CanSat 2020
Critical Design Review (CDR)
Outline
Version 9.0

#2280
Team Thor

Presentation Outline

Team Organization

- **Marco Sandoval**
  Team leader:
  Graduate
  - **Alberto Luviano**
    Faculty Advisor
  - **Mechanical, Structure & Descent Control**
    - **Alejandro Aguirre**
      Leader
      Graduate
    - **Yaoctzin Serrato**
      Junior
    - **Saúl Becerril**
      Junior
    - **Rafael Cornejo**
      Junior
  - **Electrical Components & Software Design**
    - **Aldo Bonilla**
      Leader
      Junior
    - **Jorge Hernández**
      Junior
    - **Royce Ramírez**
      Junior
  - **Ground Station & Telemetry**
    - **Rodolfo Vera**
      Leader
      Graduate
    - **Jessica Valle**
      Junior

Acronyms

- A - Analysis
- T - Test
- I - Inspection
- D - Demonstration
- VM - Verification Method
- SPI - Serial Peripheral Interface
- I2C - Inter –Integrated Circuit
- UART - Universal Asynchronous Receiver – Transmitter
- µC - Micro Controller
- #ID - Identification number
- SD - Secure Digital
- RTC - Real Time Clock
- PVC - Polyvinyl chloride
- CDH - Communication and Data Handling
- RPSMA - Reverse Polarity SubMiniature version A
- ASCII - American Standard Coder for Information Interchange
- PC - Personal Computer
- PCB - Printed Circuit Board
- MS - Mechanical Subsystem
- ES - Electrical System
- GS - Ground Station
- DC - Descent Control
- LDR - Light Depending Resistance
- SS - Sensor Subsystem

Systems Overview

Marco Sandoval

Mission Summary

Mission

Design and built a Cansat that will consist of a container and a science payload. The science payload shall be a delta wing glider that will glide in a circular pattern, once released. During descent, science payload shall send altitude, air speed and particulates in the air to ground station while gliding.

Mission Objectives

- Design and build the CanSat container to protect the science payload from damage during the launch and deployment.
- Design and implement a parachute descent system that keeps the CanSat at a descent rate of 20 [m/s].
- Design and build the decoupling mechanism system to decouple the science payload from the container at an altitude of 450 [m].
- Design and implement a delta wing glider that descents in a circular pattern with a radius of 250 [m] collecting sensor data for one minute and remain above 100 [m] after being released.
- Design and implement the electronics system necessary for the acquisition, processing, storage, and transmission of telemetry data to a ground station.
- Design a portable ground station for the reception, processing and display of received telemetry data from the science payload.

Bonus Mission Objective

Design and construct an orientation mechanism that maintains a camera pointing at coordinates provided for the duration of the glide time.

External Objectives

- Improve our obtained results on electronics and telemetry area.
- Run computer-aided simulation of falling CanSat using recovered telemetry data.

Summary of Changes Since PDR

Area	PDR	CDR
Sensor Subsystem Design	ADC on STM32F446RE Microcontroller	ADC on STM32F413ZH Microcontroller
Descent Control Design	No changes	No changes
Mechanical Subsystem Design	Shape in the container	Shape in the container
Communication & Data handling Subsystem Design	Data packet example	It is changed the format of the data packet
	STM32F446RE Microcontroller	STM32F413ZH Microcontroller
Electrical Power Subsystem Design	Power required	Power required
Flight Software Design	No changes	No changes
Ground Control System Design	GUI	Graphical User Interface modified
	There was no testing	It is add a telemetry testing and preliminary results slide.

System Requirement Summary (1/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR01	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.	In order to mantain the prescribed descent rates at all time	HIGH	DC01				
SR02	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.	So that the CanSat fits within the rocket.	HIGH	MS02		•	•	•
SR03	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard..	So that the CanSat is released freely from rocket payload section.	HIGH	MS03		•	•	•
SR04	The container shall be a fluorescent color; pink, red or orange.	For its rapid recognition in open field.	MEDIUM	MS04			•	
SR05	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	Competition Requirement	HIGH	MS05			•	
SR06	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Competition Requirement	HIGH	MS06		•	•	
SR07	The rocket airframe shall not be used as part of the CanSat operations.	Competition Requirement	HIGH	MS07		•	•	

System Requirement Summary (2/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR08	The container parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Competition Requirement	HIGH	MS08		•	•	
SR09	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s	Competition Requirement	HIGH	MS09	•			
SR10	The container shall release the payload at 450 meters +/- 10 meters.	Competition Requirement	HIGH	FSW01, FSW02,MS 10				•
SR11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container	Competition Requirement	HIGH	FSW01, FSW02, FSW03, FSW04,MS 11				•
SR12	The science payload shall be a delta wing glider.	Competition Requirement.	HIGH	MS12	•			•
SR13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s.	Competition Requirement.	HIGH	FSW03, FSW04, MS13				•
SR14	All descent control device attachment components shall survive 30 Gs of shock	Competition Requirement	HIGH	ES01, MS14				•

System Requirement Summary (3/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Competition Requirement	HIGH	EPS01, ES02			•	•
SR16	All structures shall be built to survive 15 Gs of launch acceleration.	So as the CanSat stands rocket deployment.	HIGH	MS16	•			•
SR17	All structures shall be built to survive 30 Gs of shock.	For ensuring the physical integrity of the CanSat.	HIGH	MS17	•			•
SR18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Competition Requirement	HIGH	EPS02, ES03	•	•	•	
SR19	All mechanisms shall be capable of maintaining their configuration or states under all forces.	So that them all can perform well their functions.	HIGH	MS19				•
SR20	Mechanisms shall not use pyrotechnics or chemicals.	Competition Requirement. Our design does not contemplate either pyrotechnics nor chemicals.	LOW	MS20			•	
SR21	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	HIGH	MS20		•		
SR22	The science payload shall measure altitude using an air pressure sensor.	Competition Requirement	HIGH	FSW01, FSW02, CS01 , ES05	•			•

System Requirement Summary (4/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR23	The science payload shall provide position using GPS.	Competition Requirement	HIGH	FSW04, CS02, ES05	•			•
SR24	The science payload shall measure its battery voltage	Competition Requirement	HIGH	FSW05, CS03,ES05	•			•
SR25	The science payload shall measure outside temperature.	Competition Requirement	HIGH	FSW06, CS04, ES05	•			•
SR26	The science payload shall measure particulates in the air as it glides.	Competition Requirement	HIGH	FSW07, CS05, ES05	•			•
SR27	The science payload shall measure air speed.	Competition Requirement	HIGH	FSW08, CS06, ES05	•			•
SR28	The science payload shall transmit all sensor data in the telemetry.	Competition Requirement	VERY HIGH	CS08, FSW09, GCS01, GCS02		•		•
SR29	Telemetry shall be updated once per second.	Competition Requirement	HIGH	FSW01, FSW02, FSW03, FSW10, CS07	•			•
SR30	The Parachutes shall be fluorescent Pink or Orange.	For its rapid recognition in open field.	MEDIUM	MS21			•	
SR31	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.	Competition Requirement	HIGH	CS09, FSW11, GCS04	•	•		•
SR32	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	To store the data and Competition Requirement	HIGH	GCS03				•

System Requirement Summary (5/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR33	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	HIGH	CS10, GCS04	•			•
SR34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	Competition Requirement	HIGH	FSW12, GCS09	•		•	•
SR35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Competition Requirement	HIGH	CS11, GCS06			•	•
SR36	XBEE radios shall have their NETID/PANID set to their team number.	Competition Requirement	MEDIUM	CS12, GCS07	•		•	•
SR37	XBEE radios shall not use broadcast mode	Competition Requirement	HIGH	CS13, GCS08	•			•
SR38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Competition Requirement	HIGH	-	•			
SR39	Each team shall develop their own ground station	Competition Requirement	HIGH	GCS04			•	
SR40	All telemetry shall be displayed in real time during descent.	Competition Requirement	HIGH	GCS05			•	•

System Requirement Summary (6/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Competition Requirement	HIGH	GCS06			•	•
SR42	Teams shall plot each telemetry data field in real time during flight	Competition Requirement	HIGH	GCS07				
SR43	The number 43 is not in the mission guide.	-	-	-	-	-	-	-
SR44	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	HIGH	GCS08			•	•
SR45	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	HIGH	GCS09			•	•
SR46	Both the container and probe shall be labeled with team contact information including email address.	For contacting the team in case the container or the Payload are found prior to the competition.	HIGH	MS23			•	
SR47	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	HIGH	FSW12				•

System Requirement Summary (7/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR48	No lasers allowed.	Competition Requirement	HIGH	ES04		•		
SR49	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	Competition Requirement	HIGH	EPS03, ES07			•	•
SR50	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	HIGH	EPS04, ES07			•	•
SR51	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Competition Requirement	MEDIUM	FSW01, FSW02, FSW13				•
SR52	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Competition Requirement	HIGH	ES06			•	•
SR53	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 Requirement	HIGH	EPS05	•			

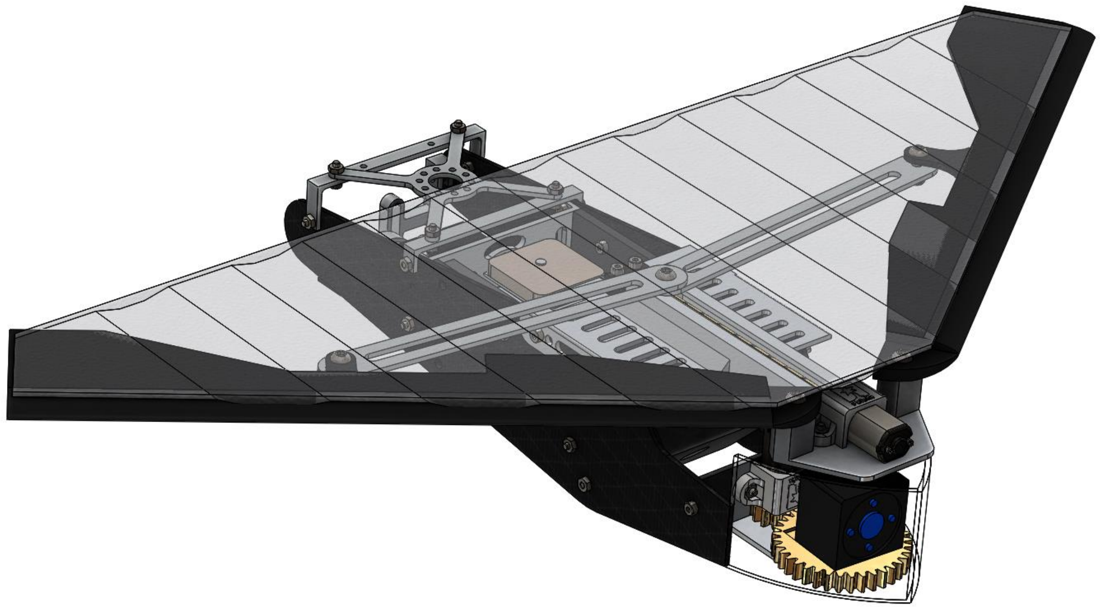
System Requirement Summary (8/8)

# ID	Requirement	Rational	Priority	Child	VM			
					A	D	I	T
SR54	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	MEDIUM	EPS06			•	
SR55	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Competition Requirement	HIGH	EPS07				•
SR56	The CANSAT must operate during the environmental tests laid out in Section 3.5	-	HIGH	-				•
SR57	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Competition Requirement	HIGH	EPS08	•	•		
SR58	Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second.	Cansat Bous requirement	LOW	ES08				•
SR59	The video shall be recorded and retrieved when the science payload is retrieved.	Cansat Bonus requirement	LOW	ES09				•
SR60	Camera must maintain pointing at the provided coordinates for 30 seconds uninterrupted.	Cansat Bonus requirement	LOW	ES10	•			•

Physical Layout (1/8)

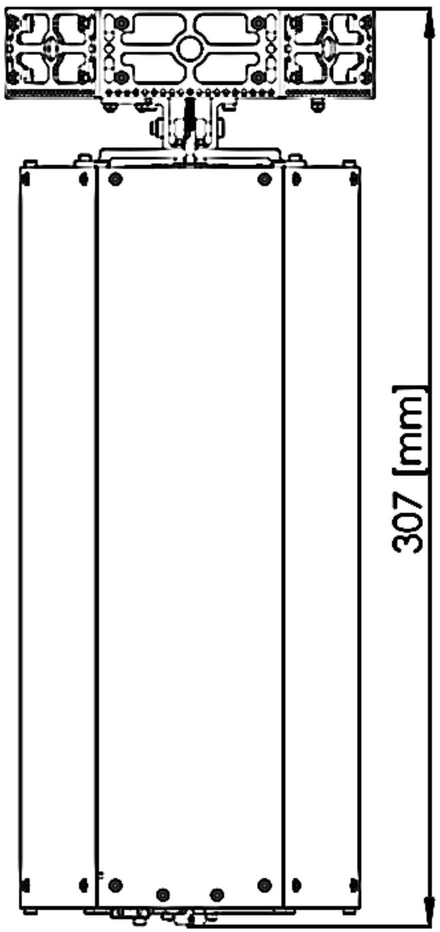
CanSat

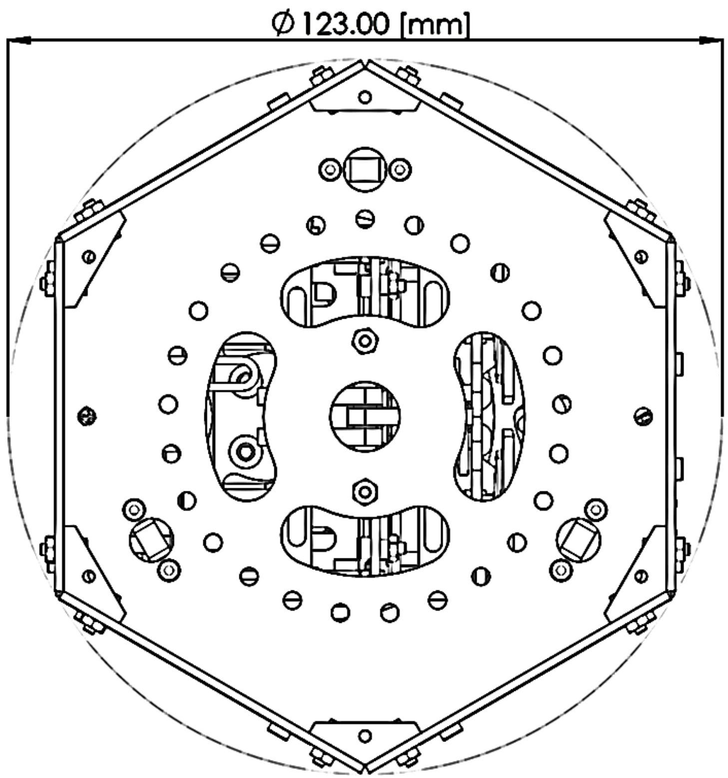
Container



Payload

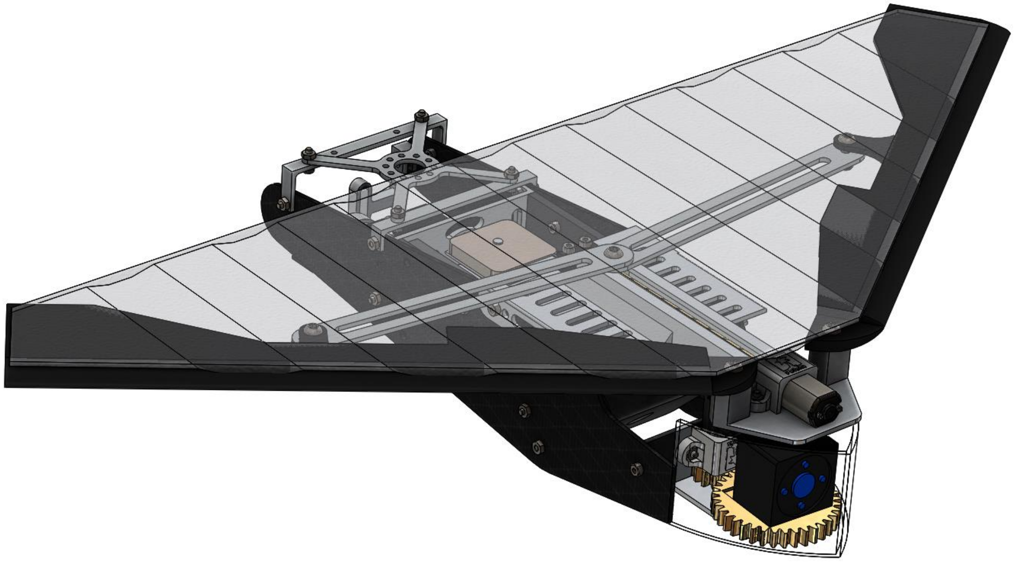
Container General Dimensions

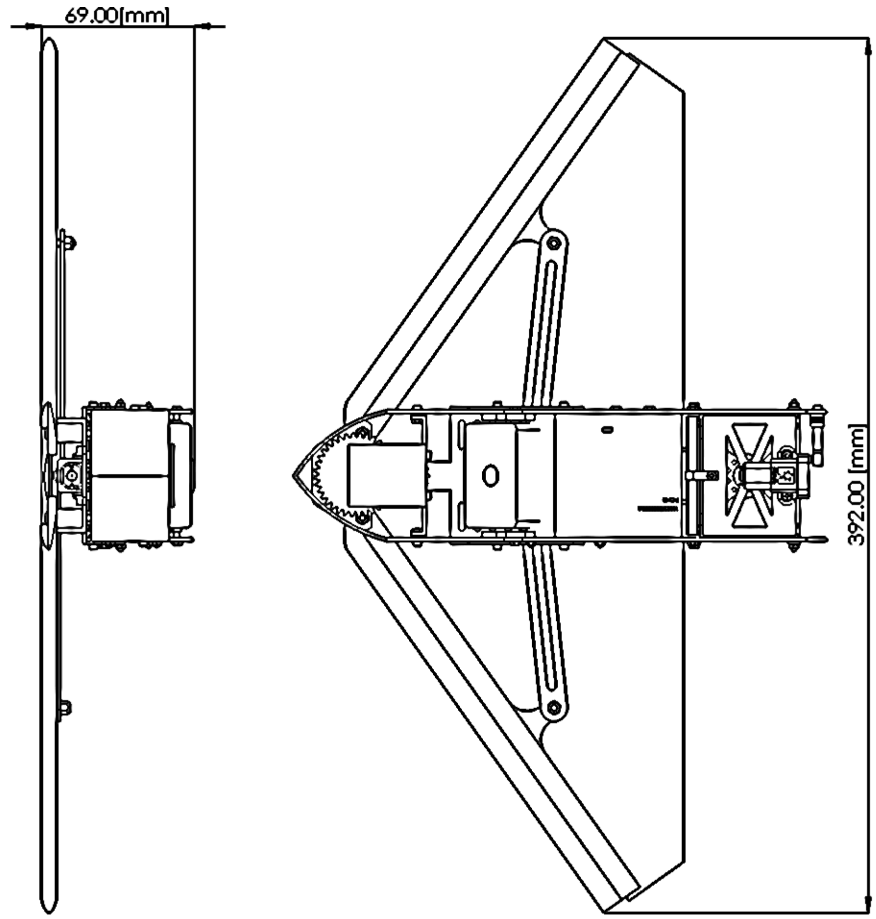




Physical Layout (3/8)

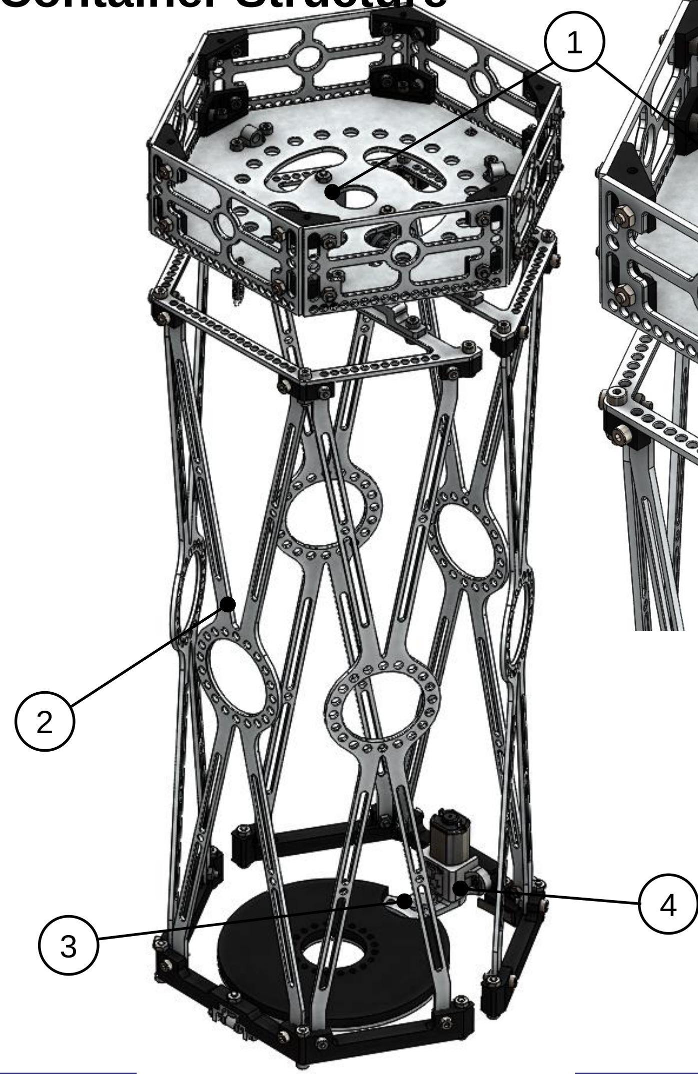
Payload General Dimensions

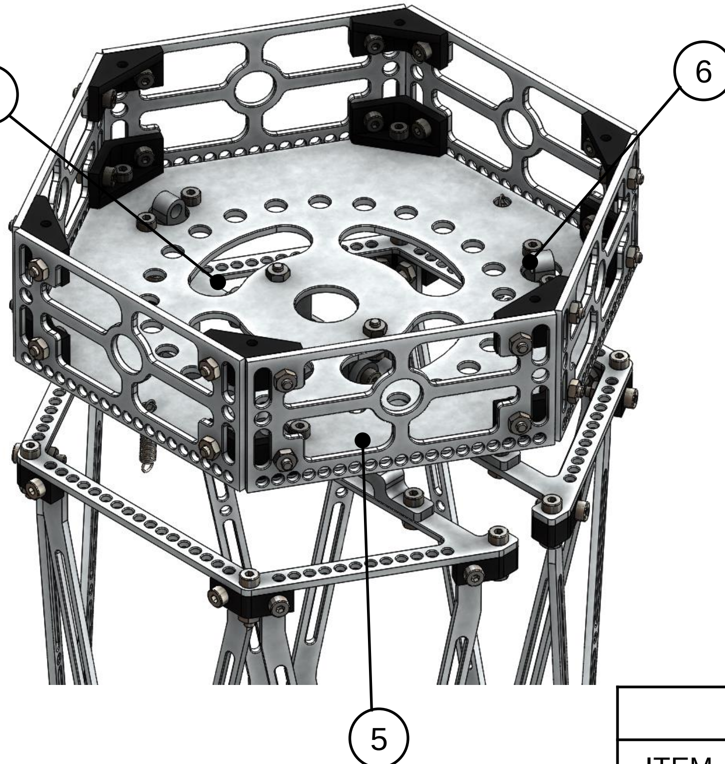




Physical Layout (4/8)

Container Structure

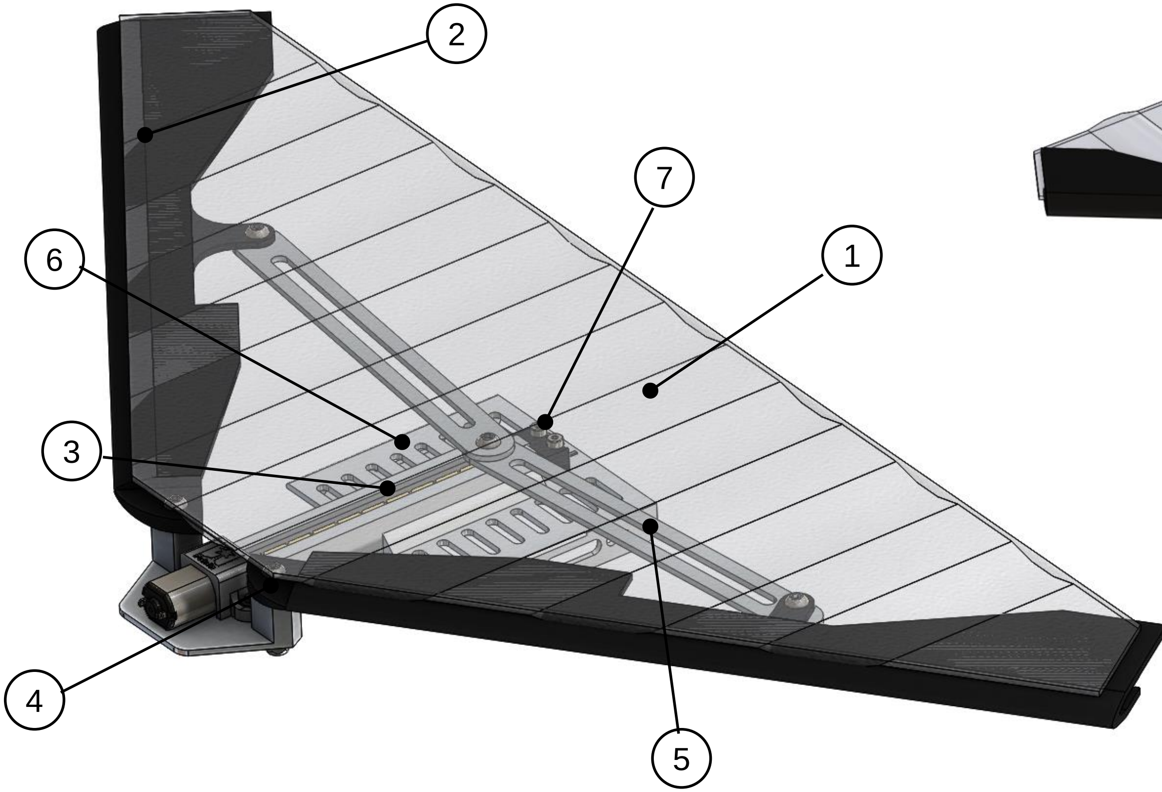


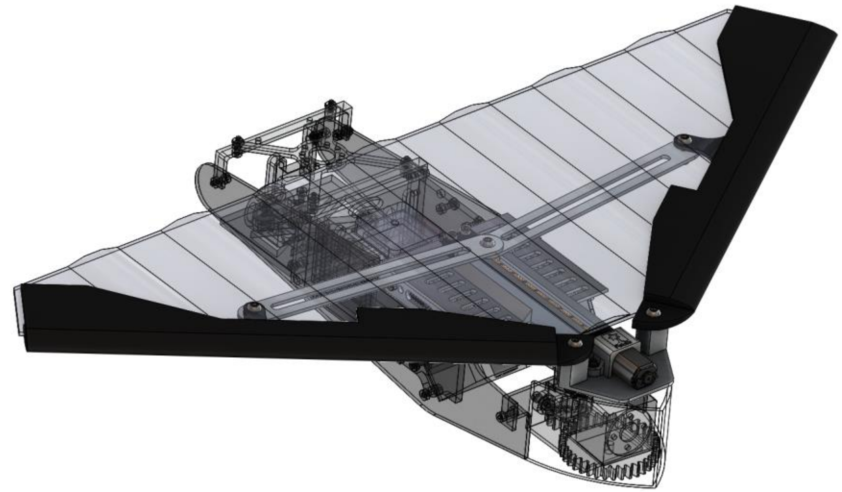


Container Componen

PARTS LIST	
ITEM	PART NAME
1	Parachute container
2	Principal structure
3	Science payload release mechanism
4	Micro gear motor
5	Hexagonal cover
6	Parachute cable attachments

Delta Wing

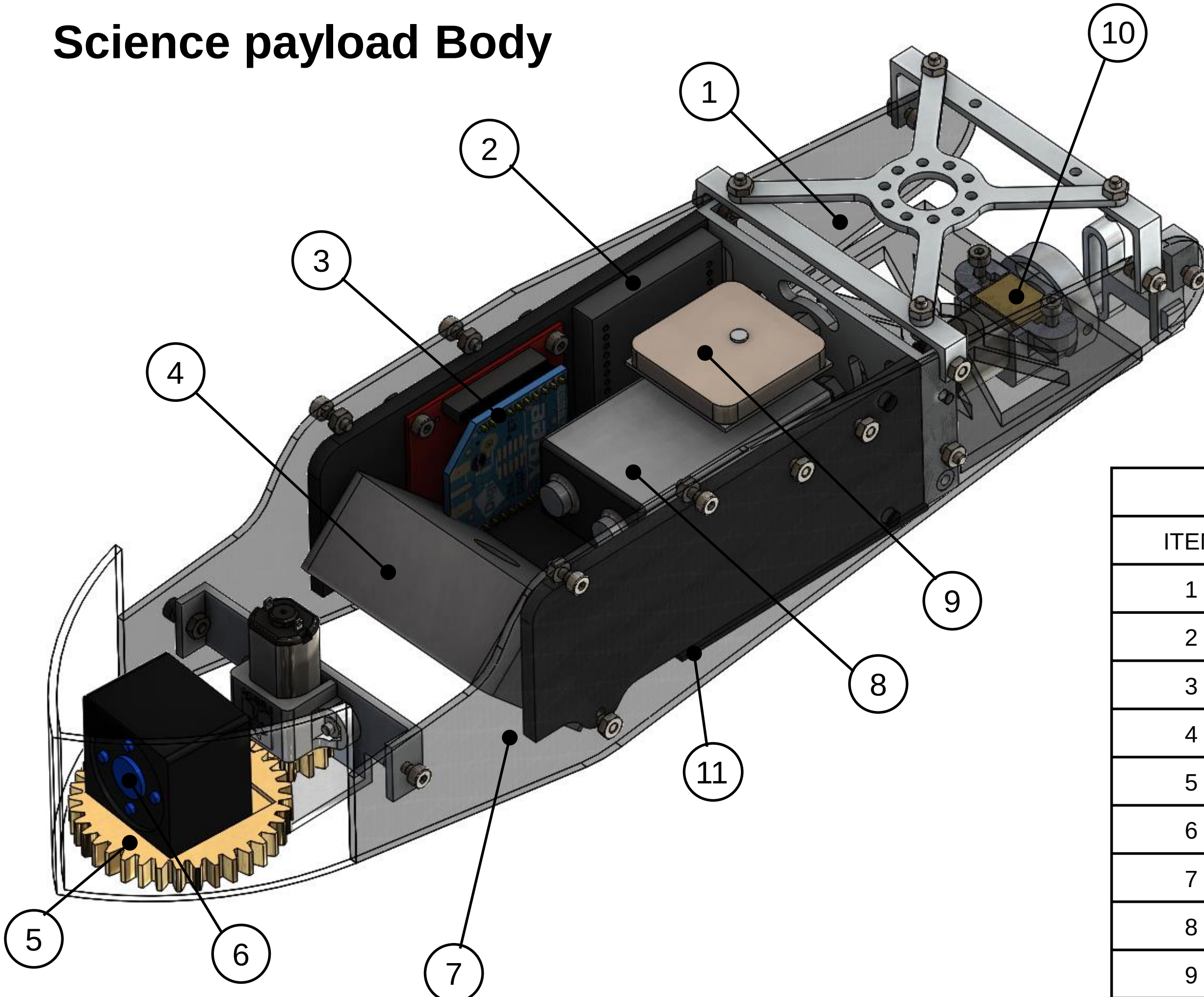


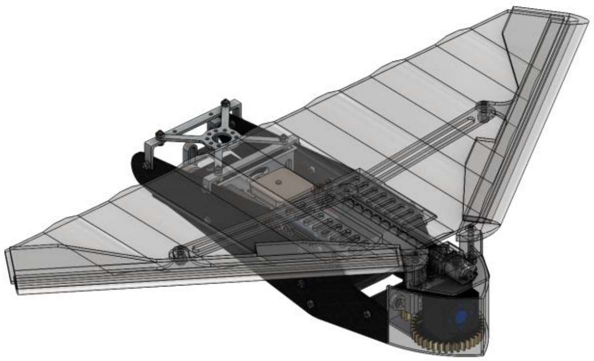


Science payload Compone

PARTS LIST	
ITEM	PART NAME
1	Nylon ripstop
2	Wing profile
3	Threaded rod
4	Micro gear motor
5	Folding link
6	science payload main structure
7	Limit Switch

Science payload Body



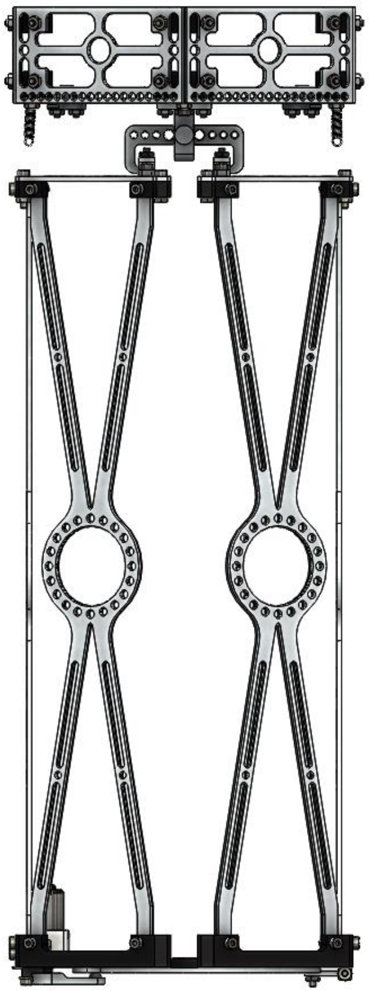


Payload Components

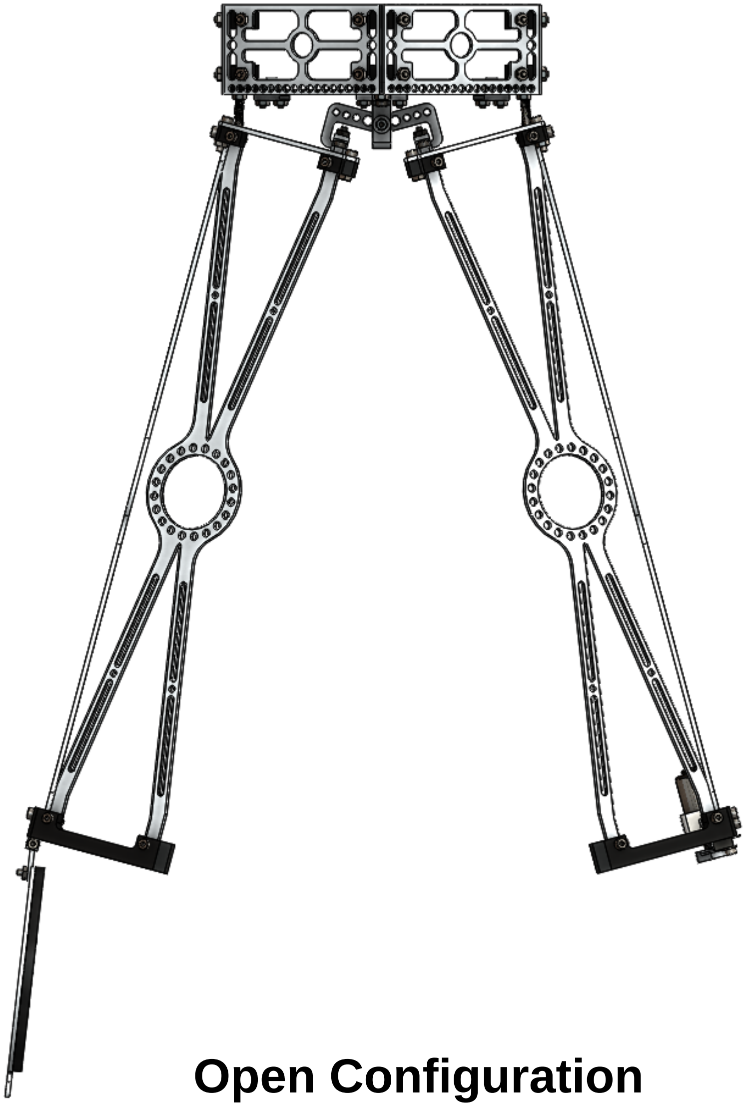
PARTS LIST	
ITEM	PART NAME
1	Parachute science payload
2	Sensor modules (has its own uC)
3	XBee
4	Particle sensor
5	Descente registration mechanism
6	Camera
7	Frame
8	Battery
9	GPS
10	Parachute science Payload release mechanism
11	Taoglas antenna

Physical Layout (7/8)

Container Configurations



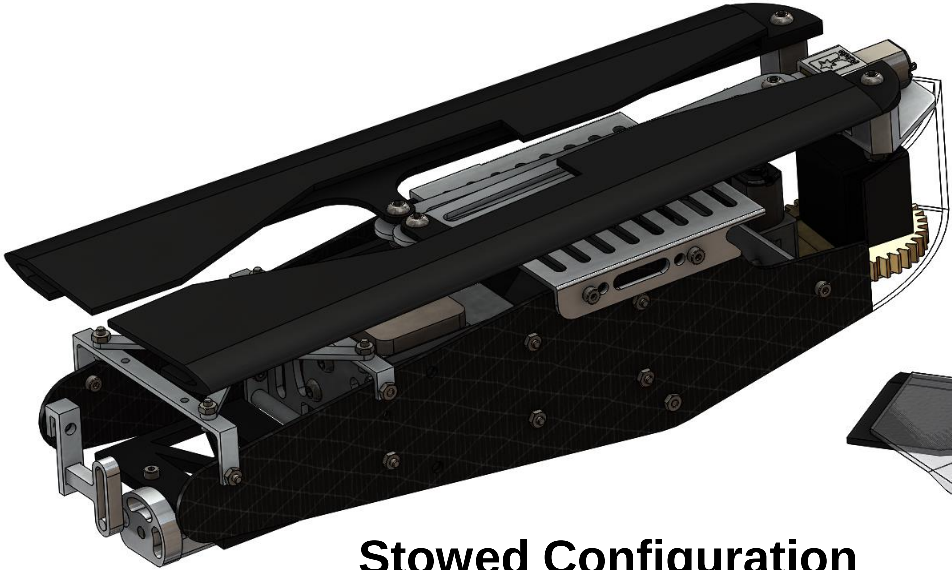
Closed Configuration



Open Configuration

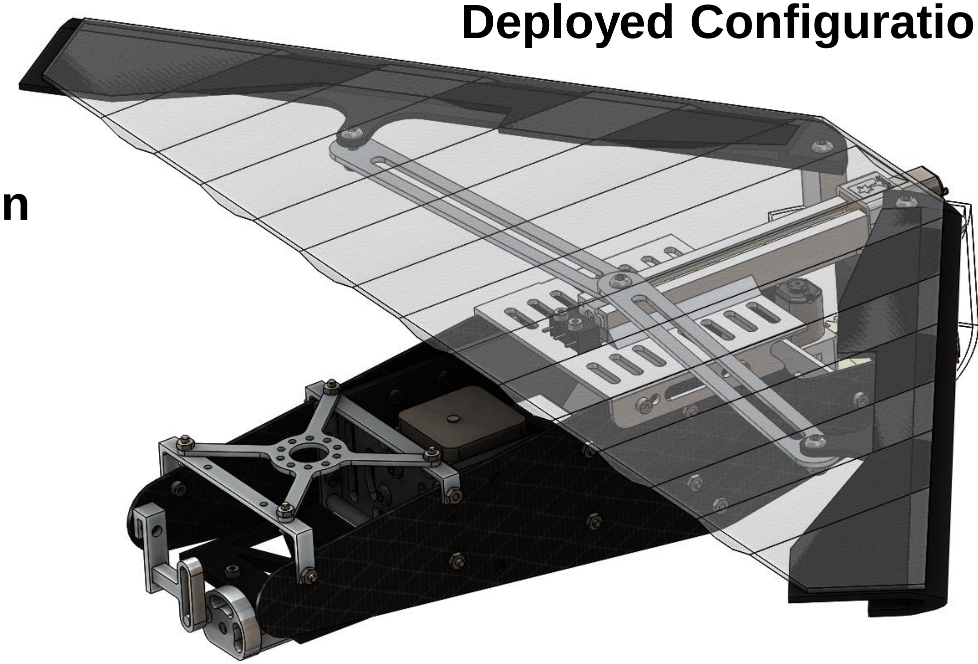
Physical Layout (8/8)

Payload Configurations

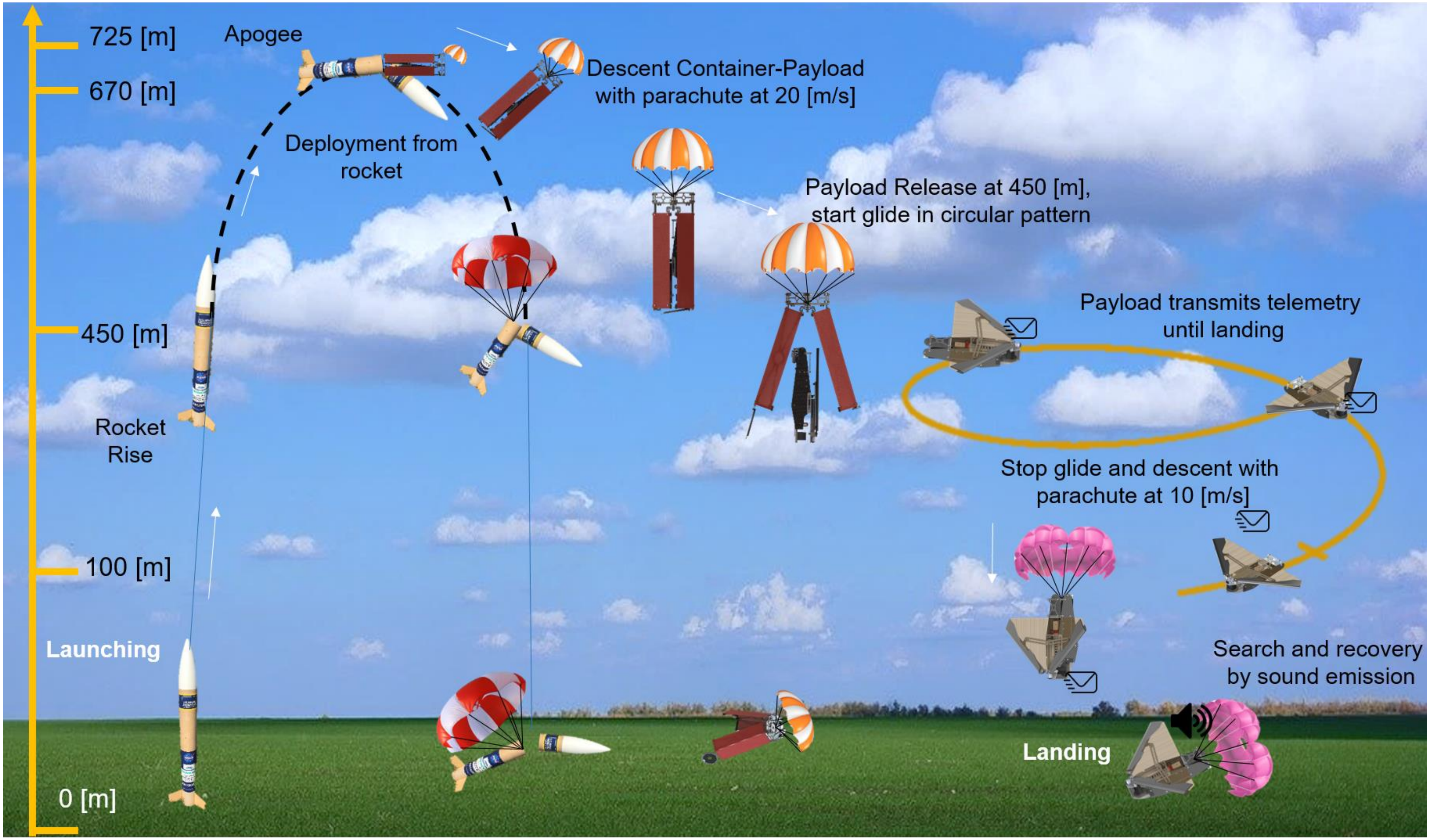


Stowed Configuration

Deployed Configuration



System Concept of Operations (1/3)



CanSat Operations

1. Connection between the Payload and the Ground Station is stablished.
2. Barometric sensor defines an altitude reference.
3. GPS stablishes a valid connection with satellites (3 at least).
4. Payload stablishes a framework with gyroscope and accelerometer in order to calculate tilt.
5. Payload recognizes a valid SD card.
6. Payload checks constantly the altitude change.
7. Once the Payload detects a negative change in the altitude value, the Container's parachute will be deployed.
8. Once the Payload reaches an altitude of 450 [m], the Payload detaches from the Container. Payload starts gliding in a circular pattern.
9. Once the Payload reaches an altitude of 100 [m], the Payload's parachute is deployed.
10. Once the Payload reaches the ground, the transmission will be stopped.
11. Audio beacon will be powered on.
12. Container and Payload will be recovered. Ground Station site must be cleared out.

Landing

Flight

Ground Operations

System Concept of Operations (3/3)

Team Operations

Team Thor

Arrival to the launch site in the morning.

Realization of final adjustments to the CanSat. Realization of some final tests.

CanSat Crew
Aldo Bonilla
Royce Ramirez
Alejandro Aguirre
Saúl Becerril

Delivery of CanSat to the judges.

Mission Control Officer
Marco Sandoval

Placement of CanSat inside the rocket.

CanSat is launched.

- Monitoring of telemetry being received in the ground station interface.
- Maintaining the antenna in place for proper communications.
- Keep an eye on the CanSat for its easy location afterwards.

Ground Station Crew
Rodolfo Vera
Jessica Valle
Jorge Hernández

Team delivers .csv file to judges.

Mission Control Officer
Marco Sandoval

Recovery team goes to find the Container and Payload.

Recovery Crew
Yaoctzin Serrato
Rafael Cornejo

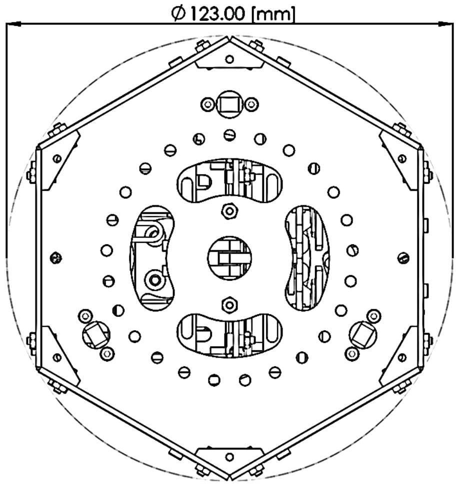
Team makes the Post Flight Review.

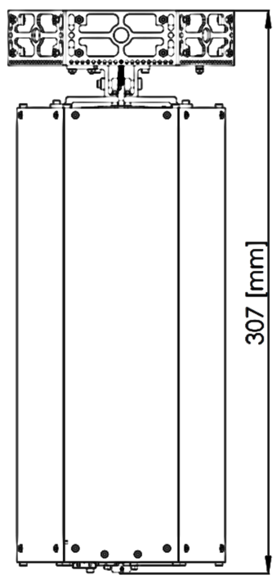
Team Thor

Presentation of the Post Flight Review is done in front of the public and judges.

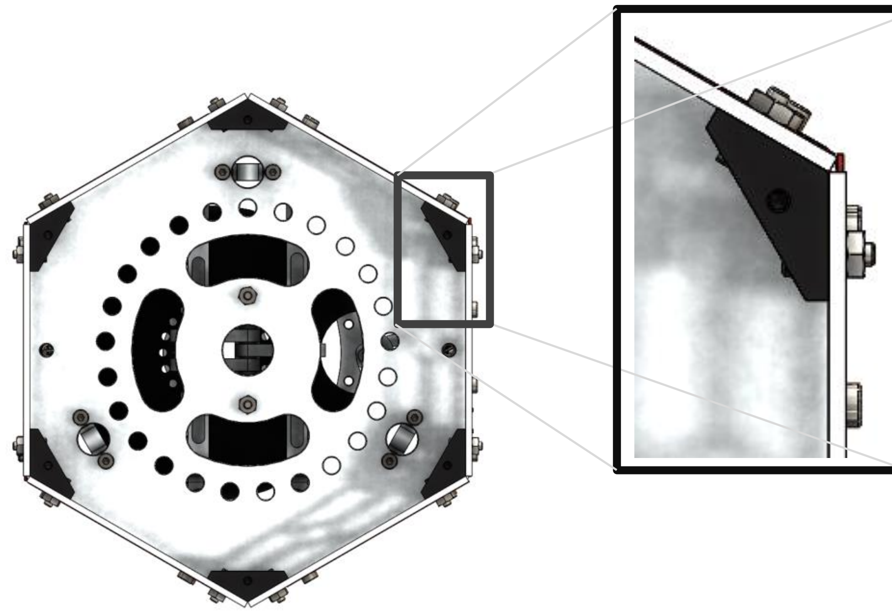
CanSat Crew
Yaoctzin Serrato
Rafael Cornejo
Rodolfo Vera

Launch Vehicle Compatibility





There are no elements that protrude from the established dimensions or have sharp edges. Pieces made with metal elements will be rounded at the edges by means of a file or sandpaper.



Payload dimension	Available value [mm]	Actual value [mm]	Clearance [mm]
Width	125	123	2
Height	310	307	3

The designed prototype has dimensions smaller than those allowed.

Sensor Subsystem (SS) Design

Royce Ramirez

Sensor Subsystem Overview

Sensor	Type	Model	Purpose
Air Pressure Sensor	Digital Pressure Sensor	DPS310	To measure the pressure outside the cansat
Air Temperature Sensor	Digital Temperature Sensor	DPS310	To measure the temperature outside the cansat
GPS	Global Positioning System	NEO-M8N	To obtain global coordinates (latitude, longitude, altitude) of the Cansat, date and time of launching
Voltage Sensor	Analog-to-Digital Pin of the MCU	STM32F413ZH	To measure the battery voltage of the Cansat
Air Speed Sensor	Digital Pressure Sensor	DPS310	To measure the air speed of the Cansat
Particle/Dust Sensor	Compact Optical Dust Sensor	GP2Y1010AU0F	To measure the particles in the air while the Cansat descends
Camera	Digital Vision Sensor	SQ10	To record the descent stage at an angles of 5 degrees.

Sensor Changes Since PDR

PDR	CDR	Rationale
ADC on STM32F446RE Microcontroller	ADC on STM32F413ZH Microcontroller	-This microcontroller has a smaller footprint -Can withstand a maximum temperature of 125°C -Requires fewer external components for proper functioning. -Simplify the overall design of the main board.

Sensor Subsystem Requirements

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
ES01	All descent control device attachment components shall survive 30 Gs of shock.	To simulate a fragile system launching	HIGH	SR14				•
ES02	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Competition Requirement	HIGH	SR15	•	•		
ESO3	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Competition Requirement	HIGH	SR18		•		•
ESO4	No lasers allowed.	Our design does not use lasers	LOW	SR48		•		
ES05	The science payload shall measure altitude, position using GPS, battery voltage, outside temperature, particles in the air as it glides and air speed.	Competition Requirement	HIGH	SR22 – SR27	•			•
ES06	Audio Beacon must have 92dB minimum	To be heard	HIGH	SR52			•	•

Sensor Subsystem Requirements

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
ES07	The probe must have an accessible power indicator and a switch to power it on	Cansat requirement	HIGH	SR49, SR50			●	●
ES08	Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second	Cansat bonus requirement	HIGH	Bonus Requirement				●
ES09	The video shall be recorded and retrieved when the science payload is retrieved	Cansat bonus requirement	HIGH	Bonus Requirement				●
ES10	Camera must maintain pointing at the provided coordinates for 30 seconds uninterrupted	Cansat bonus requirement	HIGH	Bonus Requirement	●			●

Payload Air Pressure Sensor Summary

DPS310					
Supply Voltage [V]	Supply Current [µA]	Operation Range [°C]	Max Measument Rate [Hz]	Resolution [hPa]	Interface
1.7-3.6 V	38	-40 to 85	128	0.002	I2C & SPI

- The DPS310 FIFO can store the last 32 measurements of pressure or temperature
- The sensor uses 24 bits to store the measurement result.
- The output data format is a 24 bit 2’s complement

Payload Air Pressure Sensor Summary

For the Data processing of this sensor we use the Moving Average Filter

The filter is defined by this equation

$$y[i] = \frac{1}{M}\sum_{j=0}^{M-1} x[i+j]$$

Where

x	is the input signal
M	is the number of iterations
i	is the actual point
j	is the iteration number

Payload Air Pressure Sensor Summary

The pressure measurement value is presented in a 24 bit 2’s complement format, to convert this data to an integer number the following equation is used

$$\boldsymbol{Pressure\ data}\begin{cases}\boldsymbol{ps} = \mathrm{p} & p \leq 2^{24} - 1 \\ \boldsymbol{ps} = \mathrm{p} - 2^{25} & p > 2^{24} - 1\end{cases}$$

Where

p is the 24 bit pressure measument

ps is the signed integer number

Payload Air Temperature Sensor Summary

DPS310					
Supply Voltage [V]	Supply Current [µA]	Operation Range [°C]	Max Measument Rate [Hz]	Resolution [°C]	Interface
1.7-3.6 V	38	-40 to 85	128	0.01	I2C & SPI

- The DPS310 FIFO can store the last 32 measurements of pressure or temperature
- The sensor uses 24 bits to store the measurement result.
- The output data format is a 24 bit 2’s complement

For the Data processing of this sensor we use the Moving Average Filter

The filter is defined by this equation

$$y[i] = \frac{1}{M}\sum_{j=0}^{M-1} x[i+j]$$

Where

x	is the input signal
M	is the number of iterations
i	is the actual point
j	is the iteration number

Payload Air Temperature Sensor Summary

The temperature measurement value is presented in a 24 bits 2's complement format, to convert this data to a decimal point number the following equation is used

$$\boldsymbol{Temperature\ data} \begin{cases} \boldsymbol{ts} = t & t \leq 2^{24} - 1 \\ \boldsymbol{ts} = \mathrm{t} - 2^{25} & t > 2^{24} - 1 \end{cases}$$

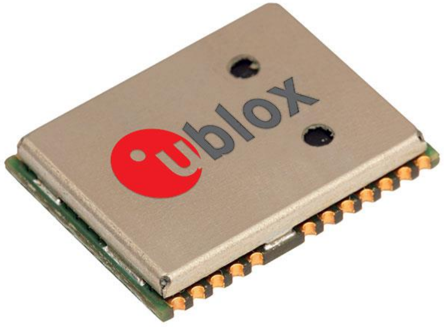
Where

t is the 24 bit temperature measument

ts is the signed integer number

GPS Sensor Summary

NEO-M8N					
Supply Voltage [V]	Current at Measurement [mA]	Channels	Maximum Temperature [°C]	Maximum Update [Hz]	Interface
1.65-3.6	67	72	85	10	UART



Data Processing

- This sensor deliver its data in a chain of comma separated values
- We get the values breaking down the chain

GPS Sensor Summary

The GPS has a serial interface at 9600 baud, configured to transmit the NMEA-GGA protocol of communication.

The GGA protocol provides a 3D location and the accuracy of the data. Below can be seen a message from the GGA protocol

$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,
46.9,M,,*47

Payload Voltage Sensor Summary

STM32F413ZH				
Supply Voltage [V]	Accuracy [mV]	Operation Range [°C]	Interface	Max Conversion Frequency [MHz]
1.7-3.6 V	0.805	-40 to 125	ADC(GPIO)	2.4

- The data format is given in a 12 bit format
- The ADC conversión can be reduced in order to increase the maximum frequency.

Data processing

- This sensor gets the value in 12 bit format
- The data is convert from binary to decimal by a simple conversión

$$V = \frac{V_{bin}\,(3.6)}{2^{12}} \text{ [volts]}$$

Where V_{bin} is the data storaged in binary

Air Speed Sensor Summary

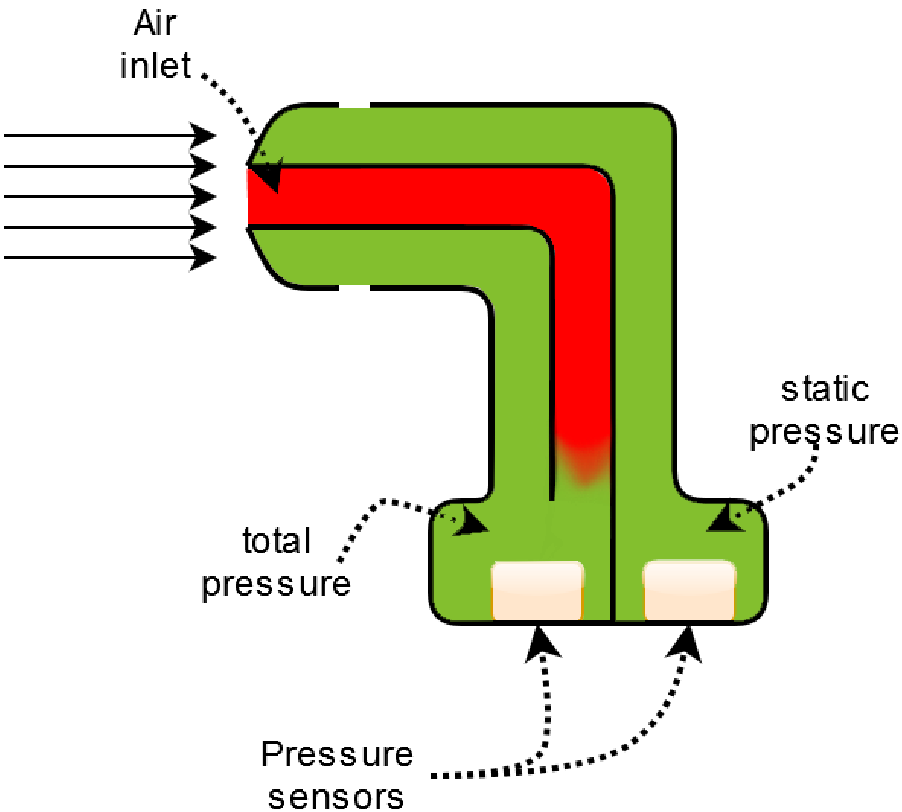
DPS310					
Supply Voltage [V]	Supply Current [µA]	Operation Range [°C]	Max Measument Rate [Hz]	Resolution [hPa]	Interface
1.7-3.6 V	38	-40 to 85	128	0.002	I2C & SPI

- The DPS310 FIFO can store the last 32 measurements of pressure or temperature
- The sensor uses 24 bits to store the measurement result.
- The output data format is a 24 bit 2's complement
- With the use of two pressure sensors an air speed sensor can be calculated

Air Speed Sensor Summary

The air speed will be calculated with the use of a Pitot tube, by measuring a static and total pressure, the air speed can be calculated with the following equation

$$v^2 = \frac{2(pt - ps)}{r}$$



Where

r is the density of the air

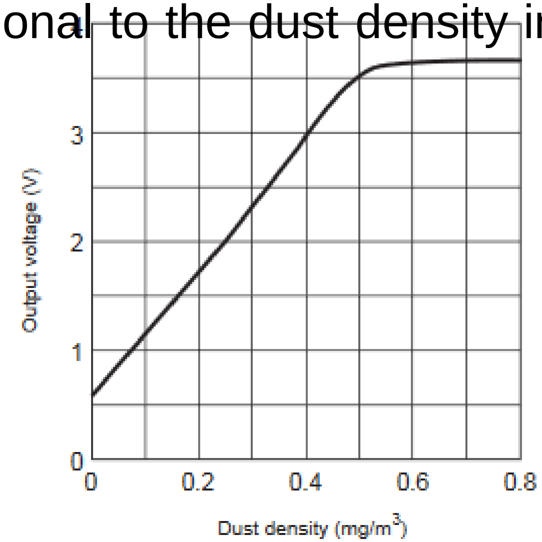
pt is the total pressure

ps is the static pressure

Particulate/Dust Sensor Summary

GP2Y1010AU0F					
Supply Voltage [V]	Consumption current [mA]	Maximum Temperature [°C]	Sensitivity [µg]	Interface	Supply Voltage [V]
-0.3-7.0	20	65	1	ADC	-0.3-7.0

- This sensor gives an analog voltage in its output pin. This voltage is proportional to the dust density in the air



SQ10			
Resolution	Weight [g]	Size [mm]	Interface
1920 x 1080	~45	22 x 22 x 22	USB

Specifications:
Video format: AVI
Video encoding: M-JPEG
Video resolutions: 1280x720P 1920x1080P
Frame rate: 30 fps
Battery Capacity: 200mAh
Charging voltage: 5V
Card Support: TF card

Container Air Pressure Sensor Summary

Container does not have electronics in it

Descent Control Design

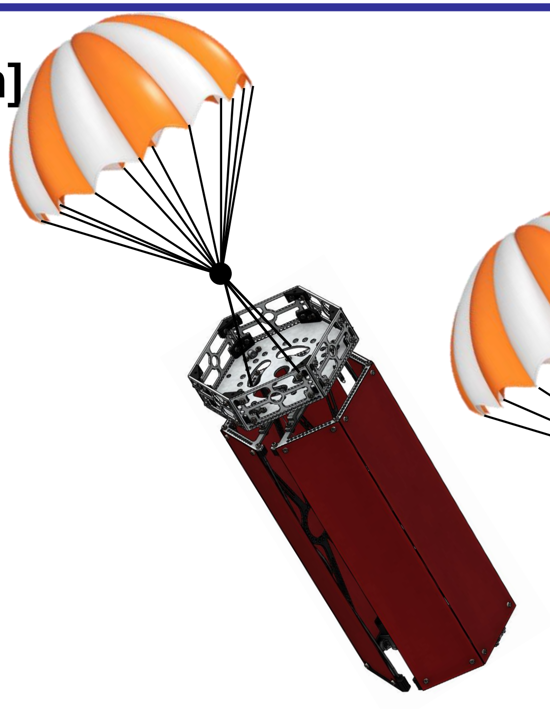
Saúl Becerril

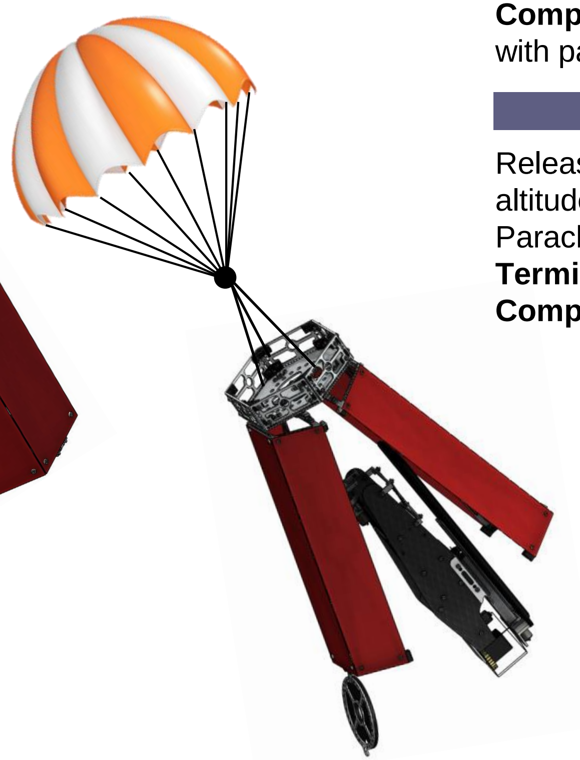
Descent Control Overview (1/2)

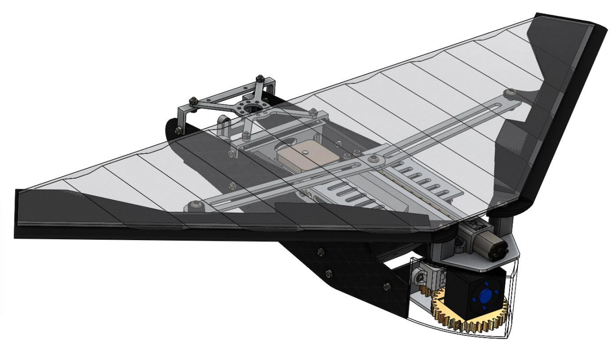
Altitude [m]

725 [m]

450 [m]







Release of the Scince payload at 450 [m]

Time [s]

Container – Science payload

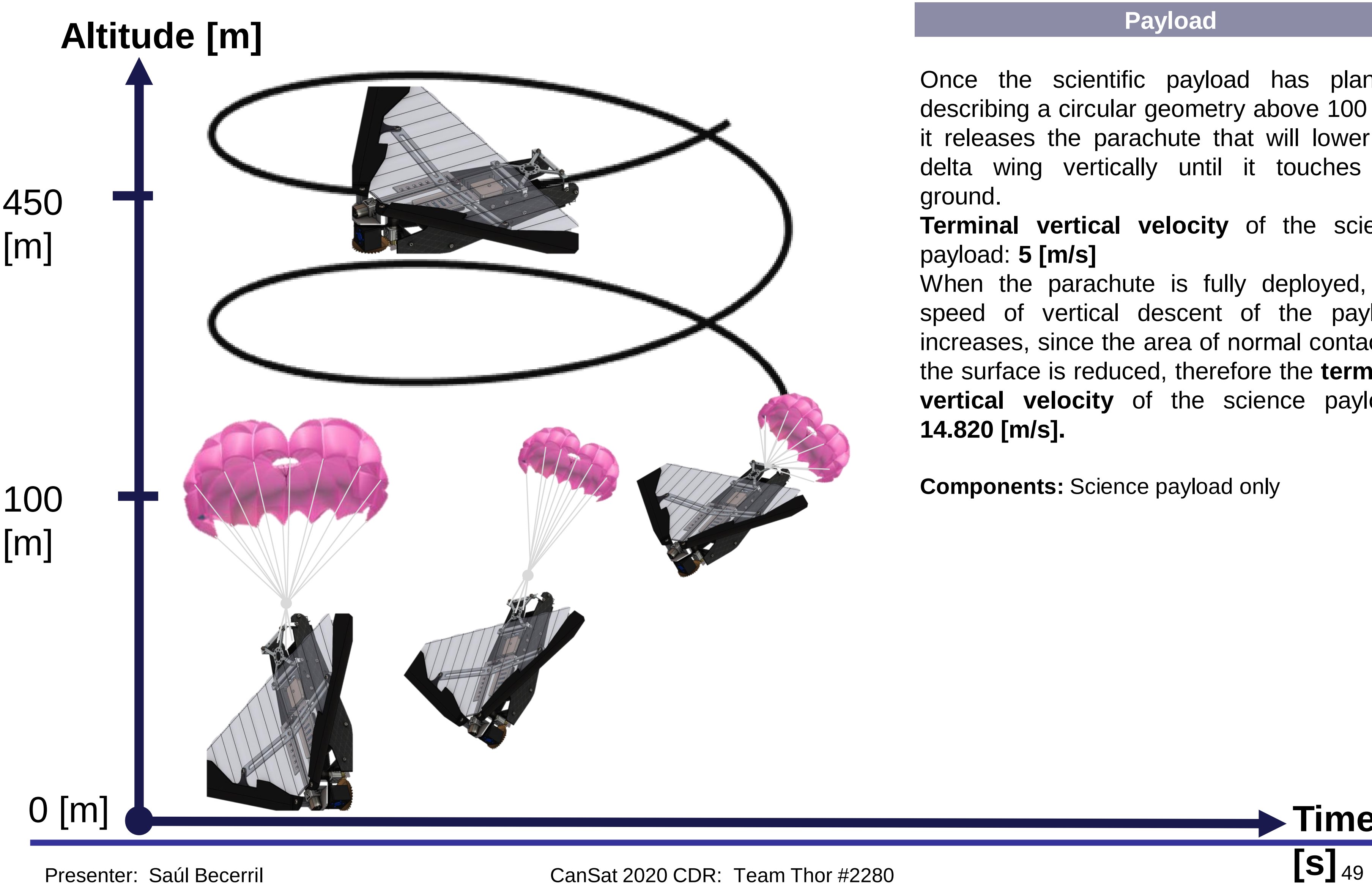
Descent from apogee* to an altitude of 450 [m].
Parachute as descent strategy.
Terminal velocity reached is **16.9592 [m/s]**.
Components: Container and Payload sections with parachute.

Container

Release the science payload and descent from an altitude of 450 [m] till landing 0 [m].
Parachute as descent strategy.
Terminal velocity reached **6.1383 [m/s]** reached.
Components: Container only, and its parachute.

*Maximum height reached by the rocket.

Descent Control Overview (2/2)



Payload

Once the scientific payload has planned describing a circular geometry above 100 [m], it releases the parachute that will lower the delta wing vertically until it touches the ground.
Terminal vertical velocity of the science payload: **5 [m/s]**
When the parachute is fully deployed, the speed of vertical descent of the payload increases, since the area of normal contact to the surface is reduced, therefore the **terminal vertical velocity** of the science payload: **14.820 [m/s].**

Components: Science payload only

Descent Control Changes Since PDR (1/2)

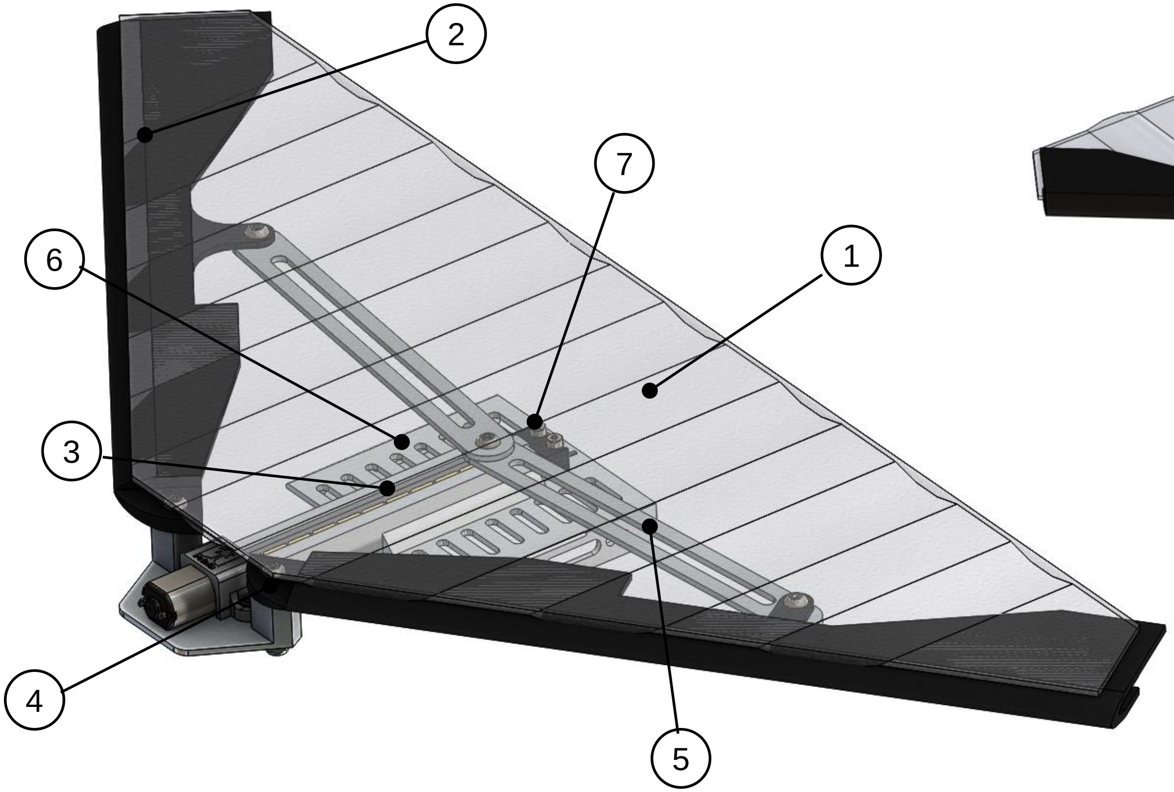
In this section there are no changes.

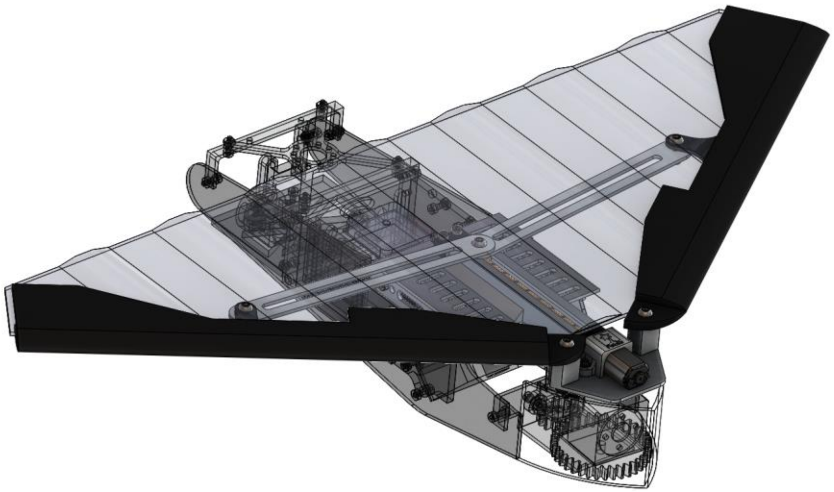
Descent Control Requirements

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
DC01	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.	In order to maintain the prescribed descent rates at all times.	HIGH	SR01		•	•	
DC02	The container parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	In order to reduce descent speed to 20 [m/s] $\pm$ 5 [m/s]	HIGH	SR08				•
DC03	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	Competition Requirement	HIGH	SR09				•
DC04	The container shall released the payload at 450 meters +/- 10 meters.	Competition Requirement	HIGH	SR10				
DC05	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after released from the container.	Competition Requirement	HIGH	SR11				•
DC06	The science payload shall be a delta wing glider.	Competition Requirement	HIGH	SR12				•
DC07	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s.	Competition Requirement. The parachute must be deployed freely	HIGH	SR13		•		
DC08	The CANSAT must operate during the environmental tests laid out in Section 3.5.	Descent control systems must operate during Environmental Tests.	HIGH	SR56				•

Payload Descent Control Hardware Summary (1/3)

Delta Wing



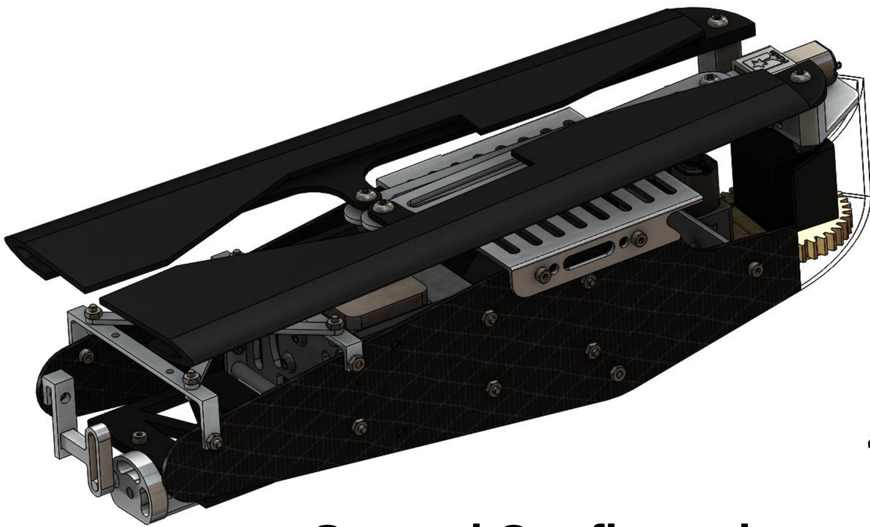


Science payload Compone

PARTS LIST	
ITEM	PART NAME
1	Nylon ripstop
2	Wing profile
3	Threaded rod
4	Micro gear motor
5	Folding link
6	science payload main structure
7	Limit Switch

Payload Descent Control Hardware Summary (2/3)

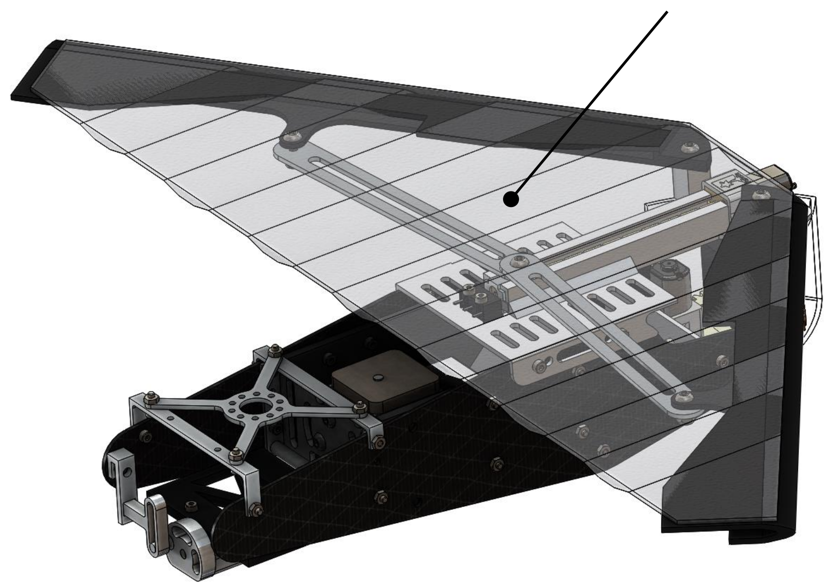
Payload Configurations



Stowed Configuration

$$\text{Area} = 0.029250\ [\text{m}^2]$$

$$AR = \frac{\text{Wingspan}^2}{\text{Area}} = \frac{390^2}{29250} = 5.2$$



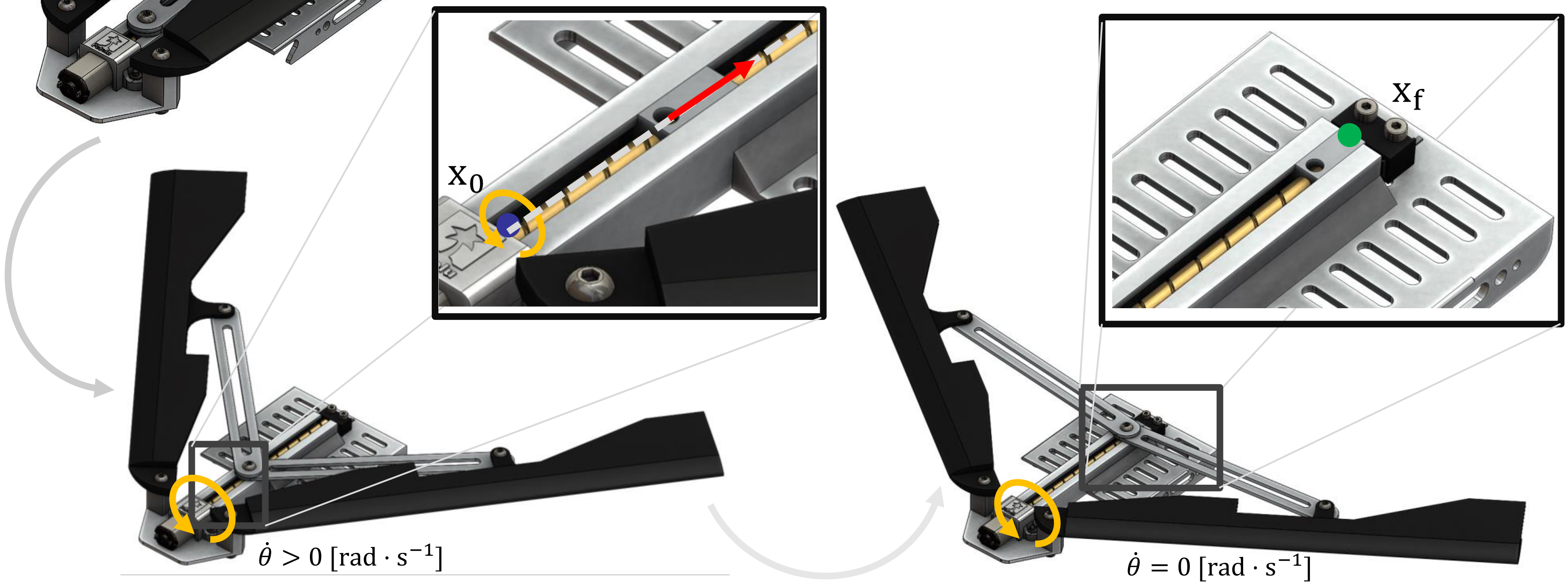
Deployed Configuration

Payload Descent Control Hardware Summary (3/3)

Payload Deployed Method

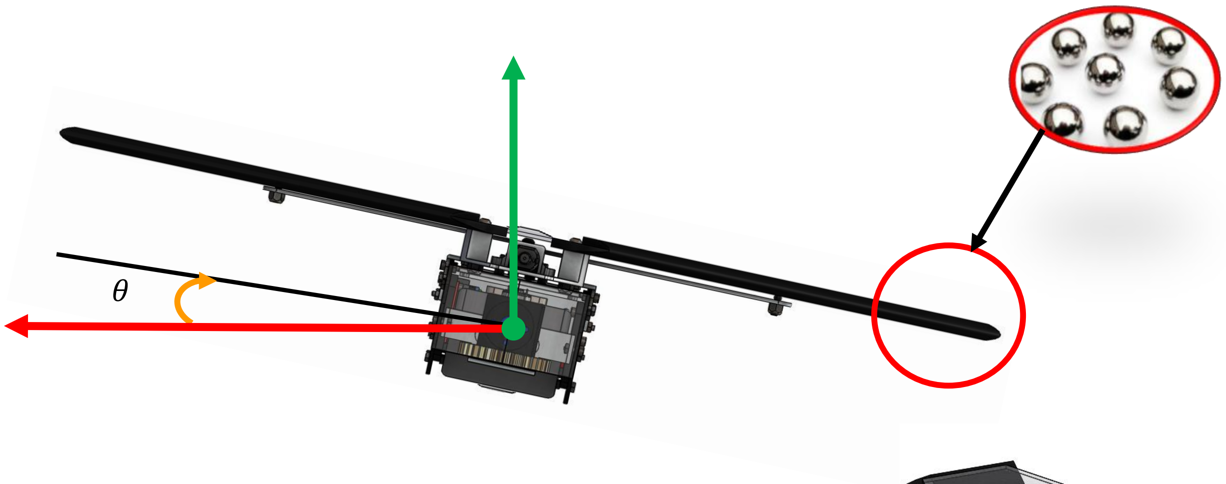
The payload detects 450 [m] height and that it's been deployed, then the micro gear motor star to work, $\mathrm{X_0}$, spinning a threaded rod that moves a slide connected with the folding links.

The motor works until the slide reach the limit switch at the end of the rail, $\mathrm{X_f}$. At that moment, the folding links will be full extended and the deployed configuration reached.

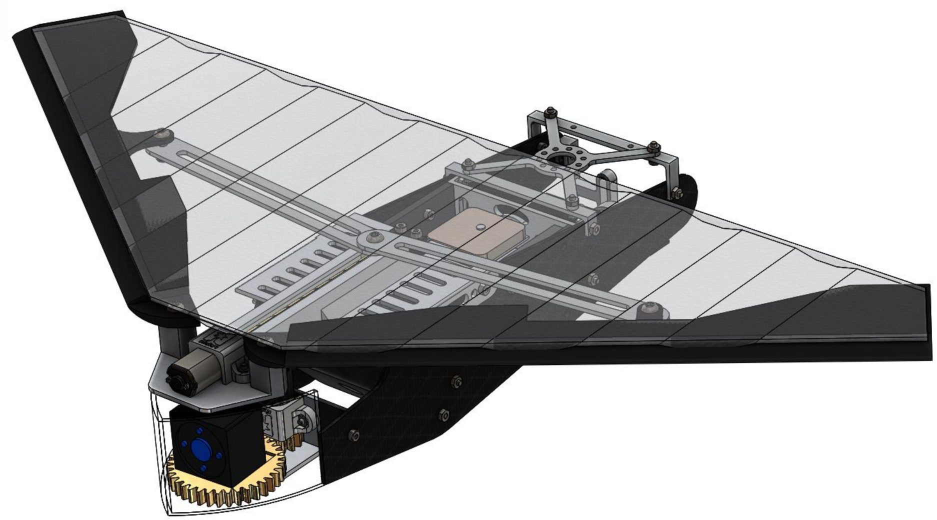


Passive Balance

Counterweight



Distribution of components



- Balance the glider with the distribution of components, or adding some **counterweight**, to achieve an equilibrium with a bank angle θ. What will work to complete the helical descending path.
- Setting the center of pressure in the same plane that the center of gravity, this to avoid any other factor that causes a different bank angle.
- Keep the entire surface of the wing flat to avoid any disturbance to the longitudinal stability.
- The wide Aspect Ratio helps in stability during flight.

$$\mathrm{AR} = \frac{\mathrm{Wingspan}^2}{\mathrm{Area}} = \frac{390^2}{29250} = 5.2$$

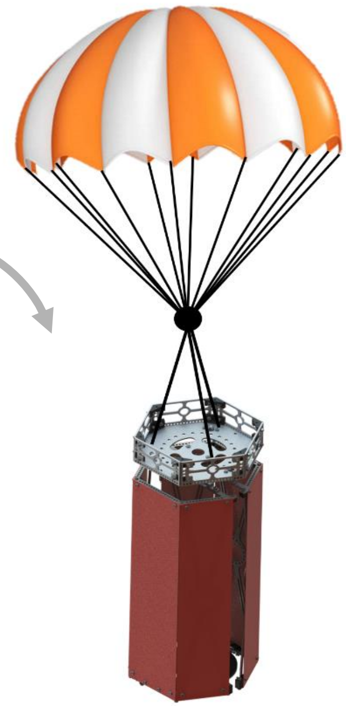
Container Descent Control Hardware Summary (1/2)

Container Configurations

The container control hardware is a **parachute**, thus, it is a passive descent. The parachute will be just one size, so, the final velocity will vary depending in container mass. It will be more detail data in the Descent Rate Estimates section.

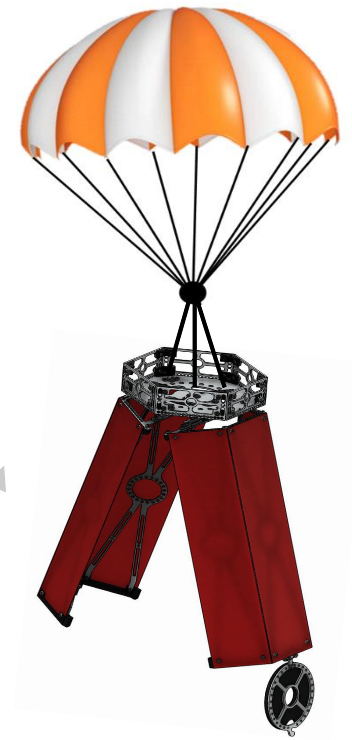
Stowed Configuration

This representation is inside de rocket. Parachute will be at the top of the container with no extra cover



Deployed Configuration

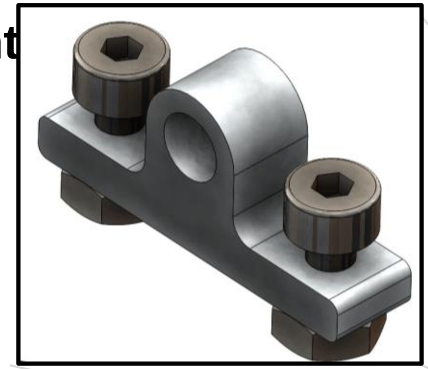
Once the CanSat is released from rocket, parachute will open with the action of wind, no extra hardware were necessary.



Released Payload Configuration

After Payload is released, container will adopt this configuration and its mass will be reduce. So, its speed will decrease.

Container Parachute attachment



At the top of the container, there will be 3 attachments for the suspension lines of the parachute. More detail will be at Container Parachute Attachment Mechanism section.

Nylon Thread will be used for the suspension lines of the parachute.
It has a very good resistance that it is not necessary to use much of it.

Descent Rate Estimates (1/10)

Mathematical model

Here we present the descent rate estimates for the following flight states:

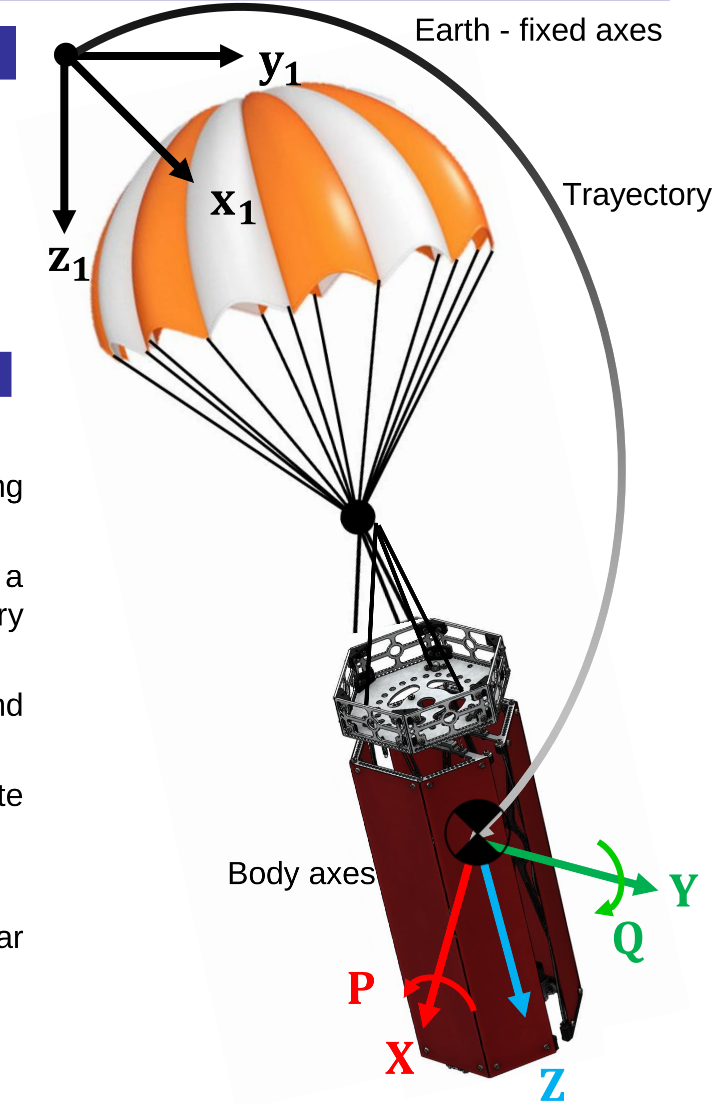
- Container- Science payload descent with parachute
- Container descent with parachute
- Science payload descent with delta wing

Container- Science payload descent with parachute

Simplifying Assumptions

In order to reduce the problem to one of an appropriate size, a number of simplifying assumptions have been made.

- The system consists of a symmetric parachute rigidly connected by a fixed – length connector, or riser, attached along the axes of symmetry to a payload.
- There are five degrees of freedom, with the roll of the parachute and payload about its axis of symmetry being ignored.
- The center of parachute apparent mass is coincident with parachute center of mass.
- Forebody wake effects are ignored.
- Unsteady fluid effects for the parachute are represented by scalar values of apparent mass and moment if inertia.



This state of flight occurs right after the CanSat is deployed from the rocket payload section. At this moment, the parachute must open immediately.

First, the parachute is modeled as a separate body (rigid canopy). The deceleration, $\dot{V}_p$, of this body is therefore calculated by extension of including the riser tension force ($\overrightarrow{F_R}$):

$$\boxed{(m_p + m_a)\frac{dV}{dt} = F_R - \frac{1}{2}\rho V^2 C_{D_p} S_p - V\frac{dm_a}{dt} + m_p g \cdot \sin(\gamma)}$$

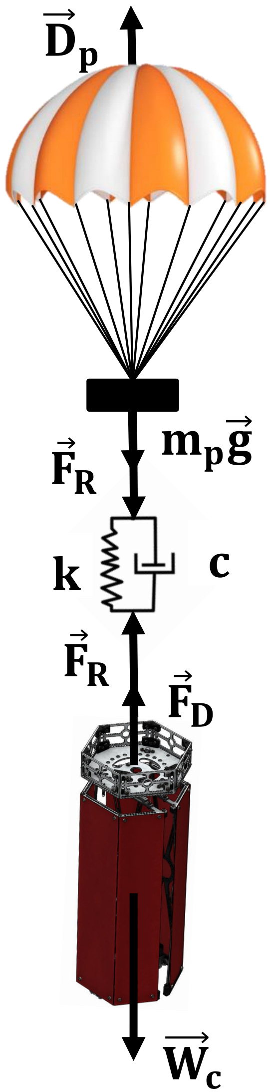
Parameters
m_a, added mass [kg]
m_p,parachute mass [kg]
ρ, air density[$kg \cdot m^{-3}$]
R_p, Inflated radius [m]
C_{D_p}, drag coefficient of parachute
S_p, total área of parachute [m^2]
p, porosity [dimensionless]

For simplicity, it is considered that $m_a(t)$ is a constant value. An ecpression for added mass, similar to that for apparent mass, that has been used widely

$$m_a = k_a \rho \frac{4}{3} \pi R_p^3$$

The values of k_a for porous hemispherical ribbon parachutes [].

$$k_a = 1.068(1 - 1.465p - 0.2597p^2 + 0.2626p^3)$$



References:

[] R. C.Maydew and C.W. Peterson, “Design and testing of high performance parachutes,” AGARD AG-319, 1991.

To simplify the calculation, it is considered that the parachute speed is constant and is the same as that existing in the payload, that is, that the deformation rate in the suspension lines is zero.

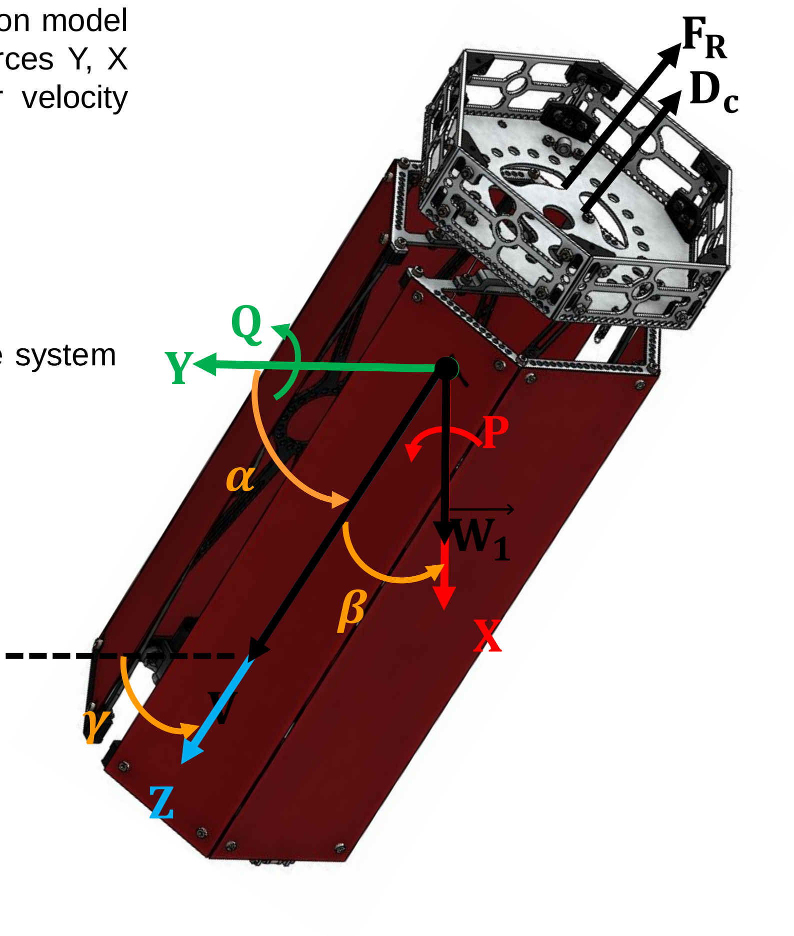
Obtained the data provided by the parachute dynamics we obtain the motion model of the system Container – Science payload after considering the axial forces Y, X (conical motion) are smaller than the vertical force Z and the angular velocity components are negligible, we have to

$$\boxed{m_{cp}\left(\frac{dV_z}{dt}\right) = Z - F_R\cos(\alpha)\sin(\beta)}$$

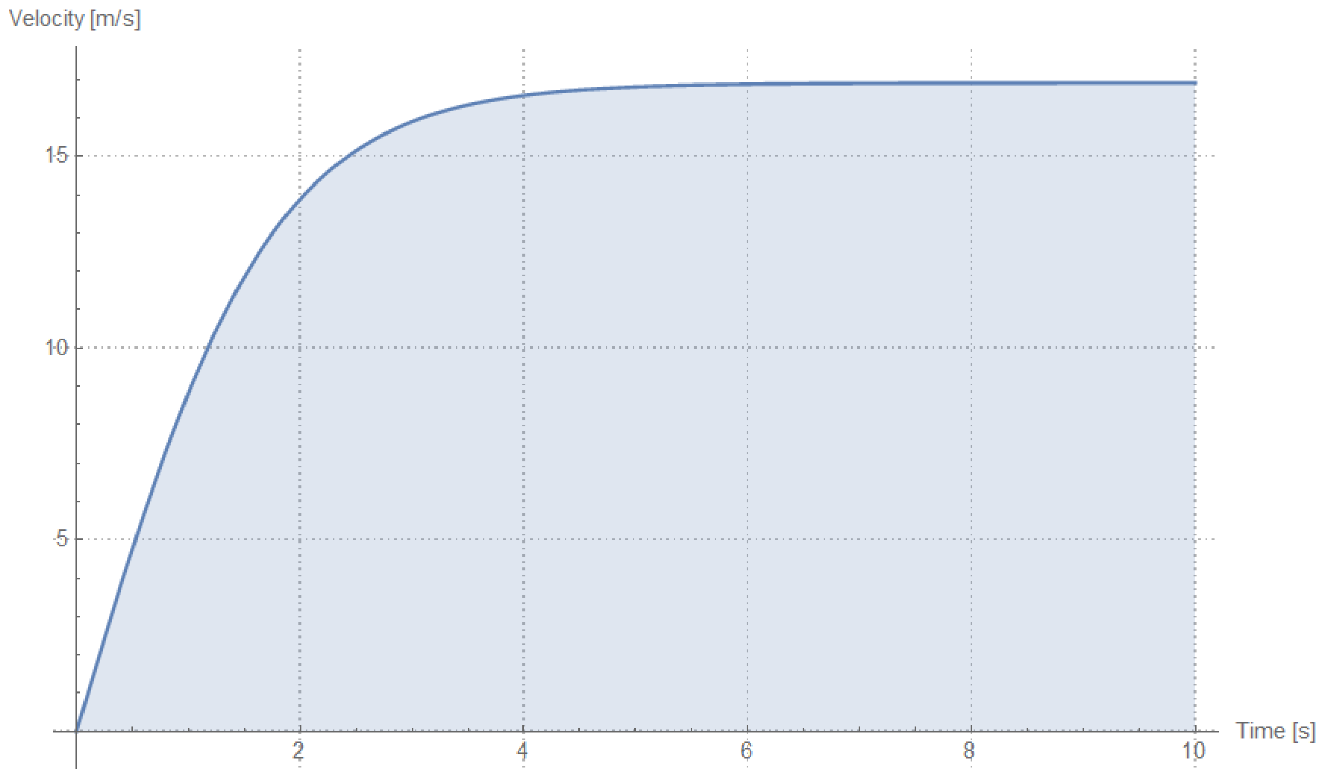
Assumptions
$\dot{V}_p = 0$
Incompressible flow
Subsonic speed (M<1).
No roll, pitch and yaw rate.
Drag coefficient of a hollow semi-sphere parachute in opposite stream.
No air currents.
Small horizontal displacements
No angular velocity components

Where Z are the aerodynamic forces on the system Container – Science payload

Right after rocket separation, the system Container – Science payload has a mass ($\mathbf{m_{cp}}$) of **0.610 [Kg]**, and an initial falling velocity, v_0, of **0 [m/s]**. The effective frontal area of the parachute is **0.0183 [m^2]** for a parachute radius of 0.0763 [m]**.** A drag coefficient of **1.33** was considered for a hollow semi-sphere parachute in opposite stream.



The mass of the parachute is greater than the added mass, it is disregarded for the calculations, in addition, It is expected that the opening time of the parachute will be immediate, It's considered a constant value for the drag coefficient of the parachute, despite the fact that the contact surface varies over a period of time, Δt.



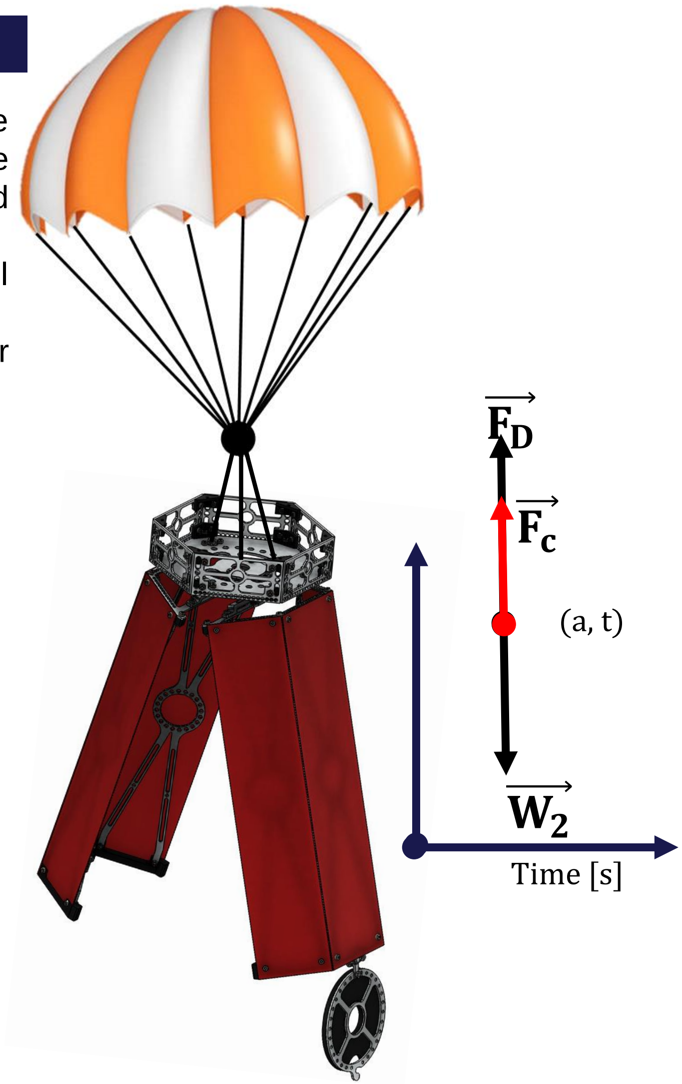
Parameters
$\rho = 1.225[\mathrm{kg} \cdot \mathrm{m}^{-3}]$
$\mathrm{A} = 0.0183\ [\mathrm{m}^2]$
$\mathrm{m} = 0.610\ [\mathrm{Kg}]$
$\mathrm{C_d} = 1.33$
$\mathrm{g} = 9.81\ [\mathrm{m} \cdot \mathrm{s}^{-2}]$
$\mathrm{v_0} = 0\ [\mathrm{m} \cdot \mathrm{s}^{-1}]$
$\mathrm{p} = 0.2\ [\mathrm{pore}/\mu\mathrm{m}]$
$\alpha = 5\ [\mathrm{degrees}]$
$\beta = 5[\mathrm{degrees}]$
$\gamma = 15\ [\mathrm{degrees}]$
$m_p = 0.030\ [\mathrm{kg}]$
$\mathrm{m_a} = 0.001\ [\mathrm{kg}]$

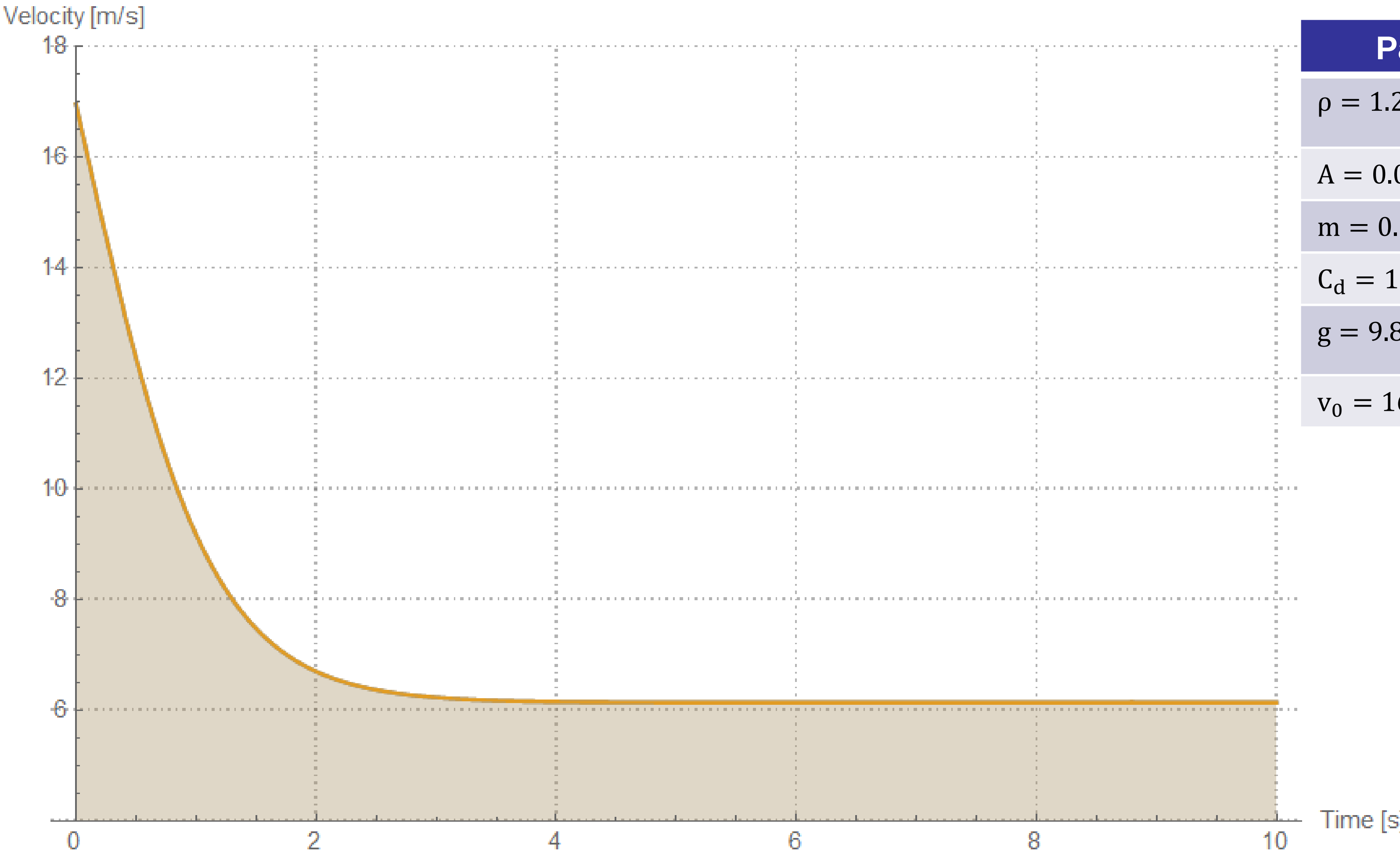
A terminal velocity of **16.9592 [m/s]** is reached. This velocity lies between the limits (15 [m/s] – 25 [m/s]). This result leaves enough margin in case the Container – Science payload system can falls faster or slower due to effects within this model, that is, the variations of α, β, γ are considered null.

Container descent with parachute (after Science payload has been released)

This state of flight occurs right after the Science payload frees itself from the Container (to be explained at the Mechanical Subsystem Design). At this point, the Container descends with the parachute, while the Science payload now has started its descent with the delta wing.
For estimating the descent rate of this state of flight, the same mathematical model from the previous section is used; the mass and initial velocity are different, though.
The same assumptions were considered. The following graph shows the results for this state of flight.

Right after Payload separation, the Container has a mass of **0.250 [Kg]**, and an initial falling velocity of **16.9592 [m/s].** The effective frontal area of the parachute is **0.0183** $[\mathbf{m}^2]$ for a parachute radius of 0.0763 [m]. A drag coefficient of **1.33** was considered for a hollow semi-sphere parachute in opposite stream.|





Parameters
$\rho = 1.225\ [kg \cdot m^{-3}]$
$A = 0.0183\ [m^2]$
$m = 0.250\ [Kg]$
$C_d = 1.33$
$g = 9.81\ [m \cdot s^{-2}]$
$v_0 = 16.9592\ [m \cdot s^{-1}]$

Terminal velocity of **6.1383 [m/s]** is reached. This velocity is smaller than the previous one as the system now has lost a considerable amount of mass (Science payload mass).

Descent Rate Estimates (7/10)

Payload Descent Glider Configuration

The requirement is to form a circular patter with a 250 [m] Radius. We will relate the radius with the bank angle of the glider. Doing a balance between forces in the moment of the turn we have in the vertical axis:

$$\boxed{\mathrm{L}\sin(\theta) = \frac{\mathrm{m}\,\mathrm{v}^2}{\mathrm{r}}}$$

Parameters
L, lift force [N]
θ, bank angle [degree]
m, mass of glider [Kg]
v, vertical velocity of glider $[\mathrm{m}\cdot\mathrm{s}^{-1}]$
r, turn radius [m]
A, area of delta wing $[\mathrm{m}^2]$

Replacing the lift force with its complete formula we can reduce the velocity and get it out of the equation. After that, we can clear the bank angle, as shown next:

$$\boxed{\theta = \sin^{-1}\left(\frac{2\,\mathrm{m}}{\mathrm{C_l}\,\mathrm{A}\,\rho\,\mathrm{r}}\right) = 8.21°}$$

Now, we have the enough information to solve for the bank angle:

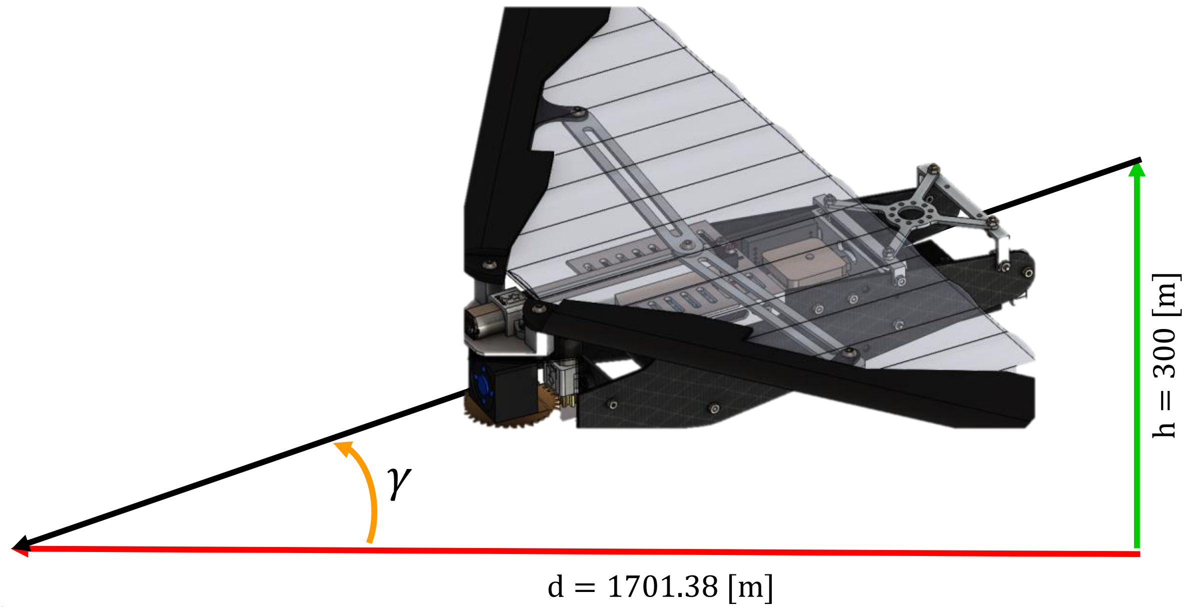
Parameters
$\mathrm{C_l}$ = 0.50
ρ = 1.225 $[\mathrm{kg}\cdot\mathrm{m}^{-3}]$
m = 0.320 [Kg]
A = 0.0292 $[\mathrm{m}^2]$
r = 250 [m]

Descent Rate Estimates (8/10)

The release of the payload shall be at 450 [m] +/- 10 meters. And stay above the 100 [m] at every time of glide. For a factor of security, we propose to be above the 150 [m], so we have a total vertical distance of 300 [m] to glide.

With that vertical distance and requirement of one minute of glide, we can calculate the vertical velocity with a simple division. We got 5 [m/s] of vertical velocity.
We propose a glide angle $\gamma = 10°$ to avoid any disturbance with a bigger angle. Thereby, we can calculate the total horizontal distance to glide.

$$d = \frac{h}{\tan(\gamma)} = \frac{300}{\tan(10)} = 1701.38\ [\mathrm{m}]$$



$$\text{Glide Ratio } \left(\frac{L}{D}\right) = \frac{1}{\tan(\gamma)} = \frac{1}{\tan(10)} = 5.671$$

$$v_{\text{horizontal}} = \frac{v_{\text{vertical}}}{\tan(10)} = \frac{5}{\tan(10)} = 28.35\ [\mathrm{m \cdot s^{-1}}]$$

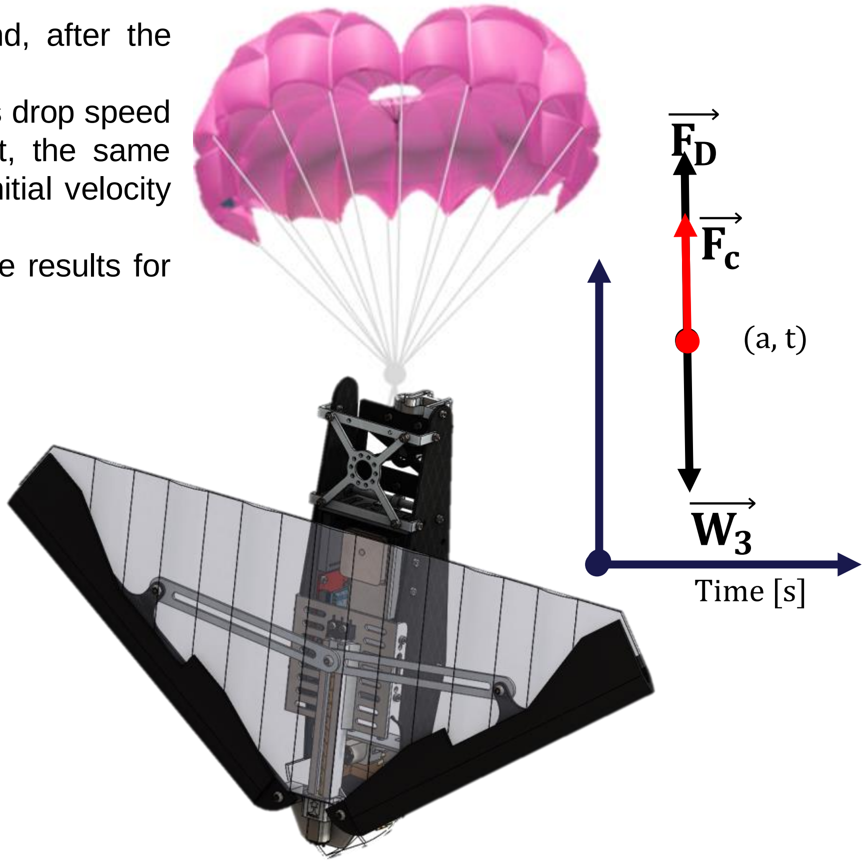
With a 250 [m] radius, the circumference is 1570.8 [m] so, we would achieve 1.08 laps for the glide.

Descent Rate Estimates (9/10)

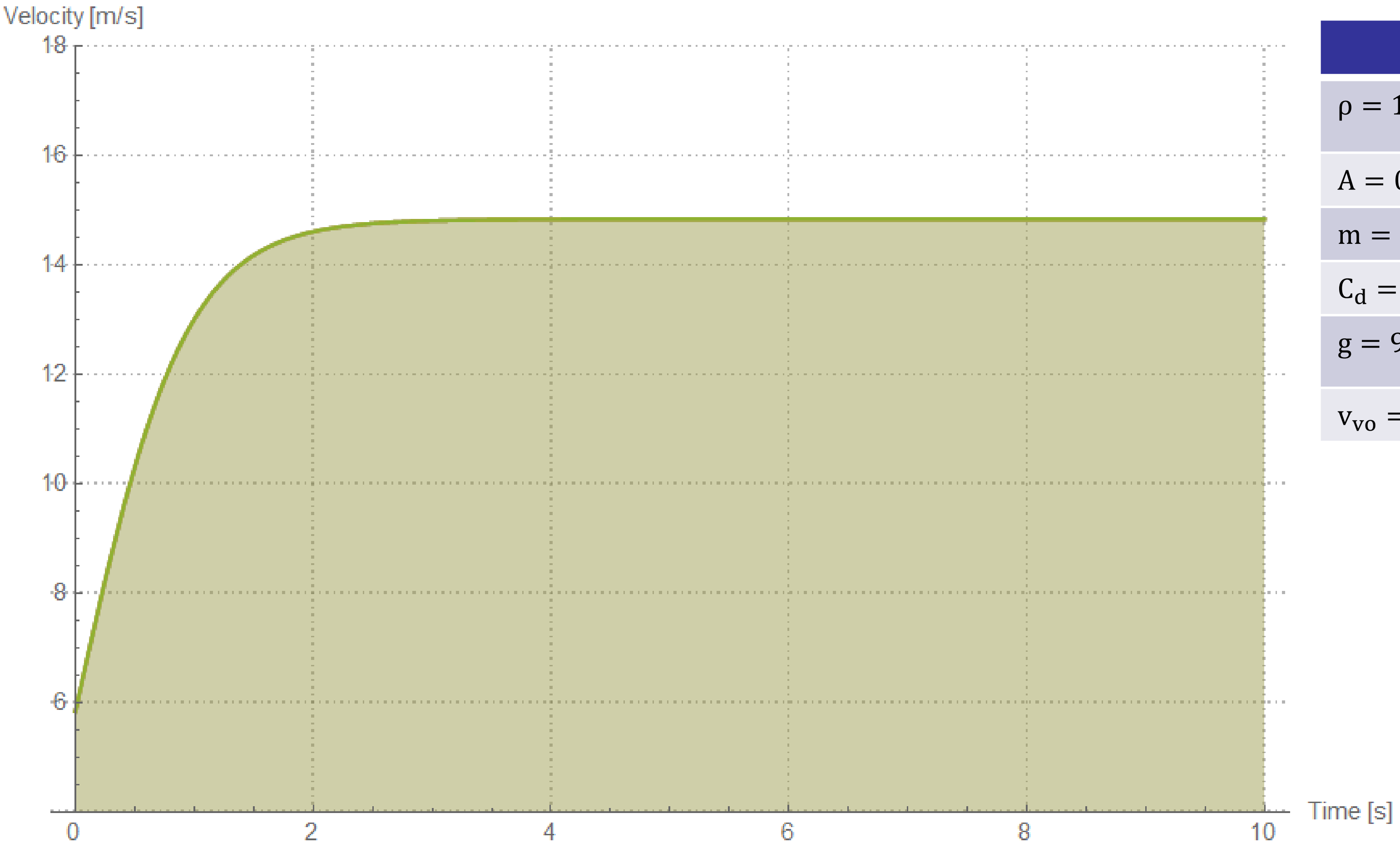
Science payload descent with parachute (after Science payload has been glided with the delta wing)

This flight status occurs at a height of 100 [m], relative to the ground, after the Science payload has been planning from a height below 460 [m].
The Science payload has to release a parachute that allows it to lower its drop speed to 10 [m/s], and for estimating the descent rate of this state of flight, the same mathematical model from the previous section is used; the mass and initial velocity are different, though.
The same assumptions were considered. The following graph shows the results for this state of flight.

Right after the expulsion of the parachute, the Science payload has a mass of **0.360 [Kg]**, and an initial vertical falling velocity, v_{vo}, of **5.83 [m/s].** The effective frontal area of the parachute is **0.0535 $[m^2]$** for a parachute radius of 0.1305 [m]. A drag coefficient of **1.33** was considered for a hollow semi-sphere parachute in opposite stream.



Descent Rate Estimates (10/10)



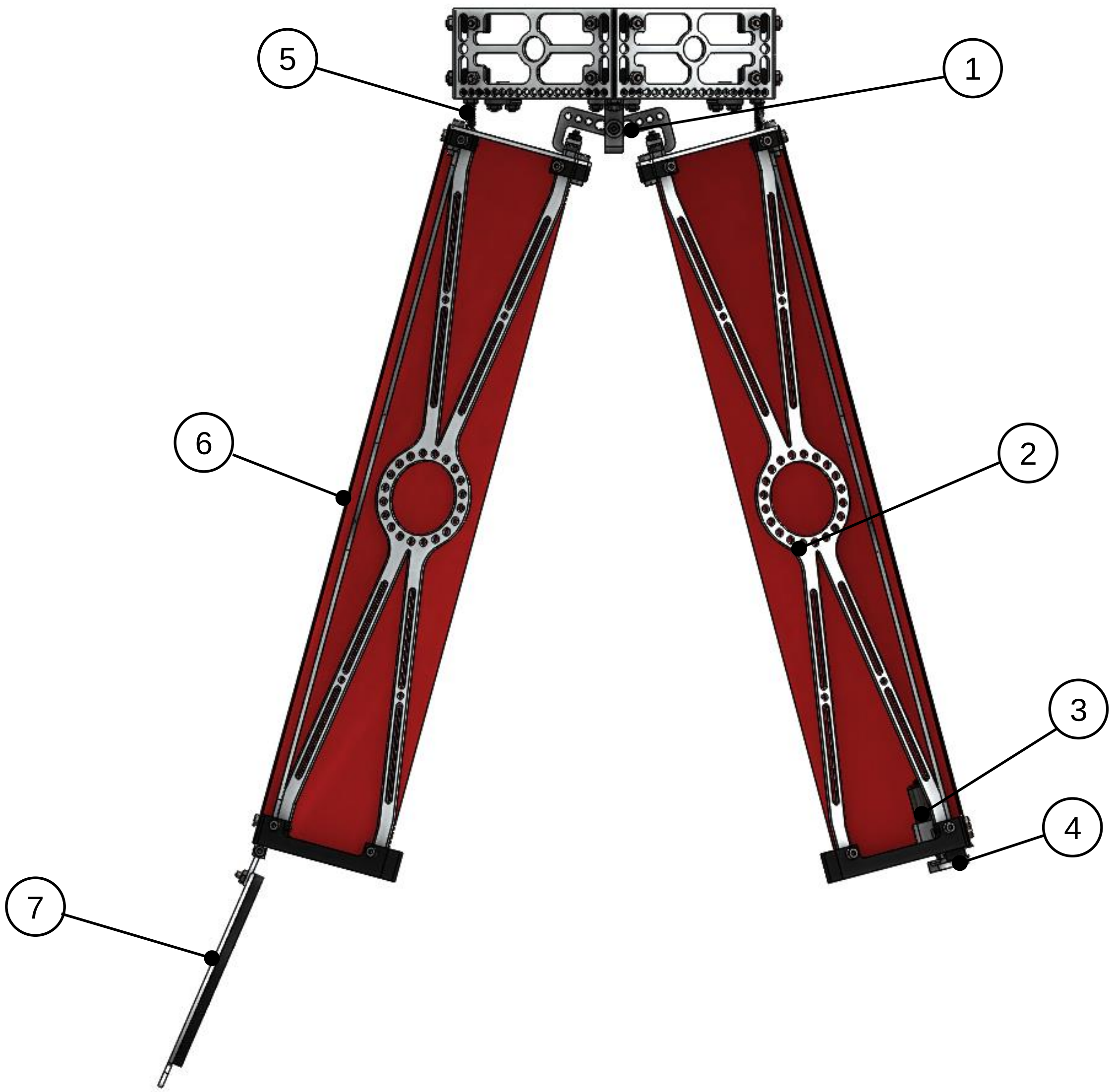
Parameters
$\rho = 1.225\ [kg \cdot m^{-3}]$
$A = 0.0535\ [m^2]$
$m = 0.360\ [Kg]$
$C_d = 1.33$
$g = 9.81\ [m \cdot s^{-2}]$
$v_{vo} = 5.83 [m \cdot s^{-1}]$

Terminal velocity of **14.8202 [m/s]** is reached. This speed is lower than the previous one and the system now has to reduce the speed of the delta wing descent.

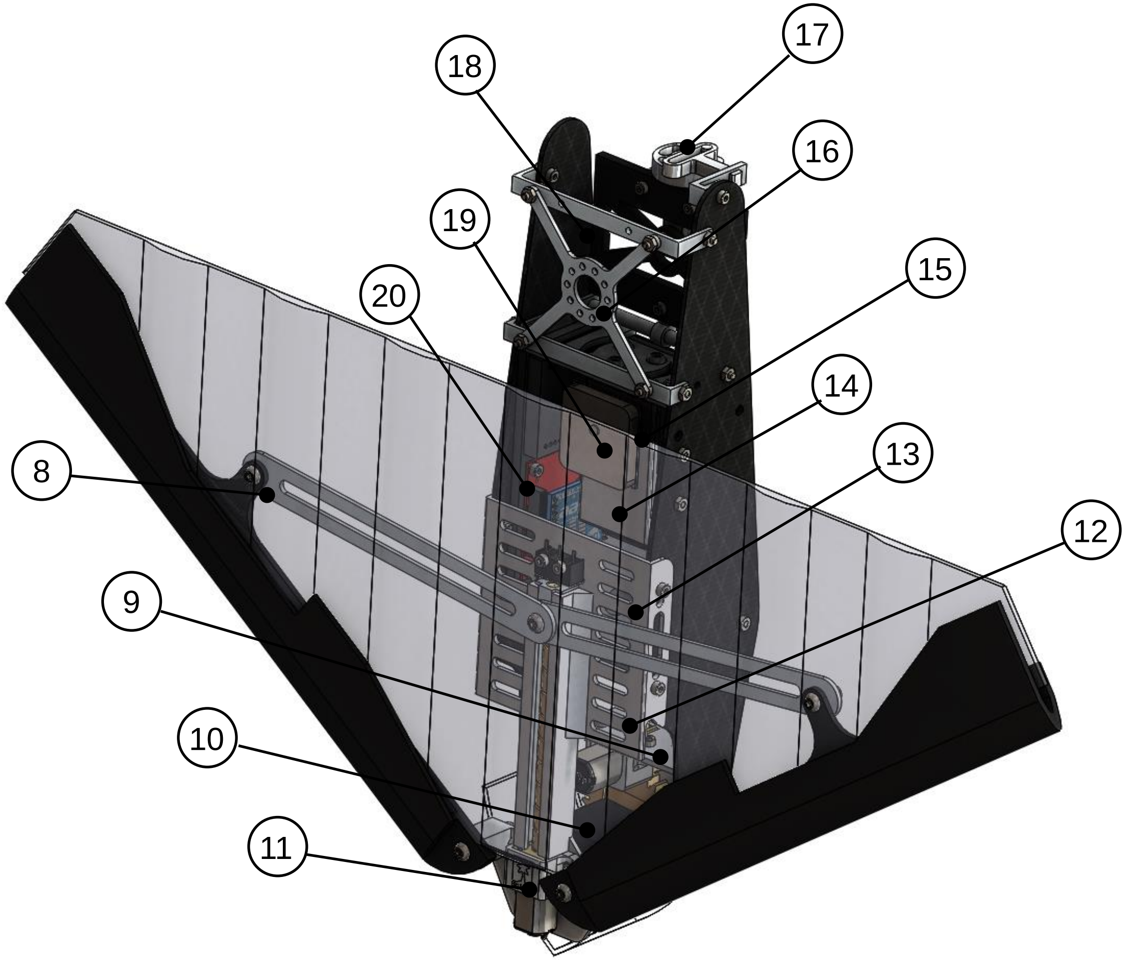
Mechanical Subsystem Design

Rodrigo Serrato

Mechanical Subsystem Overview (1/2)

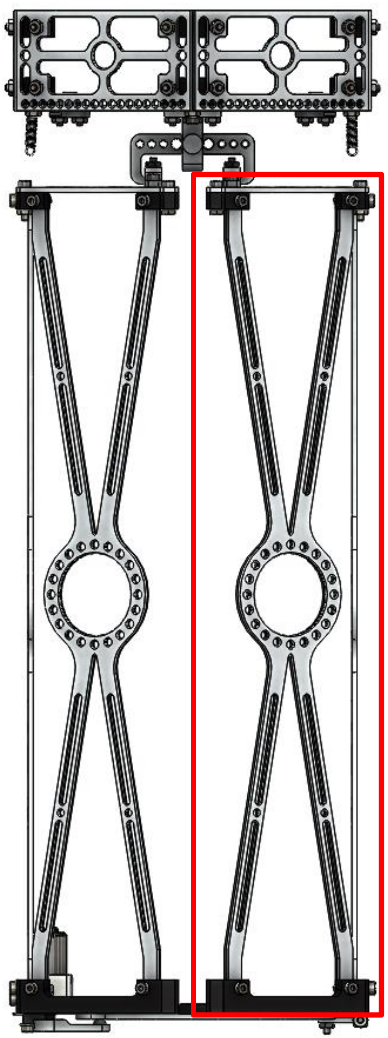


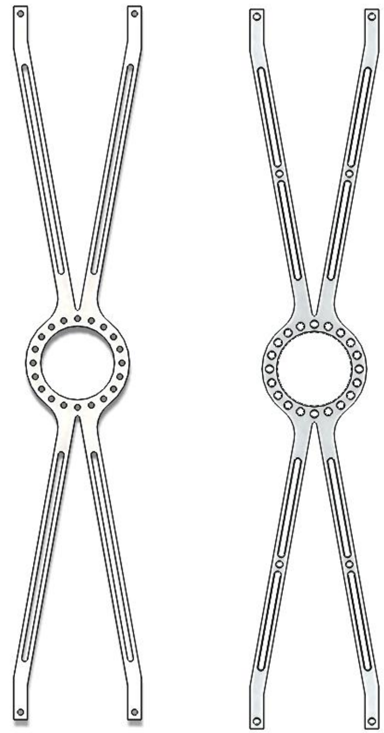
Mechanical Subsystem Overview (2/2)



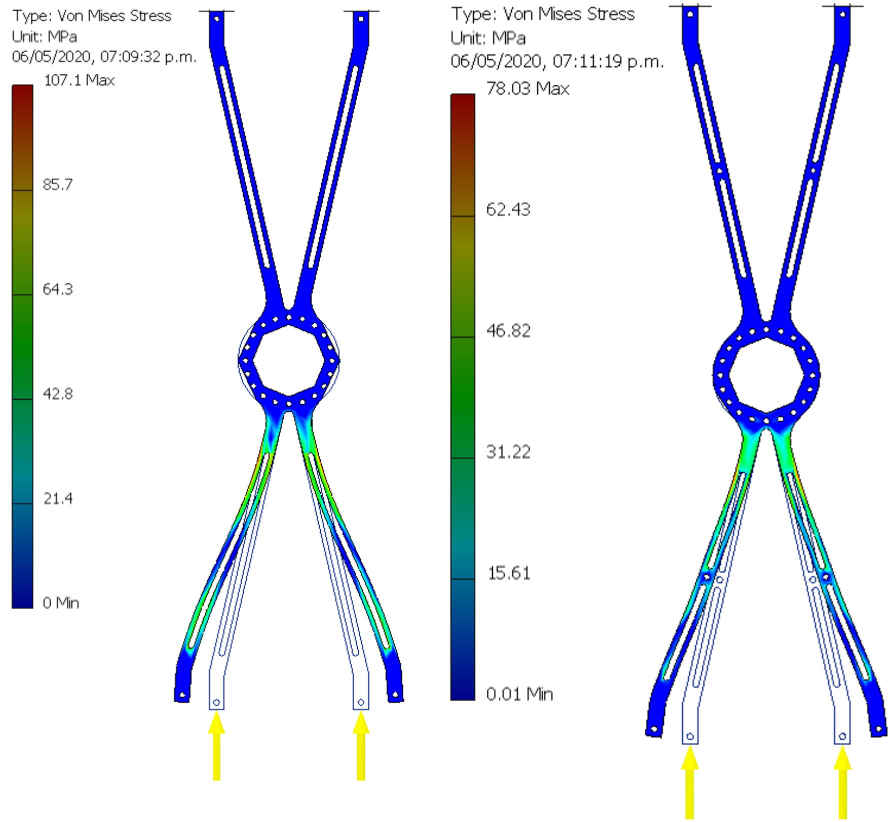
Isometric view

PARTS LIST	
ITEM	PART NAME
1	Opening mechanism
2	Principal structure
3	Micro gear motor
4	Release hook
5	Spring
6	Hexagonal cover
7	Science payload release mechanism
8	Folding Links
9	Pitot tube
10	Camera
11	Micro gear motor
12	Particulates sensor
13	Top payload structure
14	Battery
15	Power switch
16	Parachute support structure
17	Scottish yoke mechanism
18	Parachute
19	GPS antenna
20	LED indicator





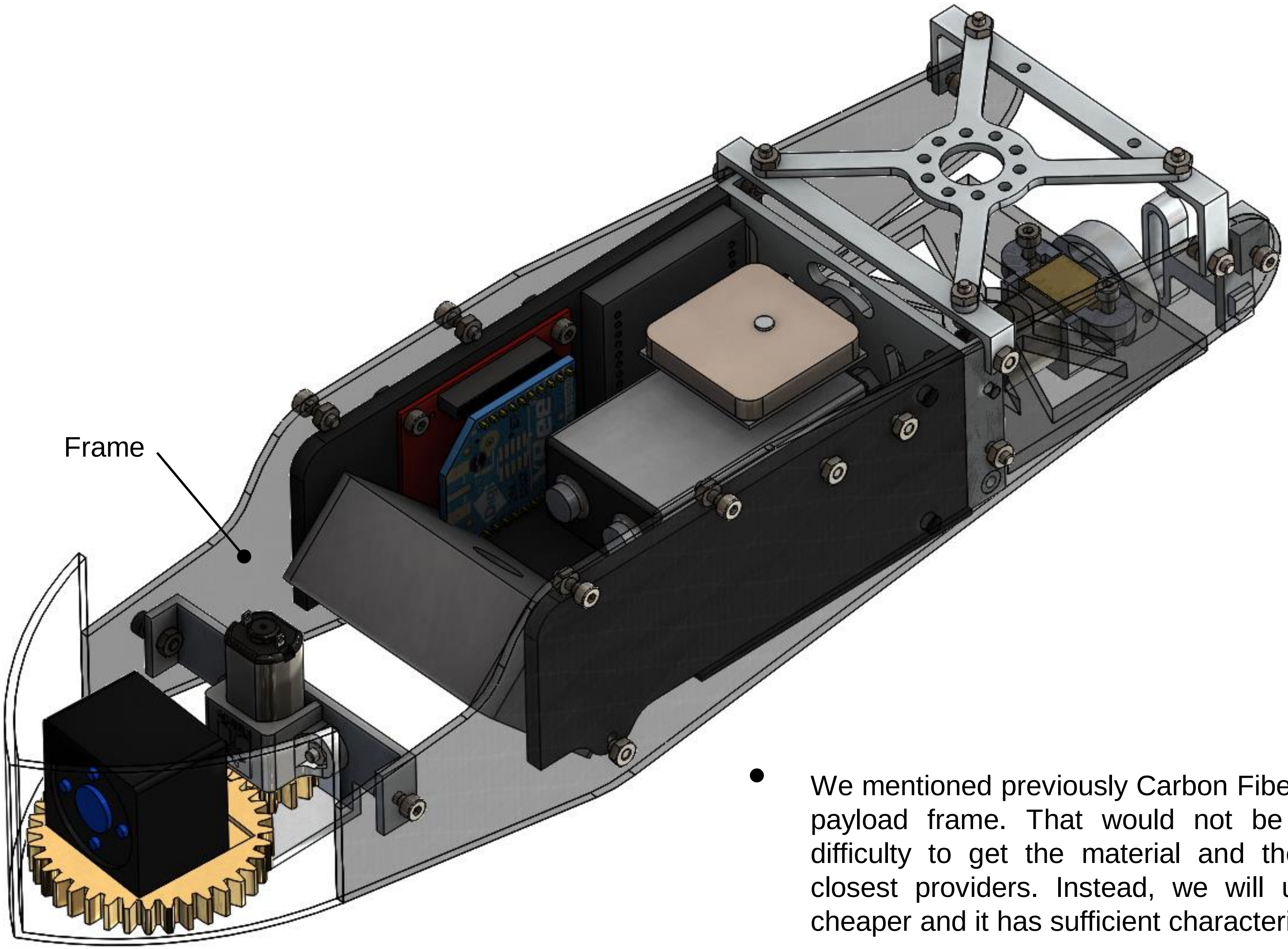
PDR design CDR design



- After subjecting the container to an acceleration of 30 [G's] in Inventor 2017®, it was observed that when dividing the groove on one side of the main structure the stress was reduced by 29 [MPa], and therefore the deformation is reduced and the factor of security increases.

  In addition, the diameter of the holes was extended and the mass of the main structure was reduced 0.435 [g].

Mechanical Subsystem Changes Since PDR



- We mentioned previously Carbon Fiber as the material for the payload frame. That would not be possible because the difficulty to get the material and the high prices with the closest providers. Instead, we will use **fiberglass,** that is cheaper and it has sufficient characteristics for the aims.

Mechanical Sub-System Requirements (1/4)

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
MS01	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.	So that the rocket can lift the CanSat	HIGH	SR01				•
MS02	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.	So that the CanSat fits within the rocket.	HIGH	SR02		•	•	•
MS03	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	So that the CanSat is released freely from rocket payload section.	HIGH	SR03		•	•	•
MS04	The container shall be a fluorescent color; pink, red or orange.	For its rapid recognition in open field.	MEDIUM	SR04			•	
MS05	The container shall be solid and fully enclose the science payload. Small holes to allow Access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	Competition Requirement	HIGH	SR05			•	
MS06	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Competition Requirement	HIGH	SR06		•	•	
MS07	The rocket airframe shall not be used as part of the CanSat operations.	Competition Requirement	HIGH	SR07		•	•	
MS08	The container parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Competition Requirement	HIGH	SR08		•	•	
MS09	The descent rate of the CanSat (container and science payload) shall be 20 meter/second +/- 5m/s.	.Competition Requirement	HIGH	SR09	•			•

Mechanical Sub-System Requirements (2/4)

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
MS10	The container shall release the payload at 450 meters +/- 10 meters	Competition Requirement. Sensors must have plain sight of view for correct measurements.	HIGH	SR10			•	
MS11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container.	Competition Requirement.	HIGH	SR11	•			•
MS12	The science payload shall be a delta wing glider.	Competition Requirement.	HIGH	SR12	•			•
MS13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s.	Competition Requirement. The parachute must be deployed freely	HIGH	SR13			•	
MS14	All descent control device attachment components shall survive 30 Gs of shock.	For ensuring the physical integrity of the delta wing and parachute systems.	HIGH	SR14	•			•
MS15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Competition Requirement. Sensors must have plain sight of view for correct measurements.	MEDIUM	SR15			•	
MS16	All structures shall be built to survive 15 Gs of launch acceleration.	So as the CanSat stands rocket deployment.	HIGH	SR16	•			•

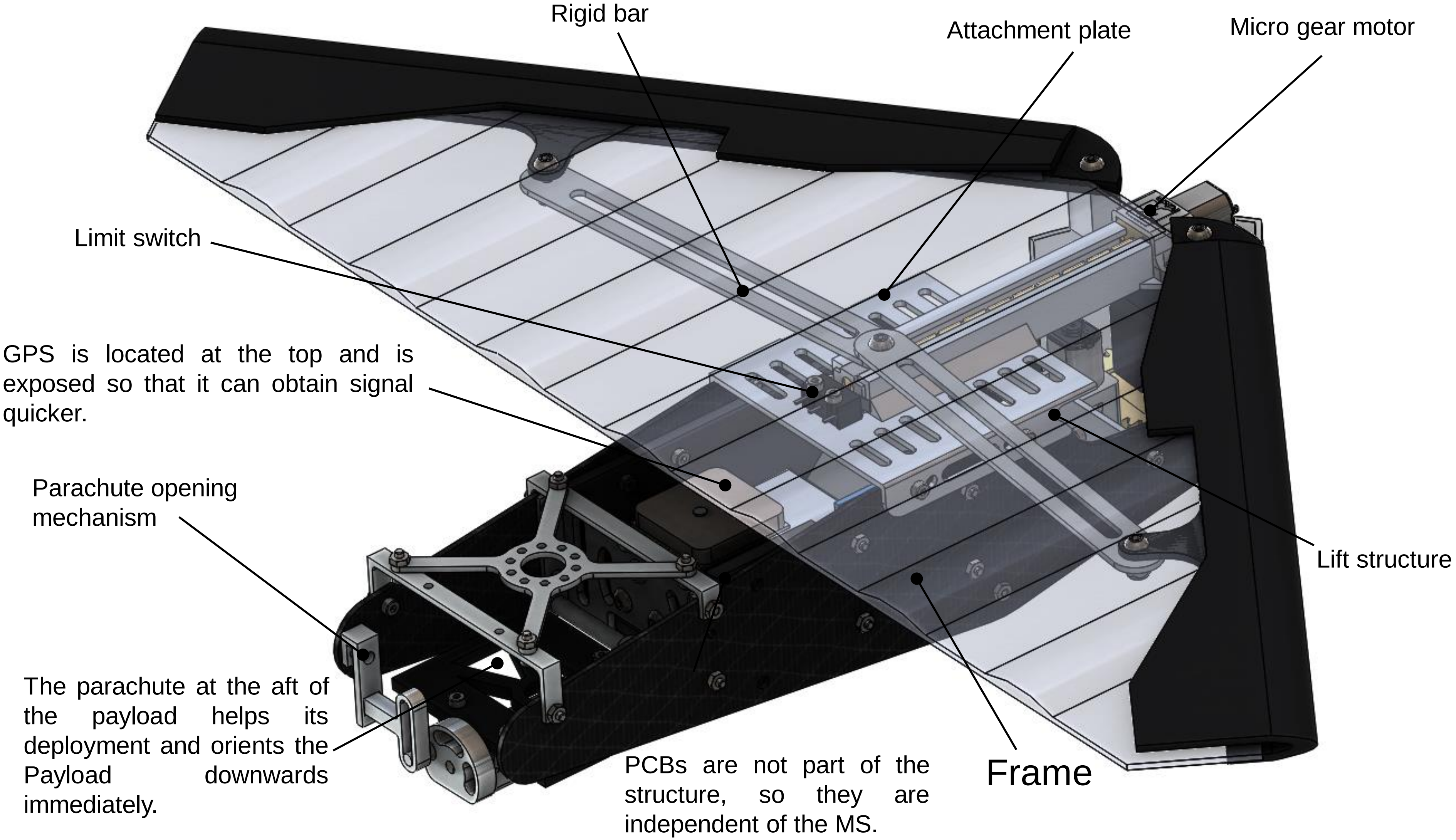
Mechanical Sub-System Requirements (3/4)

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
MS17	All structures shall be built to survive 30 Gs of shock.	For ensuring the physical integrity of the CanSat.	HIGH	SR17	•			•
MS18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	In order to ensure that all components stay in their place.	HIGH	SR18			•	
MS19	All mechanism shall be capable of maintaining the configurations of states under all forces.	So that them all can perform well their functions.	HIGH	SR19				•
MS20	Mechanism shall not use pyrotechnics or chemicals.	Competition Requirement. Our design does not contemplate either pyrotechnics nor chemicals.	LOW	SR20			•	
MS21	The parashutes shall be fluorescent Pink or Orange	For its rapid recognition in open field.	MEDIUM	SR30			•	
MS22	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Costs of the mechanical components should not contribute significantly to the overall cost.	HIGH	SR38		•		
MS23	Both the container and probe shall be labeled with team contact information including email address.	For contacting the team in case the container or the Payload are found prior to the competition.	HIGH	SR46			•	

Mechanical Sub-System Requirements (4/4)

#	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
MS24	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	For indicating that the CanSat is turned on.	MEDIUM	SR49			•	
MS25	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.	For a rapid change of batteries.	HIGH	SR54			•	
MS26	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Competition Requirement. Our design does not contemplate spring contacts.	LOW	SR55			•	
MS27	The CANSAT must operate during the environmental tests laid out in Section 3.5.	Mechanical systems must operate during Environmental Tests.	HIGH	SR56				•

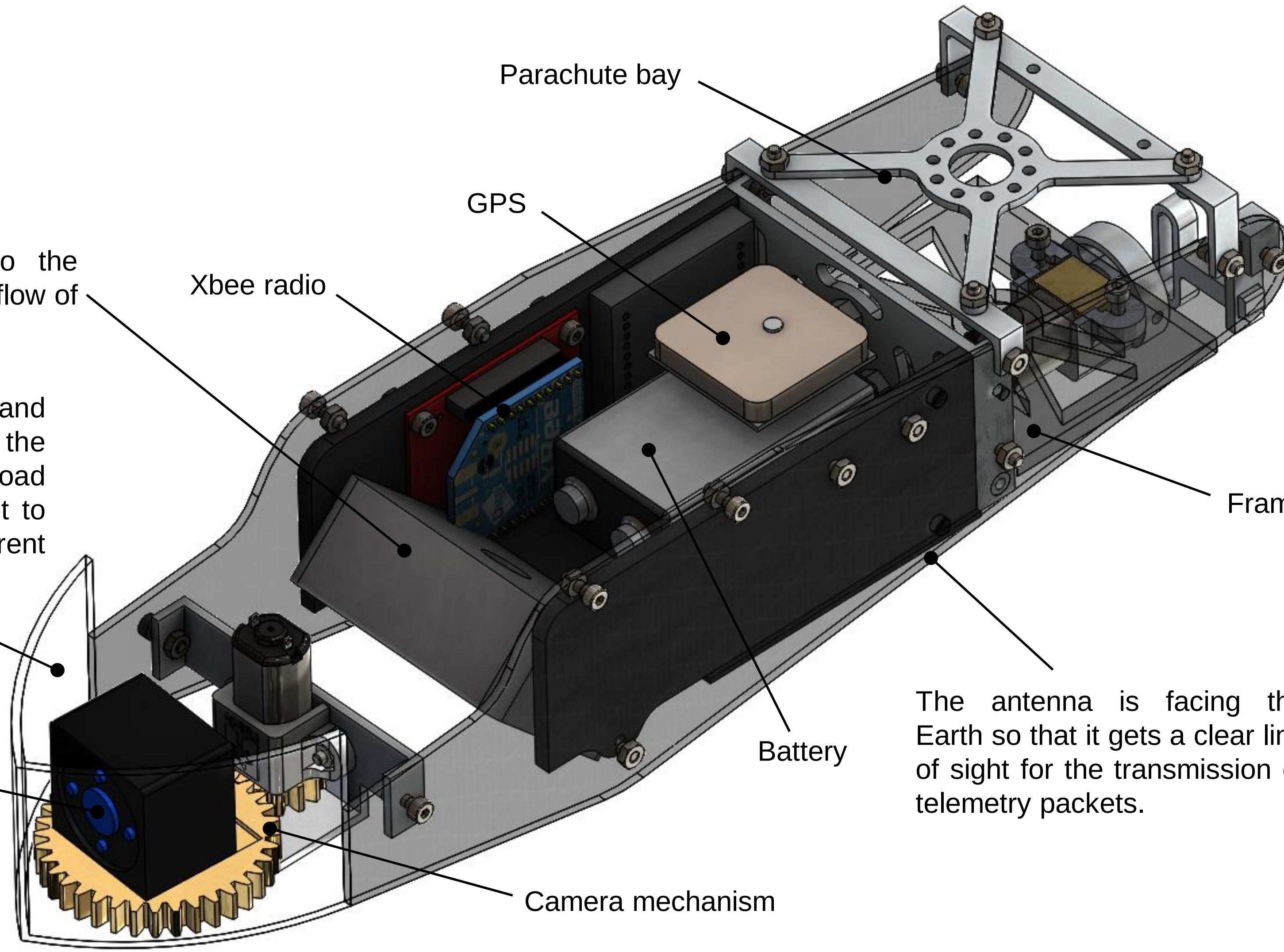
Payload Mechanical Layout of Components



Payload Mechanical Layout of Components

Particle sensor facing to the Earth to get a continuous flow of air.

Nose is transparent and rounded so that it help the aerodynamics of the payload and the camera, allowing it to record through the transparent material.



The antenna is facing the Earth so that it gets a clear line of sight for the transmission of telemetry packets.

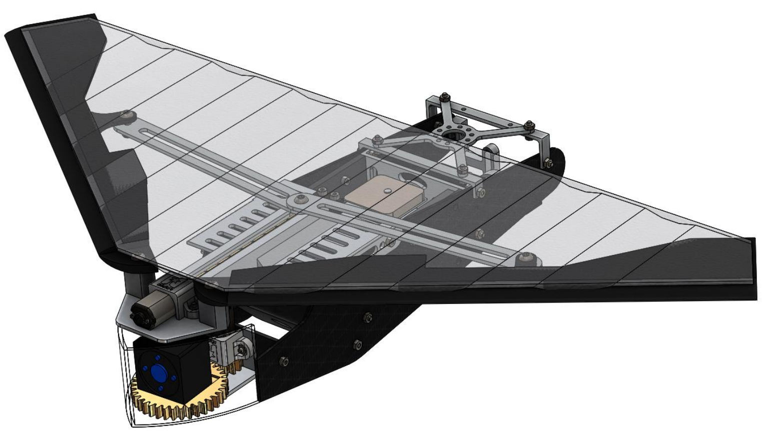
Payload Mechanical Layout of Components Trade & Selection (4/4)

Material Selection

We mentioned previously Carbon Fiber as the material for the payload frame. That would not be possible because the difficulty to get the material and the high prices with the closest providers. Instead, we will use **fiberglass,** that is cheaper and it has sufficient characteristics for the aims.

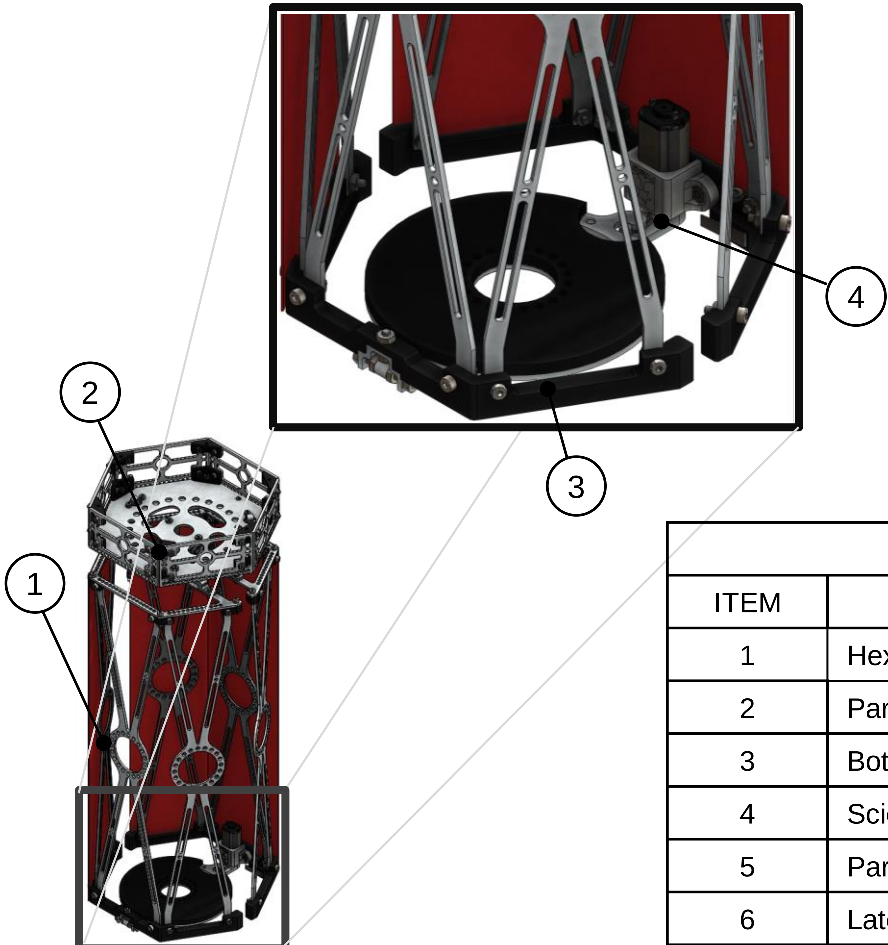
Material selection						
Material	**Density ρ** $[g/cm^3]$	**Young's Modulus** E [GPa]	**Melting (softening) temperature** [°C]	**Impact Strength**	**Cost** [USD]	**Components made of this material**
Fiberglass	1.85	18	280-300	-	30	Payload structures.
Carbon Fiber	1.60	70	-	8*	50	Payload structures.
Aluminium	2.70	68	660 - 680	10**	7°	Payload structures.

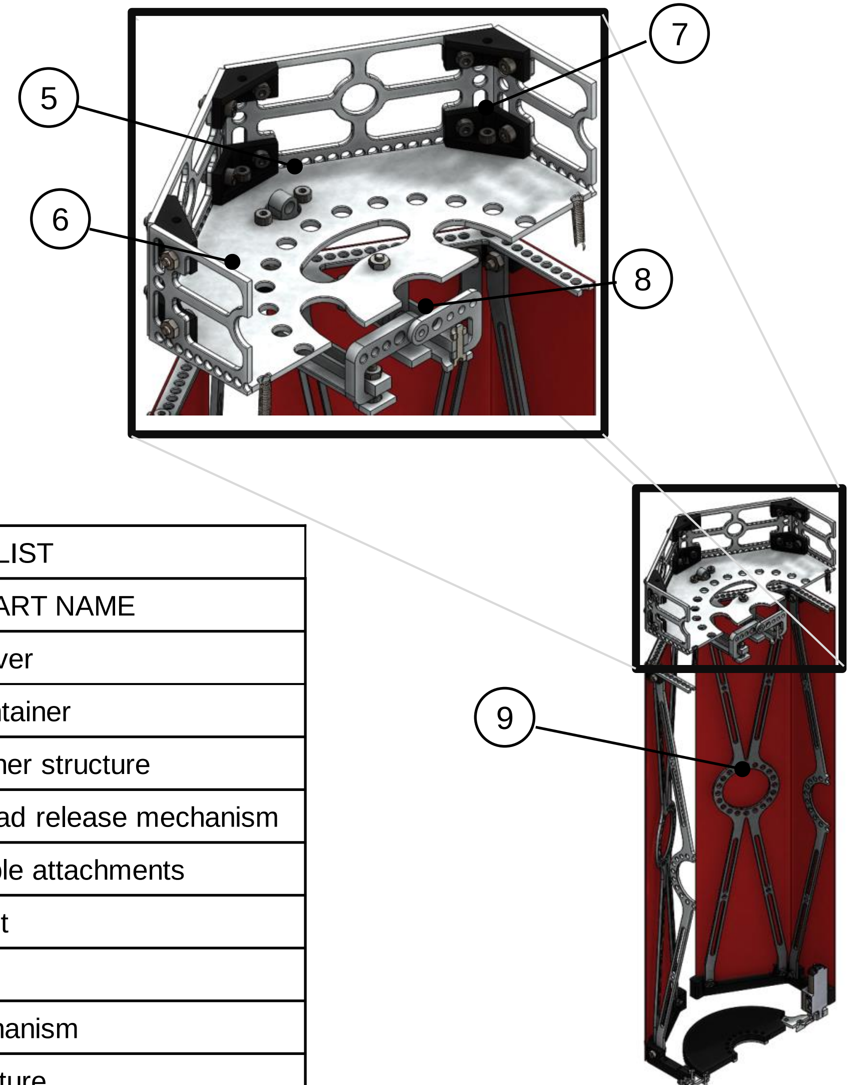
The other parts of payload are made with aluminum and 3D printing. This will depend on the resistance that this piece needs to have.



*Unnotched Izod [kJ/m^2]
**Charpy impact test [J]
° [USD/Kg]

Container Mechanical Layout of Components





PARTS LIST	
ITEM	PART NAME
1	Hexagonal cover
2	Parachute container
3	Bottom container structure
4	Science payload release mechanism
5	Parachute cable attachments
6	Lateral support
7	Top joint
8	Opening mechanism
9	Principal structure

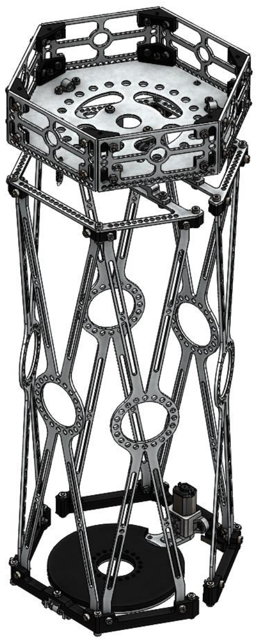
Container Mechanical Layout of Components

Material selection						
Material	**Density ρ** $[g/cm^3]$	**Young's Modulus** E [GPa]	**Melting (softening) temperature** [°C]	**Impact Strength**	**Cost** [USD/Kg]	**Components made of this material**
ABS	1.03 – 1.08	1.1-2.9	85	10.5*	26	-
PLA	1.25	3.5	65	5.1*	31	-
Aluminum	2.70	68	660 - 680	10**	7	Container and payload structures.

The Aluminium was selected to container and Science payload structure, because it is a material that has greater Young's Modulus and at high temperatures with respect to the other two materials.

To reduce the mass of the parts that make up the structure of the container can be emptied so that the safety factor greater than the unit is preserved.

In addition, the 6061-T6 alloy has excellent machinability



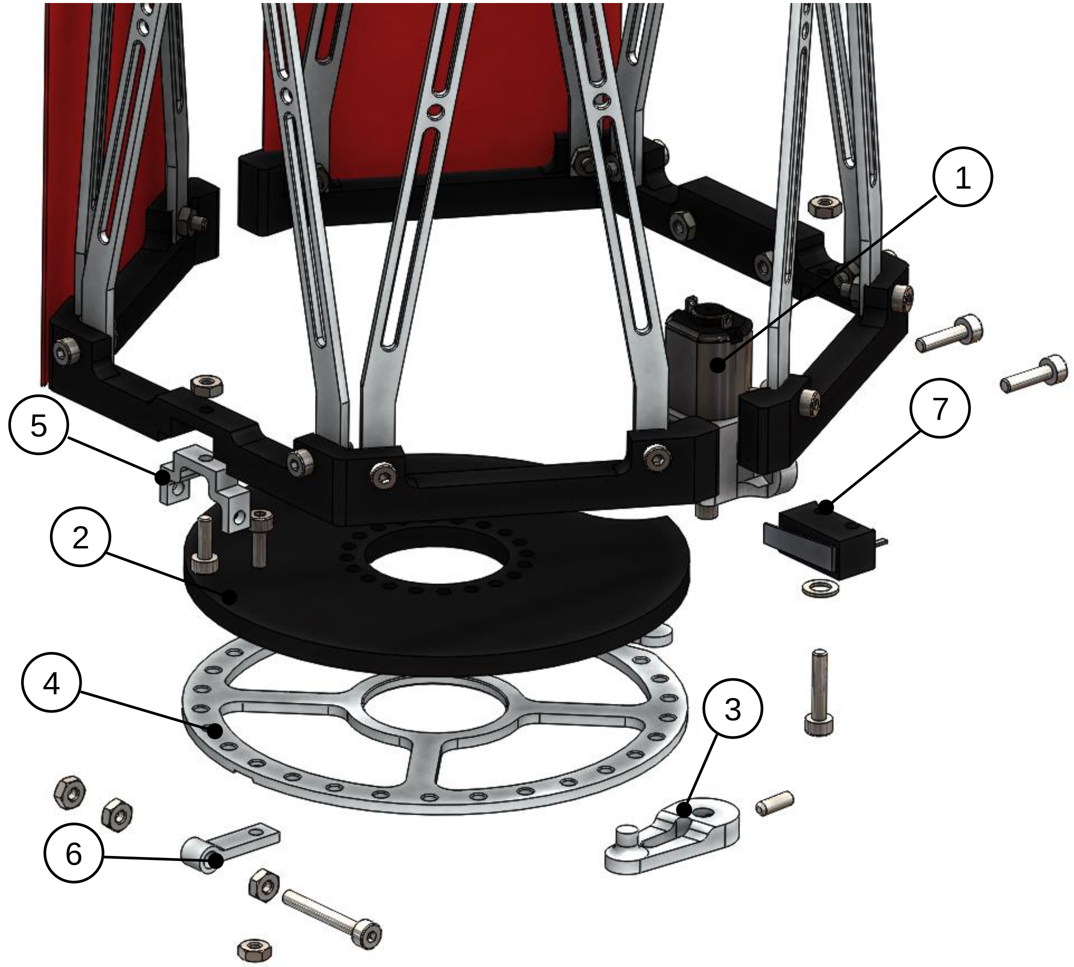
*Unnotched Izod [kJ/m^2]
**Charpy impact test [J]

Payload Release Mechanism (1/3)

Components of the payload release mechanism

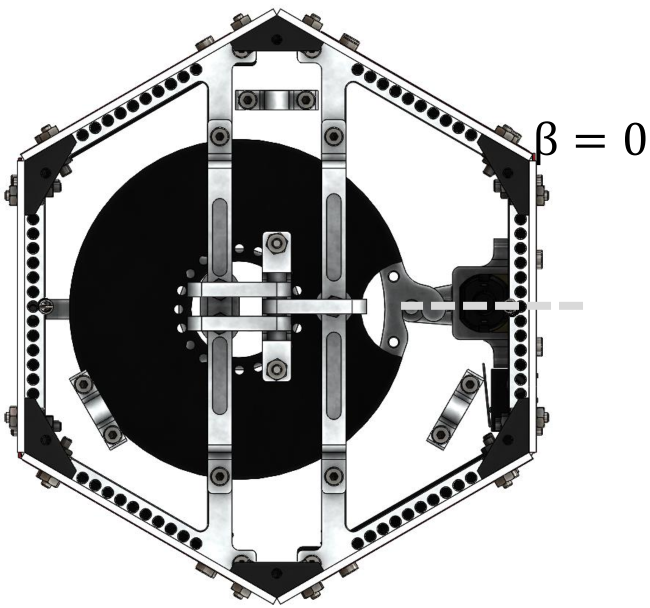
As non - permanent fasteners, which were used for the design of the payload release system were the screws DIN 912, M2X0.4x6, M2X0.4X8, with their respective nut.

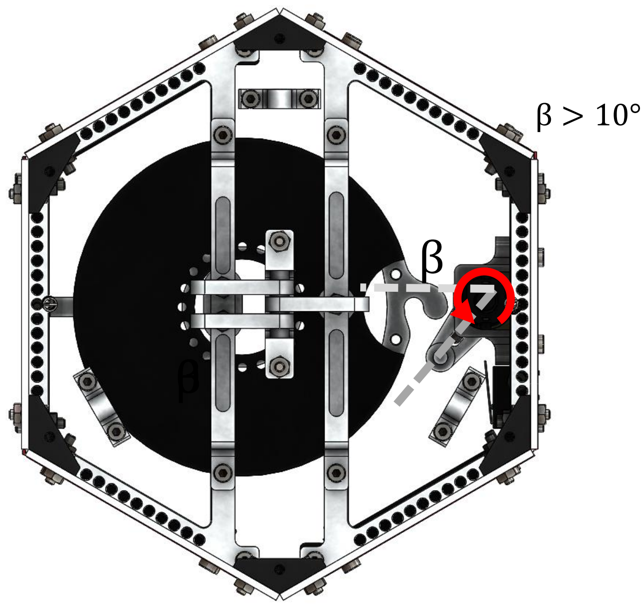
PARTS LIST	
ITEM	PART NAME
1	Micro gear motor
2	Bottom top holder
3	Release hook
4	Bottom top structure
5	Structural joint
6	Rotation base
7	Limit switch

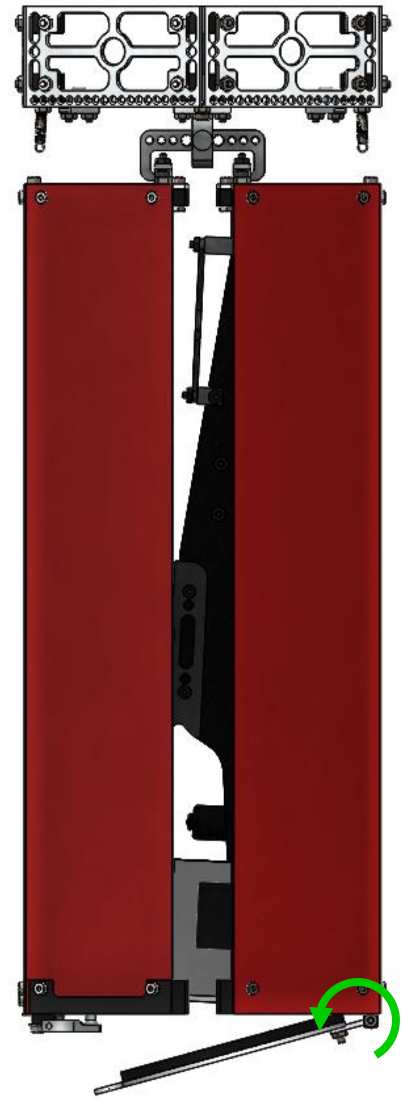


Payload Release Mechanism (2/3)

Steps to deploying of the Science payload (1/2)







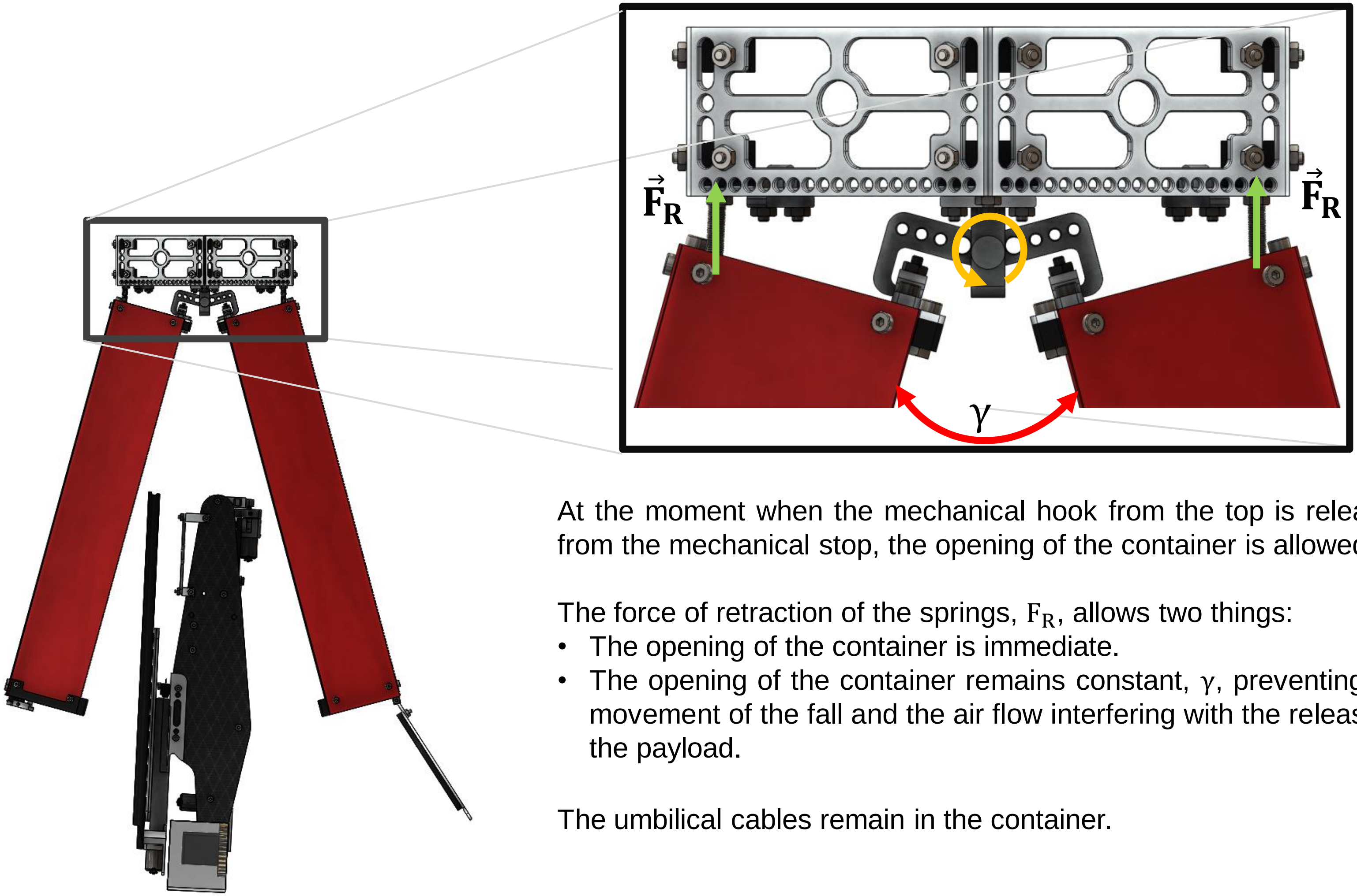
During the rise of the rocket, and during the fall of the CanSat, up to a height of 450 [m], the motor shaft does not rotate, which allows the lid not to rotate, and therefore, the science payload is kept inside the container.

All electronic devices are controlled by the payload, by means of umbilical cables.

When the CanSat reaches a height of 450 [m], in the descent, the payload must be released. When the direct current motor is activated, it starts to rotate, so that its angular displacement, β, allows the cover to rotate freely on its own axis.

The motor will rotate until the limit switch is activated, allowing the motor to stop.

Steps to deploying of the Science payload (2/2)



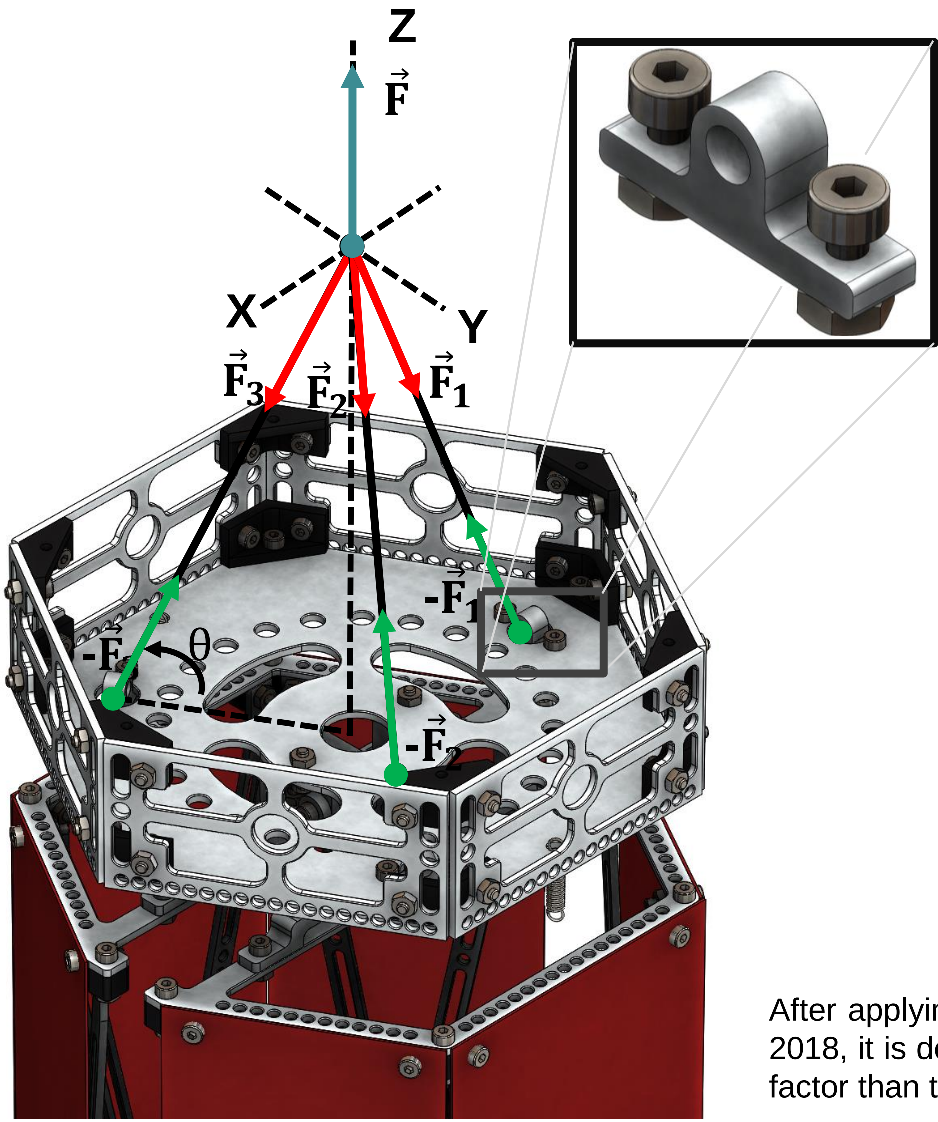
At the moment when the mechanical hook from the top is released from the mechanical stop, the opening of the container is allowed.

The force of retraction of the springs, F_R, allows two things:

- The opening of the container is immediate.
- The opening of the container remains constant, γ, preventing the movement of the fall and the air flow interfering with the release of the payload.

The umbilical cables remain in the container.

Container Parachute Attachment Mechanism (1/2)

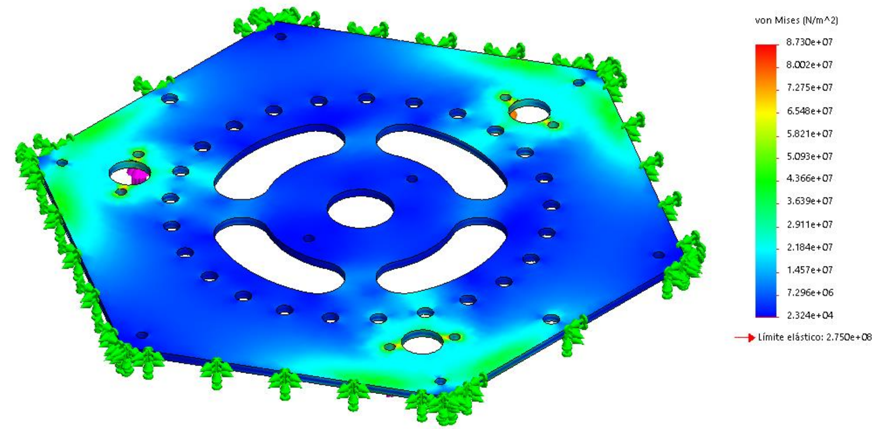


Parachute Attachment Points

Assuming that the system is in equilibrium, it has the following system of linear equations:

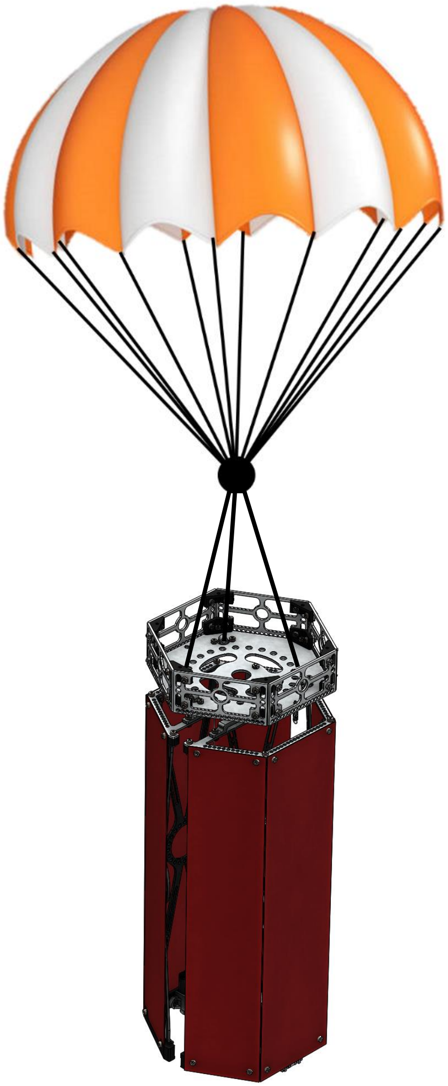
$$\begin{bmatrix} \cos(\theta) & -\cos(\theta)\cos\left(\frac{\pi}{3}\right) & -\cos(\theta)\cos\left(\frac{\pi}{3}\right) \\ 0 & \cos(\theta)\sin\left(\frac{\pi}{3}\right) & -\cos(\theta)\sin\left(\frac{\pi}{3}\right) \\ -\sin(\theta) & -\sin(\theta) & -\sin(\theta) \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ F \end{bmatrix}$$

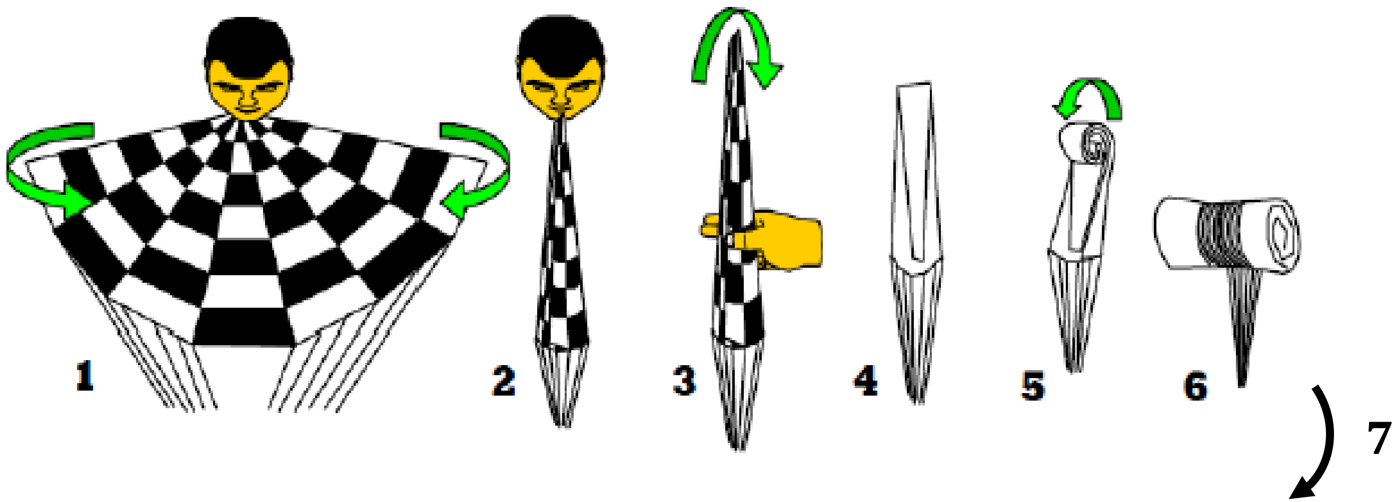
Considering the 30 G impact at the time the parachute is deployed and an angle $\theta = 70$, it's determined that F_1, F_2, F_3 = 104.39 [N].



After applying a finite element analysis to the binding points, in SolidWorks 2018, it is determined that the main base of the CanSat has a greater safety factor than the unit at the time the parachute is deployed.

Container Parachute Attachment Mechanism (2/2)





Parachute Storage Procedure

1.Fold the parachute in half.
2.Fold along the radius to form a triangular area.
3.Fold the triangular area in half.
4.Meet base and tip of parachute.
5.Roll up the parachute.
6.Roll up strings.
7.Place the parachute in the container. This step is not represented graphically, however it is important to verify that there are no components that can damage or prevent the free expulsion of the parachute during the mission.

Electronics Structural Integrity (1/2)

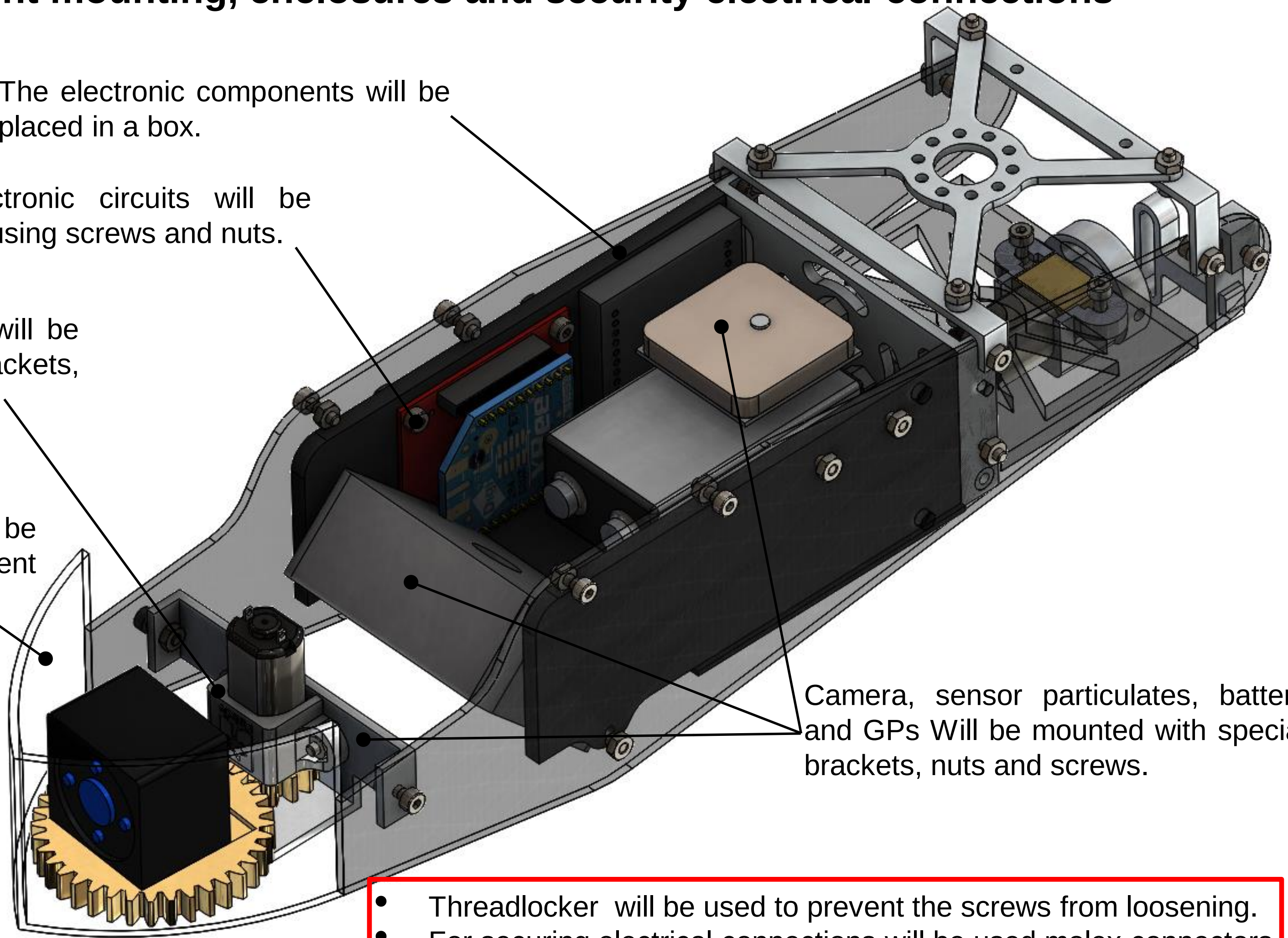
Electronic component mounting, enclosures and security electrical connections

The electronic components will be placed in a box.

All electronic circuits will be placed using screws and nuts.

All micro Gearmotors will be placed using plastic brackets, nuts and screws.

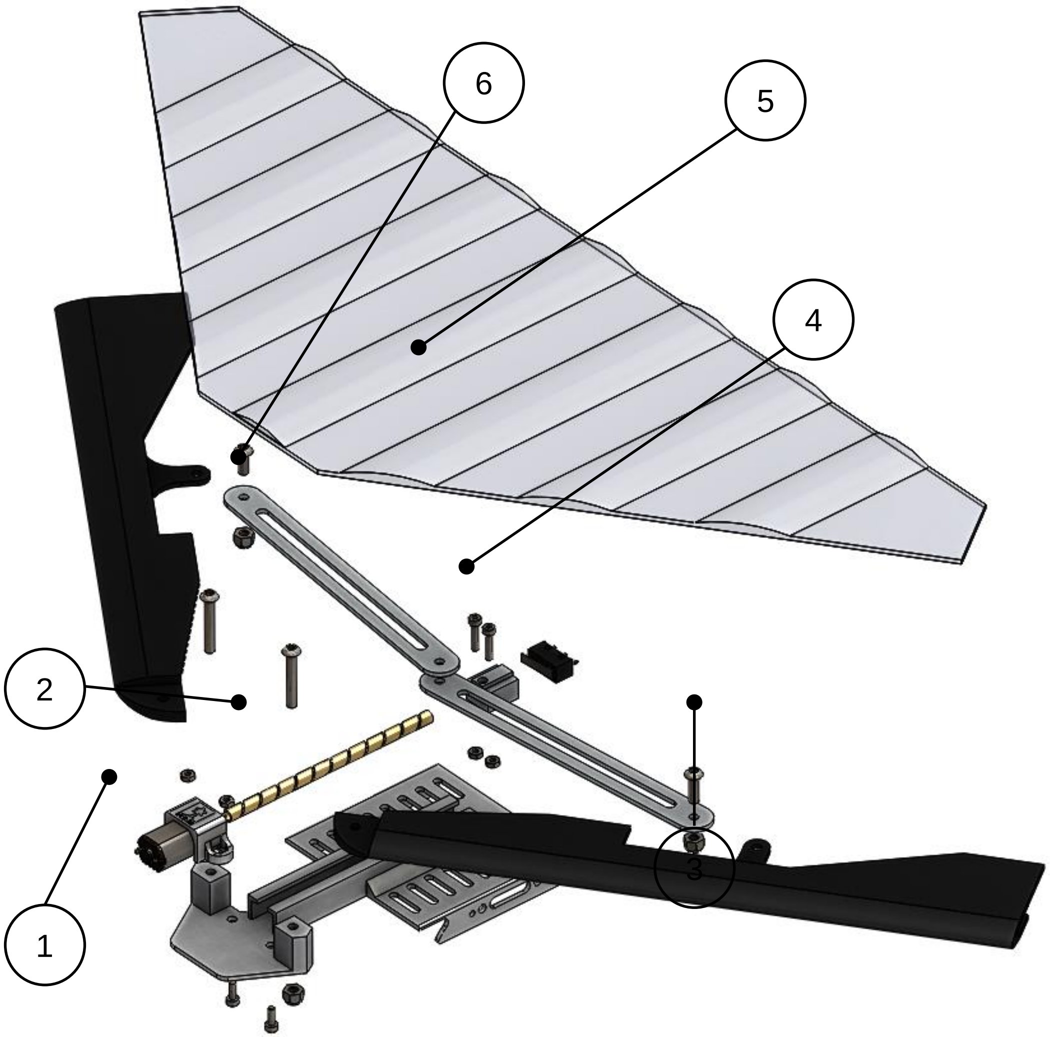
The camera will be protected by a transparent cover.



Camera, sensor particulates, battery and GPs Will be mounted with special brackets, nuts and screws.

- Threadlocker will be used to prevent the screws from loosening.
- For securing electrical connections will be used molex connectors.

Descent control attachments



Wings deployment mechanism

PARTS LIST	
ITEM	PART NAME
1	Micro gear motor
2	Threaded rod
3	Wing profile
4	Limit switch
5	Nylon ripstop
6	Folding link

Mass Budget (1/4)

Main Part	Subsystem	Component	Mass [g]	Source
Container	Mechanical Subsystem	Main base	31.482	Software Estimate
Container	Mechanical Subsystem	Lateral support	21.222	Software Estimate
Container	Mechanical Subsystem	Parachute cable attachments	1.620	Software Estimate
Container	Mechanical Subsystem	Rotation support	1.890	Software Estimate
Container	Mechanical Subsystem	Main shaft	0.702	Software Estimate
Container	Mechanical Subsystem	Clamps	3.159	Software Estimate
Container	Mechanical Subsystem	Top container	9.558	Software Estimate
Container	Mechanical Subsystem	Top joint	4.644	Software Estimate
Container	Mechanical Subsystem	Principal structure	46.923	Software Estimate
Container	Mechanical Subsystem	Hexagonal cover	36.054	Software Estimate
Container	Mechanical Subsystem	Bottom container structure	4.712	Software Estimate
Container	Mechanical Subsystem	Container joints	9.353	Software Estimate
Container	Mechanical Subsystem	Parachute	15.00	Software Estimate
Container	Science payload release mechanism	Bottom top structure	3.861	Software Estimate
Container	Science payload release mechanism	Bottom top holder	5.932	Software Estimate
Container	Science payload release mechanism	Micro gear motor with bracket	10.00	Software Estimate
Container	Science payload release mechanism	Release hook	1.134	Software Estimate
Container	Science payload release mechanism	Limit switch	2.500	Software Estimate
Container	Science payload release mechanism	Release joints	1.999	Software Estimate
Container	Science payload release mechanism	Springs	0.480	Software Estimate
Container	Science payload release mechanism	Base of rotation	0.432	Software Estimate
Container	Science payload release mechanism	Structural joint	0.243	Software Estimate

Mass Budget (2/4)

Main Part	Subsystem	Component	Mass [g]	Source
Science payload	Descent registration mechanism	Micro gear motor with bracket	10.00	Seller
		Camera fasteners	8.00	Software Estimate
		Camera	8.00	Seller
		Transmission gears	3.00	Seller
	Wings deployment mechanism	Folding Links	8.154	Software Estimate
		Lift structure	56.482	Software Estimate
		Spindle and nut mechanism	5.000	Software Estimate
		Nose	6.113	Software Estimate
		Cloth	25.00	Team Estimation
		Limit switch	2.50	Seller
	Parachute deployment mechanism	Scottish yoke mechanism	4.131	Software Estimate
		Micro gear motor with bracket	10.00	Seller
		Hinge shaft	1.431	Software Estimate
		Parachute support structure	8.073	Software Estimate
		Top payload structure	2.322	Software Estimate
		Support elements	3.456	Software Estimate
		Mechanical insurance	0.864	Software Estimate
		Rotation element	0.378	Software Estimate
		Payload top	3.046	Software Estimate
		Parachute	15.00	Team Estimation

Mass Budget (3/4)

Main Part	Subsystem	Component	Mass [g]	Source
Science payload	Electronic	Electronic container	16.297	Software Estimate
		Battery	33.00	Datasheet
		Taoglas antenna	1.20	Datasheet
		Xbee	10.00	Datasheet
		Particle sensor	20.00	Datasheet
		GPS	10.00	Datasheet
		Printed Circuit Board*	10.00	Software Estimate
		Microcontroller	0.342	Datasheet
		Pitot tube	8.00	Datasheet
	Structural system	Frame	31.872	Software Estimate

Uncertainties

- The values obtained in the design mass were calculated using the volume of the geometry and the density of the material, which allows obtaining almost exact information, however, the values may vary slightly, for example, the density of aluminum varies between 2.69 $[\mathrm{g} \cdot \mathrm{cm}^{-3}]$ - 2.70 $[\mathrm{g} \cdot \mathrm{cm}^{-3}]$, and depends on the supplier, however the variation in the mass does not increase considerably when using one or the other value.
- In the case of 3D printing, due to the fact that it is a method by material deposition, air bubbles are produced that cannot be avoided, however due to tests made with the filament of our supplier, the mass estimates, with the same method of volume and density, they vary 0.5 [g].
- On the other hand, with the bolts and nuts, the mass is almost equal to the real and estimates by software. Using a scale, the mass of 10 screws has been measured, and this data has been compared with software values and the variation is 0.2 [g].

*Considering the mass, together, of the printed circuits made to carry out the mission.

Mass Budget (4/4)

The different systems that comprise the CanSat have parts that are attached by means of non-permanent fasteners, so that the mass of the screws DIN 912, nuts and prisoners was estimated by means of the software. The masses are 70.48 [g].

Total mass of Container	212.900 [g]
Total mass of Payload	321.661[g]

The 3D printed parts were assumed to have a 50 % or less of infill. An ABS density of 1.19 $[\mathrm{g} \cdot \mathrm{cm}^{-3}]$ was used for these calculations.

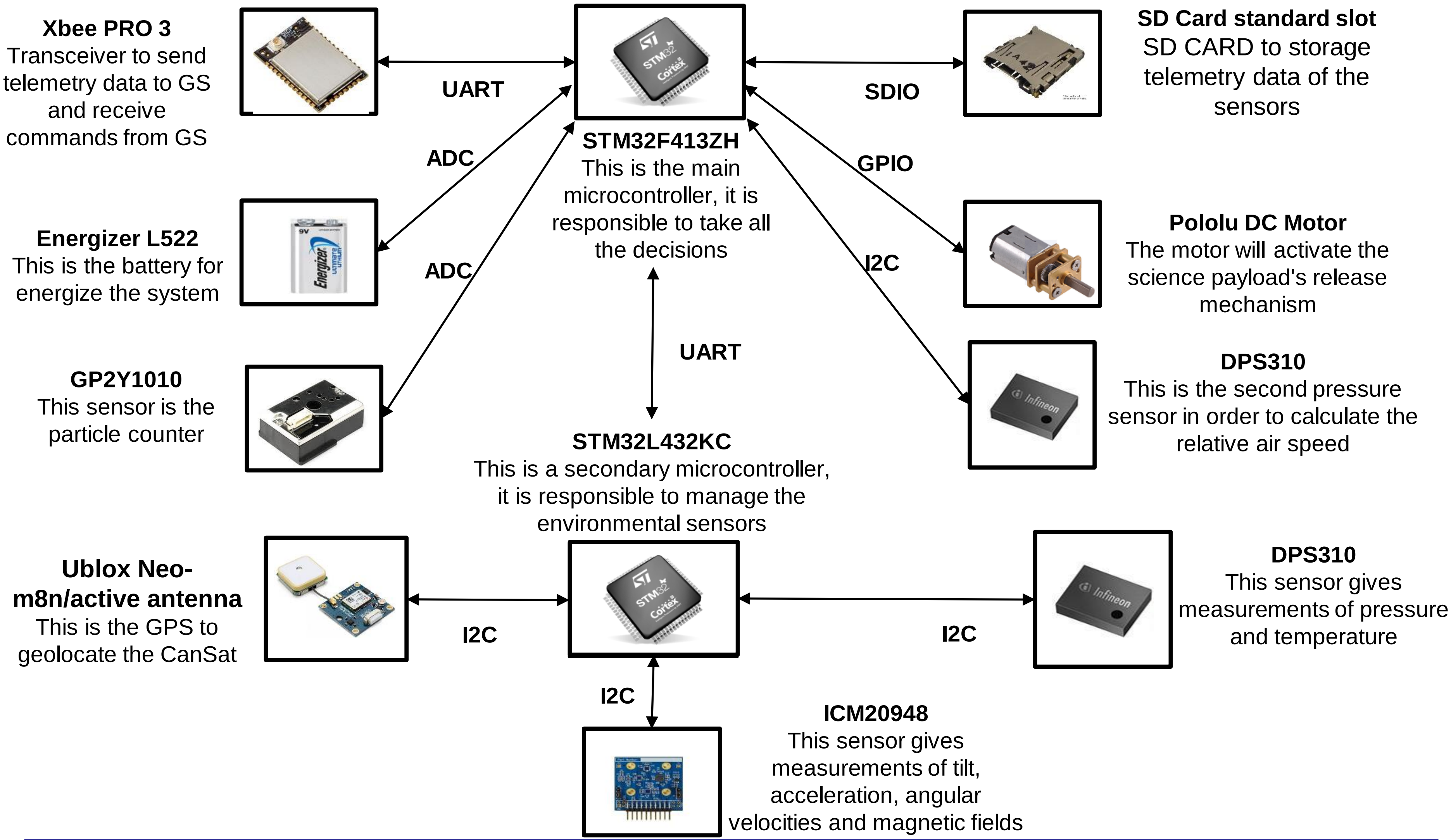
The total mass of the CanSat, considering the non-permanent fasteners (70.48 [g]).

Total mass of CanSat	605.041 [g]
Clearance	4.959 [g]

Communication and Data Handling (CDH) Subsystem Design

Rodolfo Vera-Amaro

CDH Overview



CDH Changes Since PDR

PDR	CDR	Rationale
Data packet example	It is changed the format of the data packet	The ‘<,>‘ characters are not necessary.
STM32F446RE microcontroller was selected	STM32F413ZH microcontroller is being used.	Due its size and characteristics. It fits better to the requirements.

CDH Requirements(1/2)

# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
CS01	The science payload shall measure altitude using an air pressure sensor.	Competition Requirement	HIGH	SR22	•			•
CS02	The science payload shall provide position using GPS.	Competition Requirement	HIGH	SR23	•			•
CS03	The science payload shall measure its battery voltage	Competition Requirement	HIGH	SR24	•			•
CS04	The science payload shall measure outside temperature	Competition Requirement	HIGH	SR25	•			•
CS05	The science payload shall measure particulates in the air as it glides.	Competition Requirement	HIGH	SR26	•			•
CS06	The science payload shall measure air speed.	Competition Requirement	HIGH	SR27	•			•
CS07	Telemetry shall be updated once per second.	Competition Requirement	HIGH	SR29	•			•

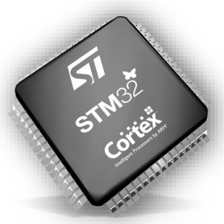
CDH Requirements(2/2)

CS08	The science payload shall transmit all sensor data in the telemetry	Competition Requirement	HIGH	SR28				●
CS09	The ground system shall command the science vehicle to start transmitting telemetry prior to launch	Competition Requirement	HIGH	SR31		●		●
CS10	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	HIGH	SR33				●
CS11	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed	Competition Requirement	HIGH	SR35			●	●
CS12	XBEE radios shall have their NETID/PANID set to their team number.	Competition Requirement	HIGH	SR36				●
CS13	XBEE radios shall not use broadcast mode	Competition Requirement	HIGH	SR37				●

Payload Processor & Memory Selection

Model	Criteria							
	Supply Voltage [V]	Supply Current [mA]	SRAM [KB]	Flash [KB]	Boot Time [ms]	Maximum Operation Speed	Communication Ports	Price [$]
STM32L432KC	1.65 to 3.6	6	64	256	1 (typ.)	80 MHZ	SPIx2, I2Cx2, USARTx4	8.42
STM32F413ZH	1.65 to 3.6	83	320	1500	1 (typ.)	100 MHz	SPIx4, I2Cx4, USARTx10	15

- **STM32L432KC (sensor subsystem) and STM32F413ZH (flight software)**



- The number of communication ports allows us to connect all the sensors required.
- It has a lot of memory and greater velocity, that allows a better performance according with calculations.
- It has low energy consumption, that allows to the payload battery a larger duration.

Payload Real-Time Clock

NEO-M8N						
Supply Voltage [V]	Current at Measurement [mA]	Channels	Maximum Temperature [°C]	Maximum Update [Hz]	Resolution [S]	Interface
1.65-3.6	67	72	85	10	0.01	UART

CONSTANT COMMUNICATION

GPS MODULE

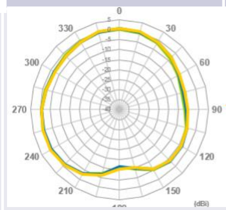
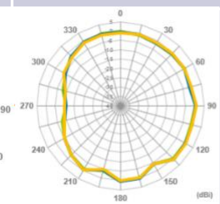
Main microcontroller will acquire constantly time through its communication with the GPS.

Since CanSat incorporates a GPS module, it could be used to maintain the time count, however, the count will depend entirely on GPS satellite fixing.

GPS module can provide a constant time count, due a constant triangulation with the satellites. The time count does not depend on the energy of the system.

- The NMEA GGA sentence contains the UTC time as the second parameter, just after ID, and since this clock doesn't depends on our electronics, the time will be maintained even after an unexpected reset.
- The time format will be received in a decimal format, as follows: HHMMSS.ss
- Where **HH is the hour, MM the minutes, SS the seconds and ss the fraction of second**

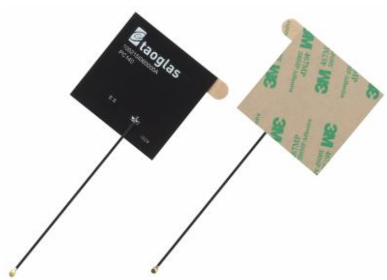
Payload Antenna Selection

Model	Frequency	Directivity	Radiation Pattern		Gain	Range *	Connector	Polarization	Price
			H-Plane	V-Plane					
PC140.07.0100A	2.4Ghz	Omnidirectional			2dBi	~1300 m	UF.L	Circular RHCP	20 USD

The selected antenna is the PC140.07.0100A.

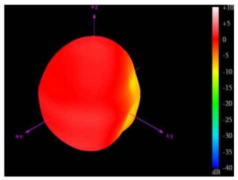
Dimensions: **57*57*0.97mm**

Weight: (**5.7g**).



Performance:

Accordingly to the Xbee manufacturer with 2dBi's antenna gain, the range can reach up to **1300m**

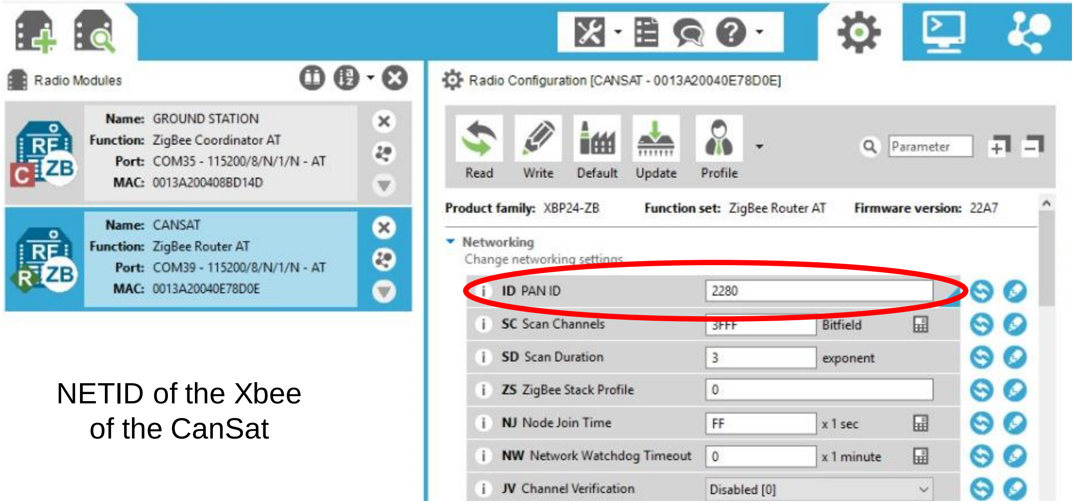

2450MHz

*Range is considering an Xbee pro 3, as transceiver with boost mode enabled (power out=19dBm) and line of sight. For Xbee Pro 2 is up to 1100Km.

Payload Radio Configuration

- The Xbee selected for the payload radio (PR) is the Xbee Pro 3 micro (with UF.L connector and Micro-Mount). **BUT WE USE THE XBEE PRO 2.0 IN OUR FIELD TESTS BECAUSE WE COULD'T USE OUR NEW ARRIVED XBEE PRO 3.0 DUE TO THE LOCKDOWN, but the only difference is that we expected longer range and smaller dimensions.**
- This Xbee will take the role as the payload radio will be the endpoint; the Xbee in the ground station (GS) will take the coordinator role.
- Both Xbees will communicate in unicast mode, **NOT** in broadcast mode.
- The **NETID/PANID** chosen is the team number: **2280**

Xbee Pro 3 2.4GHz, UF.L,MMT



NETID of the Xbee of the CanSat

- **Transmission control**
  - Calibration command: Before the launch, the coordinator (GS) will send a command to the endpoint (PR) to calibrate the telemetry data.
  - Launch and flight: At the launch and flight phases, the PR will be sending the telemetry data in burst of packets at 1Hz or less and it will be displayed in real time in the interface and stored in the SD memory card simultaneously.
  - Landing: In this phase after, the payload has landed, the telemetry data will stop sending from the PR to the GS and the GS will finish the mission, saving and creating the csv file which contains all the telemetry data received.

Payload Telemetry Format

Field	# of bytes	Format	Example	Definition
TEAM_ID	4	tttt	4784	Team number
MISSION TIME	4	mmmm	0022	Mission timing
PACKET COUNT	4	cccc	0022	Indicates packet´s ID that we sent
ALTITUDE	6	hhhh.h	2200.1	Sensor scan about the altitude [m]
PRESSURE	5	ppp.p	101.3	Sensor scan about the pressure [kPa]
TEMPERATURE	4	ee.e	27.3	Air temperature [°C]
VOLTAGE	3	v.v	3.5	Circuit´s voltage [V]
GPS TIME	9	dddddd.dd	030742.00	UTC time; since the test location is Eastern eight zones, the actual time 03+8=11(hour):07(minute):42(second)
GPS LATITUDE	11	bbbbb.bbbbb	02232.73830	Is the latitude generated by the GPS receiver.
GPS LONGITUDE	11	aaaaa.aaaaa	11404.58520	Is the longitude generated by the GPS receiver.
GPS ALTITUDE	8	xxxxx.xx	32908.09	Is the altitude generated by the GPS receiver.
GPS SATS	2	kk	12	Is the number of GPS satellites

Payload Telemetry Format (2/2)

Field	# of bytes	Format	Example	Definition
AIR SPEED	6	sss.ss	103.20	Calculated relative air speed [m/s]
SOFTWARE STATE	1	a	1	It indicates the corresponding number of the current state
PARTICLE COUNT	5	pp.pp	1.52	It indicates the dust density [mg/m3]

- Data format:

<TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>,<PRESSURE>,<TEMP>,<VOLTAGE>,<GPS TIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<AIR SPEED>,<SOFTWARE STATE>, <PARTICLE COUNT>

- Example of data packet:

2280,0022,002,2200.1,101.3,27,3.5,030742.00,02232.73830,11404.58520,32908.09,12,103.20,1,1.52

- Fields are separated by comma ','

- Data will be transmitted every second in burst transmission.

- The telemetry on the ground station will be saved as **FLIGHT_2280.csv**

- Example telemetry matches with competition guide requirements.

- Bonus Mission:

A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time

Since the container does not have electronics, it does not have to include a processor or a memory

Electrical Power Subsystem (EPS) Design

Jorge Hernández

EPS Overview

Battery
- It is used as power source of the components for at least two hours.

•P-Channel MOSFET
- Protect the circuit from a reverse polarity.

Switch
- Diverts and interrupts the current flow from battery to the electronic system.

Power Indicator
- Indicates if the system obtains energy.

Energy Distribution
- Guarantee that the other electronic will receive the correct voltage and current levels for the entire time of mission.

Microcontrollers
- Controller on which the code resides to interface of the rest of the components.

Sensors
- Used to collect information regarding the temperature, air pressure, and others.

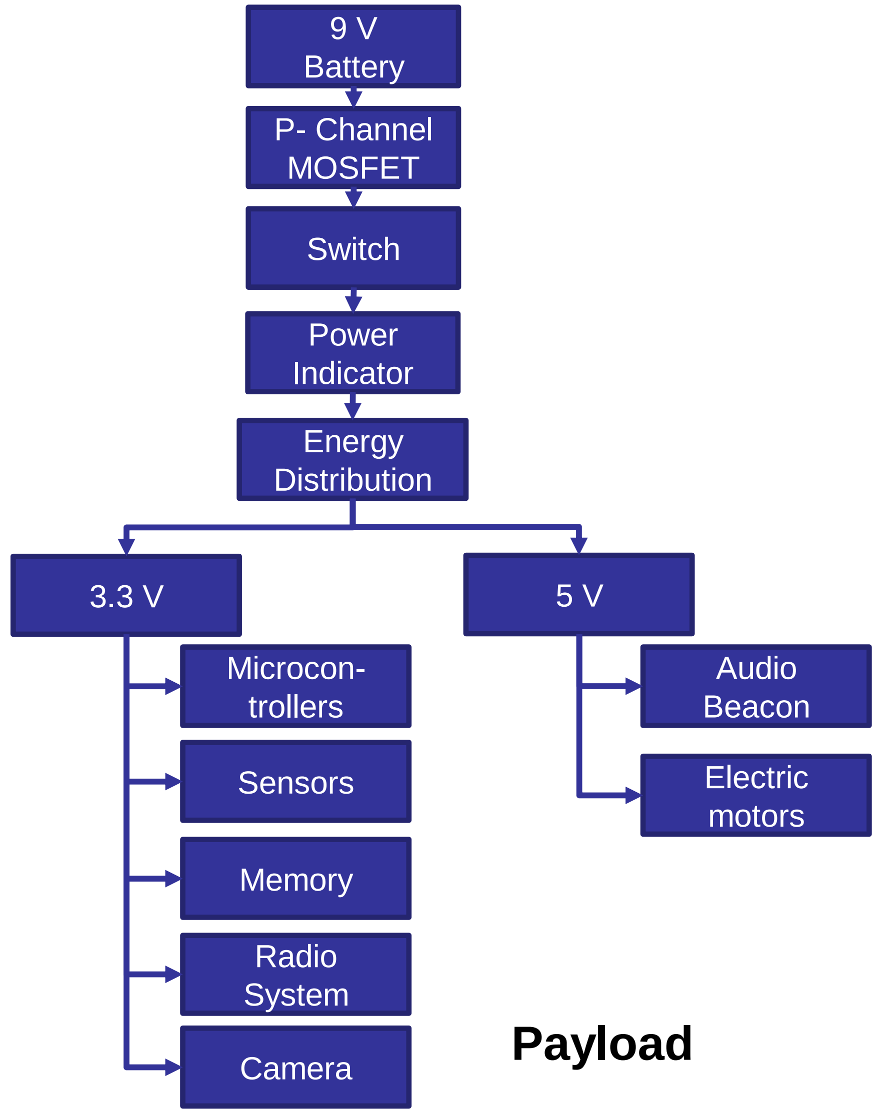
Camera
- Records a video in a point toward the coordinates provided for the duration of the glide time.

Memory
- Collects the data obtained during flight.

Radio
- Allows communication between the CanSat and the ground station.

•Audio Beacon
- It allows to find the scientific vehicle easily at the end of the mission

•Electric Motors
- They are responsible for activating the decoupling mechanisms.



EPS Changes Since PDR

Recalculation of payload power budged because of changed of some components.

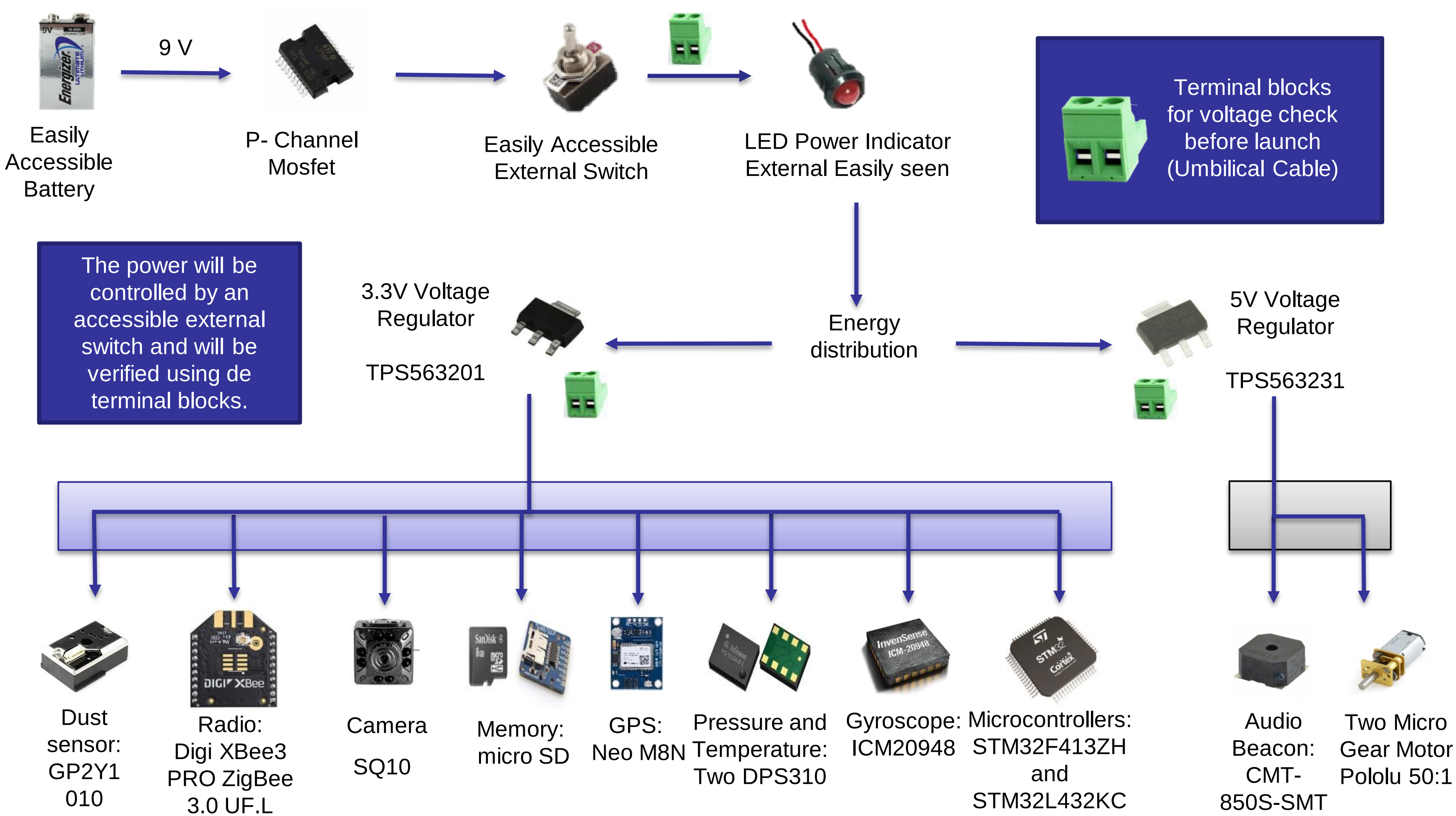
EPS Requirements (1/2)

# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
EPS 01	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Competition Requirement	HIGH	SR15			●	
EPS 02	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Competition Requirement	MEDIUM	SR18			●	
EPS 03	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	Competition Requirement	LOW	SR49			●	
EPS 04	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	MEDIUM	SR50			●	
EPS 05	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 Requirement	HIGH	SR53	●			

EPS Requirements (2/2)

# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
EPS 06	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	MEDIUM	SR54			●	
EPS 07	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Competition requirement	HIGH	SR55				●
EPS 08	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Competition requirement	HIGH	SR57	●	●		

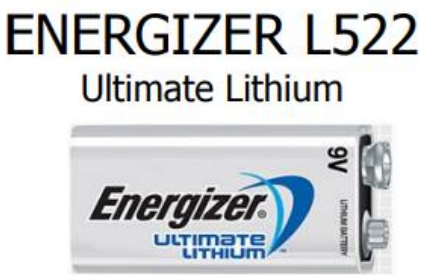
Payload Electrical Block Diagram



Payload Power Source

-Sufficient current rating.
-One battery can power all electronic components for at least two hours.
-Long-lasting charge.
-In the competition of 2018 the same battery was used and everything worked correctly.

Nominal Voltage	9.0 V
How much current battery can generate	1500 mA
Current capacity	750 mAh
Weight	33.9 g
Operating temperature discharge	-40-60 ° C



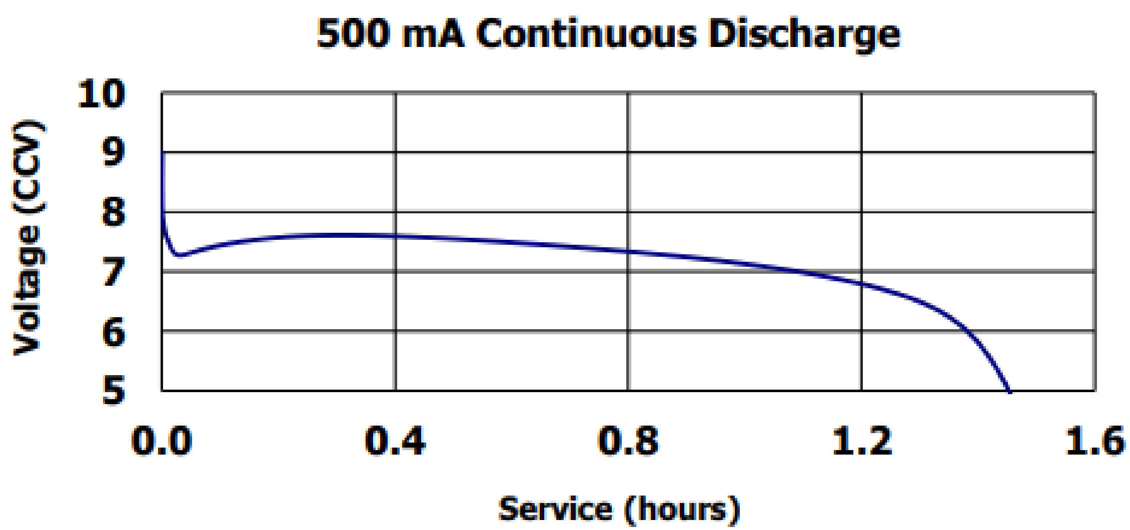


Figure 6.3. Discharge curve [Datasheet]

Payload Power Budget

Component	Qua ntity	Model	Current [mAh]	Voltage [V]	Power [mWh]	Duty cycle [%]	Source
Gyroscope	1	ICM20948	3.7	3.3	12.21	100	Datasheet
Microcontroller	1	STM32L432KC	100	3.3	330	100	Datasheet
Microcontroller-	1	STM32F413ZH	35.5	3.3	117.15	100	Datasheet
Memory	1	SD Card	100	3.3	330	100	Datasheet
Air pressure and temperature sensor	2	DPS310	1	3.3	3.3	100	Datasheet
GPS	1	NEO-M8N	67	3.3	221.1	100	Datasheet
Electric Motor	2	Micro Gear Motor Pololu 50:1	360	5	360	10	Datasheet
Camera	1	Camera SQ10	120	3.3	396	100	Datasheet
Audio Beacon	1	CMT-8540S-SMT	150	5	150	20	Datasheet
Dust sensor	1	GP2Y1010	20	3.3	66	100	Datasheet
Reception	1	Ublox CAM 8	10	3.3	33	100	Datasheet
Radio System	1	Digi XBee3 PRO	205	3.3-5	795.5	100	Estimated

POWER SOURCE	BATTERY
Power Available	9 Wh
Total power consumed	2.81 Wh
Margin	30%= 3.65 Wh

The estimated power consumption of the CanSat is 3.65 Wh , so it could operate for at least 2 hours. [2.4 hours]

Container does not have electronics or power source in it.

Container Power Source

Container does not have electronics or power source in it.

Container Power Budget

Container does not have electronics or power source in it.

Flight Software (FSW) Design

Aldo Bonilla

FSW Overview (1/3)

Programming Tools

- STM32CubeIDE
- Mbed

Programming Languages

- C
- C++

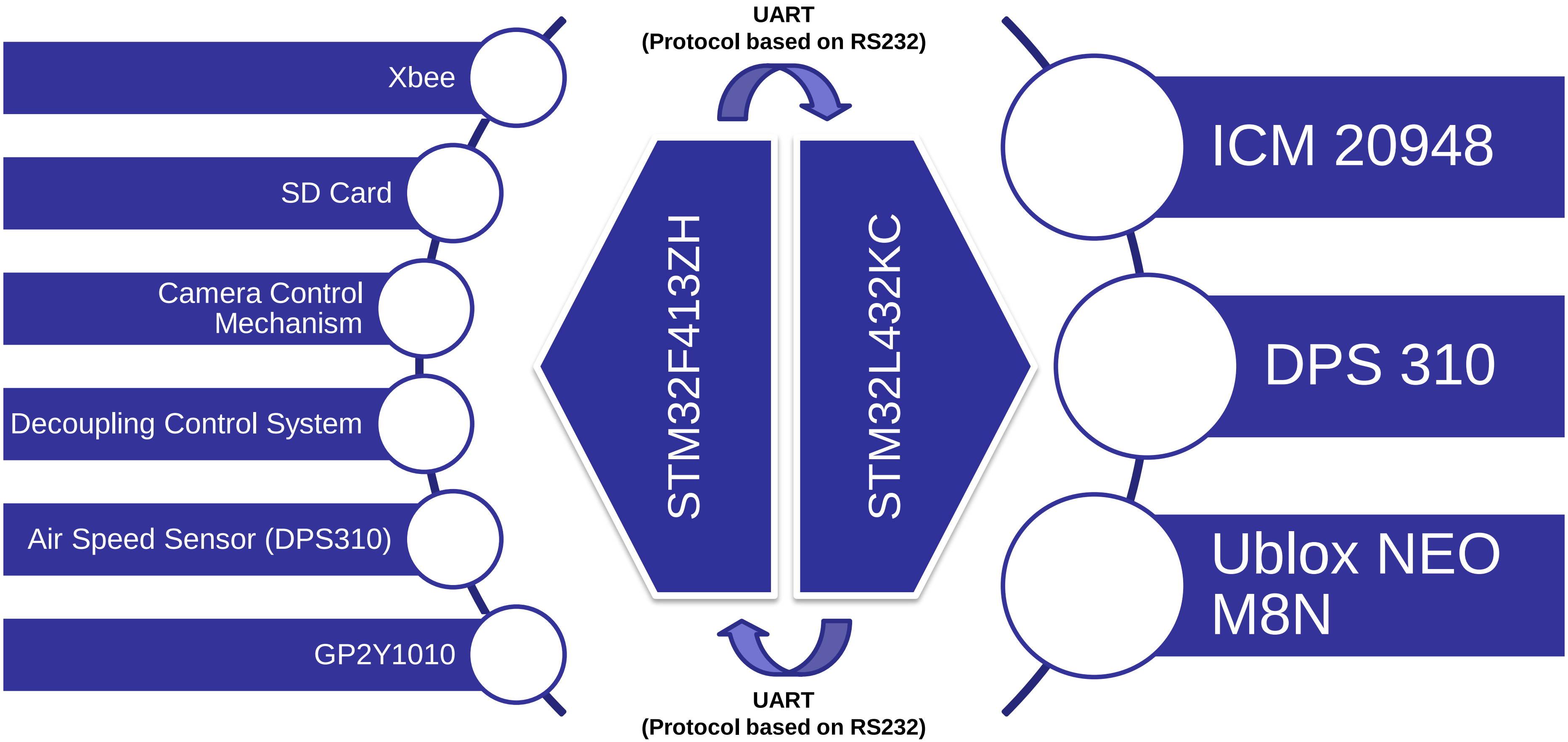
Programming Paradigms

- Procedural
- Imperative

Task Summary

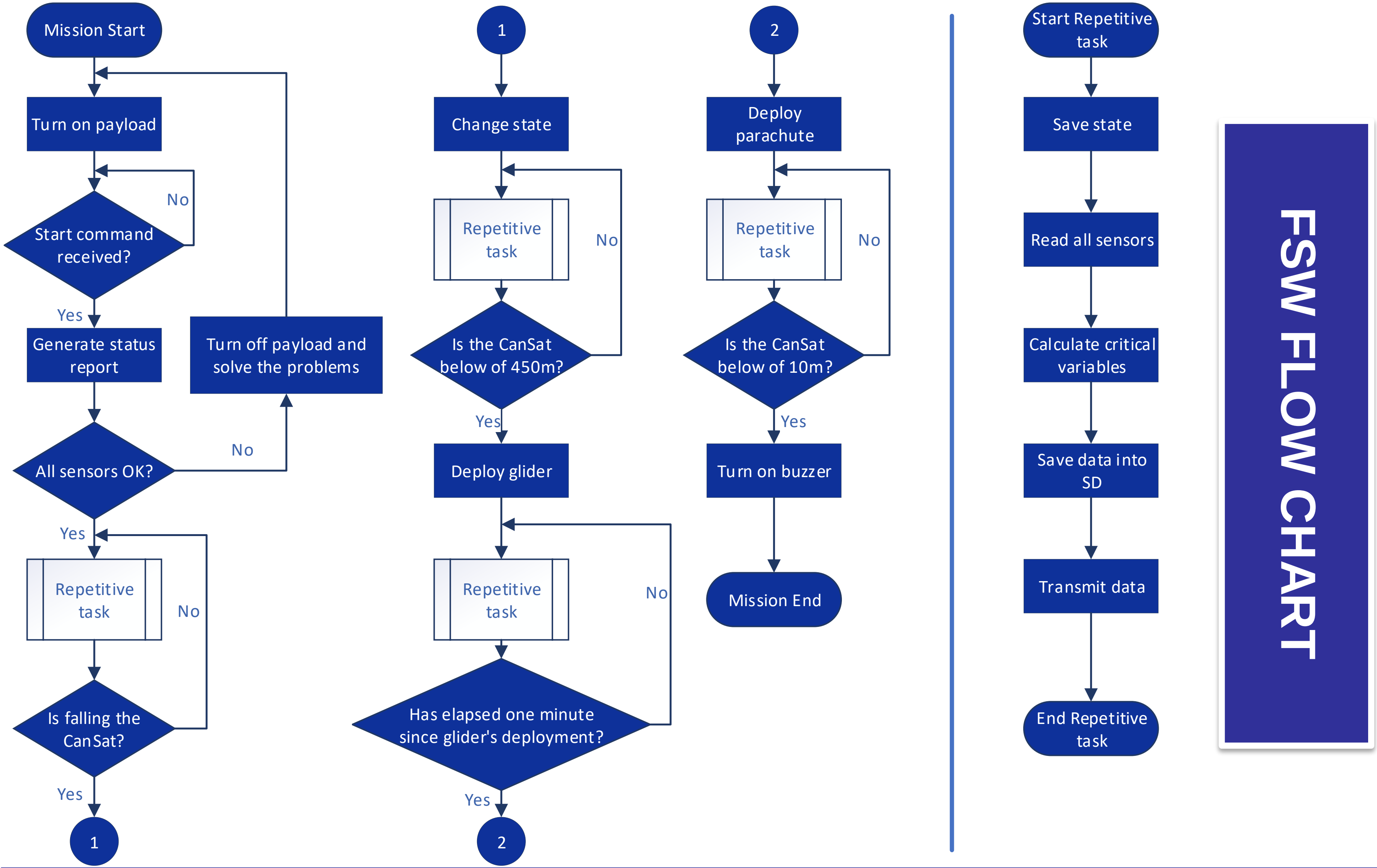
- Handle data from sensors module (transmit and store)
- Analyze acquired data for the control of the systems.
- Transmit all acquired data at 1Hz rate.
- Calculate air speed and particle density
- Control decoupling systems

FSW Overview (2/3)



FSW Architecture

FSW Overview (3/3)



FSW Changes Since PDR

No changes.

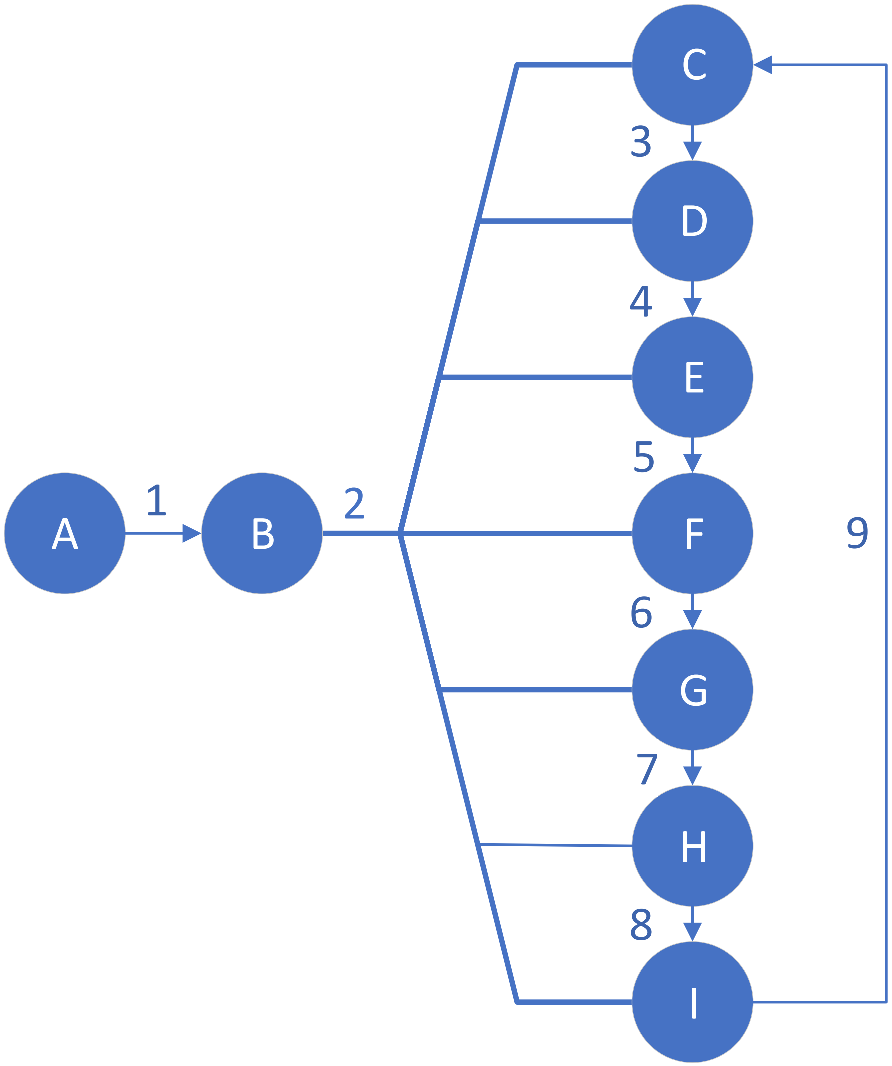
FSW Requirements (1/2)

# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
FSW01	The science payload must calculate the relative altitude constantly	To know its altitude for further calculations and decisions	VERY HIGH	SR10, SR11, SR22, SR29, SR51				●
FSW02	The science payload must differentiate between the ascent and descent	To work properly at the moment of taking decisions based on the altitude	HIGH	SR10, SR11, SR22, SR29, SR51				●
FSW03	The science payload must maintain the time count by means of an RTC or NMEA information	To update at time the telemetry and deploy parachute after one minute gliding in the air	VERY HIGH	SR11, SR13, SR29				●
FSW04	The science payload must be capable of parse the GGA NMEA message	To acquire GPS data correctly	HIGH	SR11, SR13, SR23				●
FSW05	The science payload must measure its battery voltage	Competition Requirement	HIGH	SR24				●
FSW06	The science payload must measure outside temperature	Competition Requirement	HIGH	SR25				●
FSW07	The science payload must measure particulates in the air as it glides.	Competition Requirement	HIGH	SR26				●
FSW08	The science payload must measure air speed.	Competition Requirement	HIGH	SR27				●

FSW Requirements (2/2)

# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
FSW09	The science payload must transmit all sensor data in the telemetry	Competition Requirement	VERY HIGH	SR28				●
FSW10	Telemetry must be updated once per second	Competition Requirement	HIGH	SR29				●
FSW11	The science payload must must incorporate a list of commands for multiple tasks	To be capable of do tasks individually, including starting transmission	VERY HIGH	SR31				●
FSW12	The science payload must store its current status in an non volatile memory, and restore at the beginning	To maintain its current configuration after resets	VERY HIGH	SR34, SR47				●
FSW13	The science payload must power on its buzzer at the landing stage	To save power during mission and find science payload after landing	MEDIUM	SR51				●

Payload FSW State Diagram (1/4)



- **State A:** Science payload has to initialize all sensors and peripherals
- **State B:** Science payload must determine which is the current state of the mission
- **State C**: Science payload is on land, the team has the CanSat yet.
- **State D**: Science payload is waiting for launch and it is inside the rocket. Transmission has begun.
- **State E**: Science payload is ascending.
- **State F**: Science payload was deployed from rocket and it is falling with parachute.
- **State G**: Science payload has been detached from container and it's gliding.
- **State H**: Science payload is falling with parachute.
- **State I**: Science payload is on land again.

Payload FSW State Diagram (2/4)

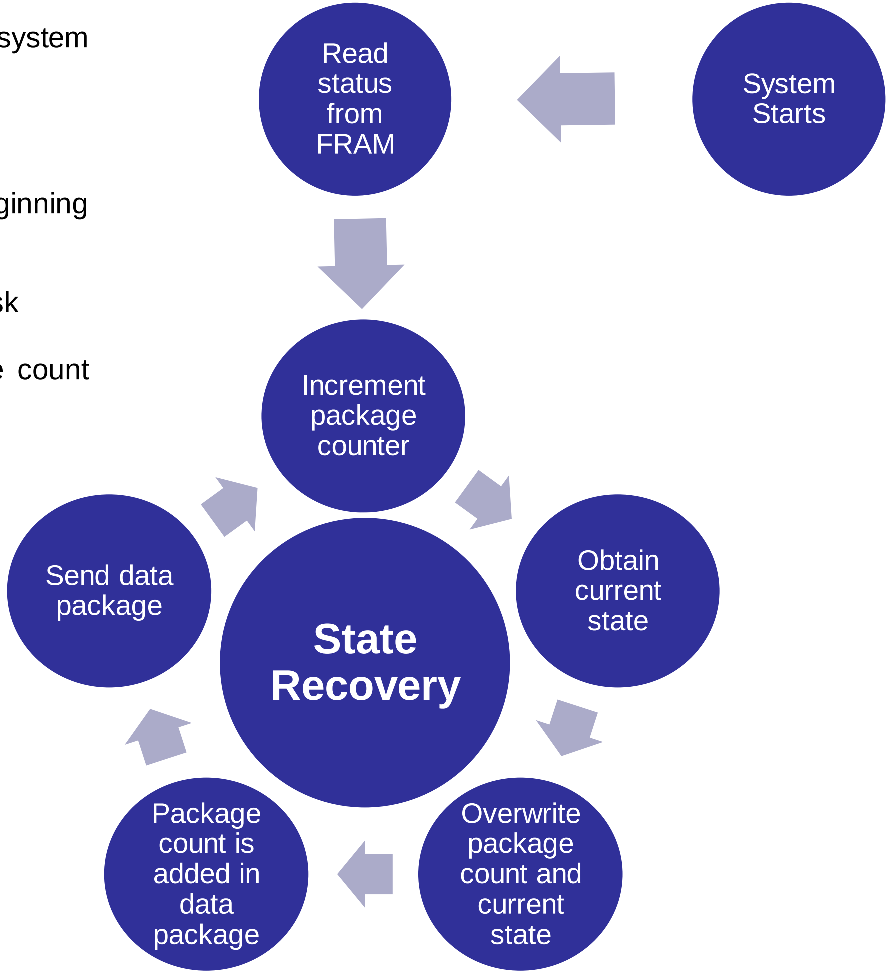
1. State will change after all sensors and peripherals have been initialized
2. State will change after the science payload determines which is the current state of the mission
3. State will change if all CanSat's systems are working properly
4. State will change after a positive altitude change
5. State will change if the CanSat detects a descent
6. State will change if probe is at an optimal altitude (around 450 m ± 1m)
7. State will change if one minute has elapsed since the science payload started gliding or if science payload is below 100 m
8. State will change if science payload is below 10 m
9. State will change after a hard reset (pressing reset button or sending a restart command)

Payload FSW State Diagram (3/4)

Sampling of Sensors	• Sensors module data will be acquired at minimum 1 Hz rate
Communications	• Data package structure will follow the structure showed in slide 102-103.
Data Storage	• All data will be stored in a SD Card • Data will be stored following the structure showed in slide 102-103.
Mechanism Activations	• Motor and servomotor for camera control system • Motor for container decoupling system

State Recovery Algorithm

- Since the system has specific tasks through the mission, the system requires a state for every task
- System will save current state and package count every second
- System will always read last state and package count at the beginning of the program
- Depending on last state, the system will jump to that specific task
- System has pre stablished values of “0” and “A” for package count and current state, respectively



Reasons of Reset

- Overcurrent due to an excessive power consumption in motors
- Misconnection in power lines due to vibrations
- Overcurrent due to a momentary short circuit

Container FSW State Diagram

Since container does not have electronics, it also does not have to manage sensors, state machines, etc..

Software Development Plan (1/3)

FEATURE DRIVEN DEVELOPMENT

Develop Overall Model
- Identify the system requirements
- Get existing information about the subjects

Build Feature List
- Discompose overall model into areas
- Generate a list of features of each area

Plan By Feature
- Determine dependencies of each feature with other features
- Plan the sequence of developing of the features

Design By Feature
- Study the reference documents in order to design the feature
- Determine the task and results that each feature must carry out

Build By Feature
- Create the source code of the feature
- Test the feature following a test methodology
- If the feature accomplish its purpose, it must be integrated in the final design

Software Development Plan (2/3)

Progress

Main Board (STM32F413ZH)

- Intercommunication between microcontrollers
- Pressure and temperature data acquisition
- State data storage in SD card
- Camera control law
- Encoders data acquisition
- DC motor control
- Air speed estimation
- Container-Payload release mechanism control
- Communication with ground station
- Air particle data acquisition
- Parachute release mechanism control

Sensors Module (STM32L432KC)

- Intercommunication between microcontrollers
- Pressure and temperature data acquisition
- 3 axis acceleration data acquisition
- 3 axis angular velocities data acquisition
- Pitch and roll estimation
- NMEA GGA message parse
- Altitude estimation

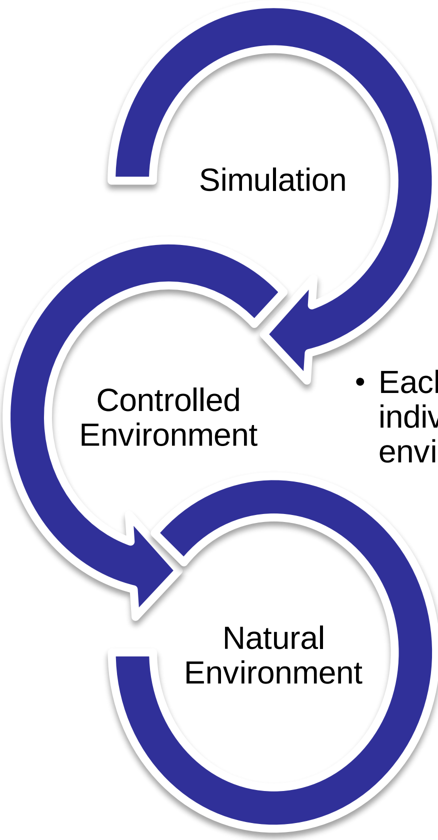
1st | 2nd | 3rd | 4th

Design Stages

- Done
- On progress
- To do

Feature Status

Test Methodology



- Every electronic subsystem will be simulated in software (proteus or multisim)
- Each subsystem will be tested individually in a controlled environment
- All subsystems will be integrated and tested outside in a natural environment

Involved team members

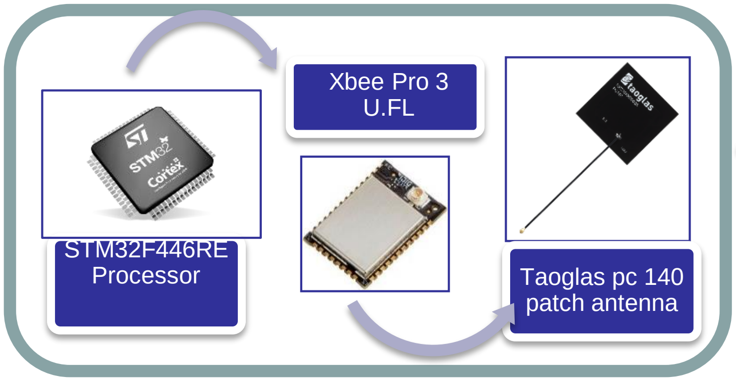
- Aldo Bonilla
  - Jorge Hernández
  - Rodrigo Y. Serrato
  - Royce Ramírez

Ground Control System (GCS) Design

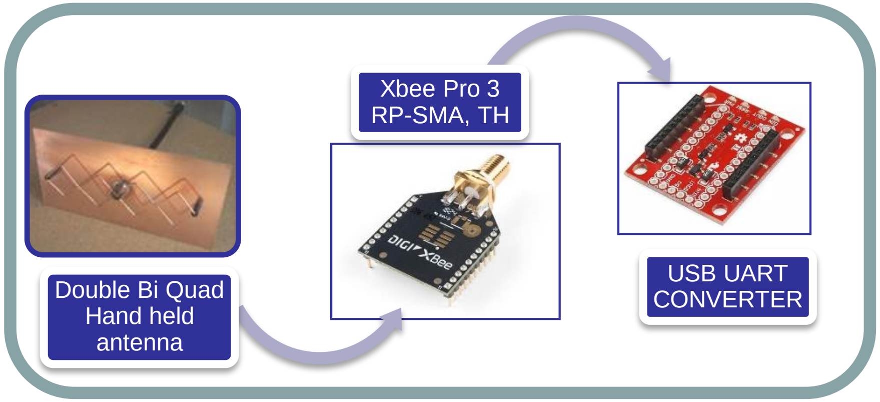
Jessica Valle

GCS Overview

- **The transmitted data from the Payload will be received by the XBee Pro 3 with a Double Bi Quad Antenna**

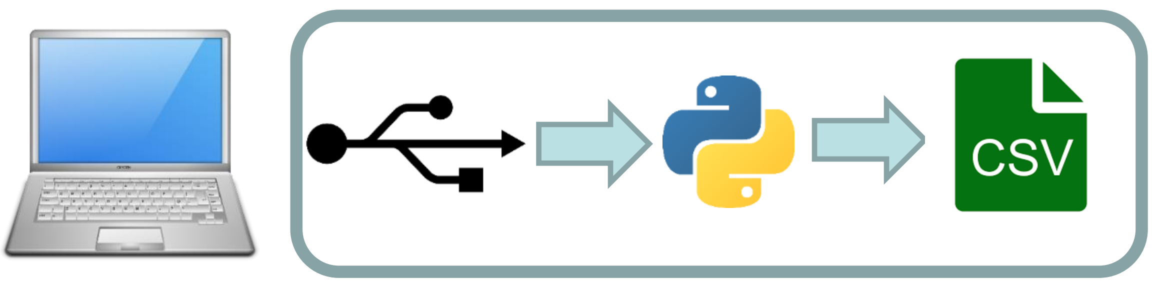


PAYLOAD



GROUND STATION: Communications

- **The received data will be transferred to the PC by means of USB connector (serial port), and processed with Python to display in real time the telemetry and finally data will be saved in a .csv file.**



GROUND STATION: Data presenting and processing.

GCS Changes Since PDR

PDR	CDR	Rationale
GUI	Graphical User Interface modified	Addition of widget elements, as graph plotters.
There was no testing	It is add a telemetry testing and preliminary results slide.	To test how our telemetry design works on a similar competition environment.

GCS Requirements(1/2)

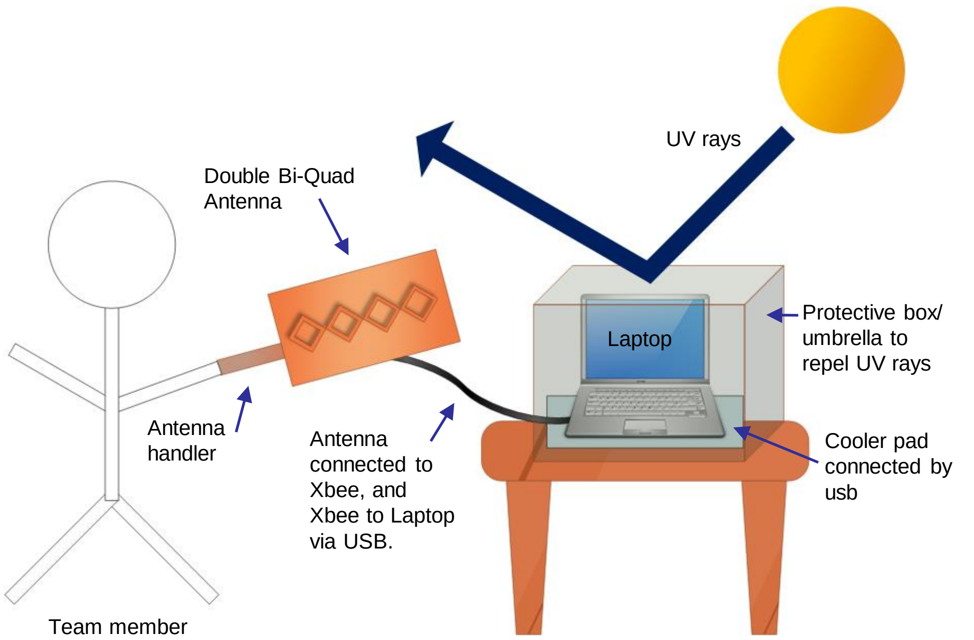
# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
GCS01	The probe shall transmit all sensor data in the telemetry	Competition Requirement	VERY HIGH	SR28				●
GCS02	The ground station shall be able to command the science vehicle to calibrate barometric altitude and roll and pitch angles to zero as the payload sits on the launch pad.	Setup the CanSat framework	HIGH	SR28				●
GCS03	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	To store the data and competition requirement	HIGH	SR29				●
GCS04	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.	Competition Requirement	HIGH	SR31	●			●
GCS05	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	HIGH	SR33	●			●
GCS06	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Competition Requirement	HIGH	SR35	●			●
GCS07	XBEE radios shall have their NETID/PANID set to their team number.	Competition Requirement	MEDIUM	SR36	●		●	●
GCS08	XBEE radios shall not use broadcast mode	Competition Requirement	HIGH	SR37	●			●
GCS09	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	Competition Requirement	HIGH	SR34	●		●	●

GCS Requirements(2/2)

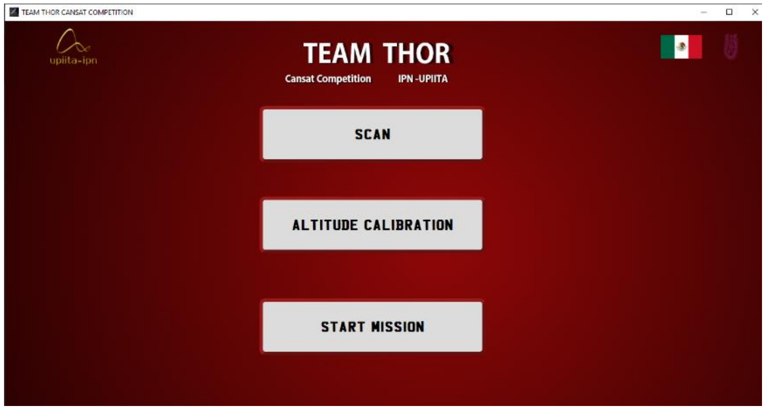
# ID	Requirement	Rational	Priority	Parent	VM			
					A	D	I	T
GCS04	Each team shall develop their own ground station.	Competition Requirement	HIGH	SR35			●	
GCS05	All telemetry shall be displayed in real time during descent	Competition Requirement	HIGH	SR40			●	●
GCS06	All telemetry shall be displayed in engineering units.	Competition Requirement	HIGH	SR41				●
GCS07	Teams shall plot each telemetry data field in real time during flight	Competition Requirement	HIGH	SR42			●	●
GCS08	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	HIGH	SR44			●	●
GCS09	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	HIGH	SR45			●	●

GCS Design

- Ground station can operate for at least two and a half hours.
- To keep the laptop cool, it will be necessary to put it under an umbrella or under an empty box, in the same way it will use a cooling panel.
- To prevent an unexpected reset of the laptop, we will disable "Windows Update" the previous night of the competition, verify possible updates and block all internet connections.
- The ground station software will also be installed to the backup laptop.

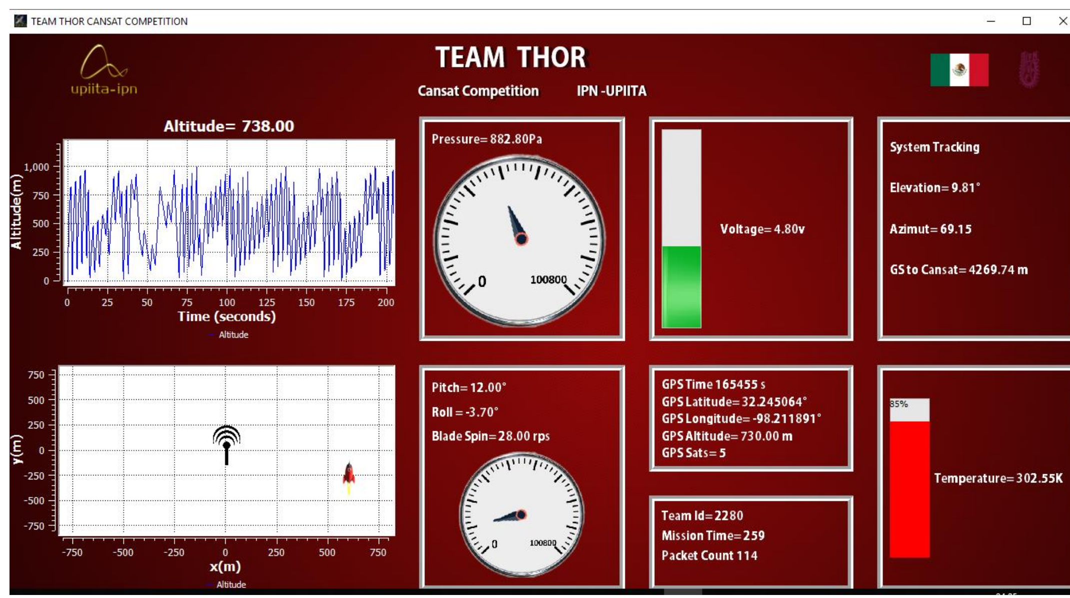


GCS Software (1/2)



The first layout shows a menu option to choose whether to check Cansat status connection, calibrate or start mission, which switch to the second layout.

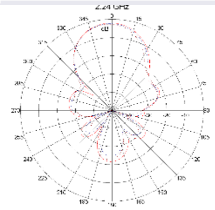
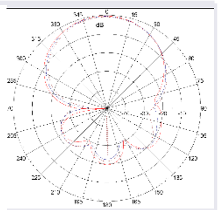
Telemetry is displayed in real time, in the second layout, by using the XBee Python Library and Qt framework, data will also be recorded into csv files.



GCS Software (2/2)

- **Commercial off the shelf (COTS) software packages used:** We work with all of them on open source platforms (Python, XCTU), therefore, there was no money expend on any software package.
- **Real-time plotting software design: :** By using python, we planed to get the data from the micro using libraries that will allow us to use the XBEE serial port and present in the interface all the telemetry data in real time using numerical values , graphical indicators and charts.
- **Command software and interface:** So far no command software it's been used since everything is supposed to be able to reach through the developed GUI (graphic user interface).
- **Progress since PDR:** Since PDR new GUI elements were added to display Telemetry.

GCS Antenna (1/3)

Model	Frequency	Directivity	Radiation Pattern		Gain	Range*	Connector	Polarization	Price
			H-Plane	V-Plane					
Custom Double Bi-Quad	2.4Ghz	Semi-Directional			14dBi	>1.2km	N-Type	Vertical, horizontal	10 USD

We selected the Double Bi-quad antenna because:

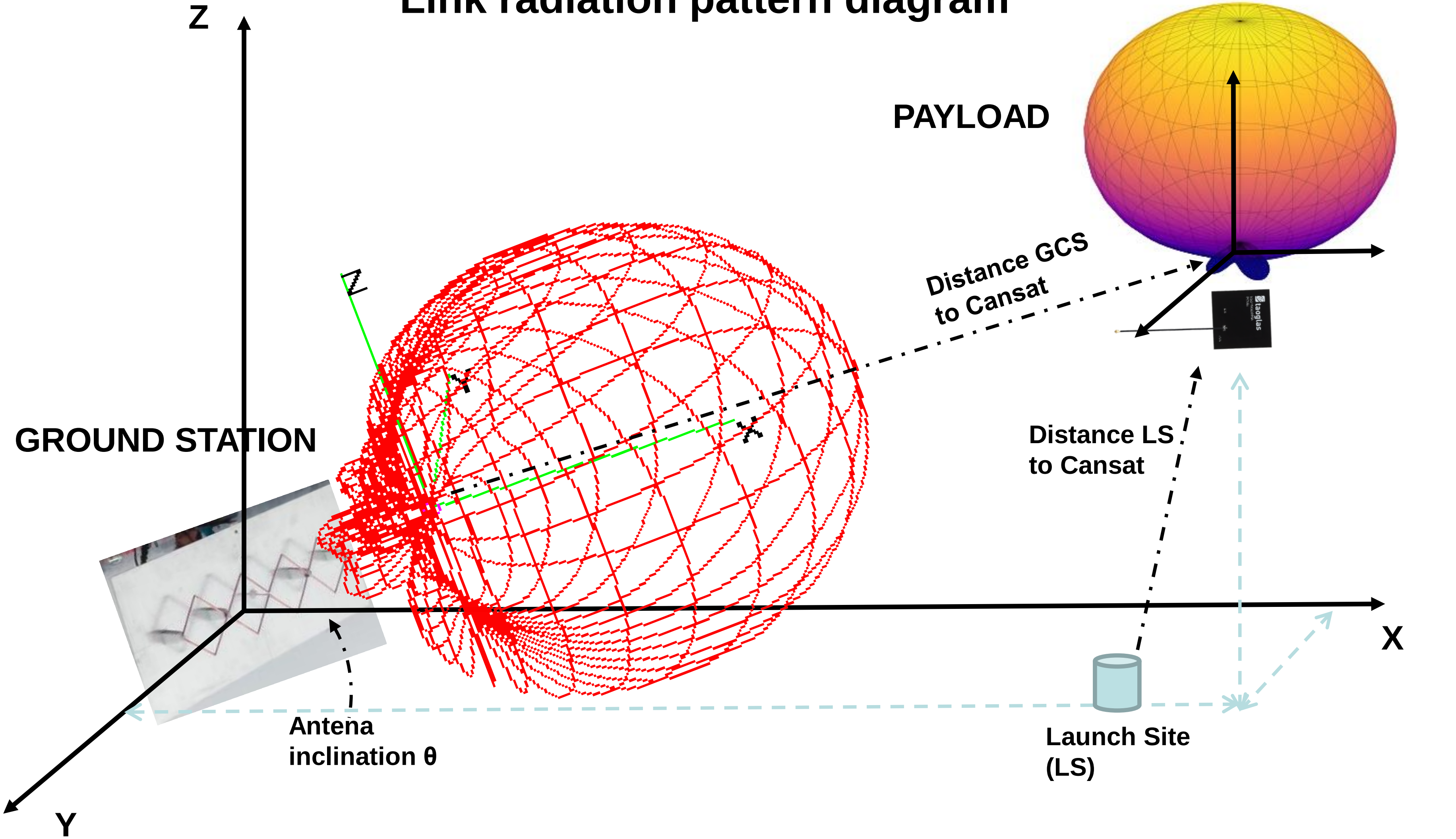
-The Cansat will fly up and in front of the GS, so a directional antenna is suitable, but due to the high and long range, the **Half Power Beam Width** (HPBW) of the radiation pattern must be **wider (>60°)** as the double Biquad antenna has in the vertical plane.

-It's a **very cheap (custom) handheld antenna**,

-13dBis is a suitable gain, considering the Xbee's used and the antenna selected on the Cansat; theoretical calculations give us **more than 1.2Km range**,

-The undesired effects of **linear polarization are compensated** with the circular polarization of the payload antenna

Link radiation pattern diagram



- **Hand-held:** at the back of the antenna a handler was added.

- **Distance Links predictions and margins:**

Link Budget (using Friis Equation)

Using a free space propagation model described by the Friis equation (1), the theoretical coverage distance (D_r) is calculated considering the xBee Pro 3 with f_O=2.4Ghz, sensitivity of -103dBm, a transmission power (P_{Tx}) of 19dBm, a reception double biquad antenna gain (G_{Rx}) of 14dBi, a *CanSat* transmission antenna gain (G_{Tx}) of 2dBi according to corresponding datasheets and simulation, and from

$$P_{Rx} = P_{Tx} G_{Rx} G_{Tx} \left(\frac{c}{4\pi D_r f_0}^2 \right), \qquad (1)$$

$$P_{Rx}(dB) = P_{Tx} + G_{Rx} + G_{Tx} + 20log\left(\frac{\lambda}{4\pi D_r} \right), \qquad (2)$$

the $P_{Rx}(dB)$= -65.05 dBm for 1Km and $P_{Rx}(dB)$= -71.07 dBm for 2Km; these $P_{Rx}(dB)$ are larger than the Xbee's sensitivity, so, **theoretically, the Xbee's could receive without problems up to 2Km, which is a reliable margin**.

CanSat Integration and Test

Rafael Cornejo

CanSat Integration and Test Overview (1/2)

Subsystem Level Testing

Mechanical
- Total mass test
- Container and science payload stress and deformation tests
- Container and science payload falling velocities tests
- Unfolding parachute tests
- Gliding pattern and drag aerodynamic tests
- Release mechanism tests

Sensors
- Sensors-microcontroller interfacing protocol test
- Sensor calibration tests
- Microcontroller's intercommunication test

Electrical Power
- Energy distribution tests
- Verify the batteries can work for 2 hours

Communications and Data Handling
- Protocol verification tests
- Radio communication tests
- xBee range tests
- Data transfer and storage tests
- Telemetry and antenna transition tests

•**Ground Control Station**
- Data transfer tests
- Telemetry reception tests
- Antenna tests
- Software tests
- Storage data tests

CanSat Integration and Test Overview (2/2)

Integrated Functional Level Testing

- Parachute opening test
- Gliding operation test
- Payload release mechanism test
- Payload's parachute opening test
- xBee range communication test between both antennas.
- Antenna tests using a drone to test the communication between the antenna in the ground station and the one onboard the CanSat.
- Bill gathering.

Environmental Test

Withstand periodic accelerations	Vibration Test
Withstand temperatures as high as 60 °C	Thermal Test
Withstand the shock force of the parachute deployment	Drop Test
Verify the CanSat fits inside the rocket	Fit Test

Subsystem Level Testing Plan (1/2)

Sensors Subsystem (SS)	Communication and Data Handling (CDH)	Electrical Power Subsystem (EPS)	Radio communications and Ground Station (GS)
• Test to the barometric pressure sensor and the altitude estimation. • Test the temperature sensor. • Test the GPS. Location and time readings. Test it has NMEA 0183 format. • Test ADC readings of the battery voltage. • Test readings of gyroscope and accelerometer for estimating pitch and roll tilts. • Test air velocity estimation using two barometric sensors • Test particle counter performance • Test the control algorithm for the orientation of the camera based on gyroscope and accelerometer readings. • Test the communication protocol of the microcontroller	• Test range of CanSat antenna. • Test communication between XBEEs. Verify that they have a proper configuration (NETID/PANID settings and no broadcast mode). • Test telemetry format. Verify that the microcontroller builds the telemetry package correctly. • Test rate of package transmission. • Test memory storage.	• Test energy distribution. • Continuous operation for at least two hours. • Test current and voltage supplied are correct.	• Test the reception of the transmitted telemetry • Test the operation of the ground station interface. It should be easy to understand all the information displayed • Test the storage of telemetry data by the ground station • Test the generation of a .csv file • Test that the ground station can be moved form one point to another

Subsystem Level Testing Plan (2/2)

Flight Software (FSW)

- Verification of the state machine operation.
- Verification of the activations of each mechanism at the time in the state machine

Mechanical Subsystem (MS)

- Test operation of delta wing release.
- Test operation of the parachute release mechanism.
- Test operation of the payload release mechanism.
- Test operation of the camera orientation mechanism.
- Test resistance of mounting methods of components inside the payload.
- Test stresses and deformations of the structure when the forces and accelerations specified in the competition guide are applied.

Descent Control (DC)

- Test falling velocity of CanSat using both parachutes.
- Test falling velocity of payload using the air gliding system.
- Test opening strategy of the wings
- Test opening strategy of the payload's parachute
- Test behavior of payload while falling. Verify its stability.

Integrated Level Functional Test Plan

Our plan to realize the Integrated Level Functional Tests is to perform a demo flight.
In the demo flight all the subsystems will be checked operating in conjunction. For performing this demo flight it is expected that a drone will be used. The maximum height, and therefore all other relevant altitudes, will depend on drone capabilities.

Integrated Functional Level Testing

- **Sensor tests**
  - Acquisition and processing of parameters (barometric pressure, temperature, tilt angles, altitude, falling velocity, etc).
- **Communication tests**
  - xBee range communication test between both antennas.
  - Antenna tests using a drone to test the communication between the antenna in the ground station and the one onboard the CanSat.
  - Test storage on board the CanSat and in the Ground Station.
- **Mechanism and Mechanical tests**
  - Gliding operation test
  - Payload release mechanism test.
  - Structure survivability.
- **Descent test**
  - Parachutes opening test
  - Velocity of descent rate
- **Deployment**
  - No interference between deployment mechanisms

Environmental Test Plan (1/2)

Drop Test

Test Description

- The CanSat's parachute will be tied to a non-stretching cord of 61 [cm] of large.
- The cord will be tied to a rigid structure with at least 1[m] high.
- The CanSat will be raised up at the knot altitude and then it will be drop.

Pass Criteria

- The CanSat should not become detached from the parachute.
- The CanSat should maintain its mechanical configuration all the time.
- All the electronics and structures must maintain their initial places.

Thermal Test

Test Description

- The CanSat will be put inside of a insulation cooler with 100 [W] light bulbs and a temperature sensor.
- The light bulbs will be connected to a contact. The wire of the bulbs will have a relay at the middle.
- The temperature sensor and the relay will be manage by a microcontroller with a preestablished routine according to the guideline.
- The routine will be maintained for two hours.

Pass Criteria

- The CanSat's structure should not be deformed.
- All the electronics should still working after the test.

Environmental Test Plan (2/2)

Vibration Test

Test Description

- The CanSat will be mounted on a sander.
- The CanSat will be secured with plastic cable ties.
- The CanSat will be turned on and it will start to transmit the accelerometer readings.
- The sander will be turned on for 10 seconds and then will be tuner off. This sequence will be repeated five times at least.

Pass Criteria

- The CanSat should maintain its mechanical configuration all the time.
- All the electronics and structures must maintain their initial places.
- All the electronics should still working after the test.

Fit Test

Test Description

- The CanSat will be set to its initial mechanical configuration simulating the real launch.
- A 3D printed structure with a centered hole of 125 [mm] of diameter will be held by a team member.
- A second team member will take the CanSat and pass it through the hole of the 3D printed structure.

Pass Criteria

- The CanSat should pass through the hole without difficulties.

Test Procedures Descriptions (1/4)

Number	Test Description	Subsystems	SR	Pass Criteria
1	Science payload will compute the altitude in the first floor of a building, then a member of the team will go up to the last floor of the building and the CanSat will compute again the altitude. Team must know the height of the building in each floor.	FSW, SS	22	The difference between the computed altitudes must be equal to the building specified heights with a ±1 meter tolerance.
2	The payload will request a message from GPS in an specific place. The obtained message will be compared with the NMEA 0183 format. Also the latitude and longitude must be compared with Google's position data obtained from the internet.	FSW, SS, CDH	23	The message format obtained from GPS must be the same of the NMEA 0183. Latitude and longitude must be equal to the Google's data with a tolerance of ±1e-3 units. Decimal format.
3	The payload will perform analogic reads of a battery with a load resistance during 60 minutes while a voltmeter performs its own readings on the same battery. Every 10 minutes team will record the readings.	FSW, SS	24	The readings of the microcontroller must be similar to the ones of the voltmeter with a ±0.1 V of tolerance.
4	Science payload will read temperature at the outside of a building meanwhile another temperature sensor (like thermometer) performs its own readings. The test will have a duration of 1 hour and every 10 minutes the team will record the readings.	FSW, SS	25	The temperature read must be equal to the external temperature sensor, with a tolerance of ±1 °C
5	The payload will compute the air speed using the measurements of both pressure sensors inside of a wind tunnel meanwhile an anemometer performs its own readings.	FSW, SS	26	Both readings must be similar during the test within a ±1 meter per second tolerance.
6	Payload will be set to an specific state, it will perform a constant transmission for at least one hour. A member of the team will reset the payload every 10 minutes.	FSW	47	Payload must continue in the same state after all resets. Package count must have a continuity after all resets.

Test Procedures Descriptions (2/4)

Number	Test Description	Subsystems	SR	Pass Criteria
7	The system will perform calculations of pitch and roll, while it is tilted by a member of the team, the results will be compared constantly with a protractor	FSW, SS, CDH	Bonus	The calculated tilt must be equal to the protractor with ±10 degrees of tolerance
8	The payload must transmit readings of all telemetry data for two hours, sending a package every second. Each package will be recorded by a computer and in an internal SD card. The transmission must be within a minimum of 200 meters. At the end of the test the received data and the stored data will be compared.	FSW, SS, CDH, GS	28, 32, 40,41, 42	The received packages must be equal to the stored one in the SD, with a tolerance of 20% of data loss.
9	Weight the CanSat once it is completely assembled.	MS	1	The total CanSat mass must be less than 610 [g].
10	Create a cylinder with the dimensions specified in the list of requirements and then introduce the CanSat into the cylinder.	MS	2	The CanSat fits within the cylinder without getting stuck.
11	Introduce the CanSat into a cylinder made of cardboard, then place the cylinder vertically at a height of 1.5 [m] and drop the CanSat.	MS	3, 5, 6, 7	The CanSat falls freely.
12	The minimum electronics for measuring altitude and velocity will be placed inside the CanSat. The CanSat will be elevated with a drone, and released afterwards. This test is practically a simulation of the entire mission, and the primarily operational aspects of the payload are checked.	MS, DC, SS, FSW	7, 9, 12, 13, 22, 51, 52, 57	The CanSat opens the parachute immediately after the drone releases it. At a certain altitude (which will be stablished based on the maximum altitude the drone can achieve), the payload is released from the container. The falling velocities measured must lie within the permissible ranges (for parachute and gliding descents). The audio beacon should start sounding right after landing, and the team should here it.
13	The system Will perform readings of the particle sensor meanwhile a team member insert different objects into the reflection area of the sensor	FSW, SS	26	The Reading must change according to the placed object.

Test Procedures Descriptions (3/4)

Number	Test Description	Subsystems	SR	Pass Criteria
14	Enter each fastening element to an analysis of finite element to tension and shear. Verify that the elements support the loads.	DC	14, 19	The clamping elements must be within the permissible range according to the theory of maximum distortion energy.
15	Submit to an analysis of a finite element the pieces that are involved in the impact. On the other hand, an impact test will be carried out on a test strip.	DC	16, 17, 19	The structure does not suffer major damage.
16	Verify that the suspension lines of the parachute support the tension produced by the overshoot during the descent.	MS	14	Because during a stress test, the suspension lines do not break.
17	Turn on rotating the payload to verify that the camera points in only one direction.	MS, FSW, SS	Bonus	The camera points in one direction when rotating the payload.
18	Perform a complete visual inspection.	MS	5, 8, 15, 20, 21, 30, 46, 48, 49, 50, 54, 55	Electronics should be protected by the containers walls. Team labels are in position, colors must be fluorescent. No lasers should be present, neither chemicals nor mechanisms that use heat. The CanSat must be turned on and off easily, and have a led indicating its state. The batteries should be easy to replace, and no spring contacts should be used.
19	Perform environmental tests described in the CanSat Competition Guide 2019.	MS, DC, SS, FSW, CDH, EPS, GS	19, 56	The CanSat operates properly during the environmental tests.
20	The CanSat will be turned on and left functioning for two hours.	FSW, CDH, EPS, GS	44, 57	The CanSat must acquire and send all telemetry data, and the ground station must receive it. The battery does not run out.
21	Gather all the bills and sum up the expenses.	Management	38	Total cost must not be over $1000 USD.

Test Procedures Descriptions (4/4)

Number	Test Description	Subsystems	SR	Pass Criteria
22	The ground station antenna will have an energy radiation pattern which will cover the front area to communicate wherever is the payload. It will be calculated the respective antenna radiation pattern from a software simulation and validate it with a practical anechoic chamber measurement.	GS	31, 28, 38	The implemented antenna's radiation pattern will have one frontal main lobe and a small rear lobe.
23	The system impedance is 50 ohms, hence the antenna must be designed at this radiation resistance. A calibrated network analyzer will be used to measure the antenna impedance at the required frequency.	GS, CDH	35	The impedance must not be less than or greater than 50 ohms.
24	All the energy is radiated if the antenna is matched with the transceiver and transmission line. We'll check that with a network analyzer and a frequency scan.	GS, CDH	35	It will be expected, that ROE less than 3 for all the frequency bandwidth system.
25	The system will perform a continuous data transmission, this transmission will have a duration of two hours and each packet will be transmitted every second. An error will be inserted in the data of some package, and the system must detect the package with error and reject them, then the system will wait for the next package.	GS, CDH	31, 33, 44	The CRC must reject 90% of the damaged packages.
26	The payload must transmit readings of all system during two hours, sending a package every second. Each package will recorded by a computer and in an internal SD card. The transmission must be within a minimum of 200 meters. At the end of the test the received data and the stored data will be compared, finally a csv file called THOR_4784 will be saved and compared with the data stored on the SD card.	GS, CDH	28, 32, 35, 37 40, 41, 45	The received packages must be equal to the stored one in the SD, with a tolerance of 20% of data loss. The Ground Station must have a computer, a handheld antenna, and must be portable.
27	The NETID/PANID and operation mode must be inspected in XCTU software	CDH	35, 36	PANID must be equal to the team number. Point to point mode must be selected.
28	The CanSat will be tilted in different positions, and a sent command must change the references for pitch and roll and barometric altitude.	CDH, GS, SS	22	Pitch, roll and barometric altitude must be stablished to zero when the command is sent.

Mission Operations & Analysis

Rafael Cornejo

Overview of Mission Sequence of Events (1/3)

Pre-Launch → Launch → Post-Launch

Arrival

Team Thor

- Arrive at launch site
- Do registration tasks
- Go to work station

Testing

- Sensor & power subsystem
  - Test batteries voltage
  - Test connections (wires and weldings)
  - Test sensor mountings
  - Test audio beacon
  - Test the switching-on of sensors
  - Test Camera
- Mechanical subsystem
  - Check the batteries positions
  - Check PCB mountings
  - Test releasing mechanism of parachute and payload.
  - Bend parachute.
  - Test the parachute deployment.
  - Working Mechanism test.
- Communication and ground station subsystem
  - Test communication between the CanSat and ground station
  - Check the computer battery
  - Test data acquisition from sensors
- Wait for judges revisions (mass and size compatibility with rocket)

CanSat Crew
Aldo Bonilla
Royce Ramirez
Alejandro Aguirre
Saúl Becerril

Launch Site

Mission Control Officer
Marco Sandoval
Ground Station Crew
Rodolfo Vera
Jessica Valle
Jorge Hernández

- Switch on the Cansat (starts sensors readings and storage of data in SD card).
- Mount the Cansat inside the rocket.
- Go to ground station operation site.
- Mount ground station computer.
- Verify the Cansat is communicating with ground station.
- Install rocket on assigned launch pad.

Overview of Mission Sequence of Events (2/3)

Pre-Launch → **Launch** → Post-Launch

Flight

- Rocket deployment.
- At apogee (670 meters to 725 meters) rocket releases the probe.
- Telemetry transmission starts.
- Parachute of container opens just after release.
- At 450 meters, the container release the science payload.
- Camera starts capturing video
- The science payload glide in a circular pattern with a radius of 250 m.
- After one minute the parachute of payload opens.
- Camera ends capturing video
- Landing of container
- Landing of payload

Ground Station Crew
Rodolfo Vera
Jessica Valle
Jorge Hernández

Landing

- Transmission ends
- Audio beacon sounds
- Team must clear out the ground station operation site

Cansat

Overview of Mission Sequence of Events (3/3)

Pre-Launch → Launch → **Post-Launch**

Recovery and Delivering

Recovery Crew
Yaoctzin Serrato
Rafael Cornejo

- Crew starts the recovery of container and payload.
- Delivering of data (.csv file) and any other items to judges (container and payload)

Analysis

Team Thor

- Analysis of telemetry data and captured images
- Preparation for PFR (presentation and document)

Field Safety Rules Compliance

Mission Operations Manual Content

- It is divided in the following sections
  - Crew Assignments
  - Cansat Set-Up (subsystems tests)
  - Ground System Configuration
  - Cansat Lunch Preparation
  - Launch Procedure
  - Recovery procedure

Development Status

- Each member team still working on their assignments and writing the subsystem final procedures.
- The Cansat Lunch Preparation, Launch Procedure and Recovery procedure sections are done.

CanSat Location and Recovery

Container recovery

The container will be of fluorescent **red**, as well as the parachute itself. A recovery crew member will spot the container during flight in order to identify the possible landing zone.

Payload recovery

The recovery crew may find the science payload by following the audio beacon sound.

The parachute of the payload will be of fluorescent **pink.**

The parachute of the container will be of fluorescent **orange.**

The CanSat container and the science payload will have a label with the following information:

- Team leader name
- Team number
- Team contact information (university, e-mail address)

Mission Rehearsal Activities

Ground system radio link check

- Two members of the Team Thor crew were placed a 500 feets and they configure the XBee radios and sent examples a data packages between them.

Powering on/off the CanSat

- A member of crew only changes the state of a mechanical switch.

Launch Configuration

- The members of the mechanical subsystem joined all the components of the CanSat structure and later added the electronic elements and the parachute.

Loading the CanSat in the Launch vehicle

- This procedure it was carried out by the fit test

Telemetry processing, archivig, and analysis

- In the tests that were made to the software of the ground station, the data from the CanSat were saved and later analyzed by the members Team Thor crew .

Recovery

- Three members of Team were waiting for the judge indications to recover the payload and the container.

Requirements Compliance

Alejandro Aguirre

Requirements Compliance Overview

- **Comply**
  - ✓ The CanSat dimensions fully fit in the space available.
  - ✓ The actual price of the prototype is lower that the maximum specified.
  - ✓ The sensors satisfy all the measures that are necessary for the mission (outside temperature, position, pressure, voltage, etc).
  - ✓ The selected batteries can power all the CanSat operations.
  - ✓ The mechanism do the requirement actions.
  - ✓ The selected elements satisfy the falling velocities.
  - ✓ The new sensors decrease the electronic mass.
  - ✓ The proposed antenna allows more distance than the last year.

- **Not fully Comply**
  - Despite all simulations, we must to probe a real model to demonstrate that the structure and internal components could resist the resistance requirements.

Requirements Compliance (1/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR01	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.	Comply	90	The simulation results specify values within the requested range.
SR02	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.	Comply	19,28	
SR03	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard..	Comply	28	
SR04	The container shall be a fluorescent color; pink, red or orange.	Comply	18	
SR05	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	Comply	18	
SR06	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	28	
SR07	The rocket airframe shall not be used as part of the CanSat operations.	Comply	21	
SR08	The container parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Comply	21	

Requirements Compliance (2/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR09	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s	Comply	57	The simulation results specify values within the requested range.
SR10	The container shall release the payload at 450 meters +/- 10 meters.	Comply	121	
SR11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container	Comply	60	The simulation results specify values within the requested range.
SR12	The science payload shall be a delta wing glider.	Comply	71	
SR13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s.	Comply	63,121	The simulation results specify values within the requested range.
SR14	All descent control device attachment components shall survive 30 Gs of shock	Comply	83	The simulation results specify values within the requested range.
SR15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	71,72	
SR16	All structures shall be built to survive 15 Gs of launch acceleration.	Comply	83	The simulation results specify values within the requested range.
SR17	All structures shall be built to survive 30 Gs of shock.	Comply	83	The simulation results specify values within the requested range.

Requirements Compliance (3/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	85,86	
SR19	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	74,75,81,82	
SR20	Mechanisms shall not use pyrotechnics or chemicals.	Comply	65	
SR21	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire	Comply	65	
SR22	The science payload shall measure altitude using an air pressure sensor.	Comply	33	
SR23	The science payload shall provide position using GPS.	Comply	35	
SR24	The science payload shall measure its battery voltage	Comply	36	
SR25	The science payload shall measure outside temperature.	Comply	34	
SR26	The science payload shall measure particulates in the air as it glides.	Comply	38	

Requirements Compliance (4/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR27	The science payload shall measure air speed.	Comply	37	
SR28	The science payload shall transmit all sensor data in the telemetry.	Comply	98	
SR29	Telemetry shall be updated once per second.	Comply	100	
SR30	The Parachutes shall be fluorescent Pink or Orange.	Comply	54	
SR31	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.	Comply	136	
SR32	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	Comply	128	
SR33	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.	Comply	117,122,123	
SR34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	Comply	117,120,121,123	
SR35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Comply	98	

Requirements Compliance (5/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR26	XBEE radios shall have their NETID/PANID set to their team number.	Comply	98	
SR37	XBEE radios shall not use broadcast mode	Comply	98	
SR38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	194-196	
SR39	Each team shall develop their own ground station	Comply	136	
SR40	All telemetry shall be displayed in real time during descent.	Comply	135	
SR41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	135	
SR42	Teams shall plot each telemetry data field in real time during flight	Comply	135	
SR43	The number 43 is not in the mission guide.	Comply	-	
SR44	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	Comply	131-135	

Requirements Compliance (6/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR45	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site	Comply	131-135	
SR46	Both the container and probe shall be labeled with team contact information including email address.	Comply	154	
SR47	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Comply	123	
SR48	No lasers allowed.	Comply	30,65	
SR49	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	Comply	65,108	
SR50	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.	Comply	65,108	
SR51	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Comply	108,117	
SR52	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Comply	108	

Requirements Compliance (7/7)

# ID	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or notes
SR53	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.	Comply	108,109	
SR54	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.	Comply	65	
SR55	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	65	
SR56	The CANSAT must operate during the environmental tests laid out in Section 3.5	Comply	139-148	
SR57	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Comply	110	

Management

Alejandro Aguirre

Status of Procurements

Component	Status	Tested / No Tested
STM32F413ZH	Arrived	No Tested
STM32L432KC	Arrived	Tested
NEO M8N	Arrived	Tested
ICM20948	Arrived	Tested
DPS310	Arrived	Tested
GP2Y1010	Arrived	Tested
DM3AT	Arrived	Tested
SQ11	Arrived	Tested
CMT-8540S	Arrived	Tested
DRV8801	Arrived	Tested
MR44V064	Arrived	Tested
SMT LED	Arrived	Tested
DMN1008UFDF	Arrived	Tested
XB3-24Z8UM	Arrived	Tested
Taoglas Freedom FXP70 2.4 GHz Flex	Arrived	Tested
Wires	Arrived	Tested

CanSat Budget – Hardware (1/4)

Electronic Hardware (1/2)

Category	Model	Quantity	Unit Price (USD)	Total Price (USD)	Determination
Microcontroller	STM32F446RE	1	11.95	11.95	Acquired
Microcontroller	STM32L432KC	1	8.42	8.42	Acquired
Sensors	NEO M8N	1	32.94	32.94	Acquired
Sensors	ICM20948	1	7.68	7.68	Acquired
Sensors	DPS310	2	2.86	5.72	Acquired
Sensors	GP2Y1010	1	15.60	15.60	Acquired
Memory	DM3AT	1	3.39	3.39	Acquired
Sensors	SQ11	1	26.67	26.67	Acquired
Actuator	CMT-8540S	1	4.33	4.33	Acquired
Power	DRV8801	3	3.33	9.99	Acquired
Memory	MR44V064	2	3.64	4.66	Acquired
Power	TPS563231	2	1.07	2.14	Acquired

CanSat Budget – Hardware (2/4)

Electronic Hardware (2/2)

Category	Model	Quantity	Unit Price (USD)	Total Price (USD)	Determination
Battery	Energizer Ultimate Lithium 9V	1	7.19	7.19	Actual
Actuator	SMT LED	5	0.5	2.5	Acquired
Power	DMN1008UFDF	3	0.585	1.755	Acquired
Communications	XB3-24Z8UM	1	24.69	24.69	Acquired
Communications	Taoglas Freedom FXP70 2.4 GHz Flex	1	4.36	4.36	Acquired
Power	Wires	-	-	10	Estimate
Power	Conectors	-	-	10	Estimate

Subtotal: 193.985 USD

Mechanical Hardware

Category	Model	Quantity	Unit Price (USD)	Total Price (USD)	Determination
Parachute	Handmade	2	Re-used	Re-used	Actual
Wing Structure	ABS 3D print	2	10	20	Estimate
Actuator	Micro Gear Motor Pololu	4	12.87	51.48	Actual
Structure	Carbon Fiber	1	50	50	Actual
Structure	Screws with nuts	40	0.7	28	Actual
Structure	Aluminum	1	20	20	Estimate

Subtotal: 169.48 USD

CanSat Budget – Hardware (4/4)

Communications Costs

Category	Model	Quantity	Unit Price (USD)	Total Price (USD)	Determination
Antenna	Double Biquad	1	1	10	Estimate
Communications	Xbee Pro S3 RP-SMA, TH	1	1	40	Acquired
Communications	Xbee Shield	1	10	10	Acquired
Wires	-	-	-	10	Estimate

Subtotal: 70 USD

Total cost: 433.46 USD

Other Costs

Category	Quantity	Unit Price (USD)	Total Price (USD)	Determination
Prototyping	.			
Travel*	11	400	4400	Estimate
Hotel*	11	-	1072.95	Estimate
Transportation*	1	-	796.26	Estimate
Food*	11	10	660	Estimate

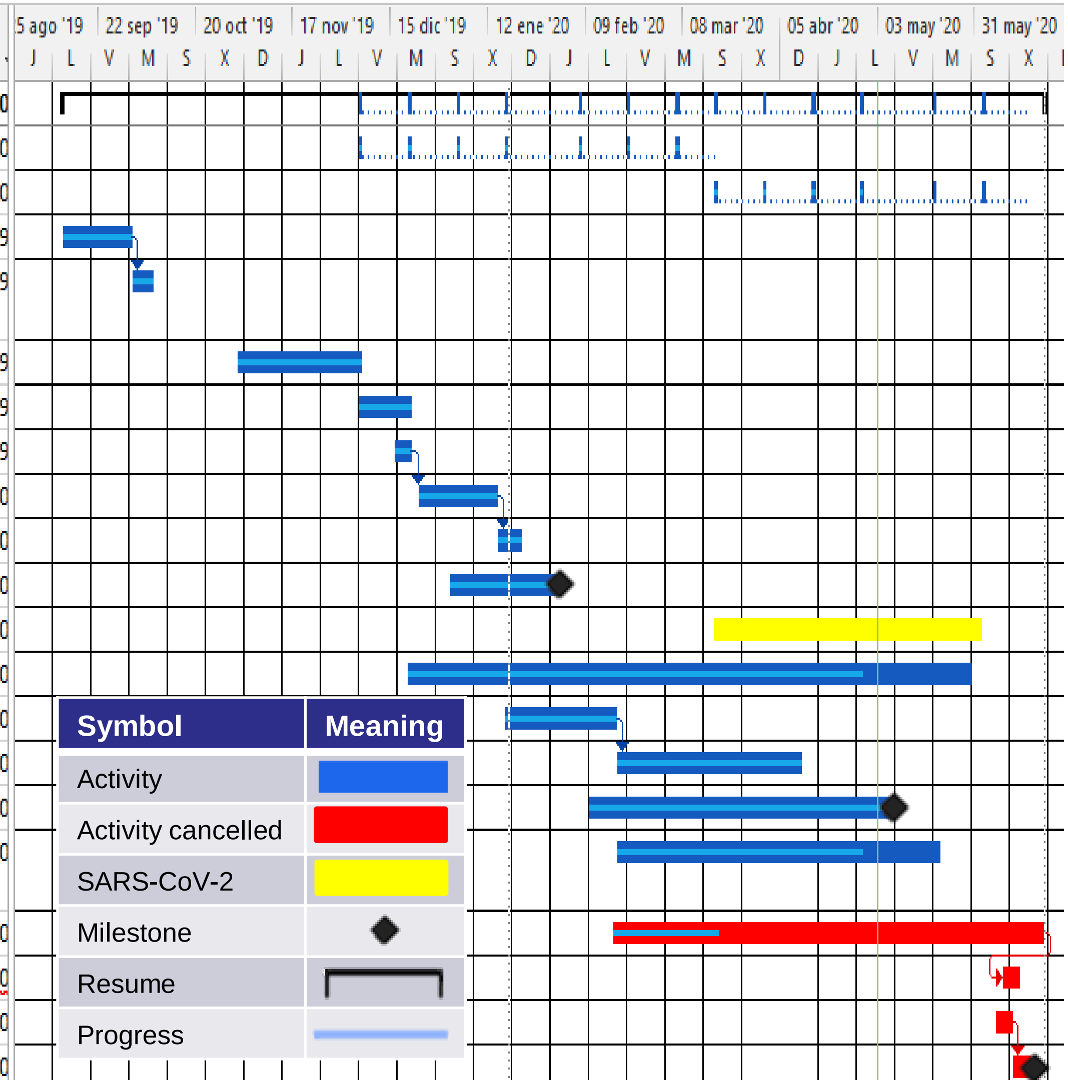
Total: 6859.215 USD

Sources of income: Provided by the University

*These sections were cancelled

Program Schedule Overview

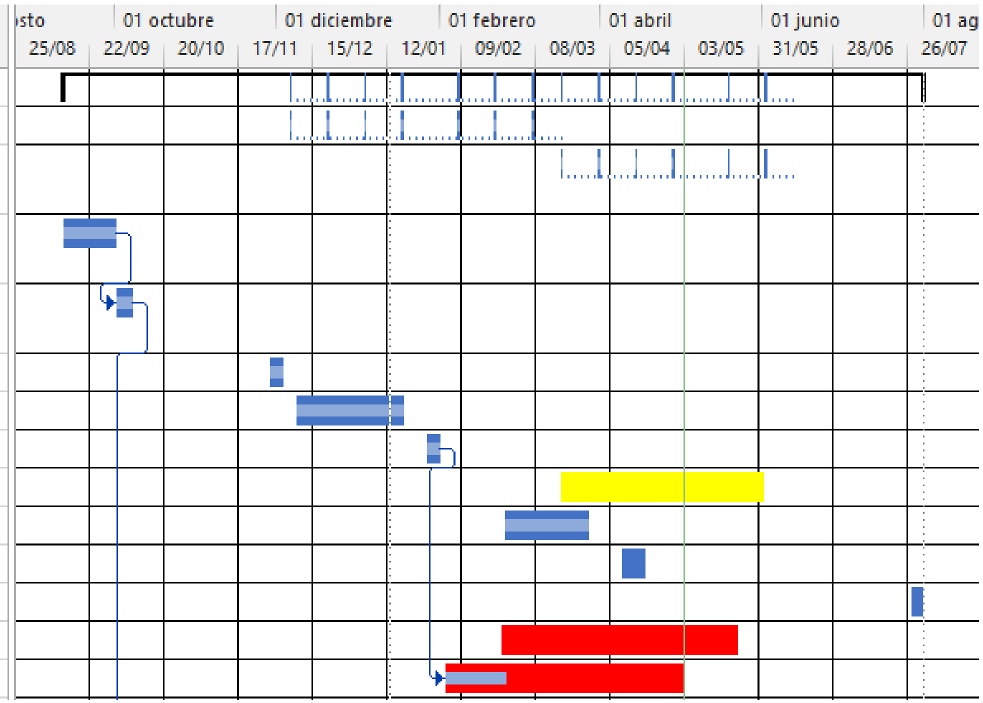
	Activity	Days	Start	End
1	CanSat competition	202	12/09/2019	19/06/2020
2 ✓	Team meetings	7	06/12/2019	17/03/2020
3	Team Videoconferences	6	17/03/2020	14/06/2020
4 ✓	Preliminary selection of the team	14	12/09/2019	01/10/2019
5 ✓	Organization of team in subsections	4	02/10/2019	07/10/2019
6 ✓	Understanding the mission guide	26	01/11/2019	06/12/2019
7 ✓	Reasearch	11	06/12/2019	20/12/2019
8 ✓	Conceptual design	5	16/12/2019	20/12/2019
9 ✓	Detailed design	17	23/12/2019	14/01/2020
10 ✓	Validation of the design	5	15/01/2020	21/01/2020
11 ✓	PDR	24	01/01/2020	01/02/2020
12	SARS-CoV-2 VIRUS	55	17/03/2020	01/06/2020
13	Material Order	116	20/12/2019	29/05/2020
14 ✓	Prototype construction	22	17/01/2020	17/02/2020
15 ✓	Verification prototype	39	18/02/2020	10/04/2020
16 ✓	CDR	64	10/02/2020	07/05/2020
17	Redesign and optimization of protype	67	18/02/2020	20/05/2020
18	Final prototype construction	90	17/02/2020	19/06/2020
19	Verification final protype	5	08/06/2020	12/06/2020
20	Enviromental test	4	06/06/2020	10/06/2020
21	Competition days	3	11/06/2020	15/06/2020



Symbol	Meaning
Activity	(blue bar)
Activity cancelled	(red bar)
SARS-CoV-2	(yellow bar)
Milestone	◆
Resume	(bracket bar)
Progress	(light blue line)

Detailed Program Schedule (1/6)

	Activity	Start	End	Progres	Assignment
1	**Administration**	**12/09/2019**	**31/07/2020**	**37%**	
2	Team meetings	06/12/2019	17/03/2020	100%	Team Thor
3	Team Videoconferences	17/03/2020	14/06/2020	65%	Team Thor
4	Preliminary selection of the team	12/09/2019	01/10/2019	100%	Leaders
5	Organization of team in subsections	02/10/2019	07/10/2019	100%	Leaders
6	Final exams	29/11/2019	03/12/2019	100%	Team Thor
7	Winter vacations	09/12/2019	17/01/2020	100%	Team Thor
8	Budget travel	27/01/2020	31/01/2020	100%	Jorge
9	SARS-CoV-2 VIRUS	17/03/2020	01/06/2020	0%	
10	Exams	25/02/2020	27/03/2020	100%	Team Thor
11	Spring vacations	09/04/2020	17/04/2020	0%	Team Thor
12	Final exams	27/07/2020	31/07/2020	0%	Team Thor
13	Procedure to get VISA	24/02/2020	22/05/2020	0%	Jessica
14	Travel planning	03/02/2020	01/05/2020	25%	Marco, Jorge

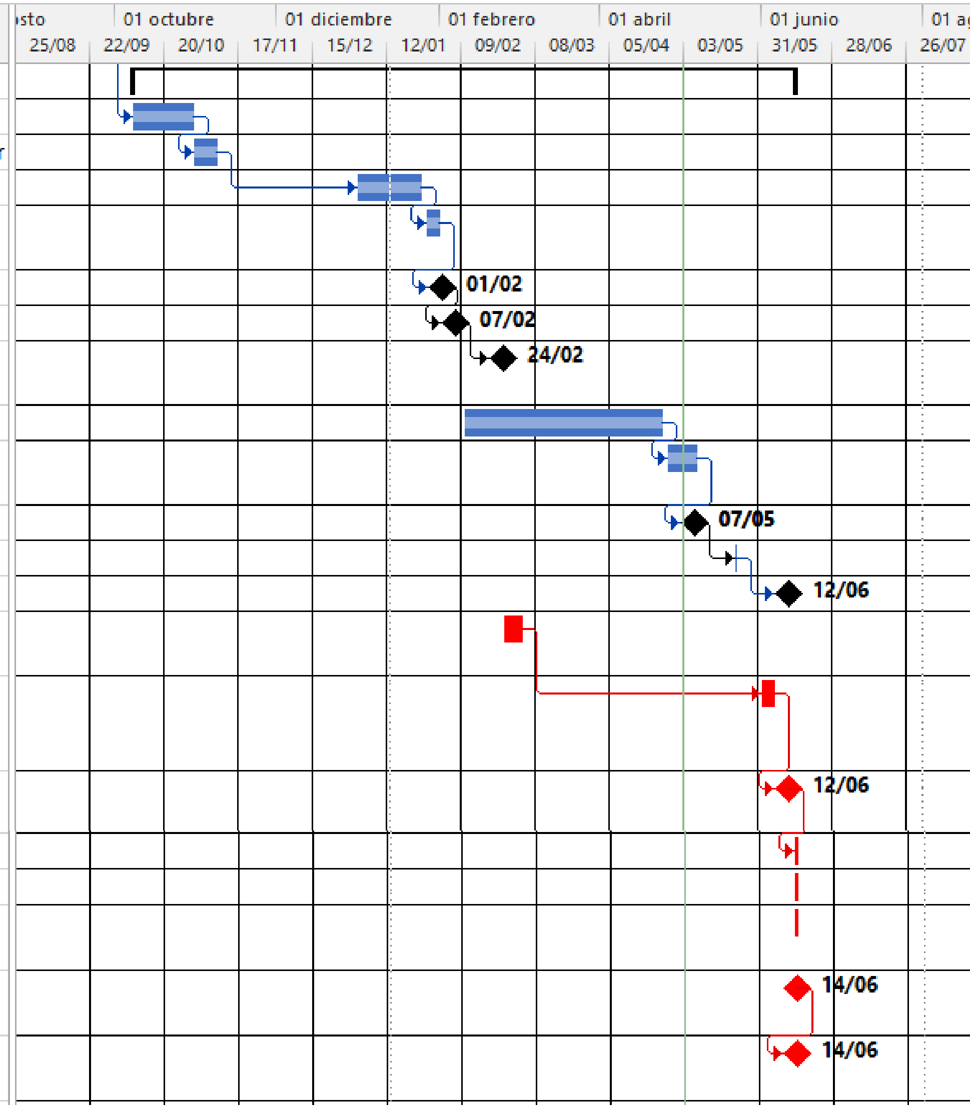


Symbol	Meaning
Activity	
Activity cancelled	
SARS-CoV-2	*
Milestone	
Resume	
Progress	

*All the period of this activity means that the team could not work in the same space or in the school's laboratories for respect the recommendations of our government, instead each member made the possible to complete each activity in time and form.

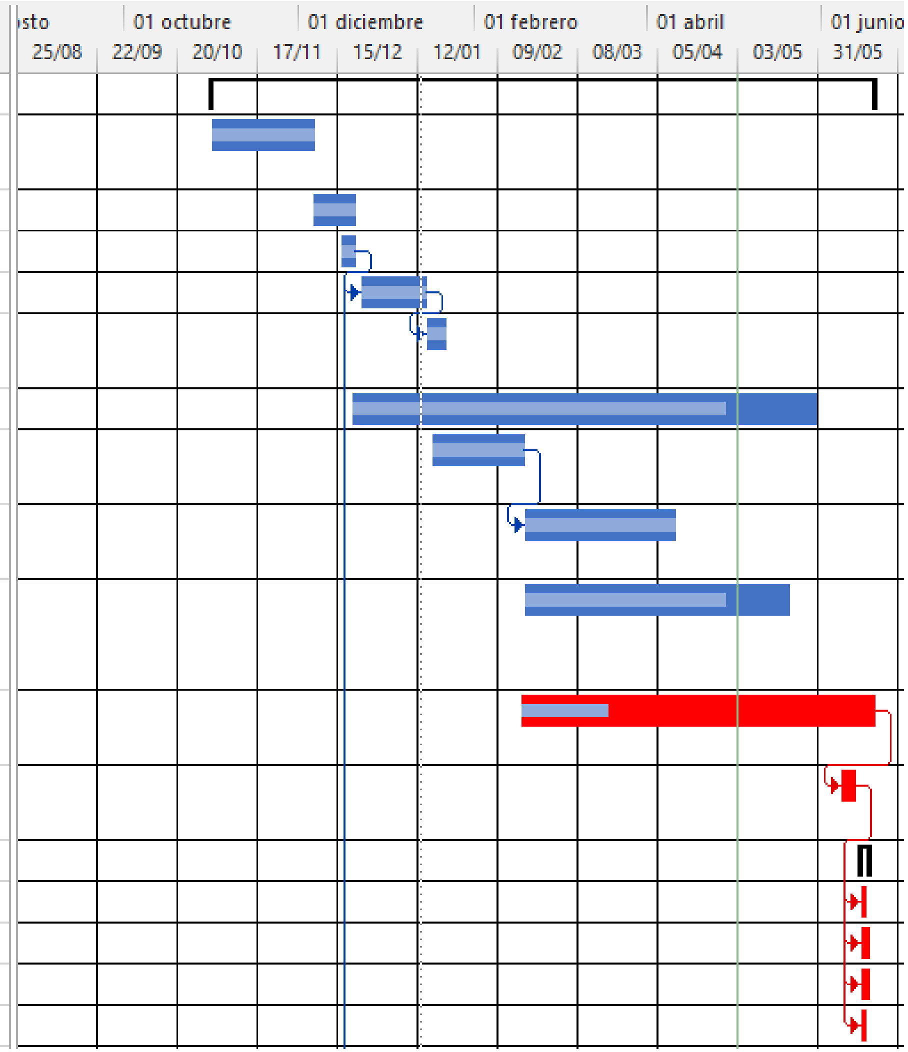
Detailed Program Schedule (2/6)

	Activity	Start	End	Progres	Assignment
15	**CanSat competition**	**08/10/2019**	**14/06/2020**	**89%**	
16	Team application	08/10/2019	30/10/2019	100%	Marco
17	Payment	31/10/2019	08/11/2019	100%	Faculty Advisor
18	Integration of PDR	01/01/2020	24/01/2020	100%	Team Thor
19	Review and corrections of PDR	27/01/2020	31/01/2020	100%	Team Thor
20	Delivery of PDR	01/02/2020	01/02/2020	100%	Marco
21	PDR slides via telecon	07/02/2020	07/02/2020	0%	Team Thor
22	Review of PDR's scoresheet	24/02/2020	24/02/2020	0%	Team Thor
23	Integration of CDR	10/02/2020	24/04/2020	100%	Team Thor
24	Review and corrections of CDR	27/04/2020	07/05/2020	100%	Team Thor
25	Delivery of CDR	07/05/2020	07/05/2020	0%	Marco
26	CDR slides via telecon	22/05/2020	22/05/2020	0%	Team Thor
27	FFR	12/06/2020	12/06/2020	0%	Team Thor
28	Integration of mission operation manual	25/02/2020	02/03/2020	0%	Jorge
29	Review and correction of mission operation manual	01/06/2020	05/06/2020	0%	Marco, Alejandro, Aldo and
30	Mission Operation Manual	12/06/2020	12/06/2020	0%	Jorge
31	Launch operation	13/06/2020	13/06/2020	0%	Team Thor
32	Integration fo PFR	13/06/2020	13/06/2020	0%	Team Thor
33	Review and corrections fo PFR	13/06/2020	13/06/2020	0%	Team Thor
34	Delivery of PFR	14/06/2020	14/06/2020	0%	Marco
35	PFR presentation	14/06/2020	14/06/2020	0%	Yaoctzin, Aldo, Rodolfo



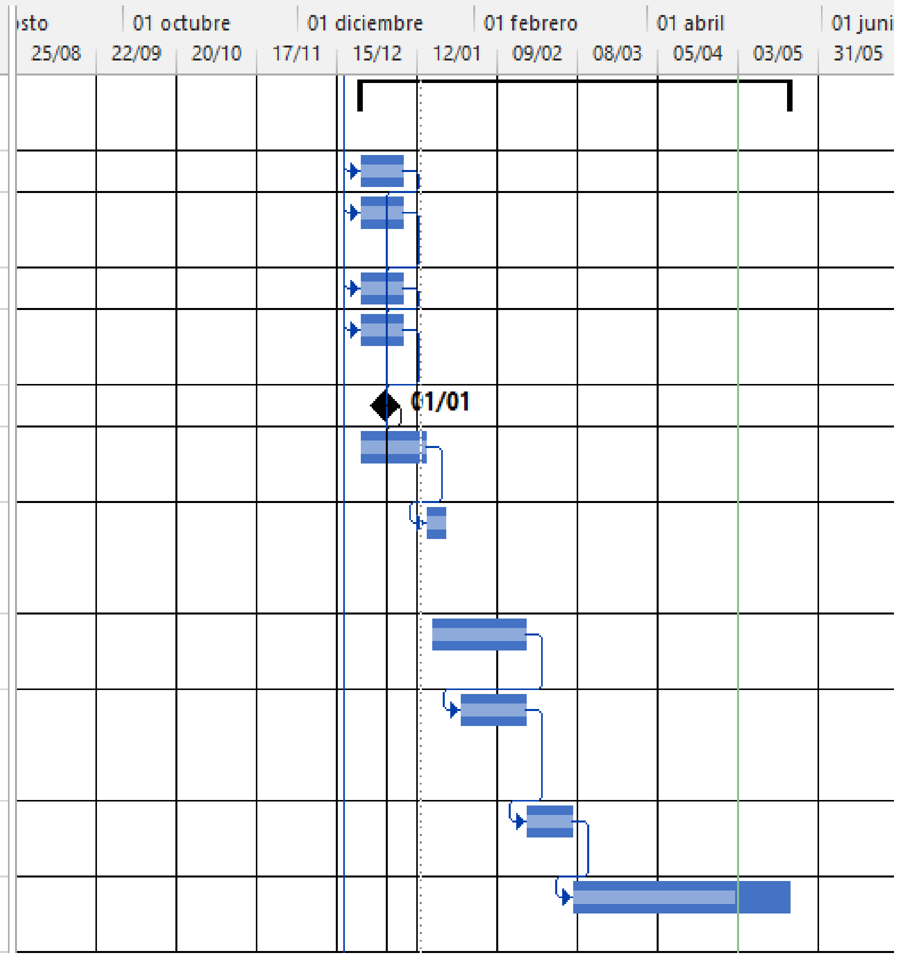
Detailed Program Schedule (3/6)

	Activity	Start	End	Progres	Assignment
36	**Mission**	**01/11/2019**	**19/06/2020**	**70%**	
37	Understanding the mission guide	01/11/2019	06/12/2019	100%	Team Thor
38	Reasearch	06/12/2019	20/12/2019	100%	Team Thor
39	Conceptual design	16/12/2019	20/12/2019	100%	Team Thor
40	Detailed design	23/12/2019	14/01/2020	100%	Team Thor
41	Validation of the design	15/01/2020	21/01/2020	100%	Team Thor
42	Material Order	20/12/2019	29/05/2020	80%	Marco
43	Prototype construction	17/01/2020	17/02/2020	100%	Team Thor
44	Verification prototype	18/02/2020	10/04/2020	100%	Team Thor
45	Redesign and optimization of protype	18/02/2020	20/05/2020	75%	Team Thor
46	Final prototype construction	17/02/2020	19/06/2020	25%	Team Thor
47	Verification final protype	08/06/2020	12/06/2020	0%	Team Thor
48	**Enviromental test**	**15/06/2020**	**17/06/2020**	**0%**	
49	drop test	15/06/2020	16/06/2020	0%	Team Thor
50	thermal test	15/06/2020	17/06/2020	0%	Team Thor
51	vibration test	15/06/2020	17/06/2020	0%	Team Thor
52	fit check	15/06/2020	16/06/2020	0%	Team Thor



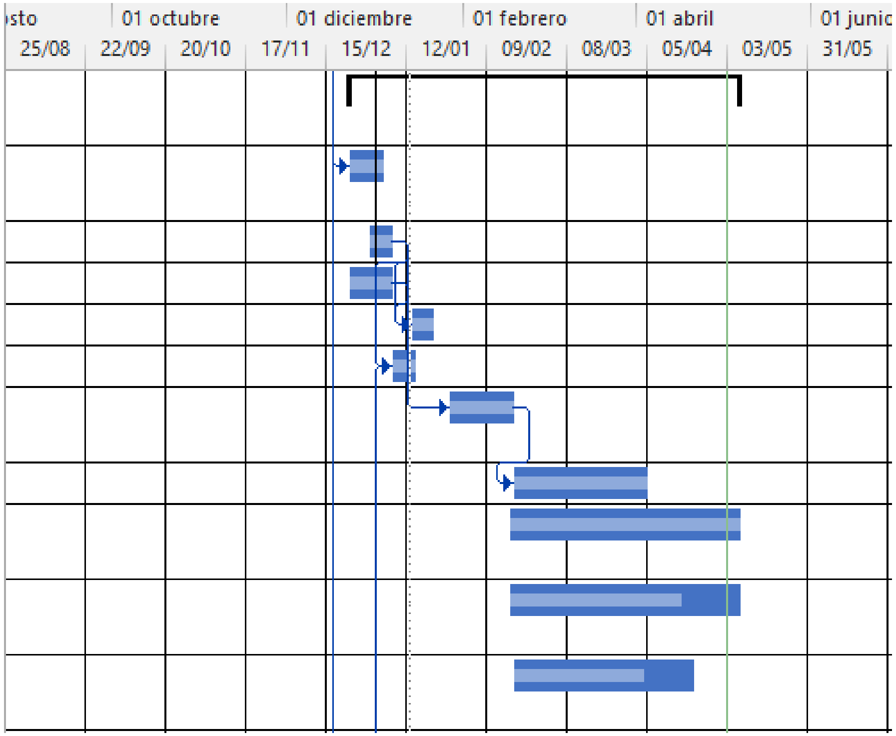
Detailed Program Schedule (4/6)

	Activity	Start	End	Progres	Assignment
53	**Mechanical structure & descent control**	**23/12/2019**	**20/05/2020**	**92%**	
54	design container	23/12/2019	06/01/2020	100%	Yaoctzin
55	design decoupling mechanism	23/12/2019	06/01/2020	100%	Saul
56	design delta glider	23/12/2019	06/01/2020	100%	Saul
57	design descent control	23/12/2019	06/01/2020	100%	Rafael
58	design bonus camera	01/01/2020	01/01/2020	100%	Yaoctzin
59	Create the computer model	23/12/2019	14/01/2020	100%	Yaoctzin, Saul
60	Simulation and validation of the model	15/01/2020	21/01/2020	100%	Rafael
61	Print the first 3D models	17/01/2020	18/02/2020	100%	Saul
62	Asembling and integration of the prototype	27/01/2020	18/02/2020	100%	Yaoctzin, Saul, Rafael
63	Mechanical and descent verification	19/02/2020	05/03/2020	100%	Alejandro
64	Redesign and optimization	06/03/2020	20/05/2020	75%	Yaoctzin, Saul, Rafael and



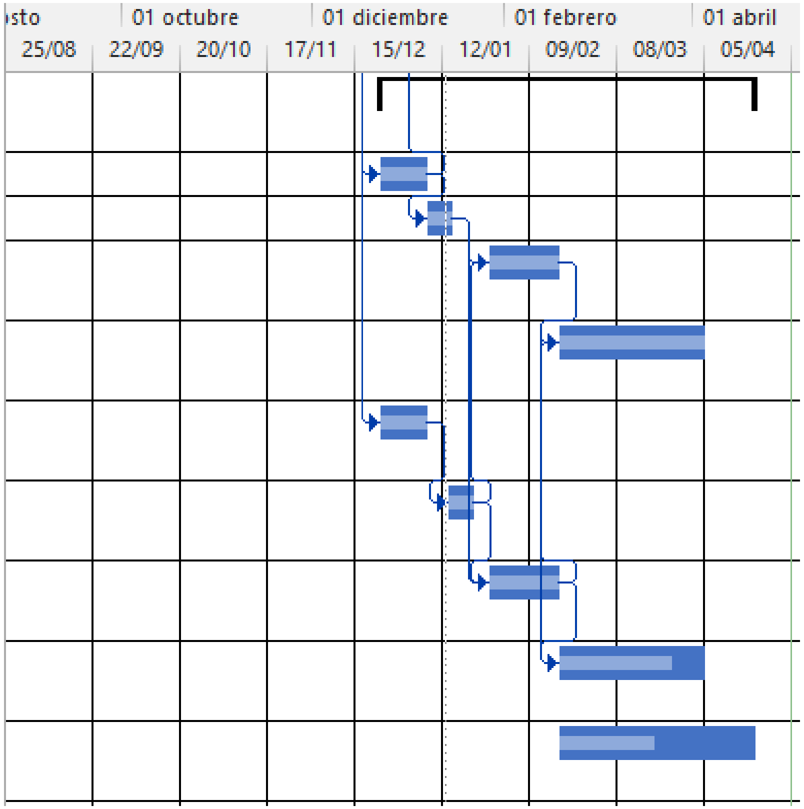
Detailed Program Schedule (5/6)

	Activity	Start	End	Progres	Assignment
65	**Electrical components & software design**	**23/12/2019**	**06/05/2020**	**90%**	
66	Sensor selection	23/12/2019	03/01/2020	100%	Richmond, Jorge
67	electronic design	30/12/2019	06/01/2020	100%	Richmond
68	Control design	23/12/2019	06/01/2020	100%	Aldo
69	Validation design	14/01/2020	20/01/2020	100%	Marco
70	energy selection	07/01/2020	14/01/2020	100%	Jorge
71	electronic construction	27/01/2020	17/02/2020	100%	Richmond, Jorge
72	electronic verification	18/02/2020	04/04/2020	100%	Marco
73	state machine programming	17/02/2020	06/05/2020	100%	Aldo
74	state machine verification	17/02/2020	06/05/2020	75%	marco
75	redesign and optimization	18/02/2020	20/04/2020	75%	Aldo, Richmond,



Detailed Program Schedule (6/6)

	Activity	Start	End	Progres	Assignment
76	**Ground station and telemetry**	**23/12/2019**	**20/04/2020**	**83%**	
77	Comunication design	23/12/2019	06/01/2020	100%	Jessica
78	Validation design	07/01/2020	14/01/2020	100%	Rodolfo
79	Comunication construction	27/01/2020	17/02/2020	100%	Jessica
80	Verification comunication	18/02/2020	04/04/2020	100%	Rodolfo
81	Ground control system design	23/12/2019	06/01/2020	100%	Jessica
82	Validation design ground station	14/01/2020	21/01/2020	100%	Rodolfo
83	Ground station construction	27/01/2020	17/02/2020	100%	Jessica
84	Ground station verification	18/02/2020	04/04/2020	75%	Rodolfo
85	Redesign and optimization	18/02/2020	20/04/2020	50%	Rodolfo and Jessica



Shipping and Transportation

Everything necessary would have been transported with us.

Carry-on baggage

To transport the CanSat we will use an aluminum briefcase with Polyurethane foam to avoid damages in the flight. The briefcase will be part of the luggage of the team.

The tools and equipment will be transported in one polypropylene suitcase, if we need fragile equipment, we will use the Polyurethane foam to protect it.

Checked baggage

Conclusions (Telemetry testing and preliminary results)

To test communication between the Ground Station and the Payload, the payload was mounted on a quadcopter.

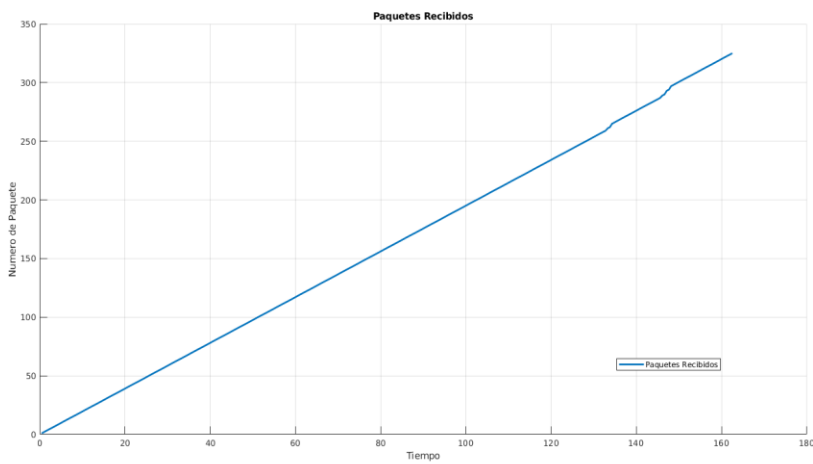
A member holding the GCS antenna, pointing towards to the drone.

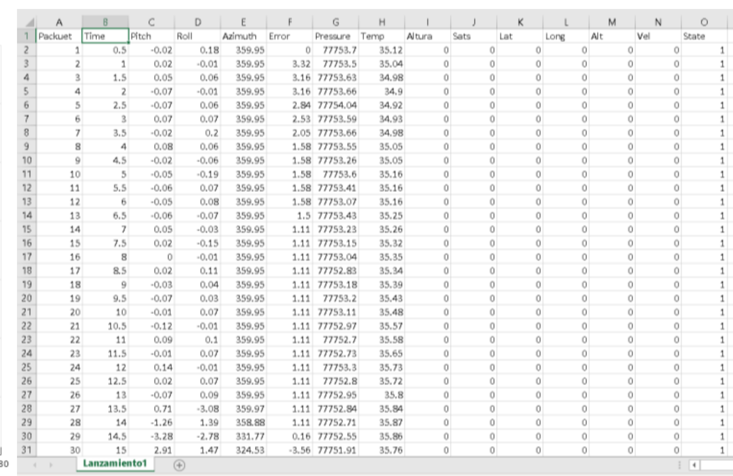
Drone trajectory/ waypoints definition.

Drone with the payload.

The GUI and communications were tested at an altitude of more than 160 meters and a distance about 20 meters from the BS to the launch site.

During T time mission, were sent 325 packets and 317 packets arrived successfully. So our successful packet percentage was 97.53% as the graphic shows, which was obtained from the .csv file generated by the GCS.





	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Packuet	Time	Pitch	Roll	Azimuth	Error	Pressure	Temp	Altura	Sats	Lat	Long	Alt	Vel	State
2	1	0.5	-0.02	0.18	359.95	0	77753.7	35.12	0	0	0	0	0	0	1
3	2	1	0.02	-0.01	359.95	3.32	77753.5	35.04	0	0	0	0	0	0	1
4	3	1.5	0.05	0.06	359.95	3.16	77753.63	34.98	0	0	0	0	0	0	1
5	4	2	-0.07	-0.01	359.95	3.16	77753.66	34.9	0	0	0	0	0	0	1
6	5	2.5	-0.07	0.06	359.95	2.84	77754.04	34.92	0	0	0	0	0	0	1
7	6	3	0.07	0.07	359.95	2.53	77753.59	34.93	0	0	0	0	0	0	1
8	7	3.5	-0.02	0.2	359.95	2.05	77753.66	34.98	0	0	0	0	0	0	1
9	8	4	0.08	0.06	359.95	1.58	77753.55	35.05	0	0	0	0	0	0	1
10	9	4.5	-0.02	-0.06	359.95	1.58	77753.26	35.05	0	0	0	0	0	0	1
11	10	5	-0.05	-0.19	359.95	1.58	77753.6	35.16	0	0	0	0	0	0	1
12	11	5.5	-0.06	0.07	359.95	1.58	77753.41	35.16	0	0	0	0	0	0	1
13	12	6	-0.05	0.08	359.95	1.58	77753.07	35.16	0	0	0	0	0	0	1
14	13	6.5	-0.06	-0.07	359.95	1.5	77753.43	35.25	0	0	0	0	0	0	1
15	14	7	0.05	-0.03	359.95	1.11	77753.23	35.26	0	0	0	0	0	0	1
16	15	7.5	0.02	-0.15	359.95	1.11	77753.15	35.32	0	0	0	0	0	0	1
17	16	8	0	-0.01	359.95	1.11	77753.04	35.35	0	0	0	0	0	0	1
18	17	8.5	0.02	0.11	359.95	1.11	77752.83	35.34	0	0	0	0	0	0	1
19	18	9	-0.03	0.04	359.95	1.11	77753.18	35.39	0	0	0	0	0	0	1
20	19	9.5	-0.07	0.03	359.95	1.11	77753.2	35.43	0	0	0	0	0	0	1
21	20	10	-0.01	0.07	359.95	1.11	77753.11	35.48	0	0	0	0	0	0	1
22	21	10.5	-0.12	-0.01	359.95	1.11	77752.97	35.57	0	0	0	0	0	0	1
23	22	11	0.09	0.1	359.95	1.11	77752.7	35.58	0	0	0	0	0	0	1
24	23	11.5	-0.01	0.07	359.95	1.11	77752.73	35.65	0	0	0	0	0	0	1
25	24	12	0.14	-0.01	359.95	1.11	77753.3	35.73	0	0	0	0	0	0	1
26	25	12.5	0.02	0.07	359.95	1.11	77752.8	35.72	0	0	0	0	0	0	1
27	26	13	-0.07	0.09	359.95	1.11	77752.95	35.8	0	0	0	0	0	0	1
28	27	13.5	0.71	-3.08	359.97	1.11	77752.84	35.84	0	0	0	0	0	0	1
29	28	14	-1.26	1.39	358.88	1.11	77752.71	35.87	0	0	0	0	0	0	1
30	29	14.5	-3.28	-2.78	331.77	0.16	77752.55	35.86	0	0	0	0	0	0	1
31	30	15	2.91	1.47	324.53	-3.56	77751.91	35.76	0	0	0	0	0	0	1

Lanzamiento1

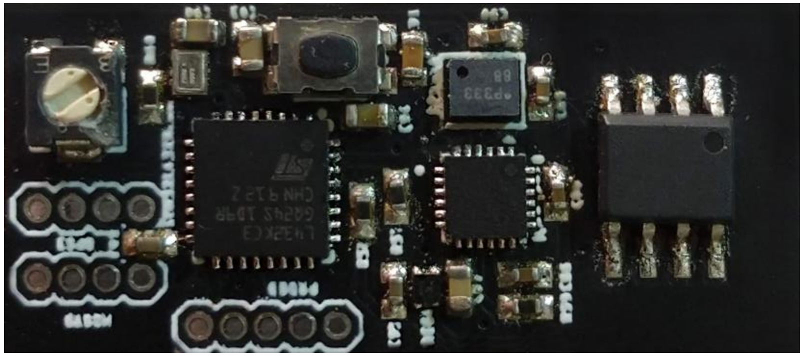
Conclusions (Sensor Board 1/2)

- **Sensor Board**

The design of a specific board for the processing of the sensor data has reduced the complexity of the code, reduced weight and increase reliability.

With a reduced complexity the system can monitor multiple tasks and in case of an unexpected reboot, it is able to return to the main program and self-calibrate with the onboard FRAM.

These boards have already passed over X hours of continuous usage, proving itself as a reliable method of data acquisition and processing



- **Data stream**

  The data is stream to the main board via a serial port, the information in this data stream has already been processed and can be directly written on the on board micro SD, this reduces the time taken by this task

```
-002.15,0001.06,0151.55,0030.92,078042.328,26.80,0000.000000,0000.000000,0000.00,000000.00,00
-001.95,0001.04,0151.55,0030.95,078042.070,26.90,0000.000000,0000.000000,0000.00,000000.00,00
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-002.14,0000.58,0151.50,0031.06,078041.031,27.15,0000.000000,0000.000000,0000.00,000000.00,00
-001.97,0001.12,0151.50,0031.02,078041.375,27.27,0000.000000,0000.000000,0000.00,000000.00,00
0-001.94,0001.02,0151.50,0031.01,078041.492,27.38,0000.000000,0000.000000,0000.00,000000.00,00
-002.03,0001.09,0151.50,0031.01,078041.461,27.39,0000.000000,0000.000000,0000.00,000000.00,00
-001.96,0000.87,0151.50,0031.00,078041.555,27.41,0000.000000,0000.000000,0000.00,000000.00,00
```
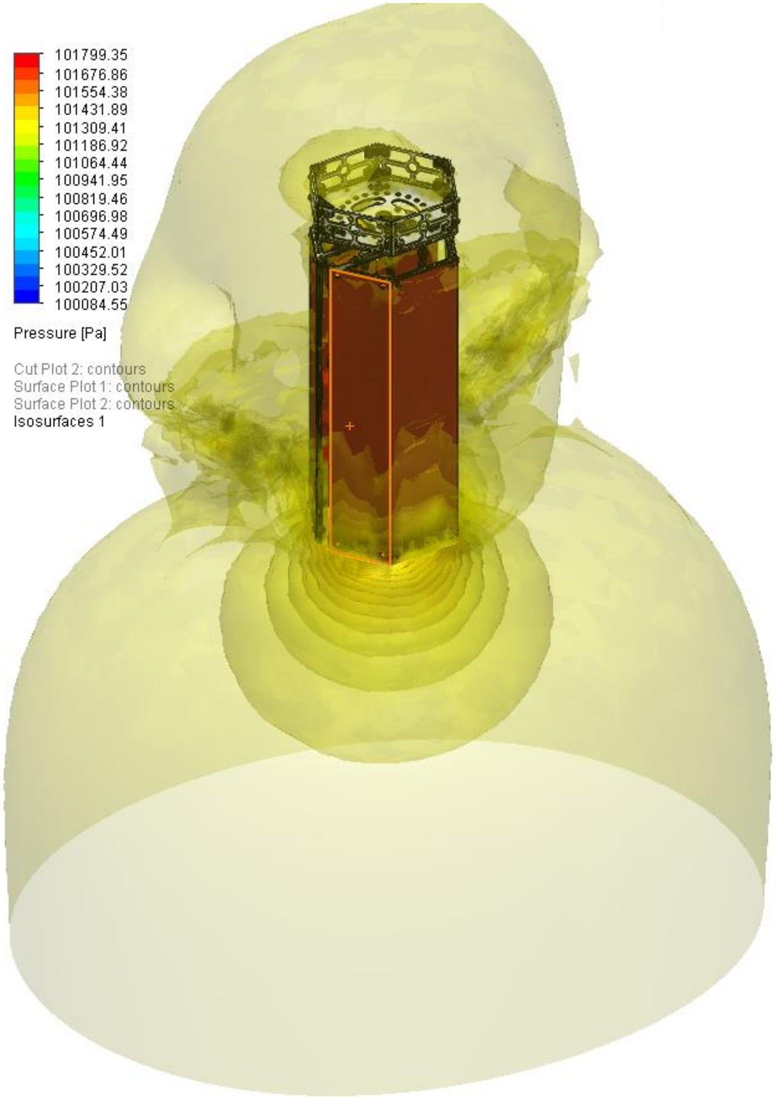

Conclusions (Descent Control 1/2)



In this section there are no changes, however it was possible to test the design using software.

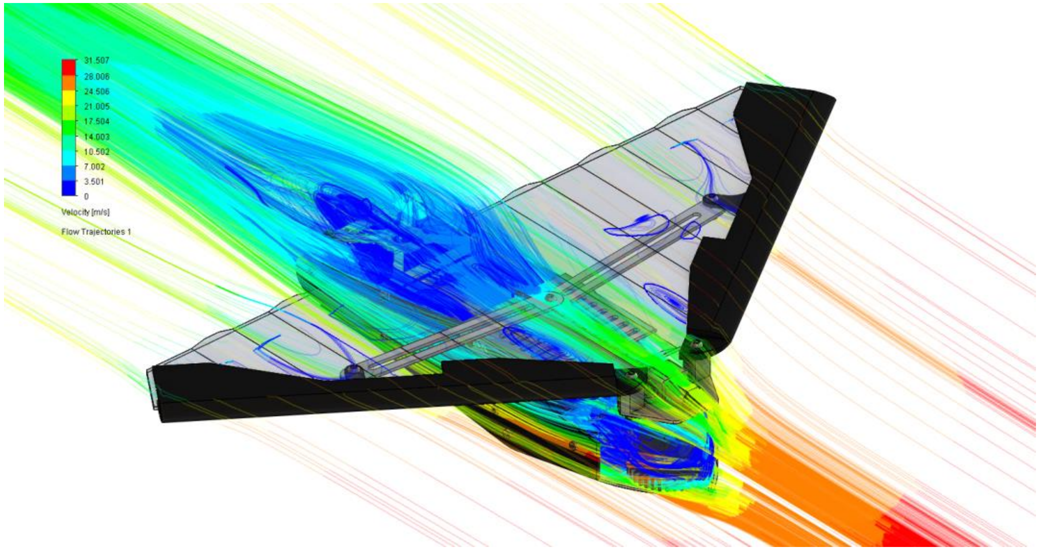
Due to the worldwide pandemic caused by the coronavirus the academic activities was suspended and the design has not been manufactured, therefore, the design of the container and the scientific payload could not be verified in real conditions of flight.

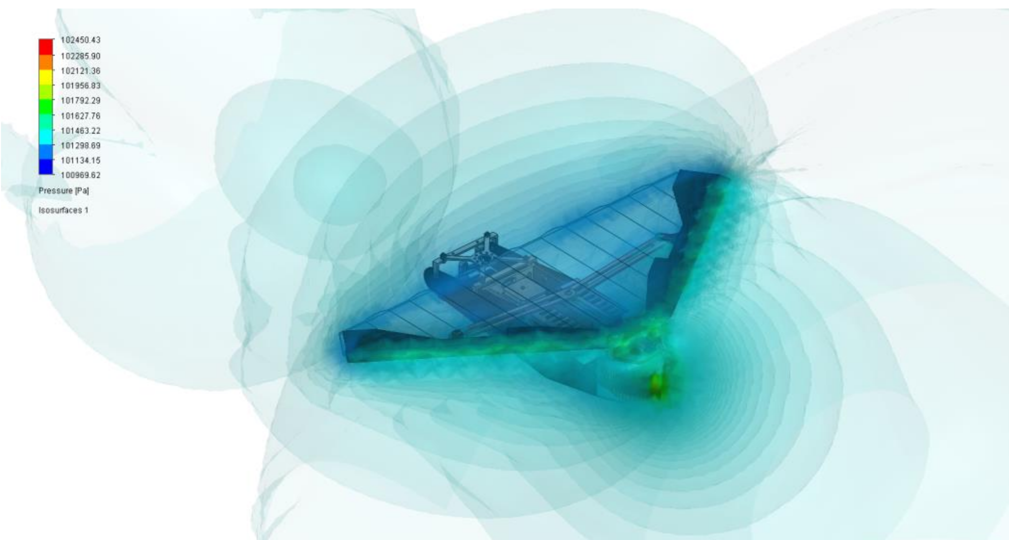
However, the design can be validated using software. The computational fluid dynamics of SolidWorks 2018® was used to know the behavior of the container design and the payload when they are found in a viscous medium (air). In the image is observed an Isosurface corresponding to the behavior of the pressure generated by the impact of the wind flow.

First, the container was subjected to a vertical wind speed of 16.950 $[\mathrm{m} \cdot \mathrm{s}^{-1}]$ to know the drag force generated by the geometry of the container, 0.995 [N], which differs by 0.45 [N] with the force considered for calculating the parachute initially (PDR design).

Being a small value, it was not considered a change in the dimensions of the parachute, but it allowed to ensure that the geometry of the container is important for calculations, and not neglect it as it is sometimes done.

Conclusions (Descent Control 2/2)





In the same way as the container, the design of payload was subjected to a fluid analysis in SolidWorks 2018®, in order to know the behavior of the design to subjected to a horizontal air flow with a speed of 28.350 $[\mathrm{m} \cdot \mathrm{s}^{-1}]$.

In the first image (from top to bottom) the interaction of the wind speed lines with the payload is presented, where it can observed that there are different speed values, being important those that are related to lift force.

On the other hand, in the second image the Isosurface of the pressure behavior is presented, where it can observed that the geometries where the pressure is concentrated are those related to the lift of the payload, and this pressure generates a force normal to the surface of the payload of 1.254 [N], which will oppose the weight of the scientific payload and allow a smooth descent.

Through fluid analysis, it was possible to validate device designs, ensuring that in real flight conditions the container and the payload will behave as desired.

Conclusions

Since the PDR we build a series of prototypes of the sensors module to test them in different personal test until obtain the final board, the mechanical system simulations shows the sustainability of the Payload finally the communications test shows a successful percentage at almost 100%.

Accomplishments

- The sensors were acquired, the new PCB was designed and manufactured. All sensors work correctly.
- The selected antennas was tested with successfully results.
- The simulations of the Delta wing shows that the pressure center is located correctly to have sustainability.
- The parachute opens and releases with the proposed system.
- The batteries were tested and can supply enough energy to the system.
- The Ground Station software can display the data in real time and save the necessary file.
- The simulations shows that the decoupling system frees the useful load without complications.
- The main board responsible for the most complex tasks during the development of the mission was being designed.

Unfinished Work

- Build the final PCB.
- Build the final protopype.

The tests realized to the subsystems shows that the communications are ready to the launch, the sensors are ready to be integrated to the main board and the data is obtained correctly, unfortunately the mechanical system just can made simulations but this shows that the proposed design is able to accomplish the mission.