CanSat 2018
Preliminary Design Review (PDR)
Version 5.0

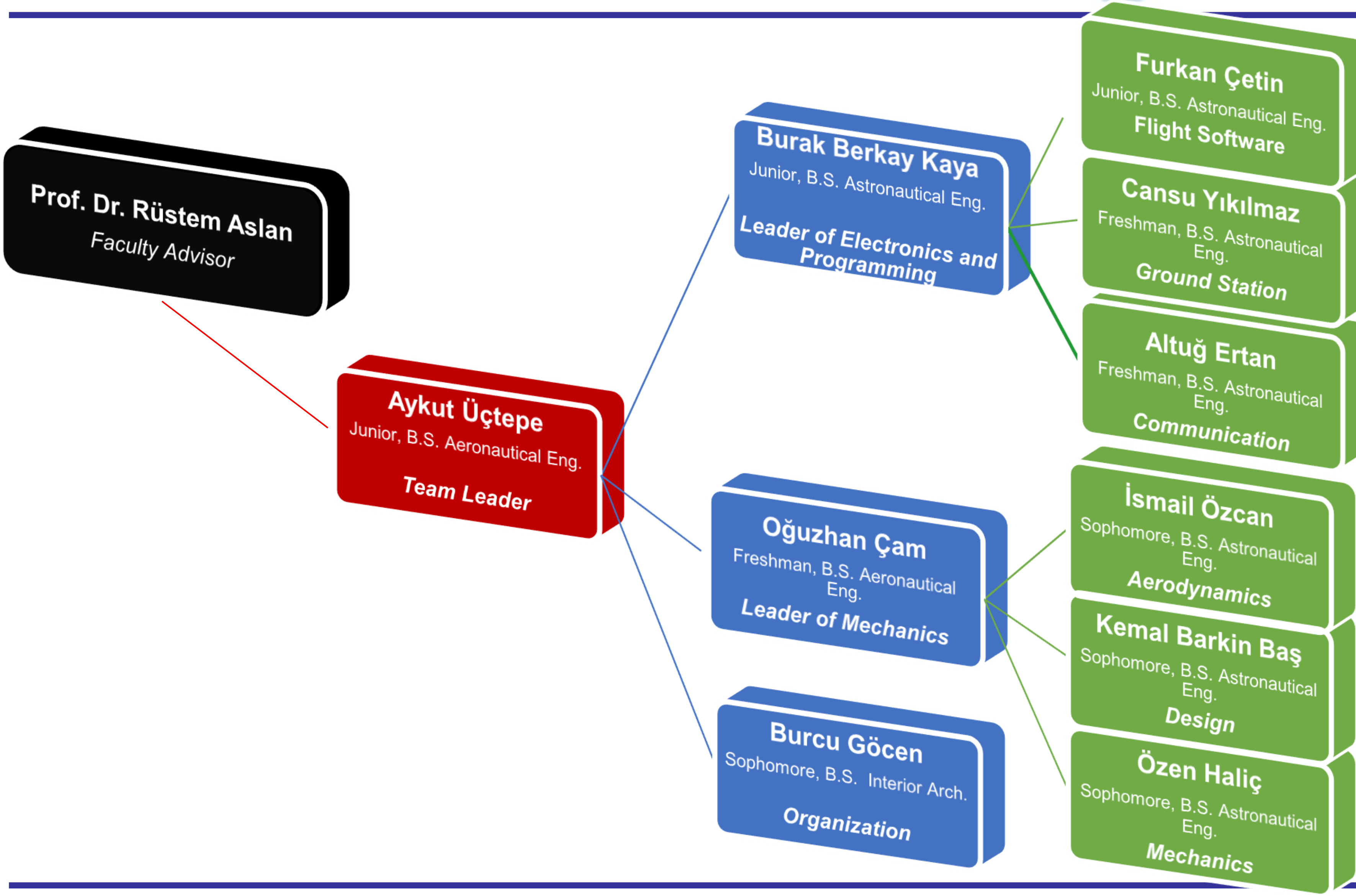
#4404

APIS AR-GE

Presentation Outline

Section	Presenter
Systems Overview	Kemal Barkin BAS
Sensor Subsystem Design	Burak Berkay KAYA
Descent Control Design	Ismail OZCAN
Mechanical Subsystem Design	Oguzhan CAM
CDH Subsystem Design	Altug ERTAN
EPS Design	Burak Berkay KAYA
FSW Design	Furkan CETİN
GCS Design	Cansu YIKILMAZ
CanSat Integration and Test	Ozen HALIC
Mission Operations & Analysis	Aykut UCTEPE
Requirements Compliance	Burcu GOCEN
Management	Aykut UCTEPE

Team Organization



Acronyms

A	Analysis
BR	Base Requirement
CanSat	Can-sized Satellite
CDH	Communication Design and Handling
CONOPS	Concept of Operations
CReq	Competition Requirement
D	Demonstration
DCS	Decent Control System
EPS	Electric Power System
FSW	Flight Software
G	G-force
GCS	Ground Control Station
HW	Hardware
I	Inspection
I2C	Inter-Integrated Circuit
I/O	Input/Output
ID	Identity

IDE	Integrated Development Environment
LED	Light Emitting Diode
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
MS	Mechanical Subsystem
PCB	Printed Circuit Board
RC	Radio Controlled
RP SMA	Reverse Polarity SMA
RTC	Real Time Clock
SMA	SubMiniature Version A
SPI	Serial Peripheral Interface
T	Testing
UART	Universal Asynchronous Receiver/Transmitter
USART	Universal Synchronous/Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
VM	Verification Method

Systems Overview

Kemal Barkin BAS

Mission Summary

Main Objectives

A payload which simulates space probe (CanSat) entering a planetary atmosphere shall sample atmospheric properties, wind velocity, heading angle and shall send sample data to ground station via transmitter module.

- Just after payload is deployed from rocket, payload shall open the aero-braking heat-shield.
- The descent rate shall be kept at 10 to 30 meters/sec till 300 meters.
- The payload must maintain a stable orientation while heat shield is limiting CanSat velocity during descent. For that, external mechanisms can be used.
- At the 300 meters, heat-shield shall be released from probe and parachute shall be opened. After that, descent rate shall be kept at 5 m/s.
- Egg shall remain intact from forces which will occur during flight .
- Stoppage of data transmission and initiation of audio beacon after landing.
- Recovery of probe and heat-shield.

Bonus Objective

- Capturing the release of the heat shield and the ground during the last 300 meters of descent with a video camera is attempted due to higher possibility of success and weight advantage.

External Objectives

- Funding for project's hardware and logistic needs.
- Funding for flight tickets which covers round trip from Istanbul, Turkey to Texas, USA.
- Promoting APIS R&D with CanSat Competition and scientific developments achieved. The aim is to gain reputation in our home university and in Turkey.
- Organizing social activities which includes BBQ parties, musical activities, studio recording to improve relationship between team members.

System Requirement Summary (1/4)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-1	Total mass of the CanSat (probe and heat shield) shall be 500 grams +/-10 grams.	Creq	BR-1	MS-1	Very High		✓		
SY-2	The aero-braking heat shield shall be used to protect the probe while in the rocket only and when deployed from the rocket.	To simulate to prevent heating of probe and decrease the descent rate.	BR-2	MS-6	Very High				✓
SY-3	The heat shield must not have any openings.	Creq	BR-3	MS-7	Very High			✓	✓
SY-4	The probe must maintain its heat shield orientation in the direction of descent.	Creq	BR-4	DCS-4	Very High	✓		✓	
SY-5	The probe shall not tumble during any portion of descent.	Creq	BR-5		Very High	✓		✓	
SY-6	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length, including tolerances.	Creq	BR-6	MS-2	Very High		✓	✓	

System Requirement Summary (2/4)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-7	The probe shall hold a large hen's egg and protect it from damage from launch until landing.	To simulate the delicate vehicle.	BR-7	MS-9	Very High				✓
SY-8	The heat shield shall not have any sharp edges.	Creq	BR-9		Very High		✓		✓
SY-9	The heat shield shall be a florescent color, pink or orange.	To distinguish the CanSat clearly during descent.	BR-10	MS-5	High		✓		
SY-10	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Creq	BR-11 BR-13		Very High		✓		
SY-11	The rocket airframe shall not be used as part of the CanSat operations	Creq	BR-12		Very High		✓		✓
SY-12	The aero-braking heat shield shall be released from the probe at 300 meters.	Creq	BR-14	MS-10	Very High	✓		✓	✓
SY-13	The probe shall deploy a parachute at 300 meters.	Creq	BR-15	MS-11	Very High	✓		✓	✓

System Requirement Summary (3/4)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-14	All structures and components shall survive30 Gs of shock and 15 Gs acceleration.	To secure the Cansat operations.	BR-16 BR-17 BR-19 BR-20	MS-12	Very High	✓		✓	
SY-15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	To strengthen CanSat against external forces	BR-18	DCS-1	High	✓		✓	
SY-16	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Creq	BR-22	BR-21	High	✓		✓	
SY-17	Flammable and explosive substances should not be used in mechanisms.	Creq	BR-23	BR-24	Very High		✓		
SY-18	During descent, the probe shall transmit all telemetry.	Creq	BR-26	CDH-1	Very High			✓	
SY-19	XBEE radios shall be used for telemetry transmission.	Creq	BR-28	CDH-4	Very High		✓	✓	

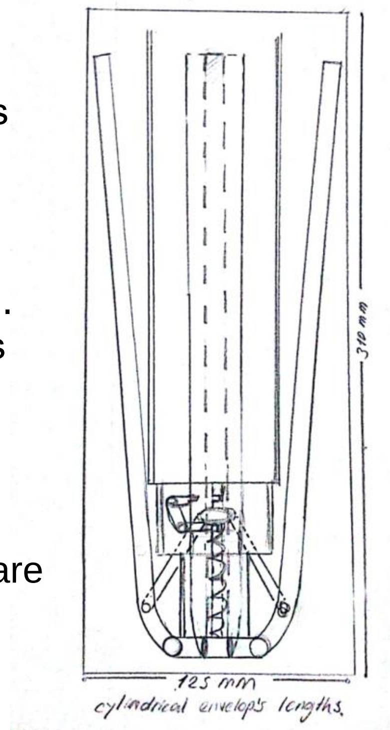
System Requirement Summary (4/4)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-20	Cost of the CanSat shall be under $1000.	Creq	BR-31		High				
SY-21	Each team shall develop their own ground station.	Creq	BR-32	GCS-1	Very High		✓		✓
SY-22	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line.	Creq	BR-37	GCS-6	High		✓		✓
SY-23	The probe must include an easily accessible power switch and a power indicator	Creq	BR-41 BR-42	EPS-2	High			✓	
SY-24	The descent rate of the probe with/out the heat shield shall be kept at the desired speed range.	Creq	BR-43 BR-44		High	✓		✓	
SY-25	A tilt sensor shall be used to verify the stability of the probe during descent	Creq	BR-49	SS-2	Very High			✓	

System Level CanSat Configuration Trade & Selection (1/2)

Configuration 1

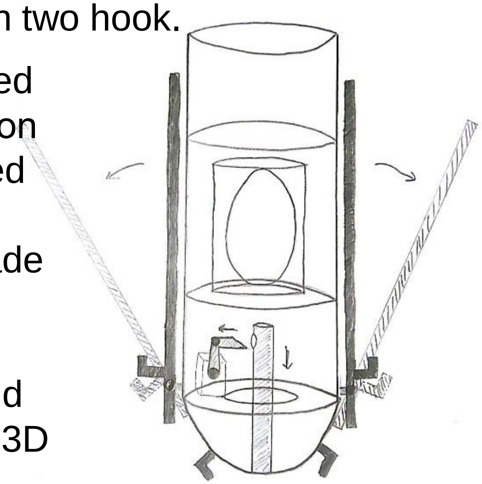
- Aero-braking heat shield's opening mechanism is inspired by umbrella.
- Spring is used to deployment of heat shield.
- Heat shield's outer rods is designed curved to decrease number of mechanism that will be used.
- All of the structurel parts are made up of 3D printed materials.



PROS	CONS
▪ Good control of heat shield and parachute ▪ Tumbling is controlled due to lower center of mass. (CREQ 5) ▪ Easy component manufacturing.	▪ Bad aerodynamic structure ▪ Hard to assembly

Configuration 2

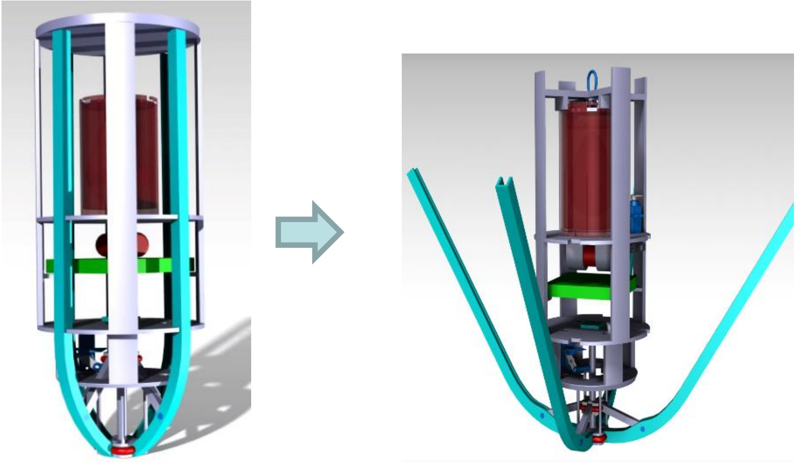
- Payload was sketched to be convenient aerodynamic structure.
- Heat shield is deployed through elastic band which tensile between two hook.
- Heat shield is deployed through servo's rotation
- Electronics are located top of probe.
- Probe structure is made up of fiberglass container.
- Layers and heat shield parts are made up of 3D printed material.

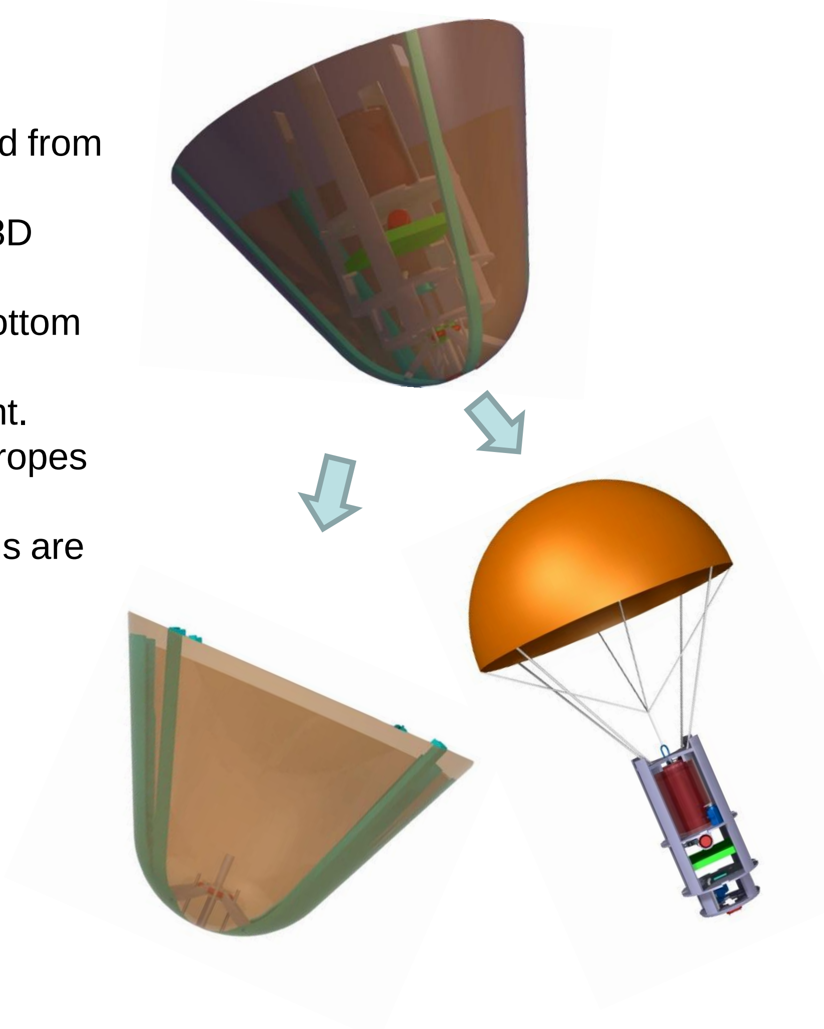


PROS	CONS
▪ Light ▪ Good aerodynamic structure	▪ Higher risk of heat shield failure ▪ Center of mass is at upper part of probe ▪ Bonus objective is harder to achieve

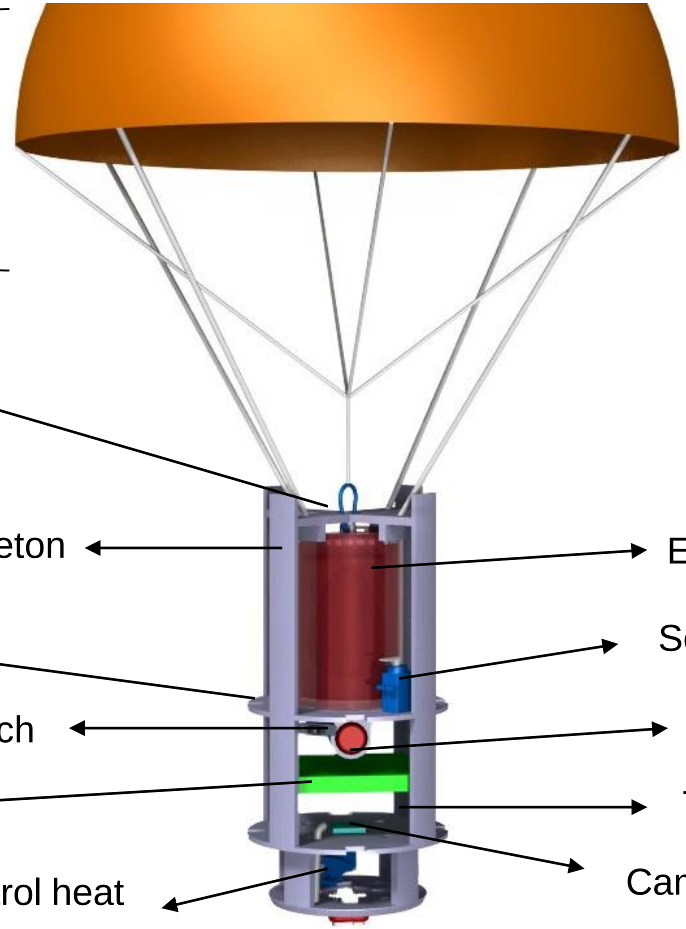
Configuration 1 (SELECTED)

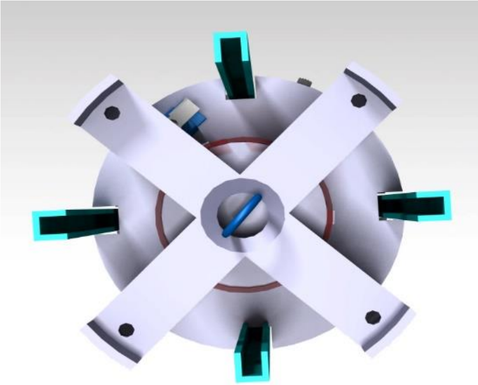
- Access to electronics is easy,electronic layer will be isolated from outside after installation is completed.
- Great number of parts of payload will be manufactured by 3D printer which is easy and time efficient.
- Tumbling will be prevented by keeping center of mass at bottom
- Probe will be harmed less when the collision occured.
- Deployment control and heat-shield release is more efficient.
- Parachute deployment mechanism will work by cutting the ropes that hold stowed parachute.
- Attachment points would not be a problem during operations are carried out.





PROBE

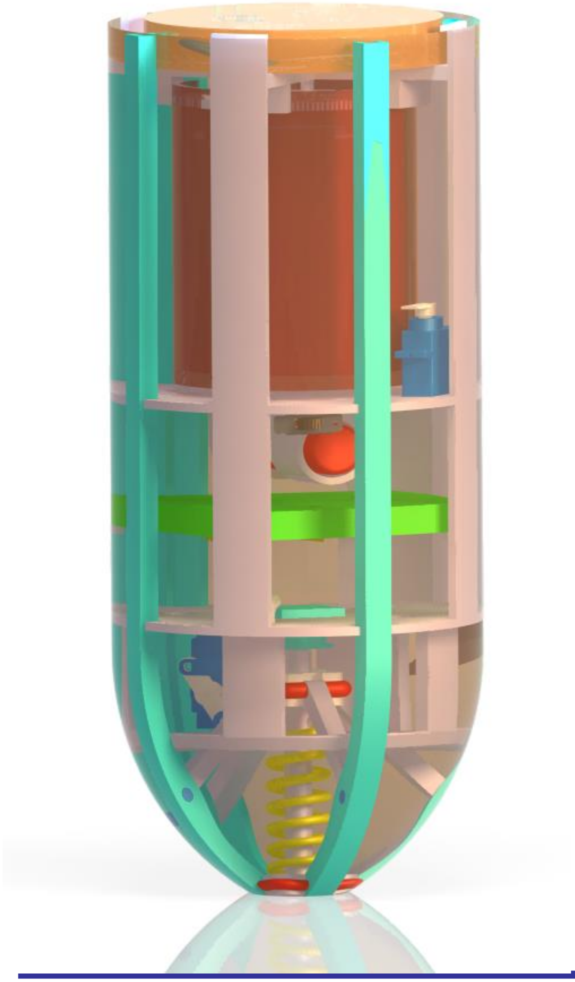




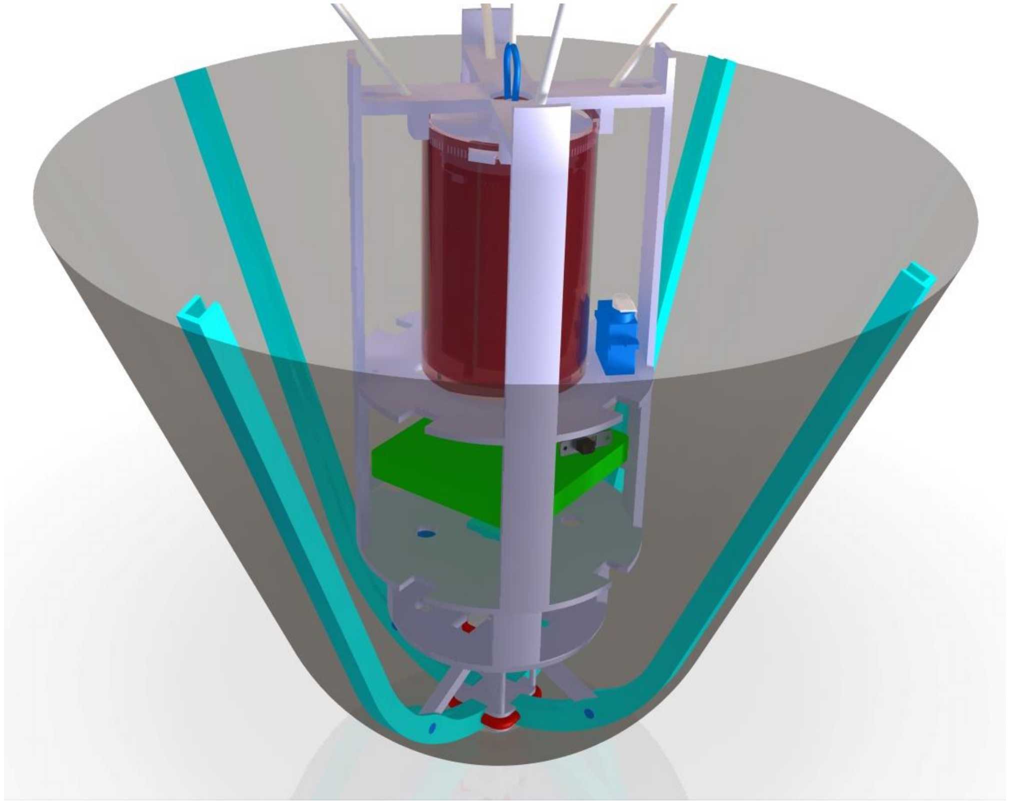
Top View

PROBE

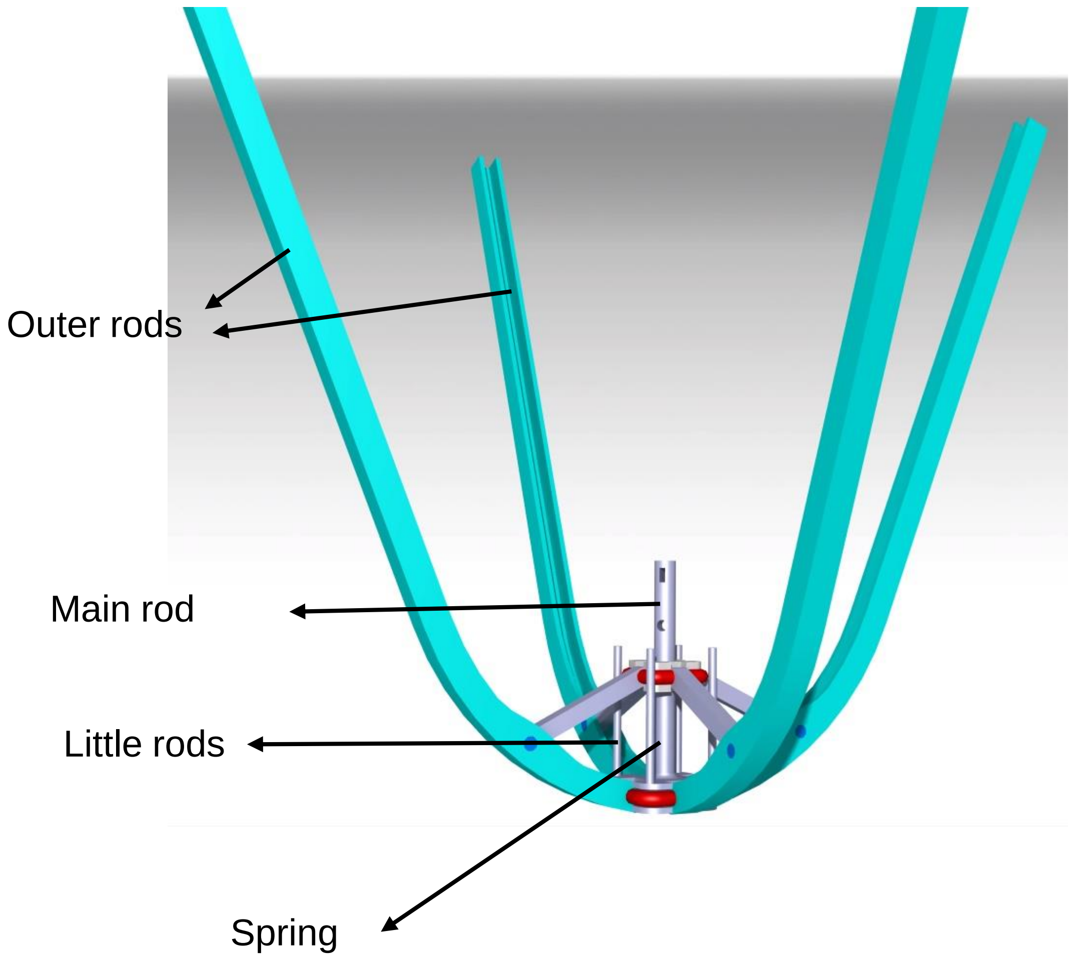
Launch Configuration

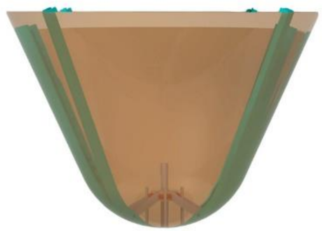


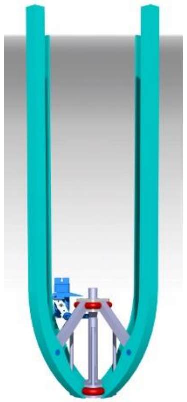
Deployed Configuration

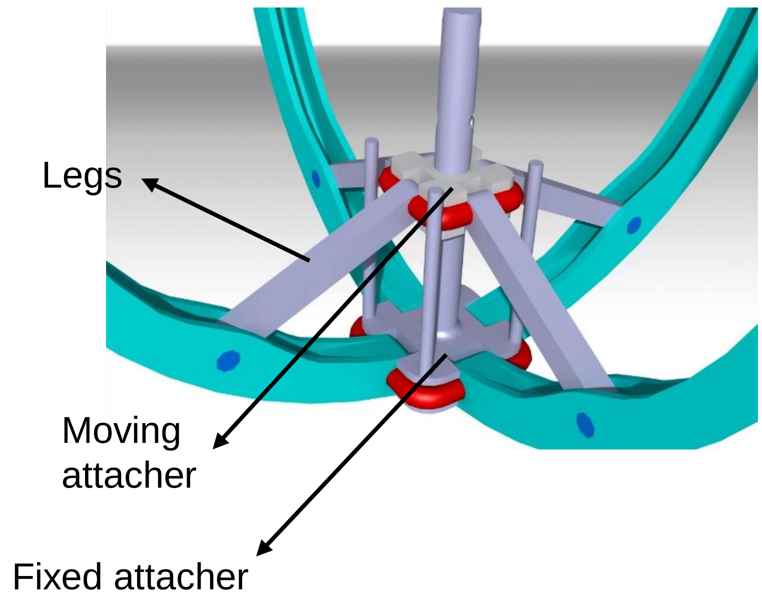


HEAT SHIELD

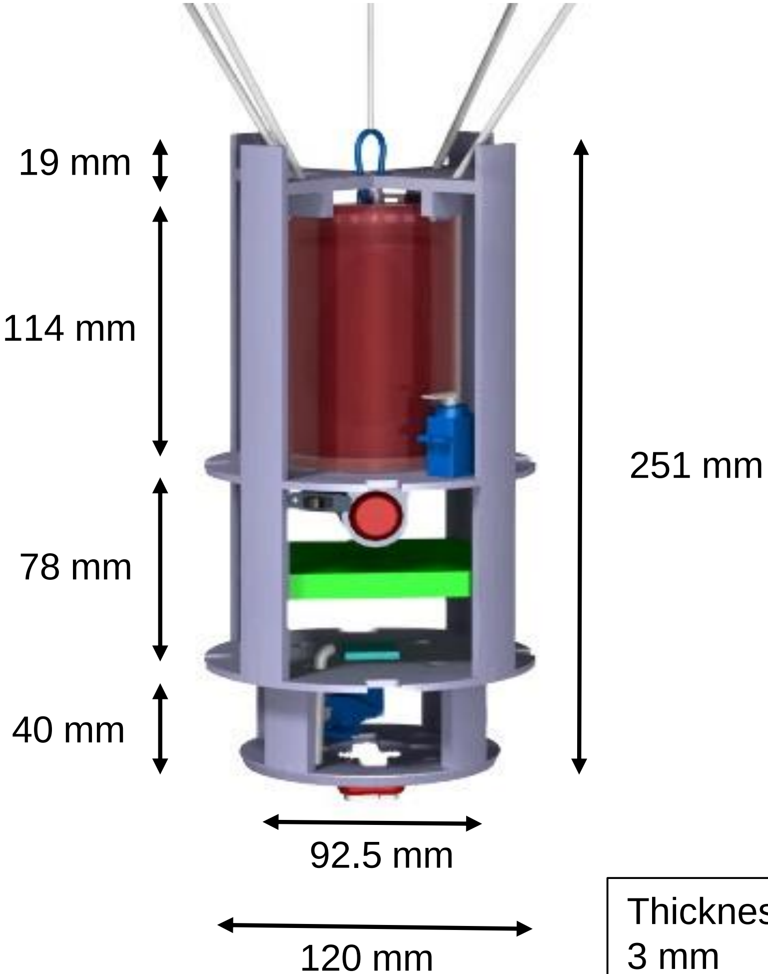

Outer rods
Main rod
Little rods
Spring





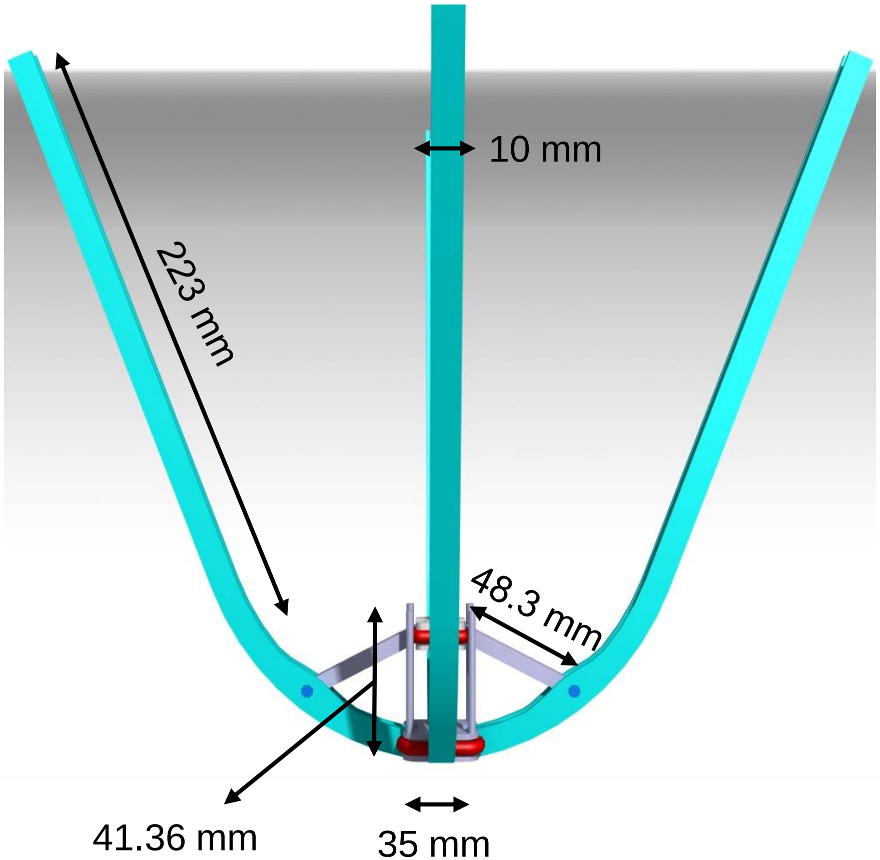

Legs
Moving
attacher
Fixed attacher

PROBE

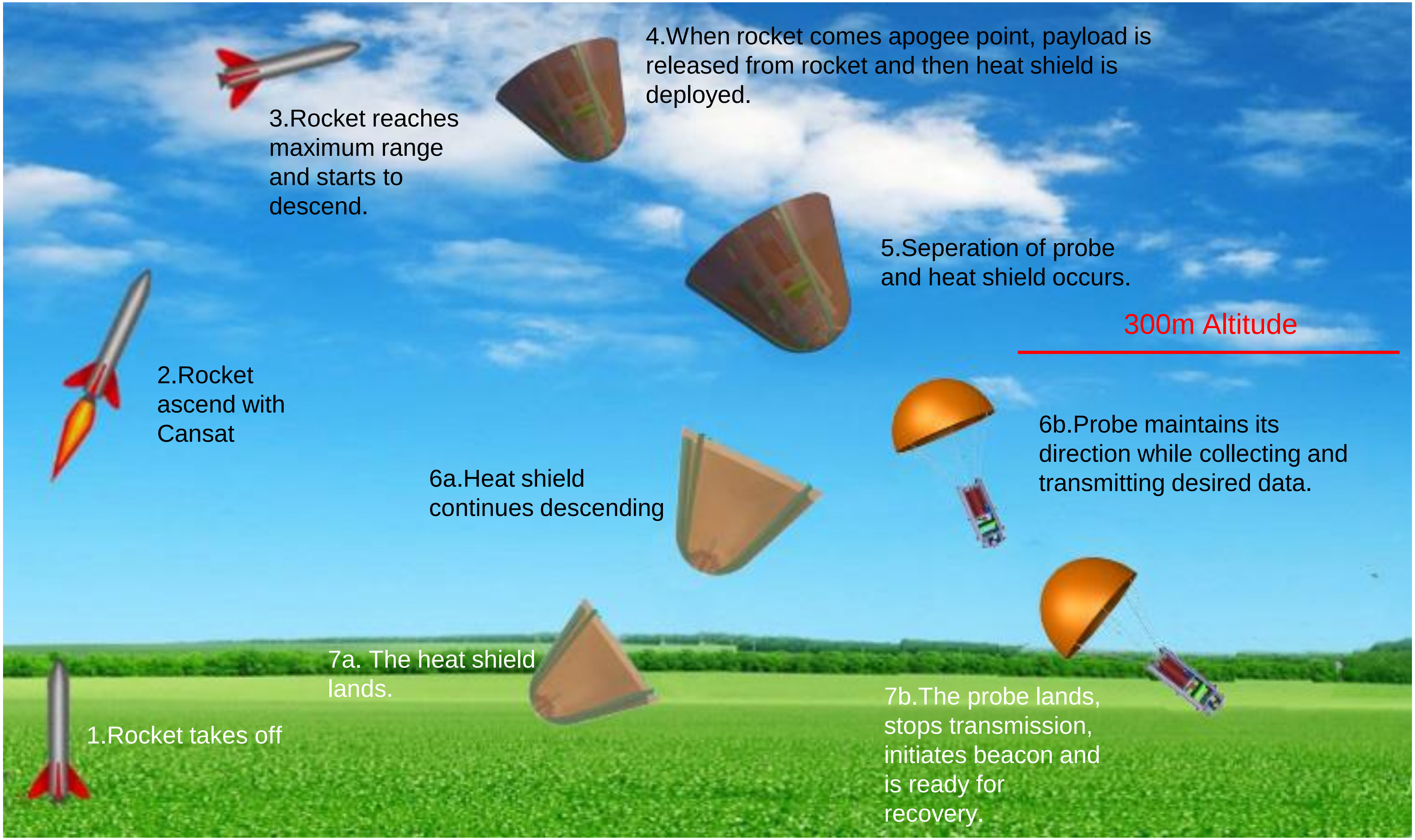


Thickness:
3 mm

HEAT SHIELD



System Concept of Operations (1/2)



System Concept of Operations (2/2)

Pre-Launch

- Team briefing.
- Electronic and mechanical integrity checks
- Competition area arrival.
- GCS set up
- Double check for final CanSat integrity configuration

Launch

- Placement of Cansat into rocket payload section.
- Launch, and events of CONOPS (previous slide).
- Telemetry data obtaining and .csv file creation via GCS software. (Steps 4, 5, 6b in previous slide)

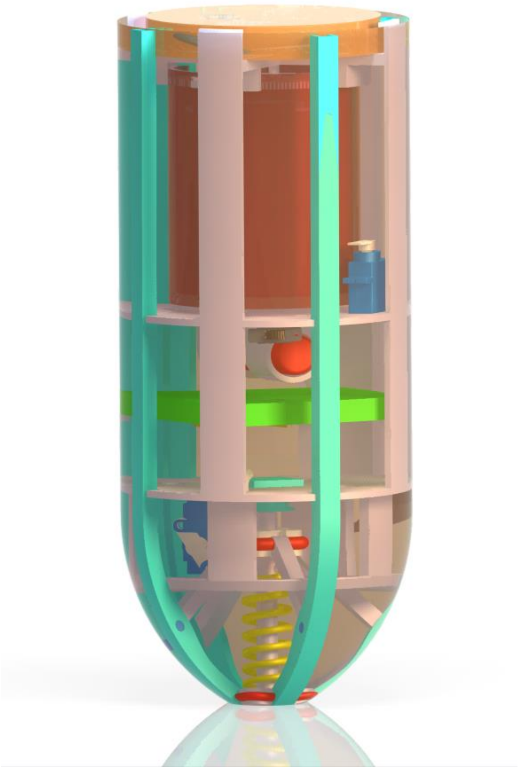
Post-Launch

- Recovery of probe and heat shield with indicators fluorescent color, GPS telemetry and audio beacon.
- Returning to GCS.
- Analysis of sampled data.
- Preparation of PFR.
- PFR presentation to jury.

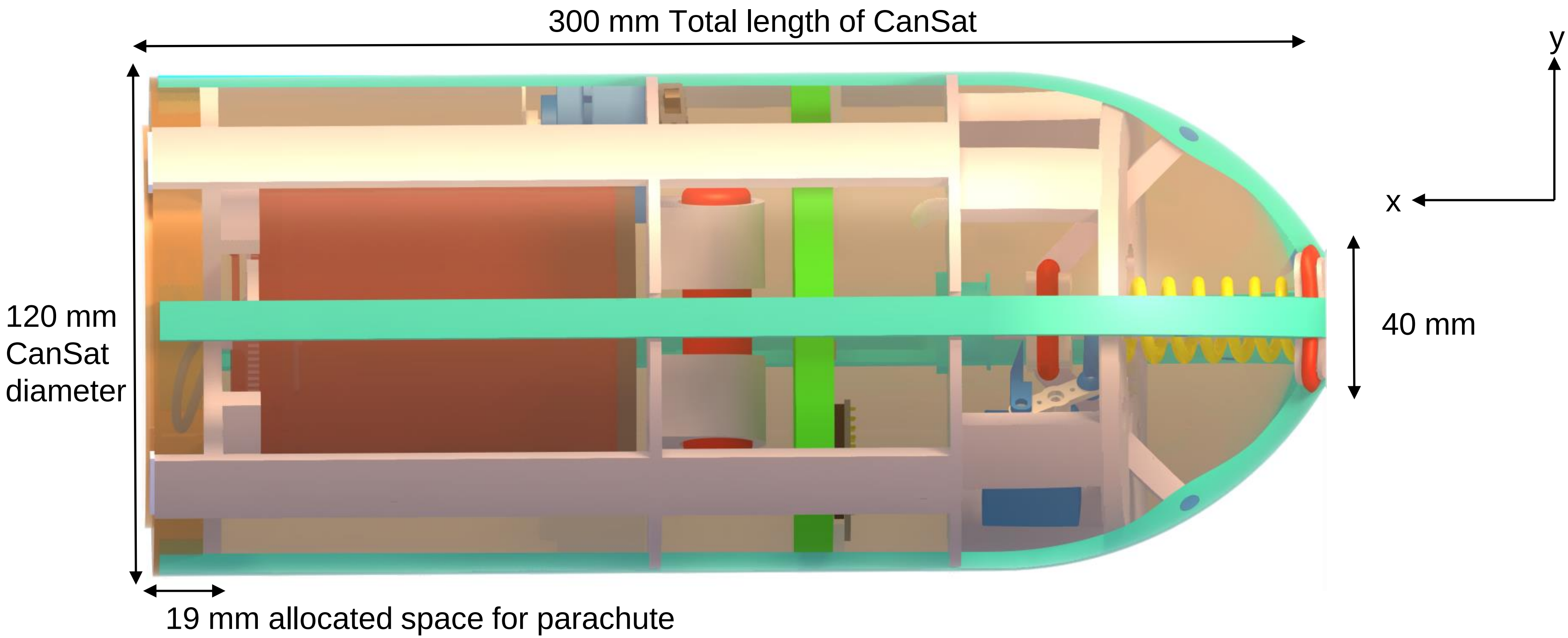
Launch Vehicle Compatibility (1/2)

- Rocket payload dimensions based Creq:
  - Height: 310 mm
  - Diameter: 125 mm
- CanSat dimensions:
  - Height: 300 mm
  - Diameter: 120 mm
- Heat shield dimensions after deployment:
  - Diameter: 220 mm
  - Height: 287 mm
- Parachute dimensions after separation:
  - Diameter: 450 mm

Launch Configuration



- CanSat design has selected to be thinning through rocket nose cone to reduce possibility of deployment failure.
- Margins left for secure deployment are examined in following slide.



Margins:

- Longitudinal(x axis): 10 mm
- Latitudinal(y axis): 5 mm

Dimensions do not extend rocket frame and CanSat have margins ensuring safe fit and deployment

Sensor Subsystem Design

Burak Berkay KAYA

Sensor Subsystem Overview

Sensor Type	Model	Purpose
Air Pressure	BMP 180	Air Pressure
Air Temperature	BMP180	Air Temperature
GPS	Adafruit Ultimate GPS	Determination of Location
Power Voltage	Arduino Pro Micro	Battery Voltage
Tilt Sensor	MPU 6050	To verify the stability
Camera	Turbowing Cylops dvr 3	Video Capture

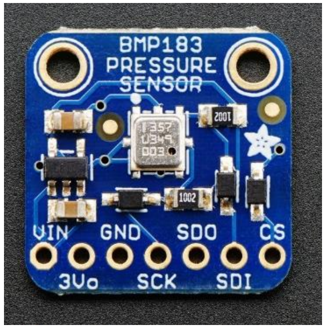
Sensor Subsystem Requirements

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SS-1	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time	Creq	BR-25		Very High	√		√	
SS-2	A tilt sensor shall be used to verify the stability of the probe during descent with the heat shield deployed	Creq	BR-49		Very High			√	
SS-3	The probe shall have a color video camera with a resolution of at least 640x480 and a frame rate of at least 30 frames/sec.	Bonus Objective			High		√		√
SS-4	The release of the heat shield and the ground during the last 300 meters of descent must be captured by the camera and the pictures captured must be stored on the probe.	Bonus Objective			High		√	√	
SS-5	The ranges of the sensors shall satisfy the minimum and maximum values during the mission.	Health Measuring			High	√	√		
SS-6	Sensors must be calibrated.	Health Measuring			High				√

Probe Air Pressure Sensor Trade & Selection

Model	Interface Type	Size	Accuracy	Weight	Pressure Range	Operatin g voltage	Current Consumption	Price
BMP280	I2C and SPI	19mm x 18mm x 3mm	±1 hPa	13gr	300-1100 hPa	1.71-3.6V	2.74 µA	10$
BMP180	I2C	14mm x 12mm x 0.93mm	-4 +2 hPa	10gr	300-1100 hPa	1.8V-3.6V	3 µA	10$
BME280	I2C and SPI	19mm x 18mm x 3mm	±1 hPa	10gr	300-1100 hPa	1.2-3.6V	3.6 µA	25$

Selected Air Pressure Sensor :Bosch BMP180
*BMP180 is compatible with Ardiuno and many microcontrollers.
*Supports I2C protocol.
*Price is affordable.
*Low current consumption.
*Enough operating voltage.



Probe Air Temperature Sensor Trade & Selection

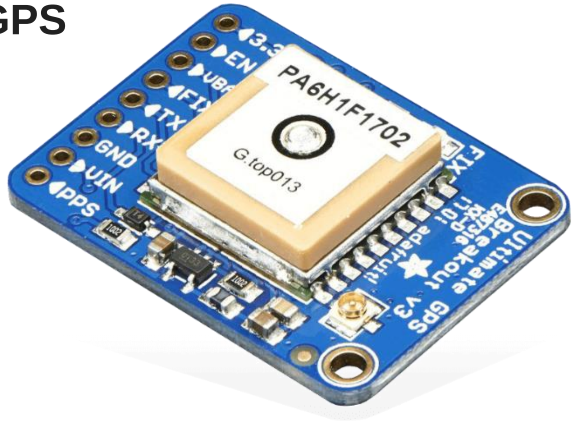
Model	Interface Type	Size	Accuracy	Weight	Temperature Range	Operating voltage	Peak Current	Price
MCP9808	I2C	21mmx 13mm x 2mm	±0.25°C	9 gr	-40°C to +125°C	2.7-5.5V	2000 µA	8$
Bosch BMP180	I2C	14mm x 12mm x 0.93mm	±2°C	10 gr	-40°C to +85 °C	1.8V-3.6V	650 µA	10$
DHT22	Digital	27mm x 59mm x 13mm	±0.5°C	12 gr	-40°C to +80°C	3.3V-5V	2500 µA	9$

Selected Air Temperature Sensor :Bosch BMP180
*Low operating voltage.
*Data transfer from I2C port is faster.
*Dimensions are appropriate.
*Low current draw.
*Appropriate range and accuracy for healthy measurement.

GPS Sensor Trade & Selection

Model	Interface Type	Size	Accuracy	Weight	Operating voltage	Current	Price
SparkFun	SPI	10mmx 10mm	2.5 m	10 gr	2.7-3.3V	90mA	$50
Adafruit Ultimate GPS	I2C	25mm x 35mm	3 m	8.5 gr	3.0-5.5V	20mA	$30
GY-NEO6 MV2 GPS	SPI,I2C UART,USB	25mmx 25mm	5 m	10 gr	3.3-5.5V	60mA	$45

Selected Air Temperature Sensor :Adafruit Ultimate GPS
*Power usage is considerably low.
*High speed, high sensitivity logging and tracking.
*Lightweight.
*Price performance ratio is high.
*Suitable accuracy for right results.



Probe Power Voltage Sensor Trade & Selection

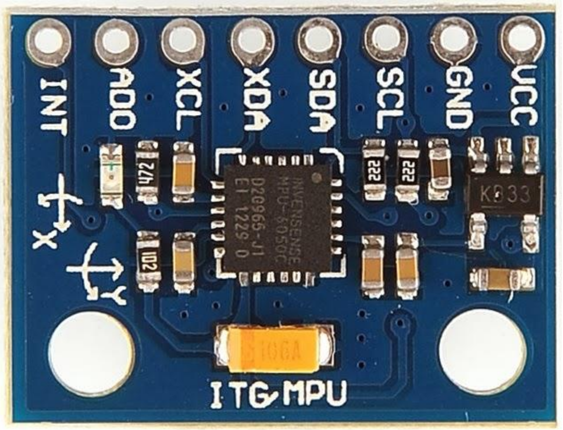
Model	Interface Type	Operating voltage	Accuracy(%)	Price
Phidgets Precision	Analog	-30V–+30V	+/-0.7	19.00$
LTC2990	I2C	3V –5.5V	+/-0.5	3.21$
Pro Micro32u4Analog	Analog	0V–5V	+/-0.1	Free

Selected Power Voltage Sensor : Pro Micro32u4's Analog Pins
*Voltage will be measured using one of the analog pins of Arduino and a voltage divider.
*More sensitive and cost-free.
*Reduces the load on I2C.
*No need for extra component.

Tilt Sensor Trade & Selection

Model	Interface Type	Size	Operating voltage	Price
AT407	Analog	7 mmx 0.4 mm	24 V(maximum)	$1.49
5pcs Tilt Angle Sensor Module	Analog	16mm x 14mm	3.3-12V	$4.31
MPU6050	I2C	2 mm x 1.6 mm	3-5V	$4.22

Selected Tilt Sensor : MPU6050
*Detecting the tilt of the probe in 3 axes by using only one component, on the base of changes in roll-pitch-yaw angles of the probe.
*Measuring the attitude and stability of the probe more accurately.
*To simulate the motion of the probe on MATLAB by using measured roll,pitch and yaw angles.
*More efficient and effective.



Bonus Camera Trade & Selection

Model	Interface Type	Size	Resolution	Operating voltage	Frame Rate(Frames/second)	Price
Eachine 2503	Analog	13mmx 13mm(card) 8mmx8mm (camera)	1920*1080 or 1280*720	3.8V-5.0V	30 or 60	$30.59
OV7670	Analog	34mmx34mm	640*480	2.45V-3.0V	30	$4.09
Turbowing Cylops dvr 3	Analog	18mmx 18mm	720*480	4.2V	30	$14.55

Selected Camera : Pro Turbowing Cylops dvr 3
*Resolution and megapixel values are suitable for the competition requirements.
*Easy to communicate.
*Affordable price.
*Less connection pins.

Bonus Wind Sensor

- **Wind sensor mission is not attempted.**

Descent Control Design

Ismail OZCAN

Descent Control Overview (1/4)

Probe:

CanSat has 12 cm diameter and 30 cm height.It is divided into segments for parachute, electronics, protection of hen's egg and heat shield seperation mechanism.

Parachute:

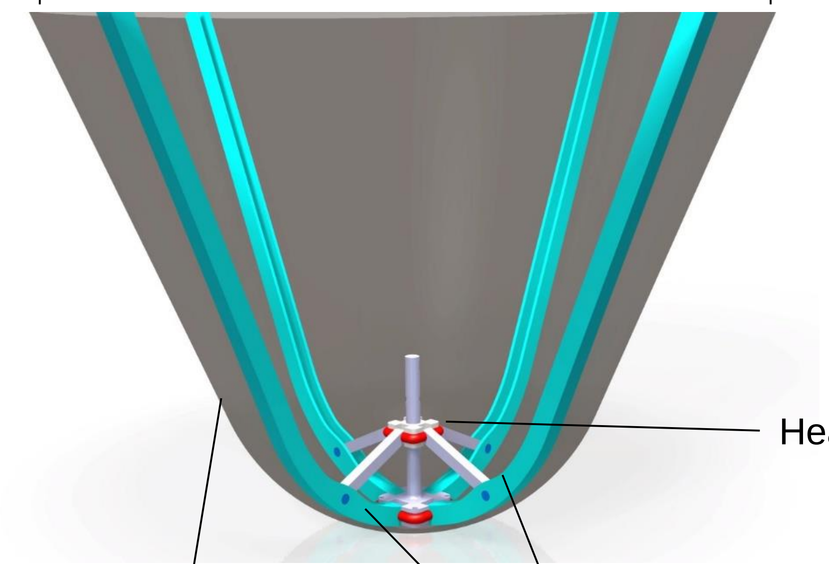
Parachute has made from 30d Silicon Nylon 66 Cloth.It has 45 cm diameter.It includes a spill hole radius of 5 cm to stabilize probe during descent.

Heat Shield:

Cone shaped heatshield has 22 cm diameter and α =45 degree.It has elevator system for controlling opening and closing.Heat shield includes 4 rods for adjusting drag force. Cone's nose is made from aluminum to resist heat.

Descent Control Overview (2/4)

Cone with 22 cm to balance velocity



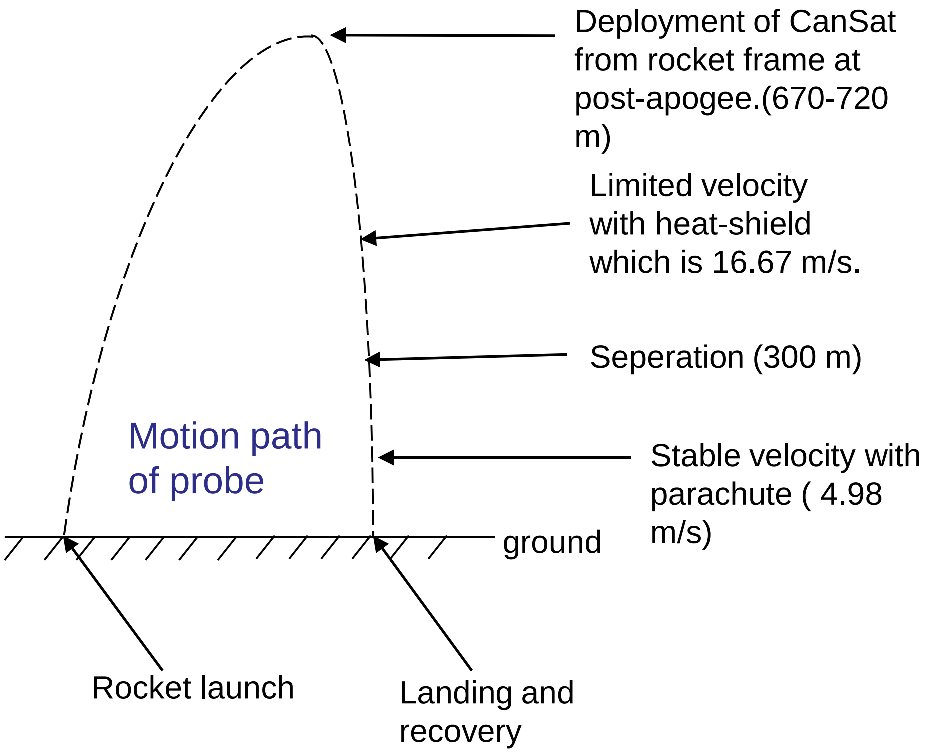
Heat Shield Mechanism

Heat Shield

Rods

Spill hole to reduce rocking

Descent Control Overview (3/4)



- The descent velocity with heat-shield is 16.67 m/s before separation time due to limited velocity.
- The probe descends with spilled hole parachute from 300 meters to ground after seperation.
- The descent velocity without heat-shield is calculated to be 4.98 m/s.

Descent Control Overview (4/4)

Configuration Selected: Cylindirical Probe with Cone Heat Shield

Components :

Component	Used in
PLA Material	Probe skeleton
PLA Material	Heat shield mechanism
Cotton line rope	Parachute connection with main frame
Rip-Stop Nylon	Heat shield’s cone
30d Silicon Nylon 66 Cloth	Parachute fabric
Hinges	Unfolding mechanism
Servo Motor	Separation system
Aluminum Foil	Cone’s nose
Copper Pipe	Holding outer rods

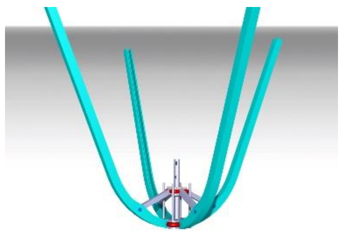
Descent Control Requirements

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
DCS-1	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	CReq	BR-18		Very High	✓		✓	
DCS-2	The CanSat, probe with heat shield attached shall deploy from the rocket payload section.	CReq	BR-13		Very High				✓
DCS-3	The aero-braking heat shield shall be released from the probe at 300 meters	CReq	BR-14		Very High	✓		✓	
DCS-4	The probe must maintain its heat shield orientation in the direction of descent.	CReq	BR-4 BR-5		Very High		✓	✓	
DCS-5	The probe shall deploy a parachute at 300 meters.	CReq	BR-15		Very High	✓		✓	
DCS-6	All descent control device attachment components shall survive 30 Gs of shock.	CReq	BR-16		High	✓		✓	
DCS-7	The descent rate of the probe with the heat shield deployed shall be between 10 and 30 m/s, parachute deployed velocity shall be 5 m/s.	CReq	BR-43 BR-44		Very High	✓		✓	

Payload Descent Control Strategy Selection and Trade (1/7)

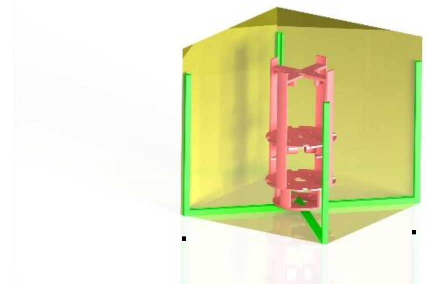
Stowing Configuration

Configuration Type 1: Parabolic rod



✓Easy to stow
✓Requires 1 rod
✓Produced easily by 3D printing
✓Same rods
✓Producing enough forces
✓Lightweight

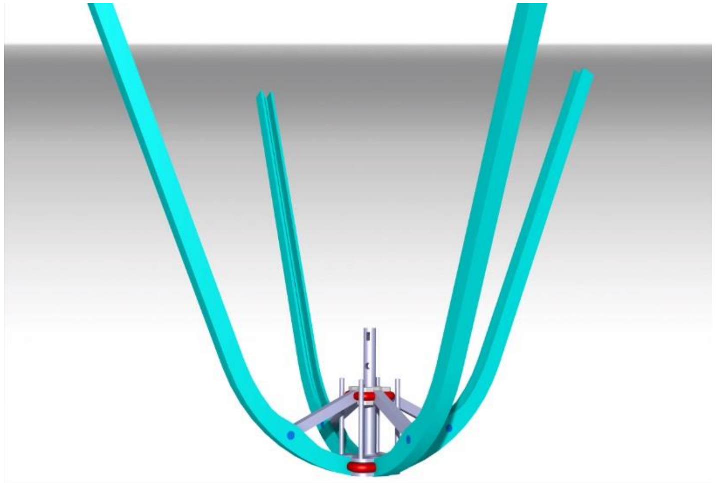
Configuration Type 2: Vertical 2 rods



✓ Easy to stow
✓Requires 2 rods
✓Produced easily by hand and 3D printing
✓Different 2 type rods
✓May produce different forces
✓Hinges for easy move

Selection	Rationale
Parabolic rod	• More stable • Easy production • Lightweight

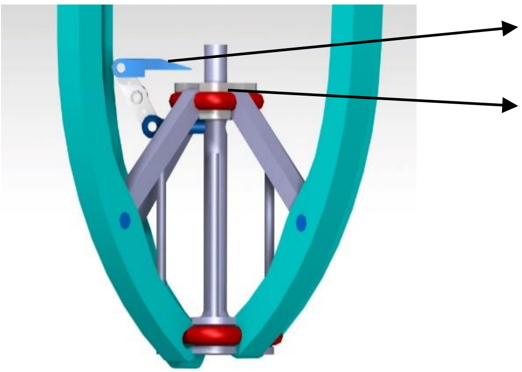
Configuration type 1 is more desirable for stowing since same rods will open at same time.Therefore, probe is not influenced by different forces which is important to get more stable descending and facing with zero tumbling. Configuration type 2 has two different rods which may cause different forces at same time;consequently, probe may tumble at the beginning of the flight .Also, 2 rods are sticked by hinges can be resulted with hinge fail.



Payload Descent Control Strategy Selection and Trade (3/7)

Deployment Mechanism

Configuration 1: elevator



- ✓ Higher chance of success
- ✓ Requires calibration
- ✓ No external mechanism needed for separation.
- ✓ Easy to produce

Configuration 2:Ni chrome wire

- ✓ Ni chrome wire holds heat shield rods together
- ✓ Wire is heated for deployment
- ✓ System must be enclosed hence hard to manufacture
- ✓ Heating requires time, delays deployment
- ✓ Another mechanism is needed for separation
- ✓ Wire can resist tear, cause failure at deployment

Selection	Rationale
Elevator	• Easy production • Higher possibility of success • No external mechanism needed for separation

Payload Descent Control Strategy Selection and Trade (4/7)

Type	Manufacture	Price ($)	Mass (g)	Diameter (cm)	Drag Coeff.	Only Probe descent rate (m/s)
Paragliding	Hand-made	3.3	17	40	0.45	9.47
Dome	Hand-made	2.8	20	45	1.5	4.98
X Type	Hand-made	3.1	15	50	0.8	5.68
Flat Round Canopy	Hand-made	3.5	16	50	0.55	8.56

Considering the price,lower mass,higher drag coefficent and final velocity for probe, Dome type parachute and X type parachutes are the first options.

$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}}$$

V = limited velocity
M = mass
A = area

ρ = 1.16 kg/m^3 (for Texas)
g = 9.81 ^m/s^2
C_d= drag coefficient

Parachute Configuration

Configuration type 1: Dome type

- ✓ Easy to manufacture
- ✓ Reduces rocking with it’s spill hole
- ✓ Less space needed when it is stacked
- ✓ Higher drag coefficient

Configuration type 2: X type

- ✓ Reduce rocking
- ✓ Lower drag coefficient
- ✓ Lightweight
- ✓ Stacking easily

- ✓ The dome type parachute was selected due to getting more desirable velocity
- ✓ The dome type parachute can be manufactured easier than X type
- ✓ The dome type parachute requires less space which is advantage to have a space for electronics

Payload Descent Control Strategy Selection and Trade (6/7)

Type	Manufacture	Price ($)	Mass (g)	Diameter (cm)	Drag Coeff.	Payload with heat shield descent rate (m/s)
Cube	Machines	20	122	17.677	0.8	26.01
Cone	Machines	30	135	22	0.8	16.67
Streamlined body	Machines	55	170	12.5	0.04	131.256
Hexagon	Machines	42	146	25	1	5.101

Considering the price and drag coefficient Cone type and Cube type heat shields were selected firstly.

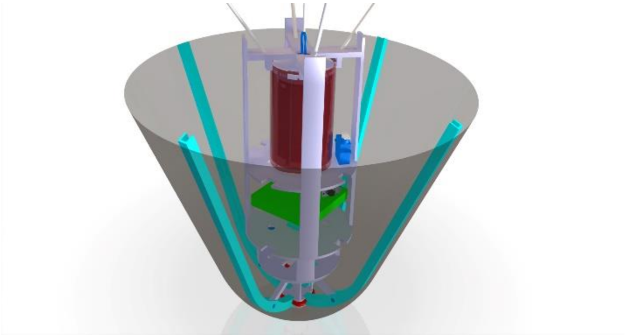
$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}}$$

V = limited velocity
M = mass
A = area

ρ = 1.16 kg/m^3 (for Texas)
g = 9.81 ^m/s^2
C = drag coefficient

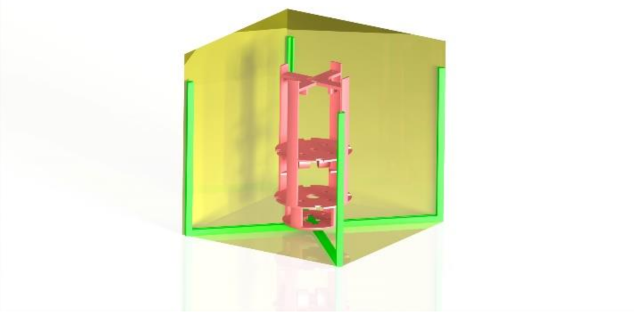
Heatshield Configuration

Configuration type 1: Cone type



- ✓ Desirable velocity
- ✓ Easy to configure
- ✓ Simple opening systems
- ✓ Advantages for deployment
- ✓ Advantages for heat shield separation
- ✓ Desirable atmospheric motion

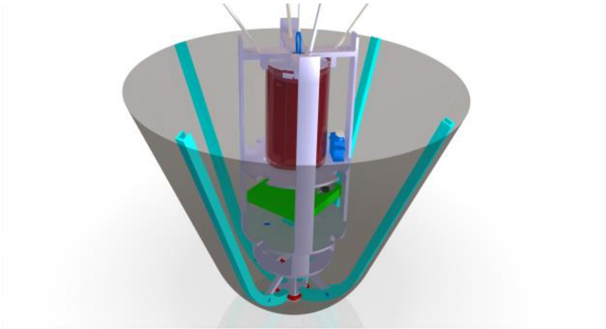
Configuration type 2: Cube type



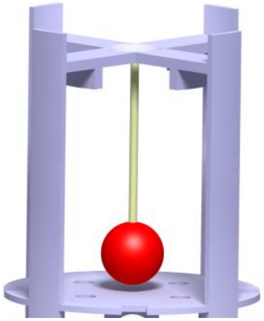
- ✓ Simple opening system
- ✓ Easy to produce
- ✓ Protective structure
- ✓ Easy to configure
- ✓ Acceptable velocity
- ✓ Desirable drag coefficient

<u>Selected Configuration: Cone Type</u>

- ✓ Cone type heatshield was chosen to get more efficient velocity.
- ✓ Cone type heatshield has more aerodynamic advantages against rocking and tumbling.
- ✓ Cone type heatshield has easier opening system because of rod based structure.



Tumbling controlling systems



Passive

- ✓ Aerodynamic, pressure and mass center are placed at same vector
- ✓ No space is required
- ✓ No more additional mass
- ✓ Fixed aerodynamic,pressure and mass center.

Active

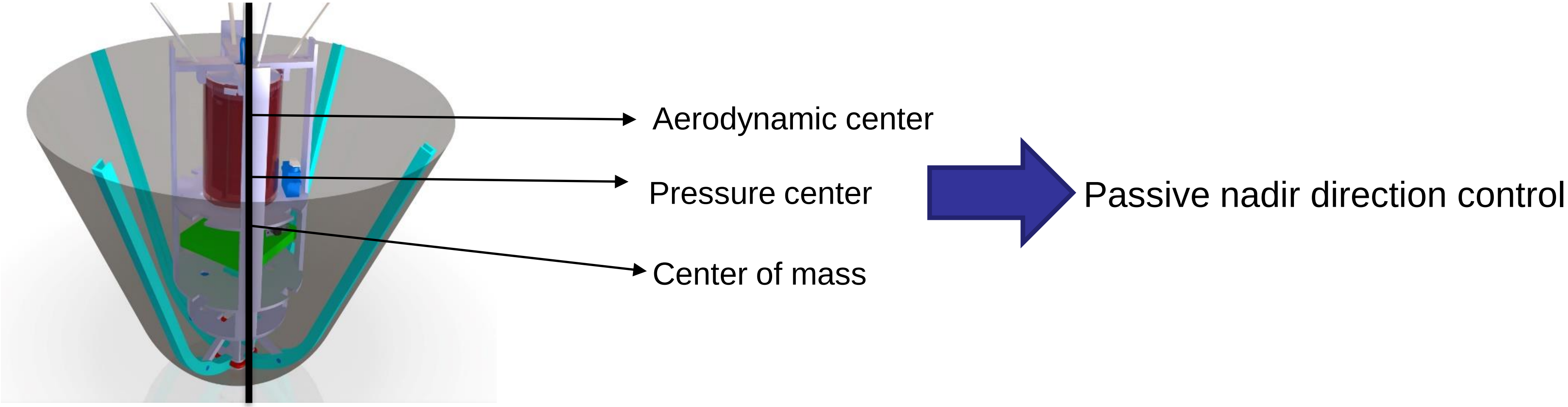
- ✓ Pendulum swings opposite direction of probe
- ✓ Pendulum requires dedicated area
- ✓ Mass margin is required
- ✓ Variable aerodynamic,pressure and mass center due to constant swing
- ✓ Too much movement can accelerate tumbling

<u>Selected Configuration:Passive</u>

- ✓ Mass budget indicates that there is only a small margin.
- ✓ Enough space for pendulum is not available.
- ✓ Nonstationary mass center is risky during flight operations

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

In order to achieve desired descent velocity, cone type and cube type heat shield configurations were considered in first occasion. Probe has a parachute which means it will keep it's nadir direction at last 300 meters. Limited velocities will disappear the tumblings. Nadir direction is also maintained since the center of mass will be positioned below pressure center and aerodynamic center. Vector passing through these points will be parallel to the descent direction. Relatively heavier electronic components are placed at lower section, moreover the main frame of probe has a decreasing density through the top in order to lower the position of center of mass.



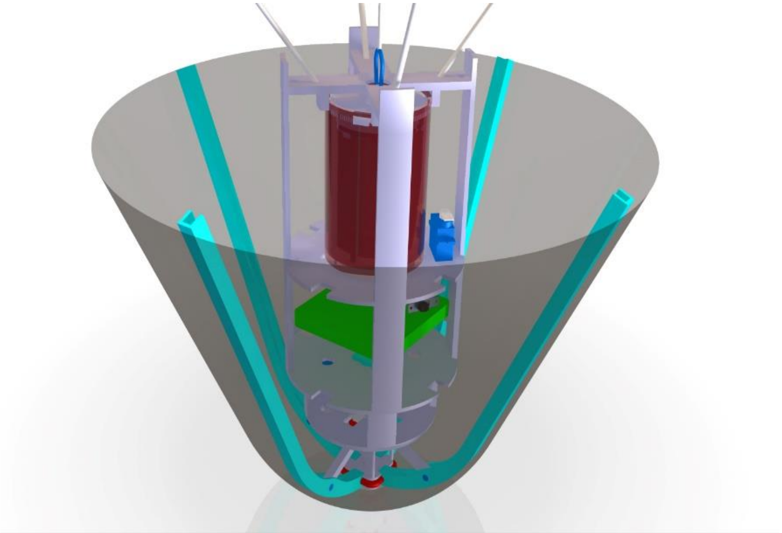
Descent Rate Estimates (1/3)

Descent with Heatshield

$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}} = \sqrt{\frac{2 \times (0.5\ kg) \times (9.81\ m/s^2)}{\pi \times (0.11\ m) \times (0.11\ m) \times (1.16\ kg/m^3) \times (0.8)}} = 16.67 m/s$$

V = limited velocity (Final velocity)	ρ = 1.16 kg/m^3 (air pressure for Texas)
M = mass (Probe + Heat shield)	g = 9.81 ^m/s^2 (acceleration of gravity)
A = area (Circular area of cone)	C = drag coefficient (0.8 for cone)

This equation concludes that limited velocity for probe with heatshield is 16.67 m/s, which is appropriate for competition scale 10-30 m/s.In addition, 16.67 m/s close to limited velocity of probe with parachute, 5 m/s. Therefore probe can withstand after parachute is released .



Descent Rate Estimates (2/3)

Descent with Parachute

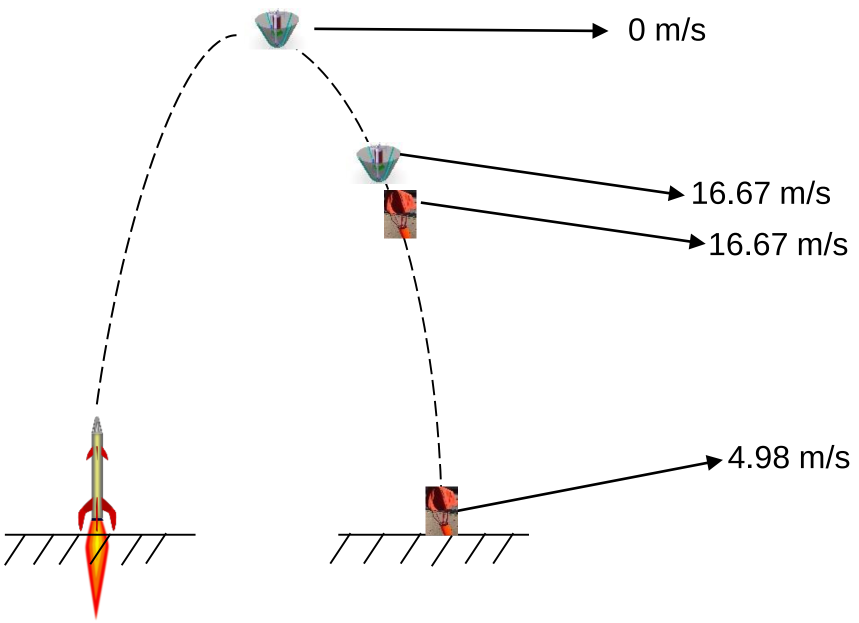
$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}} = \sqrt{\frac{2 \times (0.35\ kg) \times (9.81\ m/s^2)}{\pi \times (0.45\ m) \times (0.45\ m) \times (1.16\ kg/m^3) \times 1.5}} = 4.98\ m/s$$

V = limited velocity (Competition requires 5 m/s)	ρ = 1.16 kg/m^3 (air pressure for Texas)
M = mass (Probe only)	g = 9.81 ^m/s^2 (acceleration of gravity)
A = area (Circular area of parachute)	C = drag coefficient (1.5 for Dome type)

After the heat shield is released, first velocity of CanSat is 16.67 m/s.At the same time ,parachute opens and velocity is decelerate to limited velocity.This equation gives us that parachute with 45 cm diameter has 4.98 m/s final velocity. Acceptable velocity for competiton requirement.

Descent Rate Estimates (3/3)

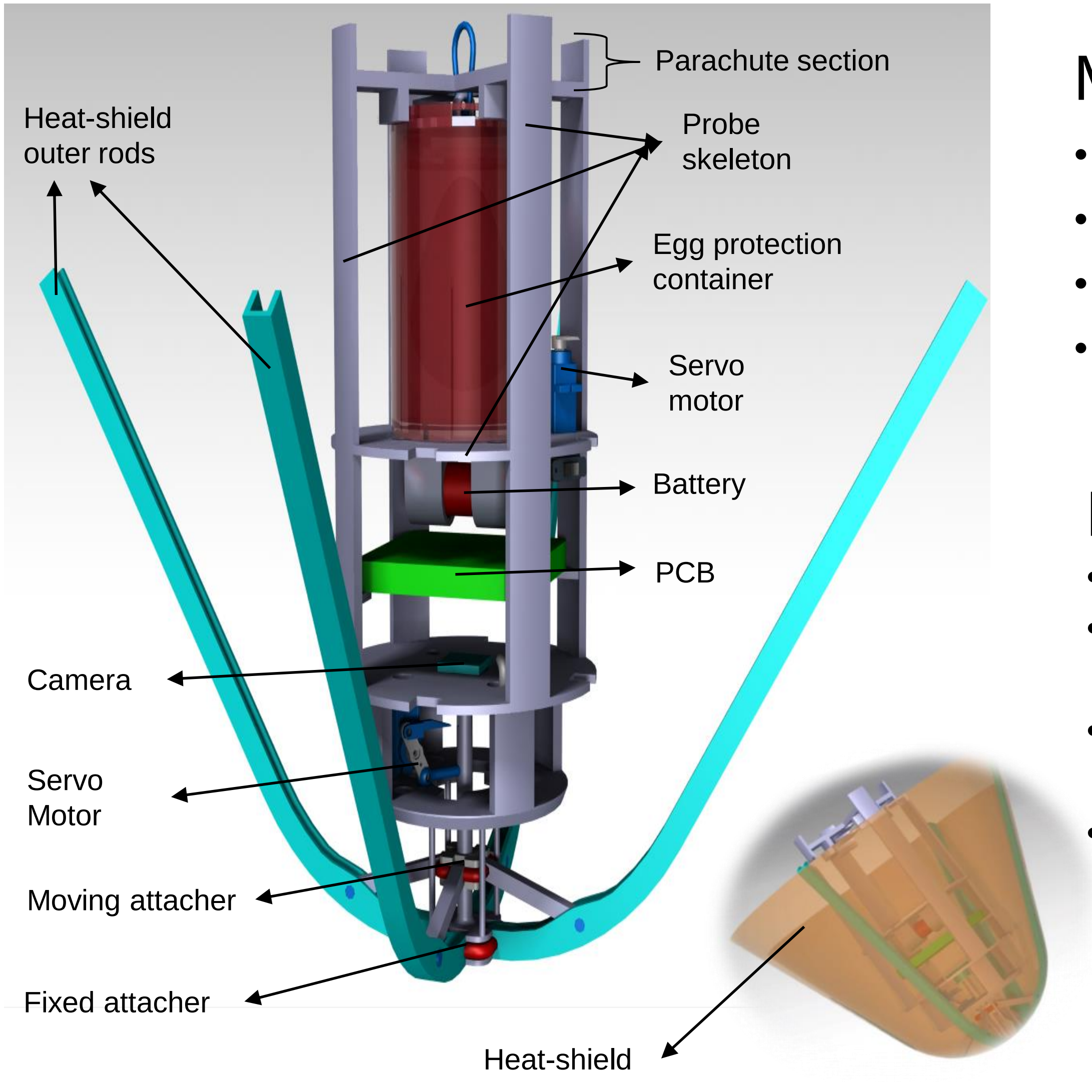
According to calculations,heatshield and probe have 0 m/s vertical velocity at apogee and will begin to accelerate due to gravity. Before the separation, probe with heatshield will have 16.67 m/s limited velocity. After the heatshield is released first velocity is 16.67 m/s for probe.As parachute creates a drag force, CanSat will be slowed down to 4.98 m/s, which depends on air pressure. However, CanSat will have nearly 5 m/s last velocity before it hits the ground.



Mechanical Subsystem Design

Oguzhan CAM

Mechanical Subsystem Overview



Major Structural Elements

- Probe
- Parachute deployment module
- Heat-shield seperation mechanism
- Heat-shield opening mechanism

Material Selection

- 3D printed PLA for Probe skeleton
- 3D printed PLA for heat-shield's rods and attachers
- Aluminum folio tape will be used at heat-shield nose cone.
- Copper pipe to hold together the outer rods.

Mechanical Sub-System Requirements (1/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
MS-1	Total mass of the CanSat should be 500gram(±10gram)	Creq	BR-1		Very High		√	√	
MS-2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length including the heat shield.	Creq	BR-6		Very High				√
MS-3	The CanSat shall not have any sharp edges to cause it to get stuck in the rocket payload section.	Creq	BR-9		Very High				√
MS-4	All electronic components shall be enclosed and shielded from the environment with the exception of sensors and all electronics shall be hard mounted using proper mounts.	To strengthen CanSat against external forces	BR-18 BR-21		High		√	√	
MS-5	The aero-braking heat shield shall be chosen a fluorescent color; pink or orange	To distinguish the CanSat clearly during descent.	BR-10		High				√

Mechanical Sub-System Requirements (2/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
MS-6	The aero-braking heat shield shall be used to protect the probe while in the rocket and the rocket airframe shall not be used as part of the CanSat operations.	Creq	BR-2 BR-11 BR-12		Very High		√		√
MS-7	The heat shield must not have any openings	Creq	BR-3		Very High				√
MS-8	The probe must maintain its heat shield orientation in the direction of descent.	Creq	BR-4	BR-5	Very High	√		√	
MS-9	The probe shall hold a large hen's egg that its measures are between 54-68 gram and 50-70 mm diameter.	Creq	BR-7 BR-8		Very High			√	√
MS-10	The aero-braking heat shield shall be released from the probe at 300 meters.	Creq	BR-14		Very High		√	√	
MS-11	The probe shall deploy a parachute at 300 meters.	Creq	BR-15		Very High		√	√	

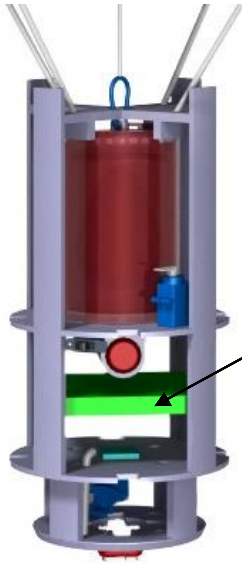
Mechanical Sub-System Requirements (3/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
MS-12	All structures and components shall survive30 Gs of shock and 15 Gs acceleration	To secure the Cansat operations.	BR-16 BR-17 BR-19 BR-20		Very High	✓		✓	
MS-13	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Creq	BR-22	BR-21	Very High	✓		✓	
MS-14	Flammable and explosive substances should not be used in mechanisms.	Creq	BR-23	BR-24	Very High		✓		

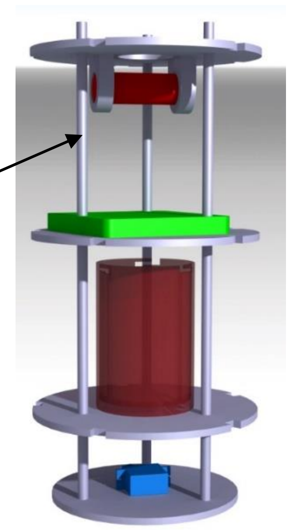
Probe Mechanical Layout of Components Trade & Selection (1/6)

Design 1 (Selected)

- This structure protects inner mechanic&electronic parts better.
- It is heavier than design 2.
- When the collision happened, the structure continues to maintain its shape under all forces. (MS-13)
- Electronic components placed at middle layer.
- Heat shield will be attached to servo at bottom layer and mounted with legs.



Electronic layer



Design 2

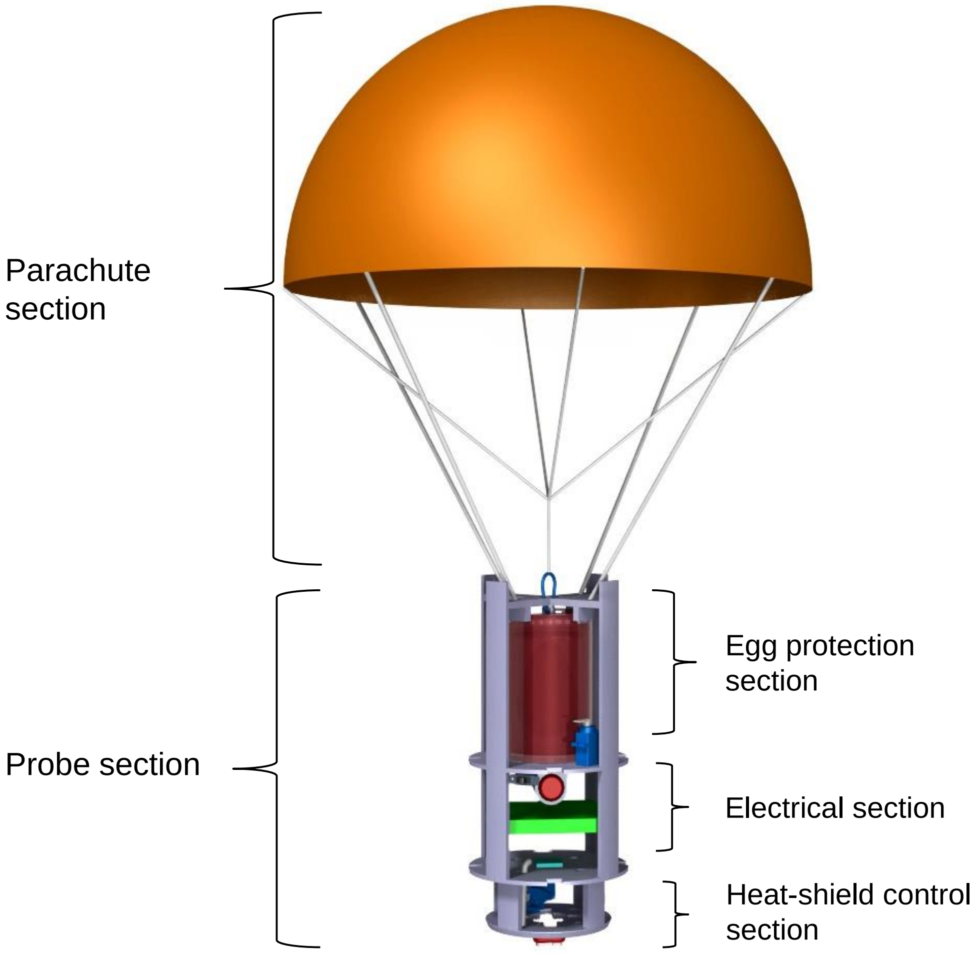
- Access to inner parts is easy.
- There is a risk of losing integrity while operations happen due to weak structure.
- The probe will be covered by duct tape after all integration process finishes.
- Electronics are placed at top layer
- Heat shield will be attached to servo at bottom layer

	Durability	Weight	Efficieny	Cost
Design 1	High	Medium	High	High
Design 2	Low	Low	Medium	Medium

SELECTED DESIGN	Rationales
Design 1	▪ Higher durability. ▪ Better component protection. ▪ More efficient integration.

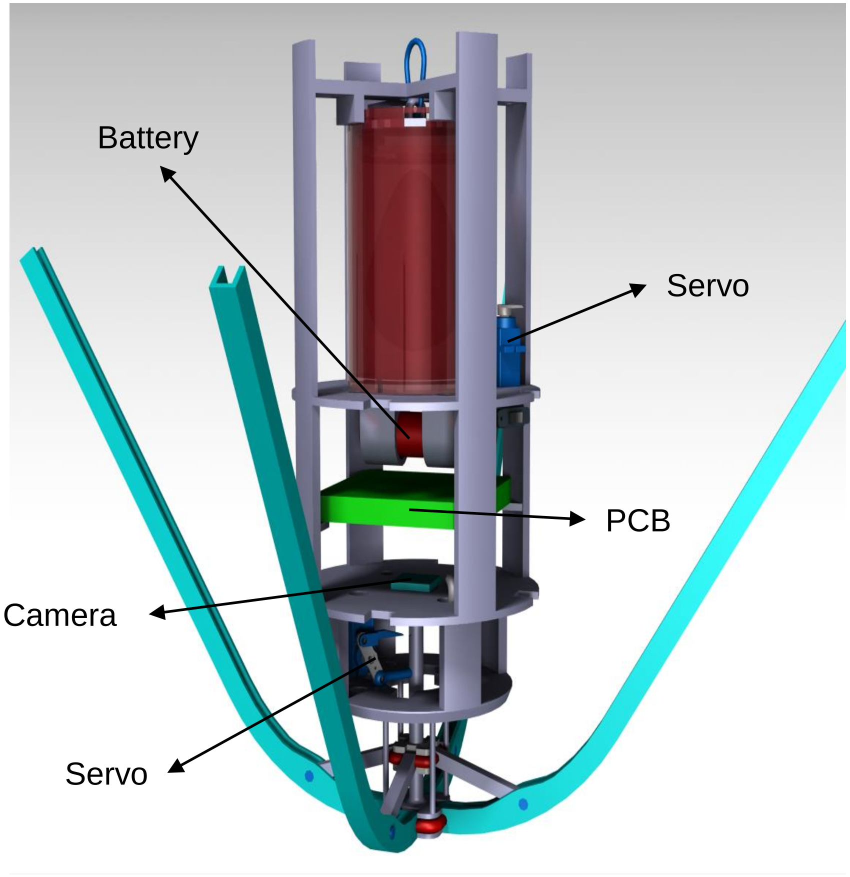
Structure of Probe:

- We decided to keep every section as light as possible.
- Sections will fill as little volume as possible.
- Joint sections of probe designed to withstand landing impact.
- Camera view angle is not blocked by other systems, a cutout will be made for camera lens.
- Egg will be protected during the flight operation inside 2 layered container.
- The center of mass is positioned below center of pressure and aerodynamic center to prevent tumbling.
- Heat-shield attachment points will hold heat-shield in a steady position.
- Access to important electronic components will be easy.



Electrical components

- The PCB is located in the center of probe and is attached to corner of structure.
- The battery is located between the PCB and egg protection section
- The servo motor is placed to last layer of skeleton to carry out the heat shield operations.
- The camera is positioned properly to show all the operations of the heat shield.



Heat shield attachment points:

- There are 4 little rods(yellow sticks) which are going into the holes in the structure. Rods are grasped by holes to prevent heat shield's shaking motion.(Figure A)
- Servo arms hold main rod(pink rod) till from opening of heat shield to separation of heat shield.

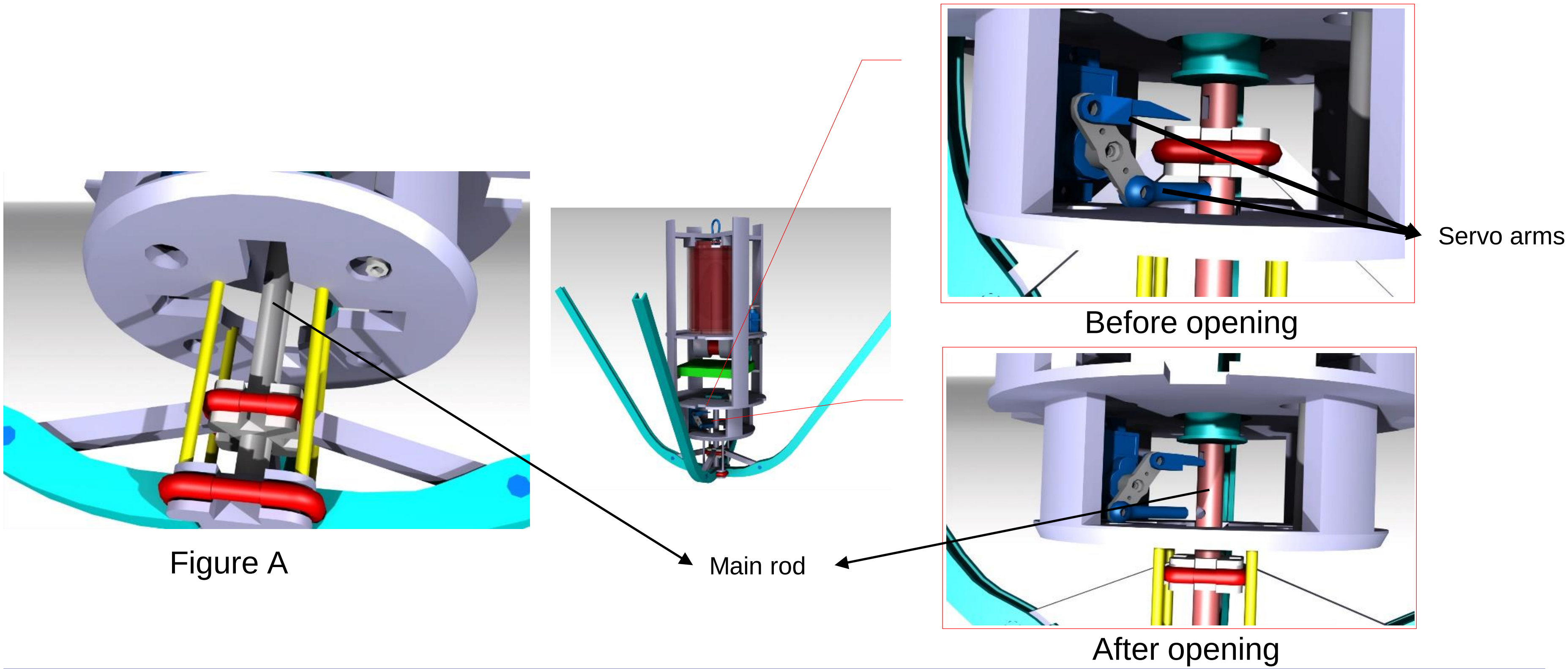
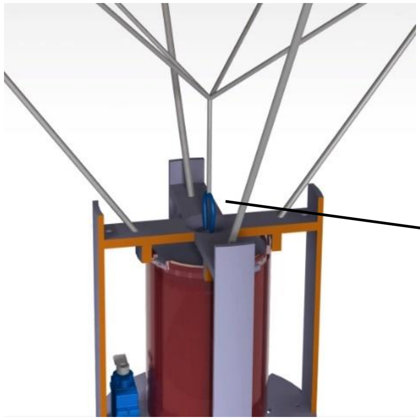
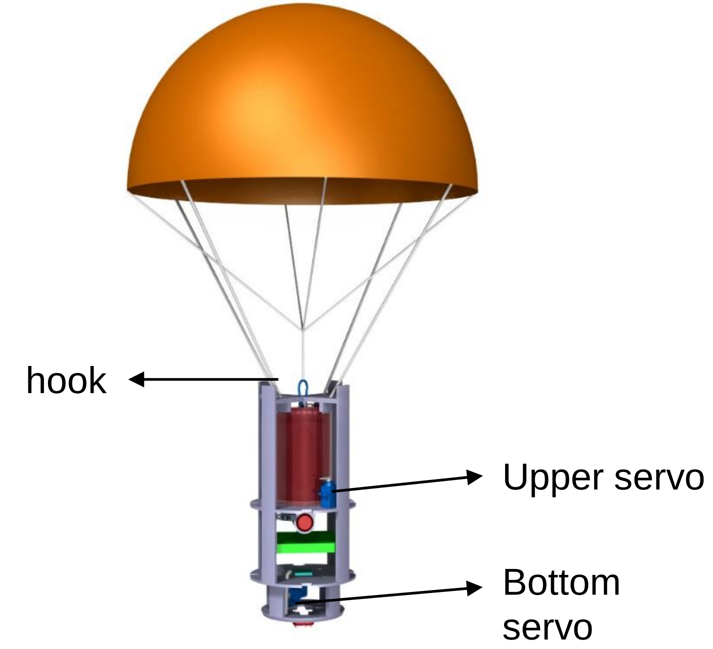


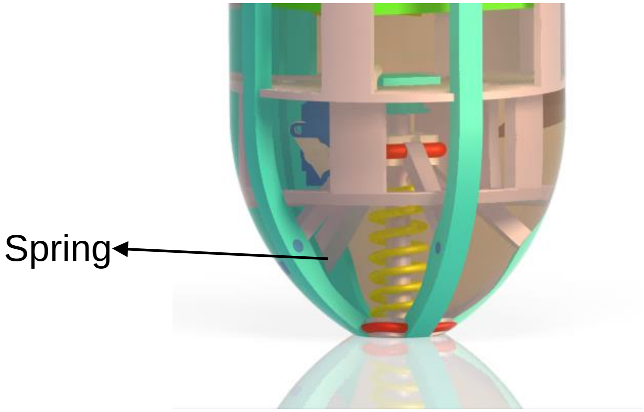
Figure A

Mechanical parts

- Upper servo will be used for opening the parachute by cutting ropes that hold parachute.
- Bottom servo will be used for control the heat shield mechanism.
- Heat shield mechanism contains a spring to be opened after deployment.
- Hook will be attached to parachute to decrease the force egg will receive.







Probe Skeleton

Material	Density (g/cm^3)	Melting Temperature (C)	Tensile Strength (MPa)	Cost ($/kg)
PLA	1.24	157.22	60.94	29.99
ABS	1.04	87.77	42.47	29.32
Polyamide(PA)	1.13	223	48	37.99

SELECTED MATERAL	Rationale
PLA	▪ Optimal melting temperature ▪ High density. ▪ Good durability. ▪ No harmful fumes while printing

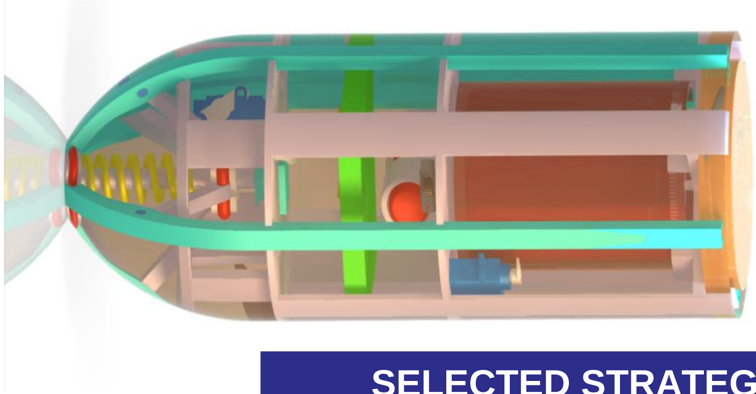
Payload Pre Deployment Configuration Trade & Selection

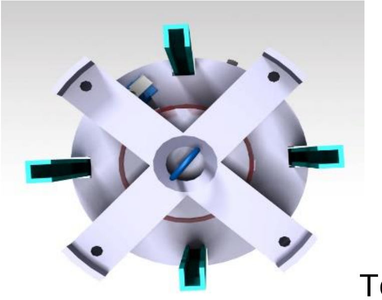
Strategy 1

- Outer rods are closed by hand force.
- After that outer rods are binded by fishing line so that rods can not open back.
- When the Cansat is deployed from rocket, another servo's blade arm cuts the line that binds the outer rods, and heat shield is opened.
- One more servo is needed for this mechanism.
- This strategy is considered to be alternative to complexity of second strategy .

Strategy 2 (selected)

- Outer rods are closed by hand force.
- When closing the outer rods, moving attacher rises through the main rod.
- Spring between the attachers is becoming tensile during the closing process.
- Moving attacher is placed between the servo motor arms.
- Servo motor's second arm rotates to enter the hole by sending command from GCS.





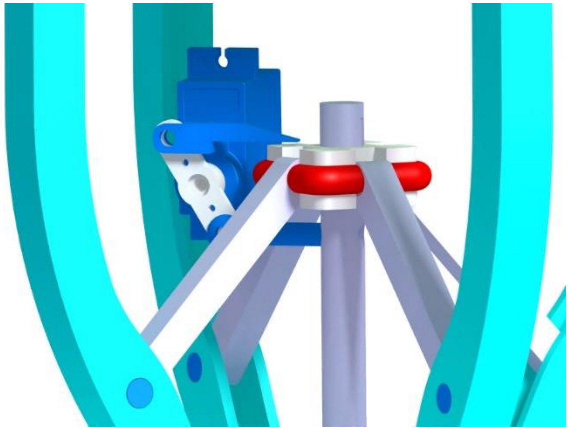
Top View

SELECTED STRATEGY	Rationale
Strategy 2	▪ Less mechanisms are needed. ▪ Opening heatshield is easy and less risky

Heat Shield Deployment Configuration Trade & Selection (1/3)

Configuration 1: Servo hinge

- Rods of heat shield is held by a servo hinge.
- Servo hinge rotates and heat shield is opened after CanSat exits the rocket frame.
- More reliable.
- Easy to produce.
- Calibration is required.

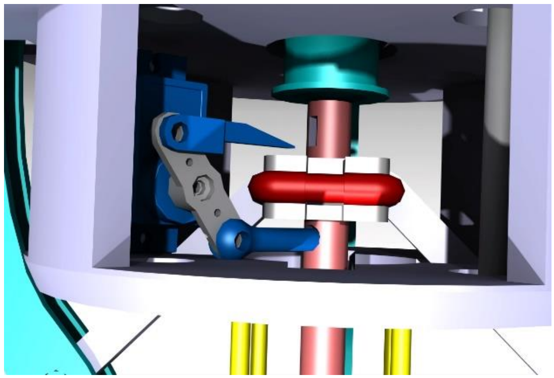


Configuration 2: Ni-chrome wire

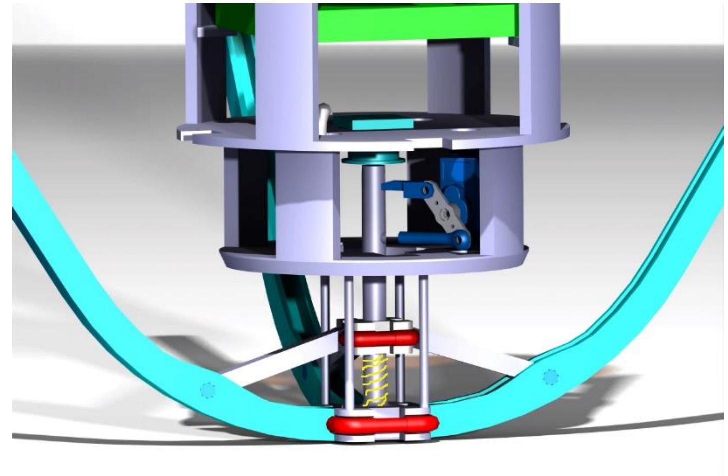
- 4 main rods of heat-shield is hold by a ni-chrome wire.
- Wire is split by heat after deployment.
- Heat is supplied by battery.
- Heating restricts electronic capacity, due to high voltage requirement.
- Risk of not opening heat-shield.
- Mechanism must be enclosed , thus requires craftsmanship.

SELECTION	Rationale
Configuration 1	▪ Heating can cause a fatal failure. ▪ More reliable mechanism. ▪ Wire can be damaged before. ▪ Easy to manufacture

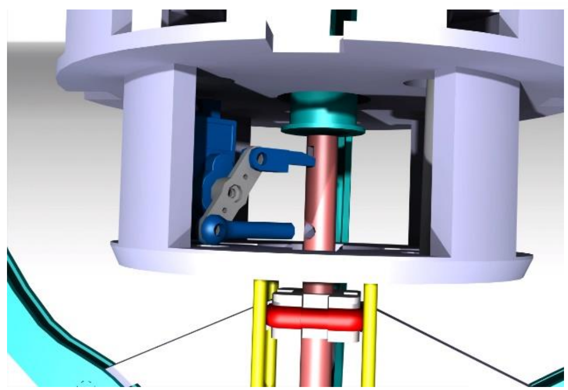
Heat Shield Deployment Configuration Trade & Selection (2/3)



2-When second arm of servo rotates back first arm enters the hole and remain the holding heat-shield.

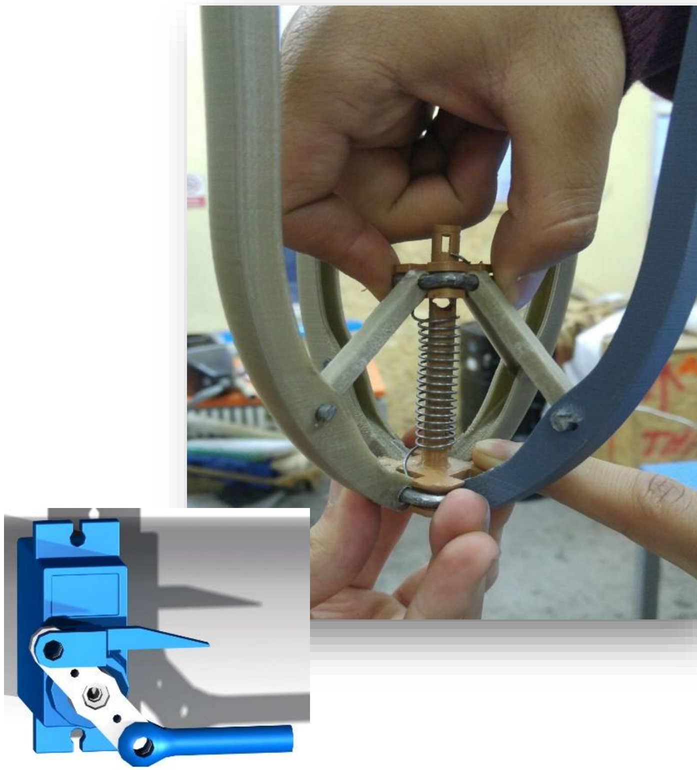


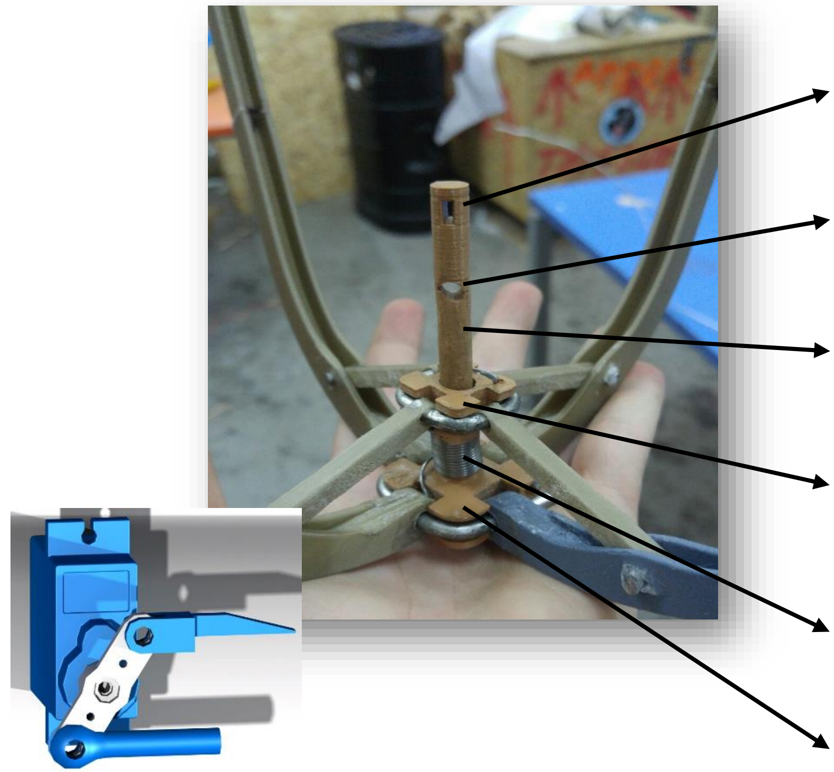
1-Moving attacher is placed between the 2 servo arms and servo holds whole heat-shield.



3-Spring pulls the moving attacher to fixed attacher through the main rod.

Heat Shield Deployment Configuration Trade & Selection (3/3)





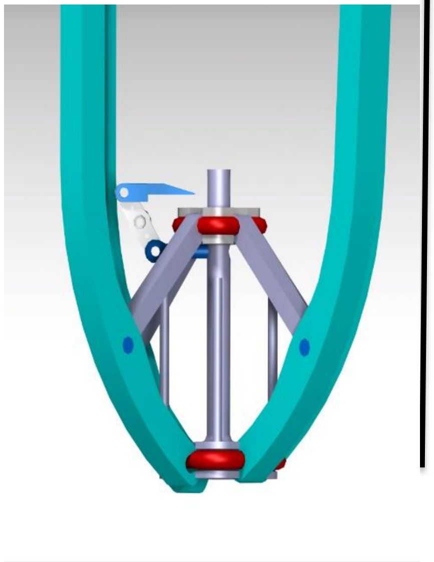
After outer rods are closed by hand force, servo's bottom arm rotates to enter Hole B. Arm will now hold both the moving attacher and main rod (actually entire heat-shield).

Just after the payload is seperated from rocket, servo rotates 90 degrees. When servo's bottom arm let moving attacher to go down and servo's upper arm enter the Hole A to hold heat-shield.

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

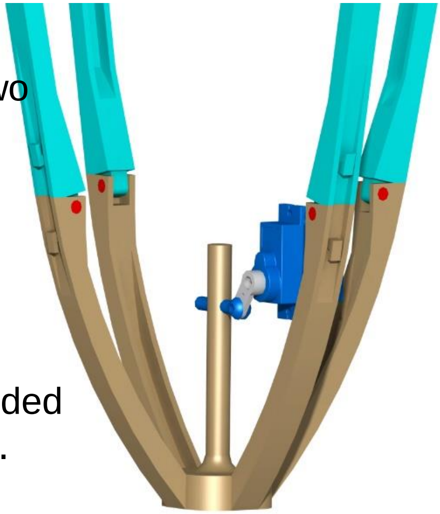
Design 1 (selected)

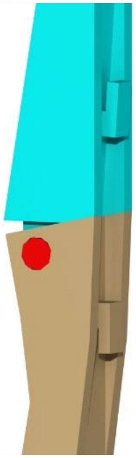
- Opening and separation mechanisms are together.
- Not much manufacturing skills are required.
- More trustable.
- Spring which is located between two attachers provide tension to deploy heat shield.



Design 2

- Deployment of heat shield carries out through elastic bands which are attached two hooks and tensile these two hooks to provide open turquoise rod.
- Releasing mechanism is controlled by servo with one command.
- Attachment to probe is provided by just one point(servo arm).
- An additional mechanism is needed to keep the heat shield in the stowed configuration.

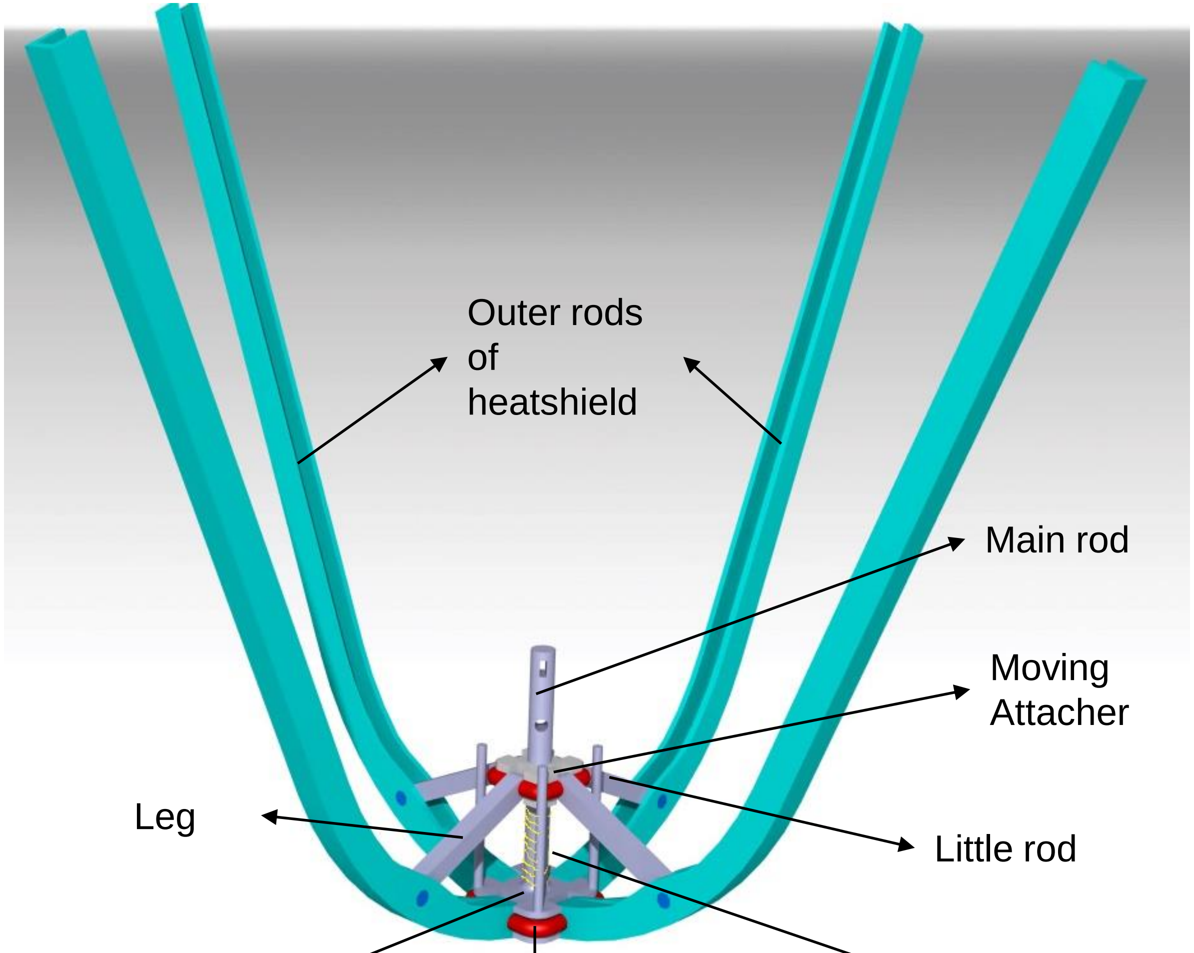




SELECTED DESIGN	Rationale
Design 1	▪ More trustable ▪ Center of mass is lower. ▪ More durable through the support rods. ▪ Spring ensures the opening of heat shield. ▪ No extra mechanism needed to carry out heat shield operations.

Key trade issues:

- All mission necessities should be considered in detailed way.
- Heat-shield must keep the velocity between 10 to 30 m/s.
- Cross-section of the Heat-shield when it is opened must be calculated.
- Heat-shield must endure the air resistance.
- Heat-shield should be covered the whole probe.
- Spring must keep its tensile position against the air resistance.
- Outer rods are coated by aluminum folio tape to shape aero-braking heat shield configuration.



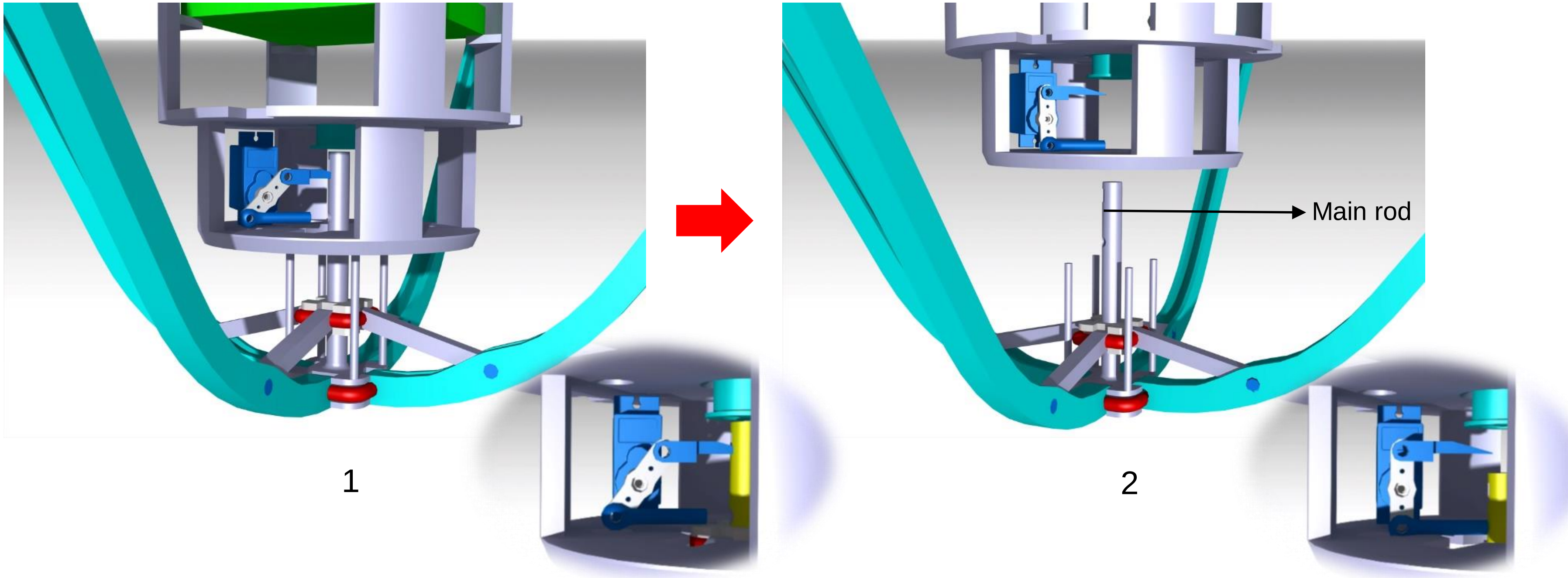
Heat Shield Mechanical Layout of Components Trade & Selection (3/3)

Heat-shield Attachment Points:

- Legs which are attached to the moving attacher and the outer rods ensure the heat shield operations.
- Outer rods and legs turn around the copper pipe
- Servo motor attached to the main rod and it helps opening and separation of the Heat-Shield.

Component	Options	Rationales
Rods	-PLA(selected) -ABS -PA	-High density -Optimal melting temp.
Deployment mechanism	-Servo motor(selected) -Step motor	-Cheaper -Easy to configure
Attachment point	-Galvanized steel pipe -Copper pipe (selected)	-Cheaper -Easier to shape -Light weight
Heat shield coating surface	-Cloth -Model aircraft cover material -Aluminum folio tape (selected)	-Refractory -Easy to integrate

Heat Shield Release Mechanism (1/2)

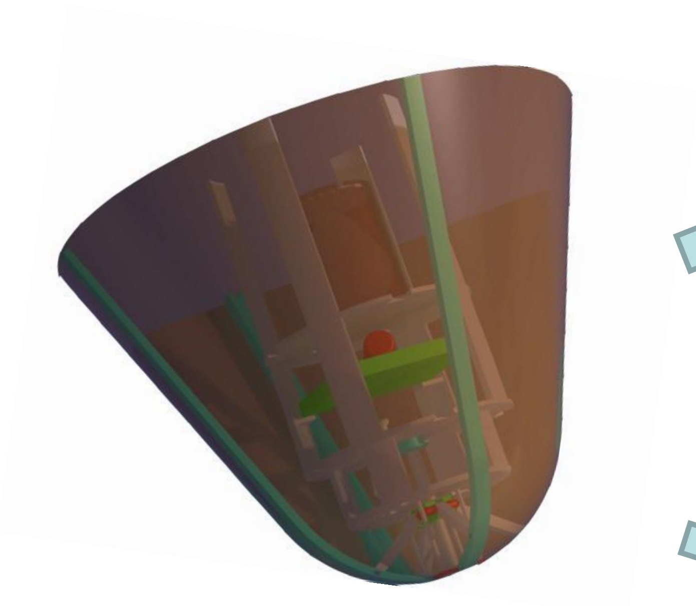


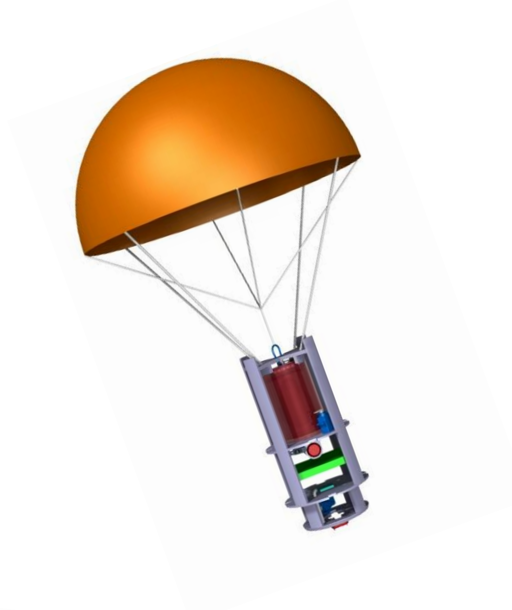
Initially, as in position 1 in the figure, heat shield is deployed and stable and motionless.

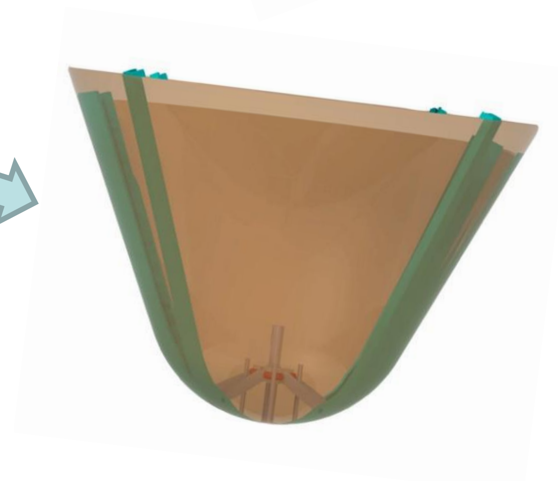
Servo arm holds main rod of heat-shield during the descent 700 meters to 300 meters.

When the altitude is measured as 300 meters for the second time, (first time will be measured by pressure sensor when rocket is rising) servo will rotates 90 degrees to release the heat-shield.

The heat-shield will now be completely free from the probe, and can start to free-fall.

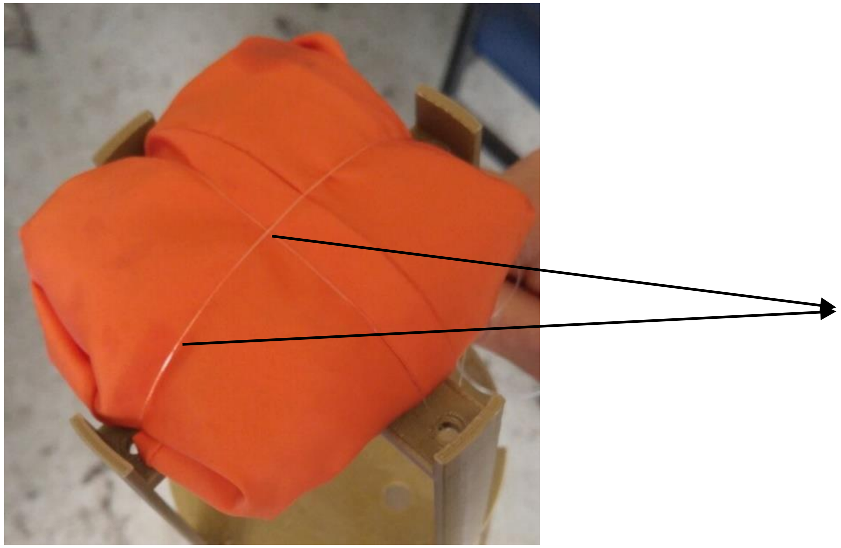


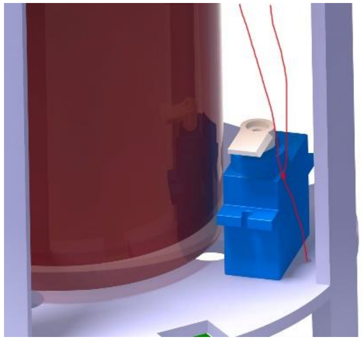




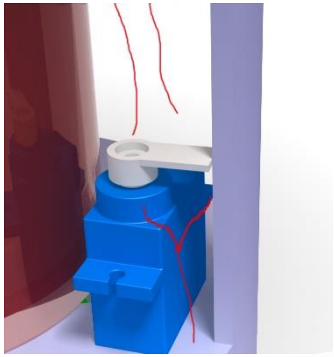
Probe Parachute Release Mechanism (1/2)

- Parachute will be attached to egg protection by 4 ropes and a hook holding together.
- Other 4 ropes will be attached to the probe itself.
- Parachute will remain folded with slimmer rope. The rope is going through the holes that placed at upper layer of the egg protection.
- Parachute will be surrounded by X shaped rope.
- Slimmer rope will end where second servo can cut it.

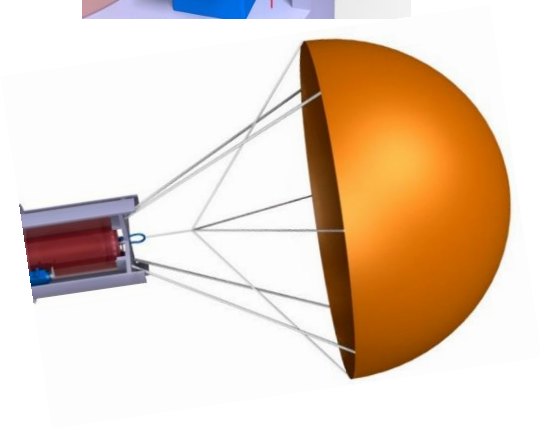




- Servo motor is motionless and waits for the 300m to move.
- In order to servo’s arm can cut it smoothly the rope is slim but strong enough to hold the parachute.



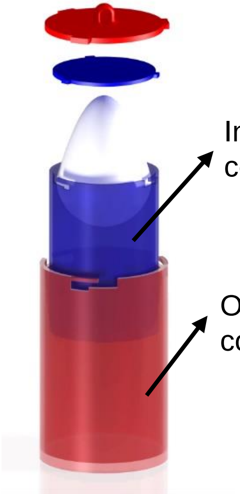
- When altitude sensor measures 300m servo is triggered and it starts to rotate to cut the rope.
- Once the rope is cut, parachute will be free to move upwards to slow down probe



- The parachute moves directly upward and is opening immediately after the rope cut due to air filling inside of the parachute
- Probe is slowed down to 4.98 m/s.

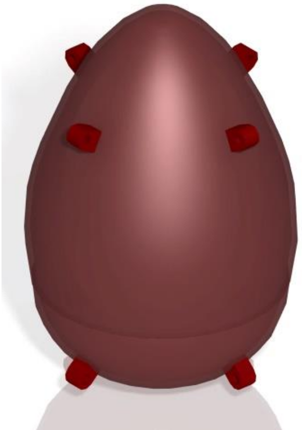
Egg Protection Structure (1/4)

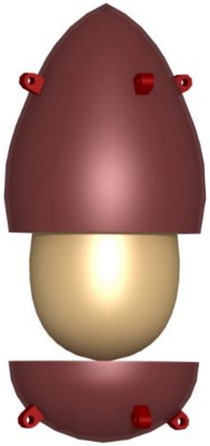
Design 1(selected)



- There are two container in this design.
- Between the layers there is bubble wrap to decrease the damage of the collision.
- Inside the inner container again there is bubble wrap.
- The hook will be connected directly to parachute and between the probe and the bottom of the outer container is empty so that will provide us more reliable environment for egg.

Design 2

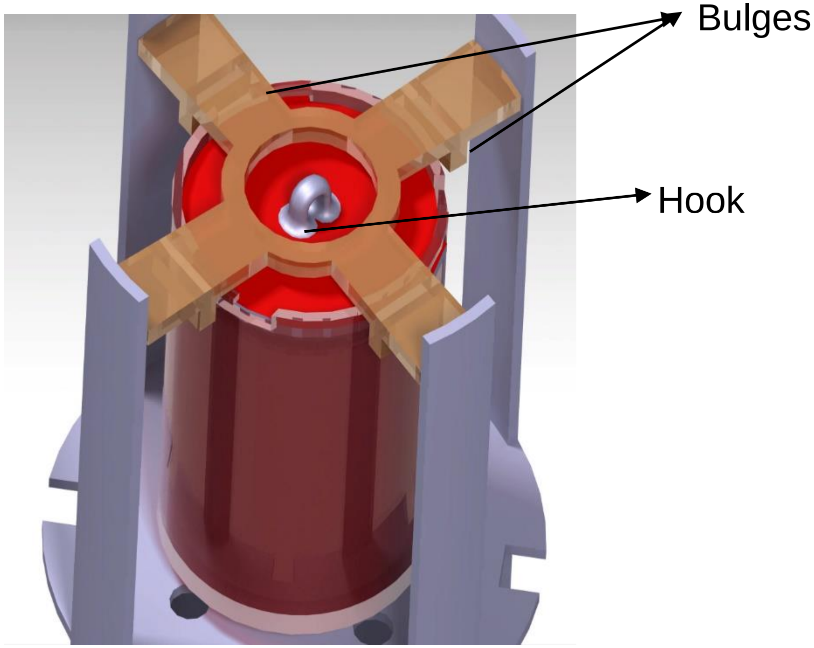




- Inner surface of container is covered by play dough.
- Once egg is placed, bottom part is fixed to upper part with adhesives.
- 8 holders on the body to connect carrier ropes.
- The ropes are connected to probe skeleton in such a way that they will be stretched.
- Protection shell is hanged in the air.
- Egg shape structure is efficient for small space.

Egg Protection Structure (2/4)

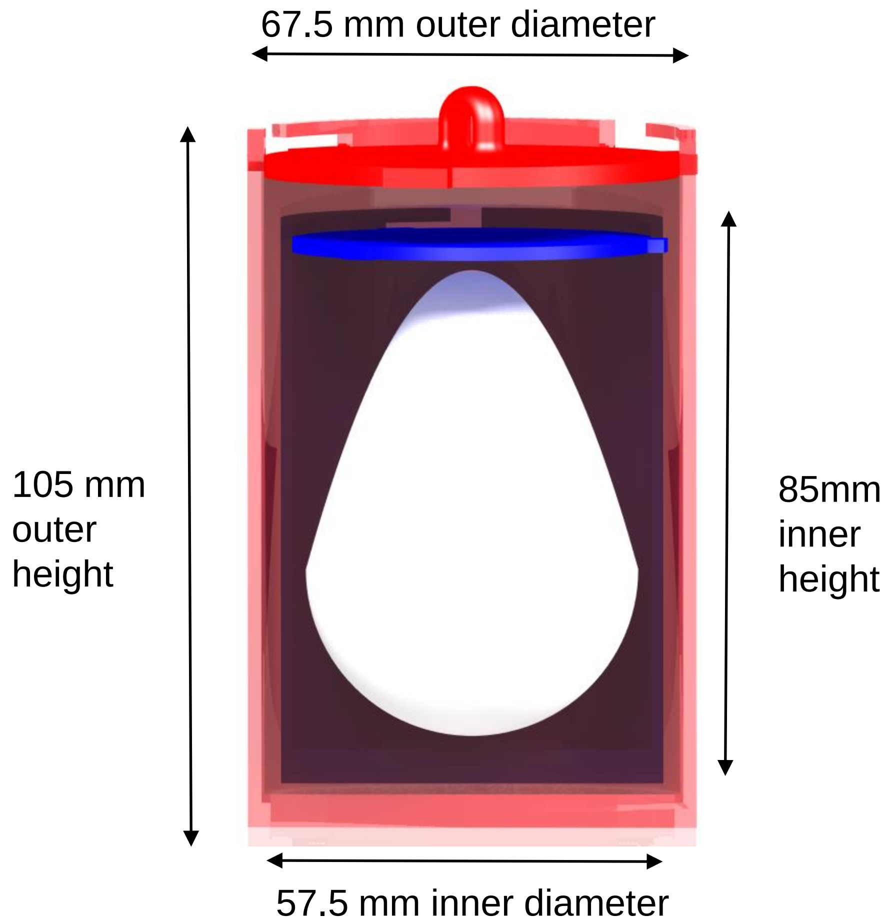
SELECTED DESIGN	Rationales
Design 1	▪ More secure area for egg. ▪ Damage reducing is higher. ▪ Easier to integrate



- There is a gap between the bottom of the container and probe.
- When we need to remove or insert egg to the container, we will pull the container to the ground and will separate the container and probe as using the gap.
- The bulges will stop the motion of container when the probe is in the air.
- Protection shell is able to move vertically but not horizontally due to bulges.
- Vertical movement will increase the time in an impact and reduces the acceleration, hence the total force egg will receive.

$$a = \frac{dV}{dt} \Rightarrow Force = mass * acceleration$$

Egg Protection Structure (3/4)



- Hen's egg provided by competition has a maximum diameter of 50 mm and maximum height of 70 mm.
- Inner shell has a margin of 7.5 mm in diameter for bubble wrap.

Egg Protection Structure (4/4)

Materials	Density(g/cm^3)	Tensile Strength(MPa)	Cost
PLA	1.24	60.94	29.99($/kg)
ABS	1.04	42.47	29.32($/kg)
E-Fiber Glass	2.55	1900	4.65($/yard)

Material	Rationale
PLA	-Light weight -High Tensile strength

Electronics Structural Integrity (1/2)

Mounting methods

- PCB is planned to have 4 holes at 4 corners of it.
- PCB is to be mounted with **M.3.5*9**mm screws.
- PCB will also be sealed with epoxy to bottom surface
- A hole is opened in the layer for the camera in a way that camera records the releasing of heat shield.
- Camera is mounted with **M.3.5*9**mm screw.
- Pin connections are sealed with polyolefin tubing.
- Battery holder with 2.5cm diameters inner pitch is specially designed for battery
- Servo's are mounted with epoxy

Enclosers

- Electronic components in skeleton are enclosed with duct-tape that will be the cover of skeleton.
- For easy access to PCB duct-tape will enclose only 3 sides of the probe. Just before the launch, non covered parts will be enclosed.

Electronics Structural Integrity (2/2)

Electrical Connections

- Depending on the connection components, proper method for securing will be used.
- Electrical connection methods are:
  - Soldering
  - Specific adhesives for electronic
  - Electric tape

Descent control attachments

•Heat-shield will be attached to probe with servo hinge.

•Parachute will be attached to probe using nylon chords.

•Parachute connections will be secured with knots behind the holes on probe.

•Parachute will have direct connection to egg protection shell.

Mass Budget (1/3)

PROBE	Weight(g)	Data Type
Skeleton of Probe	117	M
Servo x2	18	M
Parachute and Ropes	24	M
PCB	43	E
Battery	18.5	M
Egg Protection (with egg)	95	M
Camera	7.2	D
Electronic Sensors	21	D
M.3.5*9 Screw x4	2.4	D

Total Weight of Probe(g)
346.1

Source:
E:Estimated
D:Data Sheet
M:Measured

Mass Budget (2/3)

HEAT SHIELD	Weight(g)	Data Type
Outer Rod x4	66	M
Main rod(attacher x2 + little rod x4)	27	M
Spring	15	M
Copper pipe x2	16	M
Leg x4	12	M
Heat shield surface cover material	17	M

Total Weight of Heat Shield(g)
153

Source:
E:Estimated
D:Data Sheet
M:Measured

Mass Budget (3/3)

Total Weight of Payload(g)
499.1

- **Total Mass Margin of CanSat= 500 – 499.1 = 0.9 g**

Correction Methods

In case total mass measured at the launch site is different than expected, following processes is to be done.

If weight of CanSat <490g, Probe with higher density 3D printed materials is to be used.

If weight of CanSat >510g, Probe with lower density 3D printed materials is to be used.

Communication and Data Handling (CDH) Subsystem Design

Altug ERTAN

CDH Overview

Component	Type	Purpose
Arduino Pro Micro	Microprocessor	To obtain and process the sensor data
Sandisk SD Card	Storage Device	To store the sensor data and video
Arduino Crystal Oscillator	Real Time Clock	To measure mission duration with the real time
TL-ANT2405CL	Antenna	To strengthen the transmitted signals from probe to ground station
XBee Pro S2B	Transceiver	To transmit and receive data between the probe and ground station

CDH Requirements (1/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
CDH-1	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time.	CReq	BR-25		Very High		✓	✓	✓
CDH-2	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.	CReq	BR-26		Very High	✓	✓	✓	✓
CDH-3	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	CReq	BR-27		Very High			✓	✓
CDH-4	XBEE radios shall be used for telemetry. 2.4 GHz Series 1 and 2 radios are allowed. 900 MHz XBEE Pro radios are also allowed.	CReq	BR-28		Very High		✓	✓	
CDH-5	XBEE radios shall have their NETID/PANID set to their team number.	CReq	BR-29		Very High			✓	✓
CDH-6	XBEE radios shall not use broadcast mode.	CReq			Very High			✓	✓

CDH Requirements (2/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
CDH-7	All telemetry shall be displayed in real time during descent.	CReq	BR-33		Very High			✓	✓
CDH-8	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	CReq	BR-34		Very High				✓
CDH-9	Teams shall plot each telemetry data field in real time during flight	Creq	BR-35		Very High		✓	✓	✓
CDH-10	A tilt sensor shall be used to verify the stability of the probe during descent with the heat shield deployed and be part of the telemetry.	CReq	BR-49		Very High		✓	✓	✓

Probe Processor & Memory Trade & Selection (1/3)

Model	Clock Speed	Operating Voltage	Current Draw(Load)	I/O Pins	Memory	Price
Arduino Pro Micro	16 MHz	6V-20V	40mA	20	32 KB	16$
ATmega 32u4	16 MHz	2.7V–5.5V	30.5mA	20	32 KB	10$
Arduino Nano	16 MHz	6V–20V	47mA	23	16 KB	22$

Selected Processor : Arduino Pro Micro

•Affordable cost.

•Easy to program.

•Draws less current.

•Small size.

•Provides sufficient power, memory and data interface types that the system uses.

•Arduino Nano is not used because of its unnecessary pin connections and its resetting problem under load conditions.

•ATmega32u4 is not easy to program and has not enough pins for data interfaces that the system uses.

Probe Processor & Memory Trade & Selection (2/3)

The properties of Arduino Pro Micro are given below:

Operating Voltage (logic level)	5V	**Analog Input**	12
Input Voltage (limits)	6V-20V	**I²C**	2
Digital I/O Pins	20	**SPI pin**	3
PWM	5	**Uart**	2
Flash Memory	32 KB	**Price**	16$
Dimensions	3.3cm x1.77cm	**Weight**	1.5g

Probe Processor & Memory Trade & Selection (3/3)

Model	Memory	Interface	Price
SanDisk 16 GB SD Card	16 GB	SPI	5$
EM783	32 KB	I^2C	3$

Selected Memory : SanDisk 16GB SD Card

- Low cost.
- Significantly more memory than EM783.
- Better reading and writing data rate.
- Easy to use thanks to pluggable and removable structure.
- According to data interface analysis, SPI is easy to setup and more stable than I^2C.
- EM783 has not memory for storing all telemetry data.

Probe Real-Time Clock

Model	Voltage (V)	Power Consumption	Accuracy	Reset Tolerance	Price	Hardware / Software
Arduino Crystal Oscillator	-	-	+/- 555ppm	In reset condition software reads the last data from the memory	Free of charge	Software
DS-1302	2V	300mA	+/- 40ppm	In reset condition external clock continues keeping time	2$	Hardware
DS-3231	3.3V	300uA	+/-2ppm	In reset condition external clock continues keeping time	4.50$	Hardware

Selected RTC : Arduino Crystal Oscillator

•Does not draw any current.

•Free of charge.

•Easy to program.

•Does not add external weight and occupy more space since it is integrated in Arduino.

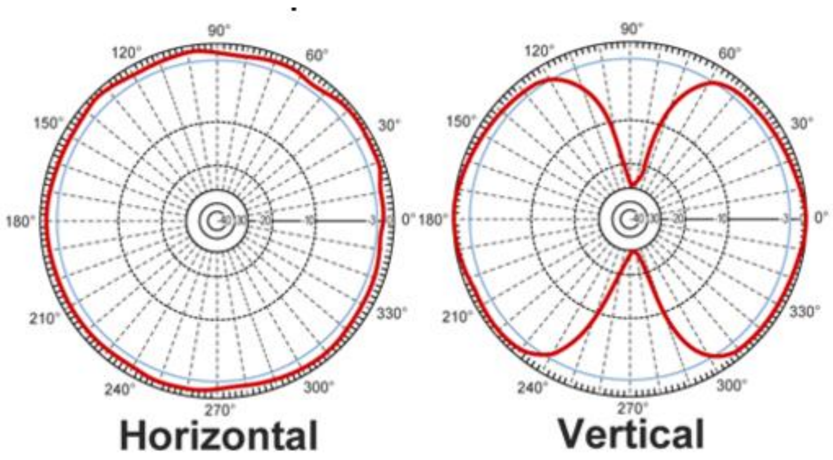
Probe Antenna Trade & Selection

Model	Connection Type	Frequency	Direction	Gain	Price
TL-ANT2405CL	SMA	2.4Ghz	Omni-directional	5 dBi	10$
TL-ANT2409CL	RP-SMA	2.4 Ghz	Omni-directional	9 dBi	18$

Selected Antenna : TL-ANT2405CL

•SMA connector is compatible with Xbee.
•Fits in the probe thanks to smaller size.
•Low cost.
•Easy setup with assembly kits.
•Resistant to weather conditions.

Radiation patterns of selected antenna



Probe Radio Configuration (1/2)

•XBee Pro series 2B is used as transreceiver for probe and ground station.

•NETID/PANID numbers of XBees are adjusted as 4404, which is our assigned team number.

•Configuration of both XBees is established with X-CTU software.

•1 Hz is adjusted as transmission rate of XBee in probe.

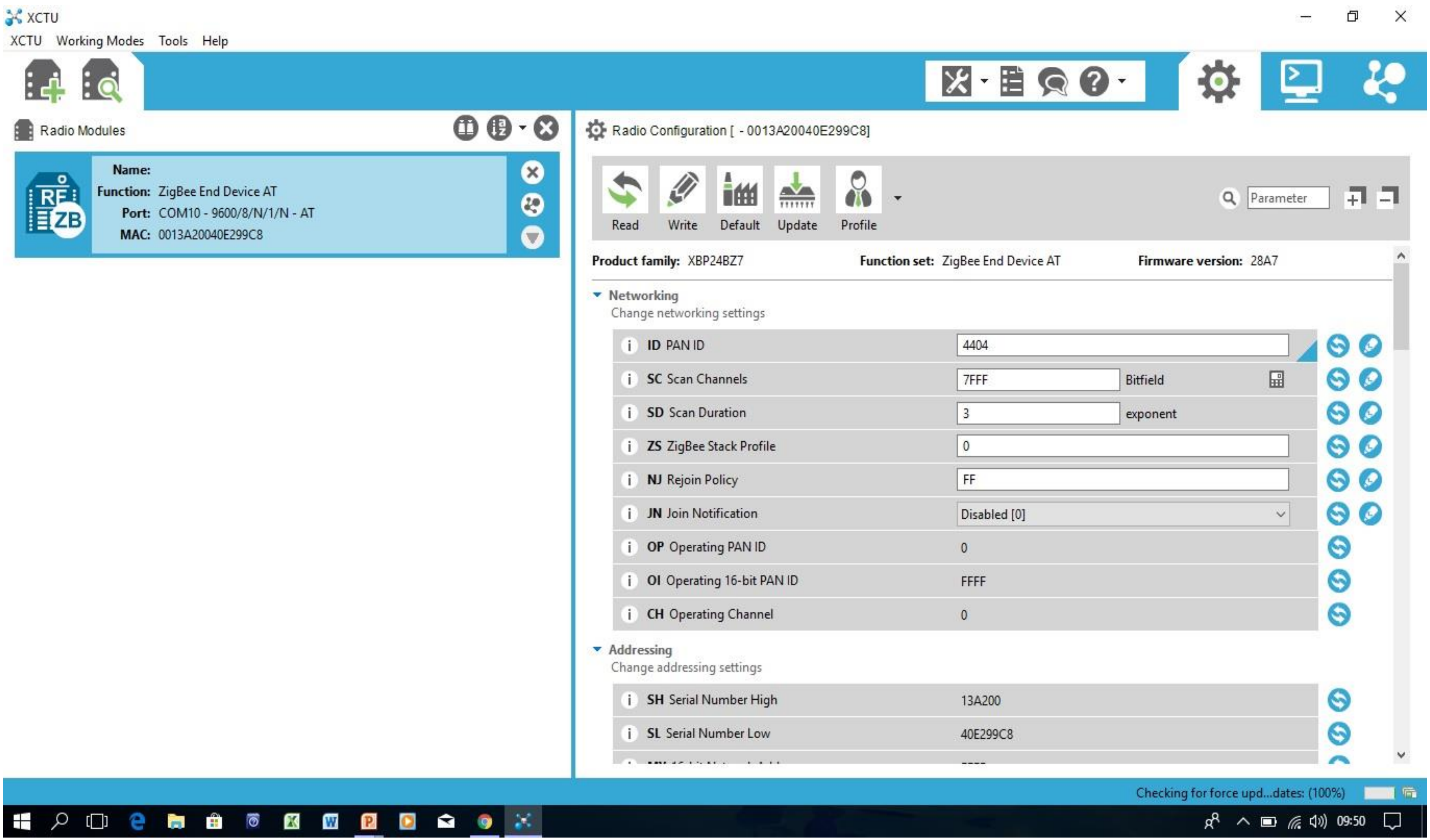
•Communication between probe and ground station is provided by using two same model XBees which are set to unicast mode.

•The XBee in the probe is adjusted as an endpoint ,and the XBee at the ground station is adjusted as a coordinator.

•The XBee used as a endpoint transmits the telemetry data to coordinator XBee.

•The XBee used as a coordinator receives the telemetry data from endpoint XBee.

Probe Radio Configuration (2/2)



Demonstration of our endpoint XBee's NETID/PANID which is adjusted as 4404.

Probe Telemetry Format (1/2)

<TEAM ID> is the assigned team identification.
<MISSION TIME> is the time since initial power up in seconds.
<PACKET COUNT> is the count of transmitted packets, which is to be maintained through processor reset.
<ALTITUDE> is the altitude with one meter resolution.
<PRESSURE> is the measurement of atmospheric pressure.
<TEMP> is the sensed temperature in degrees C with one degree resolution.
<VOLTAGE> is the voltage of the CanSat power bus.

<GPS TIME> is the time generated by the GPS receiver

<GPS LATITUDE> is the latitude generated by the GPS receiver.

<GPS LONGITUDE> is the longitude generated by the GPS receiver.

<GPS ALTITUDE> is the altitude generated by the GPS receiver.

<GPS SATS> is the number of GPS satellites being tracked by the GPS receiver.

<TILT X> Tilt sensor X axis value.

<TILT Y> Tilt sensor Y axis value.

<TILT Z> Tilt sensor Z axis value.

<SOFTWARE STATE> is the operating state of the software. (boot, idle, launch detect, deploy, etc.)

<ROLL> is degree of rotation around the front-to-back axis of probe

<PITCH> is degree of rotation around the side-to-side axis of probe

<YAW> is degree of rotation around the vertical axis of probe

<CAMERA STATE> is the situation of the camera whether it records or not after the second 300 meter.If it record state is ‘ON’, if it is not record state is ‘OFF’.

Probe Telemetry Format (2/2)

•**Data Rate of Packets**

- Burst transmission is used to transmit data.

- Data is transmitted with 1 Hz to the ground station.

•**Data Format**

<TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>, <PRESSURE>, <TEMP>,<VOLTAGE>,<GPS TIME>,<GPS LATITUDE><GPS LONGITUDE><GPS ALTITUDE>,<GPS SATS>,<TILT X>,<TILT Y>,<TILT Z>,<SOFTWARE STATE>,

<ROLL>,<PITCH>,<YAW>,<CAMERA STATE>

Example Telemetry: <4404>,<00050>,<50>,<62>,<2133.145>,<35.7>,<17>, <17:47:36.0>,<4059.5676N>,<2850.7741E><65.60>,<4>,<1.00>,<0.00>,<0.00>,<ASCEND>, <93.81>,<-8.38>,<10.86>,<OFF>

Example telemetry given above is provided with system prototype.

Example telemetry matches with competition guide requirements.

Telemetry is saved on the ground station computer as

CANSAT2018_TLM_4404_APISARGE.csv .

•**Note:**

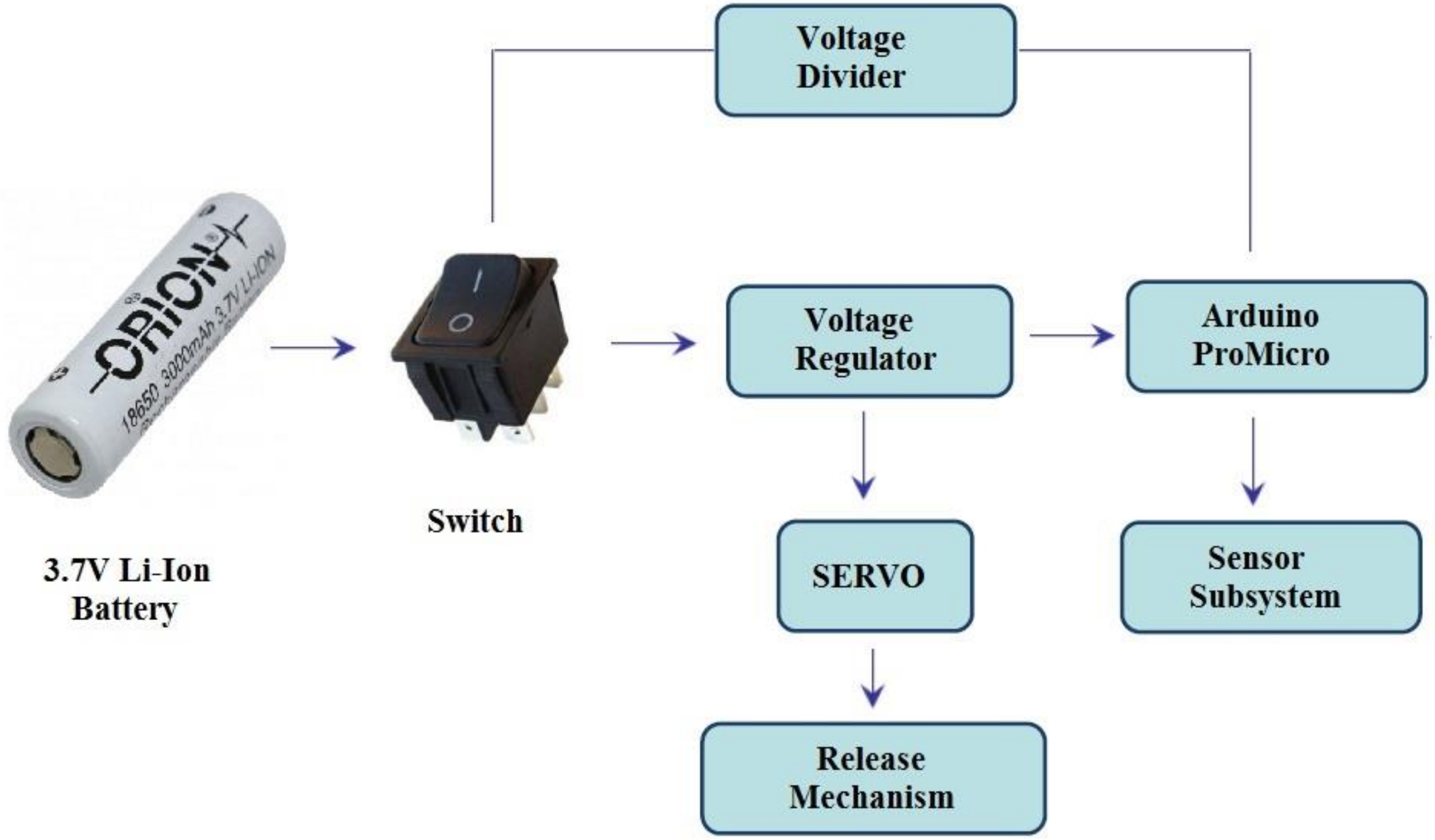
We calculate <ROLL>,<PITCH> and <YAW> telemetries by using MPU6050 gyroscope. Thus, we created an algorithm that checking tilt condition according to these telemetry values.

Electrical Power Subsystem (EPS) Design

Burak Berkay KAYA

EPS Overview (1/2)

Component	Purpose of the Component
Battery	In order to provide the required electricity to operate electronic system.
Switch	Makes the connection between battery and electronic system to supply or interrupt the power.
Voltage Regulator	To step up or down the voltage to supply appropriate voltages to sensors and processor.
Voltage Divider	To measure the voltage level from one of the processor’s analog pins.
Buzzer	Makes noise after landing and helps recovery team to find easily.


Voltage Divider
Voltage Regulator
Arduino ProMicro
SERVO
Sensor Subsystem
Release Mechanism
Switch
3.7V Li-Ion Battery
ORION
18650 3000mAh 3.7V LI-ION

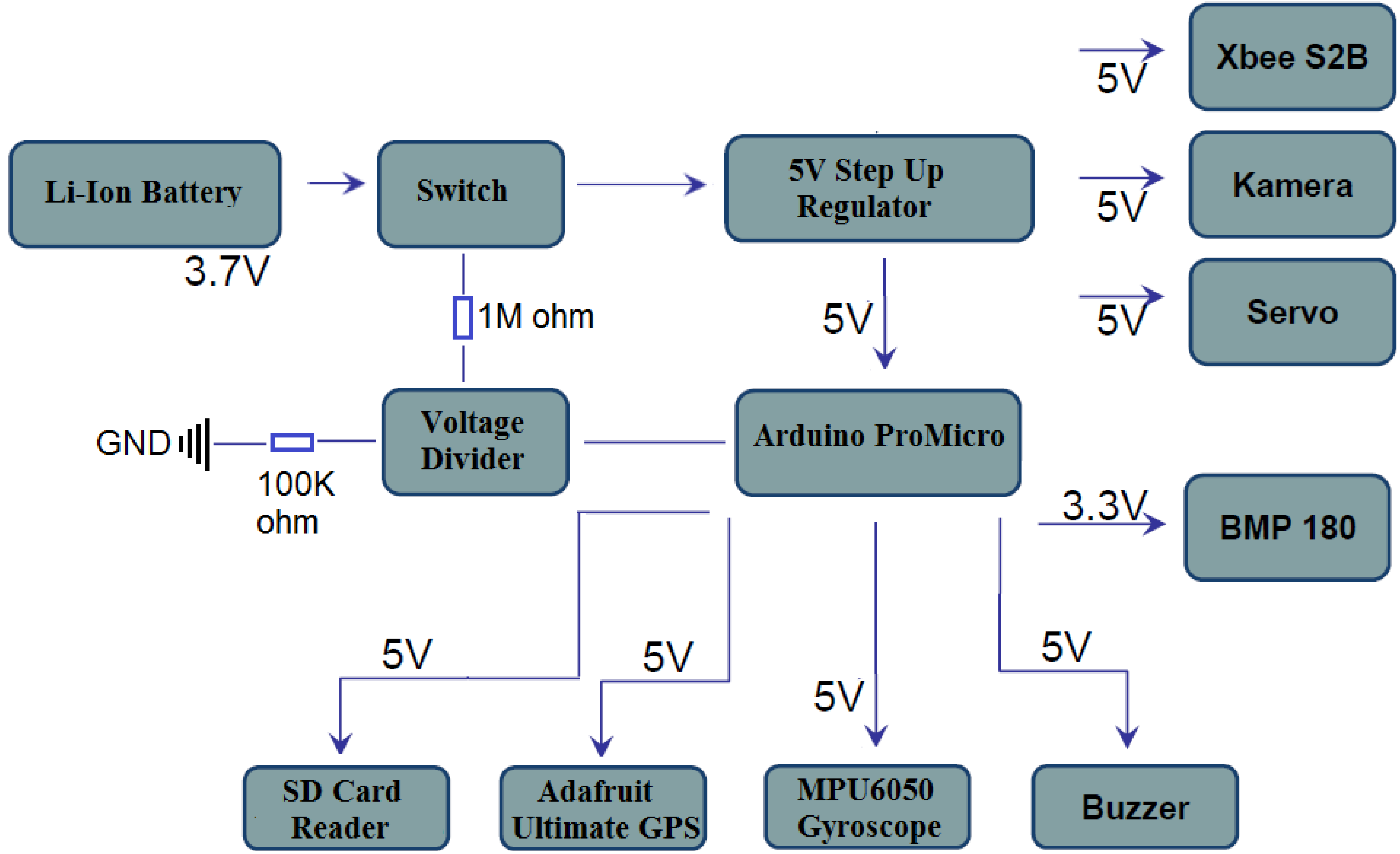
EPS Requirements (1/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
EPS-1	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time.	CReq	BR-25	SS-1	Very High	✓	✓		
EPS-2	The probe must include an easily accessible switch.	CReq	BR-41	Sy-23	Very High		✓		
EPS-3	The probe must include a power indicator such as an LED or sound generating device.	CReq	BR-42		High	✓	✓		
EPS-4	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	CReq	BR-45	FSW-5	High		✓	✓	
EPS-5	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.	CReq	BR-46		Very High		✓		

EPS Requirements (2/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
EPS-6	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	CReq	BR-47		Very High	✓	✓		
EPS-7	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	CReq	BR-48		Very High		✓		

Probe Electrical Block Diagram



- Power will be controlled by the switch without requiring disassembly since it will be placed somewhere easily accessible from exterior.
- To verify power is on, Arduino will activate buzzer for half a second during its setup.

Probe Power Trade & Selection

Model	Type	Voltage Value	Capacity	Diameter	Mass	Price
Panasonic MN1500-BP2-LR6	Alkaline	1.5V	2500 mAh	14.5 mm	48 g	4.75$
Samsung 18650	Li-Ion	3.7V	2600 mAh	18.4 mm	47 g	8$
OEM 16340	Li-Ion	3.7V	1400 mAh	16 mm	18.5 g	4$

Selected Battery: OEM 16340

- It has a lower mass than other trades.
- Its price is low.
- Its capacity is enough for our requirement.
- It takes less place in probe.
- Single battery configuration will be used.

Probe Power Budget (1/2)

Component	Current(mA)	Voltage(V)	Power (mW)	Duty Cycle(%)	Source/ Uncertainity
BMP180	0.65	3.3	2.1	100	Datasheet
Arduino ProMicro	30.5	5	152.5	100	Datasheet/ Estimate
Buzzer	25	5	125	100	Datasheet
Xbee S2B(Transmit)	205	3.3	676.5	95	Datasheet
Xbee S2B(Receive)	47	3.3	155.1	5	Datasheet
SD Card Reader	150	5	158.4	100	Datasheet/ Estimate
Turbowing 700 TVL Camera	180	5	25	20	Datasheet
Adafruit Ultimate GPS	25	5	125	100	Datasheet

Probe Power Budget (2/2)

Component	Current(mA)	Voltage(V)	Power (mW)	Duty Cycle(%)	Source/ Uncertainity
MPU6050 Gyroscope	3.9	5	19.5	100	Datasheet
2 x Mini Servo	2x100	5	2x500	5	Datasheet
TOTAL	867.05mAh		2439.1 mWh		

Total Current Consumed	Total Power Consumed	Available Capacity (mAh)	Margin
867.05 mAh	2439.1 mWh	1400 mAh	532.95 mAh

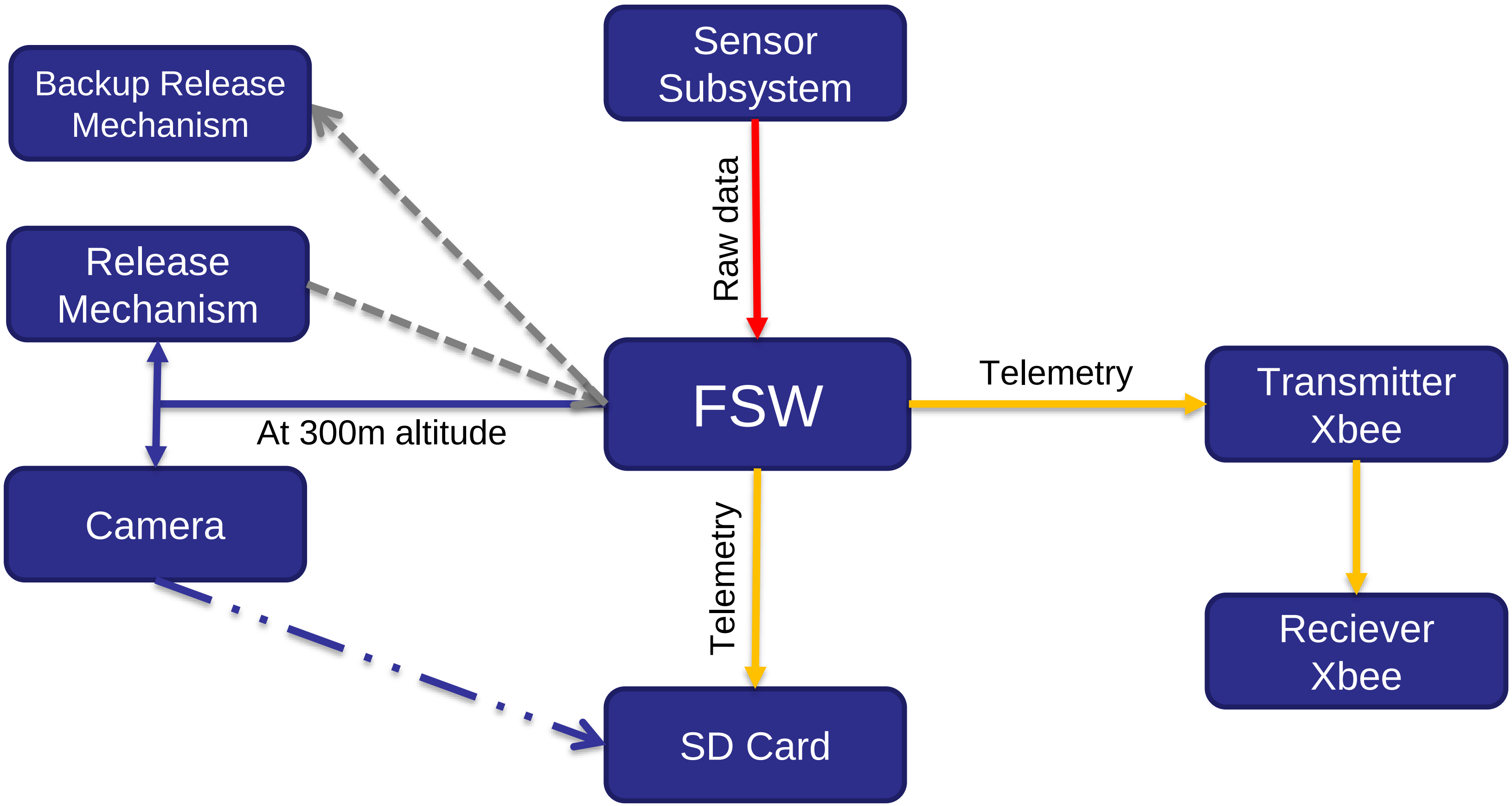
Flight Software (FSW) Design

Furkan CETIN

FSW Overview (1/2)

- **Programming Language**
  - C/C++
- **Development Environments**
  - Arduino IDE
- **FSW Tasks Summary**
  - Read raw data from sensors and convert them to physical values.
  - Create telemetry according to required format, store it in the SD card and sent to the ground station.
  - Release the heat shield and deploy the parachute at an altitude of 300 meters.
  - If the initial release attempt fails, initiate backup release mechanism.
  - As bonus objective, capture the release of the heat shield.

FSW Overview (2/2)



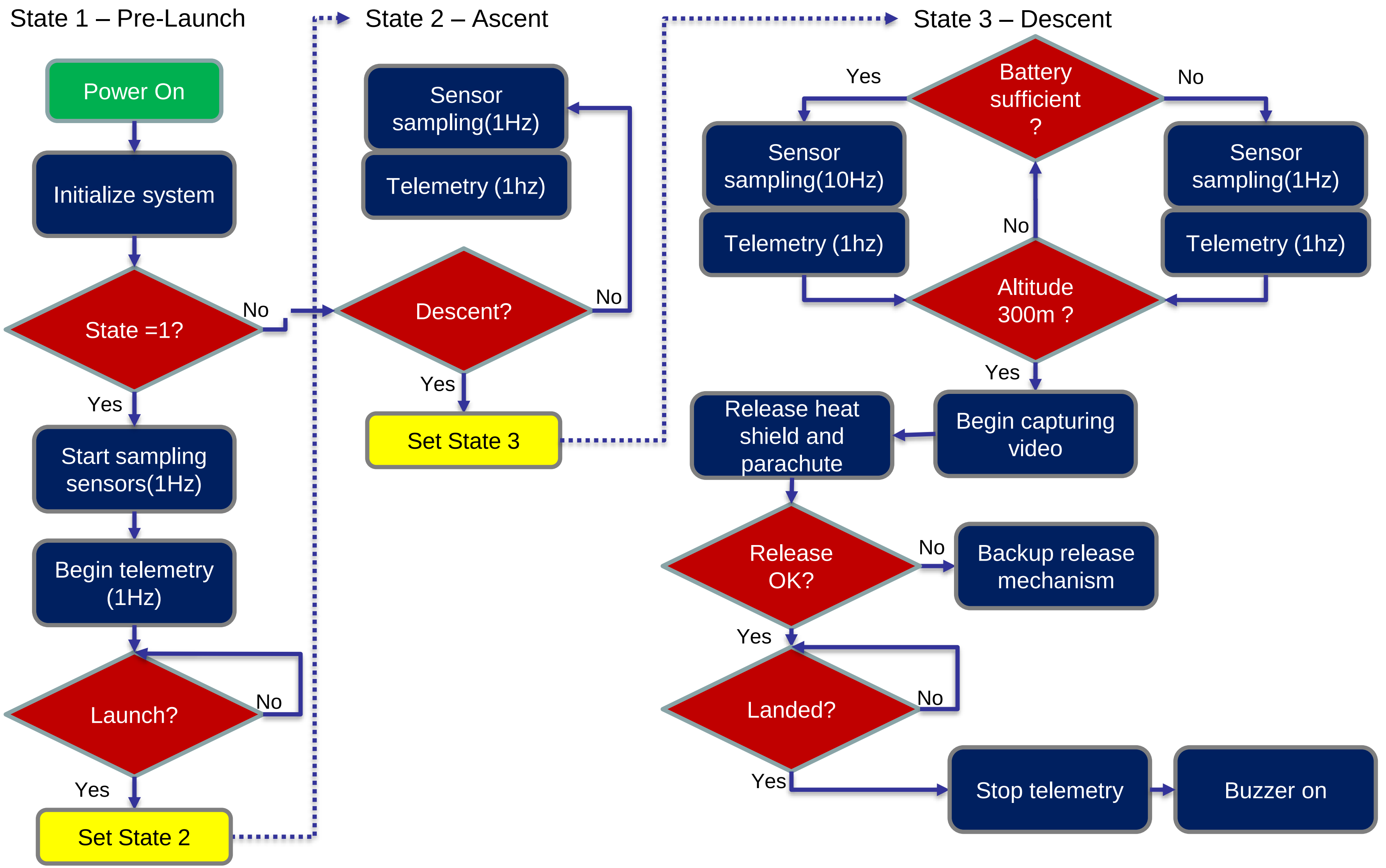
FSW Requirements (1/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
FSW-1	The CanSat, probe with heat shield attached shall deploy from the rocket payload section.	CReq	BR-13		Very High		√		√
FSW-2	The aero-braking heat shield shall be released from the probe at 300 meters.	CReq	BR-14		Very High	√	√		√
FSW-3	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time.	CReq	BR-25		Very High	√	√		√
FSW-4	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.	CReq	BR-39		Very High		√	√	√
FSW-5	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	CReq	BR-45		Very High		√		√
FSW-6	A tilt sensor shall be used to verify the stability of the probe during descent with the heat shield deployed and be part of the telemetry.	CReq	BR-49		Very High	√	√		

FSW Requirements (2/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
FSW-7	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.	CReq	BR-26		Very High	✓		✓	✓
FSW-8	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	CReq	BR-27		Very High		✓	✓	✓
FSW-9	Store the telemetry data in an external SD Card.	Data Reliability			Very High	✓	✓		✓
FSW-10	Capture the release of the heat shield and the ground during the last 300 meters of descent	Bonus Objective			High		✓		✓

Probe FSW State Diagram(1/2)



Probe FSW State Diagram(2/2)

- **Data Storage:**
  - All sampled sensor readings will be written to SD card.
  - Video will be saved to the SD card.
- **Power Management**
  - While in descent state, if battery voltage is sufficient, sampling rate of sensors will be increased to 10 Hz. Main goal of this adjustment is to minimize errors.
  - Telemetry frequency will remain as 1 Hz during whole flight.
- **State Recovery in case of Restart**
  - Flight state values will be saved to EEPROM. Therefore, if a restart occurs, last state will be known by the processor.
  - Additionally, values for packet count and mission time will be stored in EEPROM in order to maintain them in case of a processor reset.

Prototyping and prototyping environments

-Power, communication and sensor subsystems are designed in accordance with the competition and system requirements.

-Each sensor is tested separately on breadboard and ensured operating properly.

-An electronic system prototype which includes all sensors is created on breadboard and ensured that all sensors and microcontroller are working in accordance with each other.

-A PCB will be designed with the results obtained from the prototype, and it will be tested further.

Software Subsystem Development

-Available libraries for sensors are analyzed and modified to satisfy system and competition requirements.

-Arduino serial monitor and MATLAB is used to debug the code and visualize sensor outputs.

-Each sensor is individually tested and ensured working as intended.

-A code utilizing all the sensors on the prototype is written, tested, and ensured all sensors and controller working properly together.

Software Development Plan (2/3)

Software Development Schedule		
Task	**Status**	**Planned Completion**
Selection of sensors	Completed	-
Individual sensor tests	Completed	-
Library tests and modification	Completed	-
Test of prototype with all sensors active	Completed	-
Sensor output analysis using MATLAB	Completed	-
Wired serial communication with ground station prototype	Completed	-
PCB design and tests	In progress	Late February
EEPROM reboot tests for packet count and flight state	Not started	Early February
Wireless communication tests and verification of data health	Not started	Mid February
Ensure camera recording does not interrupt other processes.	Not started	Early March
Calibrate the release command altitude for heat shield to be released exactly at 300 meters.	Not started	Early March
Testing and improvement of power consumption	Not started	Mid March

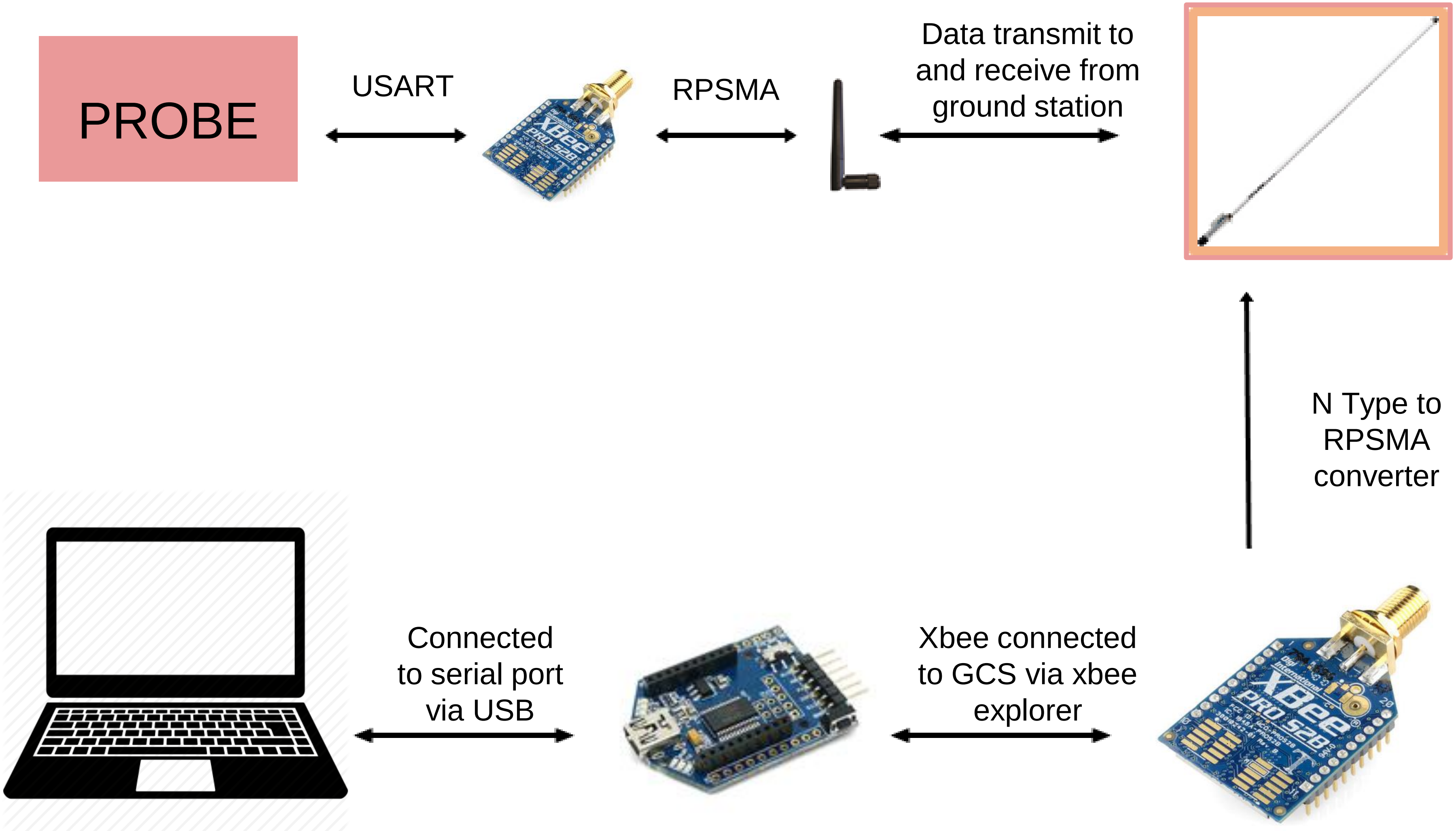
Software Development Plan (3/3)

- **Test methodology**
  - Software development and component assemblies were conducted in faculty laboratories.
  - Temperature sensor calibrated by using external hardware from faculty.
  - Pressure sensor is calibrated and verified at sea level and a location close to the airport. Therefore from METAR (Meteorological Terminal Air Report), we knew the exact sea level pressure.
  - Wireless communication tests are planned to be conducted between two coasts of Bosphorus. Distance varies between 760 meters and 3.5 kilometers, which makes it a very close competition environment and also enough for determining the limits of the system.
  - Further tests will be conducted by free falls from faculty building and using a quadcopter built by our team
- **Development team**
  - Furkan Çetin
  - Burak Berkay Kaya

Ground Control System (GCS) Design

Cansu YIKILMAZ

GCS Overview

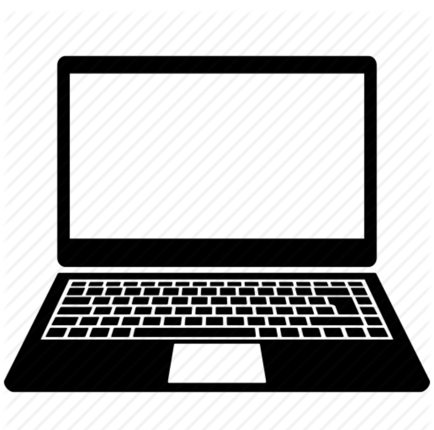


GCS Requirements

ID	Requirement	Rationale	Parent	Priority	VM			
					A	I	T	D
GCS-1	Each team shall develop their own ground station	CReq	BR-32	Very High		✓		✓
GCS-2	All telemetry shall be displayed in real time during descent.	CReq	BR-33	Very High	✓	✓	✓	✓
GCS-3	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	CReq.	BR-34	Very High	✓	✓	✓	✓
GCS-4	Teams shall plot data in real time during flight.	CReq	BR-35	Very High	✓	✓	✓	✓
GCS-5	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand held antenna.	CReq	BR-36	Very High		✓		✓
GCS-6	The ground station must be portable so the team can be positioned at the 9 ground station operation site along the flight line. AC power will not be available at the ground station operation site.	Creq	BR-37	Very High		✓		✓

Antenna connected to Xbee with N- type to RPSMA connector

Xbee module will be connected to the explorer with 2mm header



Explorer will be connected Laptop via usb cable and communicate with serial connection

- The GCS Laptop can operate 2.5 hours with battery.
- On the field, there will be an external laptop cooling fan to prevent overheating and the cooler has it's own battery.
- On Windows OS, the auto update function will be disabled on the windows update center before the launch.

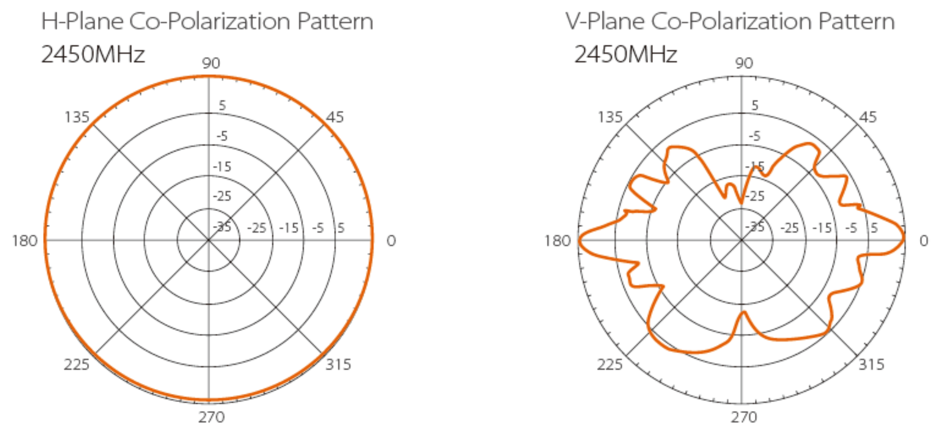
GCS Antenna Trade & Selection (1/3)

Model	Connection Type	Frequency	Direction	Gain	Price
2415D	N-Type	2.4 Ghz	Omni - Directional	15 dBi	66$
2414A	SMA	2.4 Ghz	Directional	14 dBi	98.21$

Selected Antenna : 2415D

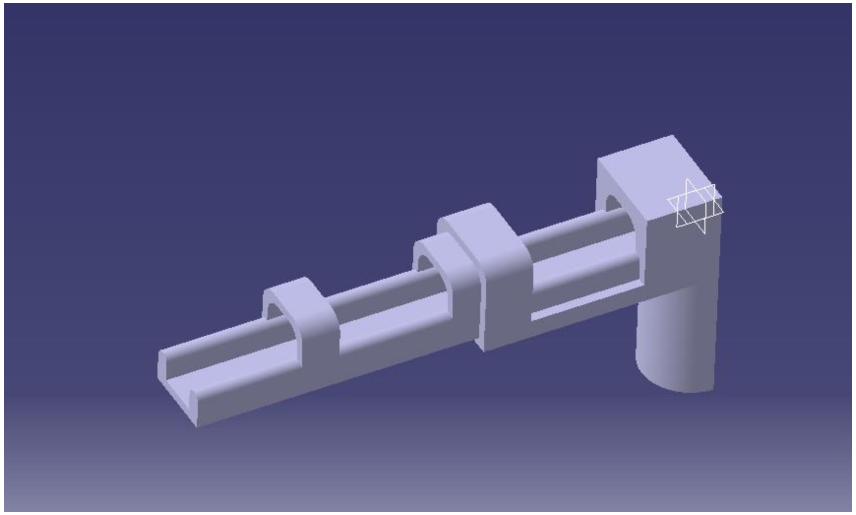
- Omni – Directional
- Better radiation pattern
- Better gain
- Cost effective
- Light

Radiation Patterns:



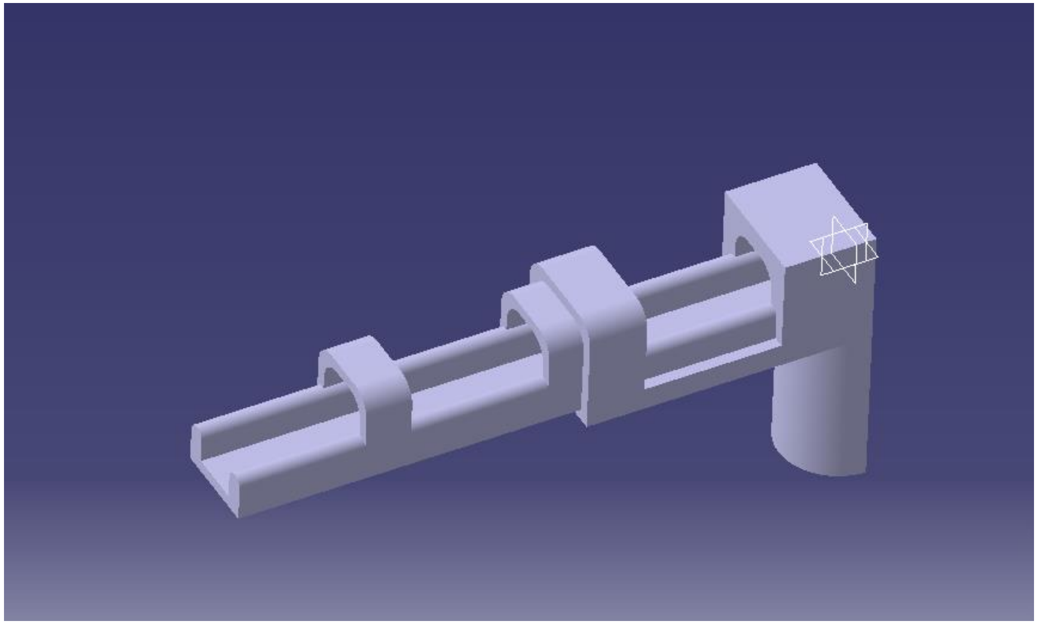
Antenna Mounting Design Selection

Model	Type	Weight	Material	Price
Table Top	3 Foot	1.8 kg	Metal and Plastic	23$
Hand Held	Hand held	1 kg	3D Printed ABS	6$



Selected Design: Hand Held

- Cost effective.
- Easy to use.
- Lightweight.
- Small and can be carried easily.



GCS Software (1/4)

Telemetry Prototype

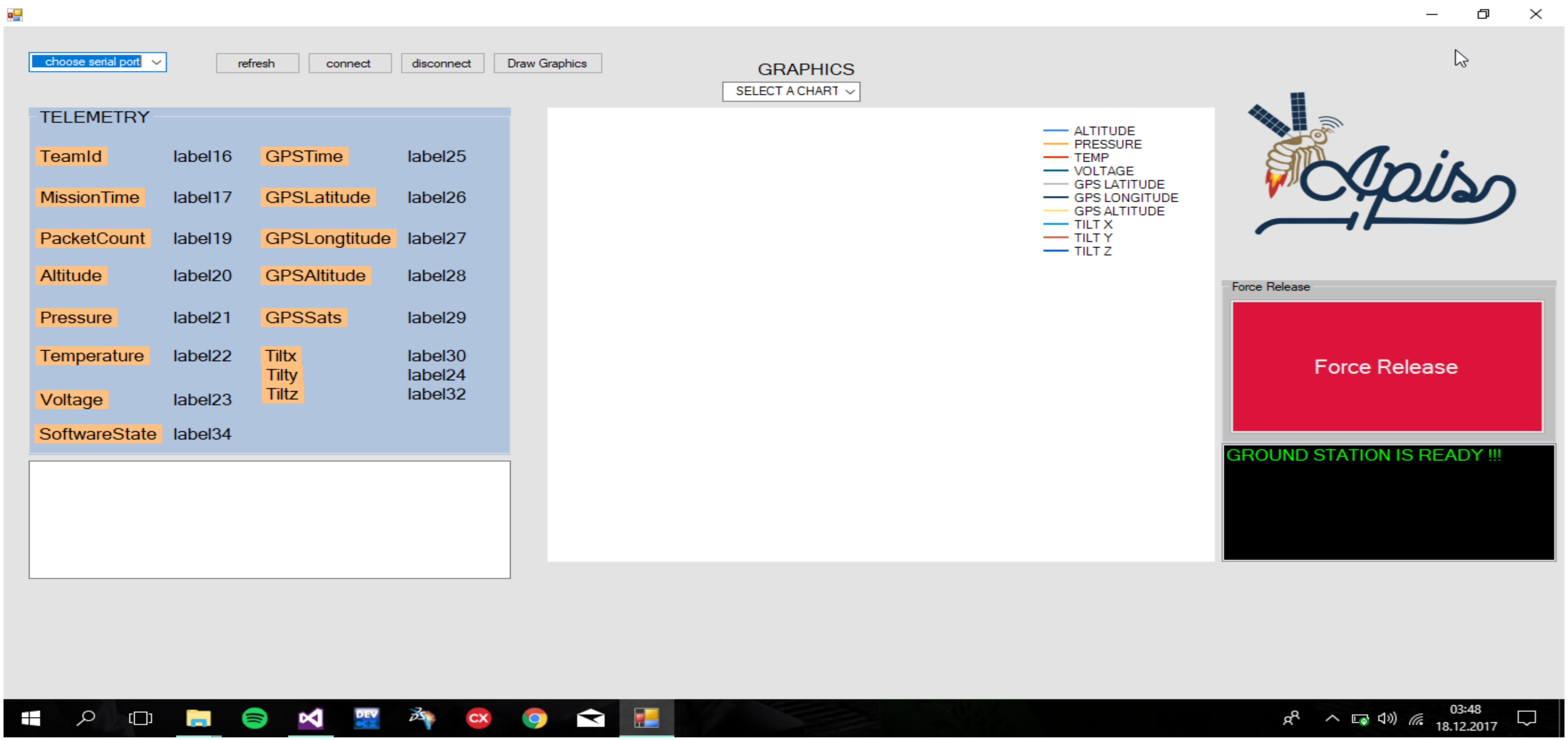
- <TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>, <PRESSURE>,<TEMP>, <VOLTAGE>,<GPS TIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<TILT X>,<TILT Y>,<TILT Z>,<SOFTWARE STATE>,<ROLL>,<PITCH>,<YAW>,<CAMERA STATE>

Commercial Software Used

- Visual Studio 2015 Community
- XCTU (Xbee Program Software)
- MATLAB 2016a Student Version

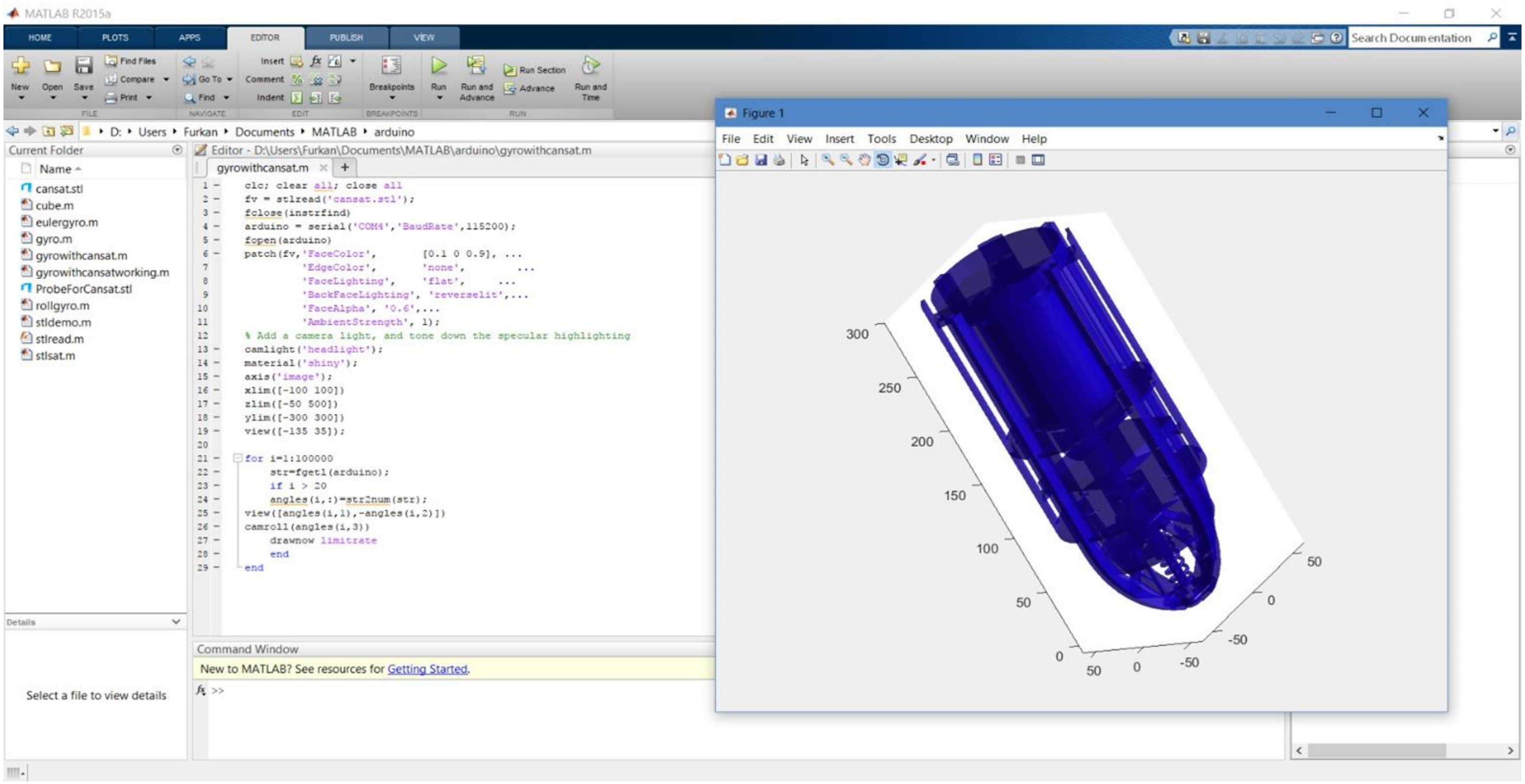
GCS Software (2/4)

Commanding and Plotting Software Design



- Received data will be displayed and plotted in real time by Visual Studio.

GYROSCOPE ORIENTATION (MATLAB)



- Orientation of the probe will be shown in the MATLAB.

GCS Software (4/4)

- Data is saved as .CSV format. In CSV format, data is separated by comma.
- Command software and interface and plotting software are programmed with Visual Studio using C# program language.
- Data is saved by the GCS program created by Visual Studio C#, after serial connection is established, each data from serial port should be saved.
- All received data is recorded in real time and plotted by GCS software.
- Telemetry data and plots will be displayed in engineering units (meters, meters/sec, Celsius, etc.).
- CSV File name should be “Flight_4404.csv”
- All data is delivered to jury via Flash Memory Stick.

GCS Bonus Wind Sensor

- **Camera task is chosen as bonus mission.**

CanSat Integration and Test

Ozen HALIC

CanSat Integration and Test Overview (1/2)

Mechanical Subsystem Tests

-Vibration
-Servo motor calibration
-Spring system Test
-Unfolding Mechanism Test

→ Successful Heat-Shield Opening

-Flow test over heat-shield
-Aerodynamic tests of probe
-Descent velocity test
-Egg Protection

→ Successful Flying

(Successful Heat-Shield Opening + Successful Flying) → Successful Operation

-Total mass (Probe+Heat-Shield) Test (500g)

Test plan:
1)Subsystem tests are to be done.
2)All subsystems are integrated and required tests are applied.
3)Appropriate environment conditions are selected for testing.

Sensor Subsystem Tests
-Sensor calibration test

CDH Subsystem Tests
-Microcontroller serial communication test
-Real time clock time keeping test

FSW Subsystem Tests
-Separation mechanism algorithm tests

Communication Tests
-Xbee range Test
-Healthy data transfer test

Descent Tests
-Separation mechanism tests
-Velocity tests

EPS Subsystem Tests
-Voltage and current leakage test

CanSat Integration and Test Overview (2/2)

•The subsystems are going to be tested individually, after that the whole system will be integrated and following tests will be performed.

- **<u>Probe Tests:</u>**

Flight and unfolding heat-shield mechanism tests will be done with actual mass and whole electronic system integrated. Egg container's protection is to be tested.

- **<u>Communication Tests:</u>**

Xbees are integrated in probe and tests covering signal quality and signal disruption are planned to be done.

- **<u>Heat-Shield Mechanism Tests:</u>**

Spring and servo motor integrated to probe suitable sections and tested whether heat-shield is folding and unfolding successfully.

- **<u>Heat-Shield Deployment Tests:</u>**

When the probe is reached 300m, the heat-shield will be deployed from the payload with servo.

Environment conditions are selected in accordance with subsystem test requirements.

•University laboratories are frequently used
•Wind tunnels of our faculty is used for flow tests in order to notice imperfections in heat shield easily.

Subsystem Level Testing Plan (1/2)

Sensors

- Data obtained from sensors must be accurate.
- Accuracy of each sensor is calibrated and verified.
- Sea level conditions is reference point for calibration process.
- Calibration will continue until most accurate data is obtained from each sensor.

CDH

- Serial communication of each sensor with microcontroller is ensured to be correct.
- Data storage is tested with SD card breakout board on breadboard level.
- CDH system is tested at breadboard and on PCB.

EPS

- Multimeter measurements ensured that calculated voltage and current level is achieved in actual model.
- Current leakage problems are detected and solved.

Radio Communication

- Xbee configurations and signal level tests are actualized with X-CTU software.
- Transmission with Xbees is tested between two coasts of Bosphorus to see whether communication is disrupted or not.

Subsystem Level Testing Plan (2/2)

FSW

- Sensor operating codes are to be tested to find most energy efficient mode.
- Time keeping algorithm is to be tested in case of microcontroller reset.
- Data verification is tested with sea level standard and analog high accuracy sensors.

Mechanical

- Rigidity test of probe and heat-shield are calculated using computer program ANSYS.
- Practical rigidity and buckling tests are to be actualized in composite lab.
- Flow tests over heat-shield is to be calculated using FLUENT.
- Vibration and temperature test are planned for future action.
- Unfolding and separation mechanism will be tested.
- Mechanical requirements must be met after all tests are completed.

Descent Control

- Servo calibration with altitude sensor is tested.
- Maximum torque that servo can handle is tested with dynamometer.
- Flight tests with various altitude from drone and rocket.
- Heat-shield separation test is done.
- Heat shield operations must be accomplished and tumble must not occur

ANSYS: Engineering simulation software
FLUENT: Software used to understand fluid motion for 3D models

Integrated Level Functional Test Plan (1/2)

Descent Testing

•According to design of probe weighs as much as calculated mass with fixed(non-folding) heat-shield is tested from various altitudes and results are evaluated for stabile flight.

•Center of gravity and aerodynamic center of probe is to be determined.

•Probe test with folding heat-shield and including mass as much as whole system is tested from 200m with drone.

•Egg protection will be tested that dropping the container from different heights with drone to achieve different velocities.

•Integration of electronic system that causes no center of gravity shifting.

•Testing of whole system with configuration according to competition requirements; besides, calculating velocity at the mission is planned.

Communication

•Communication test with Xbees one inside the probe is to be tested.

•Testing whether probe skeleton decreases signal quality.

•Two coasts of Bosphorus is selected for communication test which offers us range of 1.6km.

•How much signal quality loss will be observed in case of signal disruption with blocking layers.

Integrated Level Functional Test Plan (2/2)

Mechanism Test

•Performance of servo that is going to unfold and separate the mechanism of heat-shield is observed.

• Performance of servo that is going to release parachute will be observed.

•Tension created by spring is observed and force change with elastic deformation length is calculated.

•Time required for opening of heat-shield is observed.

•Each mechanism must successfully complete its task.

Deployment Test

•Separation with servo motor is to be tested.

•Ground impact (Drop) tests and determination of damage occurred when dropped from certain height.

•Heat-shield separation from the payload smoothly is to be tested taking account of air resistance.

•Servo motor maximum torque tests is to be done to determine maximum torque it can handle.

•Altitude sensor calibration with servo motor using elevator.

•Parachute ropes tension test to see whether ropes are attached securely.

Environmental Test Plan (1/2)

Drop Test

- Attach the payload to the quadcopter.
- Quadcopter rises until the altitude reach 700 meter.
- Drop the payload and see if probe and heat-shield separate from each other.
- Check out both probe and heat-shield if they survive after free-fall.
- Check out the egg whether is broken or not.
- Fall test is done on the roof of our faculty.

Thermal Test

- Thermal tests are planned to be done at university laboratory to see whether mechanical and electronic components can withstand at extreme temperatures.
- Set timing equal to time that payload's stay in the air.
- Check out that heat-shield can endure specific temperatures.

Environmental Test Plan (2/2)

Vibration Test

- Structural integrity, probe strength and fatigue will be determined with vibration test.
- Mount the payload to the machine.
- The sander adjusted to its max. power.
- After the power up, sander is turned off during 2 seconds of periods.
- Repeat the process for 1 minute.
- Check out if there is any damage on payload.

Communication Test

- Laboratory conditions and two coasts of Bosphorus are chosen to do communication test.
- Payload and GCS will be put the different sides of Bosphorus.
- Xbee wil be tested whether the range is enough for the mission or not.

Mission Operations & Analysis

Aykut UCTEPE

Overview of Mission Sequence of Events (1/2)

Arrival	Pre-launch	Deployment
• Team will arrive to launch site. • Integrity of CanSat will be checked for damage. • GCS and antenna will be prepared.	• Final corrections will be done for probe including separation mechanism and sensor subsystem test. • Weigh of CanSat will be measured for 500 gr . • Fit check will be performed by crew. • Probe will be stored until launch.	• CanSat will be taken and switched on before installing to rocket. • Data transfer with GCS will be confirmed. • Rocket will be delivered to staff member.
Damage control: Ozen-Altug	Mechanics: Oguzhan-Kemal Electronics: Berkay-Furkan	Mission Control Officer: Aykut

Overview of Mission Sequence of Events (2/2)

Launch
- Rocket will launch after Mission Control Officer completes flight procedures.
- Probe will free itself at apogee and start descent with heat shield until 300m.

GCS officer: Cansu

Airborne
- At 300 meters, heat shield separation mechanism will be activated and parachute will be decelerate probe to 5 m/s.
- Probe will collect telemetry data and transfer to the GCS during descent.

CanSat: Ismail-Kemal

Recovery
- Probe lands with parachute while protecting hen's egg.
- With GPS telemetry and initialized audio beacon recovery team locate the CanSat
- Recovery team will start searching when all launches are completed and area is safe.

Heat Shield Oguzhan-Ozen

Analysis
- Transmitted data will be analyzed.
- Flight data will be delivered to jury.
- Moving on to PFR.

Mission Operations Manual Development Plan

Mission Operation Manual is combination of mission guide and also required to complete competition successfully.

Mission Operations Manual

CONFIGURE THE GROUND STATION → PREPARE THE CANSAT FOR LAUNCH → INTAGRATION OF CANSAT TO ROKET → LAUNCH PROCEDURE → REMOVAL PROCEDURE → RECOVERY OF PROBE AND HEATSHIELD

Mission operation manual may change as a result of our testing and rehearsals until the launch day.

Main Objectives:

- To make sure each member of Apis Ar-Ge comprehend competition, safety rules and their responsibilities.
- To complete competition safely.

CanSat Location and Recovery

Heat Shield Recovery

The heat shield will have bright color.

Heat shield will free fall after separation, GPS data at 300 meters will provide approximate location to recovery crew.

Recovery crew will find heat shield with the help of its bright color and GPS data .

CanSat Recovery

The CanSat will be painted bright and visible color.

The CanSat will initialize audio beacon after landing.

GPS sensor will provide information about landing location.

Recovery team will detect CanSat by observating its color, hearing buzzer and analyzing last GPS coordinates.

*Team name,team leader's phone number and team's e–mail address will be labeling on Cansat.

Requirements Compliance

Burcu GOCEN

The majority of the requirements are currently complied.

There is not any requirement that does not comply with our design.

➢ <u>Further Improvement Stages</u>

- The table filled according to requirement based compliance help us to see which subsystem is needed to be developed.

-Mechanical system is theoretically completed but practical tests has not been done yet. Heat Shield margins,heat shield opening system is to be tested practically.

-Structural tests including impact, vibration and thermal must be done to check whether integrated system withstands.

-The whole electronic systems must be integrated and communication test shall be done inside the probe.

-Shock survivability tests for probe and egg protection mechanism is to be done via drop tests with various scenarios

-Aerodynamic results obtained with computer based calculations shall be actualized with free fall tests.

-Heat shield separation test should be done frequently since it is our system priority.

Requirements Compliance (1/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
01	Total mass of the CanSat (probe) shall be 500 grams +/- 10 grams.	Comply	p. 77-78-79	
02	The aero-braking heat shield shall be used to protect the probe while in the rocket only and when deployed from the rocket. It shall envelope/shield the whole sides of the probe when in the stowed configuration in the rocket. The rear end of the probe can be open..	Comply	p.14	
03	The heat shield must not have any openings.	Comply	p.68	
04	The probe must maintain its heat shield orientation in the direction of descent.	Comply	p.34	
05	The probe shall not tumble during any portion of descent. Tumbling is rotating end-over-end. .	Partial	p.34	Theoretically complies but not yet tested.
06	The probe with the aero-braking heat shield shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Comply	p.19-20	
07	The probe shall hold a large hen's egg and protect it from damage from launch until landing.	Comply	p. 72	
08	The probe shall accommodate a large hen’s egg with a mass ranging from 54 grams to 68 grams and a diameter of up to 50mm and length up to 70mm. .	Comply	p.73	

Requirements Compliance (2/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
09	The aero-braking heat shield shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	**Comply**	p.68	
10	The aero-braking heat shield shall be a florescent color; pink or orange.	**Comply**		BR-10
11	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	**Comply**	p. 61-62-63	
12	The rocket airframe shall not be used as part of the CanSat operations	**Comply**	p. 61-62-63	.
13	The CanSat, probe with heat shield attached shall deploy from the rocket payload section.	**Comply**		
14	The aero-braking heat shield shall be released from the probe at 300 meters.	**Partial**	p. 107	Theoretically complies but not yet tested.
15	The probe shall deploy a parachute at 300 meters	**Partial**	p. 107	Theoretically complies but not yet tested.

Requirements Compliance (3/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
16	All descent control device attachment components (aero-braking heat shield and parachute) shall survive 30 Gs of shock.	**Partial**		Theoretically complies but not yet tested.
17	All descent control devices (aero-braking heat shield and parachute) shall survive 30 Gs of shock.	**Partial**		Theoretically complies but not yet tested.
18	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	**Comply**	p.75	
19	All structures shall be built to survive 15 Gs of launch acceleration	**Partial**		Theoretically complies but not yet tested.
20	All structures shall be built to survive 30 Gs of shock.	**Partial**		Theoretically complies but not yet tested.
21	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	**Comply**	p.75	
22	All mechanisms shall be capable of maintaining their configuration or states under all forces.	**Partial**		Theoretically complies but not yet tested.

Requirements Compliance (4/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
23	Mechanisms shall not use pyrotechnics or chemicals.	Comply		
24	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		No heat mechanism trade is selected
25	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time.	Partial	p. 92	Theoretically complies but not yet tested.
26	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.	Partial	p. 92	Theoretically complies but not yet tested.
27	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	Comply	p.87-108	
28	XBEE radios shall be used for telemetry. 2.4 GHz Series 1 and 2 radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Comply	p.89	
29	XBEE radios shall have their NETID/PANID set to their team number.	Comply	p.89	
30	XBEE radios shall not use broadcast mode.	Comply	p.89	

Requirements Compliance (5/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
31	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	p.149-150-151	
32	Each team shall develop their own ground station	Comply	p.119-120-121	
33	All telemetry shall be displayed in real time during descent.	Comply	p.92	
34	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	p.122	
35	Teams shall plot each telemetry data field in real time during flight.	Comply	p.92	

Requirements Compliance (6/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
36	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	p.113	
37	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	p. 115	
38	Both the heat shield and probe shall be labeled with team contact information including email address.	Comply	p.137	
39	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	p.108	
40	No lasers allowed.	Comply		
41	The probe must include an easily accessible power switch.	Comply	p.13	
42	The probe must include a power indicator such as an LED or sound generating device.	Comply	p. 98	

Requirements Compliance (7/8)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
43	The descent rate of the probe with the heat shield deployed shall be between 10 and 30 meters/second.	Comply	p.44	
44	The descent rate of the probe with the heat shield released and parachute deployed shall be 5 meters/second .	Comply	p.47	
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Comply	p.97	
46	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells.	Comply	p.99	.
47	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Comply	p.13	
48	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply		
49	A tilt sensor shall be used to verify the stability of the probe during descent with the heat shield deployed and be part of the telemetry.	Comply	p.28	

Requirements Compliance (8/8)

Bonus	Add a color video camera to capture the release of the heat shield and the ground during the last 300 meters of descent. The camera must have a resolution of at least 640x480 and a frame rate of at least 30 frames/sec. The camera must be activated at 300 meters.	**Comply**	p.29	

Management

Aykut UCTEPE

CanSat Budget – Hardware (1/5)

Electronics				
Component	Model	Quantity	Unit Price[$]	Total[$]
Gyroscope	MPU6050	1	8,25 (Actual)	8,25
Barometer	BMP180	2	10,00 (Actual)	20,00
GPS	Adafruit Ultimate GPS	1	39,95 (Actual)	39,95
Camera	Turbowing DVR 700TVL	1	16,81 (Actual)	14,99
SD Card	SANDISK 32 GB	1	12,00(Actual)	12,00
XBEE	XBEES2B	2	55,00 (Actual)	110,00
Antenna (Probe)	2405CL	1	5,00 (Actual)	5,00
MICROCONTROLLER	ATMEGA 32U4	1	3,00 (Actual)	3,00
SD Card Reader	SD Card Reader	1	1,20 (Actual)	1,20
Voltage Regulator	Pololu 5V	1	7,00(Actual)	7,00
BUZZER	BUZZER	1	1,00(Actual)	1,00
Battery	OEM 16340	1	3,00(Actual)	3,00

CanSat Budget – Hardware (2/5)

Mechanical				
Component	Model	Quantity	Unit Price[$]	Total[$]
Probe skeleton	3D Print ABS	200 gr	0,40 per gr	80,00 (Actual)
Egg Protection	Bubble Wrap	1 m2	2 per m2	2,00 (Actual)
Parachute	30d silicone nylon 66 cloth	1 m2	5,00 per m2	5,00 (Actual)
Mechanism	Spring	1 m	5,00 per m	5,00 (Actual)
Release Mechanism	Servo 9gr	2	5,00	10,00 (Actual)
Other tools	Adhesive,hinge, etc	-	25,00	30,00 (Estimated)

OVERALL TOTAL:	365,39

CanSat Budget – Hardware (3/5)

Ground Station				
Component	Model	Quantity	Unit Price[$]	Total[$]
XBEE	XBEES2B	1	55,00 (Actual)	55,00
XBEE's Adapter	XBEE Explorer Dongle	1	24.95 (Actual)	24.95
Antenna(Ground)	2415D	1 Re-Used	53,00 (Actual)	53,00
Computer	Dell-inspiron 3542	1 Re-Used	Private	Private

TOTAL:	**132,95**

CanSat Budget – Other Costs (4/5)

Other Costs	Quantity	Unit Price[$]	Total[$]
Travel	10	500 (Estimate)	5000
Hotel	2x4 Days	100 (Estimate)	1000
Rent Cars	2x6 Days	80 (Estimate)	960
Prototyping	3	30 (Estimate)	90
Test facilities and equipment	University Provided	University Provided	University Provided
Fee	1	100 (Actually)	100
		TOTAL	**7150**

CanSat Budget – Other Costs(5/5)

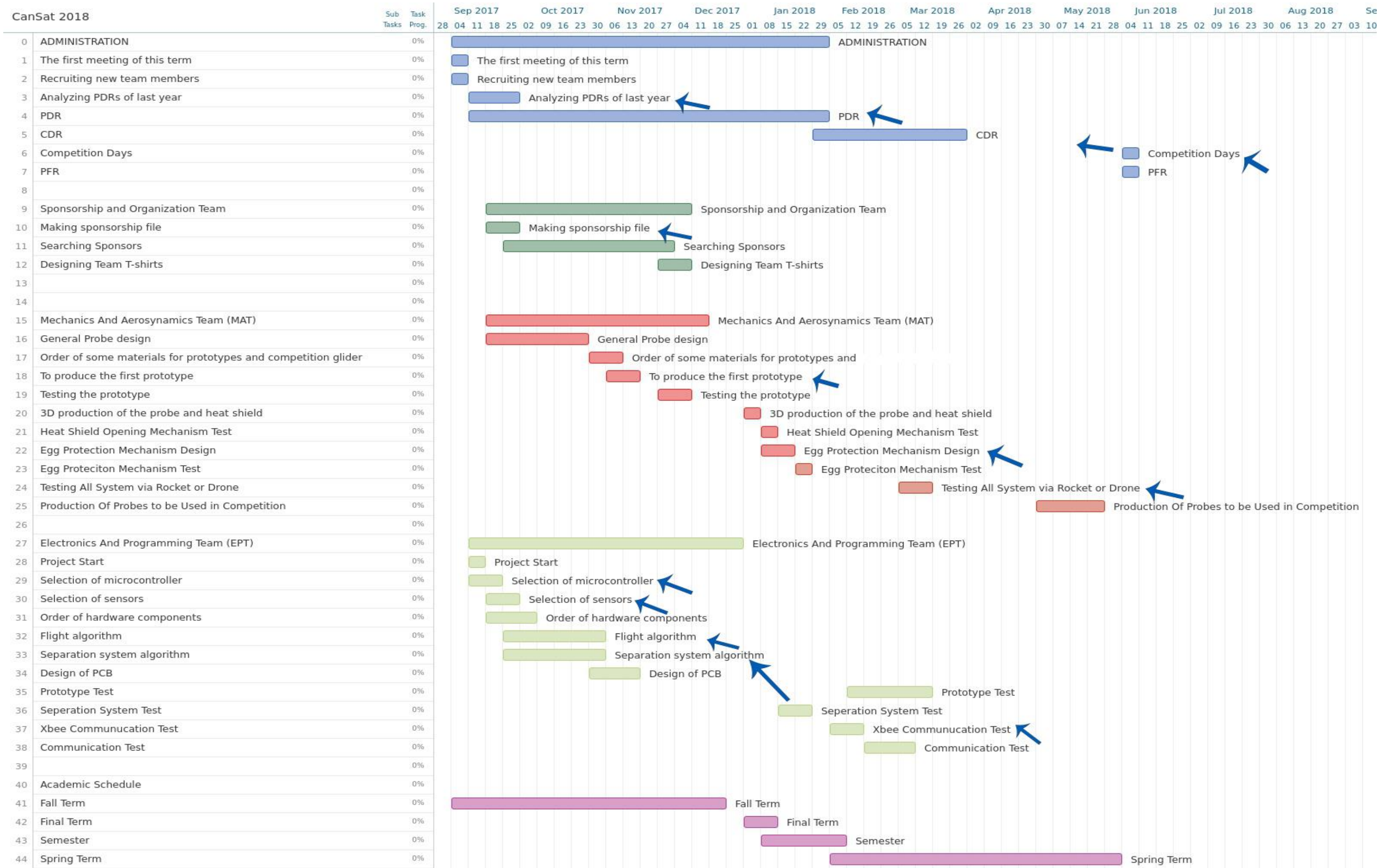
Categories	Cost [$]
Electrical and Mechanical	365,39
Ground Station	132,95
Other Costs	7150
TOTAL	7648.34 $

INCOME	10000

- Main source of 10000$ income is companies that agreed to finance our team throughout competition.

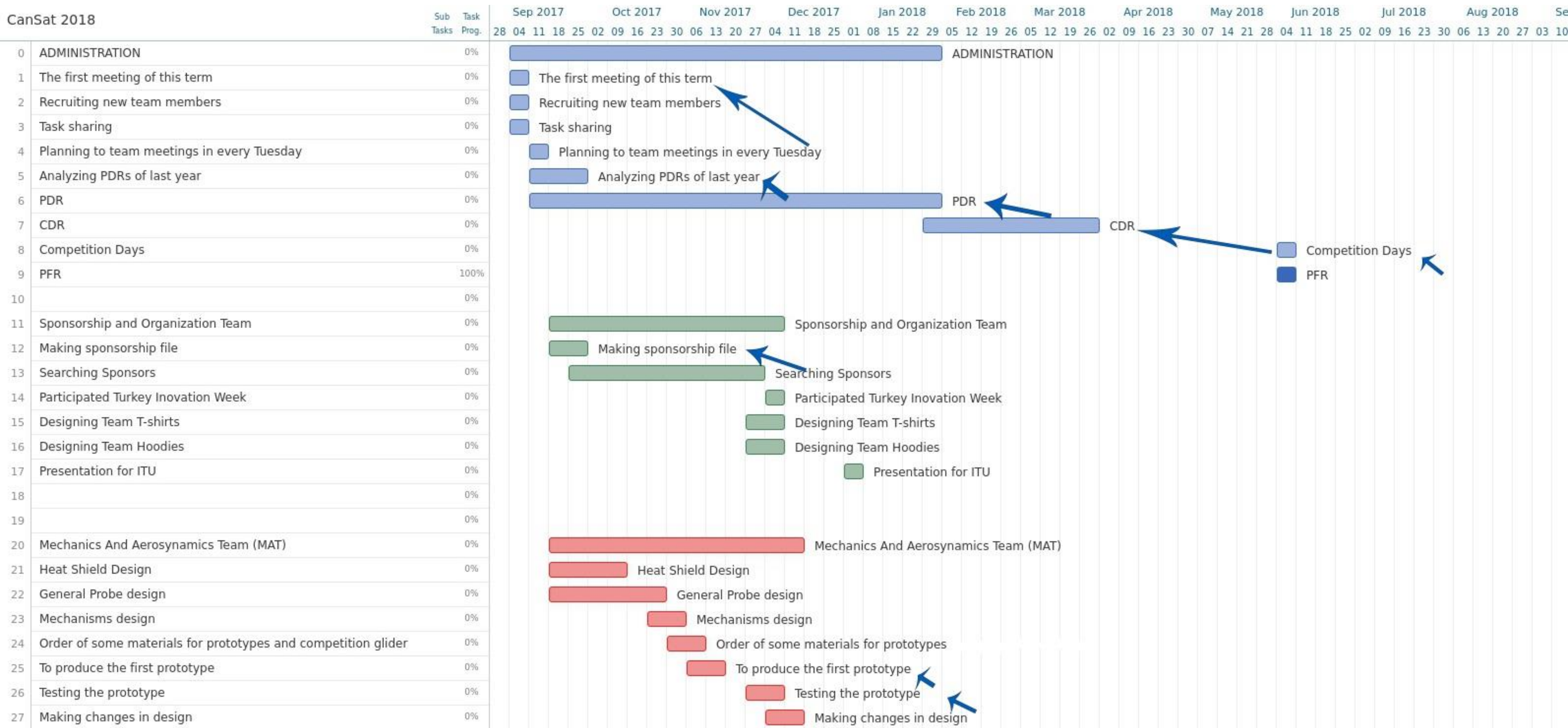
Program Schedule (1/3)

Program Summary



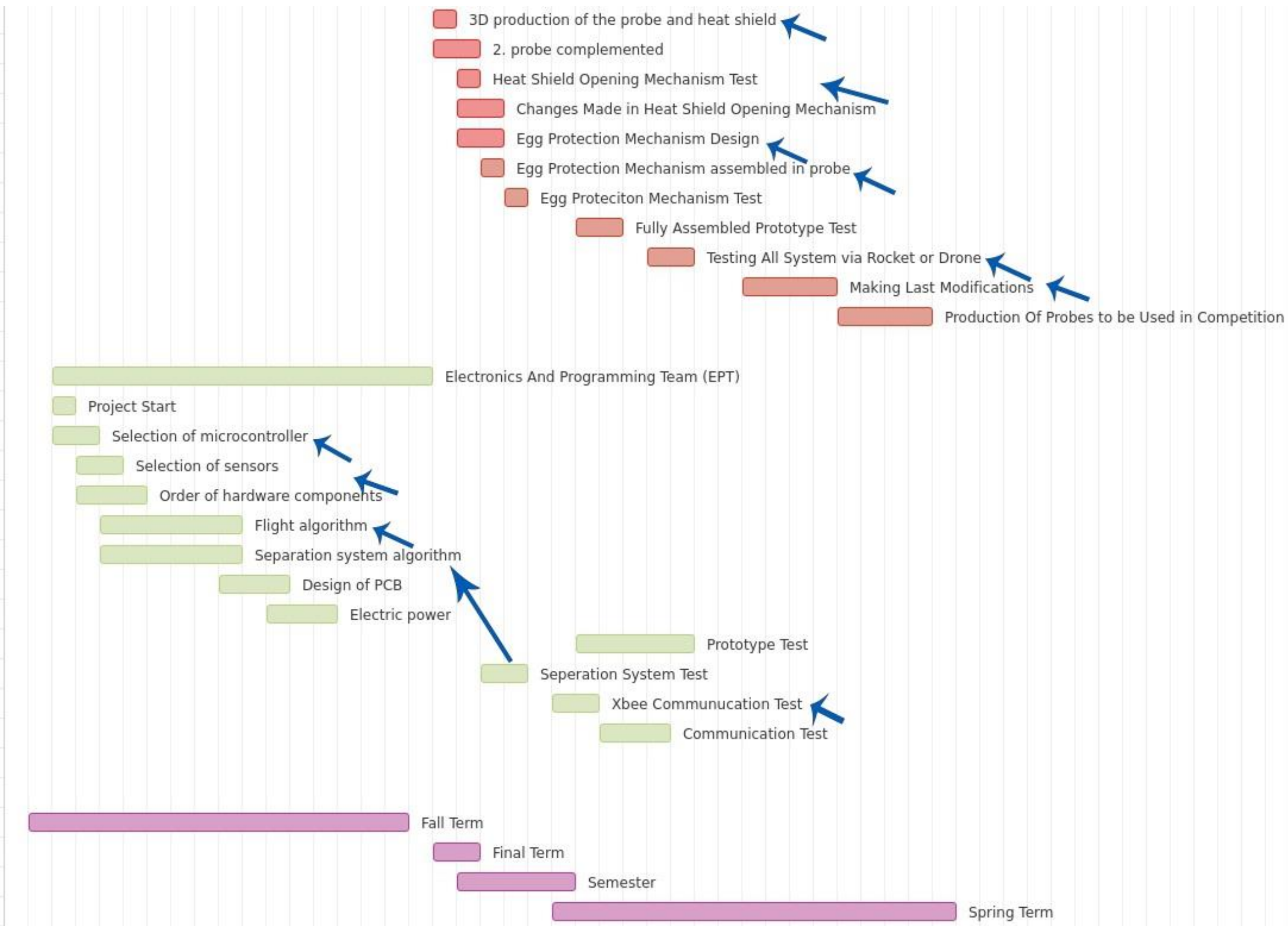
Program Schedule (2/3)

Detailed Program Chart



Program Schedule (3/3)

28	3D production of the probe and heat shield	0%
29	2. probe complemented	0%
30	Heat Shield Opening Mechanism Test	0%
31	Changes Made in Heat Shield Opening Mechanism	0%
32	Egg Protection Mechanism Design	0%
33	Egg Protection Mechanism assembled in probe	0%
34	Egg Proteciton Mechanism Test	0%
35	Fully Assembled Prototype Test	0%
36	Testing All System via Rocket or Drone	0%
37	Making Last Modifications	0%
38	Production Of Probes to be Used in Competition	0%
39		0%
40	Electronics And Programming Team (EPT)	0%
41	Project Start	0%
42	Selection of microcontroller	0%
43	Selection of sensors	0%
44	Order of hardware components	0%
45	Flight algorithm	0%
46	Separation system algorithm	0%
47	Design of PCB	0%
48	Electric power	0%
49	Prototype Test	0%
50	Seperation System Test	0%
51	Xbee Communucation Test	0%
52	Communication Test	0%
53		0%
54	Academic Schedule	0%
55	Fall Term	0%
56	Final Term	0%
57	Semester	0%
58	Spring Term	0%



Conclusions

Administration & Finance

Major Accomplishments:

1. Schedule was created.
2. Financial income was secured.
3. Airline tickets sponsors were found.
4. PDR was completed

Major Unfinished Work:

1. 5 team members visas are not applied yet.

Electronics & Programming

Major Accomplishments:

1. Electronic component choosing is fully completed.
2. Electronic design progress is done.

Major Unfinished Work:

1. The fully integrated electronic systems will be tested in order to have perfect functionality.

Mechanics & Aerodynamics

Major Accomplishments:

1. Heat Shield and probe were elaborately discussed and a choice that seemed the best for every branch was made.

Major Unfinished Work:

1. The fully finished probe needs to be tested.

Conclusion: **Nothing has been delayed, the schedules and deadlines have been met. Team APIS AR-GE is ready to move on to CDR.**