachment components shall survive 30 Gs of shock.	CanSat should be able to operate in multiple flights	All attachments are designed to fulfill durability requirements	High	x		x	
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Electronics needs to be protected from environment	Electronics is enclosed in the fiber glass SP tube.	High	x	x		

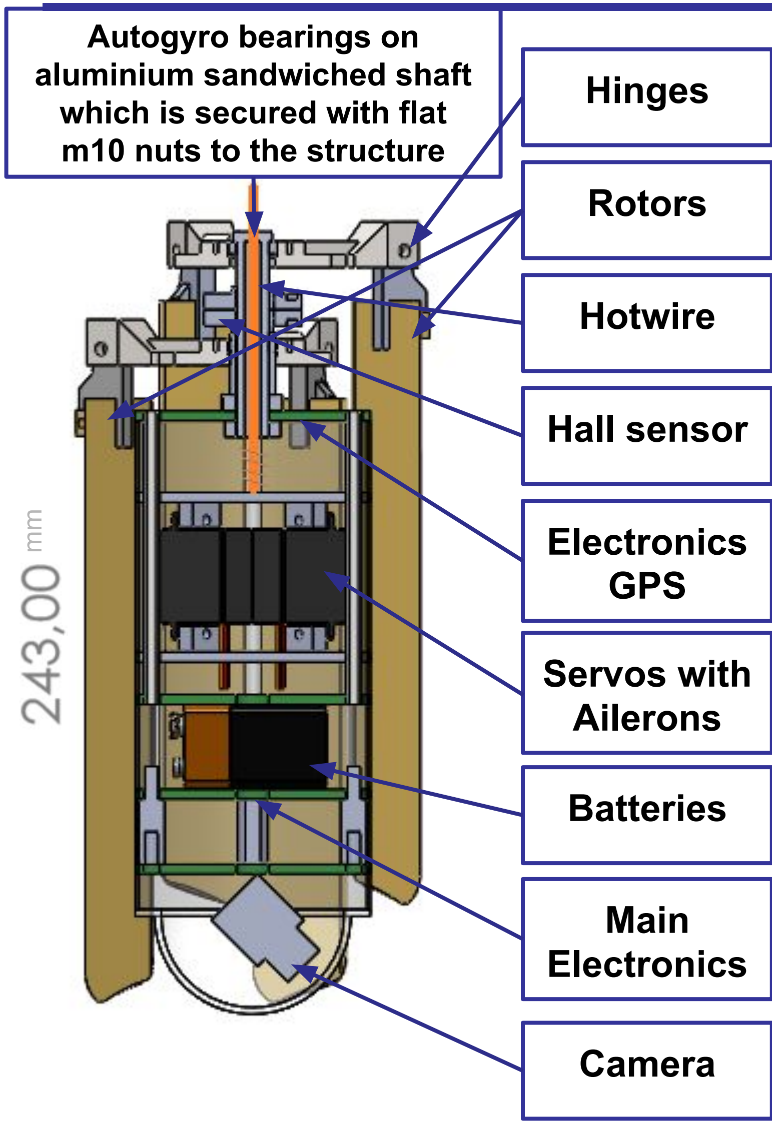
Mechanical Sub-System Requirements 2/3

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
14	All structures shall be built to survive 15 Gs of launch acceleration.	Damage prevention.	It is designed so. WIll be tested.	High	x		x	
15	All structures shall be built to survive 30 Gs of shock.	Damage prevention.	It is designed so. WIll be tested.	High	x		x	
16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Damage prevention.	Design	High			x	
17	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Safety measure.	Mechanisms are tested in all varying conditions and some simulations will be performed.	High	x	x	x	
18	Mechanisms shall not use pyrotechnics or chemicals.	Safety measure, can cause fire or contamination..	No pyrotechnics or chemicals used.	High		x		x
19	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.	Safety measure, can cause fire	Nichromewire is hidden inside the body of payload assuring safety.	High		x		x
41	Both the container and probe shall be labeled with team contact information including email address.	Safety measure, during mission failure can cause recovery after competition.	Labels are adequately placed and safely secured.	Medium		x		x
45	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	In case of electronics failure such as short circuit a safe way of aborting is needed.	Power switch is placed at top of payload, assuring easy access.	High	x	x	x	x

Mechanical Sub-System Requirements 3/3

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
46	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.	Safety measure, helps finding the CanSat after mission, reducing the environmental risks.	LED indicator and buzzer implemented to comply with requirements.	High			x	x
50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Safety measure, in case of battery discharge can recover mission success.	Design allows for replacement of batteries after removing only 4 screws and connecting cables.	High			x	x
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Can cause mission failure.	Clip on connectors are used.	Medium	x	x		
52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.	Competition requirement.	Contra rotating rotor passive system is designed.	High	x	x	x	x

Payload Mechanical Layout of Components



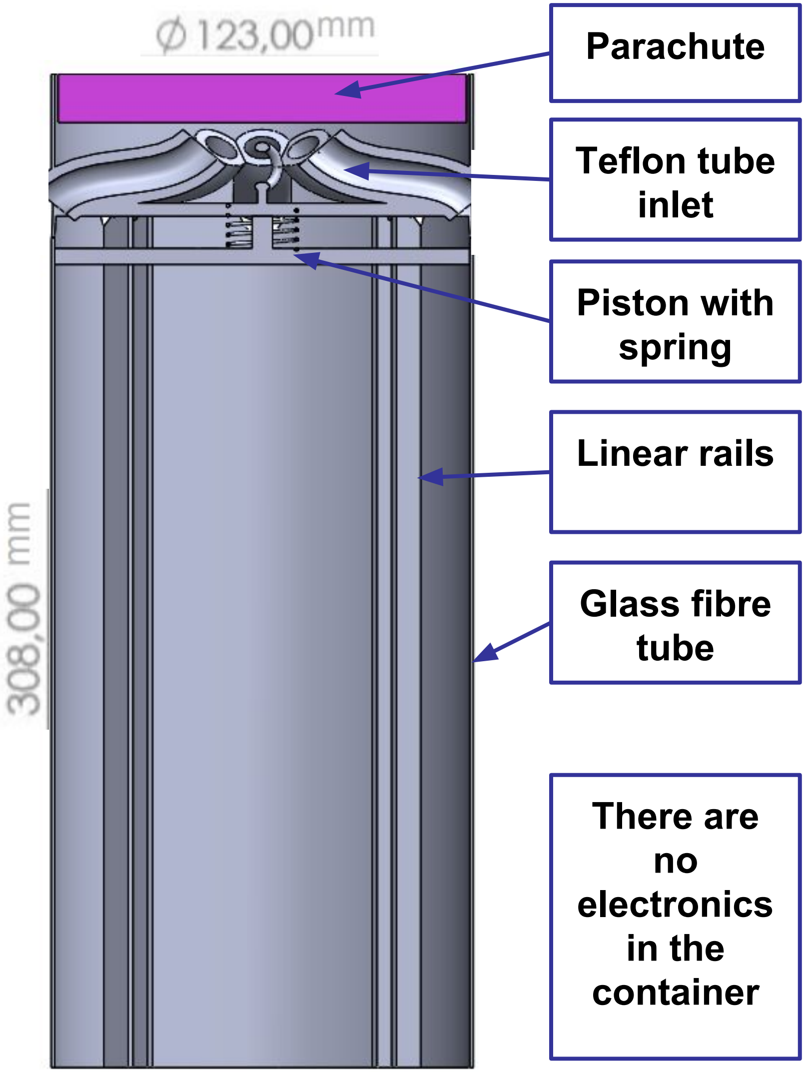
Material selection

The body of the payload is created from glass fibre laminate, to which attached are connected with screws for easy assembly ribs made from glass + kevlar laminate in epoxy resin. To which carbon rods are connected that assure the structure stiffness and a way to mount electronics safely. Container is mounted at the top via a nylon strong which will be cut with a hot-wire mechanism during ejection.

Rotors are mounted to 3D printed parts with Pa12+CF filament reinforced with metal inserts to assure no blockage possibility and act like a hinge, opened with rubber bands mounted on top of them, connected to main printed from same material hub. The hub itself nests a bearing that is screw into it, that fits tightly on aluminium shaft.

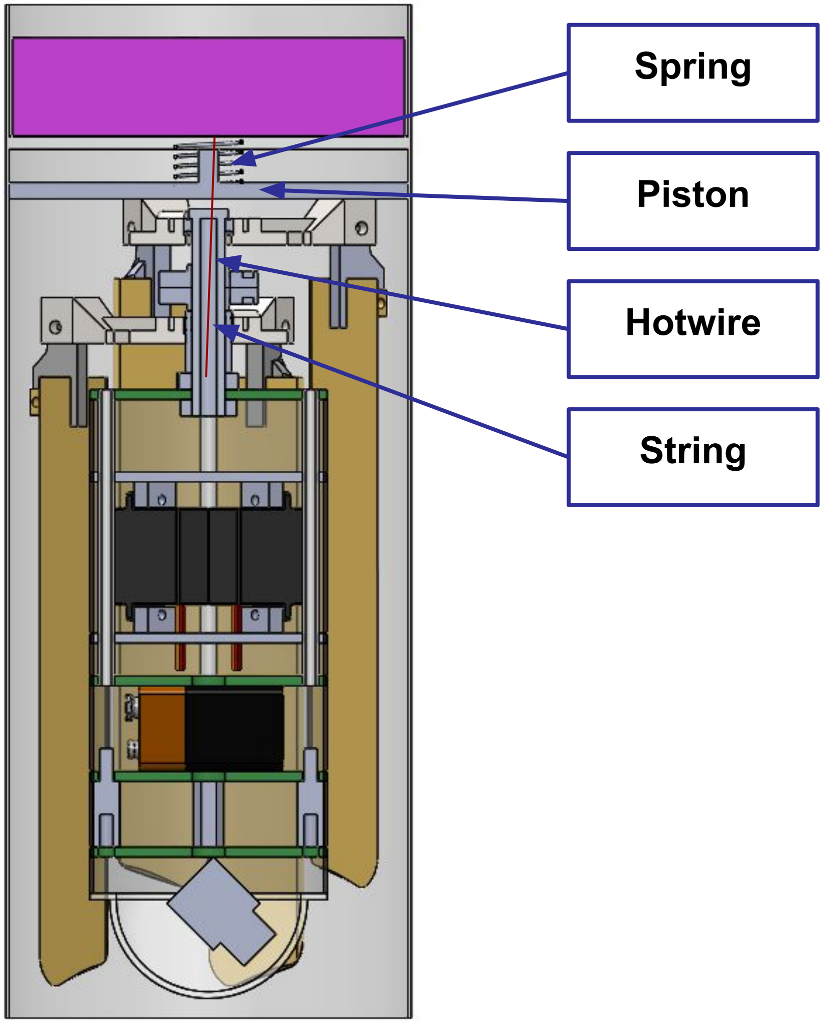
Red vertical line is the nylon string that attaches the SP to the container's piston.

Container Mechanical Layout of Components



Material selection
Parachute is made from ripstop nylon was sewn together with nylon strings. Tube inlets made from PTFE tubing and the piston and container body are made from glass fiber laminate in epoxy resin matrix.

Payload Release Mechanism



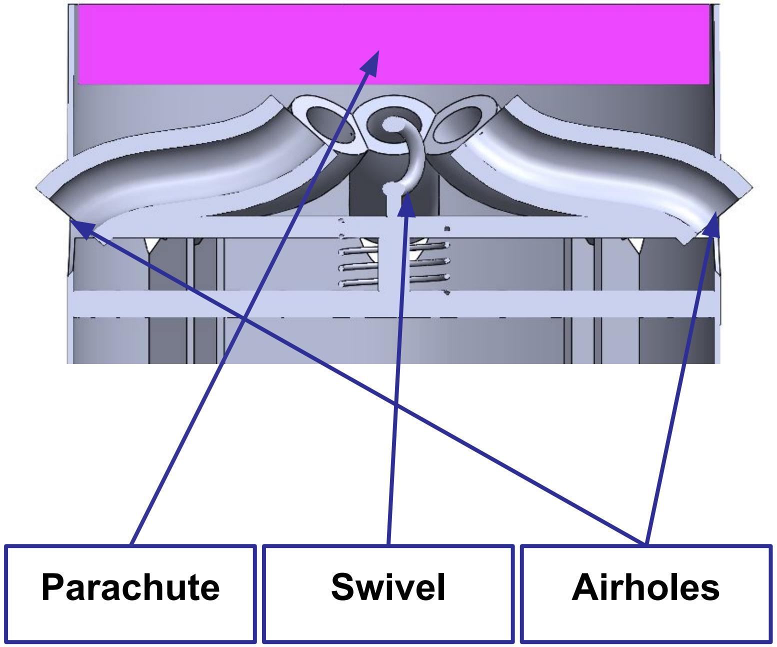
Approach to an altitude of 450 meters

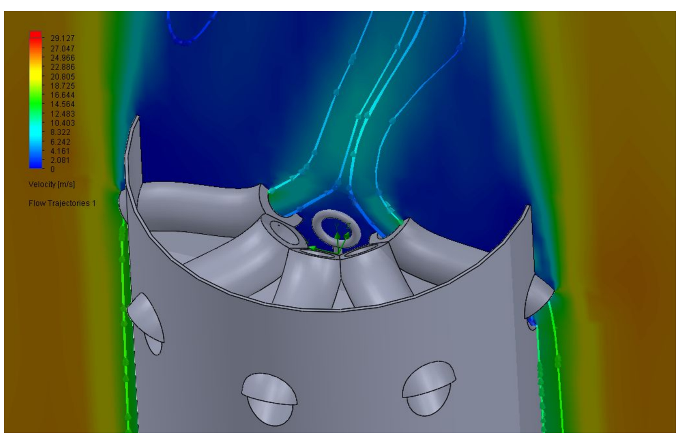
Hotwire cuts nylon strings in enclosed tube that hold piston and SP

Piston pushes SP down

SP is released

Container Parachute Release Mechanism





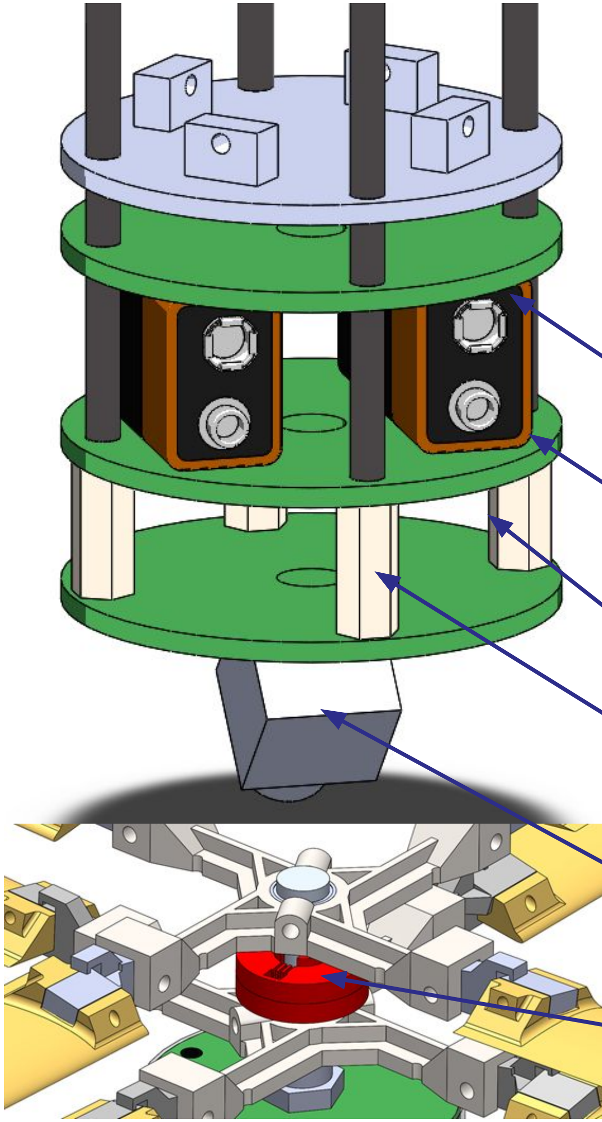
CanSat deployment from rocket section

Due to low center of mass CanSat falls pointing nadir direction

Air flows through tube inlets

Parachute attached via a metal swivel is released by airflow through teflon tubes

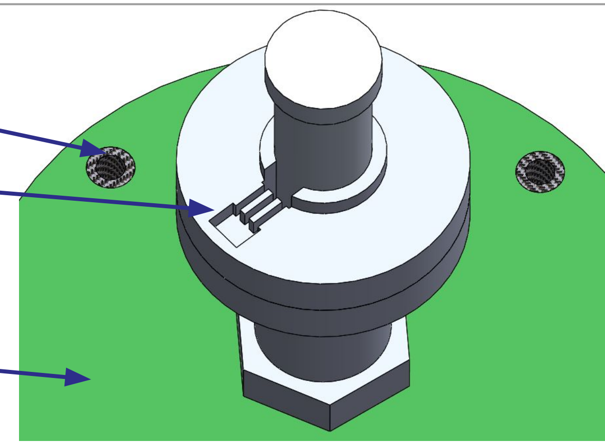
Structure Survivability 1/2



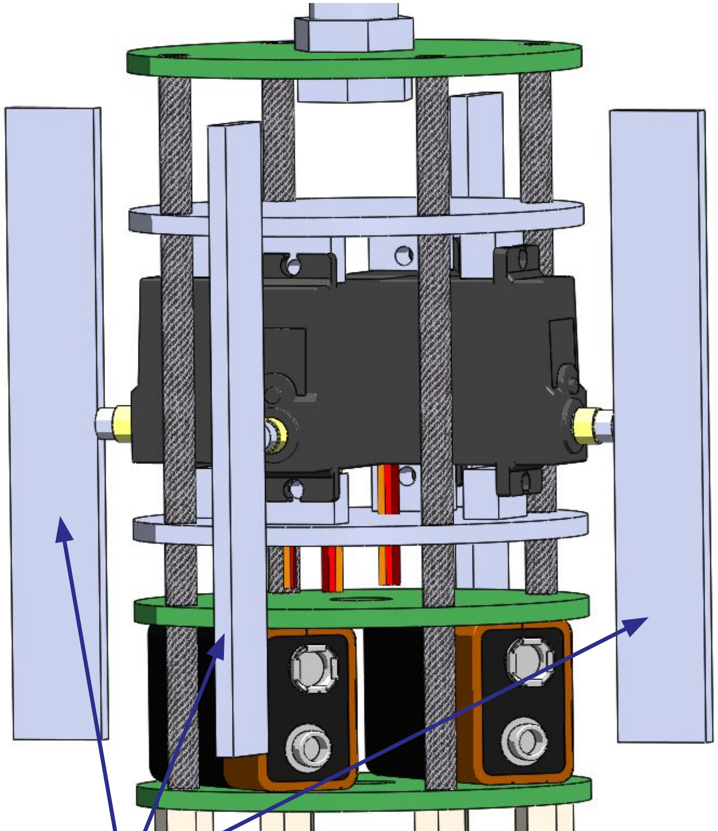
Electronics

Secure position of electronics is assured by connection with threaded distances to carbon fiber rods that use threaded inserts laminated into them and everything is bolted together. The threads will be covered with thread locking glue to counter any vibrations occurring and a possibility of loseness. Inner structure is fit tightly inside a glass fiber laminated tube which encloses all electronics.

The end nut will be a nylock type due to reasons mentioned earlier. Hall sensors are glued into 3D printed parts that are sandwiched between bearings on main shaft.



Structure Survivability 2/2



Aileron

Threaded distance

Descent control attachments

The descent control is performed by 4 ailerons that are mounted on Pa12+CF 3D printed inner rim that has brass threaded inserts melted inside ensure that the servo motors are stiffly secured with m3 screws. Ailerons have laminated screws inside them allowing for attaching after the glass fiber tube is placed. Thread locking glue will be also applied for looseness free system.

Mass Budget

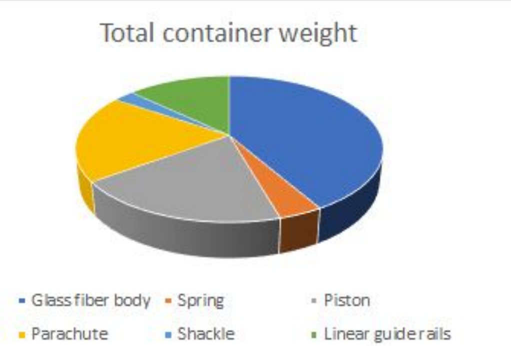
Method of correction
In case any error occurs the lower part will be equipped with extra space for increasing weight with screws and nuts. Initially it will include 6 screws that can be detached if the structure is too heavy. **Margin = 500-497.1= 2.9g**

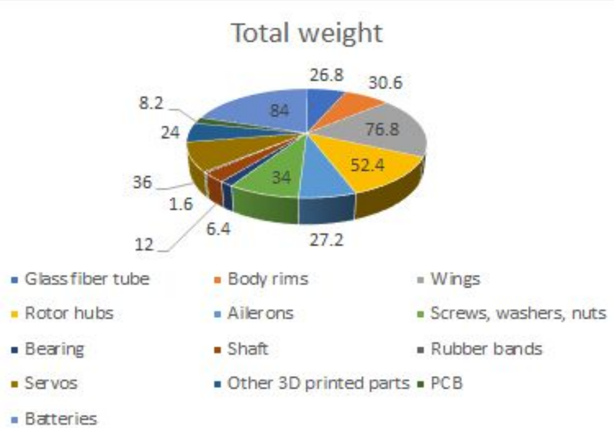
(shaded)	structure elements
(white)	components

Comparison	
Total mass	Required mass
497.1 ± 2.8g	500g ± 10g

Container		
Part	Mass	Determination
Glass fiber body	32.1±0.1g	Measured
Spring	3±0.1g	Measured
Piston	15±0.1g	Measured
Parachute	15±0.1g	Measured
Shackle	2±0.1g	Measured
Linear guide rails	10±0.1g	Measured
Total	**77.1±0.6g**	
Total structural	**62.1**±0.5g	
Total components mass	**15.0±0.1g**	

SP		
Part	Mass	Determination
Glass fiber tube	26.8±0.1g	Measured
Body rims	30.6±0.1g	Measured
Wings	76.8±0.1g	Measured
Rotor hubs	52.4±0.1g	Measured
Ailerons	27.2±0.1g	Measured
Screws, washers, nuts	34±1g	Estimated
Bearing	6.4±0.1g	Datasheet
Shaft	12±0.1g	Measured
Rubber bands	1.6±0.1g	Measured
Servos	36±0.1g	Measured
Other 3D printed parts	24±0.1g	Estimated
PCB	8.2±0.1g	Measured
Batteries	84±0.1g	Measured
Total	**420±2.2g**	
Total structural	**127.4**±1.4g	
Total components mass	**292.6±0.8g**	





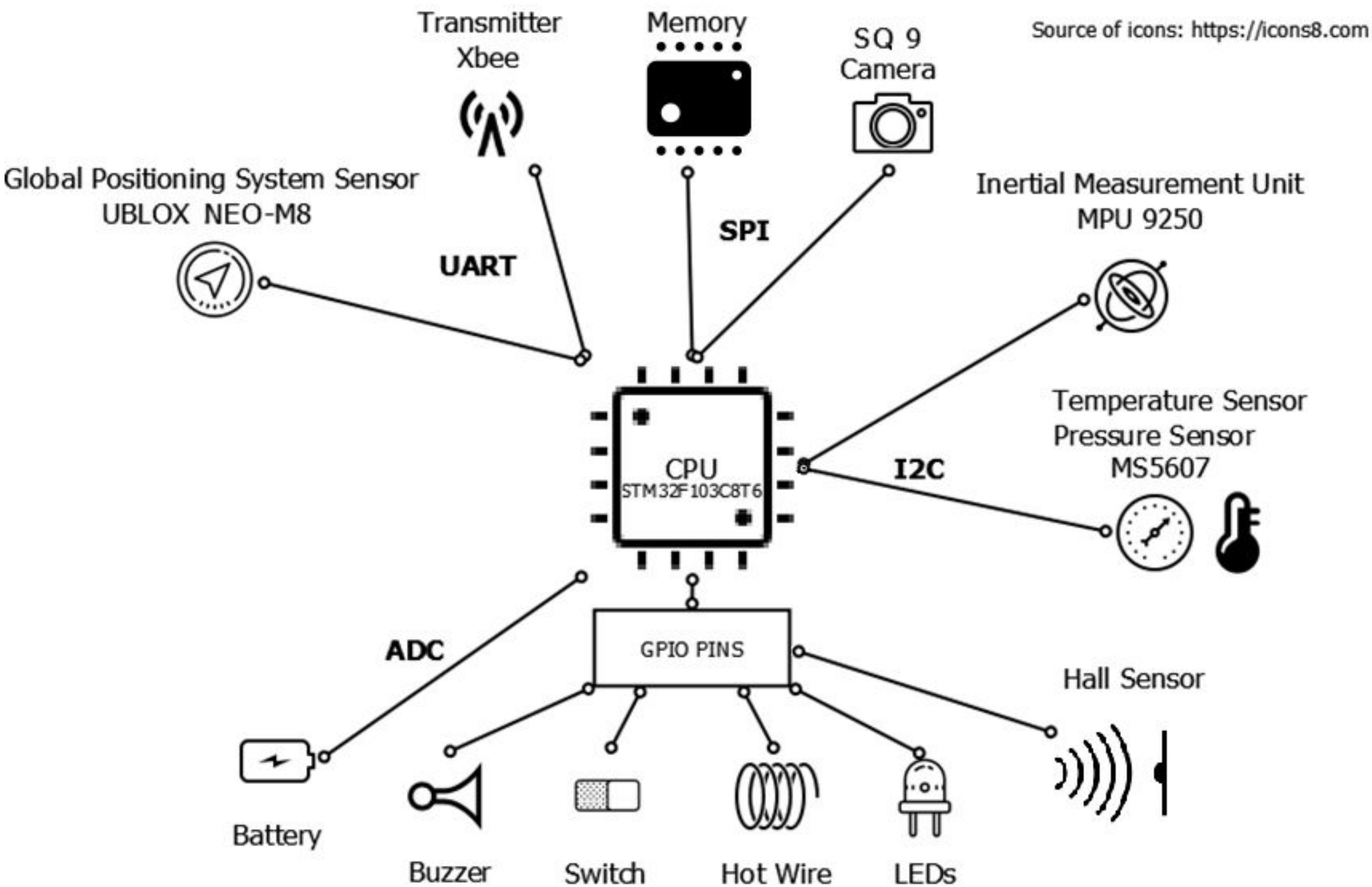
Communication and Data Handling (CDH) Subsystem Design

Mateusz Rajzer

CDH Overview 1/2

CPU - STM32F103RCT
• Receiving data and executing commands coming via USART interface from Xbee radio module • Sending data packets via USART interface to XBee radio module • Receiving and reacting for data coming via I2C interface from sensors • Writing data packets via SPI interface to external flash memory • Communication buses: SPI for sensors and on-board memory, USART for Xbee and GPS
Telemetry - XBee XB9X-DMUS-001
• Receiving data packets from CPU using USART interface • Forwarding data packets from CPU to GS using XBee • Receiving data and commands from GS using XBee • Forwarding data and commands from GS to CPU using USART interface
Data storing - S25FL512S
• Storing telemetry data • Receiving and saving data coming from CPU using SPI interface
Sensors
• Conducting a measurements in order to gather information about external environment and the probe’s performance • Forwarding data to CPU using SPI or I2C • Used sensors: barometer, IMU, magnetometer on the IMU, accelerometer on the IMU, temperature sensor on the IMU
Other
• Camera recording video at 45 degrees angle and saving it on its own SD card. • Buzzer AI-3035-TWT-3V-R 100dB loud audio beacon

CDH Overview 2/2



CDH Changes Since PDR

There are no changes since PDR.

CDH Requirements

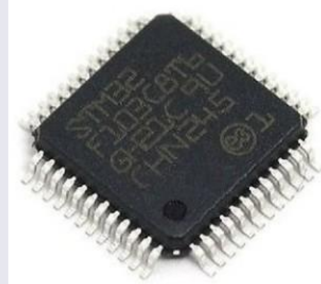
ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
26	The probe shall transmit all sensor data in the telemetry	Competition requirement	A data packet is prepared with use of readings of sensors, then it is sent in bursts by Xbee radio.	High	x		x	
30	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	Competition requirement CanSat needs to be able to work after unpredicted resets	Flash IC is used to save current software state. Mission time is added to the data packet.	High	x		x	
31	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Competition requirement. Frequencies and radios mentioned are legal to use in the USA.	Telemetry and Xbee radio works using frequency of 900 MHz	High	x			
32	XBEE radios shall have their NETID/PANID set to their team number.	Competition requirement. So that radios does not interrupt communication systems of other teams.	PANID will be set to team number.	Medium	x			
33	XBEE radios shall not use broadcast mode.	Competition requirement. So that radios does not interrupt communication systems of other teams.	An appropriate configuration of Xbee radios will be conducted.	High		x		
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Competition requirement.	Data is converted to engineering units by the CPU in the probe. GS displays those values with proper units.	Medium		x		
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Competition requirement. To make search of the CanSat easier.	CanSat has an audio beacon.	Medium		x		
48	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Competition requirement. Buzzer needs to be loud enough	Buzzer has sound pressure level of 100dB	Medium	x	x		

Payload Processor & Memory Selection

Model	Clock freq. [MHz]	Flash memory [kB]	Operating voltage [V]	Interfaces				ADC	
				I2C	USART	SPI	USB	Channels	Resolution
STM32F103RCT	**72**	**256**	**2.0 - 3.6**	**2**	**5**	**3**	**1**	**16**	**12-bit**

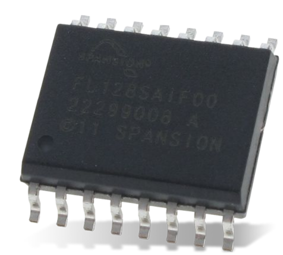
The microcontroller has high clock speed, good memory capabilities, power consumption and a sufficient amount of interfaces available. It is significantly better than competitors microprocessors in this price range eg. Atmega. The microcontroller meets all of the requirements:

- Many communication interfaces
- High clock frequency
- Multiple interrupts for real-time operations
- Boot time circa 1ms.



Model	Size [Mbit]	Read/Write speed [MB/s]	Power management
Cypress S25FL512S	**512**	**6**	**2.7V – 3.6V, max 100mA**

Previous years and many trials and errors with SD cards have thought us, that this is not the most reliable data storage. Using SPI with SD cards has proven to be troublesome, so we've decided to use proven solution which is dedicated flash IC. This solution has been favoured against EEPROM due to their smaller storage capacity in the same price range.



Payload Real-Time Clock

Model	Size	Interface	Operating voltage [V]
STM32F103C8T6 internal RTC unit	**integrated into microcontroller**	**integrated into microcontroller**	**2.0 – 3.6**

The RTC unit has appropriate accuracy, size, kind of interface and power needed. The chosen RTC unit meets all of the requirements:

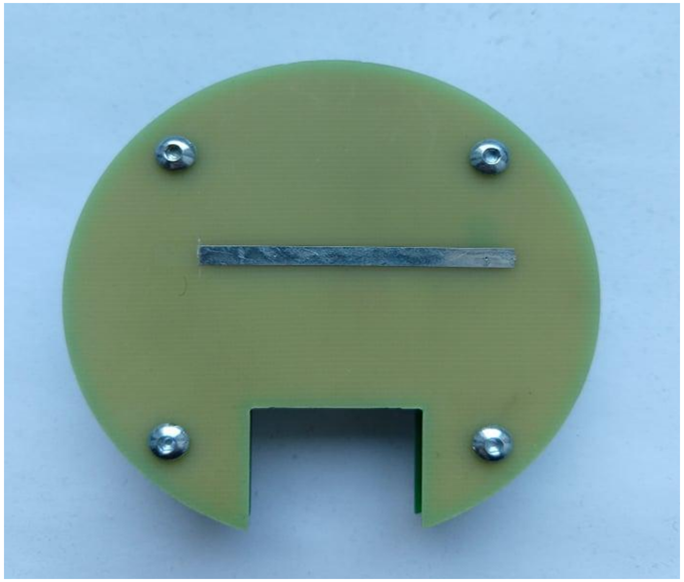
- No extra interface needed since - RTC is integrated into the CPU
- Sufficient level of accuracy
- Low power consumption

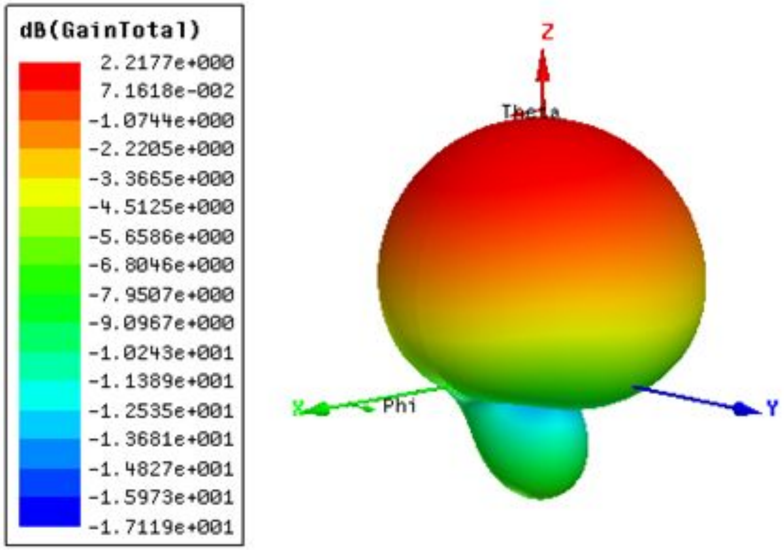
In case of processor reset accurate time is read from the GPS module, since it is able output accurate time even with weak signal.

Payload Antenna Selection

Name	Bandwidth [MHz]	Center frequency [MHz]	Gain [dBi]	Mass [g]
PIFA microstrip antenna	**10**	**900**	**2.2**	**4.2**

Testing	Description and characteristics
Testing of scattering parameters of the antenna has yielded very good results, namely 10MHz bandwidth at reflection <10dB. This, backed up with computer simulation insures us, that antenna Is working properly. Field tests are yet to be performed due to change of concept of ground station antenna.	Chosen antenna is manufactured in PCB house based on our design on FR4 laminate, and hand tuned to appropriate frequency. This gives us good quality and repeatability. It has been designed to radiate power towards the earth, giving us stronger transmit signal.





Payload Radio Configuration

Name	Range [km]	Transmitted Power [mw]	Supply voltage [V]	Supply current [mA]	RF Data Rate [kbps]	Connector
XB9X-DMUS-001	4	32	3.3	55	120	U.FL

Overview of Radio Configuration

- Xbees are operating in one network with the same PANID/NETID number. PANID/NETID number is set to TeamID: 3193.
- Xbees local number is set to listen the other Xbee.
- Communication will be held in AT command mode which simplify whole communication.
- Unicast mode was chosen, which enables data acknowledgement.

Ground Station Xbee module

- This device is the coordinator in this network.
- Operation channel number is the same as coordinator's.
- Source address (SL+SH parameters) is equal to coordinator's destination address.

CanSat Xbee module

- This device is an endpoint.
- The destination address is set to coordinator address.

Transmission control

After CanSat is turned on, the communication is established between GS and payload and data is being send with 1Hz frequency. Operator can at this point start/stop mission mode which starts telemetry transmission until touchdown event, when the transmission stops.

XBee XB9X has moderate output power, very high sensitivity and low operating frequency which accounts for really long coverage. If we use Friis Transmission equation we would find out that this module yields much greater communication distance than other 2.4GHz XBee radios.

Payload Telemetry Format

Telemetry Data Packet			
<TEAM ID>	Team ID number.	**<GPS LATITUDE>**	Latitude measured by the GPS receiver.
<MISSION TIME>	Time since the power up (in seconds).	**<GPS LONGITUDE>**	Longitude measured by the GPS receiver.
<PACKET COUNT>	Transmitted packet count, which is to be maintained through processor reset.	**<GPS ALTITUDE>**	Altitude measured by the GPS receiver.
<ALTITUDE>	Altitude as returned by air pressure sensor	**<GPS SATS>**	Number of satellites being tracked by the GPS receiver.
<PRESSURE>	Measured by air pressure sensor.	**<PITCH>**	Payload pitch.
<TEMP>	Temperature Measured temperature sensor inside the probe	**<ROLL>**	Payload roll.
<VOLTAGE>	Battery voltage	**<BLADE SPIN RATE>**	Payloads blade spin rate.
<GPS TIME>	The time generated by the UBLOX GPS chip.	**<SOFTWARE STATE>**	The operating state of the software.
		<BONUS DIRECTION>	Camera direction relative to north

Data Format

Each field is comma separated, packet terminated with a carriage return sign:
<TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>,<PRESSURE>,<TEMP>,<VOLTAGE>,<GPS TIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<PITCH>,<ROLL>,<BLADE SPIN RATE>,<SOFTWARE STATE>,<BONUS DIRECTION>

Example: 3668,4,2,332,1001.3,25.4,3.5,1201439195,N5003.55600,E01955.3633,440,2,0,0,40000,0001,5

Requirements

Data packets are sent in burst mode at frequency of 1 Hz. Requirements of the telemetry format are met.

Container Processor & Memory Selection

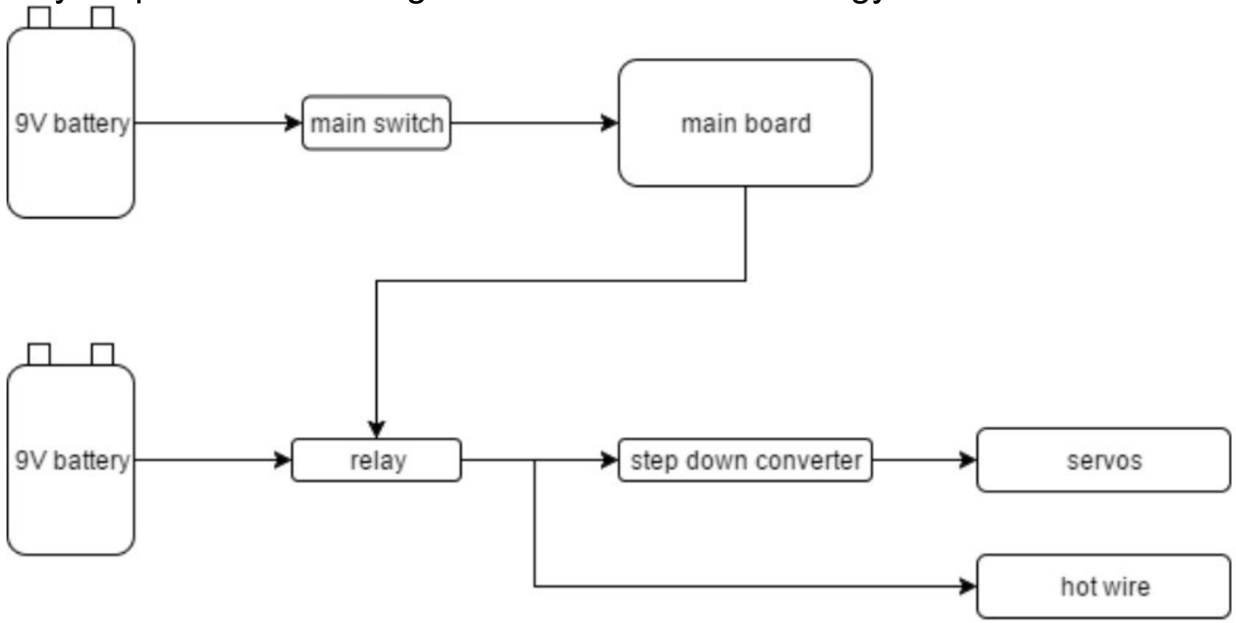
There are no electronics in the container.

Electrical Power Subsystem Design

Kornel Kowalczyk

Main EPS Assumptions

- Due to high current consumption by servos and hot wire, we've decided to use two 9V alkaline batteries, one to supply the main board with sensors and the other to power said components.
- Voltage for servos shal be supplied via step down converter to save energy and deal with high heat generation which would be caused by linear regulator.
- Servos shall only be powered on in flight mode to conserve energy.



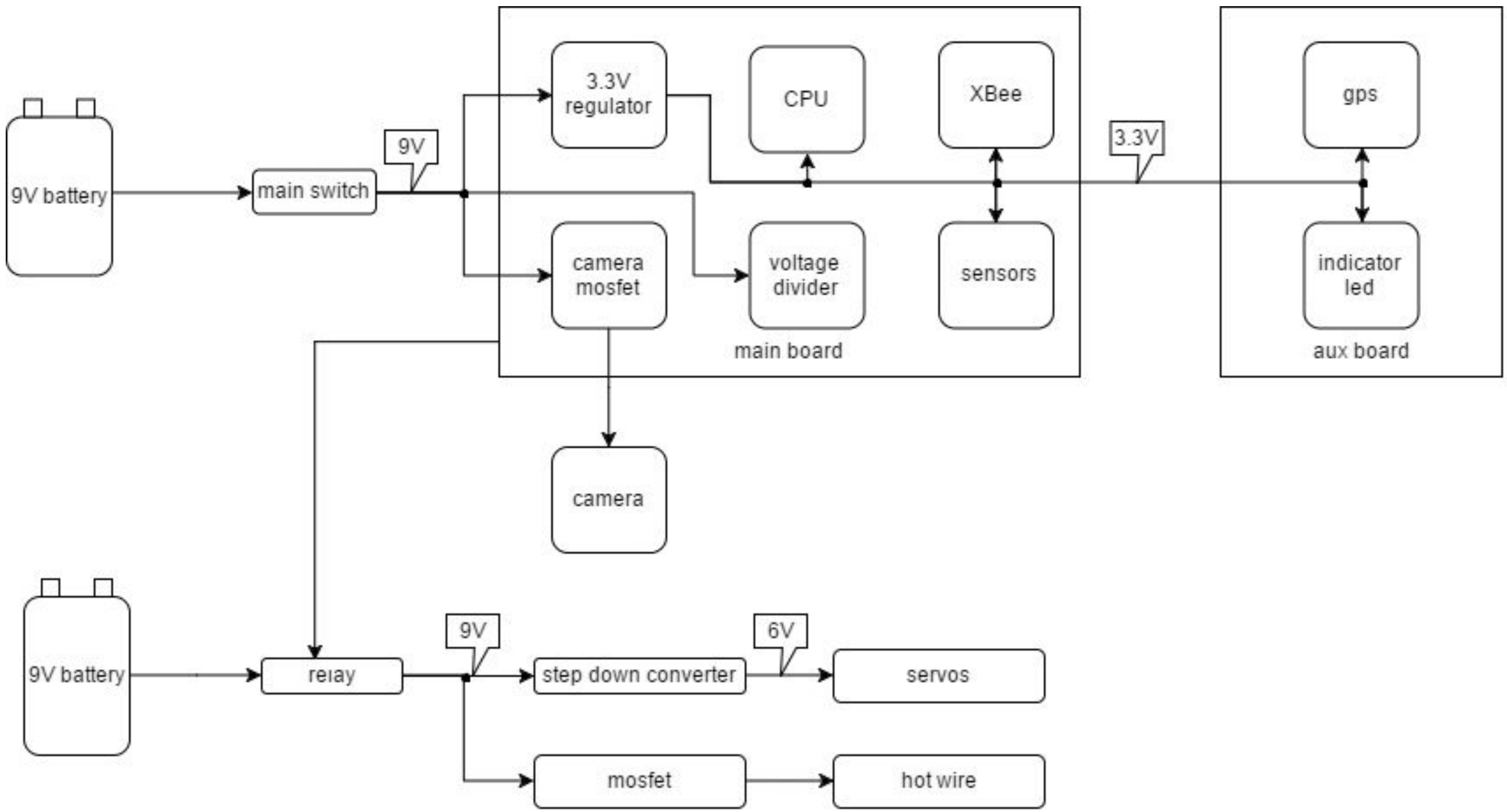
EPS Changes Since PDR

There are no changes since PDR.

EPS Requirements

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
45	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	Competition requirement	Power switch is easily accesible.	High	x	x		
46	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.	Competition requirement. Safety measure, helps finding the CanSat after mission, reducing the environmental risks.	LED indicator and buzzer implemented to comply with requirements.	High		x		x
49	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.	Competition and safety requirement.	Alkaline batteries are used.	High	x		x	
50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Competition requirement. If necessary power source can be easily replaced.	Access to batteries is easy.	High	x	x		
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Competition requirement. Power source must be reliable.	No spring contact used.	Medium	x	x		
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Competition requirement. Power source must operate during whole mission, including time at launch pad, which can be long due to weather and other conditions.	CanSat has enough power to operate minimum for two hours.	High	x	x	x	

Payload Electrical Block Diagram 1/2



Payload Electrical Block Diagram 2/2

- As mentioned before, key power saving feature of payload is ability to switch off power consuming components like servos and camera, and enabling them to be turned on only in flight mode. This feature lets us operate and communicate with CanSat for period significantly longer than duration of the competition.
- Power switch shall be located at the very top of CanSat for easy accessibility. Furthermore, switch we've chosen is a DIP type, which is very hard to accidentally toggle, which turned out to be a major problem in previous year. Next to it is located an LED indicator ensuring us whether the electronics is turned on or off.
- No lasers are used as they can cause harm or fire.
- Use of 9V batteries meant using dedicated battery clips which can be easily interlocked and thus without any additional connectors we can hook up auxiliary power supply for testing purposes in order not to drain

Payload Power Source

Power Source
We decided to use two independent power rails with 9V Duracell Alkaline cell each. One to supply main board and one to supply hotwire and servos.
Each battery has 1.7 Ohm internal resistance.
Allows up to 2 hours of constant 250mA current drainage, and more than 12 hours of 50mA.
Each battery has 310mAh of capacity.

Payload Power Budget

Component	Power Consumption [Wh]	Duty cycle	Source of calculation
CPU	0.198	100%	Datasheet / Estimation
IMU	0.002	100%	Datasheet
Barometer	<0.0001	100%	Datasheet
GPS	0.172	100%	Datasheet
Flash	0.66	2%	Datasheet
Camera	2.716	2%	Datasheet
Hall sensor	<0.0001	100%	Datasheet
XBee	0.365	100%	Datasheet
Servos	9.6	2%	Test
Hot wire	10.8	2%	Test

Duration time has been calculated based on assumption that CanSat may be turned on for 2h, while the actual flight time might be 2min. Energy drained from each battery is as follows:

- First battery: 0.8Wh
- Second battery: 0.4Wh

Given, that typical battery has capacity of at least 2.7Wh, we should not run out of power.

Container Electrical Block Diagram

There are no electronics in the container.

Container Power Source

There are no electronics in the container.

Container Power Budget

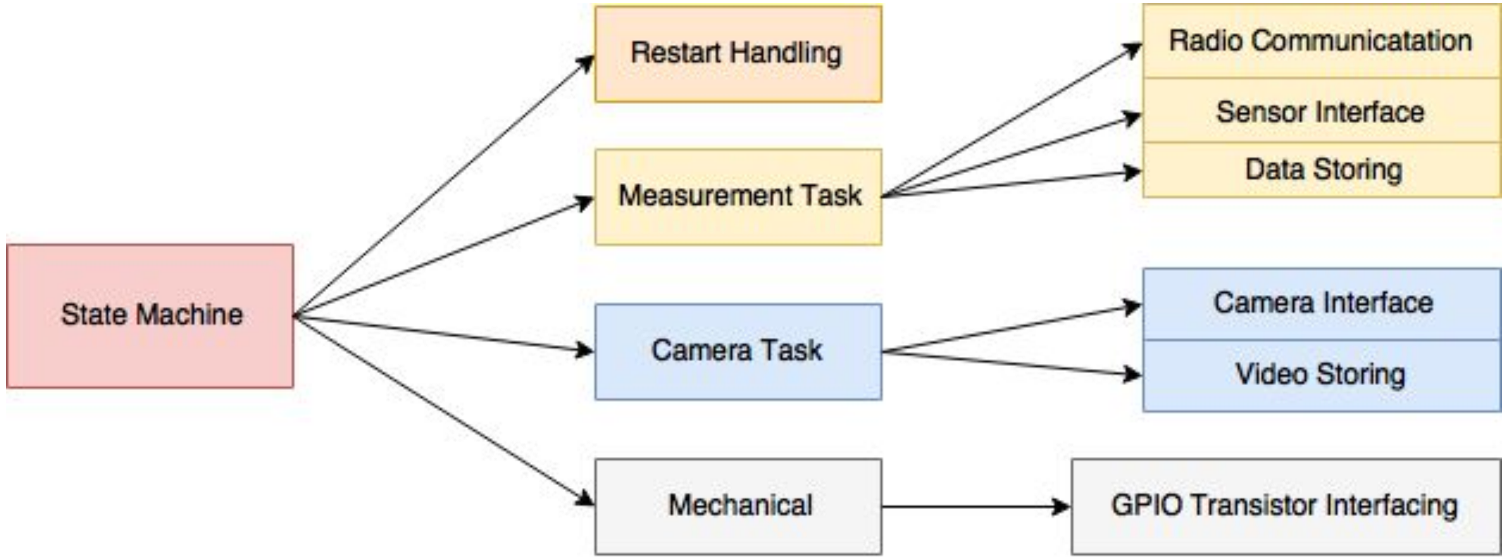
There are no electronics in the container.

Flight Software (FSW) Design

Mateusz Rajzer

FSW Overview 1/2

Main FSW Assumptions
Flight software will be developed in C++ language.
SW architecture is based on state machine system.
Code will be created and debugged in Eclipse environment, extended by STM processor plugins.
Program flow has to be restart resistant and restore its state in case of such failure.
We distinguished following FSW subtasks:



FSW Overview 2/2

Main FSW Operations

On the ground, before start:

- Awaiting on arming signal from CGS,
- Continuous communication with ground starts now,
- Measurement Task is started, measured values are transmitted and also stored on flash memory

After arming operation:

- Probe waiting for release CanSat from the rocket.

When released from rocket:

- All previous tasks are maintained.
- Video recording is triggered,
- CanSat is awaiting for desired altitude.

After critical altitude crossing:

- Cansat is being released from container,
- Cansat is awaiting for landing.

After landing:

- Camera and measurement operations will be no longer performed,
- Buzzer signalization starts, and transmission stops.

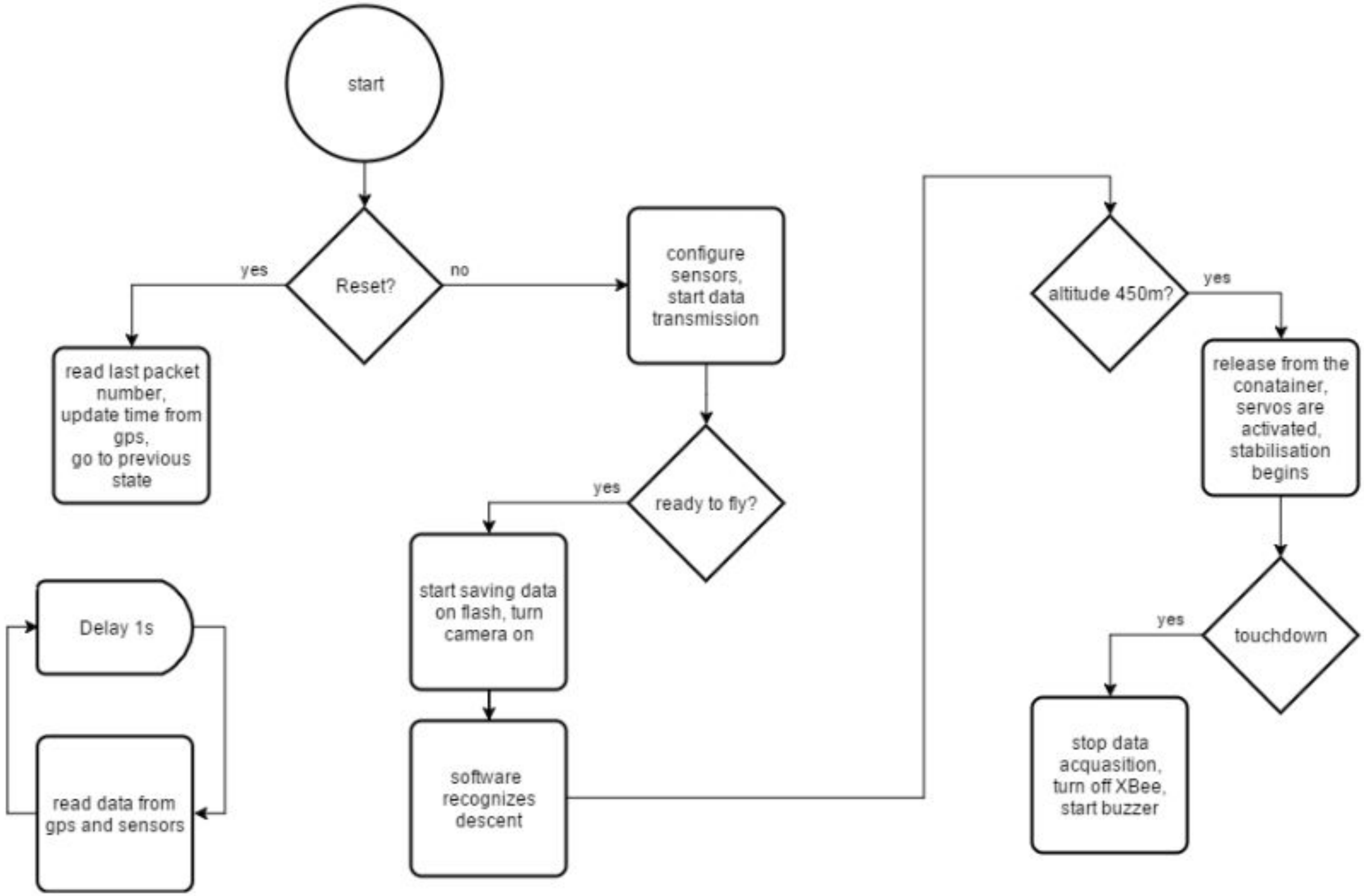
FSW Changes Since PDR

There are no changes since PDR.

FSW Requirements

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
9	The container shall release the payload at 450 meters +/- 10 meters	Enables safe descent of SP. Competition requirement	Actions will be executed on this exact altitude based on barometer readings. Probe microcontroller will perform action via GPIO pins and HotWires.	High	x	x	x	
20	The science payload shall measure altitude using an air pressure sensor.	Allows SP to separate from container at required altitude, Competition requirement	Data will be collected from barometer via I2C line	High		x	x	
21	The science payload shall provide position using GPS.	Competition requirement	Coordinates will be collected from GPS via UART	High		x	x	
22	The science payload shall measure its battery voltage.	Competition requirement	Battery voltage will be read by ADC	High		x	x	
23	The science payload shall measure outside temperature.	Competition requirement	Data will be collected from sensor via 1-Wire interface	Medium		x	x	
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	Competition requirement	Data will be collected via GPIO pins from Hall sensor	Medium		x	x	
25	The science payload shall measure pitch and roll.	Enables using servos with ailerons for stabilisation, Competition requirement	Pitch and roll data will be collected continuously from IMU	High		x	x	
26	The probe shall transmit all sensor data in the telemetry	Competition requirement	Telemetry will be sent by Xbee module with 1Hz frequency	High	x	x	x	
42	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.	Competition requirement	Software counter will be maintained and incremented through all mission time. Value of the counter will be kept on memory card to survive processor restarts.	High	x	x	x	

Payload CanSat FSW State Diagram 1/2



Payload CanSat FSW State Diagram 2/2

Software can recognise if payload is descending based on rotation speed of blades and velocity calculated as a derivative of height, which is calculated from pressure.

As far as power management goes, all devices apart from two shall be turned on all the time. Said components are servos and hot wire. Their activation has been marked on flow diagram, and they are not to be turned off until end of the mission.

After reset of processor in flight mode, previous state of mission together with last packet count can be retrieved from flash. This information with current gps time is sufficient to continue mission. It must be mentioned, that gps has an external battery, which enables it to quickly recover from reset state and output accurate time.

Potential reset causes are countless, yet most likely of them are:

- Temporary battery disconnection due to poor quality of connection,
- Watchdog, triggered by software bug which caused program to freeze.

Container CanSat FSW State Diagram

There are no electronics in the container.

Software Development Plan 1/2

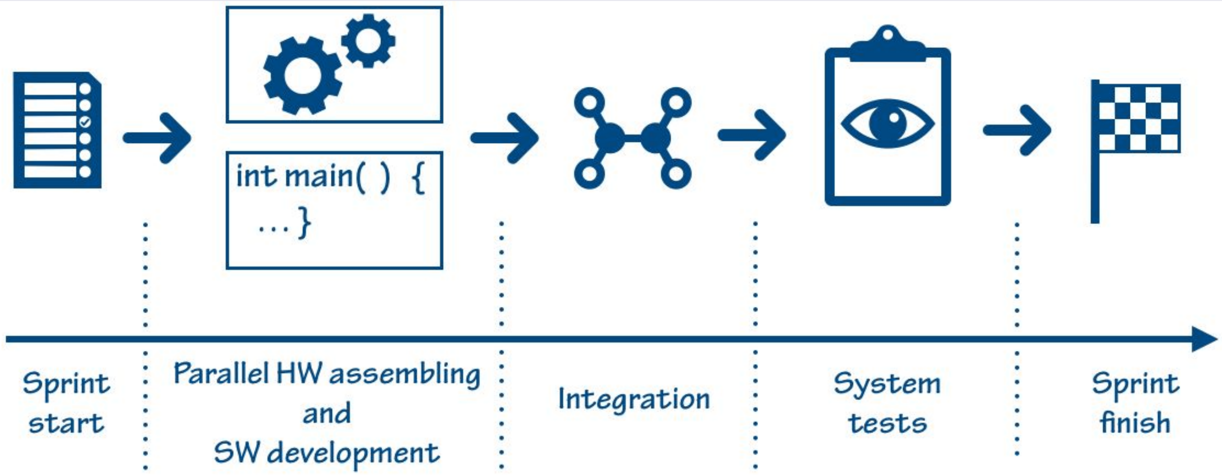
Agile development and integration strategy

- All software tasks, based on requirements will be listed and described in project's backlog. Storing tasks in backlog will be connected with categorization. Each division will be linked with one functionality of CanSat, for example: *main state machine, IMU measurements, communication, heat shield actions, etc.*

- To prevent late software development we decided to develop each section described above parallely with hardware components mounting.

- Each software/hardware division is being developed in separate Agile's methodology sprints (1-2 weeks). Meantime the sprint software and hardware section will be developed simultaneously. Sprint finishes when both sections are completely tested and cooperate with each other.

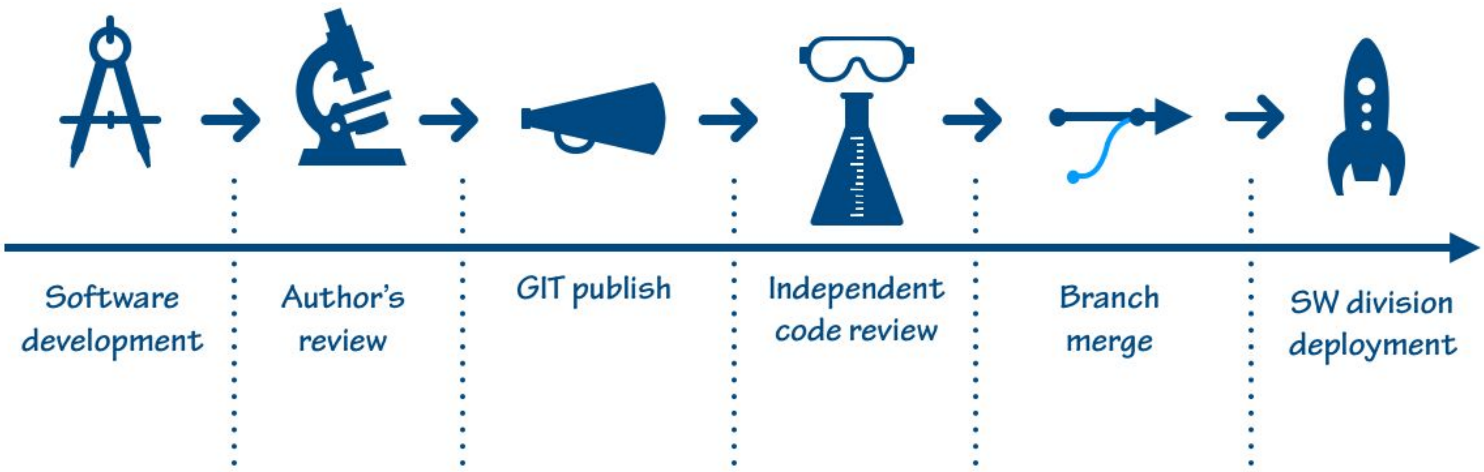
- This strategy allows us not to delay SW development on account of hardware assembling. In effect, at the end of each sprint we acquire new functionality both on hardware and software sides.



Software Development Plan 2/2

Code publishing and reviewing process

- In each sprint, one division from Software Development Plan will be completed.
- SW developer can work on one task, chosen from current sprint's division.
- Finished code, after author's revision will be published into the GIT repository on private developer's branch.
- Each committed change needs to be reviewed by independent tester.
- After positive result of code review (desk check) and compilation verification, developer's branch can be merged into master branch.
- Before closing the sprint, all committed changes will be integrated into existing software from previous sprint. At this point, system tests will be performed. In test procedure development teams will test functionality of the software division and cooperation with whole software system.

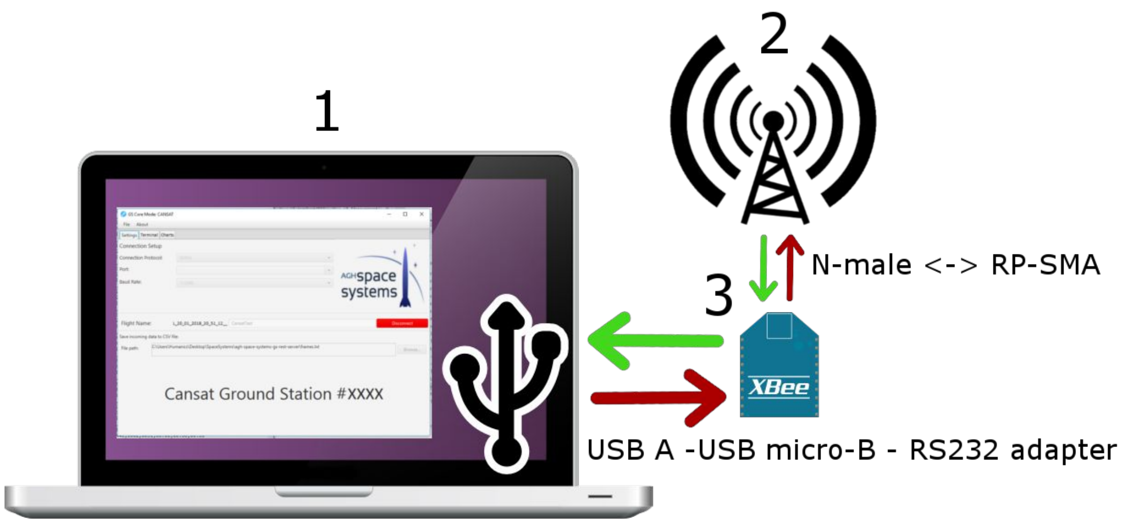


Ground Control System (GCS) Design

Mateusz Rajzer

GCS Overview

Overview
Main Computer (1) is a laptop running GS application. The application is configured in GUI so that an appropriate port and baud rate can be selected.
QHA antenna (2) receives data from the probe and transmits commands.
XB9X-DMUS-001 (3) module forwards data to RS232/microUSB adapter.
The adapter then relays data to GS’s Main Computer (1) using a microUSB-to-USB cable.
GS application, written in Java, saves and displays data. It also serves received data in a local area network.
Green arrows in the diagram represent data that is collected and red arrows represent data that is sent.



GCS Changes Since PDR

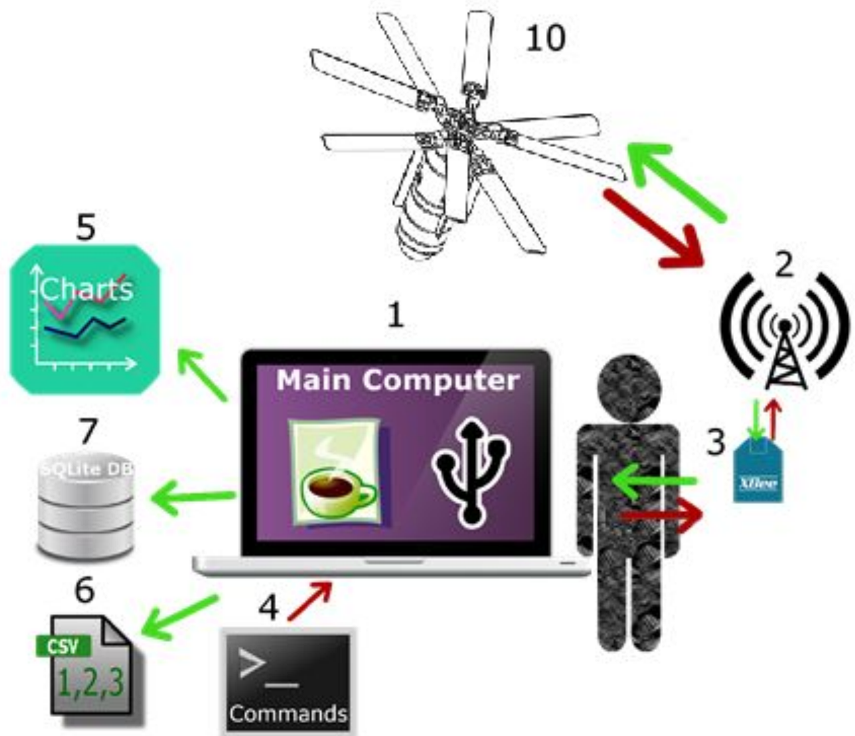
Ground station antenna has been changed.
Details are presented in GCS Antenna section.

GCS Requirements

ID	Requirement	Rationale	Fulfillment	Priority	VM			
					A	I	T	D
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.	Competition requirement CanSat needs to be remotely operable to fulfill safety reasons	CanSat will be remotely operable	High		x		
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	Competition requirement	csv file will be generated	High			x	
36	All telemetry shall be displayed in real time during descent.	Competition requirement	Data is displayed on the computer monitor immediately when computer receives it.	Medium		x		
38	Teams shall plot each telemetry data field in real time during flight.	Competition requirement. Enables to control data during descent.	Javafx charts plot each numerical values. The rest is displayed by various controls.	Medium		x		
39	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	Competition requirement. A laptop computer is a sufficient tool for analyzing data from XBee. Battery is required to last through whole mission.	GS consists of Laptop with battery able to work up to 4 hours, XBee module and tabletop antenna.	High	x		x	
40	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.	Competition Requirement. Enables to set up ground station easily and fast.	The whole GS consists of one laptop computer, xbee radio and a antenna which makes it easy to move it by one person.	Medium	x		x	

GCS Design 1/3

Data Flow and Components
The antenna (2) receives data over radio from the probe (10).
Using N-male to RP-SMA female cable, forwards data to the Xbee module (3) using tabletop antenna (2).
XB9X-DMUS-001 (3) module forwards data to GS's Main Computer (1) using microUSB to USB cable.
Software developed in Java parses and then displays data using JavaFX library in engineering units (5) and save them into a CSV file (6) and a SQLite Database (7).
Main computer (1) is capable of sending predefined commands(4) to the probe.



GCS Design 2/3

Major Components 1		
ID	**Component**	**Description**
1	Main Computer	An efficient laptop computer with an i7 Intel processor with 8gb of ram needed for running application. The laptop also has a good battery which lasts up to 3 hours of intensive usage. It also runs the main GS application and RESTful server. The main application is responsible for configuring USB Serial Port connection and for parsing data and sending it to its gui submodules.
2	Crossed dipole antenna	Antenna used to transfer data from the probe to the GS. More information presents the GCS Antenna slide.
3	Xbee XB9X-DMUS-001	Xbee radio module is used for communication of GS with the probe.
4	Command terminal incorporated in GS application	Terminal allows user to send commands to the probe and to plot raw telemetry frames as well as application internal notifications to user.
5	Real time charts	GS consists of Laptop with battery able to work up to 4 hours, XBee module and directional antenna.
6	CSV files	The main application saves data to a CSV file.

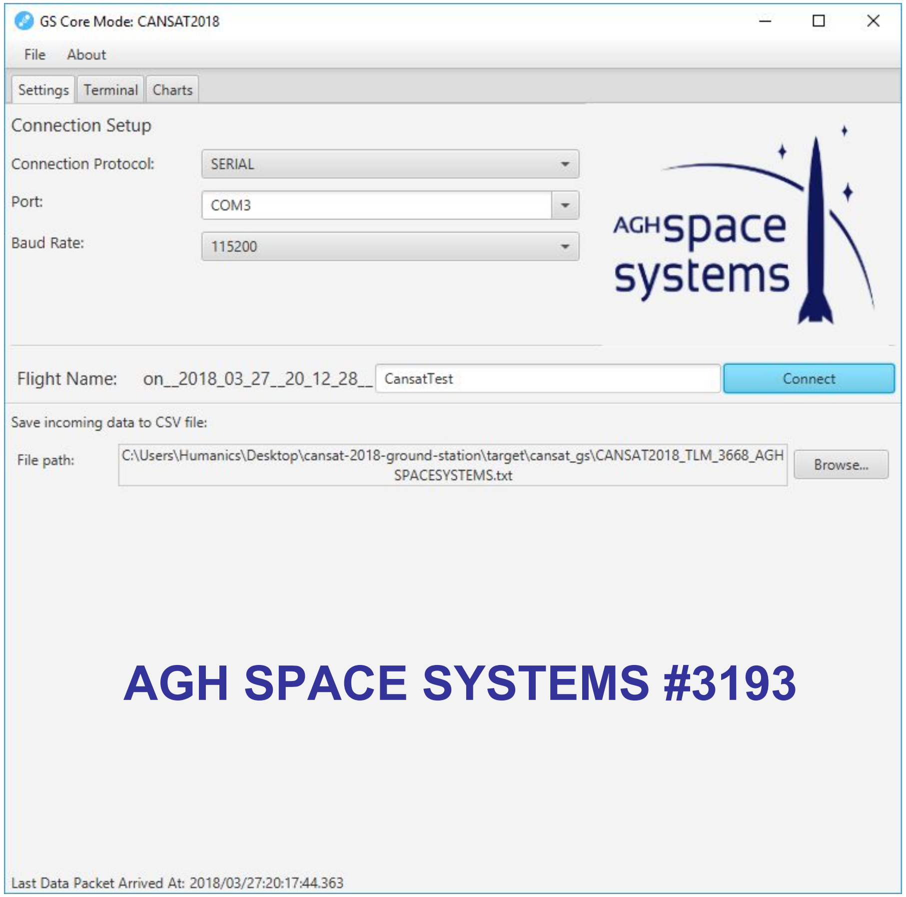
GCS Design 3/3

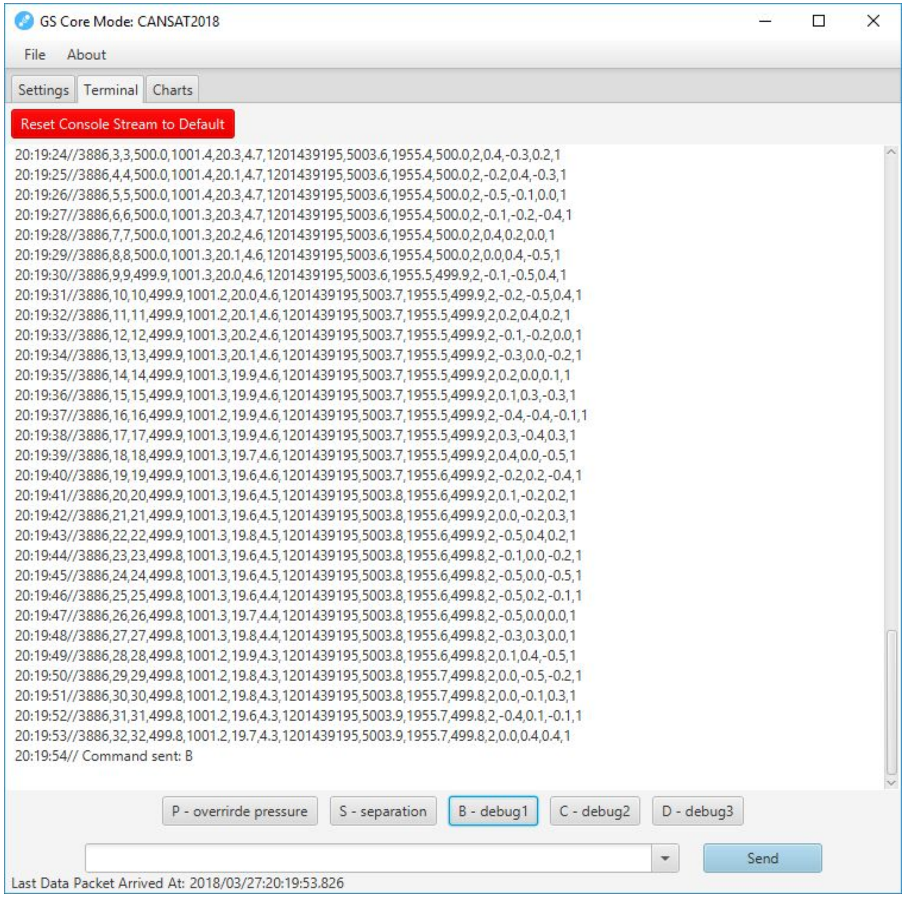
Major Components 2		
ID	**Component**	**Description**
7	Sqlite3 database	The main application saves telemetry data to a database table with a timestamp of telemetry frame arrival. The main application only writes to the DB, then the data is read by Java RESTful Server which serves it in JSON format for Web Applications.
8	Java RESTful Server	Written with lightweight Javaspark framework and DB utilities it can read the data from a database and return it in JSON format when asked. It also serves simple Web Application html/css/js files.

Specification
Ground Station can operate on battery at ease up to 3 hours and longer with an extra power bank.
Ground Station team member carries an umbrella to cast a shadow on the main computer in case of a sunny day. Before start the main computer is kept in a special thermal case.
Main Computer runs Windows offline and all possible automatic updates are turned off.

GCS Software 1/3

Software Screen Shots – Settings & Command Software

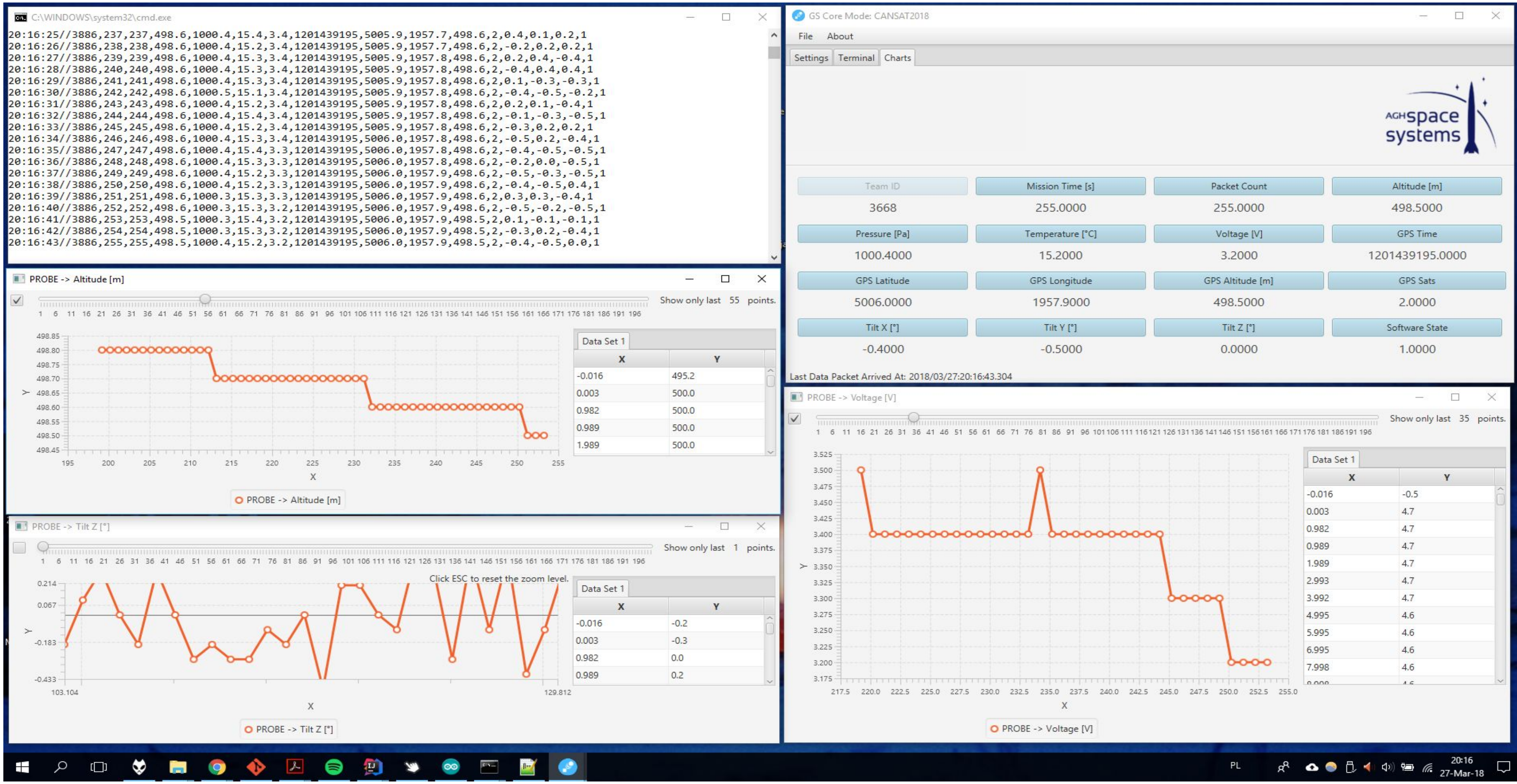




The Settings Tab provides features as: setup of serial connection with GCS' XBee radio, naming the flight in a database, setting the telemetry log file path and saving configuration. Terminal tab serves to provide insight in raw data and internal logs of the application as well as allows to send commands to CanSat during the mission and testing.

GCS Software 2/3

Software Screen Shots – Real Time Data & Plots



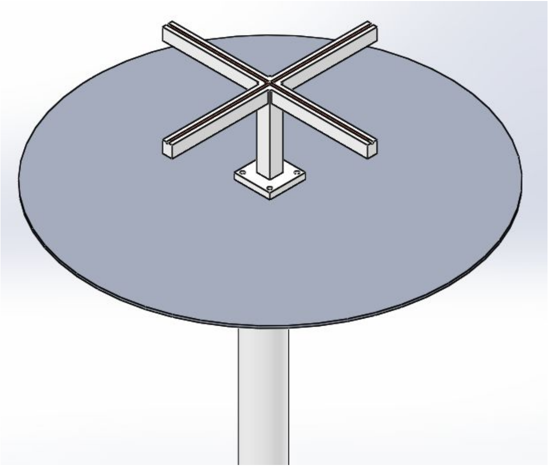
The Charts Tab displays received data fields with buttons to launch a Plot Module for selected field. Plot Module is used for displaying received data in real time plotting them as a function of mission time.

GCS Software 3/3

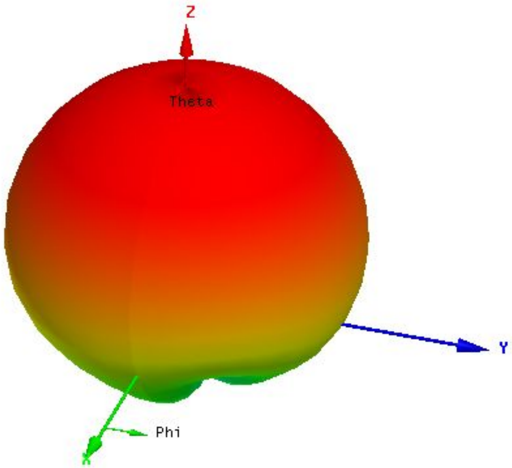
Software specifics
Real-time data is received via microUSB-USB cable. Application is analyzing the beginning and end of each telemetry frame. After being received, a frame is divided into parts and directed into the data flow and then the whole frame or its part is sent to software listeners like in e.g. SQLite Database module or a real time chart module.
GUI is equipped with indicators which inform about mission phase and onboard computer system state.
No COTS software packages were used.
Real-time plotting software relies on JavaFX chart components which are configured to listen to data providers. JavaFX charts are optimized for handling real time data. There is also Web Application showing near real time data to team members.
Command software and interface is included in the application as the Terminal Tab.
It is possible to send predefined and custom commands to the probe with the Terminal Tab.
The CSV file is created by writing every telemetry frame with an End Of Line sign at the end to a file with a proper name.

GCS Antenna

The design of the antenna has changed since PDR due to difficulty in tunability of previous design. Laboratory test have proven, that solution proposed in this document works and is easier to manufacture.
Under assumption of worst case scenario, where both antennas have the smallest gain (just before landing), using Friis equation we were able to calculate, that max distance between ground station and Payload can be up to 1km, which we find more than sufficient.
Current antenna is a crossed dipole with a right hand circular polarisation, 8dBi gain, and 30MHz bandwidth at 900MHz. It consists of two perpendicular dipoles placed on 3D printed holder, which is screwed to the reflector. Whole assembly will be mounted on top of PVC pipe, and placed on table. To add durability , the antenna will be enclosed in fiberglass dome (not included on the render).



Antenna assembly

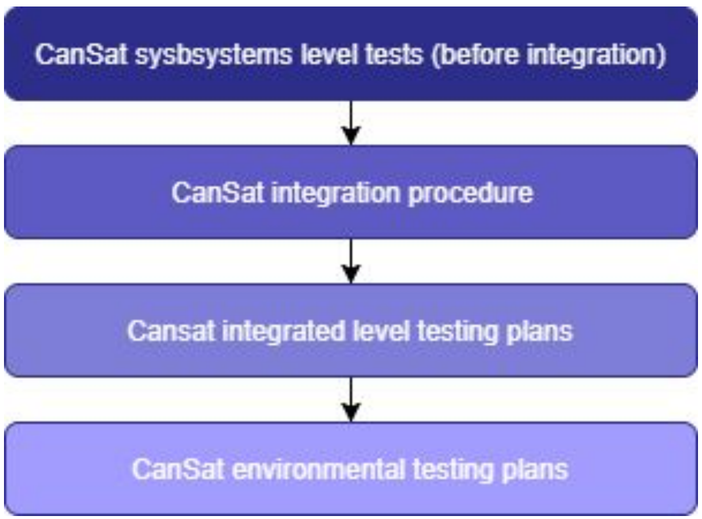


3D radiation pattern

CanSat Integration and Test

Dagmara Stasiowska

CanSat Integration and Test Overview



Before integration of the CanSat each individual required subsystem was tested in order to reassure that CanSat as a unit also will work properly. Tests allow us confirm if everything works as expected, if something needs to be replaced or if there is better solutions for some tasks. For example critical was checking the parameters of auto-gyro, flight stability and communication quality of radio modules to exclude the possibility of failure of the whole subsystem.

After performing all planned tests of subsystems integration of CanSat can be done - details are provided in the following slides.

Integration allows to check if all systems work as desired as a unit. Simplified mission in the drone as well as in our own rocket can verify also main objectives of the competition - communication between the CanSat and the ground station, recovery system, auto-gyro and structure durability.

Environmental tests such as drop, thermal rocket and vibration tests show if CanSat can operate without failure during the mission in various conditions (such as 15Gs of launch acceleration and 30Gs of shock), what will lead to successful mission. Fit check, performed with usage of our rocket, which has the same diameter as required, will assure us that CanSat will be deployed as desired, without any troubles.

Subsystem Level Testing Plan 1/2

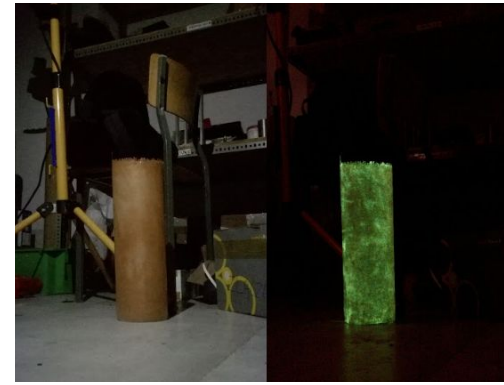
All procedures for Subsystem Level Tests are given on the separate, following slides.

CanSat subsystems level tests (before integration)		
Sensors		Sensors will be checked and properly calibrated separately, before mounting them to a CanSat. It will assure us, that all used components are fully functional and will not cause mission failure. Calibration will be done with usage of oscilloscope sending the data via UART to PC and checking if the values are correct.
CDH		Preliminary tests for data acquisition – checking if sample data send via radio modules can be properly handled by ground station software. Checking the time of sending data along working under various conditions. Checking if data frame format is as desired.
EPS		Supplying a voltage divider with various voltages of a battery working range from laboratory power supply to determine the correct behaviour of the circuitry. Checking for damage such as short circuits. Battery tests will be performed - maximum current consumed by hot wires need to be compromised with battery parameters - checking if they make hotwire hot enough. Checking battery lifetime. Voltage checking on the checkpoints.
Communications	**Radio communications**	Sending and receiving known amount of packets and checking the loss percentage in various areas, such as between buildings/trees or on an open field. Verification of radio modules parameters and communication quality on ground.
	FSW	Checking designed software functionalities such as: proper visualization of sample data, sending remote commands to the onboard computer. Sequences chronology and order will be tested in all possible scenarios and events.

Subsystem Level Testing Plan 2/2

CanSat subsystems level tests (before integration)

Mechanisms	**Mechanical**	All mechanical elements separately must be checked if they are made properly and have good dimensions. Then, components must be preassembled in order to see if a whole structure is stiff enough and have no looseness. Checking if fast moving and rotating structure does not cause any problems. If not, then we test all mechanisms used separately if they work properly – e.g. if wings can be opened and closed easily. Container has to be checked on the ground for its stiffness and durability and visually if a composite does not have any cracks and flaws. Container must be fluorescent colour to be easy to find - test of luminescent addings to glass fiber composite.
	Descent Control	Checking if parachute descent is stable with a sample mass attached. For probe - checking if descent rate of the designed wings is as desired and what is their rotation rate. Test performed in aerodynamic tunnel. Rotation rate checked by suitable sensor.



Comparison of Container in daylight versus in dark room - luminescent addings used

Photo from rotors tests in aerodynamic tunnel

Completing all tests will allow us to move to the main procedure of CanSat integration and checking if all subsystems work as a unit in CanSat.

Subsystem Level Testing Plan - Test Procedures Descriptions 1/3

Tests level	Test	Test Proc	Test Description	Rqmts	Pass Fail Criteria
CanSat subsystem level tests	Sensors	1. Powering up a sensor. A sensor is powered up in a good way if it connects to the microcontroller. 2. Forcing a sensor to measure the proper physical variable 3. Calibrating a sensor. 4. Checking if the performance of a sensor is the same as in its specification. 5. Comparing the measured values to these measured with a reference sensor.	These tests will show if chosen sensors are working as expected and without any problems. If their resolution is the same as specified in their documentation and if they can be calibrated without any troubles.	20, 23, 24, 25, 28	Proper, continuous performance and resolution of data (according to datasheets of each sensor). Proper calibration procedure during ground tests.
	CDH	1. Setting up the radio modules (transmitter & receiver) 2. Connecting the receiver to a laptop with the ground station application. 3. Sending some sample data and checking if they can be properly received and showed in the application under various conditions.	This test will show if sample data sent to the ground station via radio modules can be handled and used e.g. for a visualization purposes by its application.	21, 28, 29,31,32,33,36,37,38, 39,40	Receiving sample data sent via radio modules with the same frame format and using them for a visualization in the ground station application. Time of sending data is acceptable.
	EPS	1. Testing battery with voltage divider, checking visually for damage 2. Checking for short circuits in the system, if the wiring is correct. 3. Reading data using potentiometer 4. Checking if battery voltage is enough for hotwire to burn string. 5. Checking battery lifetime.	These tests will show if battery is fully charged and capable of supplying enough power for the mission and for proper hotwire operation.	22, 49,50,51,55	Battery voltage below acceptable level. Hotwire is not hot enough to cut nylon string.

Subsystem Level Testing Plan - Test Procedures Descriptions 2/3

Tests level	Test		Test Proc	Test Description	Rqmts	Pass Fail Criteria
CanSat subsystem level tests	Communications	Radio communications	1. Setting up the radio modules (transmitter and receiver). 2. Continuous sending sample data between the transmitter & receiver while increasing the distance between them – checking the limit and testing it in different terrain.	This test will show if chosen radio modules will be able to send data on distance equal to the distance between the CanSat and the ground station during the actual mission and what will happen if something, e.g. tree, will appear between CanSat and GS.	21, 26, 28,29,30,39,40,53	Proper performance of radio modules with distance that can occur between CanSat and GS during the actual mission with a safe margin.
		FSW	1. Sending sample data and checking its visualisation. 2. Sending remote commands to the onboard computer. 3. Testing sequences chronology in different scenarios.	These tests will show if designed functionalities work properly and how they behave in different scenarios.	21, 26, 28, 29,42	CanSat receives remote commands and reacts properly.

Subsystem Level Testing Plan - Test Procedures Descriptions 3/3

Tests level	Test		Test Proc	Test Description	Rqmts	Pass Fail Criteria
CanSat subsystem level tests	Mechanisms	Mechanical	1. Visual inspection of the mechanical structure, does it have any cracks or flaws. Dimensions and mass verification. 2. Stiffness checking during fast moving and rotating, checking if such moves do not cause any problems. 3. Checking wings opening mechanism. 4. Checking if Container has proper colour - is it easily visible from far distance.	These tests will show us is structure is ready to use and if there is no serious damage. If everything works as desired and if all mechanisms are stiff/lose enough and if CanSat will be visible enough during competition.	1,2,3, 4,5,6, 7,27,	There is no visible damages, structure is stiff while rotating, wings open easily, CanSat has eye-catchable colour.
		Descent control	1. Checking parachute descent stability during test with sample mass attached. 2. Rotation rate checked in aerodynamic tunnel. 3. Rotors descent rate calculated - verification of calculations.	Tests will show descent rates of designed parachute and rotors. Auto-gyro mechanism descent rate verification will be performed during integrated level tests, as for this stage we can only check it in aerodynamic tunnel.Testing servo, checking if it works as desired and if its repeatability is proper.	8,10, 11,52	Parachute descent rate, rotation rate of the rotors is as desired. Calculations are correct. Servo's step is as desired.
			1. Plug in servo to testing unit. 2. Supply servo with adequate PWM signal 3. Check repeatability for 30 minutes.			

Integrated Level Functional Test Plan

All procedures for Integrated Level Functional Test Plan are given on the separate, following slides.

CanSat subsystems level tests (after integration)		
Descent Testing		Testing if the flight is stable with rotors. We check it by deploying CanSat from high building with known height - recording the test with the camera lets us calculate descent rates of parachute and rotors. Testing if detumbling system works as desired and stabilizes Probe during auto-gyro descent and if recording from camera is stable. Preliminary tests were performed with our rocket and with the drone. Checking if container can also deploy from a prepared rocket payload section smoothly.
Communications	**Ground station software**	CanSat is deployed from a drone - we check if data looks as expected.
	Telemetry	Tests on-ground are conducted - we send sample data frame and check if received data is the same as send one.
	Antennas	CanSat with antenna on-board is flown at various heights/distances by a drone - we check how far antenna is usable.
Deployment	**Release trigger**	Checking if the Probe is well fitted to the Container, and checking if after releasing it will deploy from the Container without any trouble. Spring piston and hotwire SP deployment mechanism test. Pressure sensor is checked if it measures values properly and if it will release probe at desired altitude.
	Payload parachute release	Testing the parachute from a smaller height if it opens, is stable and if the descent rate is appropriate. Parachute deployment test from a drone. Rocket tests confirms correct working principle.
Mechanisms		Testing if rotors open well and work in desired way and if elastic bands give enough force for unfolding rotors. Everything is well-fitted and the capsule is able to slide easily in the structure. Mechanical parts are tested to survive required force limits with the help of drop test on a string.

Our rocket, used as testing platform during CanSat tests

Integrated Level Test Procedures Descriptions 1/2

Tests level	Test		Test Proc	Test Description	Rqmts	Pass Fail Criteria
Integrated Functional level testing	Descent testing		1. Attaching SP to the string. 2. Dropping SP from high building with known height, while recording.	Those tests will assure us if descent rates of all systems are as desired and if detumbling stabilizes camera properly - mission simulation with usage of our rocket and drone shows if all next steps of mission occur without any trouble and does not disturb each other. Checking if CanSat deploys smoothly from rocket.	8,9,11	Auto-gyro mechanism works properly and its descent rate is as desired. Detumbling system stabilizes camera. CanSat deploys smoothly from the rocket.
			1. Attaching Probe to the drone and dropping it from known height. 2. Detumbling system check by camera stability checking.			
			1. Putting CanSat to prepared rocket payload section. 2. Tilt the rocket. 3. Check if CanSat can deploys smoothly.			
	Communications	Ground station software	1. Attaching CanSat to the drone. 2. Drone goes up. 3. Deployment of CanSat. 4. Checking data correctness.	This tests checks if CanSat as a unit communicates with GS correctly and if wireless modules work, if data frame is proper and what is maximum range of antenna.	21,29, 30,31, 32,33, 39,40, 42,53	CanSat communicates with GS. Received data format is the same as send one. Antenna range is as desired.
		Telemetry	1. Sending sample data frame. 2. Receiving data. 3. Checking data frame format.			
		Antennas	1. Attaching CanSat with on-board antenna inside to the drone. 2. Drone flies up at various heights/distances. 3. Checking maximum antenna range.			

Integrated Level Test Procedures Descriptions 2/2

Tests level	Test		Test Proc	Test Description	Rqmts	Pass Fail Criteria
Integrated Functional level testing	Deployment	Release trigger	1. Closing rotors. 2. Putting SP to the Container and attaching it to the hotwire via nylon string with stowed spring piston mechanism. 3. Attaching whole CanSat to the stand. 4. Hotwire mechanism activation. 5. Checking if SP slides easily from the Container.	Tests check if hotwire-spring piston mechanism has enough force to deploy SP without any trouble and if SP can be easily released from the Container. Checking if parachute opens and works as desired and stays attached. Checking if pressure sensor properly detects altitude.	7,9,19	SP deploys from the Container, parachute stays attached, opens and has proper descent rate. Pressure sensor data correct.
			1. Pressure sensor in turned on. 2. We climb on the highest floor of building. 3. Check if height change is proper.			
		Payload parachute release	1. Attaching CanSat with stowed parachute to the drone. 2. Flying up. 3. Releasing CanSat and checking if parachute opens properly and stays attached			
	Mechanisms		1. Closing rotors. 2. Putting SP to the Container and attaching it to the hotwire via nylon string. 3. Hotwire mechanism activation.	Tests show if SP can easily open the rotors and elastic bands has enough force to open them after releasing from Container, if whole CanSat easily releases from the rocket and if all mechanical parts will survive required force limits.	2,3,5,6, 7, 10, 17, 18, 19	Rotors open. CanSat releases from the rocket easily. All mechanisms survived, visual inspection correct.
			1. Attaching CanSat to unstretchable cord. 2. Cord attaching cord to the stand about 2 meters high. 3. Dropping CanSat from height. 4. Visual inspection of CanSat			
			1. Putting CanSat to the rocket. 2. Tilting the rocket. 3. Checking if CanSat deploys easily from the rocket.			

Environmental Test Plan

All procedures for Integrated Environmental Test Plan are given on the separate, following slides.

CanSat Environmental Tests	
Drop Tests	Drop tests will show if CanSat as a unit can survive sudden acceleration (all structures and descent control devices attachment components shall survive 30Gs shock). Test will be performed by dropping CanSat on a string from known, proper altitude - about 1.5m. We power on CanSat and check if telemetry is being received, then attach it via parachute to the cord. We release the CanSat and verify the CanSat did not lose power. Then inspection for any damage, or detached parts is made and verify telemetry is still being received.
Thermal Tests	Thermal tests will show if high temperature, which can occur during the mission in rocket, does not cause any major harm to the CanSat (e.g. to electronics, communication with Ground Station, structure). Test will be performed by using a thermometer, heater and a closed box. CanSat will be turned on for 2 hours in thermal chamber in about 60 degrees Celsius. Communication and electronics test will be performed for all time when CanSat will be heated. After, when CanSat is still warm, mechanical parts and joints will be checked
Vibration Tests	Vibrations tests will verify if all components of CanSat are properly integrated, if any screws does not unscrew during the mission or structure loosens, what would cause CanSat to fail a mission. Test will be performed with usage of device provided by our University, to which we will attach CanSat. After powering on the CanSat accelerometer data collecting is verified. Then we power up device for 5 seconds, then power down. Repeat test 5 times while still verifying accelerometer data collecting. After this, mechanical parts and their functionality are being checked. After it, we power down CanSat.
Fit check	Fit check will be performed by using a pipe of proper size in order to check if CanSat can be easily deployed from rocket.

Environmental Test Procedures Descriptions 1/2

Tests level	Test	Test Proc	Test Description	Rqmts	Pass Fail Criteria
Environmental testing	Drop test	1. Setting up a stand that can be used for a drop test – e.g. consisting a stiff construction (about 2m high) with a string attached. 2. Attaching the CanSat to the string. 3. Releasing the CanSat so it can fall freely and be stopped with shock when the string is tight. 4. Performing integrated test of the whole unit sent in our rocket to an appropriate height.	This test will tell us if the CanSat as a unit and all of its components can survive a shock without any major damages.	12, 14, 15, 16, 17, 54	CanSat survives the shock test as a unit without any damages.
	Thermal test	1. Setting up a stand that can keep the proper test temperature (aprox. 50 ~ 60 Celsius degrees) – e.g. using a closed box and a heater. 2. Placing the CanSat inside the stand – e.g. the mentioned box and powering up the heater for a few minutes. 3. Stopping the heater and checking the CanSat for any damages and problems with subsystems – e.g. checking if the electronic components / mechanical elements are fine and fully capable of working.	This test will tell us if all of the CanSat components can survive the temperature which can appear during the actual mission.	17, 54	CanSat survives the thermal test as a unit without any major damages and all components are still capable of working.

Environmental Test Procedures Descriptions 2/2

Tests level	Test	Test Proc	Test Description	Rqmts	Pass Fail Criteria
Environmental testing	Vibration test	1.Attaching the CanSat to a shaker which vibrates with desired rates. 2. Starting up the device for few minutes. 3. Stopping the device and checking if CanSat has any loose screws or if it was damaged in any way visually, and then by testing integrated system.	These tests will tell us if all of the CanSat components are properly integrated together and if CanSat as a unit can survive this kind of vibrations.	12, 14, 15, 16, 17, 54	CanSat survives vibration test without any major damages which may cause dysfunction.
	Fit check	1. Assembling the CanSat. 2. Measuring all important dimensions and checking if it fits inside rocket payload section. 3. Visual inspection if everything is in correct place.	This test will tell us if CanSat fits inside the rocket payload section	2, 3, 6, 54	External dimensions of CanSat enable it to fit easily inside the rocket payload structure.

Mission Operations & Analysis

Adam Kolusz

Overview of Mission Sequence of Events 1/3

Arrival

- Check in
  - Weight and fit-check of the CanSat
  - Check for any damages caused by the travel

Setting up Ground Station

- Localization of the place allocated for the ground station
- Antenna assembly and setting up ground station
- Checking communication devices and algorithms

CanSat Preparation and Assembly

- Initial checklist:
  - Communication test
  - CanSat structure has no mechanical damages
  - Unfolding and folding rotor blades
  - Checking if Science Payload moves freely in container guides
- CabSat Assembly
- Final Check

Overview of Mission Sequence of Events 2/3

Preparation for flight	• Power CanSat on • Integrate CanSat into rocket payload • Confirmation of telemetry data reception by line judge
Mission	• After powering on the CanSat, telemetry is constantly transmitted to the ground station and monitored • Parachute opens right after deployment of the CanSat from the rocket • Separation mechanism is triggered when altitude drops below 450 m (forced from GS otherwise) • Separation is followed by activation of unfolding mechanism • Buzzer is turned on upon landing. • After landing, telemetry is no longer transmitted to the ground station and GPS is turned off.
Recovery	• After all launches for 1 hour period, recovery crew can enter the field to search for CanSat parts • Localization of field judge and delivery of the score card • Obtaining permission to recover CanSat parts • Retrieval of the Container and the SP • Delivery of the telemetry data file to a line judge for inspection

Overview of Mission Sequence of Events 3/3

Analysis

- Collection of data acquired by the camera
- If communication failed – telemetry recovery via USB connection
- Analysis of obtained data
- Mission assessment and preparation of the presentation
- Delivery of the presentation on the next day

In the past years the sequence of events was similar and helped our team to have everything well-planned. Because of this fact, we are going to follow the very similar procedure.

Team member roles and responsibilities

Name	Members	Responsibilities
Mission Control Officer	Adam Kolusz	Informing about CanSat readiness.
Ground Station Crew	Mateusz Rajzer, Kornel Kowalczyk	Monitoring the ground station for telemetry reception and issuing commands to the CanSat.
Recovery Crew	Dagmara Stasiowska, Artur Biernat	Tracking the CanSat and going out into the field for recovery, making sure all field scores are filled in.
CanSat Crew	Adam Kolusz, Kornel Kowalczyk, Dagmara Stasiowska	Preparing the CanSat, integrating it into the rocket, and verifying its status.

Field Safety Rules Compliance

Mission operation manual content		
Safety issues: Results of environmental tests: • Vibration test • Drop test • Thermal test • Fit check	Procedures for: 6 checklist/operation procedures: 1. Pre-flight CanSat test 2. Preparation and set up of GS 3. Launch preparation - communication test: a. Electronics b. Structure c. Descent control 4. Integration CanSat with the rocket: a. final pre-flight communication test 5. Launch procedure: a. countdown to the launch 6. Removal procedure Development status: 85%	Crew Assignment: **Mission Control Officer:** Adam Kolusz **CanSat Crew:** Adam Kolusz Kornel Kowalczyk Dagmara Stasiowska **Recovery Crew:** Dagmara Stasiowska Artur Biernat **Ground Station Crew:** Mateusz Rajzer Kornel Kowalczyk

Responsibilities are divided between team members. The drafts of procedure descriptions are made, they will be performed and validated during future rocket and drop tests.

CanSat Location and Recovery

Science Payload

- Structure with pink colour reinforced with fluorescent dust reflecting UV light.
- Buzzer giving high pitch sound signal
- Location will be taken from pre-landing GPS data

Container

- Bright orange parachute
- Fluorescent structure

Additional labeling

- Each component will be equipped with team leader’s address, contact information and phone number
- Recovery crew will be equipped with GPS and to have the possibility to head to the landing zone

Mission Rehearsal Activities 1/2

Ground system radio link check → Powering on/off CanSat → Launch configuration preparations

Ground system radio link check

Parts:

- Connecting Xbee to Panel Antenna using RPSMA Male to N Male cable
- Placing XBee on the XBee Adapter
- Connecting XBee to laptop using miniUSB to USB cable.
- On board computer with XBee
- XBee antenna

Rehearsed during GS tests.

Powering on/off CanSat

Parts:

- On-board computer

Rehearsed during rocket test.

Launch configuration preparations

Parts:

- Folding the wings
- Putting Payload to the Container
- Parachute

Rehearsed during rocket test.

Mission Rehearsal Activities 2/2

Loading CanSat in launch vehicle → Telemetry processing, archiving and analysis → Recovery

Parts:
- Folding wings
- Putting to Container
- Parachute

Rehearsed during rocket test.

Parts:
- On-board computer
- Connecting Xbee to Panel Antenna using RPSMA Male to N male cable
- Placing Xbee on the Xbee Adapter
- Connecting Xbee to laptop using miniUSB to USB cable
- On-board computer with Xbee
- Xbee antenna

Rehearsed during communication tests.

Parts:
- Rotors
- Parachute
- Buzzer
- GPS system

Rehearsed during rocket test.

Requirements Compliance

Dagmara Stasiowska

Requirements Compliance Overview

- All requirements are fully satisfied.
- Mechanical, telemetry, electronics and Ground Station requirements are already reached.
- Management requirements are met.
- However, more test are planned to reassure that whole system can work many times, without any failure.

- There are no problems with construction.

- There are no serious issues, as all of the requirements were taken into consideration during designing process and have been applied.

Requirements Compliance 1/5

ID	Requirement	Compliance	Slide no.	Comments
1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.		55	
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.		15	
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.		15	
4	The container shall be a fluorescent color; pink, red or orange.		33	
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.		15	
6	The rocket airframe shall not be used as part of the CanSat operations		15	
7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.		12,13	
8	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.		29	
9	The container shall release the payload at 450 meters +/- 10 meters		29	
10	The science payload shall descend using an auto-gyro descent control system.		38	
11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.		38	
12	All descent control device attachment components shall survive 30 Gs of shock.		54	
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		53	

Requirements Compliance 2/5

ID	Requirement				Slide no.	Comments
14	All structures shall be built to survive 15 Gs of launch acceleration.				102	
15	All structures shall be built to survive 30 Gs of shock.				102	
16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.				53	
17	All mechanisms shall be capable of maintaining their configuration or states under all forces.				106	
18	Mechanisms shall not use pyrotechnics or chemicals.				42	
19	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.				51	
20	The science payload shall measure altitude using an air pressure sensor.				17, 20	
21	The science payload shall provide position using GPS.				17, 22	
22	The science payload shall measure its battery voltage.				17, 23	
23	The science payload shall measure outside temperature.				17, 21	
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.				17, 25	
25	The science payload shall measure pitch and roll.				17, 24	
26	The probe shall transmit all sensor data in the telemetry				65	

Requirements Compliance 3/5

ID	Requirement		Slide no.	Comments
27	The Parachute shall be fluorescent Pink or Orange		29, 36	
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.		93	
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.		97	
30	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.		64, 65	
31	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		63	
32	XBEE radios shall have their NETID/PANID set to their team number.		64	
33	XBEE radios shall not use broadcast mode.		64	
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.		133	
35	Each team shall develop their own ground station.		92	
36	All telemetry shall be displayed in real time during descent.		97	
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		92	
38	Teams shall plot each telemetry data field in real time during flight.		97	
39	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		93	

Requirements Compliance 4/5

ID	Requirement				Slide no.	Comments
40	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.				93	
41	Both the container and probe shall be labeled with team contact information including email address.				117	
42	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.				65	
44	No lasers allowed.				72	
45	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.				72	
46	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.				72	
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.				57,83	
48	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.				57	
49	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.				73	
50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.				53	
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.				53	
52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.				42	

Requirements Compliance 5/5

ID	Requirement	Status	Slide no.	Comments
53	The GPS receiver must use the NMEA 0183 GGA message format.	Green	22	
54	The CANSAT must operate during the environmental tests laid out in Section 3.5.	Green	109, 110, 111	
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Green	74	
-	A video camera shall be integrated into the science payload to record the descent. It shall be stabilised with 10deg accuracy	Green	26	

Management

Adam Kolusz

Status of Procurements

Subsystem	Part	Status
Structure	Container	Made 01.2018
	Composite materials	Received 12.2018
	3D printing filament	Received 11.2018
	Epoxy resin	Received 11.2018
	Threaded distances	Received 12.2018
	Springs	Received 01.2019
GCS	Antenna for radio module	Received 12.2018
	Radio module	Received 01.2019
	Radio adapter - PVC pipes	Received 12.2018
CDH + EPS	Battery	Received 12.2018
	Main on-board computer	Received 01.2019
	Microcontroller with real-time unit	Received 01.2019
	Flash memory	Received 01.2019
	Radio module	Received 02.2019
	Electrical components	Received 01.2019
	Switches	Received 12.2018
	Servos	Received 12.2018

Subsystem	Part	Status
Recovery	Rip-stop nylon	Received 01.2019
	Strings	Received 01.2019
	Buzzer	Received 01.2019
	Swivel	Received 02.2019
	Rotors and holders	Made 12.2018
	Nichrome wire	Received 01.2019
	Ailerons	Made 02.2019
	Bearings	Received 11.2018
Sensors	Hall sensor	Received 01.2019
	Tilt sensor	Received 01.2019
	Air pressure and air temperature sensor	Received 01.2019
	Camera	Received 01.2019
	GPS	Received 01.2019
	Camera holder	Made 01.2019
	Payload Power Voltage Sensor	Made 12..2018
	Buzzer	Received 01.2019

CanSat Budget – Hardware 1/3

Part	Description	Quantity	Price per unit [USD]	Total [USD]	Determination
Sensors subsystem					
SS411P	Hall sensor	2	0.54	1.08	Actual
MPU-9250	Tilt sensor	1	7.82	7.82	Actual
MS5607	Air pressure and air temperature sensor	1	2.68	2.68	Actual
SQ9	Camera	1	10.00	10.00	Actual
UBLOX NEO-M8	GPS	1	7.72	7.72	Actual
Camera holder	3D printed	0.02kg	20.54	0.40	Estimated
Voltage divider + CPU's ADC	Payload Power Voltage Sensor	1	0.10	0.10	Estimated
PKM22EPPH2001	Buzzer	1	0.99	0.99	Actual

CanSat Budget – Hardware 2/3

Part	Description	Quantity	Price per unit [USD]	Total [USD]	Determination
Recovery subsystem					
Rotors and holders	Auto-gyro mechanism	8	1.50	12.00	Estimated
Tube	Auto-gyro mechanism	0.5m	1.78	0.89	Estimated
Bearings	Auto-gyro mechanism	2	3.60	7.20	Actual
Spring	SP deployment mechanism	1	3.62	3.62	Actual
Nichrome wire	Hotwire	0.1m	0.91	0.09	Estimated
Rip-stop nylon	Parachute material	0.5m2	10.40	5.20	Estimated
Other parts	Parachute strings, thread etc.	-	2.80	2.80	Estimated
Swivel	Parachute detangling system	1	0.97	0.97	Actual
Ailerons	Stability control system	4	0.65	2.60	Estimated

CanSat Budget – Hardware 3/3

Part	Description	Quantity	Price per unit [USD]	Total [USD]	Determination
CDH subsystem					
PCB	Main on-board computer	2	1.00	2.00	Estimated
STM32F103RCT	Microcontroller with real-time unit	1	25.91	25.91	Actual
Cypress S25FL512S	Flash memory	1	13.23	13.23	Actual
XB9X-DMUS-001	Radio module	1	34.35	34.35	Actual
Other parts	Electrical components	-	10.00	10.00	Estimated
Electrical Power Subsystem					
sg92r servo	Servos	4	3.64	14.56	Actual
9V Li-Ion Battery	Power Supply	2	5.46	10.92	Actual

Total [USD] (+10%) **142.78 (157.06)**

CanSat Budget – Other Costs 1/2

Part	Description	Quantity	Price per unit [USD]	Total [USD]	Determination
Testing & Prototyping					
Glass fibre	Prototype component	1.5m2	2.08	3.12	Estimated
Carbon fibre	Prototype component	0.5m2	15.08	7.54	Estimated
PA12+CF	3D printing filament	0.5 kg	20.54	10.27	Estimated
Screws, nuts, springs etc.	Prototype components	-	1.37	1.37	Estimated
Epoxy	Prototype component	150g	42.9	6.44	Estimated
Tapes	Prototype component	2	1.82	3.64	Estimated
Pipes	Prototype component	1m	3.55	3.55	Actual
Threaded distances	Prototype component	30	0.23	6.90	Actual
Ground Control System					
XB9X-DMUS-001	Radio module	1	34.34	34.34	Actual
900MHz antenna	Antenna for radio module	1	20.00	20.00	Actual
PVC pipes	Radio adapter	1	-	12.00	Estimated

CanSat Budget – Other Costs 2/2

Part	Description	Quantity	Price per unit [USD]	Total [USD]	Determination
Competition fee	N/A	1	100.00	100.00	Actual
Car rental	N/A	1	380.00	380.00	Estimated
Computers	Provided by team members	2	-	-	Actual
Flights*	N/A	5	832.00	4160.00	Estimated
Accommodation	N/A	5	104.00	520.00	Estimated
Meals	N/A	60	15.00	900.00	Estimated

Total [USD] (+10%) **6169.17 (6786.09)**

*All team members have valid visas, so there is no need to include it into costs.

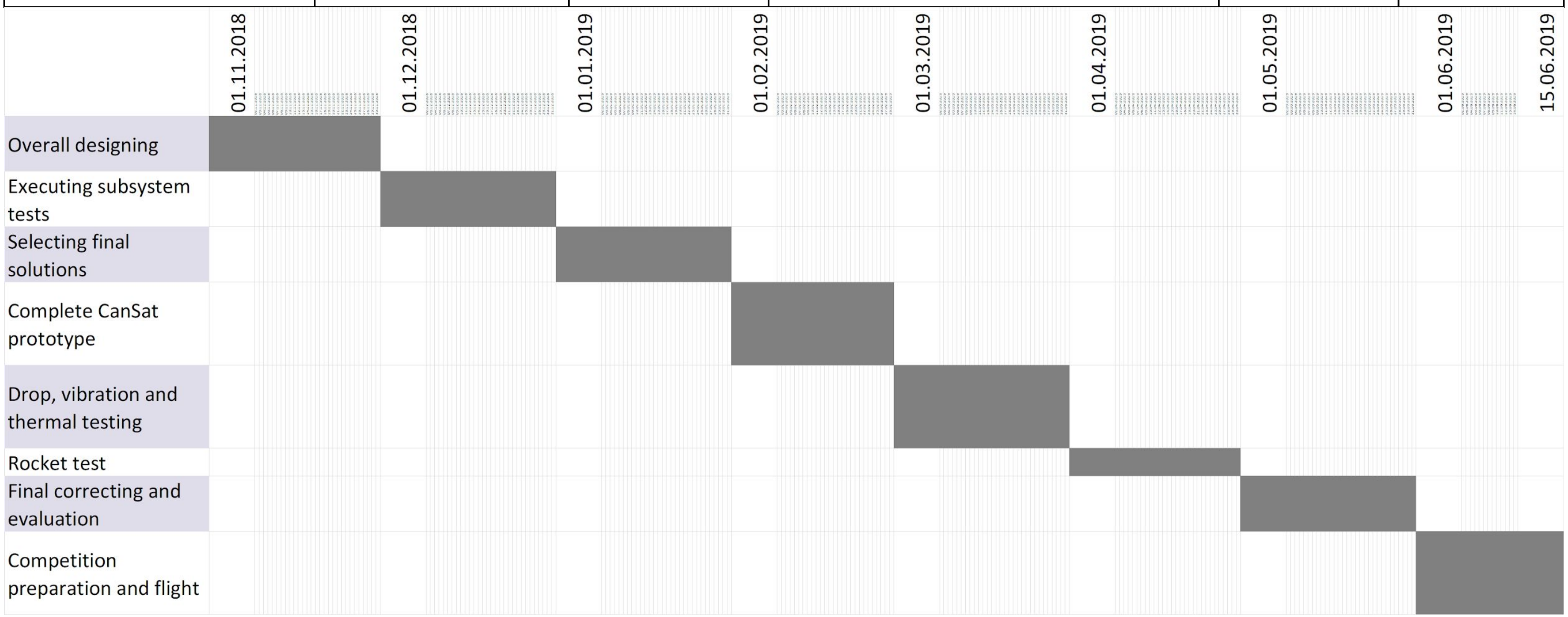
Sources of income	
University	1500.00$
Government	2100.00$
External sponsors	3700.00$

Exchange Rate: (1 PLN =) $0.27
Exchange Rate Date: 02/26/2019 @ 11:38 GMT
Source: cinkciarz.pl

Budget summary		
Income - total		+7300.00$
Overall cost of mission	CanSat Budget - Hardware	-157.06$
	CanSat Budget - Other Costs	-6786.09$
Balance		**+356.85$**

Program Schedule Overview

Position number	Start date	End date	Name	Day number	Task duration
1	18/11/01	18/11/30	Overall designing	0	30
2	18/12/01	18/12/31	Executing subsystem tests	30	31
3	19/01/01	19/01/31	Selecting final solutions	61	31
4	19/02/01	19/02/28	Complete CanSat prototype	92	28
5	19/03/01	19/03/31	Drop, vibration and thermal testing	120	31
6	19/04/01	19/04/30	Rocket test	151	30
7	19/05/01	19/05/31	Final correcting and evaluation	181	31
8	19/06/01	19/06/15	Competition preparation and flight	212	15



All components were received or made by 02/2019.

Detailed Program Schedule

Tasks		November				December				January				February				March				April				May				June			
High level tasks		Overall Designing				Executing subsystems tests				Selecting final solutions				Creating Complete CanSat prototype				Drop, vibration & thermal tests				Performing rocket tests				Final correcting & evaluating				Competition flight			
Description		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Can Sat Development	Creating conception of CanSat (Kornel)																																
	Subsystems & first structure prototyping (Artur)																																
	Selecting materials (Dagmara)																																
	Improving tested subsystems (Dagmara)																																
	Working on CanSat’s final structure (Adam)																																
	Prototyping Electronics & Telemetry (Mateusz)																																
	Creating complete prototype & testing (Adam)																																
	Introducing necessary corrections (Mateusz)																																
	Rocket tests (Kornel)																																
	final corrections (Artur)																																
	Performing demo flight (Adam)																																
Team’s Work	Recognition and division of tasks																																
	Registration for Competition																																
	Testing the recovery subsystems																																
	Ordering electronics																																
	Reaching weight & cost requirements																																
	PDR preparation																																
	Presentation prep.																																
	Teleconference																																
	Testing Electronics & Telemetry																																
	Evaluating progress																																
	CDR preparation																																
	Planning & preparing visit																																
	Final evaluating																																
	PFR preparation																																
Academic schedule		Fall semester												Exams		Holiday		**Spring semester**															

Work completed at time of CDR: ~85%

Shipping and Transportation

Chosen airline: Lufthansa.
Planned arrival to Dallas: 06/13/2019
CanSat can be transported in carry-in baggage, that decreases the risk of losing or breaking it (approved by Lufthansa). Airport authorities were asked if CanSat passess security check - the reply: *The device can be transported in carry-in baggage, it will be checked as any other large electronic device like notebook etc.* We checked it in previous years and there were no problems indeed.
Tools and other important equipment will be transported in our suitcases. These are easily accessible items, so in case of luggage delay we can buy them in US.
During competition, all equipment will be transported in a rented car.

Conclusions 1/2

Accomplishments

- Team is formed and responsibilities are assigned.
- All subsystems are designed.
- All the subsystems are mostly manufactured.
- Ground Station application is fully developed.
- We have ordered all of the missing components.
- Two rocket tests performed along few subsystem tests.
- Drop tests and aerodynamic tunnel testing shown promising data and shown correctness of design.
- Flight software is already functional.

Unfinished work

- External objective is still in development as it is an advanced and long term project that aims to aid creating multiple projects.

Next stage of development

- There are no issues related to our development process, we are ahead of deadlines.
- We do not have any delays.
- All of the components are received or ordered.
- We are ready to manufacture the final version completely.
- More aerodynamic tunnel testing to reassure desired stabilization level.

Conclusions 2/2

Thank you for attention