CanSat 2023
Preliminary Design Review (PDR)
Outline
Version 1.0

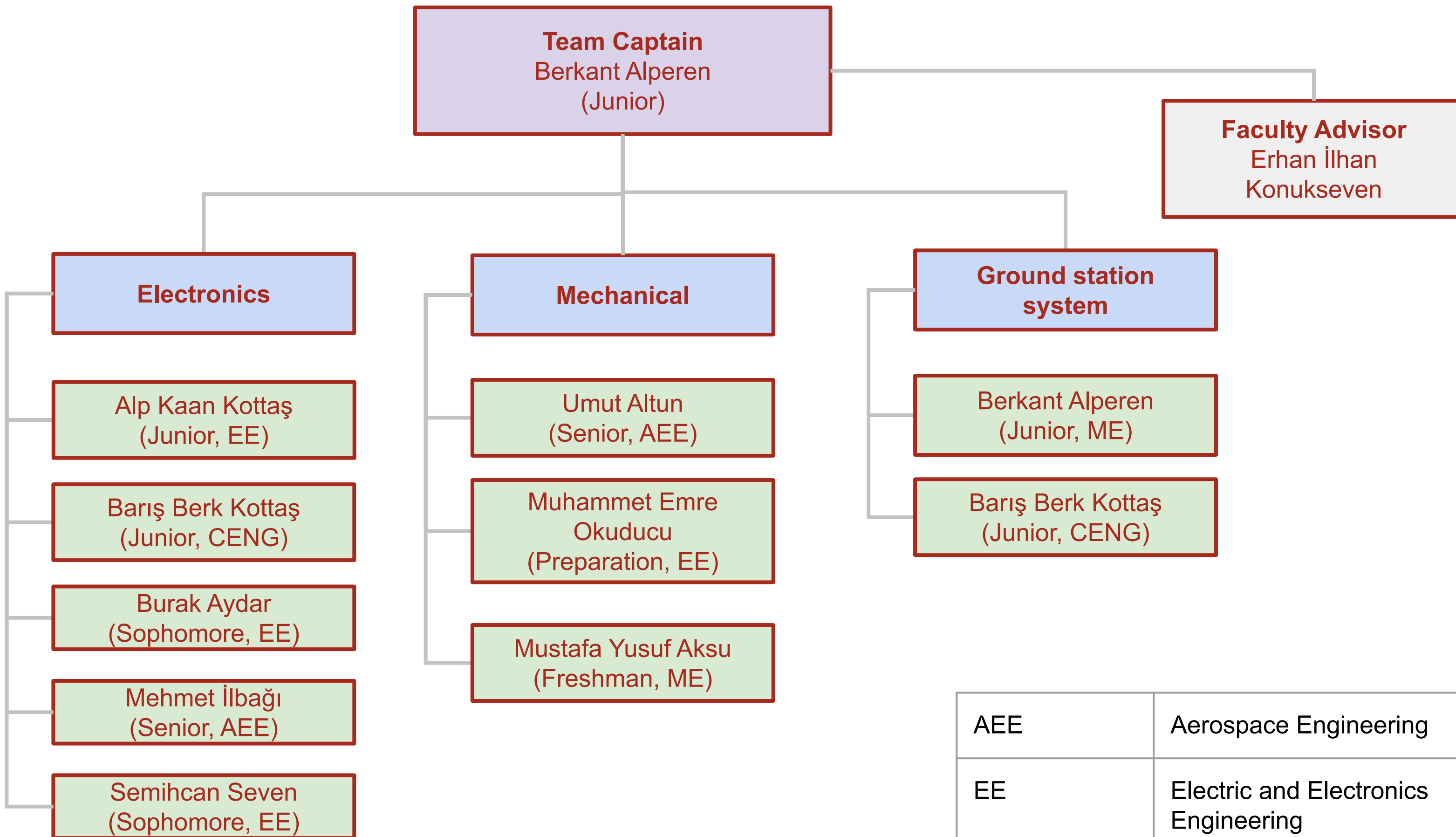
#1068

METUOR SPACE

Presentation Outline

Number	Contents	Presenter	Page No.
1.	Introduction	Berkant Alperen	1
2.	Systems Overview	B. Alperen, U. Altun, M. Y. Aksu	5
3.	Sensor Subsystem Design	Alp Kaan Kottas	31
4.	Descent Control Design	Emre Okuducu	40
5.	Mechanical Subsystem Design	Umut Altun, Mustafa Y. Aksu	60
6.	CDH Subsystem Design	A.Kottas, B. Aydar, B. Kottas	87
7.	Electrical Power Subsystem Design	Mehmet İlbağı	100
8.	Flight Software Design	Burak Aydar, Baris B. Kottas	106
9.	Ground Control System Design	Baris Kottas, Berkant Alperen	114
10.	CanSat Integration and Test	Umut Altun, Semihcan Seven	122
11.	Mission Operations & Analysis	Semihcan Seven	130
12.	Requirements Compliance	Berkant Alperen	136
13.	Management	Berkant Alperen	148

Team Organization



AEE	Aerospace Engineering
EE	Electric and Electronics Engineering
ME	Mechanical Engineering
CENG	Computer Engineering

Acronyms

GCS	Ground control system
CNC	Computer numerically controlled
COTS	Commercial off the shelf
GPS	Global positioning system
CONOPS	Concept of operation
FSW	Flight software subsystem
EPS	Electrical power subsystem
DCS	Descent control system

CW	Clockwise
CCW	Counterclockwise

GUI	Graphical user interface

ABS,PLA+,PTEG	3D printing materials

SPI	Serial peripheral interface
UART	Universal asynchronous receiver transmitter
ADC	Analog-to-digital converter
DC	Direct current
CDH	Communication and data handling
PCB	Printed circuit board
RTC	Real time clock

All SI Unit system

Systems Overview

Berkant Alperen, Umut Altun, Mustafa Yusuf Aksu

Mission Summary

Mission Objectives:

- Design a Cansat that shall consist of a container and a probe.
- The Cansat shall be launched to an altitude ranging from 670 meters to 725 meters above the launch site and deployed near apogee (peak altitude).
- The Cansat shall descend using a parachute at a rate of 15 m/s.
- At 500 meters, the Cansat shall release a probe that shall open a heat shield that will also be used as an aerobraking device with a descent rate of 20 meters/second or less.
- At 200 meters, the probe shall deploy a parachute and slow the descent rate to 5 meters/second.
- Once the probe has landed, it shall attempt to upright itself and raise a flag 500 mm above the base of the probe when the probe is in the upright position.
- A video camera shall be included and point toward the ground during descent.

Bonus Objectives (Attempted):

- A video camera shall be integrated into the container and point toward the probe. The camera shall record the event when the probe is released from the container. The video shall be recorded and retrieved when the container is retrieved.

  Rationale: We have enough space for the required avionics in our container and these avionics were also light enough to not exceed our mass budget so attempting the bonus objective was rational.

System Requirement Summary (1/10)

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

System Requirement Summary (2/10)

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

System Requirement Summary (3/10)

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

System Requirement Summary (4/10)

Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
24	The probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the cansat and in the stowed state.	Very High	Electronics		X		X
25	An audio beacon is required for the probe. It shall be powered after landing.	Very High	Electronics		X		X
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	High	Electronics		X		X
27	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	Very High	Electronics		X		
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Very High	Mechanical / Electronics		X		X
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Very High	Mechanical / Electronics		X		

System Requirement Summary (5/10)

Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
30	The Cansat shall operate during the environmental tests laid out in Section 3.5.	Very High	Mechanical / Electronics	X		X	
31	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Very High	Electronics	X		X	
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Very High	Mechanical / Electronics			X	X
33	The probe shall deploy a heat shield after leaving the container.	Very High	Mechanical / Electronics			X	X
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	Very High	Mechanical	X		X	
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/-1 m/sec.	Very High	Mechanical / Electronics			X	X

System Requirement Summary (6/10)

Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
36	Once landed, the probe shall upright itself.	Very High	Mechanical / Electronics			X	X
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	Very High	Mechanical / Electronics			X	X
38	The probe shall transmit telemetry once per second. .	Very High	Electronics	X		X	X
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	Very High	Electronics / GCS			X	X
40	The probe shall include a video camera pointing down to the ground.	Very High	Mechanical / Electronics		X		
41	The video camera shall record the flight of the probe from release to landing.	Very High	Electronics	X		X	

System Requirement Summary (7/10)

Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
42	The video camera shall record video in color and with a minimum resolution of 640x480.	Very High	Electronics			X	X
44	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Very High	Electronics	X		X	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss. .	Very High	Electronics	X		X	
46	The probe shall have its time set to within one second UTC time prior to launch.	High	Electronics		X	X	
47	The probe flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	Very High	Electronics / GCS		X	X	X

System Requirement Summary (8/10)

Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
48	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the payload altitude.	Very High	Electronics / GCS	X		X	
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Very High	Electronics / GCS		X	X	
50	The ground station shall command the Cansat to start calibrating the altitude to zero when the Cansat is on the launch pad prior to launch.	Very High	Electronics / GCS		X	X	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Very High	GCS		X	X	X
52	Telemetry shall include mission time with 1 second or better resolution.	High	Electronics		X	X	X
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Very High	Electronics			X	X

System Requirement Summary (9/10)

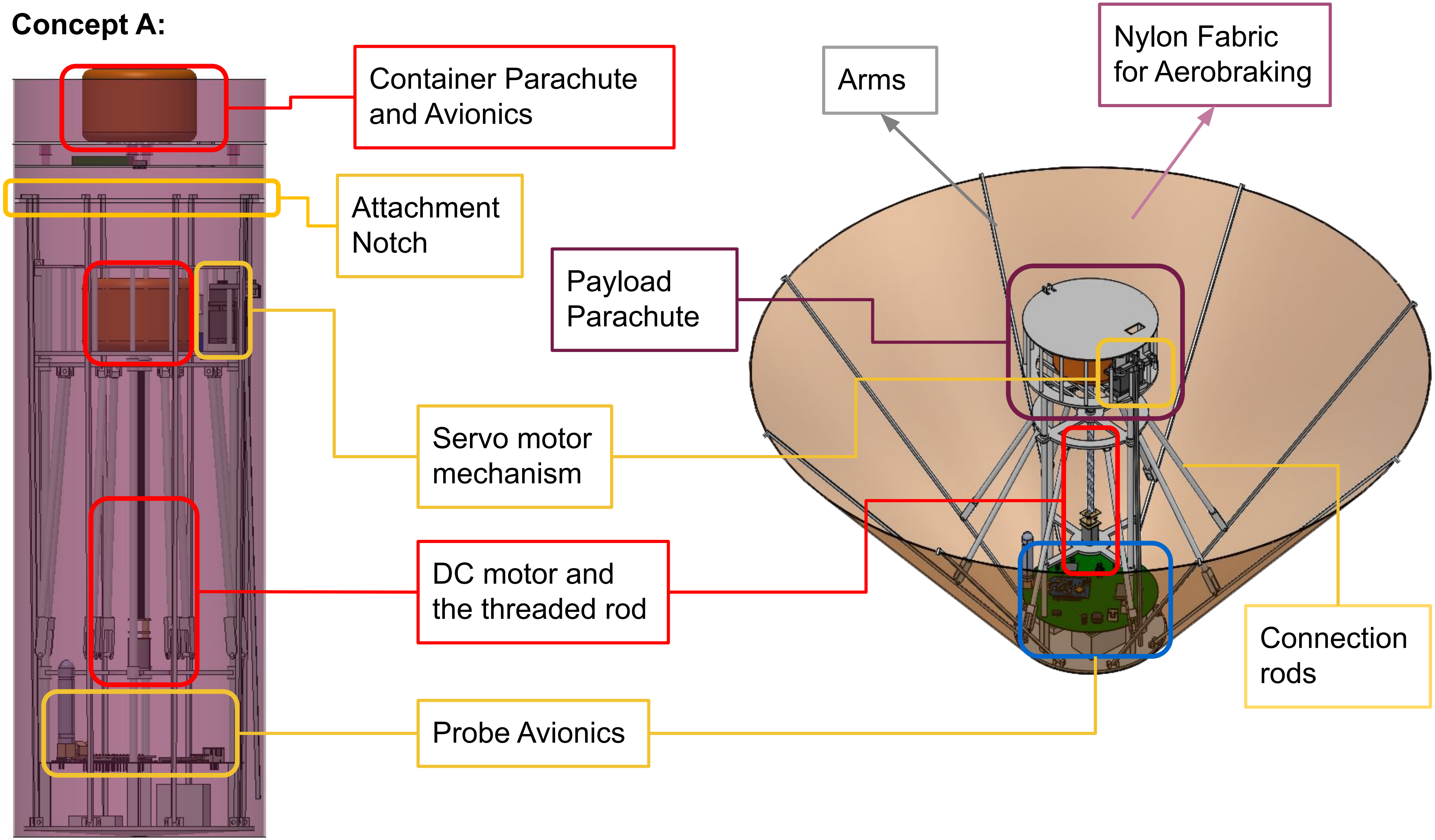
Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
54	Each team shall develop their own ground station.	Very High	GCS		X		X
55	All telemetry shall be displayed in real time during descent on the ground station.	Very High	GCS		X		X
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	High	GCS	X	X		
57	Teams shall plot each telemetry data field in real time during flight.	High	GCS		X	X	X
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	Very High	GCS	X	X		X
59	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	High	GCS				X

System Requirement Summary (10/10)

Number	Requirement	Priority	Subsystem	Verification			
				A	I	T	D
60	The ground station software shall be able to command the payload to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Very High	Electronics / GCS			X	X
61	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the cansat.	Very High	Electronics / GCS	X	X	X	

System Level CanSat Configuration Trade & Selection (1/4)

Concept A:

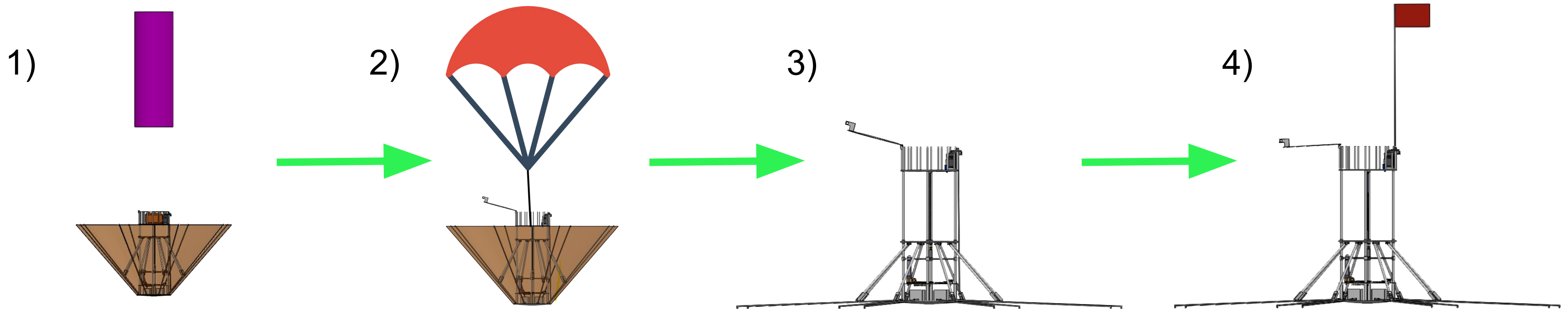


Main Features of Concept A:

- Three major operations; probe separation, aerobraking and uprighting are achieved with the use of a set of arms which are controlled by a DC motor, a threaded rod and a plate.
  As the plate moves up and down with motor control, the plate pulls and pushes the arms radially with the connection rods.
- A two stage servo motor mechanism is present at the top of the probe. The first stage movement of the servo motor initiates probe parachute deployment and when it moves to the second stage flag mast operation is accomplished.

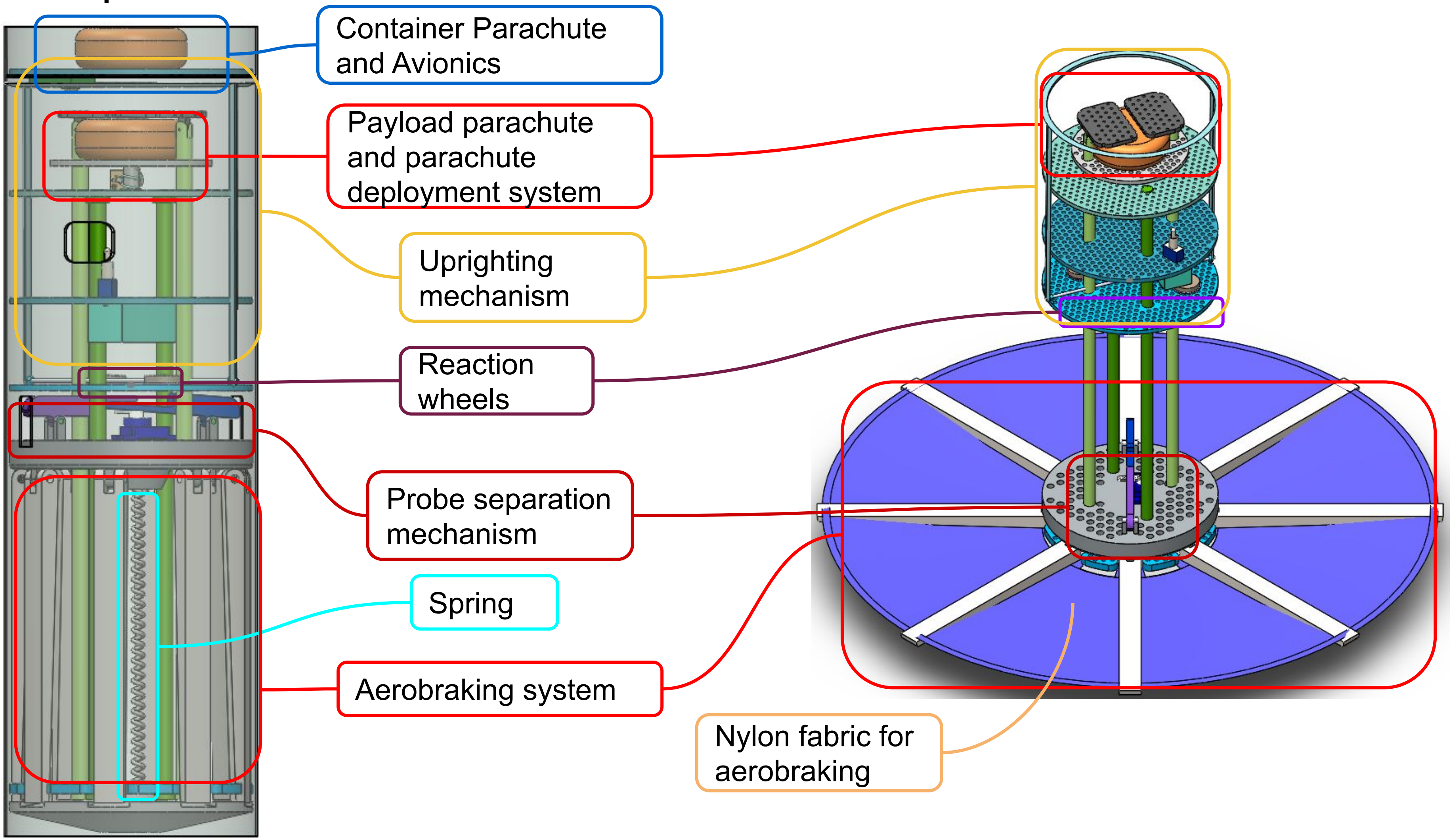
Summary of CONOPS:

1. At 500 m, the probe leaves the container by moving the plate up and retracting arms to an inner radius. After separation, the plate moves down by some length, enabling aerobraking.
2. At 200 m, the servo motor mechanism initiates first stage and releases the probe parachute.
3. After landing, the plate moves down and the arms push the probe in upright orientation.
4. Finally, the servo motor mechanism initiates second stage and releases a radial spring that raises the flag mast.



System Level CanSat Configuration Trade & Selection (3/4)

Concept B:



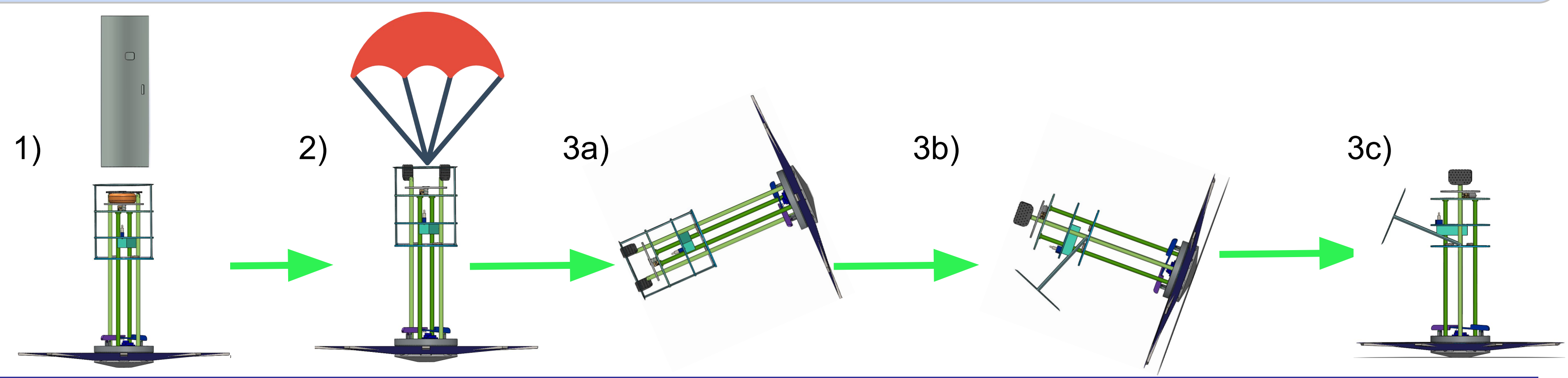
System Level CanSat Configuration Trade & Selection (4/4)

Main Features of Concept B:

- Three major operations; probe separation, aerobraking and uprighting, are achieved with the use of a set of arms which are enabled movable by a spring and air friction, a lock mechanism controlled by a servo motor and an uprighting lever controlled by another servo, respectively.
- The servo motor unlocks the lock mechanism and releases probe before the bottom plate is pulled by air resistance and the spring.
- Another spring and servo motor are present at the top of the probe, which initiates probe parachute deployment at the requested altitude.
- After landing, the uprighting mechanism uprights the probe.

Summary of CONOPS:

1. At 500 m, the probe leaves the container by unlocking the lock mechanism. After separation, the bottom plate is pulled by the spring and the help of air resistance, and enables aerobraking.
2. At 200 m, the servo motor rotates the lock of the probe parachute deployment system, and another spring releases the probe parachute.
3. After landing, in order to enable uprighting the probe, the uprighting lever is activated by the servo motor of the uprighting system, and the lever pushes the probe in an upright orientation.



System Level Configuration Selection

Selected Design: Concept A
The selected design has motorized conical heat shield that is stable due to its center of pressure being higher than its center of mass. At 500 meters, the probe is released from the container. Most of the container and payload is made of fiberglass, which is strong enough for the shock forces and sustained acceleration. We will not be using pyrotechnics or chemicals.

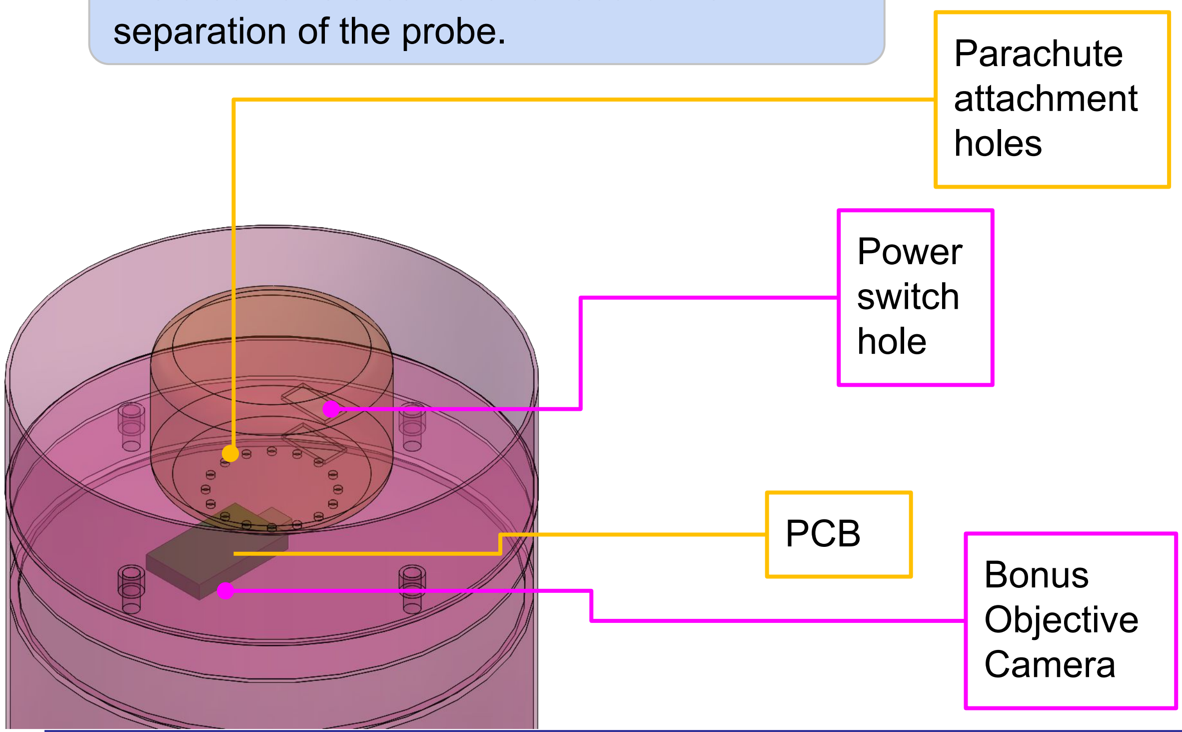
Pros	• Fully enclosed container • Lightweight probe design • Multifunctional Motors • Minimal Usage of electronics • Low center of mass • High center of aerodynamic pressure
Cons	• Fiberglass is hard to manufacture • Descent rates and motor torque

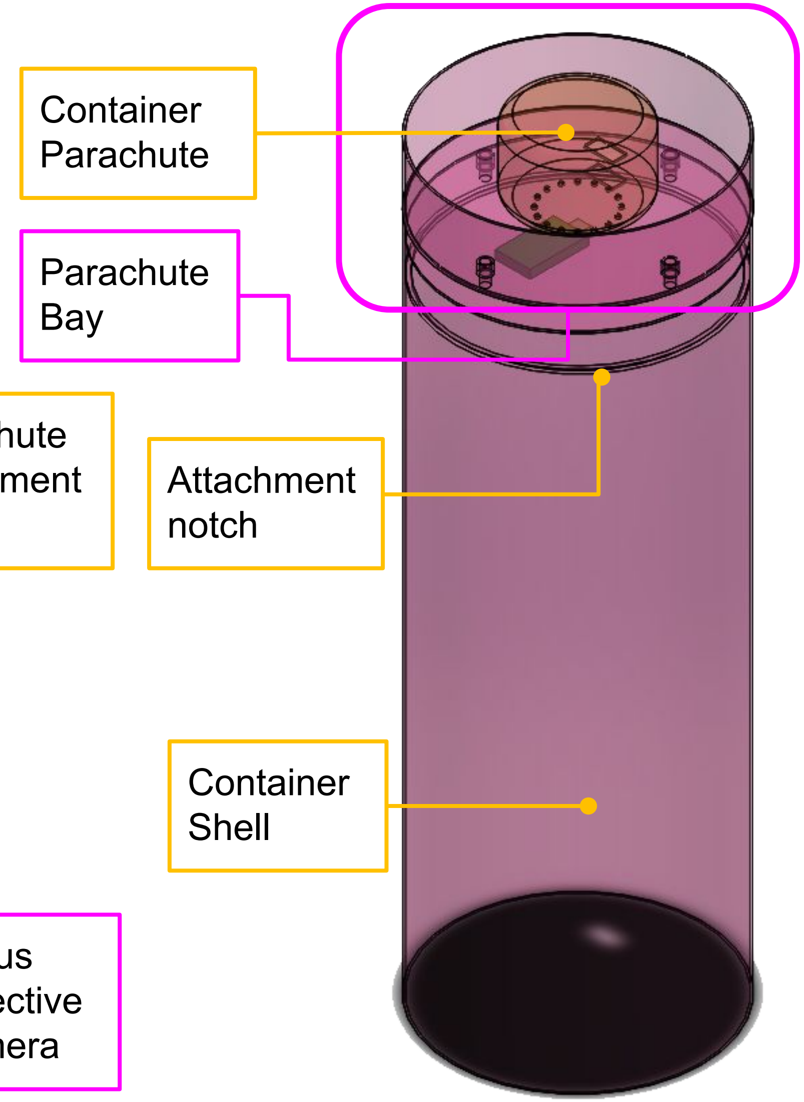
Summary: This design is far more reliable and lighter compared to our other design.

Physical Layout (1/5)

Container Layout

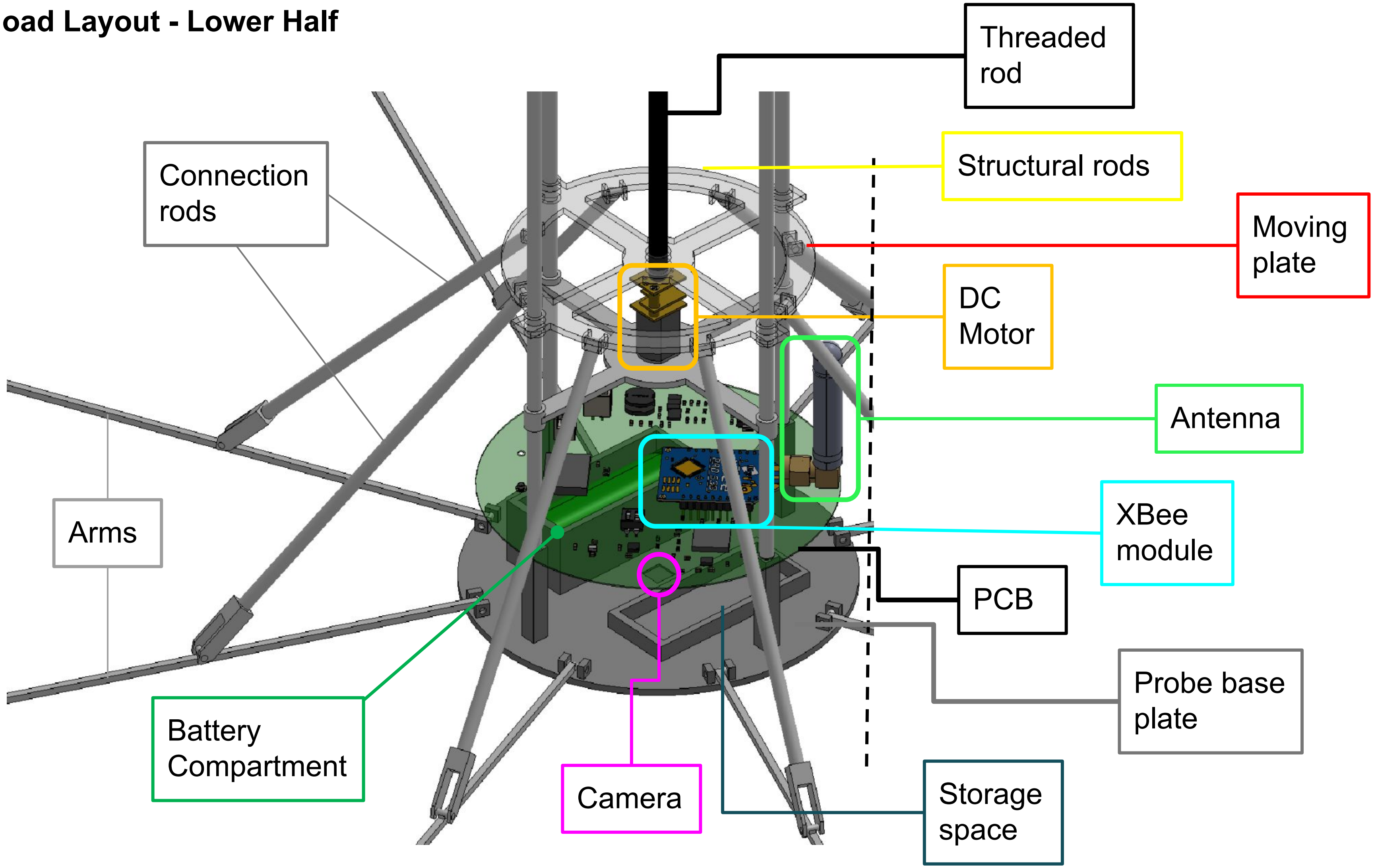
Our container fully encloses the probe, it features a hole that goes through the entire container for the power switches for the container and probe. It has a notch which is used to secure the probe to the container. We also have a camera to record the separation of the probe.





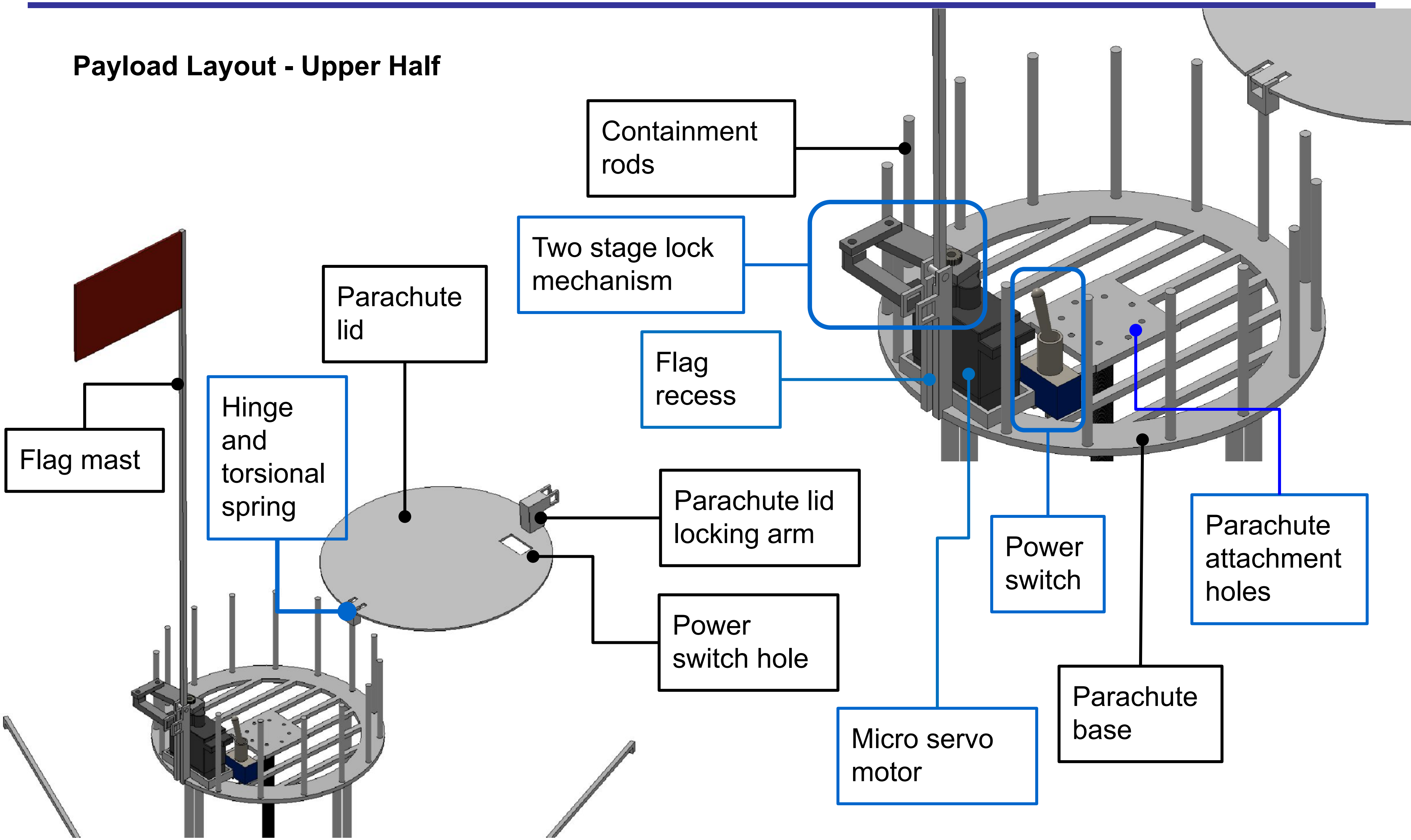
Physical Layout (2/5)

Payload Layout - Lower Half



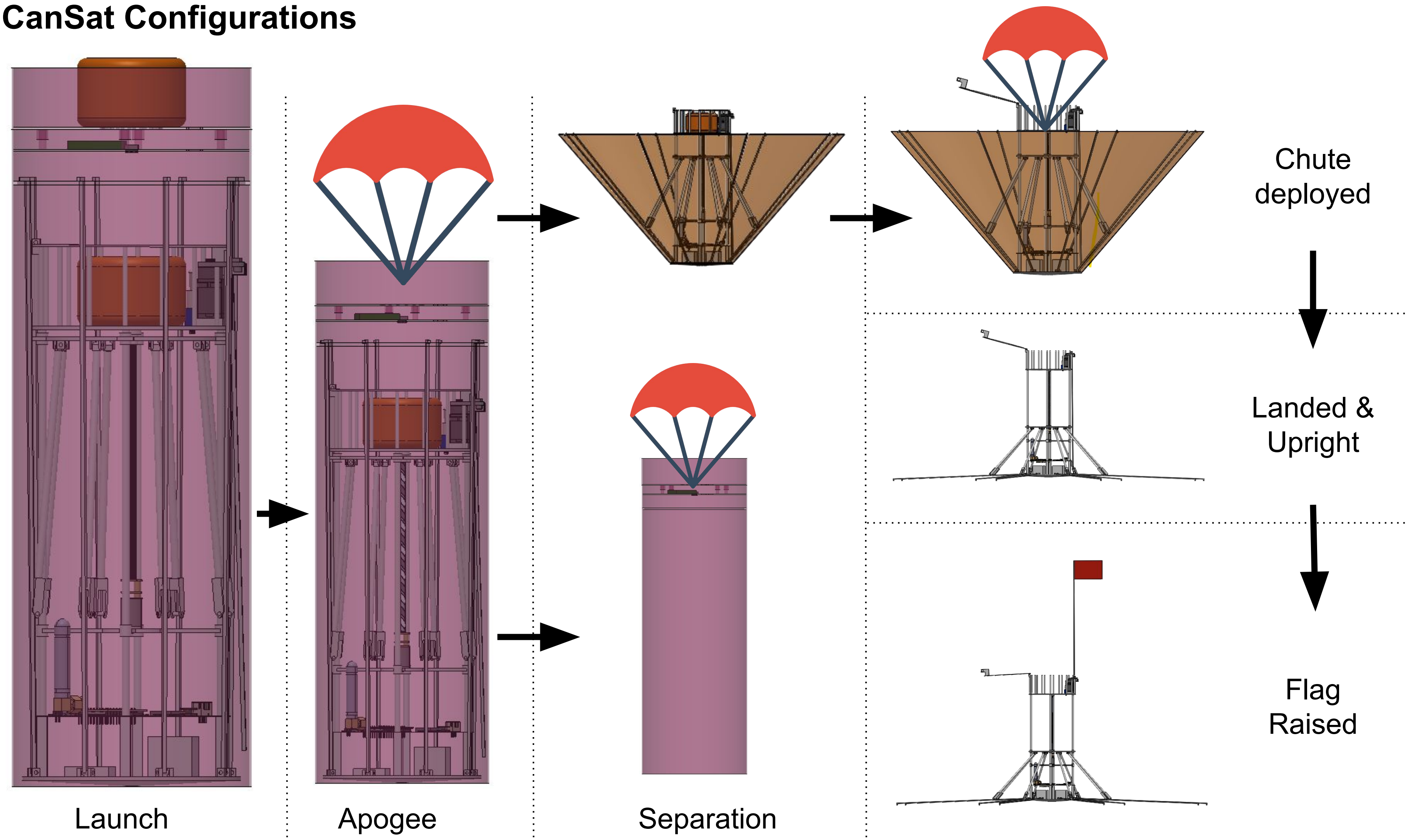
Physical Layout (3/5)

Payload Layout - Upper Half

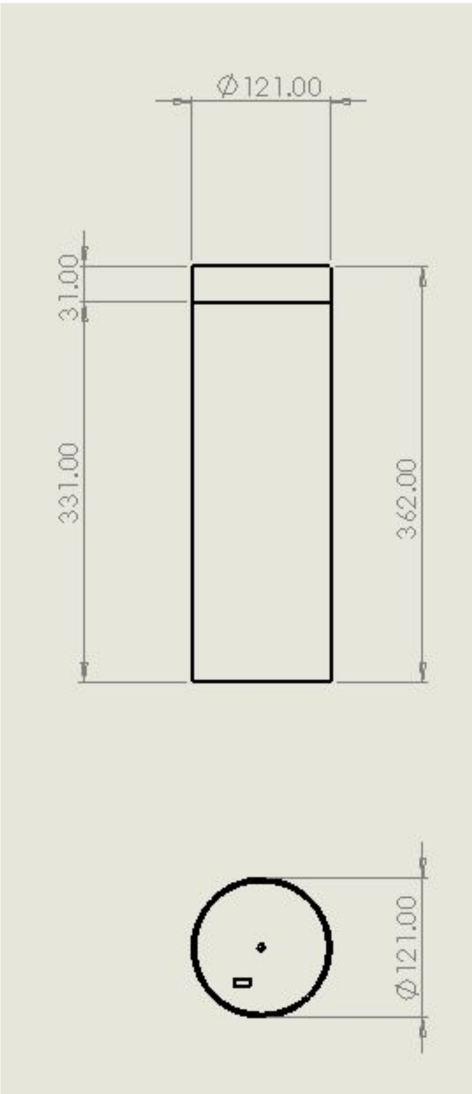


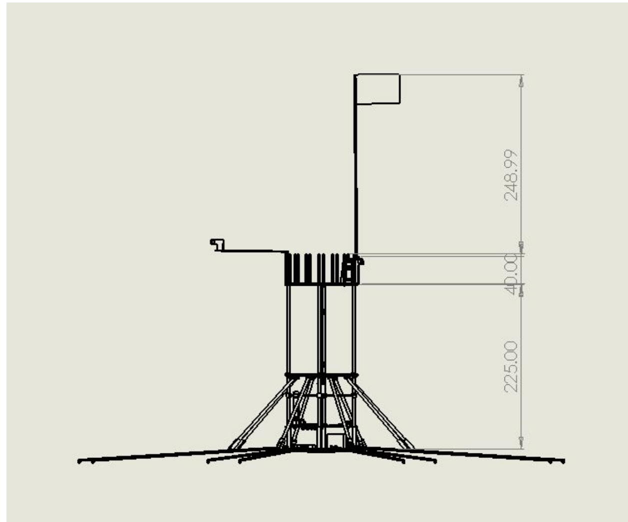
Physical Layout (4/5)

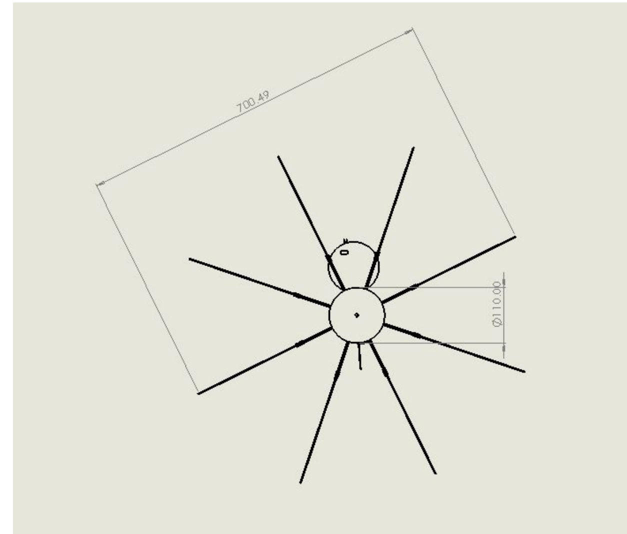
CanSat Configurations



Physical Layout (5/5)



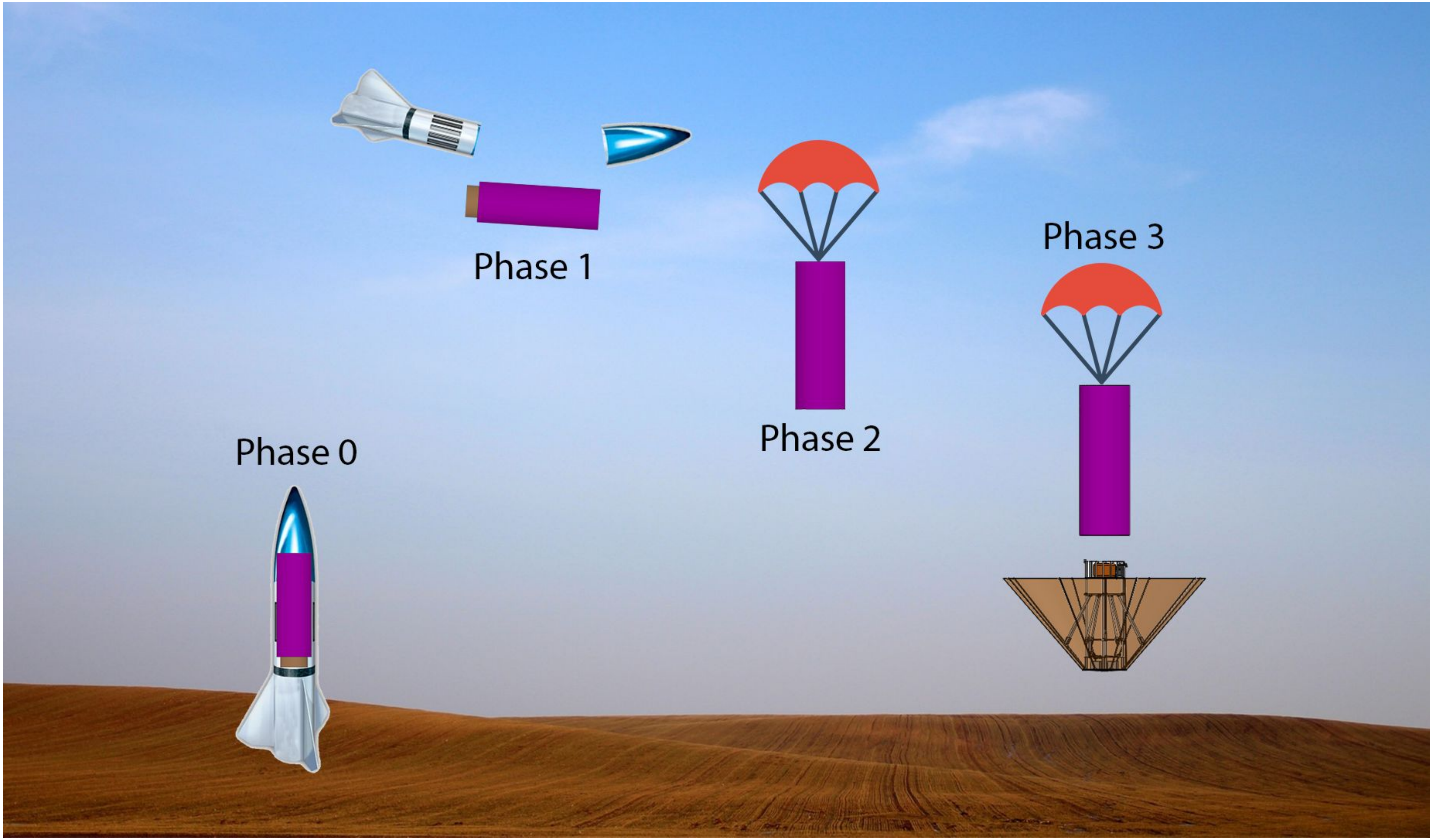




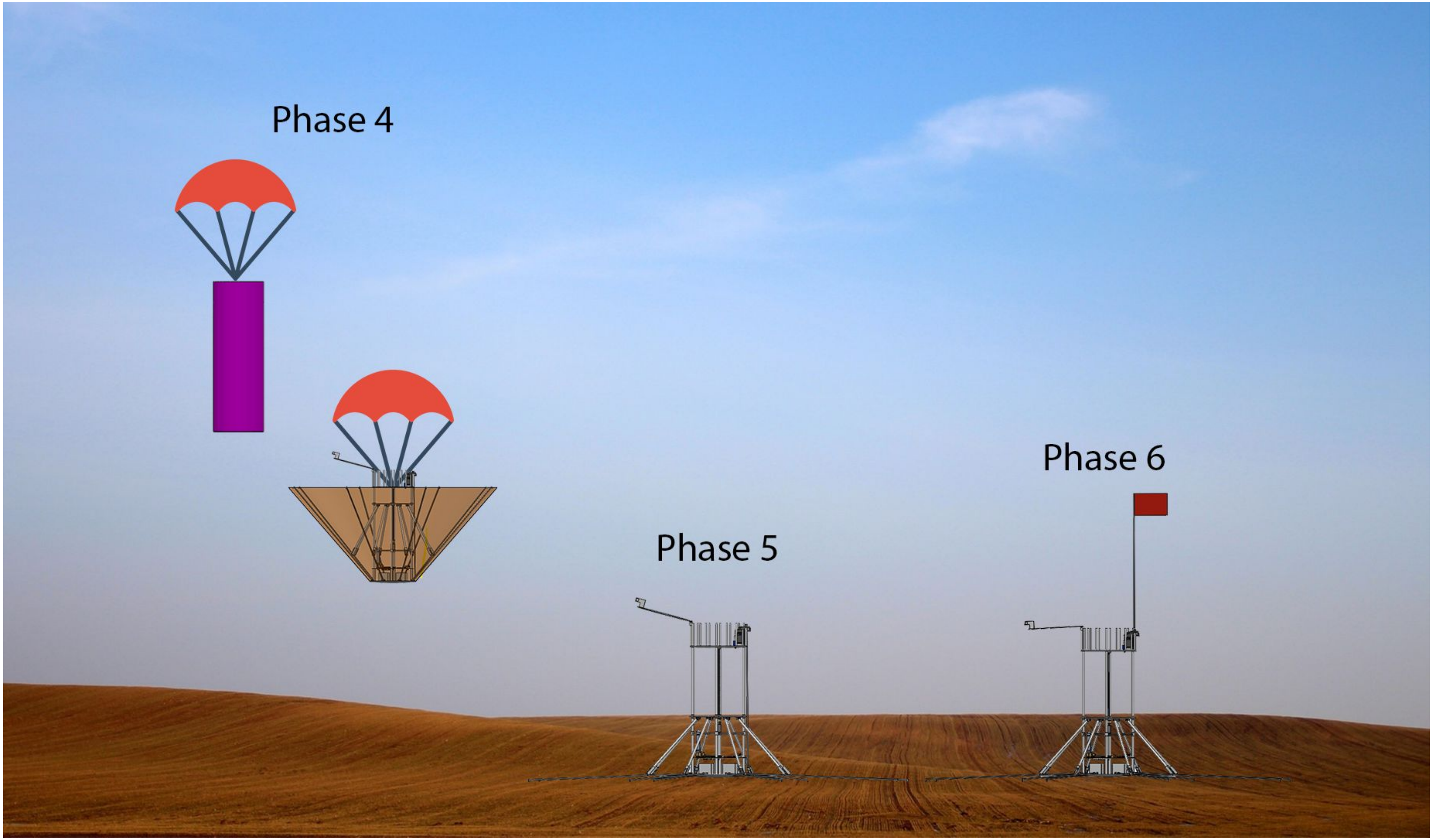
drawn in millimeters

- On the left: dimensions for the container
- On the middle height dimensions for the payload
- On the right, radial dimensions for the cansat

System Concept of Operations (1/3)



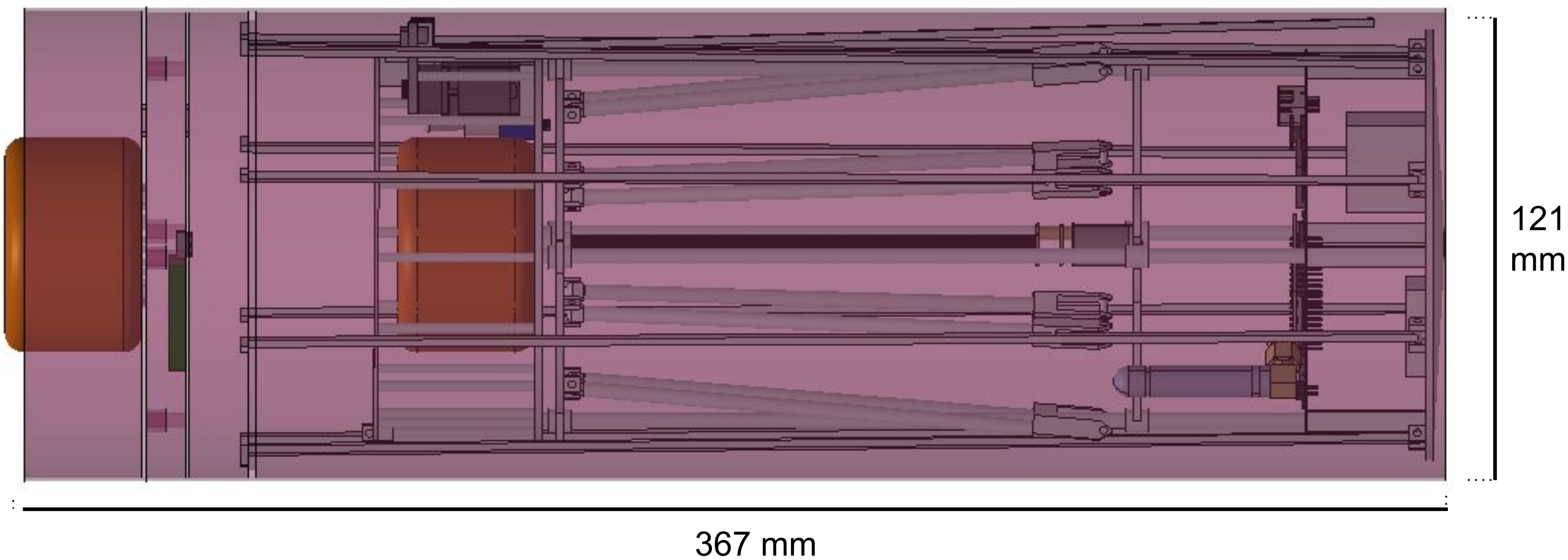
System Concept of Operations (2/3)



System Concept of Operations (3/3)

- **Phase 0 (Pre Launch):**
  - CanSat is turned on and GCS connection is established.
  - CanSat is placed in the rocket at launchpad.
  - Sensors are calibrated and data transmission begins.
- **Phase 1 (Apogee):**
  - CanSat is separated from the rocket and container parachute is deployed.
- **Phase 2 (Descent):**
  - CanSat starts to descend at a rate of 15 m/s.
- **Phase 3 (Separation and Aerobraking):**
  - At 500 meters, the probe is released from the container.
  - The container continues to descend separated from the probe.
  - The heat shield is initiated and the probe starts to descend at a rate of 20 m/s.
- **Phase 4 (Probe Parachute Deployment):**
  - At 200 meters, the probe deploys a parachute and slows it descent rate to 5 m/s.
- **Phase 5 (Landing and Upright Operation):**
  - The probe uprights itself after landing.
- **Phase 6 (Flag Mast Operation):**
  - The probe raises a flag 500 mm above its base.
- **Phase 7 (Recovery and Data Reduction):**
  - Audio beacon is turned on.
  - CanSat is recovered with the help of GPS data, audio beacon and fluorescent colors.
  - Data recovered are formatted and submitted.

Launch Vehicle Compatibility



	Envelope	Stowed Container	Clearance
Diameter (mm)	125	121	2 *(radially)*
Length (mm)	400	367	33

The CanSat is designed to have no protrusions and enough clearance to sit within the vehicle payload envelope in stowed configuration to enable safe deployment from the rocket.

Sensor Subsystem Design

Alp Kaan Kottas

Sensor Subsystem Overview

Sensors	Manufacturer	Functions
BMP280	Bosch Sensortec	- Measure the air pressure and temperature throughout the flight to determine altitude
STM32 Onboard ADC	STMicroelectronics	- Measure the battery voltage with a resistor voltage divider
MPU9250	Invensense	- Measure the acceleration, angular velocity, and magnetic field intensity in three mutually perpendicular axis - Obtain the orientation of the probe
NEO-M8N	u-blox	- Receive the geolocation and time data provided by the satellites - Track the location of the payload
3202 Mini Spy Camera	Adafruit	- Record the flight of the probe from release to landing - Record the probe when it is released

Payload Air Pressure Sensor Trade & Selection

Air Pressure Sensor	Resolution (mbar)	Operating Pressure Range (mbar)	Dimensions (mm)	Weight (g)	Cost ($)
BMP280	0.0016	300-1100	2.0 x 2.5 x 0.95	Negligible	2.30
BME280	0.0018	300-1100	2.5 x 2.5 x 0.93	Negligible	4.48
MS5611	0.012	450-1100	5.0 x 3.0 x 1.0	Negligible	8.06

Selected Sensor

BMP280

Reasons

- Better resolution
- Better operating range
- Cost and size advantages

Payload Air Temperature Sensor Trade & Selection

Air Pressure Sensor	Interface	Resolution (°C)	Operating Temperature Range (°C)	Dimensions (mm)	Weight (g)	Cost ($)
BMP280	I2C/SPI	0.01	-40 - +85	2.0 x 2.5 x 0.95	Negligible	2.30
BME280	I2C/SPI	0.01	-40 - +85	2.5 x 2.5 x 0.93	Negligible	4.48
MS5611	I2C/SPI	0.01	-40 - +85	5.0 x 3.0 x 1.0	Negligible	8.06

Selected Sensor

BMP280

Reasons

- Already chosen as pressure sensor
- Cost and size advantages

Payload Battery Voltage Sensor Trade & Selection

Voltage Sensor	Interface	Resolution (bits)	Dimensions (mm)	Weight (g)	Cost ($)
Onboard ADC (MCU) - Voltage Divider	Analog	12	N/A	N/A	N/A
ADS1100A	Analog	16	3.0 x 3.05 x 1.1	Negligible	3.45
MCP3221A	Analog	12	3.0 x 3.05 x 1.1	Negligible	1.93

Selected Sensor

Onboard ADC (MCU)

Reasons

- No cost
- Enough resolution
- Space advantage

Payload Tilt Sensor Trade & Selection

Tilt Sensor	Interface	Resolution (bits)	Dimensions (mm)	Weight	Cost ($)
BNO055	I2C/UART	14	5.20 x 3.80 x 1.00	Negligible	14.33
MPU9250	I2C/SPI	16	3.00 x 3.00 x 1.00	Negligible	7.72
BMI270	I2C/SPI	16	3.00 x 2.50 x 0.830	Negligible	6.79

Selected Sensor

MPU9250

Reasons

- Better resolution
- Lower cost
- Experience with the sensor

Payload GPS Sensor Trade & Selection

GPS Receiver	Interface	Horizontal Position Accuracy (m)	Maximum Update Rate (Hz)	Dimensions (mm)	Weight (g)	Antenna Support	Cost ($)
NEO-6M	I2C/SPI/ UART	2.5	5	15.5 x 15.5 x 6.3	1.6	External Passive/Active	20.55
NEO-M8N	I2C/SPI/ UART	2.5	10	12.2 x 16 x 2.4	1.6	External Passive/Active	31.50
SAM-M8Q	I2C/SPI/ UART	2.5	18	15.5 x 15.5 x 6.3	7.5	On-Board	31.50

Selected Receiver

uBlox
NEO-M8N

Reasons

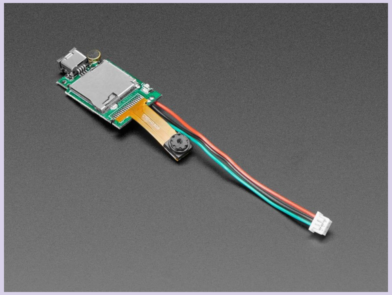
- Fast update rate
- External antenna support
- Experience with the module

Payload Camera Trade & Selection

Camera	Interface	Resolution (pixels)	Micro SD Support	Dimensions (mm)	Weight (g)	Cost ($)
Adafruit 3202 Mini Spy Cam	Discrete	640x480 @ 30 fps	32 GB	28.5 x 17 x 4.2 + 6.2 x 6.2 x 4.4	2.8	12.5
OV7670	SCCB/I2C	640x480 @ 30 fps	N/A	~35 x ~34 x ~25	~15	5.37

Selected Camera

Adafruit 3202 Mini Spy Cam



Reasons

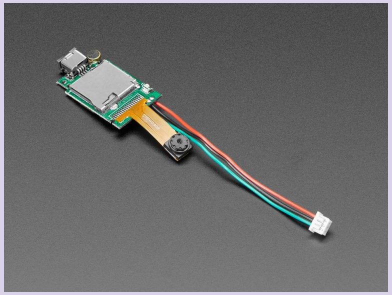
- Enough resolution
- Weight advantage
- No need to program, ready to use out of the box

Bonus Camera Trade & Selection

Camera	Interface	Resolution (pixels)	Micro SD Support	Dimensions (mm)	Weight (g)	Cost ($)
Adafruit 3202 Mini Spy Cam	Discrete	640x480 @ 30 fps	32 GB	28.5 x 17 x 4.2 + 6.2 x 6.2 x 4.4	2.8	12.5
OV7670	SCCB/I2C	640x480 @ 30 fps	N/A	~35 x ~34 x ~25	~15	5.37

Selected Camera

Adafruit 3202 Mini Spy Cam



Reasons

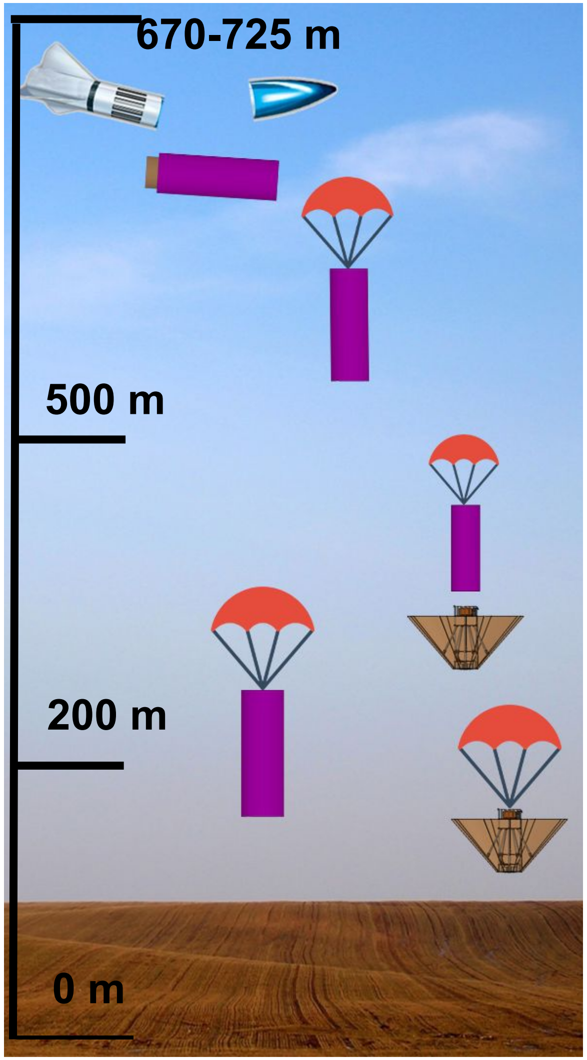
- Enough resolution
- Weight advantage
- No need to program, ready to use out of the box

Note: We are planning to use an IR/Phototransistor system to communicate probe and container to trigger the camera at the beginning of Phase 3. We will use a CR2032 to power-up bonus camera.

Descent Control Design

Muhammet Emre OKUDUCU

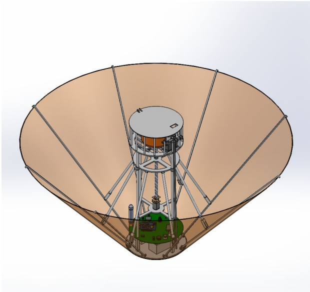
Descent Control Overview



Container separates from the rocket at 670-725 m. The container will descent 15 m/s (±5 m/s) using first parachute.

At 500 meters, the probe is released from the container. The container continues to descend separated from the probe. The heat shield is initiated and the probe starts to descend at a rate of 20 m/s.

At 200 meters, the probe deploys a parachute and slows it descent rate to 5 m/s.

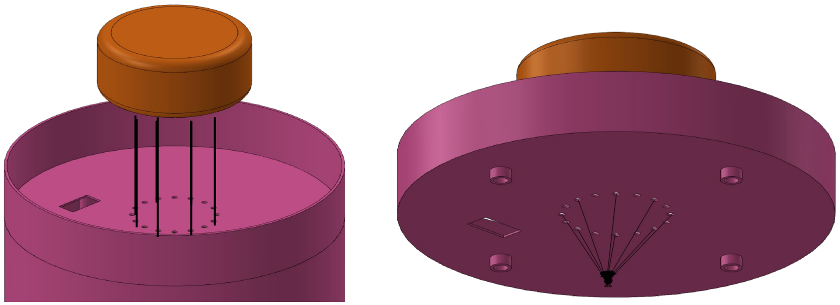


Container Parachute
- Ripstop Nylon parachute.
- Round with 28 cm diameter and spill hole of 3 cm diameter.
- Attached to CanSat, sits passively at the top, deployed on release.

Heat shield
- Ripstop Nylon
- Conic in shape with the base diameter of 50 cm
- Attached close to the tip of the arms and the baseplate of the cansat using tie points and adhesives

Payload Parachute
- Ripstop Nylon parachute.
- Round with 71 cm diameter and spill hole of 8 cm diameter.
- Attached to probe,held by the cover attached to the servo

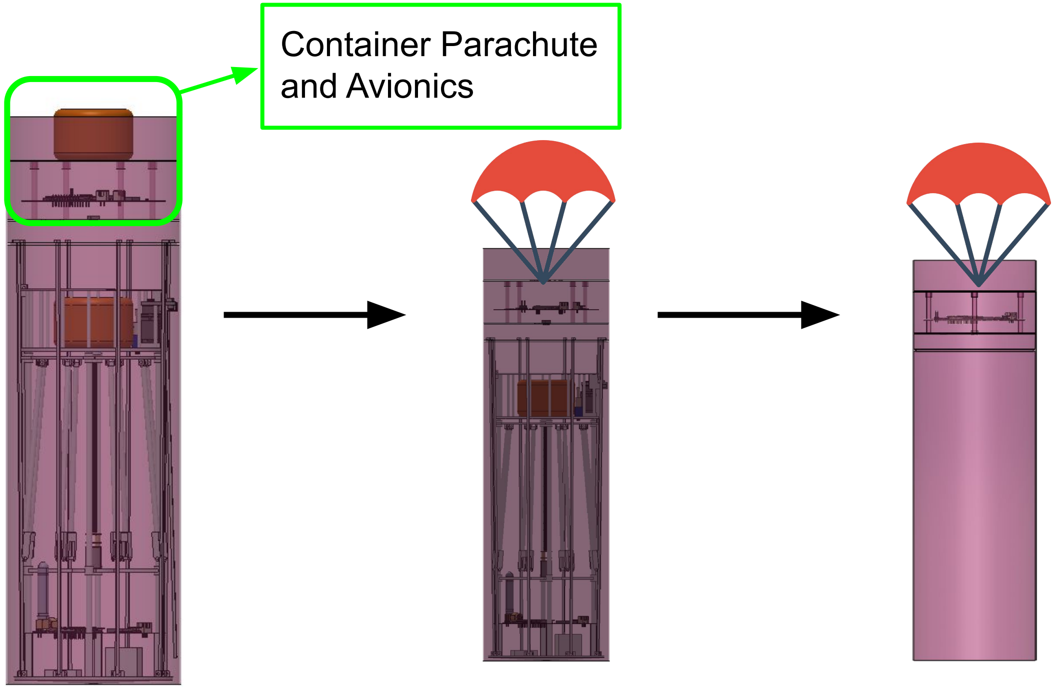
Container Descent Control Strategy Selection and Trade(1/2)

Design 1	Design 2
	
• The parachute will be folded and attached to the container by its eight strings passing through the holes on top of the container. • These strings will be knotted by use of a Figure-eight loop (Flemish loop) inside the container. • The parachute bay will restrict the parachute from getting stuck between the container and the rocket payload envelope.	• The parachute will be folded and attached to the container by eyebolt. • By using an eyebolt, a stronger structure can be established. In addition, eyebolt will create excessive weight.

Selected Design	Rationale
Design 1	Parachute does not generate a large force on the container, so a strong structure is not necessary. Design 1 was preferred due to its lighter weight.

Container Descent Control Strategy Selection and Trade(2/2)

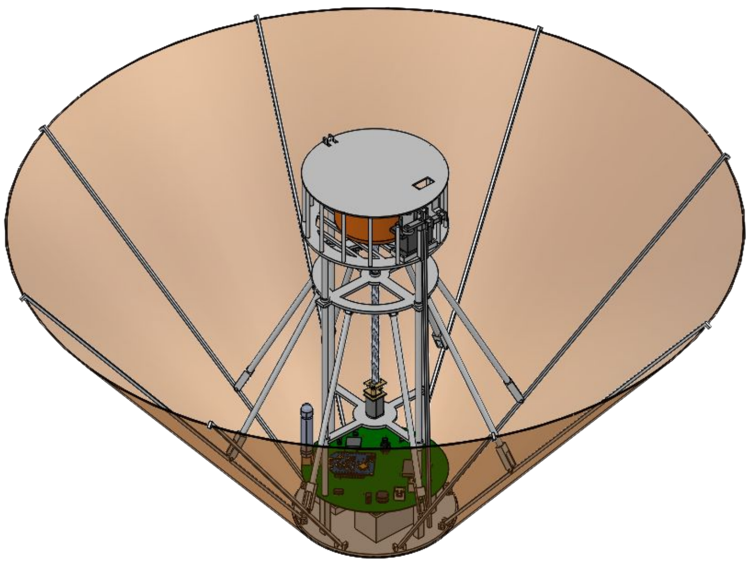
Container Parachute Design
Made of Nylon
Design of parachute is Hemispherical
Parachute diameter is **31cm.**
Spill hole diameter is **34mm.**



After the container separates from the rocket at apogee, its parachute is released. In this way, it falls at a speed of 15 m/s up to 500 meters. At 500 meters, the container separates from the probe and begins to fall on its own, descending to the ground at approximately 8 m/s.

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

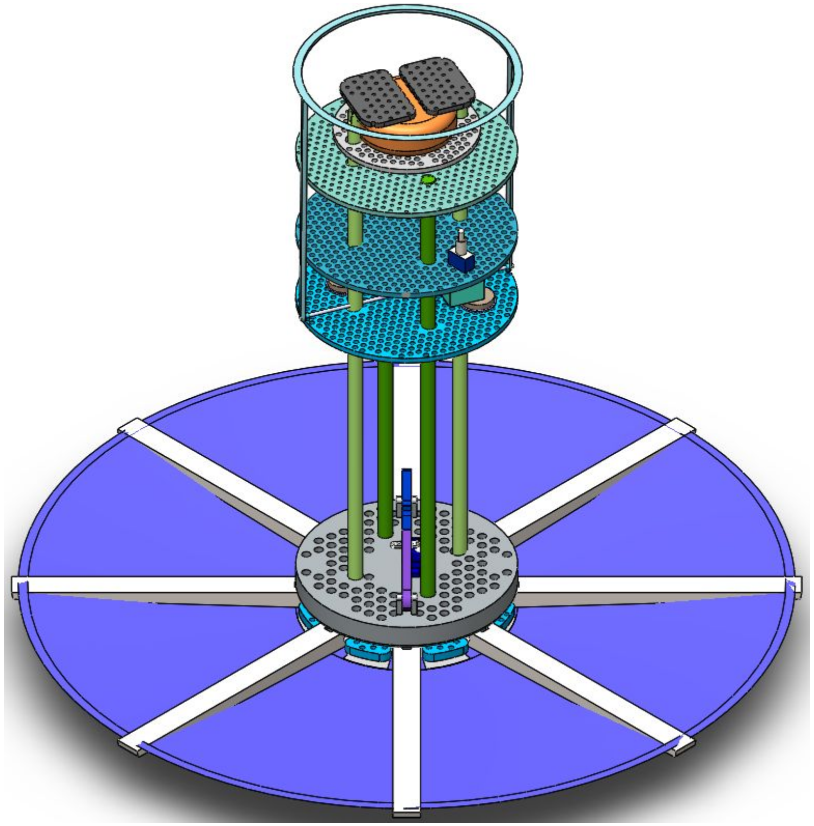
Design A: Motor Actuated Heat Shield/Aerobraking System



This design uses a DC motor to drive a moving plate up and down to actuate arms that are connected to a moving plate. This moving plate moves to a predetermined height and actively keeps the distance from the center. Arms form a conical aerobraking system formed by a ripstop nylon fabric.

Stability of the aerobraking system is controlled passively, the center of aerodynamic pressure sits higher than the center of mass of the probe, giving it a natural stability. this stability increases with the difference between the two centers giving us the ability to actively change the center of aerodynamic pressure.

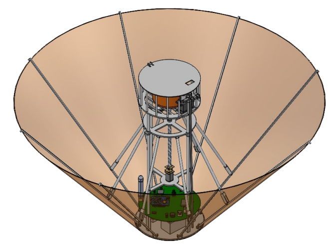
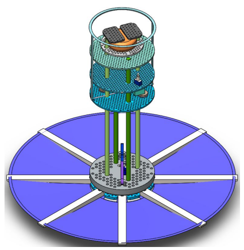
Design B: Spring-Actuated Heat Shield/Aerobraking System



This design uses a spring to drive a moving plate up to actuate arms that are connected to a stable plate. This moving plate moves to a predetermined height and actively keeps the distance from the centre. Arms form a conical aerobraking system formed by ripstop nylon fabric.

The stability of the aerobraking system is controlled by two reaction wheels, the rotational moment of those wheels creates resistance to the change in stability.

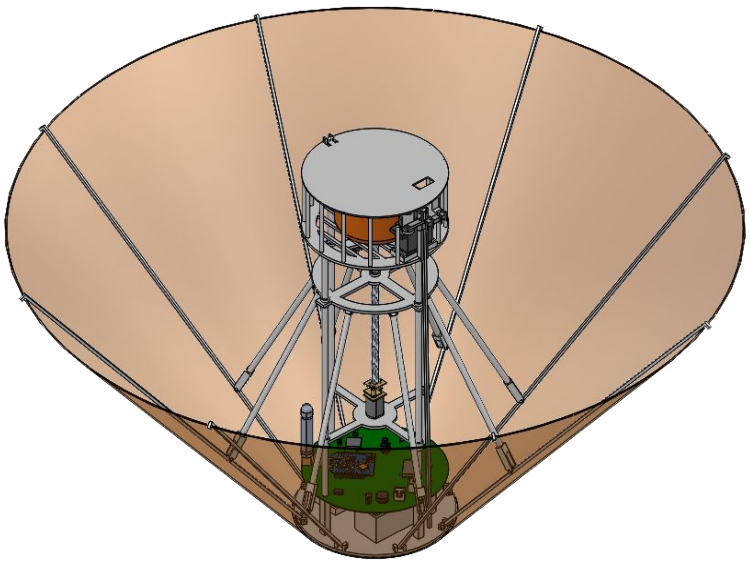
Payload Aerobraking Descent Control Strategy Selection and Trade(3/3)

Aerobraking Descent Design Trade		
Concept	Concept A	Concept B
Drawing		
Advantages	• Passively Stable. • Can be used to drop lower than the target velocity. • Can be used as an uprighting mechanism.	• Actively stable • Light • Uses air resistance and a spring instead of a motor
Disadvantages	• Heavy. • Requires a powerful motor.	• Center of mass sits higher than center of pressure •.Requires motors to rotate reaction wheels •.Can not be used as an uprighting mechanism.

Selected Design	Rationale
Concept A	Doubles as an uprighting mechanism and an active control algorithm can be implemented if needed.

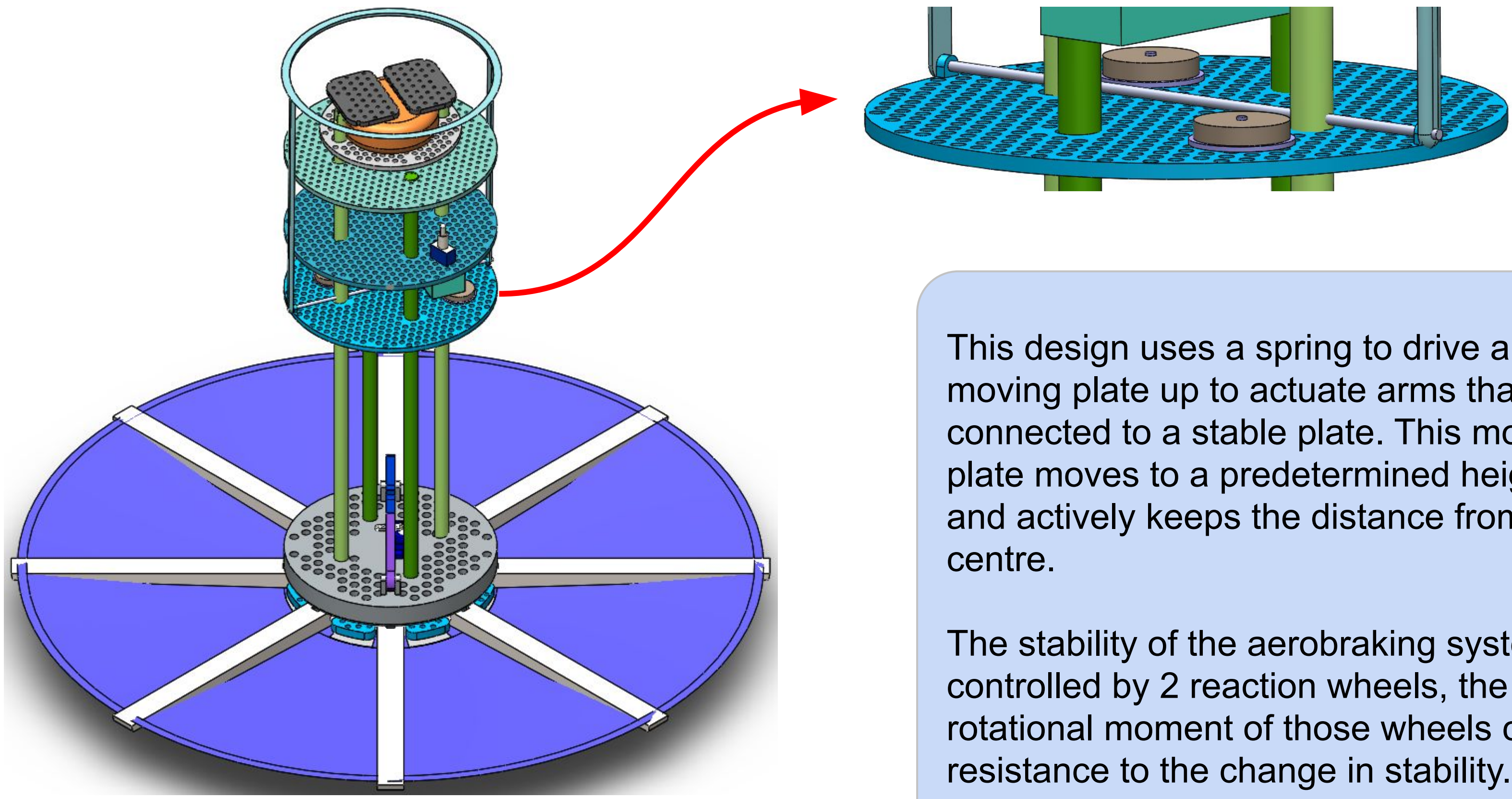
Payload Aerobraking Descent Stability Control Strategy Selection and Trade (1/3)

Design-A (Passive Stability Control)



This design uses a high torque DC motor to release the probe from the container and subsequently open the aerobraking system. The aerobraking system will open up to a preprogrammed level, the descent forces are not expected to be strong enough to close . Stability of the aerobraking system is controlled passively, the center of aerodynamic pressure sits higher than the center of mass of the probe, giving it a natural stability.

Design-B (Active Stability Control)



This design uses a spring to drive a moving plate up to actuate arms that are connected to a stable plate. This moving plate moves to a predetermined height and actively keeps the distance from the centre.

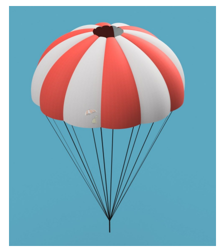
The stability of the aerobraking system is controlled by 2 reaction wheels, the rotational moment of those wheels creates resistance to the change in stability.

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

Aerobraking Descent Stability Control Strategy Trade		
Design	**Concept A**	**Concept B**
Advantages	• No extra algorithms needed. • Easily optimizable • The design of the probe compliments the system very well	• Unique and easy to manufacture design • No extra algorithms needed.
Disadvantages	• Requires a high torque dc motor to extend the aerobraking system.	• Low drag coefficient. • Opening time is long. • Requires extra motor • Wheels are heavy

Selected Design	Rationale
Concept A (Passive Stability Control)	The integration and optimization process is easier compared to Concept B. The moving plate and arm design is going to be integrated into other mechanisms of the probe.

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

Parachute Design Trade		
Design Feature	Hemispherical parachute	Cross parachute
Diagram		
Advantages	• Very common. • High stability with spill hole. • Good for low drop altitude, high drag.	• Easy to make. • Simple folding.
Disadvantages	• Time consuming to make.	• Low drag coefficient. • Opening time is long.

Selected Parachute Design	Rationale
Hemispherical parachute	Easy to manipulate to achieve the required descend rate. Cheap and provide a high drag.

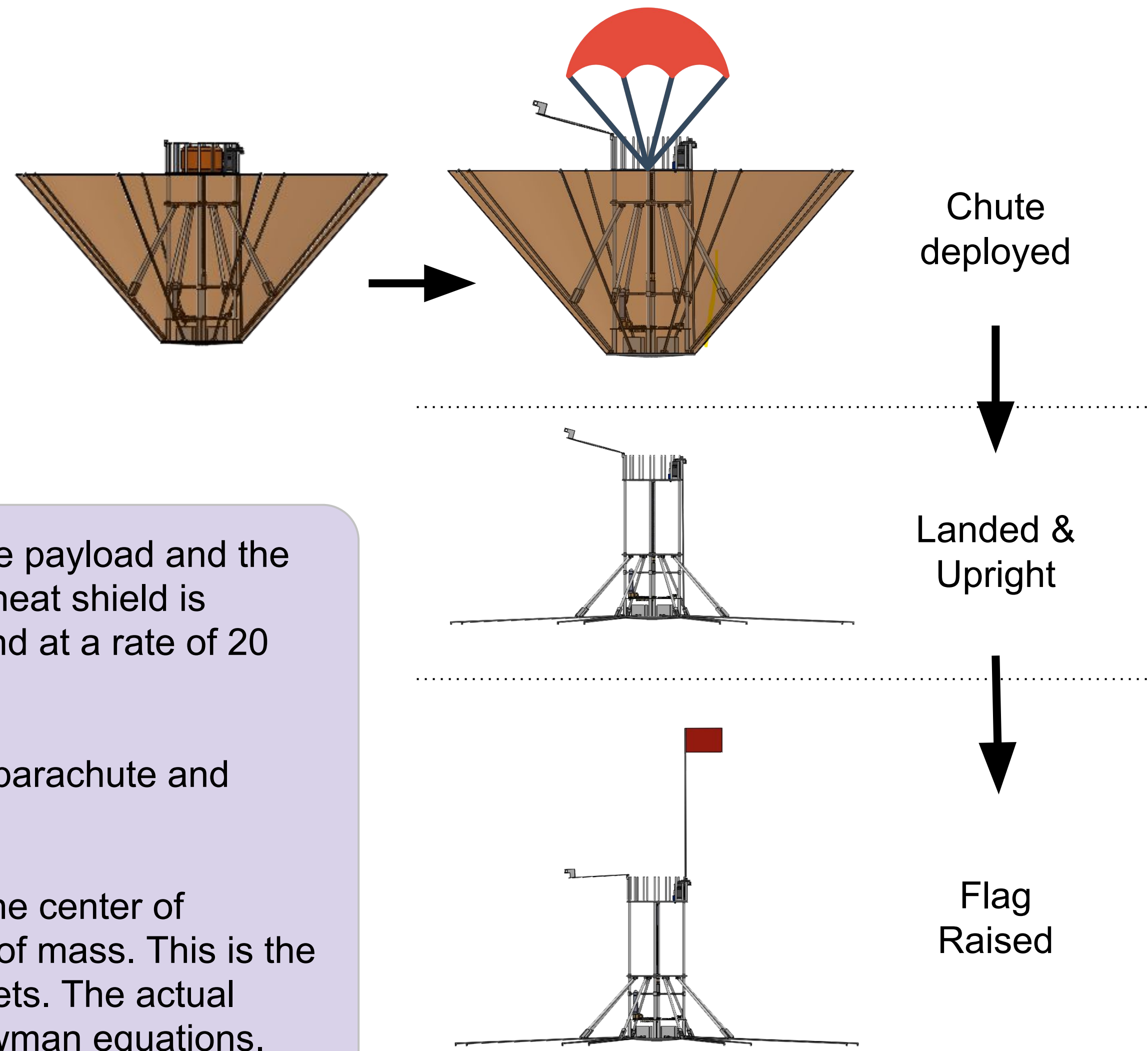
Payload Parachute Descent Control Strategy Selection and Trade(2/3)

Material	Advantages	Disadvantages
Nylon	Common material, elastic	Melts at high temperatures
Dacron	Temperature resistant	Requires chemical stability
PTFE	Low friction	Expensive, weaker
Kevlar	Very strong, does not melt or burn	Sensitive to UV, very little fiber elongation

Selected Material	Rationale
Nylon	- Higher strength and elasticity compared to other alternatives - Easily accessible - No need for temperature resistivity since the mission won't take too much time.

Payload Parachute Descent Control Strategy Selection and Trade(3/3)

Payload Parachute Design
Made of Nylon
Design of parachute is Hemispherical
Parachute diameter is **77cm**.
Spill hole diameter is **86mm**..



At 500 meters, the container leaves the payload and the payload begins to fall on its own. The heat shield is initiated and the probe starts to descend at a rate of 20 m/s.

At 200 meters, the payload deploys a parachute and slows it descent rate to 5 m/s.

Stability of the CanSat is ensured by the center of pressure being higher than the center of mass. This is the same principle used in stabilizing rockets. The actual stability will be calculated using Barrowman equations.

Descent Rate Estimates (1/7)

Constants		Variables from equations	
g	Acceleration due to gravity = 9.81 m/s²	Fd	Drag force
M	Mass of CanSat = 700g	D_1,D_2	1 st & 2nd parachute diameter
ρ	Density of air = 1.112 kg/m³	V	Terminal velocity of CanSat
Cd_1	Coefficient of drag for round parachute = 0.75	A	Area of the parachute with a spill hole(m²)
π	3.14159	D_3	Heat Shield diameter
Cd_2	Coefficient of drag for heat shield = 0.55		

Descent Rate Estimates (2/7)

Assumptions

- Drag is equal to weight at terminal velocity.
- There is no wind presence or other weather effects.
- When fully deployed, parachutes are fully inflated and contribute to the drag on the CanSat.
- The density of the air at 1000 m (launch location altitude + deploy altitude) is assumed to be 1.112 kg/m³.
- Drag coefficient for parachutes and heat shield is assumed to be 0.75 and 0,55 respectively.

Formulas

The Formula for drag force: F_D $\frac{1}{2}C_D\rho A v^2$

Formula for parachute area: $\frac{1}{4} \times \pi \times D^2$

Rearrange for parachute area: $A = \frac{2mg}{C_D \rho v^2}$

Gravitational Force: F_G = mg = F_D at terminal velocity

Descent Rate Estimates (3/7)

Dimensions Calculations

Container Parachute

Area calculation at 15 m/s:

$$A = \frac{2mg}{\rho C_d V^2} = \frac{2 * 0.7 * 9.81}{1{,}112 * 0.75 * 15^2} = 0{,}0732$$

$$A = \frac{1}{4} \times \pi \times D^2$$

$$D_1 = \sqrt{\frac{4 * 0{,}0732}{3{,}14159}} = 0{,}3053 \cong 0{,}31 \text{ m}$$

Parachute diameter chosen as **31cm** for ease of assembly

Shroud lines length = 115% parachute diameter = **35,65 cm**

Payload Parachute

Area calculation at 5 m/s:

$$A = \frac{2mg}{\rho C_d V^2} = \frac{2 * 0.5 * 9.81}{1{,}112 * 0.75 * 5^2} = 0{,}4705$$

$$A = \frac{1}{4} \times \pi \times D^2$$

$$D_2 = \sqrt{\frac{4 * 0{,}4705}{3{,}14159}} = 0{,}774 \cong 0{,}77 \text{ m}$$

Parachute diameter chosen as **77cm** for ease of assembly

Shroud lines length = 115% parachute diameter = **88,55 cm**

Spill hole area (m^2) = 5% of parachute projected area

- 0,0732 x 0,05= 0,00366 m^2
  Container Parachute spill hole area
- 0,4705 x 0,05= 0,023525 m^2
  Payload Parachute spill hole area

$$Spill\ hole\ radius = \sqrt{\frac{\text{Spill hole area (m2)}}{\pi}}$$

- $\sqrt{\frac{0,00366}{3,14159}} = 0,03413$ Container Parachute spill hole radius chosen as **34mm** for ease of assembly
- $\sqrt{\frac{0,032935}{3,14159}} = 0,0865$ Payload Parachute spill hole radius chosen as **86mm** for ease of assembly

Descent Rate Estimates (5/7)

Heat Shield Calculations

Area calculation at 15 m/s(our choice):

$$A = \frac{2mg}{\rho C_d V^2} = \frac{2 * 0.5 * 9.81}{1,112 * 0.55 * 15^2} = 0,0713$$

$$A = \frac{1}{4} \times \pi \times D^2$$

$$D_3 = \sqrt{\frac{4 * 0,0713}{3,14159}} = 0,3013 \quad \cong 0.30 \text{ m}$$

Heat Shield diameter chosen as **30cm** for ease of assembly

Descent Rate Estimates (6/7)

Velocity Calculations

Container Parachute

$$V = \sqrt{\frac{2mg}{\rho C_d A}}$$

$$= \sqrt{\frac{2 * 0,7 * 9,81}{1,112 * 0,75 * 0,0732}}$$

V = 14,99 m/s

Container landing speed:

$$= \sqrt{\frac{2 * 0,2 * 9,81}{1,112 * 0,75 * 0,0732}}$$

V= 8,0172 m/s

Payload Parachute

$$V = \sqrt{\frac{2mg}{\rho C_d A}}$$

$$= \sqrt{\frac{2 * 0,5 * 9,81}{1,112 * 0,75 * 0,4705}}$$

V = 5,000 m/s

Heat Shield

$$V = \sqrt{\frac{2mg}{\rho C_d A}}$$

$$= \sqrt{\frac{2 * 0,5 * 9,81}{1,112 * 0,55 * 0,0713}}$$

V= 14,9987 m/s

Descent Rate Estimates (7/7)

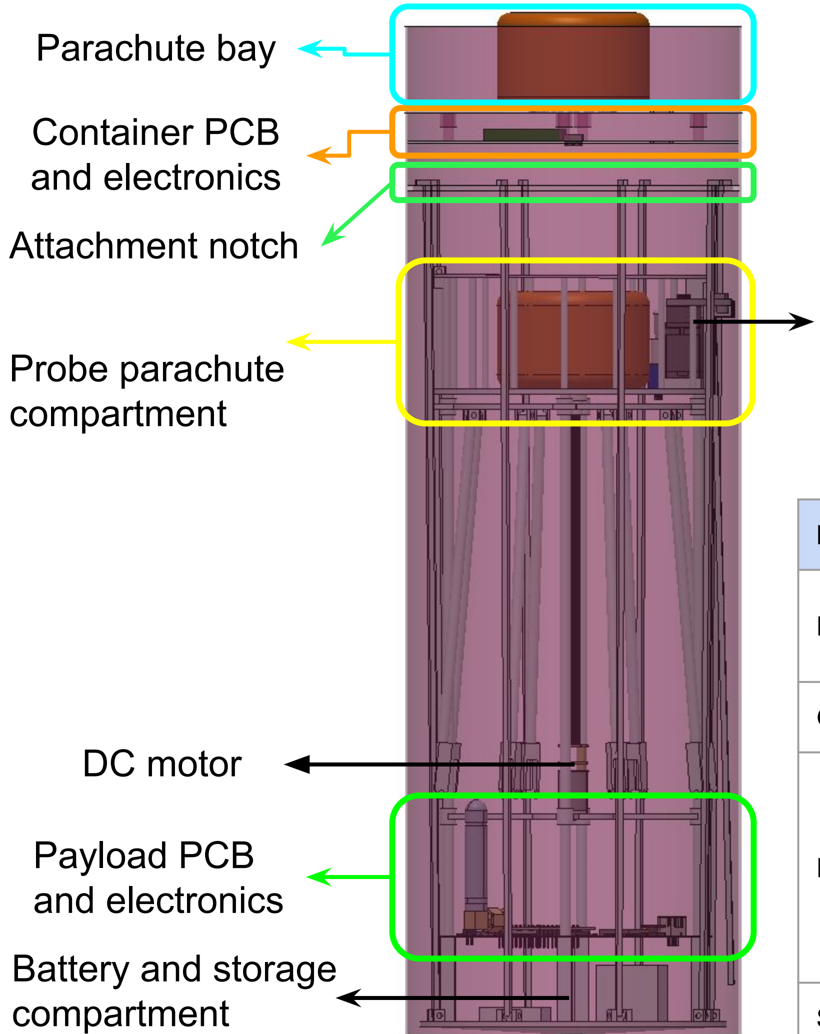
Summary

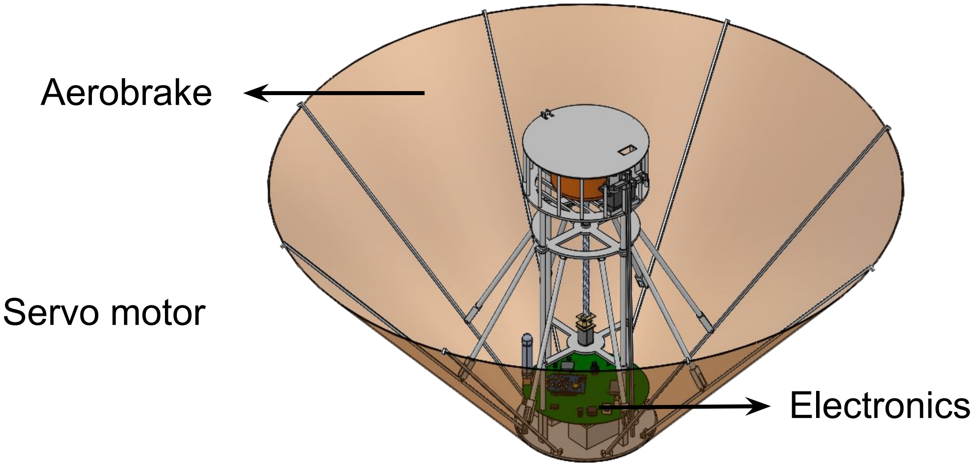
Dimensions	Container Parachute	Payload Parachute	Heat Shield
Diameter	31cm	77cm	30cm
Spill Hole Diameter	34mm	86mm	-
Shroud Line Length	35.65cm	88,55cm	-
Colour	Orange		
Shape	Hemispherical		Conical
Material	Nylon		
Shroud Material	Paracord		-
Number of Shrouds	8		-

Mechanical Subsystem Design

Umut Altun
Mustafa Yusuf Aksu

Mechanical Subsystem Overview

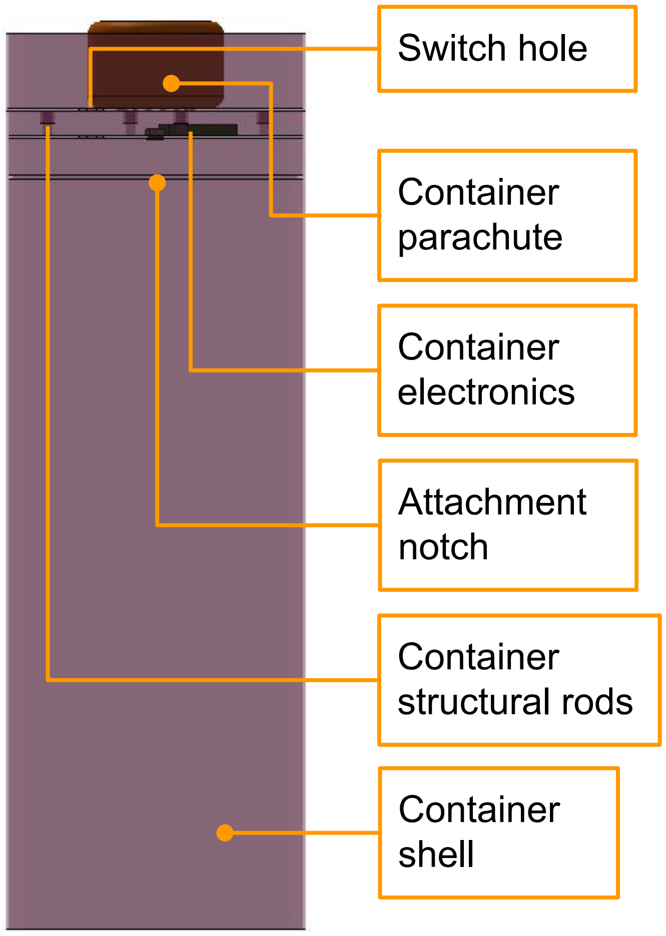




Material	Structural Element
Ripstop Nylon Fabric	Aerobrake, Container Parachute, Probe Parachute
Generic Fabric	Flag
Fiberglass	Probe Base, Probe Structural Rods, Arms, Connection Rods, Motor Plate, Moving Plate, Parachute Lid, Parachute Containment Rods, Parachute Containment Base, Servo Arms, Parachute Lid Locking Arm
Steel	Threaded Rod, Pins, Springs, Hinges

Container Mechanical Layout of Components Trade & Selection (1/3)

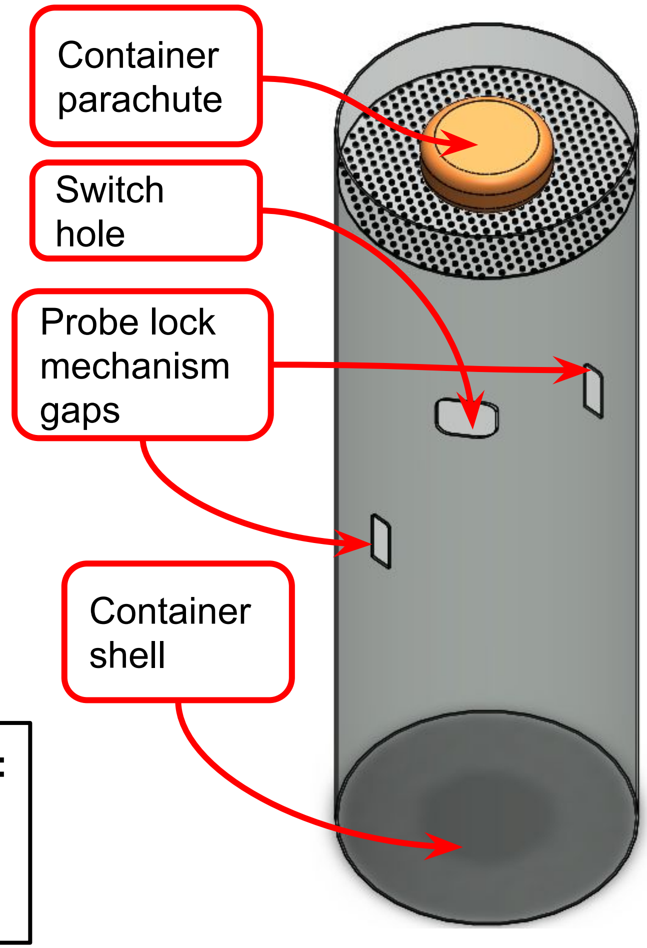
Concept A:



Container Electronics:

- Adafruit Mini Spy Cam
- Battery

Concept B:



Container Mechanical Layout of Components Trade & Selection (2/3)

Aerobraking Descent Stability Control Strategy Trade		
Design	**Concept A**	**Concept B**
Advantages	• Easy to manufacture • Impact resistant • Easy to reach the power switch	• Light • Easy to reach components
Disadvantages	• Heavy • Camera is hard to reach	• Holes may disturb aero features

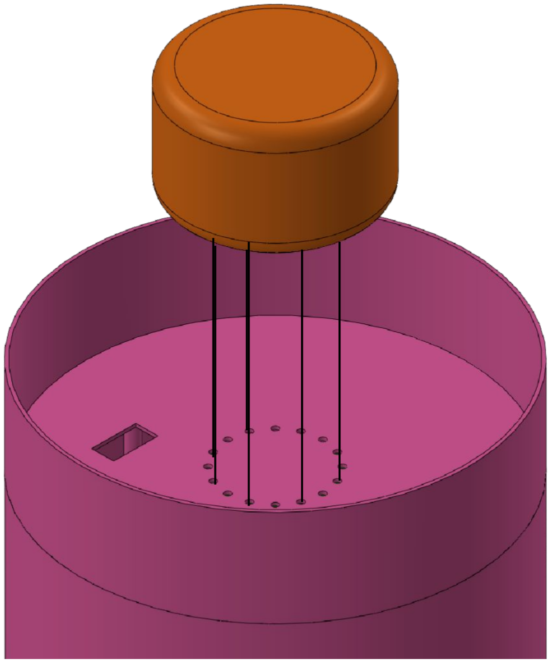
Selected Design	Rationale
Concept 1	Concept 1 provided a reliable separation from the rocket and reliable separation of the probe from the container. This concept also provides a larger tolerance to the changes in the design as we move to the CDR.

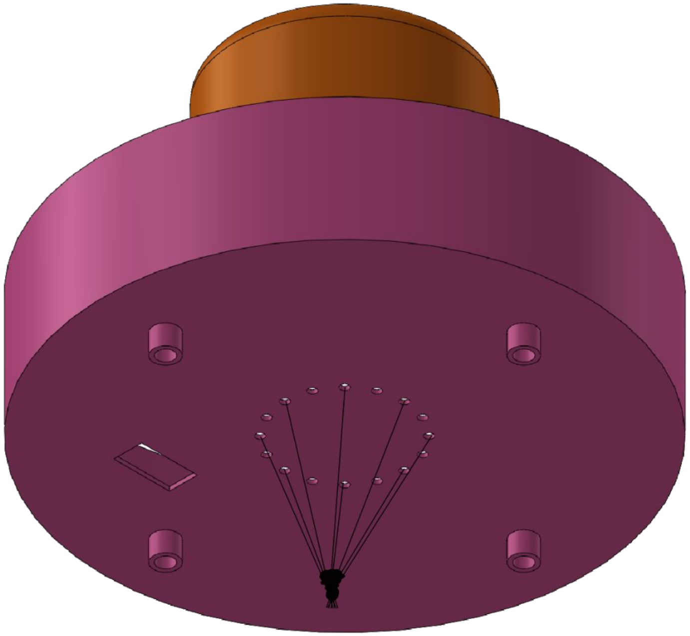
Container Mechanical Layout of Components Trade & Selection (3/3)

Container Structural Material Selection						
Material	**Density (g/cm3)**	**Impact Strength**	**Tensile Strength (MPa)**	**Melting Temperature (C)**	**Manufacturing Process**	**Comments**
ABS	1.05	Low	45	200	3D printing	Low strength
PLA	1.24	Low	37	170-180	3D printing	Low strength
Fiberglass	2.54	High	3445	1135	Vacuum moulding	Relatively heavy
Carbon fiber	1.9	High	3000-7000	3652	Vacuum moulding	Blocks radio signals
Titanium	4.5	Very High	240	1668	CNC cutting	Too expensive Heavy Blocks radio signals

Rationale: Fiberglass was chosen for container structural material due to its incredibly high impact strength and tensile strength. It has a lower thermal stability compared to carbon fiber but provides sufficient performance. It also has a higher density compared to carbon fiber but due to it having electromagnetic shielding effect, we can not use carbon fiber.

Container Parachute Attachment Mechanism



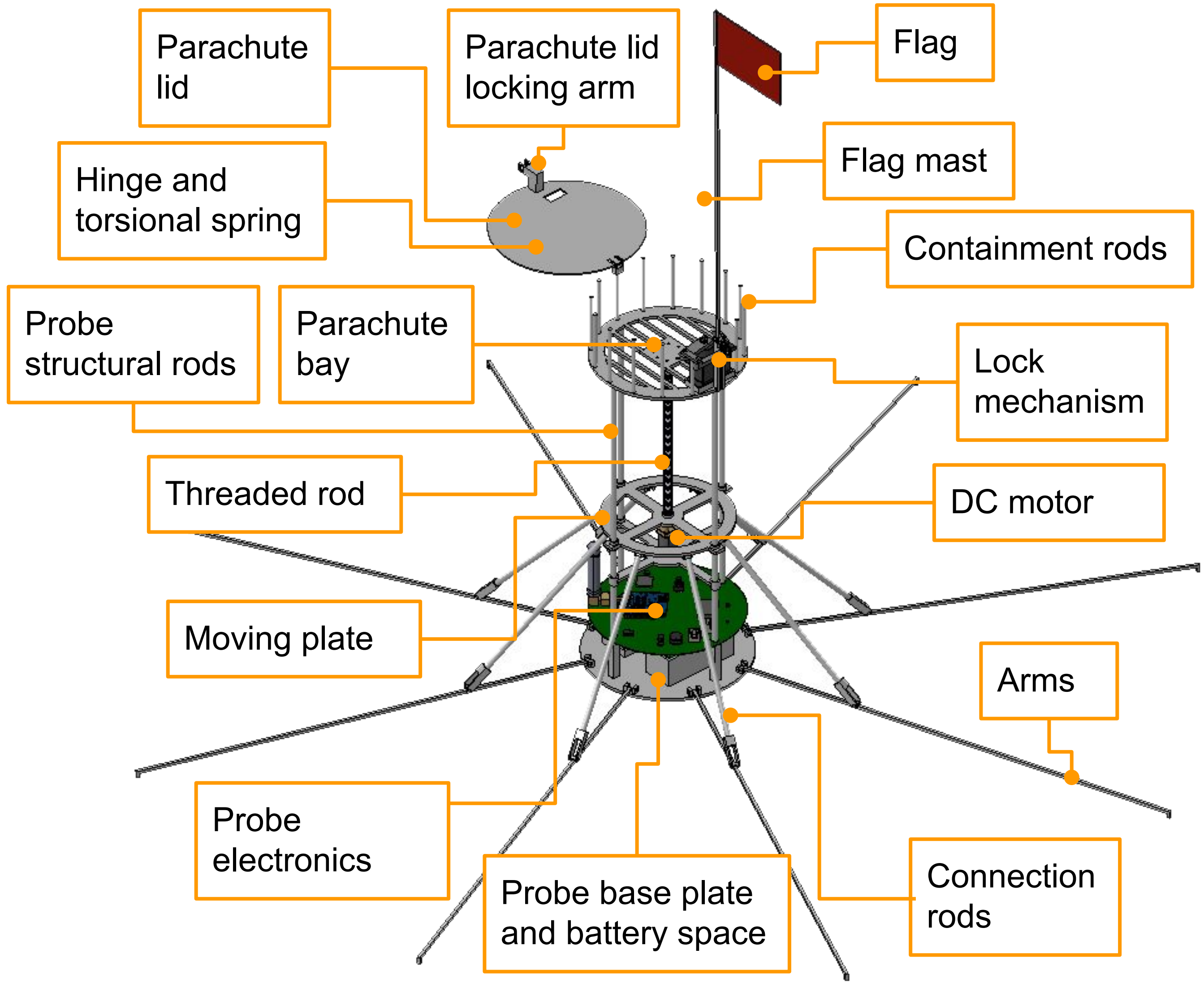


- The parachute will be folded and attached to the container by its eight strings passing through the holes on top of the container.
- The top part of the container will be mounted onto the container using the rods and corresponding holes. Adhesives will be applied to secure the top part of the container to the main body
- These strings will be knotted by use of a Figure-eight loop (Flemish loop) inside the container.
- The parachute bay will restrict the parachute from getting stuck between the container and the rocket payload envelope.
- The parachute will be released with the CanSat when it deploys and will be opened by the drag force applied by the wind.

Payload Mechanical Layout of Components Trade & Selection (1/3)

Concept A:

The main driving factor for our probe design was to ensure that the center of mass was as low as possible. We also aimed to utilize all motors such that they have at least two functions in the operation of the probe.



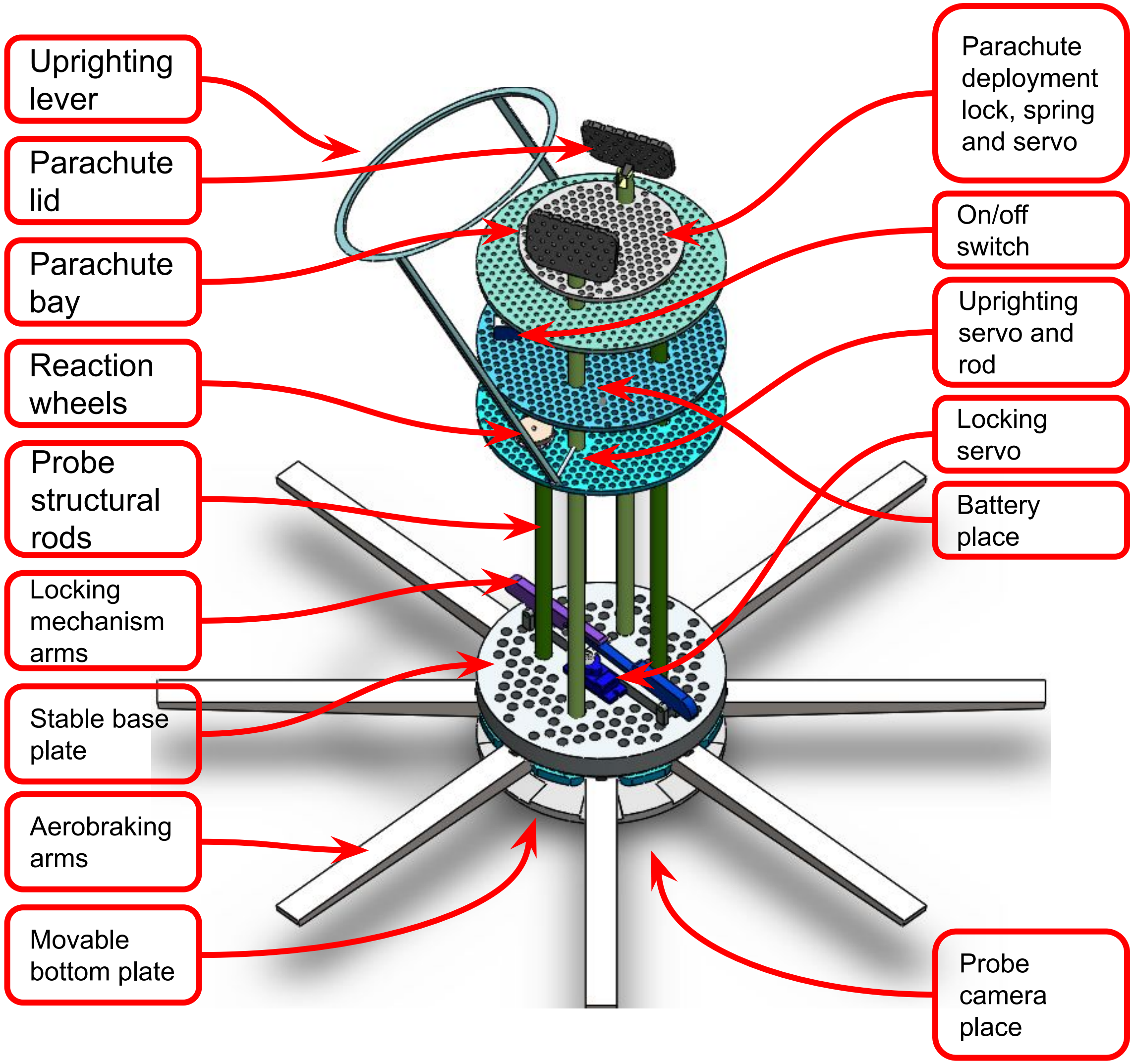
Probe Electronics:

- XBee
- Antenna
- Microcontroller
- Sensors
- Motors
- Battery etc.

Payload Mechanical Layout of Components Trade & Selection (2/3)

Concept B:

Main factor for this probe design was to use springs instead of motors to ensure a light design. We also aimed for a diverse design for the aerobraking system, which was enabled by using air resistance to our advantage.

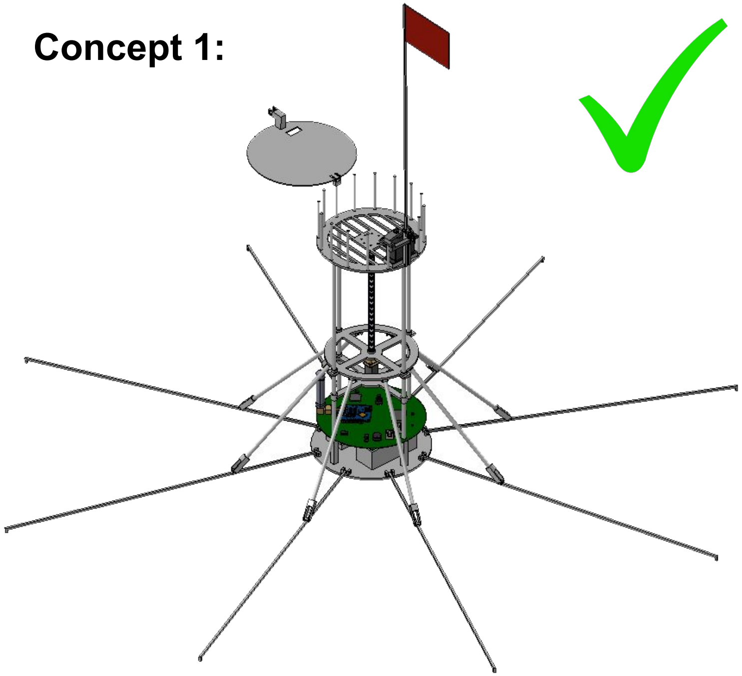


Probe Electronics:

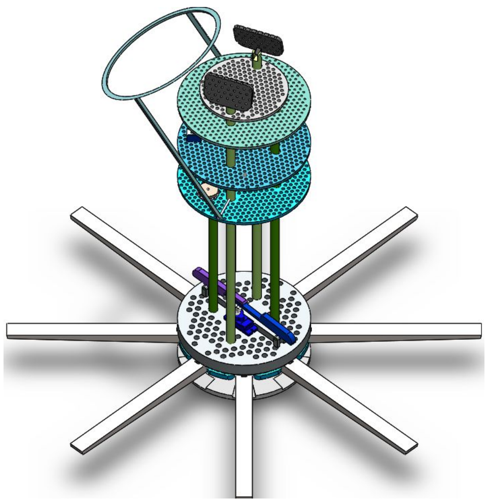
- XBee
- Antenna
- Microcontroller
- Sensors
- Motors
- Battery etc.

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

Concept 1:



Concept 2:

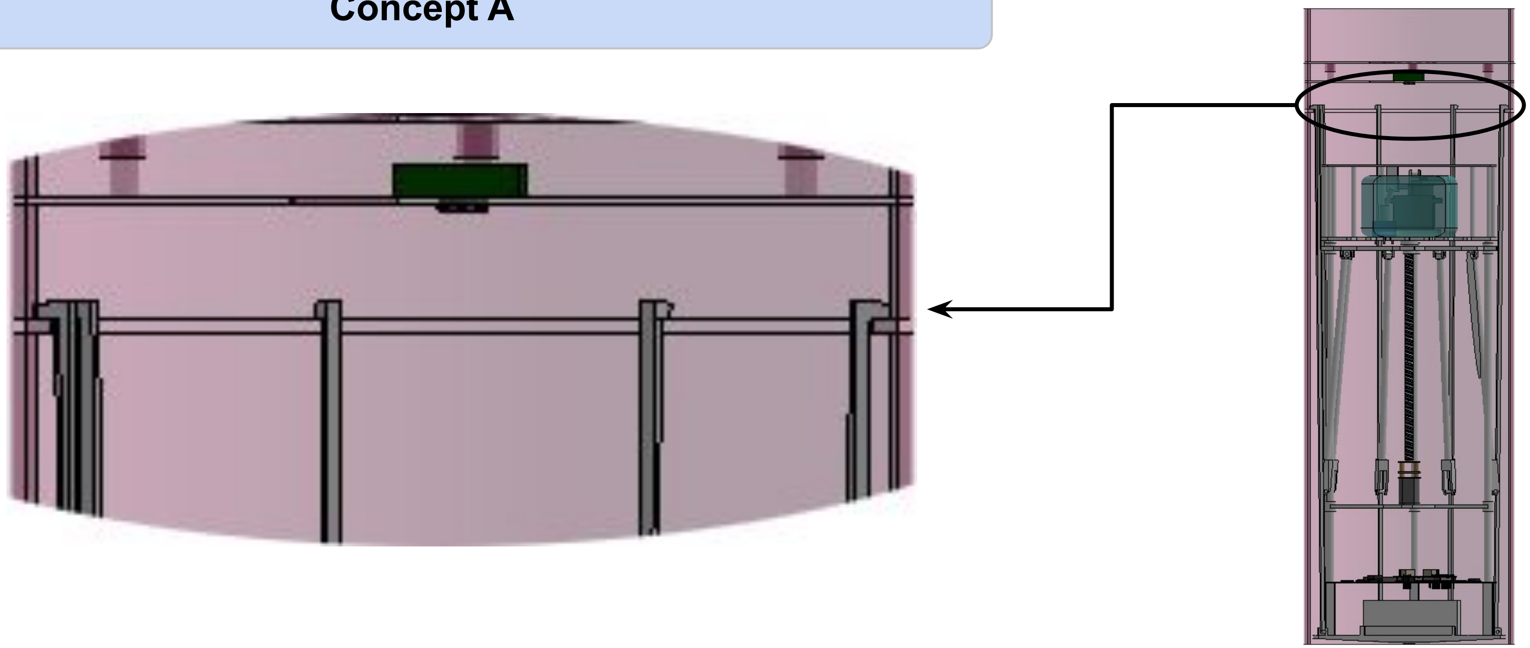


Selection Rationale:

- Concept 1 is lighter
- Concept 1 has a simpler design
- Concept 1 is more stable
- Concept 1 is more reliable
- Concept 1 has an easier optimization process

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

Concept A

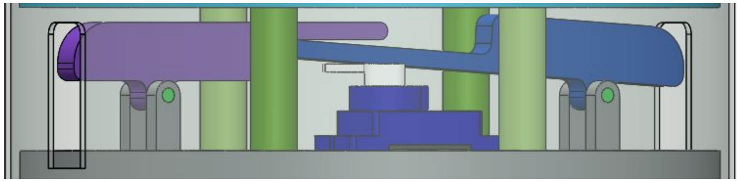


Our moving plate/arms system acts as a locking mechanism which is used to secure the probe to the container. The interlocking notches of the arm and container provide a secure connection between the container and probe, which will be confirmed by testing.

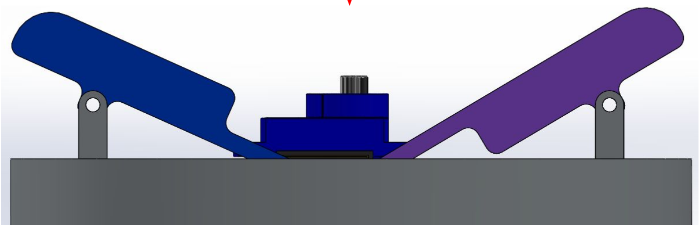
At 500 meters, the probe will retract its arms and fall out of the container.

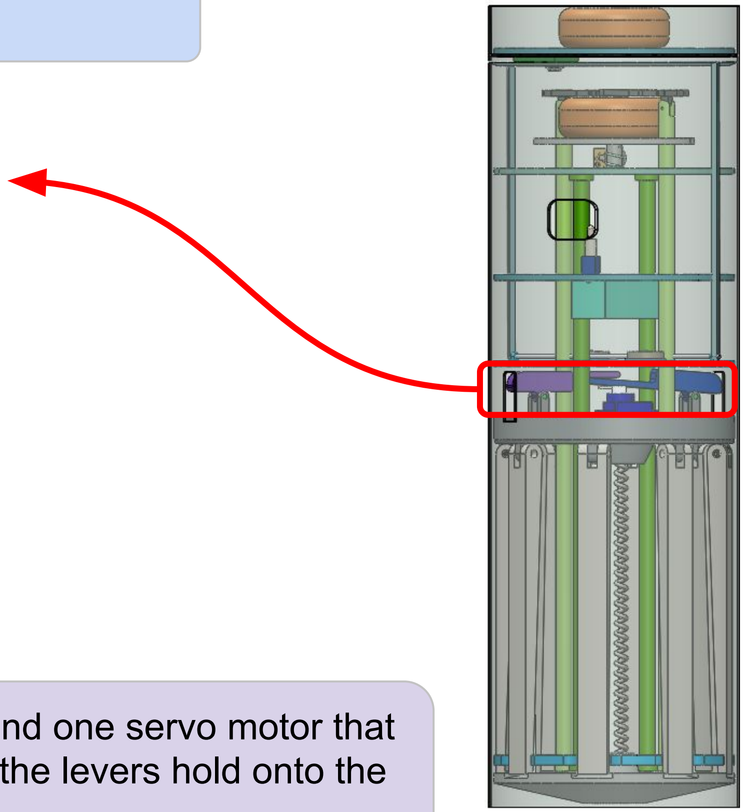
Concept B

Before



After





The locking mechanism consists of two locking levers and one servo motor that controls the system to enable the prob-container bond, the levers hold onto the gaps in the container.

At 500 meters, the servo will unlock the system, the levers leave the container gaps, and the separation will occur.

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

Aerobraking Pre Deployment Trade		
Concept	Concept A	Concept B
Advantages	• Doesn’t require an additional system • Has a larger Locking surface • Does not need to protrude out of the container	• Actively stable • Light • Uses air resistance and a spring instead of a motor
Disadvantages	• Locking notch needs to be intricately designed and manufactured • Excessive lateral forces need to be accounted for	• Center of mass sits higher than center of pressure •.Requires motors to rotate reaction wheels •.Can not be used as an uprighting mechanism.

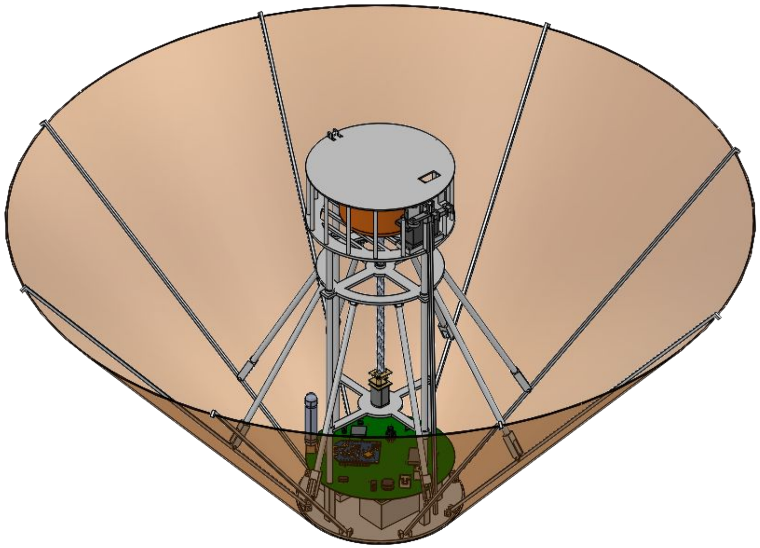
Selected Configuration	Rationale
Concept A	-Better fit for the selected aerobraking system -Does not require an extra locking system -High axial force tolerance

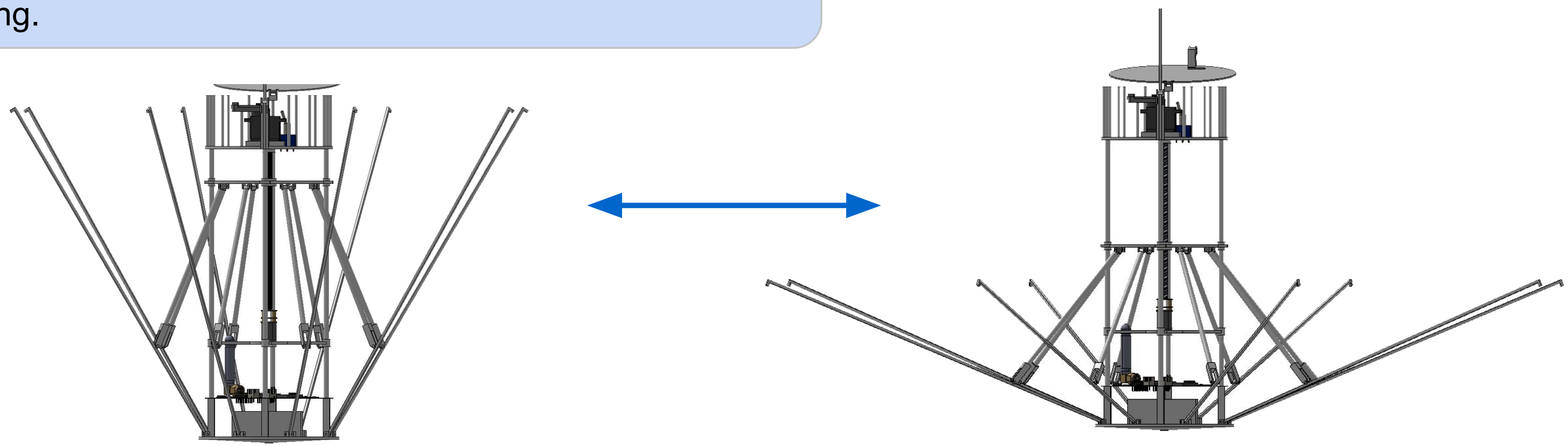
Concept A

After release, the heat arms will once again expand to the predetermined diameter of 30cm,
which will slow the probe down to 15 m/s.

Expansion of the arms are facilitated by a high voltage dc motor which turns a threaded rod that moves a moving plate. The rods that connect the moving plate and the arms are always located at an angle such that torque is applicable to the arms at any configuration

These values will be confirmed by wind tunnel and flight testing.

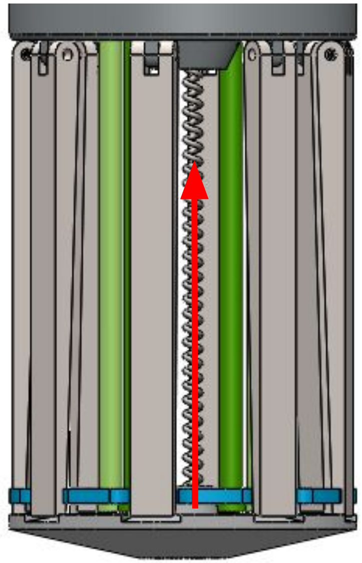


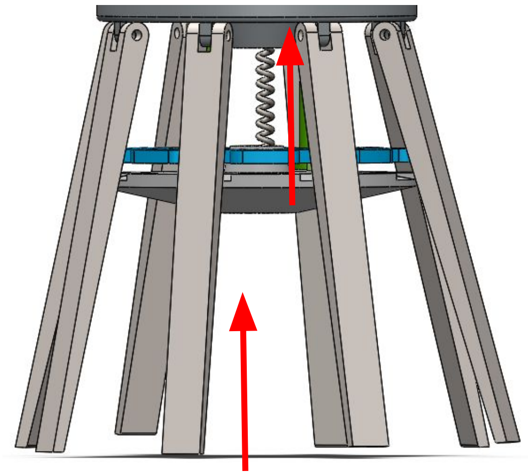


Payload Aerobraking Deployment Configuration Trade & Selection (2/3)

Concept B

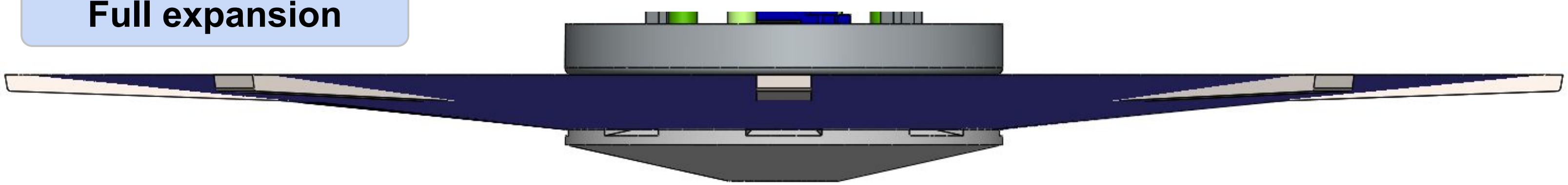
Initial position





- After release, the heat arms will expand to the their ideal diameter to slow the probe down to 15 m/s.
- Expansion of the arms is ensured by a spring and air resistance any motor will not be used. Pulling off the bottom plate by the spring and pushing the heatshield with air will be enabled the expansion.

Full expansion



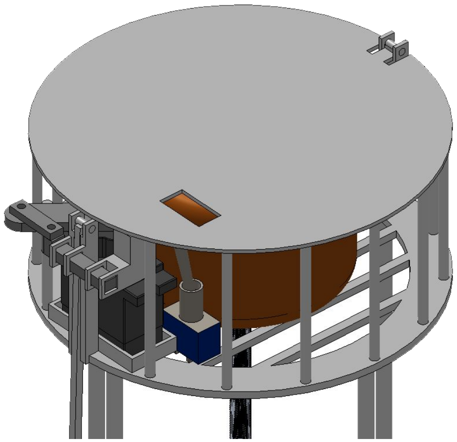
Payload Aerobraking Deployment Configuration Trade & Selection (3/3)

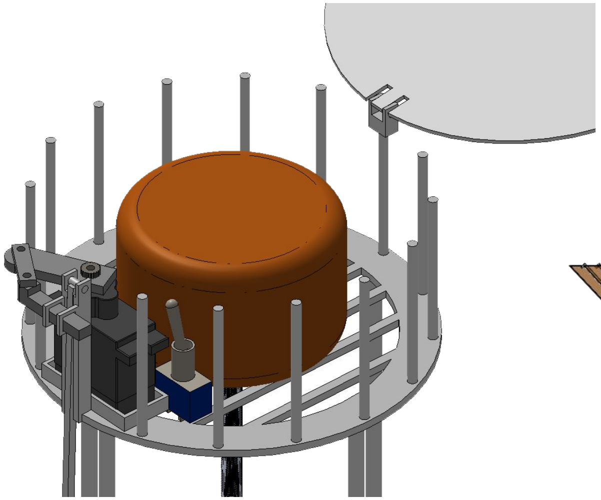
Aerobraking Deployment Trade		
Concept	Concept A	Concept B
Advantages	• Can also be used as an uprighting mechanism • Descent speed optimization can be done much faster without the change of any parts • Passively Stable	• Light • Uses air resistance and a spring instead of a motor
Disadvantages	• Requires a dc motor • A lot of testing is needed to confirm reliable operation	• Center of mass sits higher than center of pressure • Needs an active stabilization mechanism •Can not be used as an uprighting mechanism.

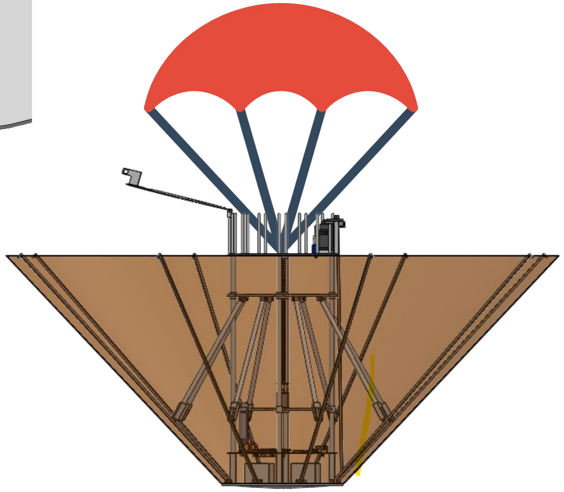
Selected Configuration	Rationale
Concept A	- Active stabilization is not something that we are very confident in - Using the heat shield as an uprighting mechanism.

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

Concept A





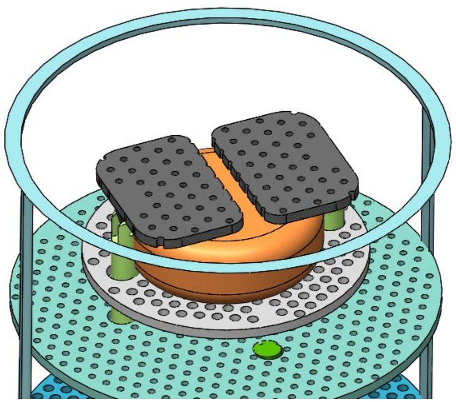


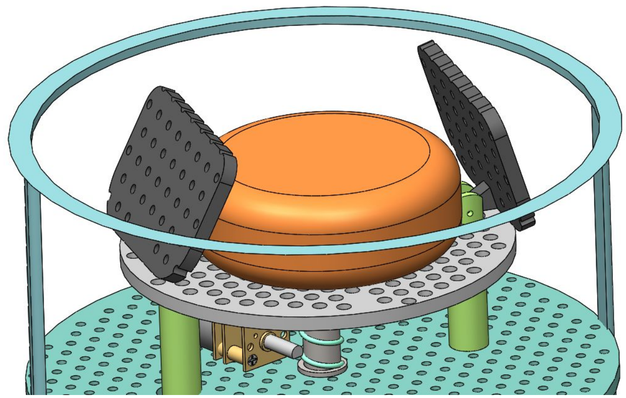
- Initially the servo rod locks the parachute lid in place
- When the predetermined altitude is reached the servo turns a predetermined amount to release the parachute lid
- When the parachute lid is released, the torsional spring located at the hinge of the parachute lid assists the operation.
- After the lid is open, the parachute is free to move and opens with the air resistance.

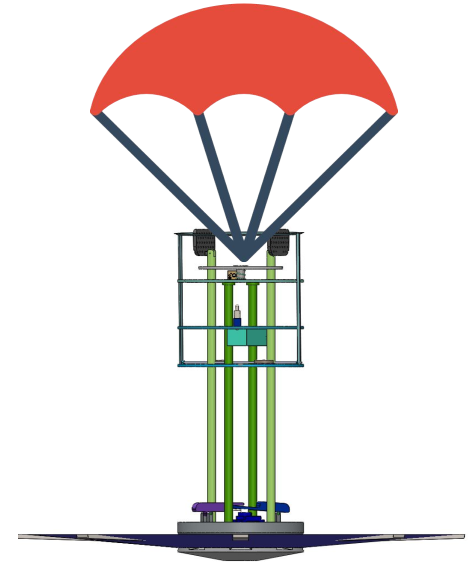
Payload Parachute Deployment Configuration Trade & Selection (2/3)

Concept B

Before	After







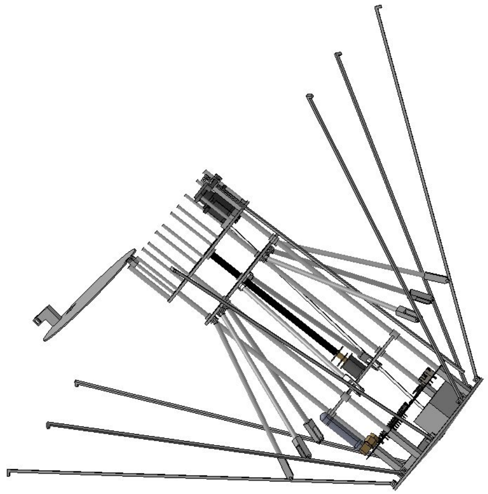
- Initially, two magnets hold the lids of the parachute deployment system.
- When the predetermined altitude is reached, the servo turns the lock of the system to release the spring.
- The spring pushes the plate to release the parachute, and separates the magnets that hold the lids together.
- After the lids are separated by the parachute, the parachute deploys.

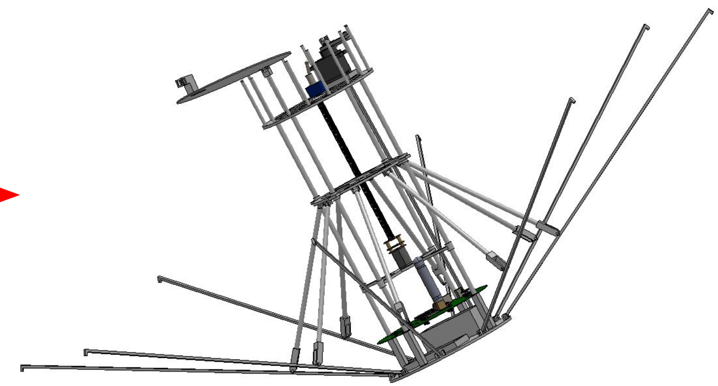
Payload Parachute Deployment Configuration Trade & Selection (3/3)

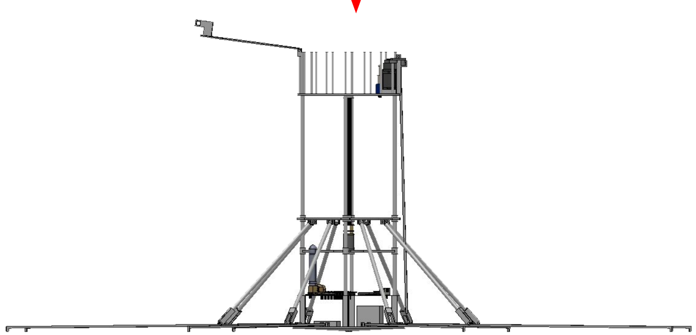
Parachute Deployment Trade		
Concept	Concept A	Concept B
Advantages	• Can also be used as an uprighting mechanism • Descent speed optimization can be done much faster without the change of any parts • Passively Stable	• Light • Uses spring and magnets instead of motors • Not complex
Disadvantages	• Requires a dc motor • A lot of testing is needed to confirm reliable operation	• Magnets are unable to controlled • A lot of testing is needed to confirm reliable operation • Requires a dc motor

Selected Configuration	Rationale
Concept A	- Active stabilization is not something that we are very confident in - Using the heat shield as an uprighting mechanism.

Payload Uprighting Configuration Trade & Selection (1/3)

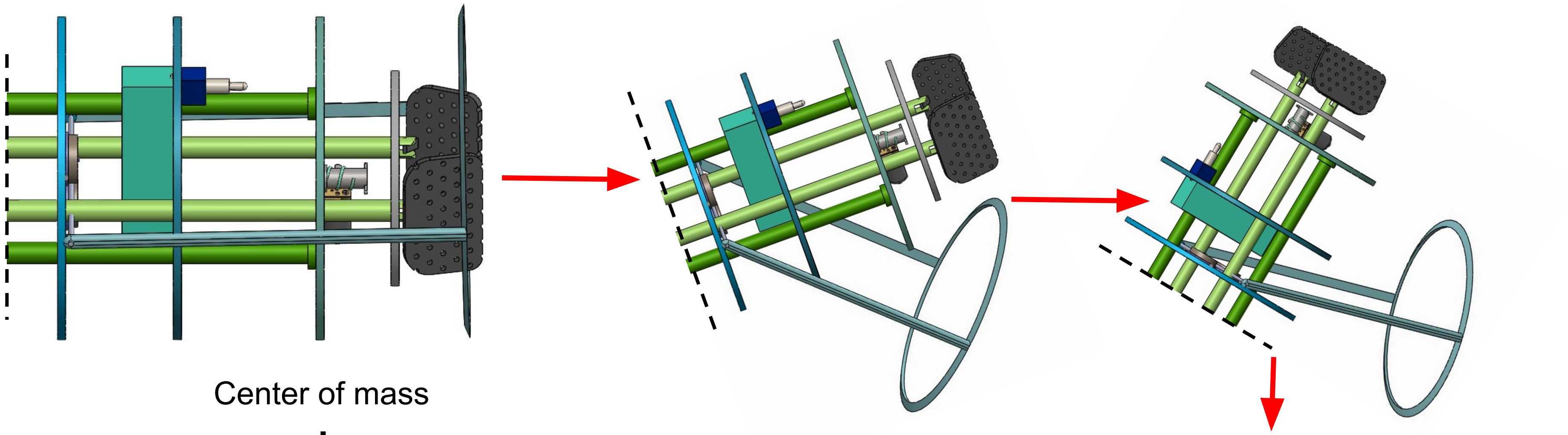


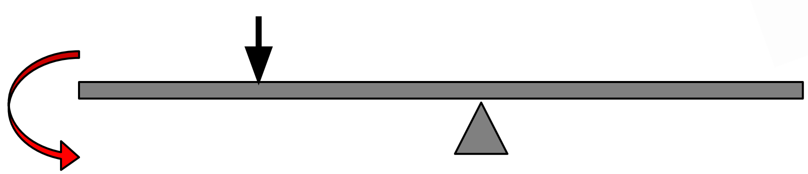


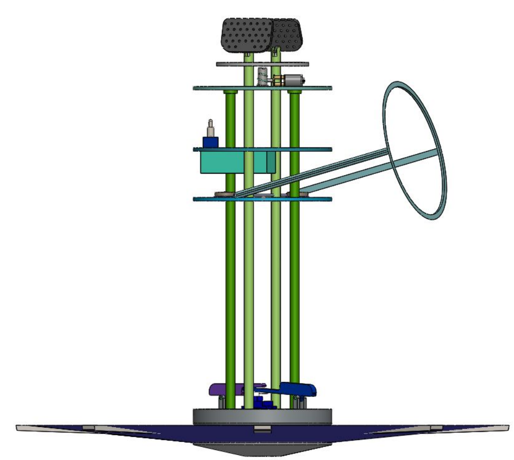


- First, the probe will land on its side.
- Then, the high torque dc motor will gradually move the **arms** to the fully extended position to upright the probe.

Concept B:







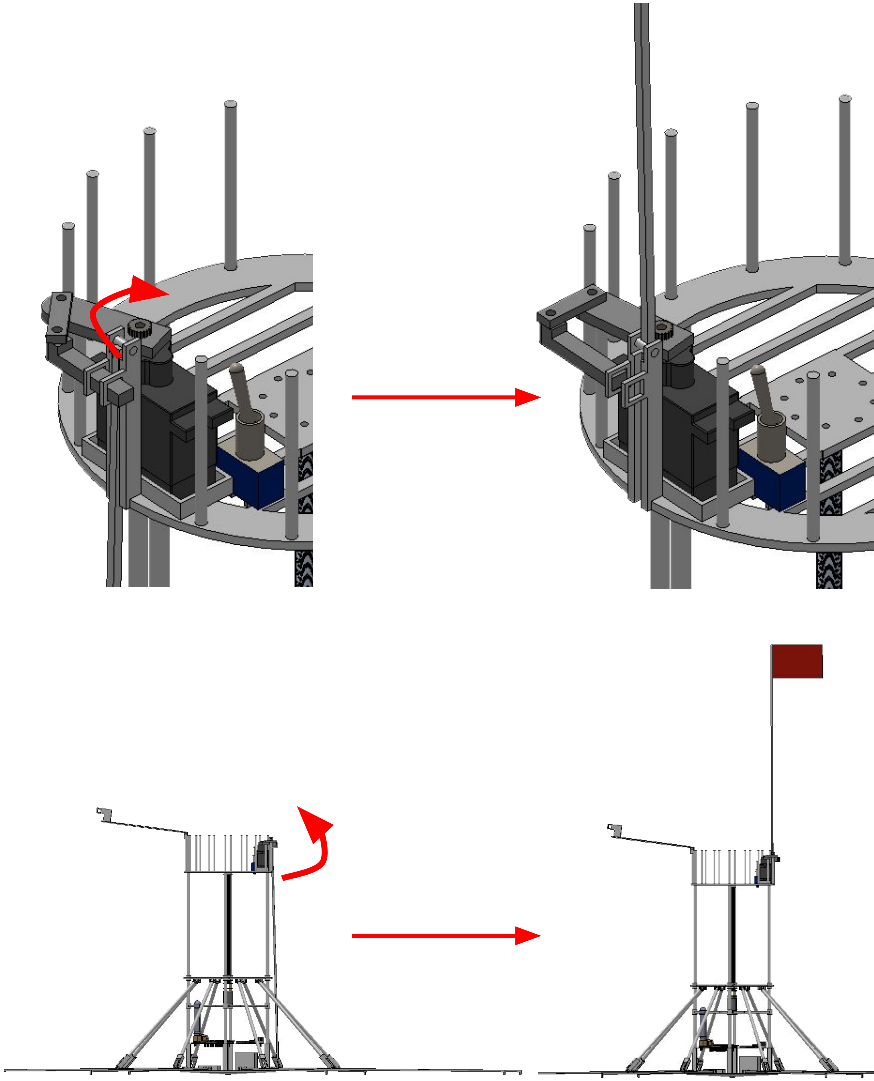
- First, the probe will land on its side.
- Then, the high torque dc motor will gradually move the lever of the uprighting mechanism till the probe can turn around the system's joint, such as above, using its centre of mass.

Payload Uprighting Configuration Trade & Selection (3/3)

Payload Uprighting Trade		
Concept	Concept A	Concept B
Advantages	• Uses the moving plate/arms mechanism • Surface variances does not affect the uprighting • Can upright itself from a wide range of landing situations	• Light • Basic concept • Not complex
Disadvantages	• Requires a DC motor • Requires a lot of power from the batteries • Requires testing to confirm reliable operation	• Depends on the ground shapes it must be flat • Requires an additional dc motor

Selected Configuration	Rationale
Concept A	- We need to account for a lot of landing conditions - An integrated system is easier to implement .

- Servo motor rotates to its final position and releases the flag mast.
- When the flag mast is released, a torsional spring located at its hinge raises it to full mast.



Electronics Structural Integrity

All electronics will be mounted using high performance adhesives and some standoff mechanism, we will use a PCB which will be used to integrate all of the electronics on the probe.

We only have a camera and a small PCB on the probe. They will be mounted using high performance adhesives.

Wires going up to the power switch, down to the camera and battery are going to secured using tape and zip ties.

Mass Budget (1/4)

Payload Mass Budget (1/2)

Component	Mass (g)	Source
PCB	28	Estimated
BMP280	0.5	Estimated
MPU9250	0.5	Estimated
NEO-M8N	4	Estimated
STM32F401RET6	1	Estimated
Li-Ion Battery 18500	34	Datasheet
Adafruit Mini Spy Cam	2.8	Datasheet
Payload Antenna	6.7	Estimated
SG90 Servo	9	Datasheet
Flash Memory	0.5	Estimated
N20 DC Motor	9.5	Datasheet

Component	Mass (g)	Source
CR2032 Button Cell	2.92	Measured
XBee Pro S3B	8	Measured
Parachute	45	Estimated
Base Plate	65	Estimated
Arms	20	Estimated
Connecting Rods	24	Estimated
Structural Rods	45	Measured
Moving Plate	10.51	Estimated
Threaded Rod	20	Estimated
Motor Plate	7.5	Estimated
Flag Mast	10	Estimated

Mass Budget (2/4)

Payload Mass Budget (2/2)

Component	Mass (g)	Source
Parachute Containment Bay	35.5	Estimated
Payload Parachute	45	Estimated
Aerobraking Fabric	30	Estimated
Parachute Lid	13	Estimated
Servo Arms	3	Estimated
Total	470.9	

Mass Budget (3/4)

Container Mass Budget

Component	Mass (g)	Source
Adafruit Mini Spy Cam	2.8	Datasheet
CR2032 Button Cell	2.92	Measured
Container Shell	170	Analysis
Container Structural Rods	10	Analysis
Parachute Bay	22.97	Analysis
Parachute	15	Estimated
Total	223.7	

Mass Budget (4/4)

Total Mass Budget

Component	Mass (g)
Payload	470.9
Container	223.7
Total	694.6

Communication and Data Handling (CDH) Subsystem Design

Alp Kaan Kottas, Burak Aydar

Payload Command Data Handler (CDH) Overview

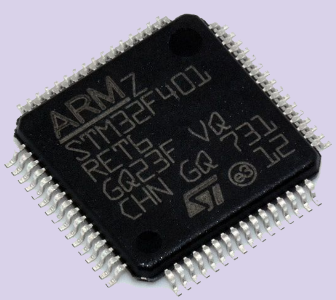
Type	Component	Functions
Processor	STM32F401RET6	Controlling all the sensors and processing data, triggering events and communicating with the ground station.
SPI Flash Memory	Winbond W25Q32JVSSIQ	Used to store calibration and the state of the CanSat.
RTC	Internal RTC in STM32F401RET6	Keep track of real time to measure the mission time.
GCS Antenna	ZQTMAX Yagi-Uda Antenna	Increase the receiving sensitivity of the XBee
Payload Antenna	Linx Tech. ANT-916-CW-RAH-SMA	Increase the gain of the XBee transmission
Payload Radio	XBee-PRO S3B	Telemetry transmitter
GCS Radio	XBee-PRO S3B	Telemetry receiver

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

Microcontroller	Boot time	Clock Frequency	Data Interfaces	Non-volatile Memory	Volatile Memory	Dimensions (mm)	Cost ($)
STM32F401RE T6	85 ms	84 MHz	3 x I2C 4 x SPI 3 x USART	512 kB Flash	96 kB	10.0 x 10.0	10.84
STM32F103C8 T6	≤20 ms	72 MHz	2 x I2C 2 x SPI 3 x USART	64 kB Flash	20 kB	6.0 x 6.0	9.31
Atmega2560	2.5 s	16 MHz	1 x I2C 5 x SPI 4 x USART	256 kB Flash 4 kB EEPROM	8 kB	14.0 x 14.0	16.24

Selected Microcontroller

STM32F401 RET6



Reasons

- Enough data interfaces
- More volatile memory
- Cheaper than Atmega2560
- Experience with the microcontroller
- Enough number of GPIO pins

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

Flash Memory	Max Supported Frequency	Memory Interfaces	Memory	Write cycle time	Size	Cost ($)
Winbond W25Q32JVSSIQ	133 MHz	SPI	32 MB	3 ms	5.30mm Width	1
Winbond W25Q128JVSI	133 MHz	SPI	128 MB	3 ms	5.30mm Width	4

Flash Memory

Winbond

W25Q32JVSSIQ

Reasons

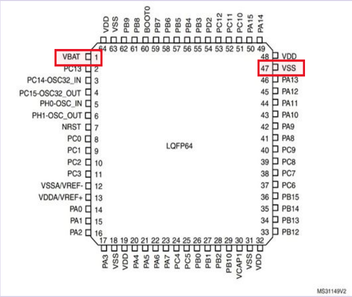
- Sufficient memory
- Cheaper
- Higher availability

Payload Real-Time Clock

RTC	Reset Tolerance	Weight (g)	Dimensions (mm)	Cost ($)
STM32F401RET6 Built-in RTC	Unaffected due to coin battery backup	Integrated in STM32	Integrated in STM32	0
DS3231 Precision RTC Module	Unaffected due to coin battery backup	2.3	38.0 x 22.0 x 14.0	4.14
Adafruit DS1307 RTC	Unaffected due to coin battery backup	8	25.5 x 21.7 x 5	16.24

Selected Microcontroller

STM32F401 RET6 Built-in RTC



Reasons

- High precision
- No extra space and weight since onboard
- No additional cost since it is built-in
- Resolution is better than **1 second**

Note: A 3V lithium button cell will be connected between VBAT and VSS pins of STM32 as an external backup supply throughout the mission for the RTC.

Payload Antenna Trade & Selection(1/3)

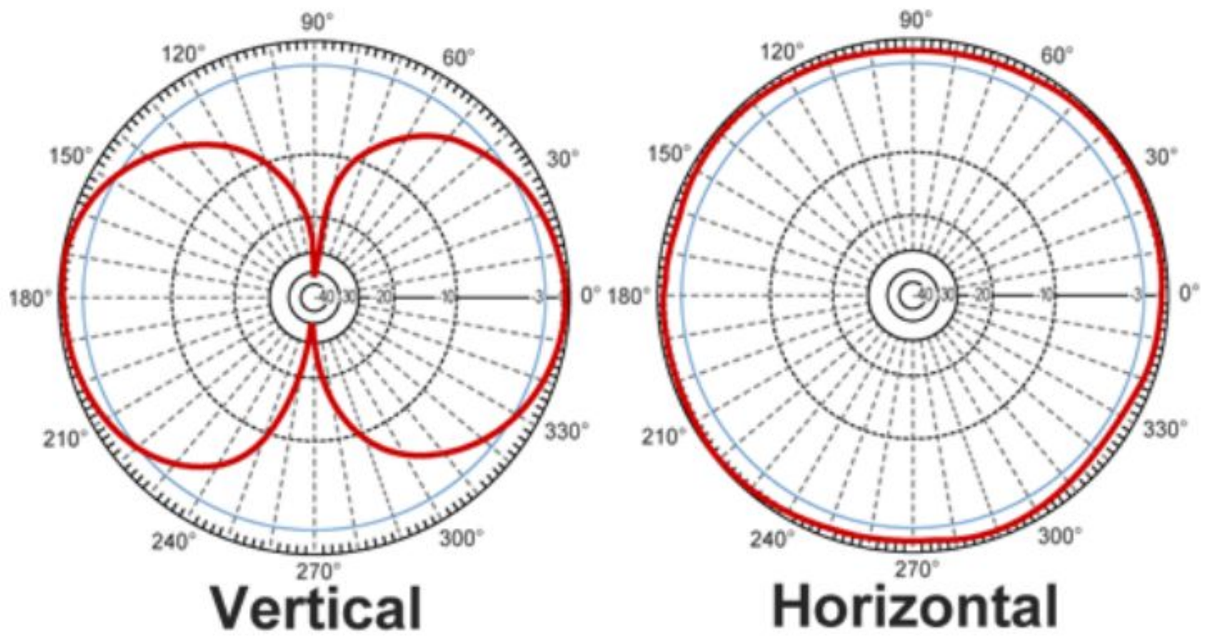
Payload Antenna Model	Radiation Pattern	Gain (dBi)	Frequency Range (MHz)	Dimensions dia. x h (mm)	Weight (g)	Cost ($)
Linx Tech. ANT-916-CW-RAH-SMA	Omni-Directional, Toroidal	2.2	850 - 970	8 x 46.5	6.7	7.87
HyperLink 900mhz Duck Antenna	Omni-Directional, Toroidal	3	860 - 960	33 x 60	30	20.39

Selected Antenna

Linx Tech. ANT-916-CW-RAH-SMA

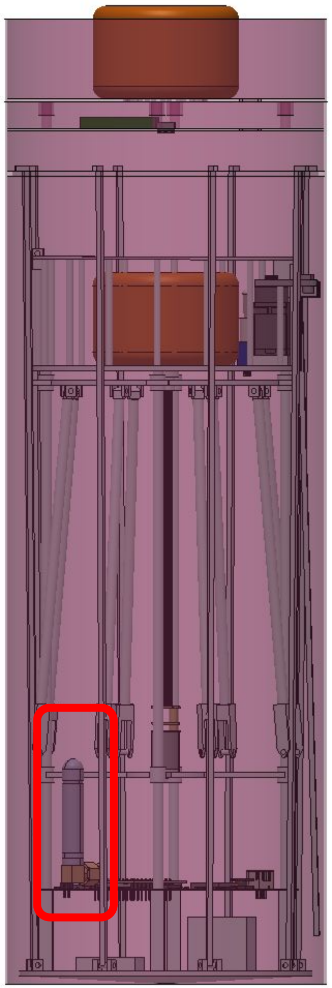
Reasons

- Less weight
- Smaller size
- Cheaper

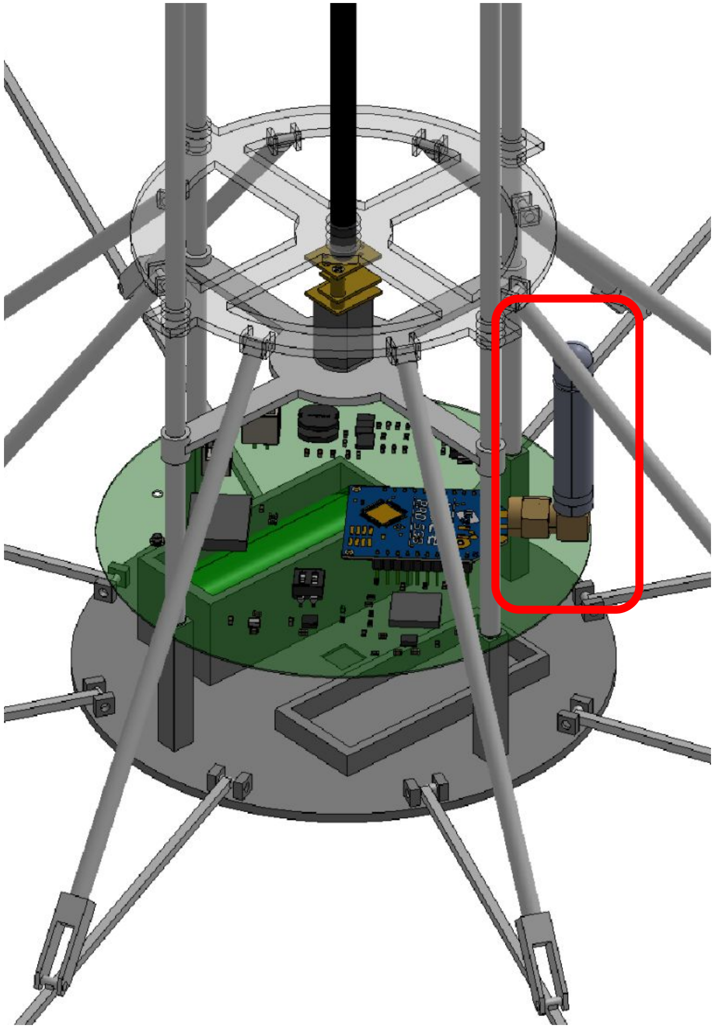


Linx Tech. ANT-916-CW-RAH-SMA Radiation Pattern

Payload Antenna Trade & Selection(3/3)



Antenna location on integrated Cansat



Antenna location on landed payload

Payload Radio Configuration

Radio Model	Operating Frequency	Transmit Power	Rx sensitivity
Xbee-Pro-S3B-900HP	920 MHz	250 mW (24 dBm)	-101 dBm

XBEE Configuration

XBEE Radio Selection: Xbee-Pro-S3B-900HP

NETID: Will set it to be the same as our team number. **(#1068)**

Transmission Mode: **Unicast** mode will be used instead of Broadcast mode.

Transmission Control

- After CanSat is turned on, communication will start between the ground station and the payload.
- The data transmission frequency will be **1 Hz** throughout the entire mission.
- After the flag mast operation is complete, the packet transmission will be stopped by FSW.

Payload Telemetry Format (1/2)

Data Type	Description
TEAM_ID	assigned team number
MISSION_TIME	time in UTC tracked by rtc
PACKET_COUNT	# of transmitted packets
MODE	F for flight, S for simulation
STATE	operating state
ALTITUDE	altitude relative to the launch site in meters
HS_DEPLOYED*	P if heat shield is deployed
PC_DEPLOYED*	C if parachute is deployed
MAST_RAISED*	M if flag is raised
TEMPERATURE	temperature in celsius

***: N otherwise**

Data Type	Description
PRESSURE	air pressure in kPa
VOLTAGE	battery voltage in Volts
GPS_TIME	time given by GPS
GPS_ALTITUDE	altitude given by GPS
GPS_LATITUDE	latitude given by GPS
GPS_LONGITUDE	longitude given by GPS
GPS_SATS	# of tracked GPS satellites
TILT_X	angle from the x-axis in degrees
TILT_Y	angle from the y-axis in degrees
CMD_ECHO	last command received and processed by FSW

Payload Telemetry Format (2/2)

Data Format	Each packet will be sent to the ground station as a string (array of chars) in CSV (comma-separated values) format. - "TEAM_ID, MISSION_TIME, PACKET_COUNT, MODE, STATE, ALTITUDE, HS_DEPLOYED, PC_DEPLOYED, MAST_RAISED, TEMPERATURE, VOLTAGE, PRESSURE, GPS_TIME, GPS_ALTITUDE, GPS_LATITUDE, GPS_LONGITUDE, GPS_SATS, TILT_X, TILT_Y, CMD_ECHO"
Example Payload Frame with Sample Data	"1068, 13:20:22, 23, F, PRE_LAUNCH, 0.09324, N, N, N, 25, 4.2, 92, 09:20:22, 932.021, 39.891388, 32.784721, 8, 0.4023, 0.2014, CAL"

The telemetry data file will be named "Flight_1068.csv".

The presented format matches the Competition Guide Requirements.

Payload Command Formats (1/2)

Command Data Format	Each command will be sent to GCS as a string (array of chars)

Command Type	**Command**	**Description**
CX - Telemetry On/Off	CXON	enables and activates telemetry
	CXOFF	disables and deactivates telemetry
ST - Set Time	CMD,1068,ST,<UTC_TIME>	sets time to the time within 1 second UTC time provided by the ground station
	CMD,1068,ST,GPS	sets time to the time given by GPS
SIM - Simulation Mode	CMD,1068,SIM,ENABLE	enables simulation mode
	CMD,1068,SIM,ACTIVATE	activates simulation mode
	CMD,1068,SIM,DISABLE	disables and deactivates simulation mode
SIMP - Simulated Pressure Data	CMD,1068,SIMP,<PRESSURE>	provides the flight computer with a simulated pressure reading
CAL - Calibrate Altitude to Zero	CAL	calibrates the altitude value to zero

Payload Command Formats (2/2)

Example Commands	CXON: enables and activates telemetry CXOFF: disables and deactivates telemetry CMD,1068,ST,14:25:12: sets time to 14:25:12 on the payload flight computer CMD,1068,ST,GPS: sets time to the time given by GPS CMD,1068,SIM,ENABLE: enables simulation mode CMD,1068,SIM,ACTIVATE: activates simulation mode CMD,1068,SIM,DISABLE: disables and deactivates simulation mode CMD,1068,SIMP,92000: provides the flight computer with a simulated pressure reading that is equal to 92000 Pa. CAL: calibrates the altitude value to 0 relative to the ground level at launch site.

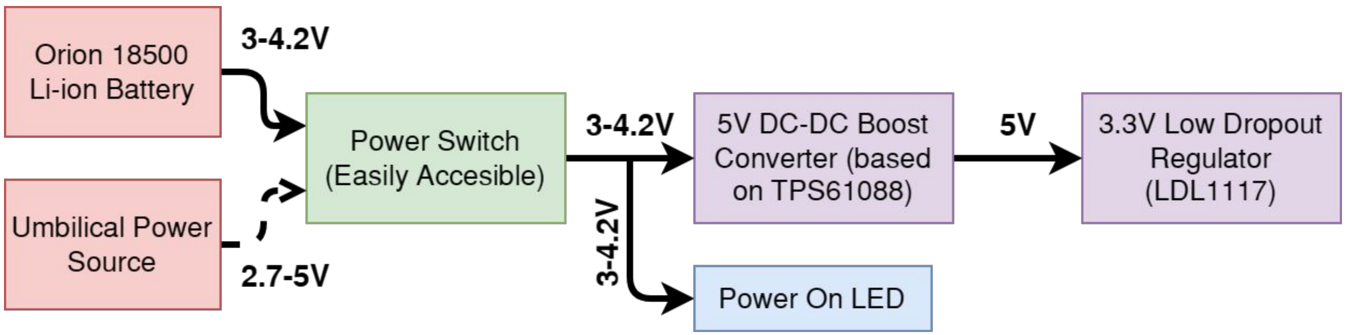
The presented format matches the Competition Guide Requirements.

Electrical Power Subsystem (EPS) Design

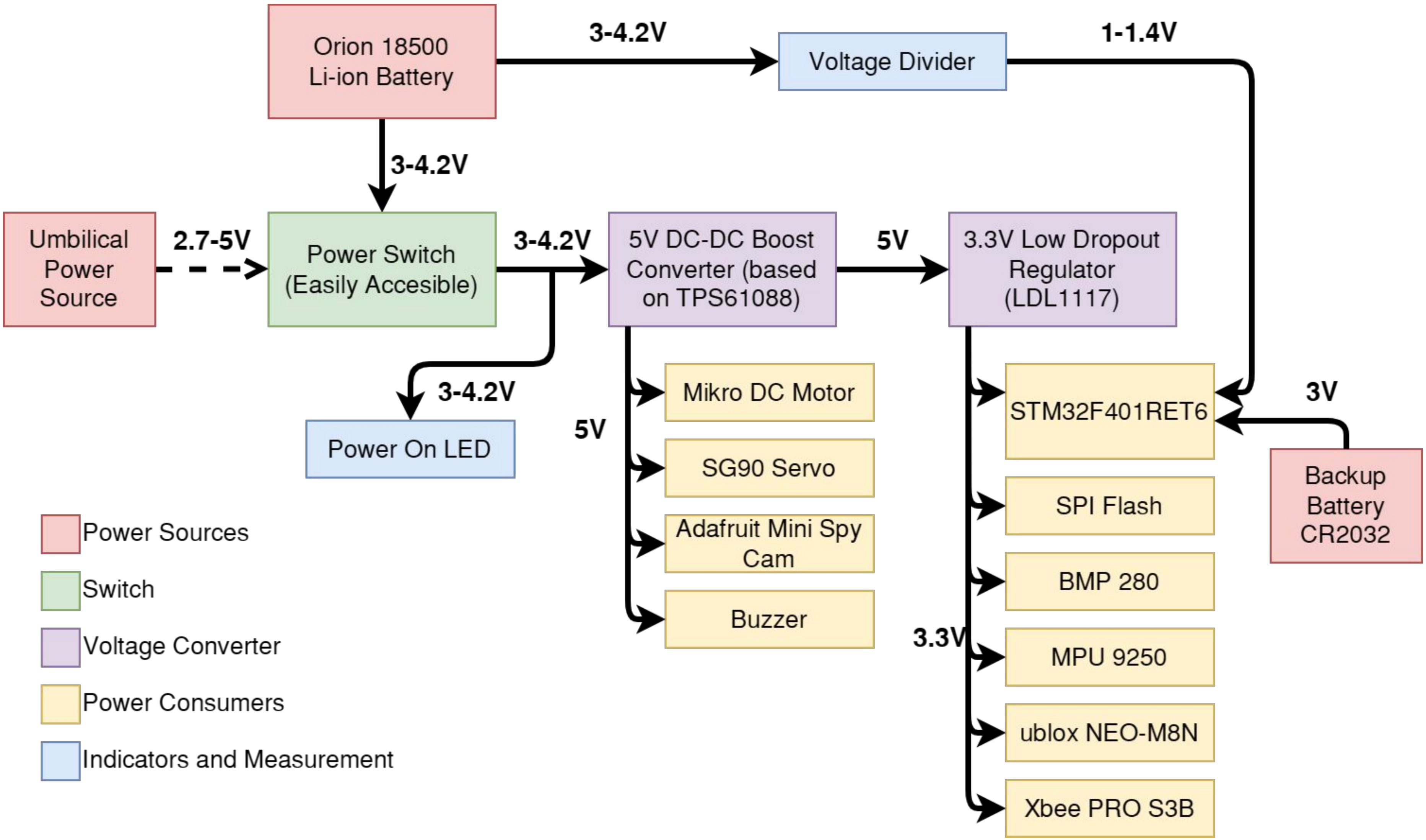
Mehmet İlbağı

EPS Overview

Components	Functions
Orion 18500 Li-Ion Battery 3.7V	Main power source of probe
External Power Switch	Gives ability to turn on and off main power
5 Volt DC-DC Boost Converter (based on TPS61088)	Supplies power for servos, buzzer, and 3.3 Volt LDO Regulator.
3.3 Volt LDO Voltage Regulator (LDL1117)	Supplies power for MCU, sensors, XBee radio and LEDs.
Power On LED	Power Indicator
Umbilical Power Source	Cansat power supply for tests



Payload Electrical Block Diagram



Payload Power Trade & Selection

Cell	Chemistry	Voltage (V)	Capacity (mAh)	Capacity (Wh)	Size dia. x h (mm)	Weight (g)	Cost ($)
Sony VTC6 18650	Li-Ion	3.7	3000	11.1	18 x 65	46.6	8.11
Samsung INR18650-35E	Li-Ion	3.7	3500	12.95	18 x 65	50	13.45
Orion 18500/15	Li-Ion	3.7	1500	5,55	18 X 50	34	4.76

Selected Battery

Orion 18500/15 Li-Ion Battery

Reasons

- Less weight
- Smaller Size
- Cheaper

Note: Battery will be used at **single cell** configuration. A cable with connector will be point welded to terminals of battery. Power traces are fused at the PCB.

Payload Power Budget (1/2)

Components	Voltage (V)	Current (mA)	Duty Cycles (h:min:sec)	Total Power Consumption (Wh)	Source
XBee Pro S3B	3.3	215	02:00:00	1.419	Datasheet
STM32F401RET6	3.3	15.8	02:00:00	0.104	Datasheet
Adafruit Mini Spy Camera	5	110	00:05:00	0.0458	Datasheet
BMP280	3.3	0.0042	02:00:00	Neglected	Datasheet
MPU9250	3.3	3.7	02:00:00	0.0244	Datasheet
Heat Shield DC Motor	5	450	00:10:00	0.375	Datasheet
Parachute Lock Servo	5	270	00:00:05	0.0019	Datasheet
uBlox Neo-M8N	3.3	32	02:00:00	0.2112	Datasheet
Buzzer	5	80	00:30:00	0.2	Datasheet
Power Ind.LED	3.3	20	02:00:00	0.132	Estimated

Payload Power Budget (2/2)

Available Total Power (Wh)	5.55
Total Power Consumption (Wh)	2.52
Power Consumption Margin (Wh)	3.03
Possible Operating Time	**4 hour 56 minutes**

Note: We also have a CR2032 coin cell for the RTC built-in STM32F401RET6. We did not include it in this budget.

Flight Software (FSW) Design

Burak Aydar, Baris Berk Kottas

FSW Overview (1/3)

Overview of Flight Software

- The main task of the FSW is to evaluate the data coming from the sensors and to take some actions according to the stage of the cansat.
- "Kalman Filter" will be used during the evaluation of the data coming from the sensor, so that the errors in the incoming data will be minimized.
- Even if the processor is reset with the SPI Flash in the flight computer, the FSW will continue to work from where it left off.

Programming Languages

- C++ language will be used to program the processor.
- Various C libraries will be supported in sensor programming and filtering.

Development Environments

- **STM32CubeIDE**, **STM32CubeMX** and **Keil** are used to program the processor.
- XBee configurations will be made through the **XCTU** program.
- We use **VSCode** to build libraries and optimize our code.

FSW Overview (2/3)

FSW Tasks

PRE_LAUNCH
- CanSat is turned on with a power switch
- Sensor calibrations take place
- Establish the connection to GCS
- Send telemetry and calibration data to GCS and save to flash memory (1 Hz)

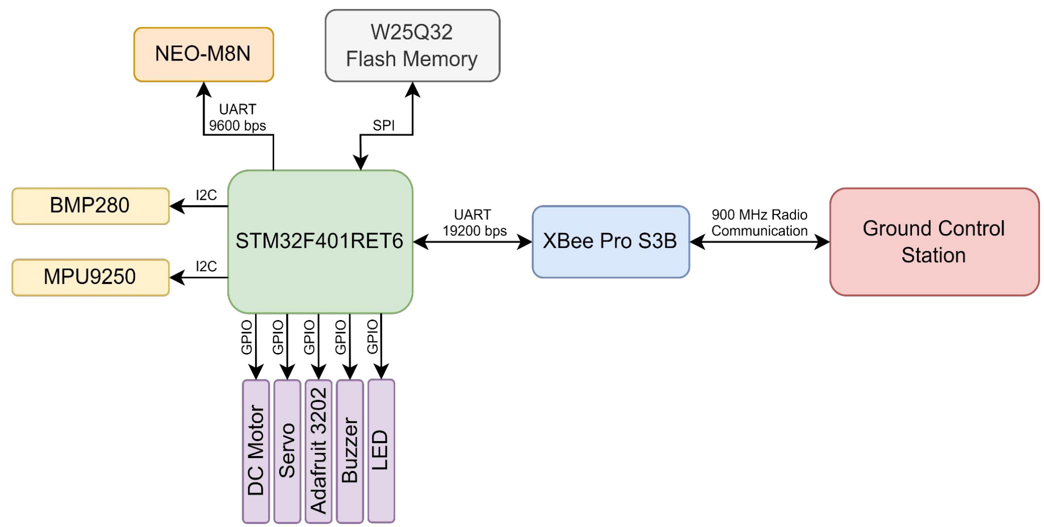
ASCENT
- Start recording the video and save the video to integrated SD module

DESCENT
- Release the probe from the container at 500 meters

AEROBRAKING
- Deploy the probe parachute at 200 meters

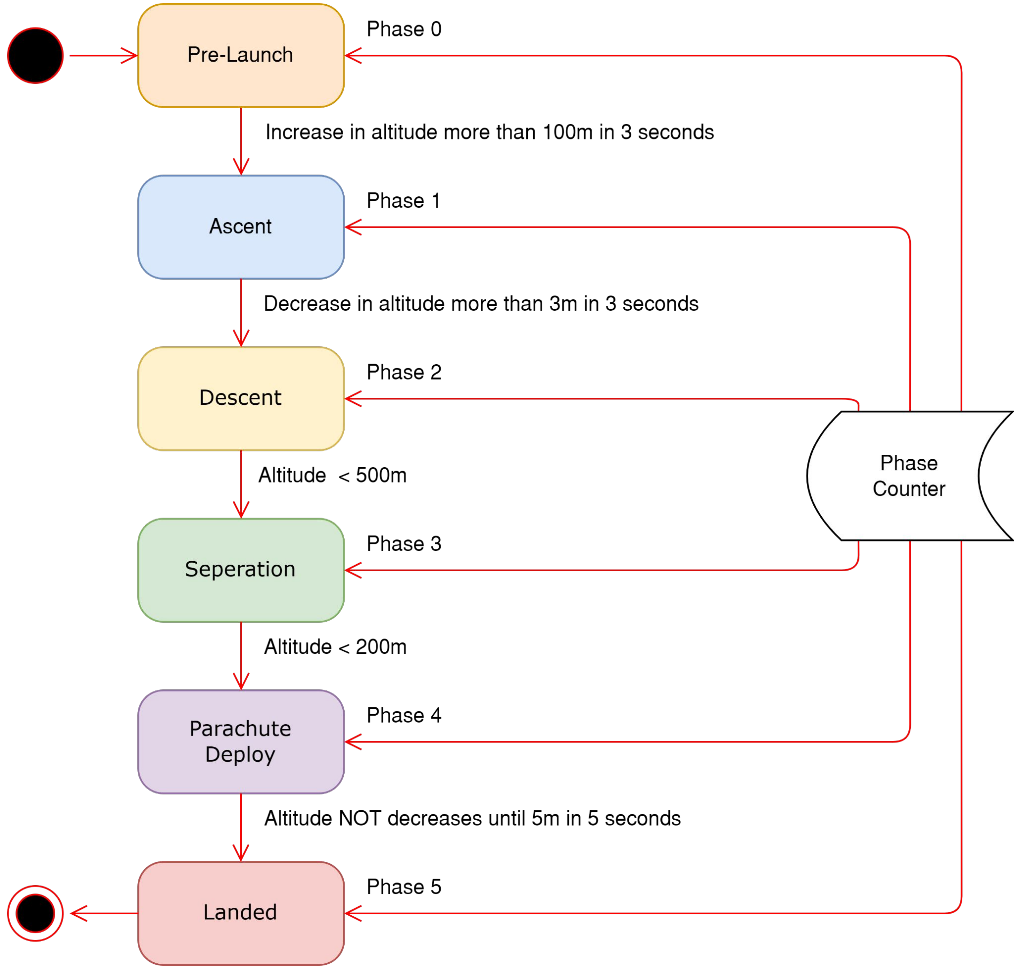
LANDED
- Obtain the orientation and upright the probe if needed
- Raise a flag 500 mm above
- Turn on the audio beacon (buzzer)

Hardware Block Diagram

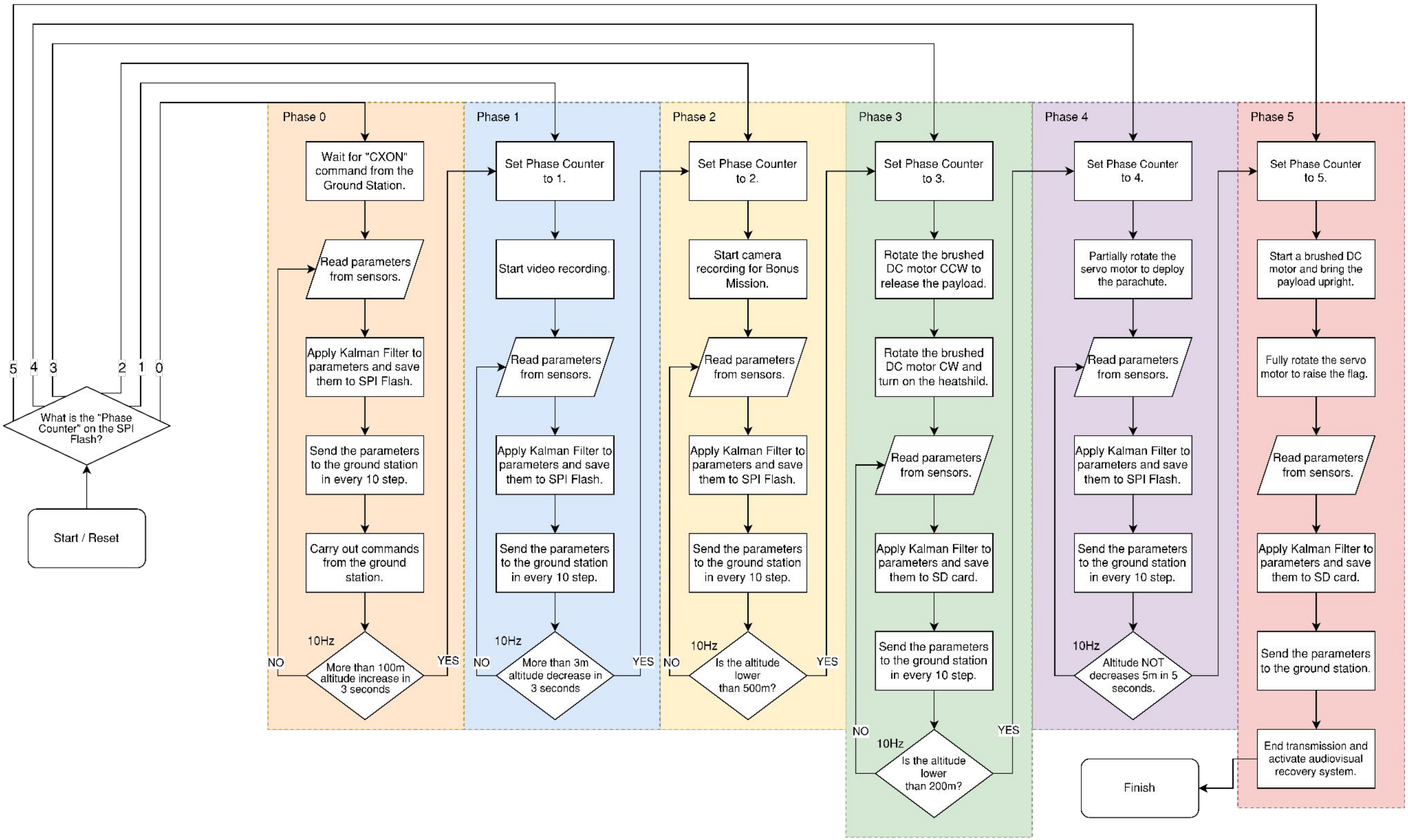


FSW Overview (3/3)

All states writes its phase number into the phase counter as their first job.



Payload FSW State Diagram (1/2)



Payload FSW State Diagram (2/2)

The following will be kept in the SPI flash:

Time

Calibration data

Phase counter

High acceleration, high temperature, static shock, excessive vibration and voltage fluctuations can cause the processor to reset.

As a precautionary measure in case of a reset, FSW will regularly perform a phase check and packet number check from the SPI Flash.

When a reset is detected, the phase is detected by the FSW, calibration is adjusted and CanSat continues from where it left off.

Simulation Mode Software

- The SIM commands, ENABLE and ACTIVATE, will be sent to the CanSat to activate the simulation mode.
- Once the simulation mode is activated, the pressure **sensor data will be overridden**. FSW will use the pressure data sent using the SIMP command to calculate the altitude. The pressure data will be taken from a .csv file.
- The other sensor values such as tilt, acceleration, orientation, etc. will not be affected due to the transition between flight and simulation mode. These sensor values will keep getting collected and processed by FSW no matter what.
- Using the SIM command, DISABLE, will be sent to the CanSat to switch the payload back to flight mode. FSW will thereupon resume using the pressure data collected from the sensor.

SIM - Simulation Mode Control Command (CMD,<TEAM_ID>,SIM,<MODE>)
CMD,1068,SIM,ENABLE - disable the flight mode and switch to the simulation mode
CMD,1068,SIM,ACTIVATE - activate the simulation mode
CMD,1068,SIM,DISABLE - disable the simulation mode and switch back to the flight mode

SIMP - Simulated Pressure Data (CMD,<TEAM ID>,SIMP,<PRESSURE>)
CMD,1068,SIMP,100000 - send the given pressure data from GCS to the payload if the simulation mode is activated

- In simulation mode, the ground station will be able send pressure data at 1 Hz.

Software Development Plan

Software Development Plan → Write the libraries for selected sensors → Test each sensor separately → Put together the system with all sensors → Write FSW and test algorithms

Prototyping

- The libraries of each sensor will be written in VS Code.
- After all the sensors are confirmed to be working separately, the electronic system will be put together on a breadboard to perform specific tests.
- Finally, PCB will be assembled to perform environmental tests.

Software Subsystem Development Sequence

- Github is used to work collaboratively on our flight software.
- Prepare the FSW state diagram
- Develop the necessary algorithms to accomplish the mission objectives.

FSW Development Team: Alp, Barış and Burak

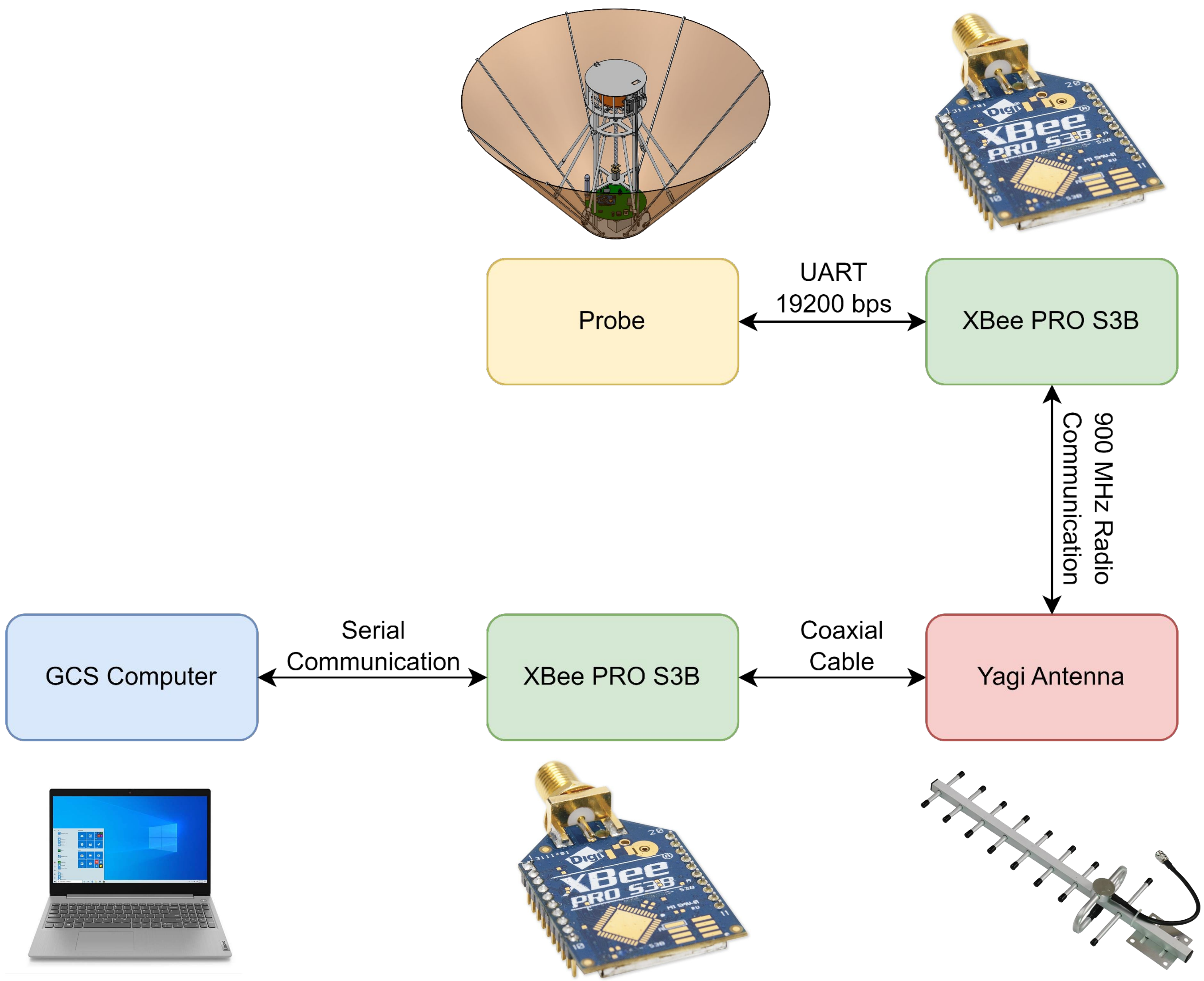
Test Methodology

- FSW will be tested to confirm whether the algorithms working as intended.
- The following environmental tests will be performed on the electronic system;
  - Drop test
  - Thermal test
  - Vibration test
  - Fit Check
  - Vacuum test

Ground Control System (GCS) Design

Barış Berk Kottas, Berkant Alperen

GCS Overview



GCS Design

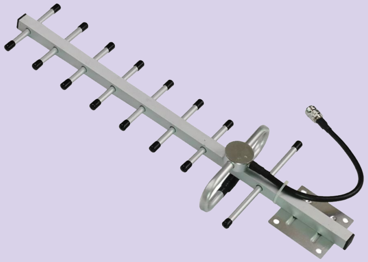
Specifications	
Operation Time	GCS can operate for minimum 2 hours with the internal battery of the laptop.
Overheating Mitigation	We will protect the computer from sunlight with an umbrella.
Auto Update Mitigation	Windows automatic updates will be paused for 5 weeks using the settings app.

GCS Antenna Trade & Selection (1/3)

GCS Antenna Model	Type	Gain (dBi)	Frequency Range (MHz)	Size (cm)	Cost ($)
ZQTMAX Yagi-Uda Antenna	Yagi-Uda Antenna (with folded dipole)	13	806 - 960	50	21.16
HyperLink Wireless 900MHz	Patch Antenna	8	908-928	22 x 22	106.99

Selected Antenna

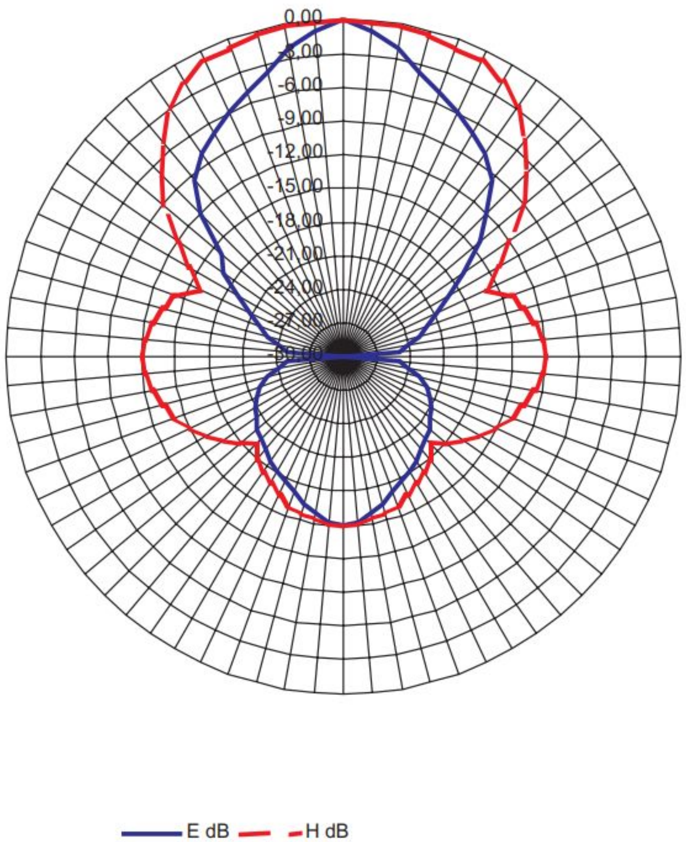
ZQTMAX Yagi-Uda Antenna



Reasons

- Cheaper
- Better gain

GCS Antenna Trade & Selection (2/3)



ZQTMAX Yagi-Uda Antenna Radiation Pattern

GCS Antenna Trade & Selection (3/3)

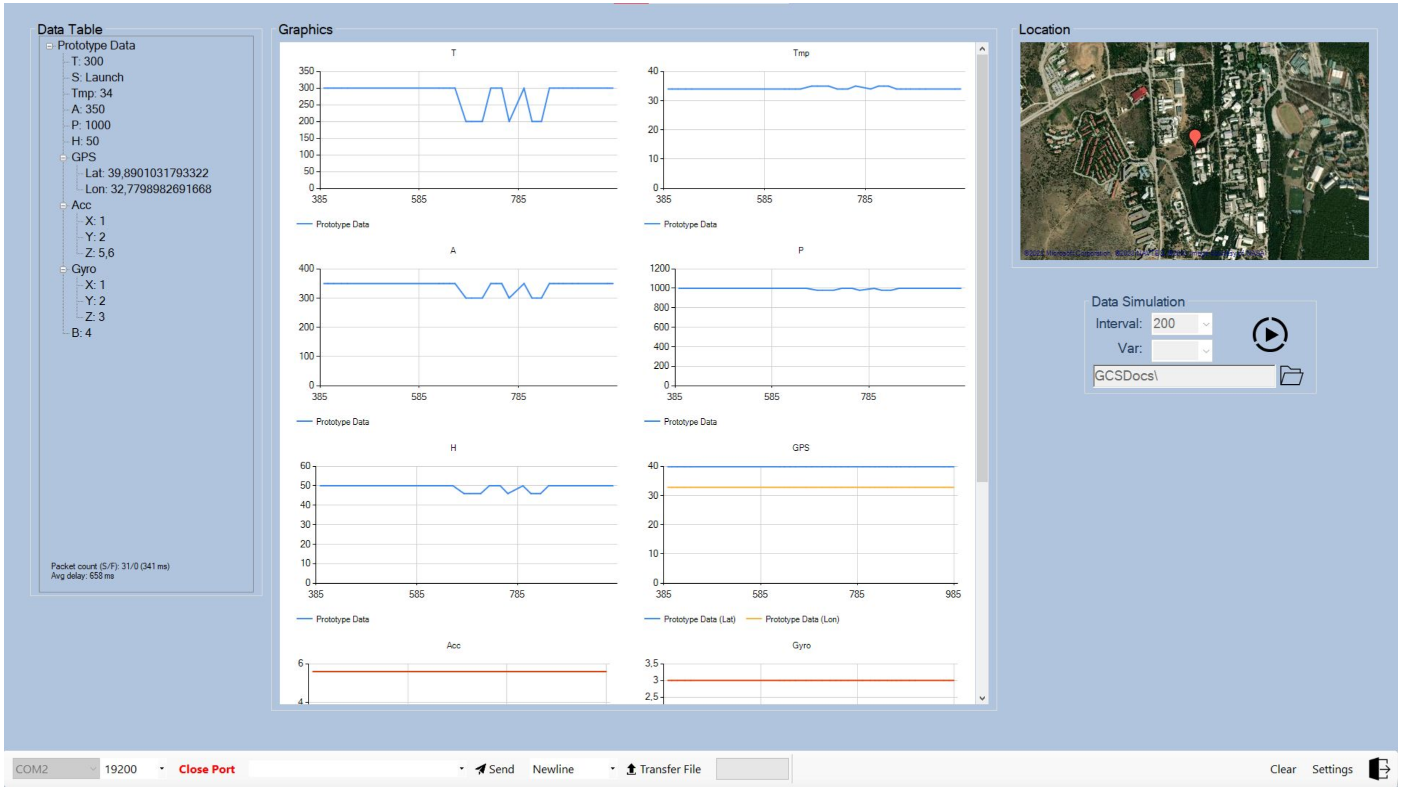
Handheld Antenna

Tripod Mounted

Selected Antenna Mounting	Reasons
Handheld Antenna	- Easy to direct antenna to the CanSat - Cheaper than the tripod mounted design

GCS Software (1/2)

GCS Prototype Overview



Ground station software is developed on Microsoft Visual Studio .NET Framework using C# in order to achieve high performance throughout the mission. It is advantageous to have multi-threading software to not miss any telemetry packet while rendering multiple charts.

GCS Software (2/2)

- **Packages used:** Two NuGet packages are used in developing the GCS software. CSVHelper for data logging and simulation and GMAP for GPS mapping.
- **Telemetry display:** Telemetry data will be displayed as simple text at the TreeView control on the left of the screen. Numeric data will be displayed on “Graphics” panel as well. GPS data will be shown in the map on the right of the screen Real data will be shown with the appropriate scientific units.
- **Plotting:** Plotting will be done in real time using the built-in Chart package of .NET Framework. Each numeric variable will have its own chart.
- **.csv telemetry file creation for judges:** All received data will be logged along with their names on the computer in “csv” format using the “CSVHelper” package.
- **Calibration command and verification:** Calibration command will be sent to CanSat using the serial communication panel at the bottom of the screen. All commands will be added to autocomplete library. Verification will be done by checking the data being received from the logs (saved as .csv files) after the command has been sent.
- **Telemetry data recording and media presentation to judges:** Data log files will be transferred to judges via a USB drive after the launch operations.
- **Simulation mode:** Simulation file will be selected from the simulation tools panel under the GPS. A timer will be started with a given time interval and will be passing related data to the “data_received” function which handles the data. To activate the simulation mode, the serial communication control will be used to send commands to the CanSat.

CanSat Integration and Test

Umut Altun, Semihcan Seven

CanSat Integration and Test Overview

We will use the following workflow for integration and testing

Subsystem Level Testing → Integrated Level Testing → Simulation Testing → Environmental Testing

- Sensors
- CDH
- EPS
- Radio
- FSW
- Mechanical
- Descent Control

- Descent Testing
- Communications
- Mechanisms
- Deployment

- Simulation Mode
- Sensor Mode

- Drop Test
- Thermal Test
- Vibration Test
- Fit Check
- Vacuum Test

Subsystem Level Testing Plan (1/3)

Sensor Tests	Test Method
GPS Sensor test	The data from the GPS Sensor will be compared and tested with Google maps.
Payload Rotation Sensor test	Orientation of payload will be checked with respect to the Earth magnetic field
Battery Voltage Sensor test	Measure and compare battery with Voltmeter
Air Pressure Sensor test	Measuring altitude location comparing known altitudes
Air Temperature Sensor test	Compare measured temperature with thermometer

CHD Tests	Test Method
Telemetry format test	Use the same XCTU setup, test telemetry data format with some message sent between the two Xbees, verification of received data.
Simple transmit test	Telemetry transmission will be tested up to 1 km range for determining antenna range which will provide the distance like field competition.
Range test	Cansat will be taken to a location where two antennas are around 1.5 km away.

Subsystem Level Testing Plan (2/3)

EPS Test	Test Method
Voltage Regulation Test	Main power line will be checked if when required the current flows on it is steady or not.
Components’ power supply test	All components will be checked separately whether they are powered properly or not.
Battery high current test	When power consumption is high, battery will be checked if it withstands the high current.
Battery discharge time test	Battery will be tested if it can supply current at max power consumption.
Voltage regulators	Proper and desired voltage on all power lines under load

Descent Control Test	Test Method
Velocity test	Descent velocity will be tested by dropping CanSat from a high building.
Payload parachute test	Payload parachute will be tested with a dummy weight.
Change between flight states	States changes will be tested with simulating transition conditions.

Subsystem Level Testing Plan Mechanical (3/3)

Mechanical Tests	Test Method
Servo Operation Test	Servo will be operated after being installed on the probe to ensure it can reliably release the parachute lid and flag mast.
DC Motor Operation Test	DC motor will be tested throughout its full range of motion - Probe release test - Heat shield extension test - Uprighting test

Descent Control Tests	Test Method
Container Parachute Deployment Test	Container will be released from a high building to confirm descent rate calculations
Parachute Testing	Independent parachutes will be tested to ensure that they match the calculated drag forces.

Integrated Level Functional Test Plan

Subsystem	Test
Descent Testing	A drone will be used to raise the cansat to an altitude of 700 meters and released.
	The probe will deploy its aerobrake and parachute at the predetermined altitudes
Communications	Communication between the sensors and components on the PCB will be tested to check any possible failure such as short circuit, malfunctioning of any sensors.
	Consistency and quality of the data flow will be checked.
Mechanisms	The uprighting mechanism will be tested on different types and slopes and surfaces.
	Flag mast mechanism operation will be tested while stationary on the ground.
Deployment	That each deployment subsystem works according to our expectations will be tested.
	The probe and container (in stowed configuration) will be held upright and arms will be retracted, probe will be caught by hand.

Environmental Test Plan

Subsystem	Test
Drop Test	CanSat will be tied up to an eyebolt fixed high-up from the ground using a 61 cm non-stretching cord. CanSat will be raised to same level as the eyebolt and then it will be released to generate 30 g's of shock on the system. It will be verified that all systems work without any problems during the test.
Thermal Test	CanSat will be put in a thermal insulator and turned on. The air temperature will be increased by use of a heat gun. After the temperature reaches 55-60C every part and subsystem of the CanSat will be observed for two hours to ensure they work properly.
Vibration Test	CanSat will be put on a sander and turned on. The sander will be operated at full speed for 5 seconds. During this time it will be observed whether the CanSat shows any disfunction or error in collecting data and whether there are damages on the CanSat. This will be repeated 4 times.
Fit Check	All moving parts will be checked independently to ensure that they move freely. Parts will also be checked if they are connected strong enough.
Vacuum Test	CanSat will be put in a vacuum chamber and turned on. Vacuum chamber will start pulling vacuum and stop when the vacuum represents the peak altitude. The air will be allowed to enter the chamber slowly. The collected data will be monitored during the process.

Simulation Test Plan

The ground station will provide simulated pressure data readings to test if the FSW and the mechanical subsystems work properly. When testing, we will check if each transition condition is satisfied successfully.

The simulated pressure data readings will represent a real flight.

Implementation	We will have an if condition such that when the simulation mode is enabled, the sensor data will be overwritten by the data provided by the ground station.
Pseudocode	if SIM_ENABLED: getStationData() else: getSensorData()

Mission Operations & Analysis

Semihcan Seven

Overview of Mission Sequence of Events (1/3)

Arrival	Pre-Launch	Launch
• Arrive at the launch site • Check if the CanSat is physically and functionally okay. • Check if the GCS is functioning properly.	• Moving the ground control station to dedicated location. • Electrical components will be tested. • Loading the payload • Assembly will be completed. • The ground station crew calibrates the altitude to 0	• CanSat will be stowed. • Executing launch order.
Team Members	**Team Members**	**Team Members**
• CanSat Crew: - Umut Altun - Alp Kaan Kottaş - Mustafa Yusuf Aksu - Emre Okuducu • Ground Station Crew: - Barış Berk Kottaş - Berkant Alperen	• Ground Station Crew: - Barış Berk Kottaş - Berkant Alperen • Assembly Team: - Umut Altun - Alp Kaan Kottaş	• CanSat Crew: - Umut Altun - Alp Kaan Kottaş - Mustafa Yusuf Aksu - Emre Okuducu • Mission Control Officer: - Berkant Alperen

Overview of Mission Sequence of Events (2/3)

Free fall	Recovery	Analysis
• CanSat is released and starts descending. • The ground station team verifies that everything is going smoothly.	• Container and probe will land with parachute. • Heading out to recover the probe. • Recovery of the probe	• State of the payload and container checked. • Received telemetry data will be analyzed.
Team Members	**Team Members**	**Team Members**
• Ground Station Crew: - Barış Berk Kottaş - Berkant Alperen	• Recovery Crew: - Mustafa Yusuf Aksu - Emre Okuducu	• CanSat Crew: - Umut Altun - Alp Kaan Kottaş - Mustafa Yusuf Aksu - Emre Okuducu

Overview of Mission Sequence of Events (3/3)

Antenna construction and ground system setup

- An umbrella will be used to protect GCS from sunlight and rain.
- Ground station will be set up and made working.
- Hand-held antenna will be placed properly after connecting to the workspace and the computer.
- Connection between GCS and CanSat will be controlled.

Mission Operations Manual Development Plan

Ground Station Configuration
- Set up computer, XBee, antenna, etc.
- Check whether the baud rate is selected as 19200 on GCS software
- Ensure the communication is established with probe
- Check the state of CanSat and calibration data

CanSat Preparation
- Make sure the battery is fully charged
- Turn on the power switch of electronics
- Monitor the sensor data on GCS software
- Perform mechanical parts to confirm the descent control is working properly

CanSat Integration
- Attach container parachute to CanSat
- Lock the payload to the container
- Mount CanSat into the rocket

Launch Preparation

This plan is already available on a document published by CanSat competition

Launch Procedure

This plan is already available on a document published by CanSat competition

CanSat Location and Recovery

CanSat recovery strategy:

- Both the container and the probe will have a fluorescent pink color and it will also have an attached parachute with a fluorescent orange color so it can be easily spotted from a distance.
- The whereabouts of the container will be determined by observing the flight path and the latest relevant GPS data.
- The probe will have an easier recovery since it will be transmitting GPS data throughout the mission.
- The sound of the audio beacon will also be an important factor in locating the probe.
- Both the container and the probe will have a label placed on them with the university, team name, team number, contact email information on them.
  Example:

  Middle East Technical University,
  METUOR Space Team (#1068),
  metuor.uzay@gmail.com

Requirements Compliance

Berkant Alperen

Requirements Compliance Overview

We have prepared and designed CanSat by analyzing and identifying the CanSat Mission Guide 2023 . System tests will be done in accordance to CanSat Integration and Test section.

- We comply with 56 requirements based on CanSat Mission Guide 2023.
- There are 5 partial complied requirements that will need more testing. We will build some test satellites to test our concepts.
- There aren't any requirements that we do not comply with.

Green	= Comply
Yellow	= Partial
Red	= No Comply

Requirements Compliance (1/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams.	**Comply**	86	We are within mass constraints.
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	**Comply**	30	
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	**Comply**	30	
4	The container shall be a fluorescent color; pink, red or orange.	**Comply**	135	
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open.	**Comply**	22	
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	**Comply**	30	
7	The rocket airframe shall not be used as part of the CanSat operations.	**Comply**	30	
8	The container's parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	**Comply**	22, 42	

Requirements Compliance (2/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
9	The Parachute shall be fluorescent Pink or Orange	Comply	135	
10	The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	Comply	29, 58, 59	
11	0 altitude reference shall be at the launch pad.	Comply	98	
12	All structures shall be built to survive 15 Gs of launch acceleration.	Comply		To be tested
13	All structures shall be built to survive 30 Gs of shock.	Comply		To be tested
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	82	
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply		To be tested
16	Mechanisms shall not use pyrotechnics or chemicals.	Comply	21	

Requirements Compliance (3/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	**Comply**	-	our cansat does not have such systems
18	Both the container and probe shall be labeled with team contact information including email address.	**Comply**	135	
19	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost. Equipment from previous years shall be included in this cost, based on current market value.	**Comply**	152	
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	**Comply**	95	
21	XBEE radios shall have their NETID/PANID set to their team number.	**Comply**	95	
22	XBEE radios shall not use broadcast mode.	**Comply**	95	
23	The container (if needed) and probe shall include an easily accessible power switch that can be accessed without disassembling the cansat and science probes and in the stowed configuration.	**Comply**	22, 24	

Requirements Compliance (4/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
24	The probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the cansat and in the stowed state.	Comply	102	
25	An audio beacon is required for the probe. It shall be powered after landing.	Comply	108	
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	Comply		TBD, not easily reachable
27	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	Comply	103	
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Comply	23	
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	103	

Requirements Compliance (5/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
30	The Cansat shall operate during the environmental tests laid out in Section 3.5.	Comply		To be tested
31	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Comply	105	
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Comply	29, 52	
33	The probe shall deploy a heat shield after leaving the container.	Comply	29, 41	
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	Comply	41, 57, 58	
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/-1 m/sec.	Comply	29, 55, 56, 58	

Requirements Compliance (6/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
36	Once landed, the probe shall upright itself.	**Comply**	29, 78	
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	**Comply**	29, 81	
38	The probe shall transmit telemetry once per second.	**Comply**	108,110	
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	**Comply**	96, 97	
40	The probe shall include a video camera pointing down to the ground.	**Comply**	23	
41	The video camera shall record the flight of the probe from release to landing.	**Comply**	32	

Requirements Compliance (7/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
42	The video camera shall record video in color and with a minimum resolution of 640x480.	**Comply**	38	
44	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	**Comply**	96, 97	
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss. .	**Comply**	111	
46	The probe shall have its time set to within one second UTC time prior to launch.	**Comply**	98	
47	The probe flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	**Comply**	112, 129	

Requirements Compliance (8/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
48	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the payload altitude.	**Comply**	112, 129	
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	**Comply**	98, 112	
50	The ground station shall command the Cansat to start calibrating the altitude to zero when the Cansat is on the launch pad prior to launch.	**Comply**	98, 131	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	**Comply**	121	
52	Telemetry shall include mission time with 1 second or better resolution.	**Comply**	91	
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	**Comply**	111	

Requirements Compliance (9/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
54	Each team shall develop their own ground station.	**Comply**	120	We developed our own ground station.
55	All telemetry shall be displayed in real time during descent on the ground station.	**Comply**	121	
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	**Comply**	121	All the units are in engineering units.
57	Teams shall plot each telemetry data field in real time during flight.	**Comply**	121	
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	**Comply**	115, 116	
59	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	**Comply**	115	Our ground station is portable.

Requirements Compliance (10/10)

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
60	The ground station software shall be able to command the payload to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	**Comply**	121	
61	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the cansat.	**Comply**	121	

Management

Berkant Alperen

CanSat Budget – Hardware (1/2)

Electronics				
Component	**Description**	**Quantity**	**Total Cost ($)**	**Actual / Estimate**
XBee Pro S3B	Communication Module	2	110	Actual
STM32F401RET6	Microprocessor	1	9.97	Actual
Adafruit Mini Spy Camera	Payload/Bonus Cam	2	25	Actual
BMP280	Barometric Pr. Sensor	1	2.30	Actual
MPU9250	Inertia Mea. Sensor	1	11.21	Actual
Micro DC Motor	Heat Shield DC Motor	1	5.00	Actual
SG90 Servo	Parachute Lock Servo	1	3.50	Actual
uBlox NEO-M8N	GPS	1	34.23	Actual
92 dB Buzzer	Buzzer	1	4.00	Estimate
LED	Power Indicator LED	1	0.50	Estimate

CanSat Budget – Hardware (2/2)

Electronics				
Component	**Description**	**Quantity**	**Total Cost ($)**	**Actual / Estimate**
Printed Circuit Board	Board of Flight Computer	1	12	Estimate
CR2032 Battery	For RTC and Bonus Camera	2	2.5	Actual
W25Q32JVSSIQ	Winbond SPI Flash	1	1	Actual
Other Passive Components	Including resistor, capacitors, crystals etc.	-	30	Estimate
Mechanical				
Fiberglass	Material of container, probe base plat, arms, moving plate, motor plate, flag mast	$1m^2$	100	Estimate
Parachutes	Descent	2	13	Estimate
Fiberglass Rod	Connecting Rods, Structural Rods	3m	40	Actual

CanSat Budget – Other Costs (1/2)

Ground Control Station Costs				
Component	**Description**	**Quantity**	**Cost ($)**	**Actual / Estimate**
Xbee Pro S3B	Comms. module	1	55	Actual
ZQTMAX Yagi-Uda Antenna	GCS Antenna	1	21.16	Actual
Xbee to USB adapter	Adapter	1	7	Estimate
Umbrella	For sun protection	1	20	Estimate

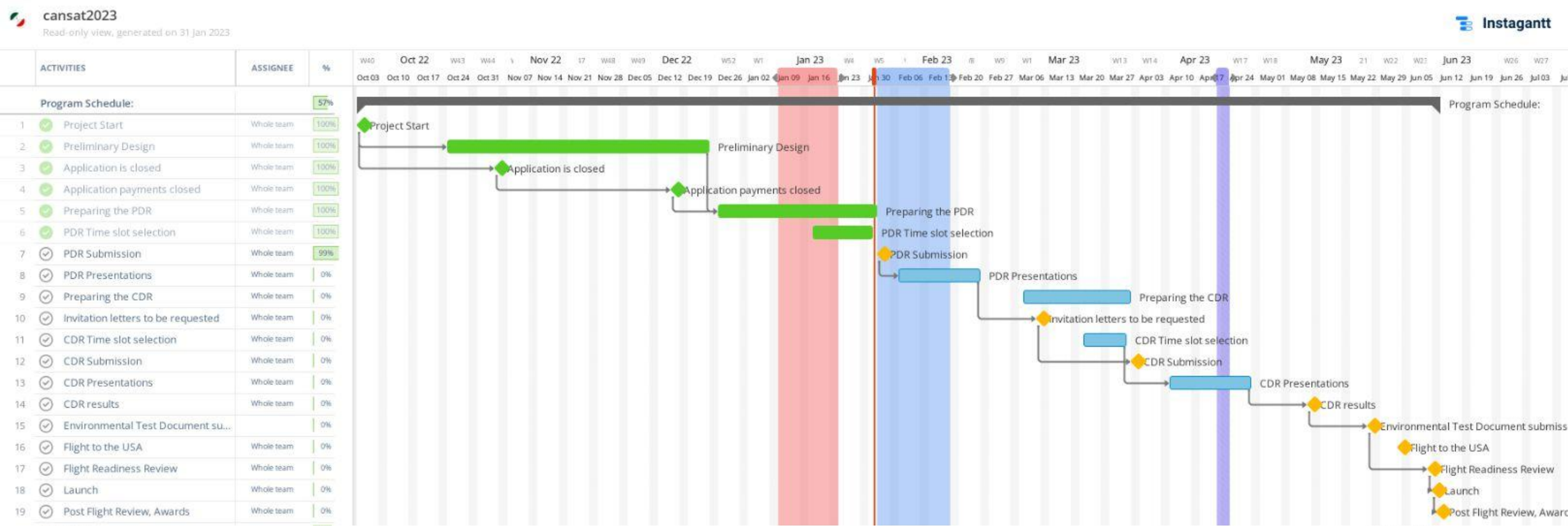
Other Costs				
Component	**Description**	**Quantity**	**Cost ($)**	**Actual / Estimate**
Prototyping	3D filaments etc.	-	50	Estimate
Travel	Flight to the USA	10	1000*10=10000	Estimate
Rental	Accomodation	-	4000	Estimate
Visa fees		10	170*10=1700	Actual
Registration fee		1	200	Actual

CanSat Budget – Other Costs (2/2)

Income	
Source	**Amount ($)**
Sponsors	250
Society support	250

Total costs	
Name	**Amount ($)**
Hardware	404.21
GCS costs	103.16
Other costs	15950
TOTAL	16.457,37

Program Schedule Overview



Red	Final Exams
Light blue	Semester Break
Purple	Ramadan Holiday

We arranged our schedule so that we would not have a heavy workload during finals and we used the time after finals and the semester break as an opportunity to further work on this project.

Detailed Program Schedule (1/3)

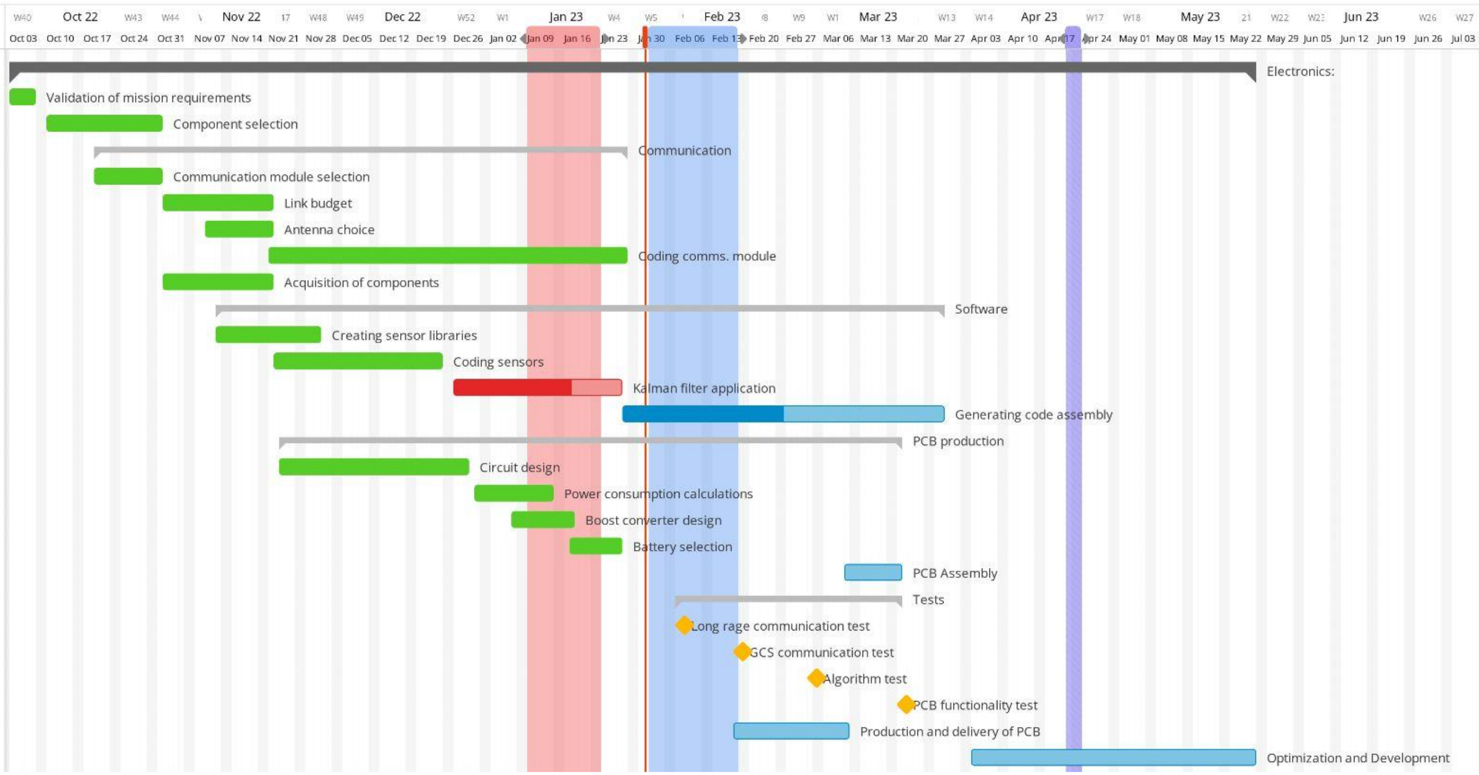
Electronics

cansat2023

Read-only view, generated on 31 Jan 2023

Instagantt

	ACTIVITIES	ASSIGNEE	%
	Electronics:		72%
1	Validation of mission requirements	Mİ, BA, AK, BK, SS	100%
2	Component selection	AK, BK, BA, Mİ, SS	100%
	Communication	AK, BK, BA, Mİ	100%
4	Communication module selec...	Burak Aydar	100%
5	Link budget	Alp Kottaş	100%
6	Antenna choice	Mİ, AK	100%
7	Coding comms. module	BK, BA	100%
8	Acquisition of components	Berkant Alperen	100%
	Software	AK, BK, BA, SS	73%
10	Creating sensor libraries	AK, BA, SS	100%
11	Coding sensors	AK, BA, SS, BK	100%
12	Kalman filter application	Burak Aydar	70%
13	Generating code assembly	AK, BA	50%
	PCB production	Mİ, AK	88%
15	Circuit design	Mehmet İlbağı	100%
16	Power consumption calculatio...	Mİ, AK	100%
17	Boost converter design	Mehmet İlbağı	100%
18	Battery selection	AK, Mİ	100%
19	PCB Assembly	Mehmet İlbağı	0%
	Tests	AK, BK, BA, Mİ, SS	0%
21	Long rage communication test	AK, BK, BA	0%
22	GCS communication test	AK, BK, BA, BA	0%
23	Algorithm test	BA, AK	0%
24	PCB functionality test	Mİ, BA, AK, BK, SS	0%
25	Production and delivery of PCB	Mİ, BA	0%
26	Optimization and Development	AK, BK, BA, Mİ, SS	0%



Final Exams | Semester Break | Ramadan Holiday

Detailed Program Schedule (2/3)

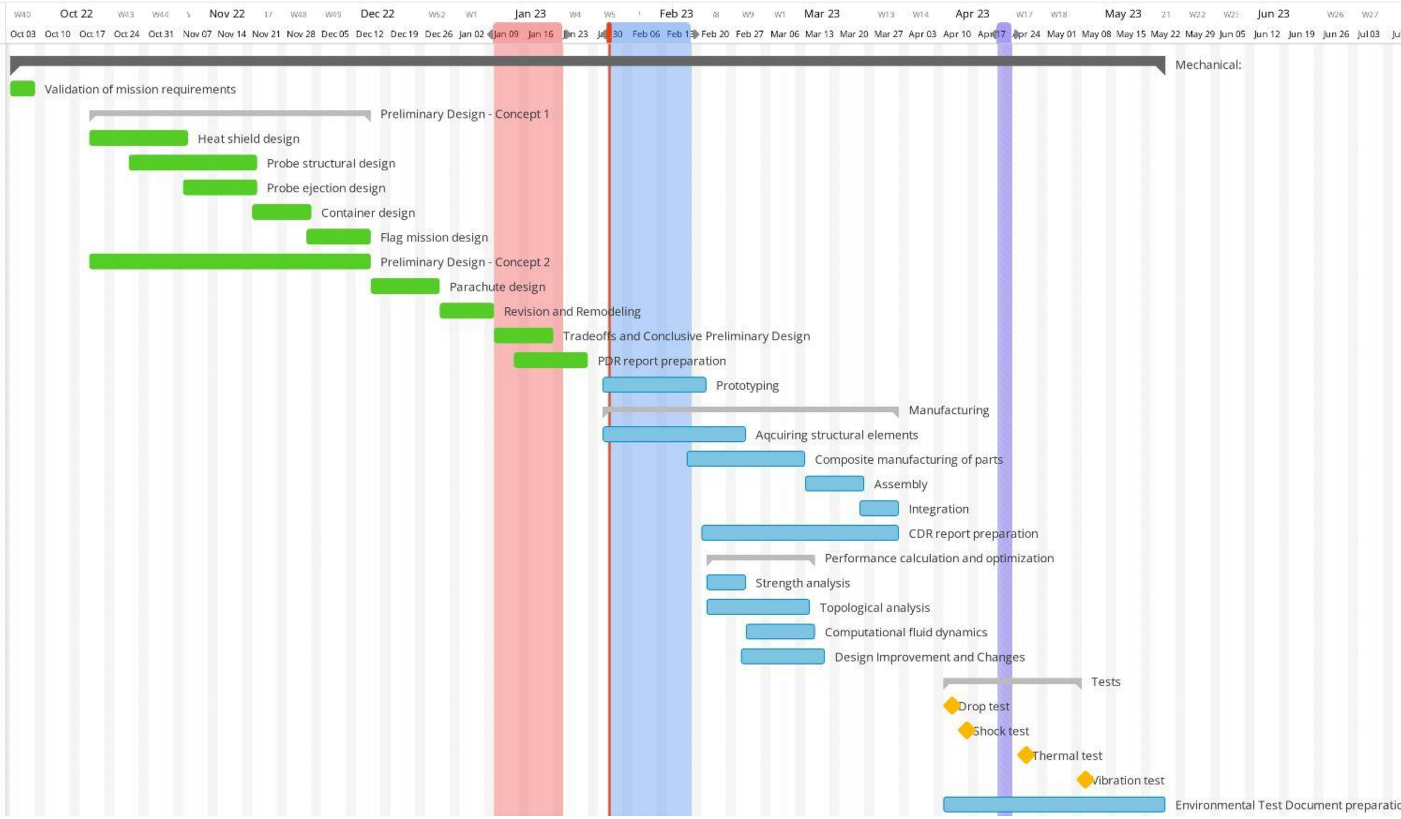
Mechanical

cansat2023

Read-only view, generated on 01 Feb 2023

Instagantt

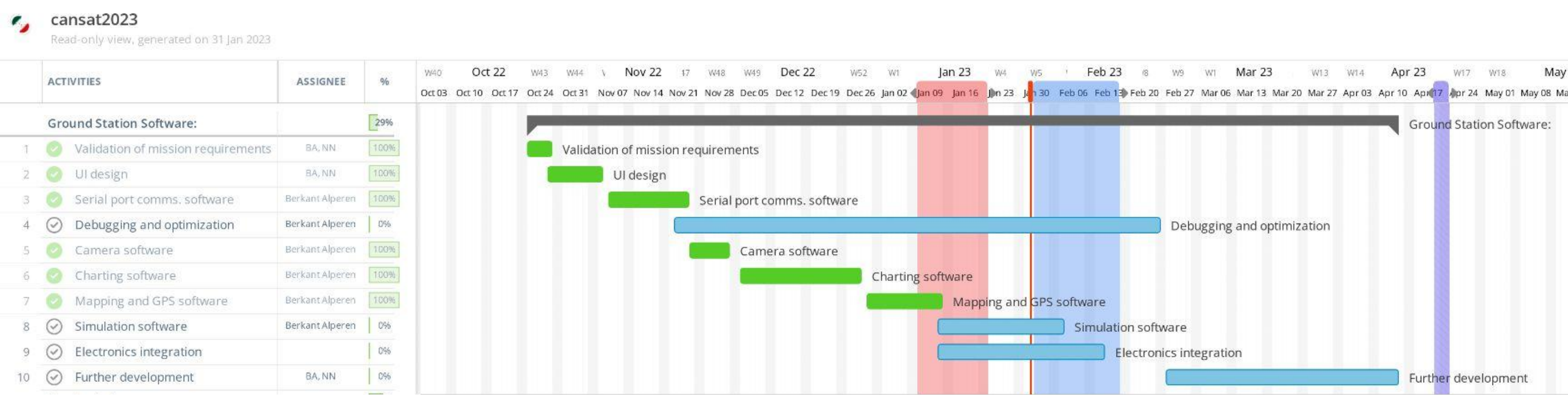
	ACTIVITIES	ASSIGNEE	EH	START	DUE	%
	Mechanical:		-	03/Oct	24/May	45%
1	Validation of mission requir...		-	03/Oct	07/Oct	100%
	Preliminary Design - Conce...	Umut Altun	-	19/Oct	14/Dec	100%
3	Heat shield design	Umut Altun	-	19/Oct	07/Nov	100%
4	Probe structural design	Umut Altun	-	27/Oct	21/Nov	100%
5	Probe ejection design	Umut Altun	-	07/Nov	21/Nov	100%
6	Container design	Umut Altun	-	21/Nov	02/Dec	100%
7	Flag mission design	Umut Altun	-	02/Dec	14/Dec	100%
	Preliminary Design - Conce...	Mustafa Y. Aksu	-	19/Oct	14/Dec	100%
14	Parachute design	UA, MY	-	15/Dec	28/Dec	100%
15	Revision and Remodeling	MY, UA	-	29/Dec	08/Jan	100%
16	Tradeoffs and Conclusive Pr...	MY, UA	-	09/Jan	20/Jan	100%
17	PDR report preparation	UA, MY	-	13/Jan	27/Jan	100%
18	Prototyping	MY, UA	-	31/Jan	20/Feb	0%
	Manufacturing	UA, MY	-	31/Jan	31/Mar	0%
20	Aqcuiring structural ele...	UA, MY	-	31/Jan	28/Feb	0%
21	Composite manufacturi...	UA, MY	-	17/Feb	12/Mar	0%
22	Assembly	UA, MY	-	13/Mar	24/Mar	0%
23	Integration	Whole team	-	24/Mar	31/Mar	0%
24	CDR report preparation	MY, UA	-	20/Feb	31/Mar	0%
	Performance calculation an...	UA, MY	-	21/Feb	14/Mar	0%
26	Strength analysis	Mustafa Y. Aksu	-	21/Feb	28/Feb	0%
27	Topological analysis	Mustafa Y. Aksu	-	21/Feb	13/Mar	0%
28	Computational fluid dyn...	Umut Altun	-	01/Mar	14/Mar	0%
29	Design Improvement and C...	MY, UA	-	28/Feb	16/Mar	0%
	Tests	Whole team	-	10/Apr	07/May	0%
31	Drop test	Whole team	-	10/Apr	10/Apr	0%
32	Shock test		-	13/Apr	13/Apr	0%
33	Thermal test	Whole team	-	25/Apr	25/Apr	0%
34	Vibration test	Whole team	-	07/May	07/May	0%
35	Environmental Test Docum...	Whole team	-	10/Apr	24/May	0%



Final Exams Semester Break Ramadan Holiday

Detailed Program Schedule (3/3)

Ground Control System



Final Exams Semester Break Ramadan Holiday

Conclusions

Major Accomplished Works:

- The team has been formed and tasks were given to individuals according to competition schedule.
- PDR is completed.
- Two different preliminary design concepts are done.
- Descent calculations and parachute design are done.
- Final preliminary design is determined after revisions and remodeling and is ready for manufacturing.
- Code libraries for all sensors are created and tested. Communication module is coded and tested.
- PCB is designed and ready to produce.

Major Unfinished Works:

- The team still needs sponsors for travel costs.
- Applying Kalman filter to the algorithm a bit late on schedule.

Why are we ready to proceed to next state to development?

- We are satisfied with our design and we are aiming to start the manufacturing process for our first prototype in the upcoming weeks. Some operations need real life testing to confirm reliable operation and we are positive that we are able to overcome any challenges which may arise.