00:25

ITION

CanSat 2018
Preliminary Design Review (PDR)

1138
Robotics for Space Exploration (RSX)

Presentation Outline

00:25

Team Organization

00:25

TITION

Team Leads
Johnny Wang (M.A.Sc.)

Faculty Advisor
Prof. Jonathan Kelly, PhD

Mechanical Lead
MC De Beer (M.A.Sc AERO)

- Ali Mahdavifar (3rd year AERO)

Aerodynamics Lead
Ryan Taylor (M.A.Sc AERO)

- Andrew Bustard (3rd year AERO)

Electronics & Software Lead
Johnny Wang (M.A.Sc. ECE)

- Shahin Jafari (3rd year ROBO)
- Eric Boszin (3rd year ECE)

AERO = Aerospace
ECE = Electrical and Computers
ROBO = Robotics and Mechatronics

Acronyms

00:25

Acronym	Meaning
AC	Alternating Current
C_D	Coefficient of Drag
CDH	Communication and Data Handling
CoG	Center of Gravity
COTS	Commercial Off-the-Shelf
DC	Direct Current
EPS	Electrical Power System
FSW	Flight Software
GCS	Ground Control System
GPS	Global Position System
HS	Heat Shield

Acronym	Meaning
IDE	Integrated Development Environment
LED	Light Emitting Diode
LOS	Line of SIght
Ni-Cad	Nickel-Cadmium Battery
Ni-MH	Nickel-Metal Hydride
PB	Probe
UART	Universal Asynchronous Receiver Transmitter

03:45

Systems Overview

Ryan Taylor

Mission Summary

03:45

- As per the mission requirements, the CanSat shall:
  - Upon release, deploy a heat shield which shall
    - Reduce the velocity of the CanSat to 10-30 m/s
    - Stabilize the CanSat to prevent tumbling
  - At an altitude of 300 m, the heat shield shall be ejected and a parachute deployed to slow the vehicle to 5 m/s.
  - The CanSat shall collect and broadcast atmospheric data throughout the flight and protect one egg from damage during descent.
- In order to pursue simplicity, the bonus objective is not to be attempted.
- No external objectives are required/attempted.

System Requirement Summary

No.	Requirement
1	Total mass of the CanSat (probe) shall be 500 grams +/- 10 grams.
2	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.
6	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.
7	The probe shall hold a large hen's egg and protect it from damage from launch until landing.
11	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.
12	The rocket airframe shall not be used as part of the CanSat operations.
13	The CanSat, probe with heat shield attached shall deploy from the rocket payload section.
14	The aero-braking heat shield shall be released from the probe at 300 meters.
15	The probe shall deploy a parachute at 300 meters.
22	All mechanisms shall be capable of maintaining their configuration or states under all forces.

System Requirement Summary

03:45

No.	Requirement
23	Mechanisms shall not use pyrotechnics or chemicals.
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.
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.
26	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.
31	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.
32	Each team shall develop their own ground station.
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.
38	Both the heat shield and probe shall be labeled with team contact information including email address.
40	No lasers allowed.
41	The probe must include an easily accessible power switch.

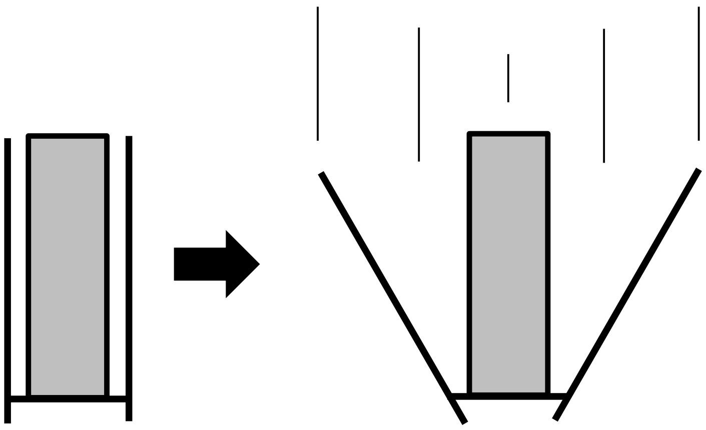
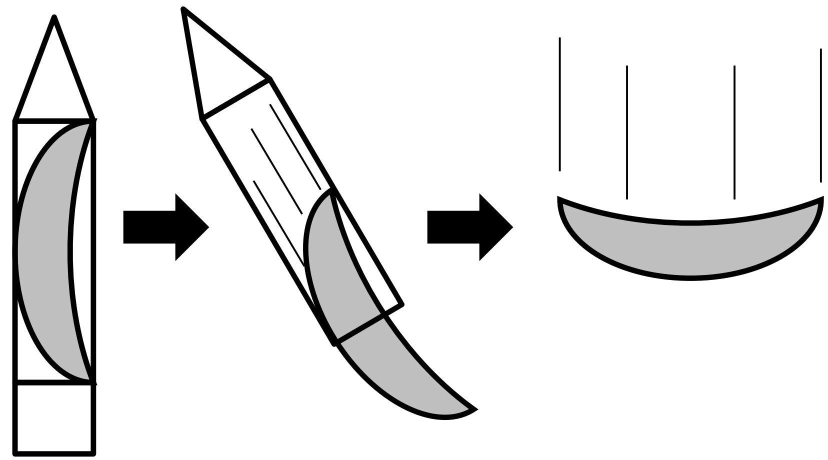
System Requirement Summary

03:45

No.	Requirement
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.
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.

System Level CanSat Configuration Trade & Selection

03:45

Deployed Heat Shield	Static Heat Shield
	
• Upon ejection from fairing, the payload will deploy/extend the heat shield to decelerate. • Allows for a greater effective heat shield area while remaining within fairing tolerances.	• Uses a heat shield without moving parts to slow the craft. • Upon exit from the fairing, the payload may re-orient itself depending on heat shield design.

System Level CanSat Configuration Trade & Selection

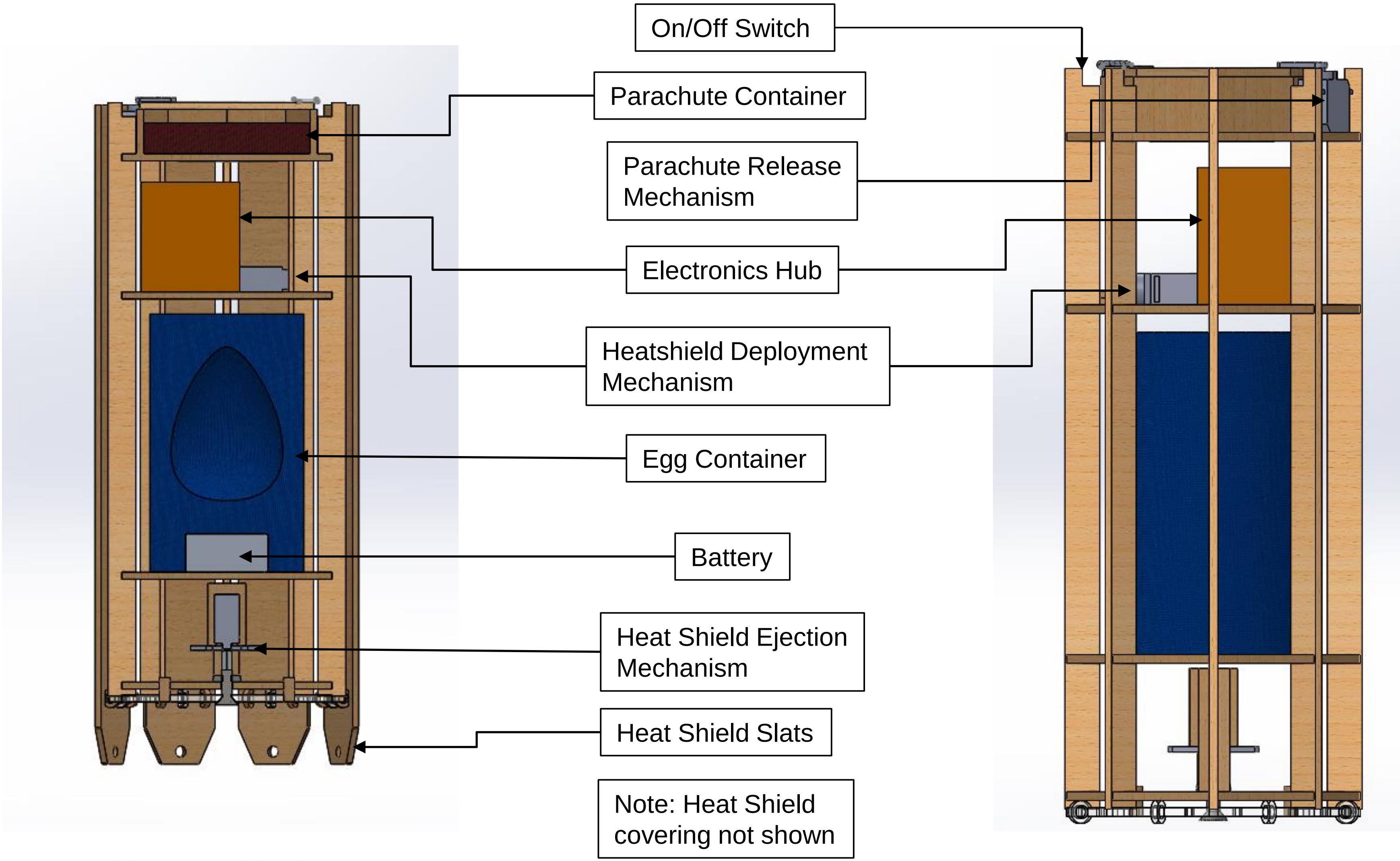
03:45

Criterion [Metric]	Deploying Heat Shield	Static Heat Shield
Utility [Internal Volume]	The vast majority of the volume can be allocated to non-heat shield components.	Due to constraints imposed by stability requirements, the internal volume will be minimal.
Complexity [number of components]	Requires mechanisms to lock the heat shield in both non-deployed and deployed configurations, which must be somehow decoupled at heat shield release.	No mechanisms required before heat shield release.
Aerodynamics [drag force]	A deploying heat shield can significantly increase the surface area and be tuned to reach target velocities.	It is unclear if a heat shield that fits in the envelope (30x12 cm) would be able to limit terminal velocity adequately.
Chosen Solution: Deploying Heat Shield	Despite the attractive possibility of having no moving parts in the heat shield, the disadvantage of extremely low internal volume and concerns over the performance of such a heat shield suggest that opting for a more mechanically-complex but more predictable deploying heat shield is the best choice.	

Good	Average	Bad

Physical Layout

03:45



With Heat Shield Slats

Without Heat Shield Slats

System Concept of Operations

03:45

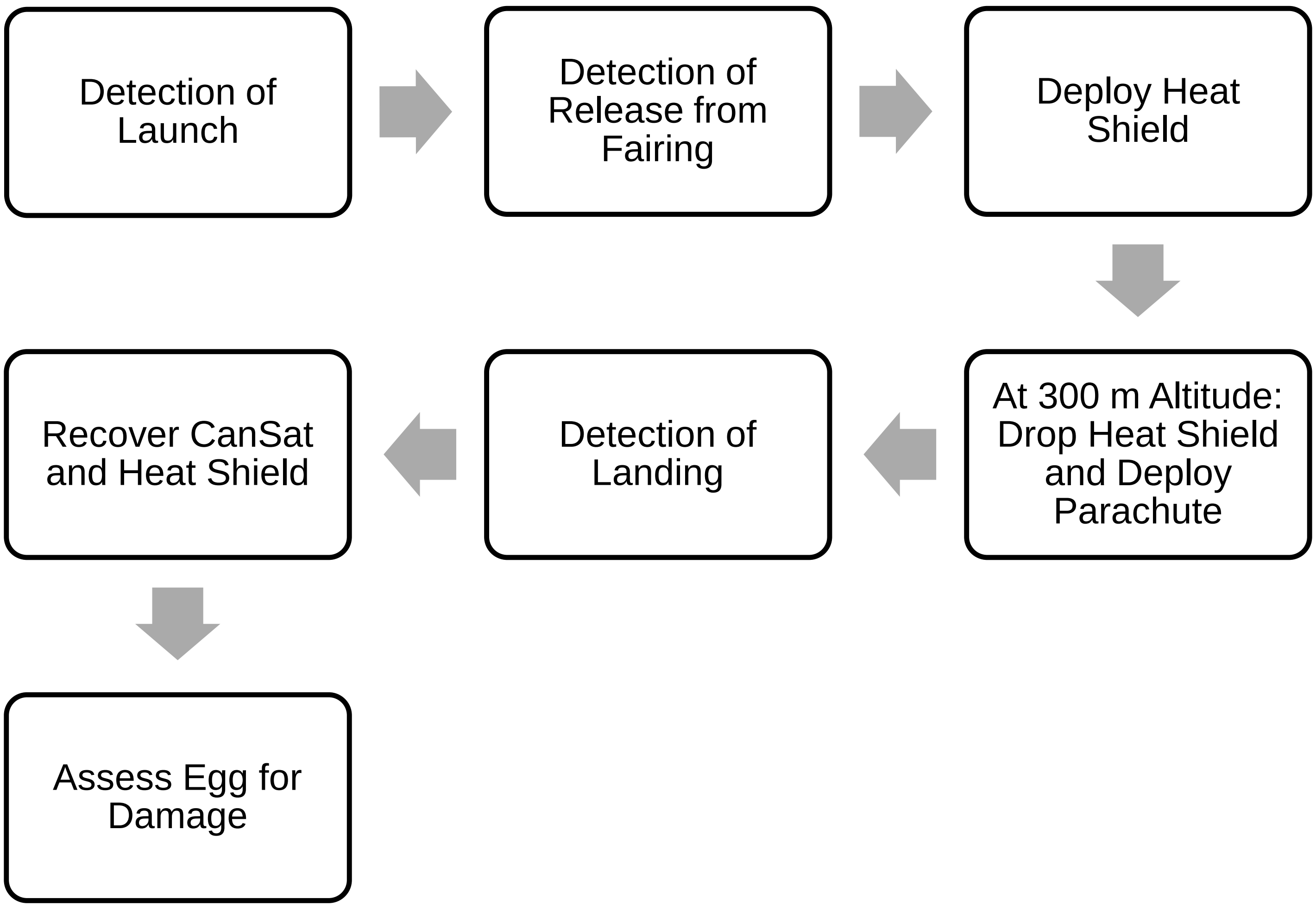
Pre-Launch

Installation of Fresh Battery → Confirmation of Sensor Function → Placement of Egg in Container → Final Pre-Flight Checks → Close Heat Shield and Secure for Launch → Load CanSat into Rocket Fairing → Launch

System Concept of Operations

03:45

Post-Launch



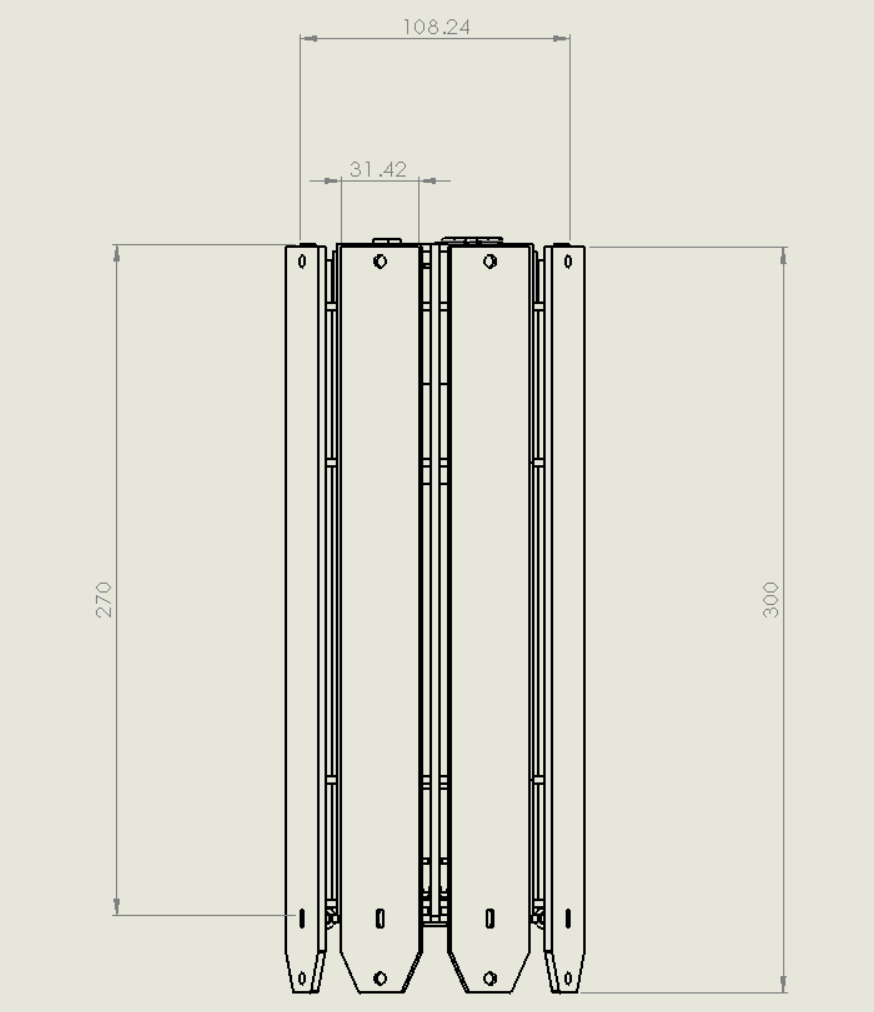
System Concept of Operations

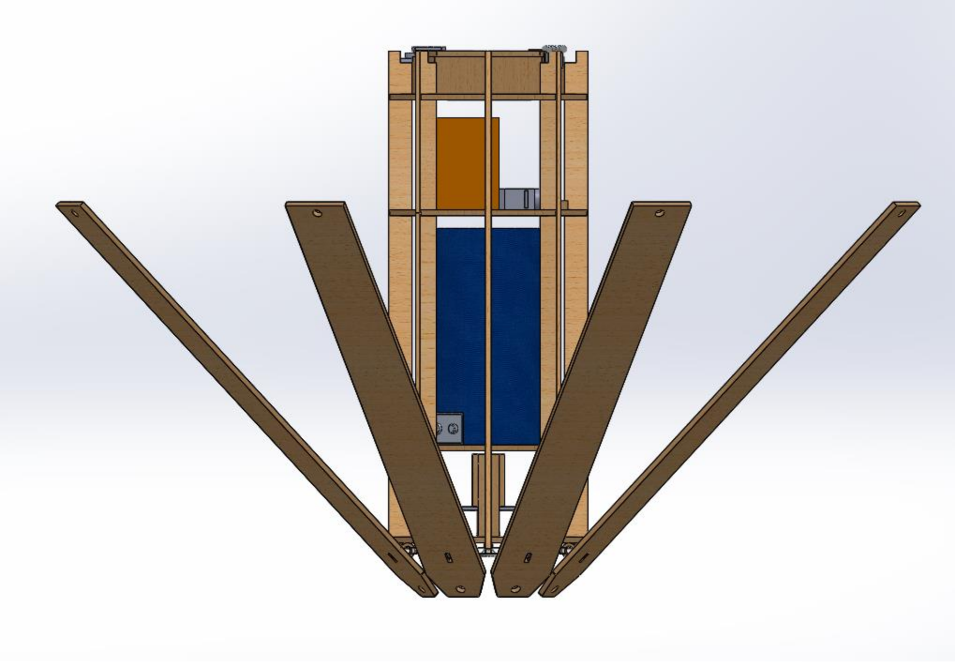
03:45

Ground Station

1. Confirm Telemetry from Pre-Launch Checks
2. Monitor Launch and Descent of CanSat
3. Post-Process Collected Data for PFR
4. Compile PFR Document Based on Flight

Launch Vehicle Compatibility





07:05

Sensor Subsystem Design

Shahin Jafari

Sensor Subsystem Overview

07:05

Sensor Type	Sensor Model	Description
Magnetometer	MPU-9250	Used to obtain direction measurements, as well as the tilt.
Air Pressure	BMP180	Used to obtain atmospheric pressure, temperature and altitude.
GPS	NEO-7M-C	Used to calculate the location of the probe.
Air Temperature	BMP180	Used to obtain atmospheric pressure, temperature and altitude.
Power Voltage Sensor	Voltage Divider Circuit, two 10KΩ resistors	Used to measure voltage of power source.

Sensor Subsystem Requirements

07:05

No.	Requirement
18	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.
21	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.
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.
41	The probe must include an easily accessible power switch.
42	The probe must include a power indicator such as an LED or sound generating device.
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.
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.
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.
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.

Probe Air Pressure Sensor Trade & Selection

07:05

Criterion [Metric]	MS5803-14BA	MPL3115A2	BMP180	MPL115A1
Operating voltage [V]	1.8 to 3.6	1.95V to 3.6	1.8 V to 3.6	2.375 to 5.5
Operating current [μA]	3.2	40	5	5
Cost [USD]	59.95	14.95	9.95	12.95
Size [mm]	6.4x6.2x2.9	5x3.3x1.1	3.8x3.6x0.93	5x3x1.2
Operating pressure range [kPa]	0 to 1400	0 to 500	30 to 110	50 to 115
Operating temperature range [°C]	-40 to 85	-40 to 85	-40 to 85	-40 to 105
Accuracy [kPa]	0.02	0.3	0.25	1
Interface	I2C/SPI	I2C	I2C	SPI
Mass [g]	Due to extremely small size, mass is ignored			
Chosen Solution: BMP180	Candidate 3 was chosen because “cost” was the main concern and after that, the “size” criterion was given the highest priority. Operating conditions were given the lowest priorities since we will not reach their limits in the operation.			

Good	Average	Bad

Probe Air Temperature Sensor Trade & Selection

Criterion [Metric]	BMP180	MCP9808
Cost [USD]	9.95	4.95
Operating Voltage	1.7-3.6 V	2.7 - 5.5 V
Current Draw [μA]	7 at 1Hz (high resolution mode)	200
Resolution [°C]	0.1 best from 0°C to 60°C 2 in standard mode	0.25 from -40°C to +125°C 0.5 from -20°C to 100°C
Dimensions [mm]	20x20	21x13
Operating Temperature [°C]	-40°C to 85 °C but 0°C to 60°C for maximum accuracy	-20°C to 100°C
Weight [g]	5	8
Chosen Solution: BOSCH BMP180	BMP180 was chosen primarily due to its several operating modes and ability to measure air pressure, air temperature and altitude at the same time. With the help of this chip, the electronics' components and their size are reduced greatly.	

Good	Average	Bad

GPS Sensor Trade & Selection

07:05

Criterion [Metric]	NEO-7M-C	Adafruit Ultimate GPS Breakout	Venus GPS
Operating voltage [V]	1.65V to 3.6V	5V	2.8V to 3.6V
Operating current [mA]	35mA	20mA	30mA
Position Sensitivity	2.5m	3m	2.5m
Cost [USD]	$20.19	$39.95	$49.95
Size [mm]	15.9x12.1x2.2	16x16x3	28x15x2.3
Special Features	Includes Antenna	Requires external antenna	Requires external antenna
Operational altitude limit	50000m	18000m	18000
Update rate	1 Hz	1 Hz	1 Hz
Mass [g]	Due to extremely small size, mass is ignored		
Chosen Solution: NEO-7M-C	Candidate 1 was chosen because the "size" and "Cost" criterion were given the highest priority. The operational limits was important as well, since due to the size constraint, battery selection for power supply purposes was also limited and hence, power management becomes a dictating factor.		

Good	Average	Bad

Probe Power Voltage Sensor Trade & Selection

07:05

Criterion [Metric]	AttoPilot 180A	Voltage divider circuit Two 10KΩ resistors
Size [mm]	4x15x19	2.3 diameter x 6 height
Max tolerating voltage [V]	51.8	350
Cost [USD]	19.95	0.2
Mass [g]	Due to extremely small size, mass is ignored	
Chosen Solution: Voltage divider circuit	Candidate 2 was chosen because of the extremely small relative size and cost.	

Good	Average	Bad

Tilt Sensor Sensor Trade & Selection

07:05

Criterion [Metric]	MPU-9250	MAG3110	LSM303C
Operating voltage [V]	2.4 – 3.6	1.95V to 3.6	1.9 V to 3.6
Operating current [mA]	3.8	1.9915	0.27
Full scale range of magnetometer [G]	±48	±10	±16
Cost [USD]	14.95	14.95	14.95
Size [mm]	3x3x1	2x2x0.85	2x2x1
Special Features	Gyroscope, accelerometer, magnetometer	Magnetometer	accelerometer, magnetometer
Sensitivity of magnetometer [μT]	0.6	0.1	0.058
Mass [g]	Due to extremely small size, mass is ignored		
Chosen Solution: MPU-9250	Candidate 1 was chose because it has a built-in gyroscope as well as its magnetometer and both can be used to measure tilt. The higher sensitivity and range were other reasons for this selection.		

Good	Average	Bad

Bonus Camera Trade & Selection

07:05

- **This bonus will not be pursued due to results of score function analysis**
  - To achieve camera bonus, all primary objectives need to achieved
  - Choose to focus on all primary objectives
  - If we are confident all primary objectives will be achieved, we will pursue the bonus given the resources and time.

Bonus Wind Sensor

07:05

- **The wind sensor bonus will be pursued if time permits**
  - This will be an add-on to the ground station
  - No significant changes needs to be made to the core design if we decide to use the remaining time to pursue this bonus

11:15

ITION

Descent Control Design

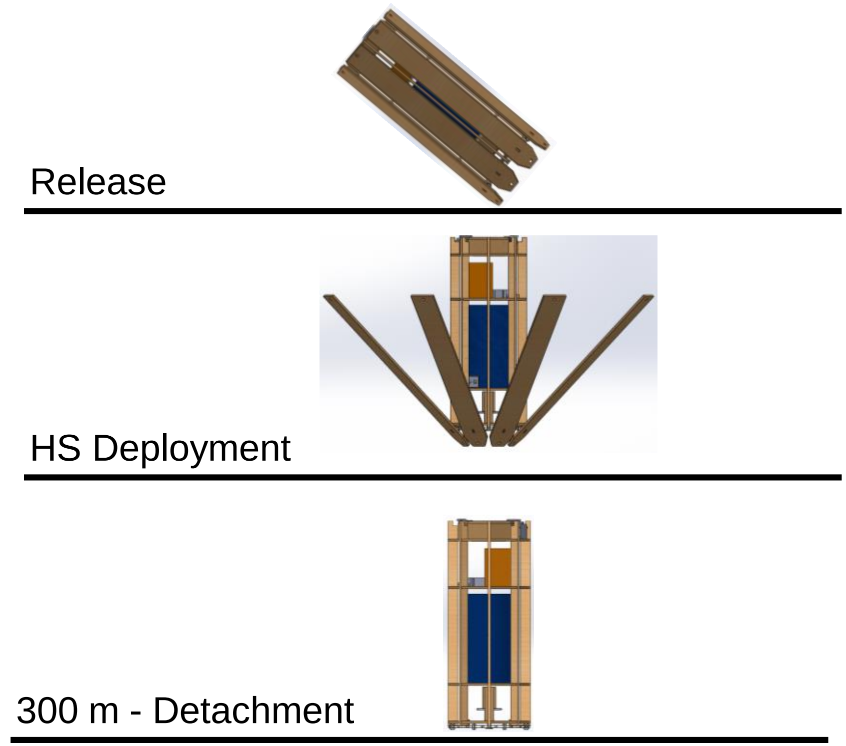
Ryan Taylor

Descent Control Overview

11:15

1. **Upon deployment, the payload will deploy the heat shield to slow and passively stabilize its descent.**

2. **Upon reaching 300 m altitude, the probe shall detach the heat shield and deploy its parachute to further slow its descent.**



Descent Control Requirements

11:15

No.	Requirement
2	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.
3	The heat shield must not have any openings.
4	The probe must maintain its heat shield orientation in the direction of descent.
5	The probe shall not tumble during any portion of descent. Tumbling is rotating end-over-end.
6	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.
9	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.
10	The aero-braking heat shield shall be a florescent color; pink or orange.
11	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.
14	The aero-braking heat shield shall be released from the probe at 300 meters.

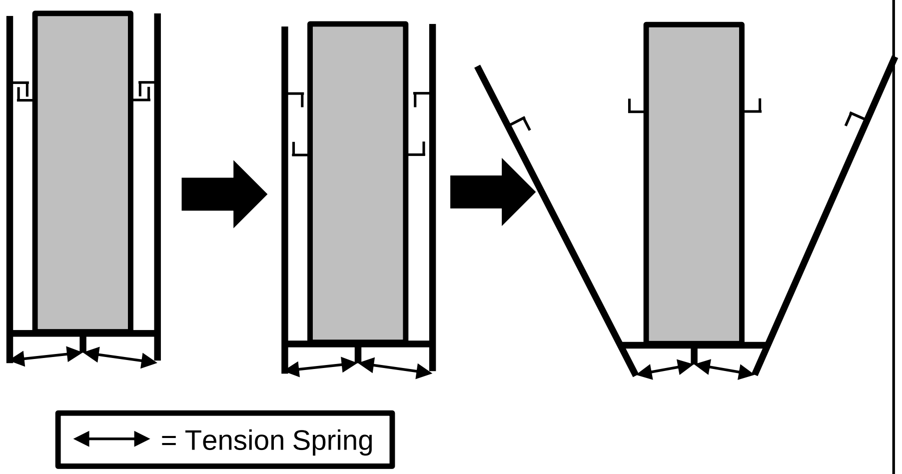
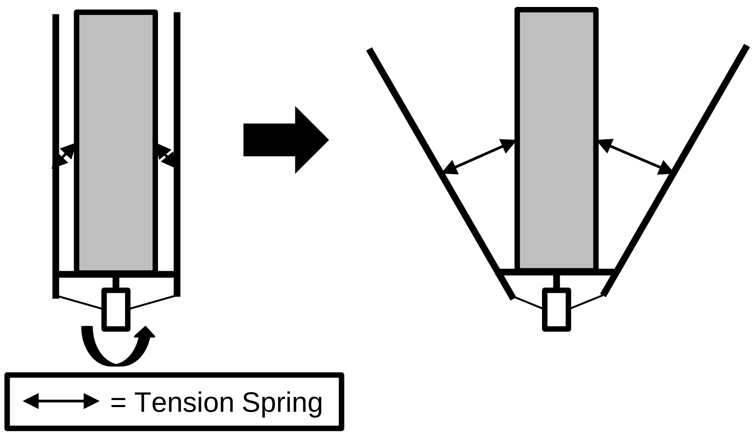
Descent Control Requirements

11:15

No.	Requirement
15	The probe shall deploy a parachute at 300 meters.
16	All descent control device attachment components (aero-braking heat shield and parachute) shall survive 30 Gs of shock.
17	All descent control devices (aero-braking heat shield and parachute) shall survive 30 Gs of shock.
22	All mechanisms shall be capable of maintaining their configuration or states under all forces.
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.
38	Both the heat shield and probe shall be labeled with team contact information including email address.
43	The descent rate of the probe with the heat shield deployed shall be between 10 and 30 meters/second.
44	The descent rate of the probe with the heat shield released and parachute deployed shall be 5 meters/second.

Payload Descent Control Strategy Selection and Trade

11:15

Latch-and-Release	Winched Deployment
	
• The heat shield will be composed of several slats, initially held flush with the sides of the probe. • These slats will be held under tension by a latching mechanism. • Upon release of the latch, the slats will spring outwards, thus deploying the heat shield to its fullest extent.	• The slats of the heat shield will initially be held flush with the sides of the probe by tension. • An actuated mechanism, such as a spool/winch or a geared mechanism, will provide the force required to extend the slats and maintain their position.

Payload Descent Control Strategy Selection and Trade

11:15

Criterion [Metric]	Latch-and-Release	Winched Deployment
Deployment Control [Chance for failure inside fairing]	Failure of restraining mechanisms could cause the payload to remain in the fairing, causing immediate mission failure.	Failure of restraining device(s) are unlikely to cause failure of the mission.
Redundancy [Dependency of deployment mechanisms]	Failure of the tensioning mechanism on any one slat does not impact other slats, creating redundancy.	Failure or jamming of winch mechanism by any one slat causes all to fail, resulting in mission failure.
Detachment [Ease of separation]	The heat shield is not attached directly to any actuators, making detachment straightforward and relatively risk-free.	Since the heat shield is directly connected to an actuator, heat shield separation would have to be accomplished by cutting lines or wires.
Chosen Solution: Latch-and-Release	The ease with which the heat shield can be separated with a Latch-and-Release mechanism and the redundancy in deployment mechanisms mitigates the risk of failure due to non-deployment.	

Good	Average	Bad

Descent Stability Control Strategy Selection and Trade

11:15

Active Stability	Passive Stability
• Four of the eight heat shield slats would have independently-controllable positioning, likely by independent actuators. • This allows the heat shield to be altered in shape to steer the payload during descent. • A control system would be created to maintain stability throughout descent for a neutrally-stable or lightly unstable payload design (we assume that passive stability is not possible if this design is chosen)	• Relies on the natural stability of an inverted cone. • Requires that the CoG be located below the one-third mark (measured from top of cone) to ensure stability.

Descent Stability Control Strategy Selection and Trade

11:15

Criterion [Metric]	Active Stability	Passive Stability
Complexity [number of actuators]	Requires several actuators dedicated to altering slat angles, which also have to be disconnected upon heat shield detachment	No actuators are required, keeping mass and power requirements low.
Stability Control [Time to steady state]	Allows relatively rapid stabilizing of initial perturbation.	Depends significantly on initial conditions of probe tumble and distance of CoG from center of pressure
Reliability [Chance of failure]	Failure of any one actuator could cause tumbling, particularly if the control system is not robust.	Fails only if no slats deploy, which indicates mission failure already.
Chosen Solution: Passive Stability	The complexity and increased weight and power requirements for active control negates the advantages of increased stability control. The need to connect actuators to the heat shield in some way also increases detachment complexity.	

Good	Average	Bad

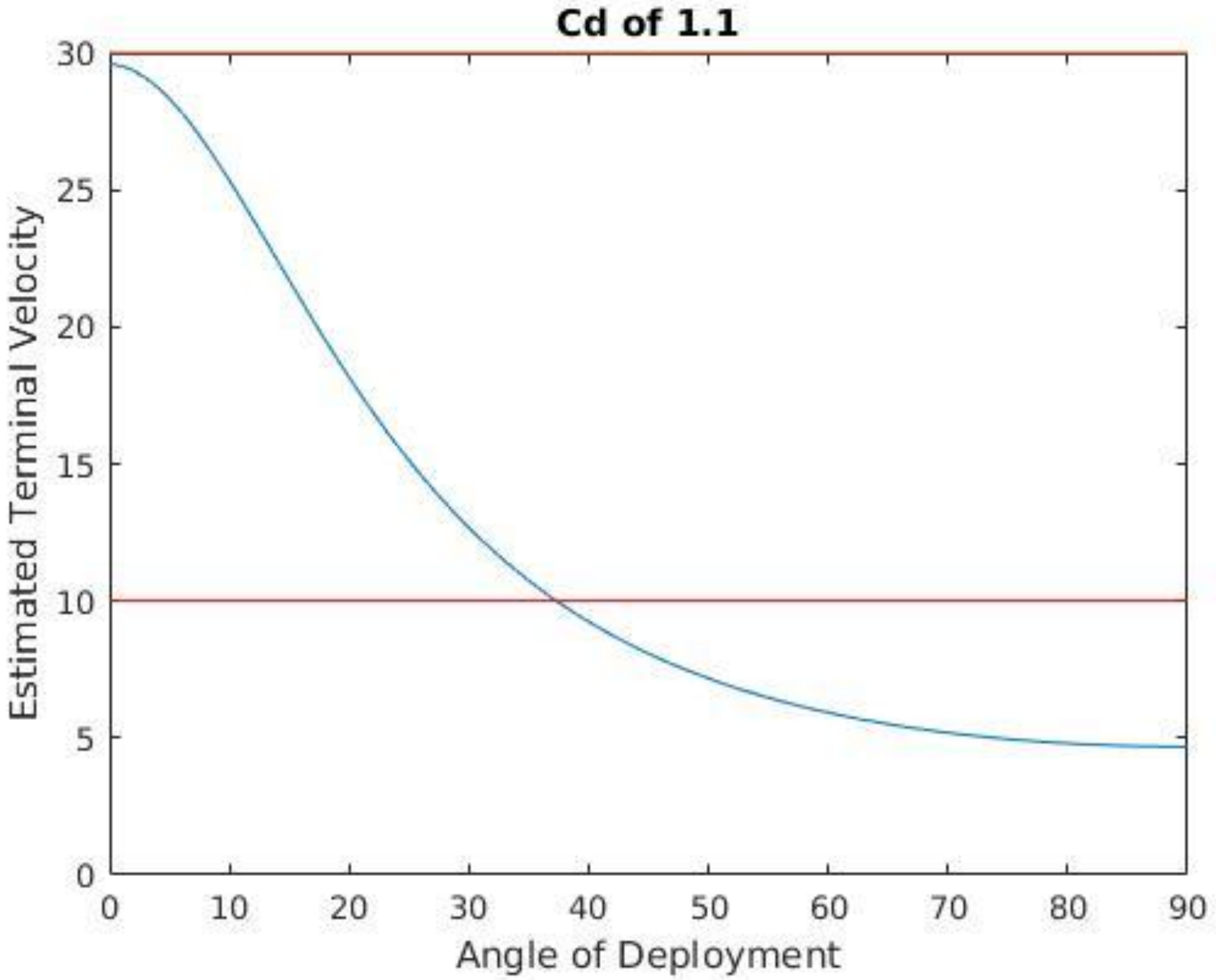
Descent Rate Estimates

- Estimates of the Coefficient of Drag (C_D) are challenging to confidently state.
- In order to estimate the rate of descent, three separate C_D's were used to calculate the terminal velocity of the payload and compared.
- These included:

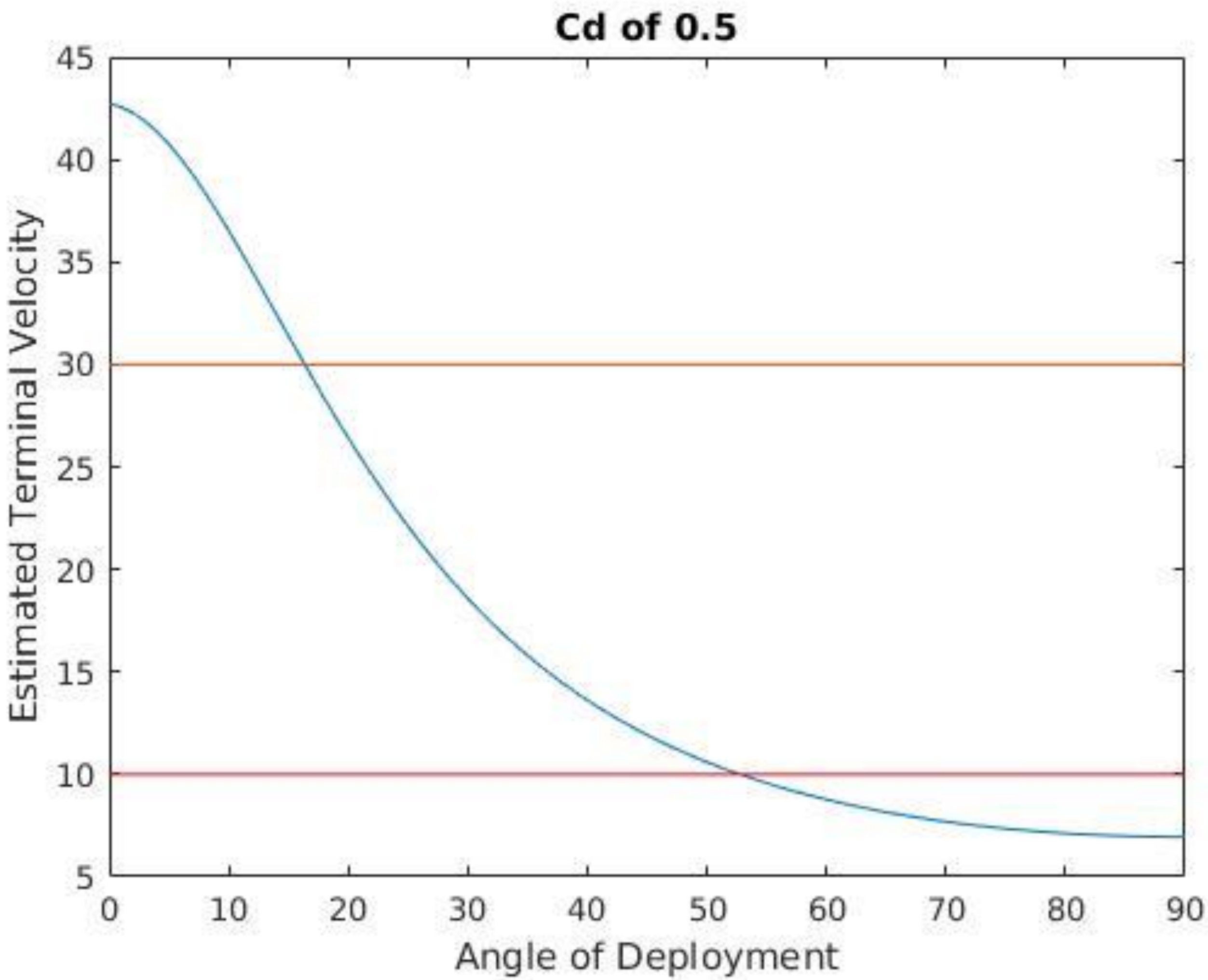
Case	Flow Case	C_D	Reynold's Number
Best Case	Flat Plate	1.1	Low ($\sim 10^4$)
Best Estimate	Cone	0.5	Low ($\sim 10^4$)
Worst Case	Bullet	0.295	High

Descent Rate Estimates

11:15

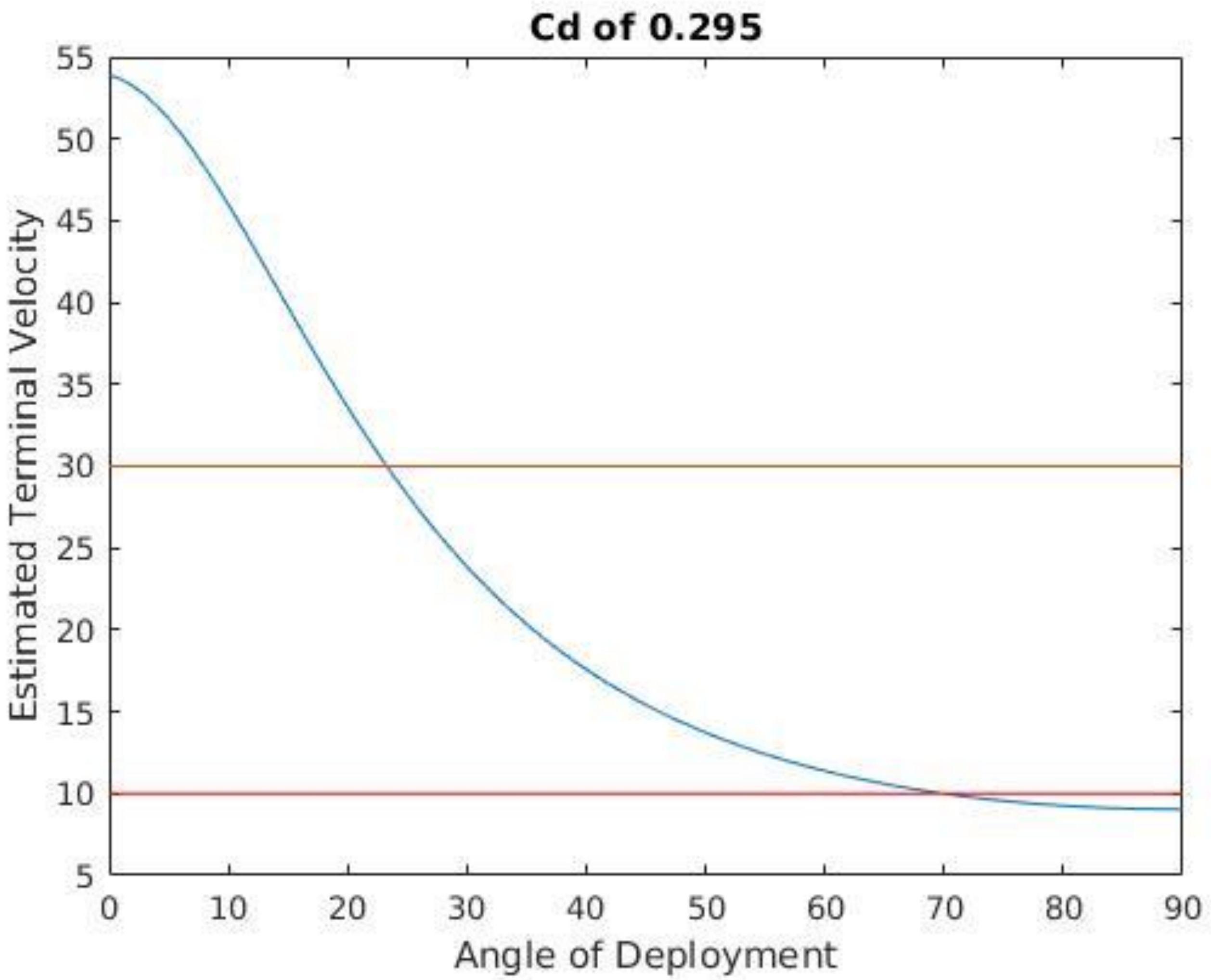


Descent Rate Estimates



Descent Rate Estimates

11:15



Descent Rate Estimates

11:15

- **The table below shows the estimates of descent rate at a heat shield angle of 40º.**
- **Additionally, the parachute has been sized to produce a descent rate of 5 m/s as per the requirements. (Estimation: ~60cm in diameter)**

Stage	Pre-Deployment	Deployed Heat Shield	Detached Heat Shield
Best Case (C_D = 1.1)	29 m/s	9 m/s	6 m/s
Best Estimate (C_D = 0.5)	43 m/s	14 m/s	8 m/s
Worst Case (C_D = 0.295)	54 m/s	17 m/s	12 m/s

Mechanical Subsystem Design

MC De Beer, Ali Mahdavifar

Mechanical Subsystem Overview

18:45

Device	Material	Description	Interface
Heat Shield	Balsa wood reinforced with carbon fiber	Induces drag, slows down and stabilizes the payload to allow for parachute deployment. Attached to the probe and released via a motorized screw.	A central screw attached to a motor connects the heatshield to the probe. Additional passive pins prevent rotation.
Parachute	Ripstop Nylon 1.7 oz. fabric	Induces drag, slows down the payload to allow for landing. Attached to the probe and released via spring-and-cap mechanism.	Parachute will be threaded through holes at the top of the probe. Will also be hooked up with a rubber band to absorb some shock at deployment.
Egg Containment	Insulating foam core	Foam core helps to absorb shock and dampen forces on the egg during launch and upon impact of probe with ground.	Light adhesive (two part epoxy) to stick to probe frame.
Circuit Board Platforms	Perforated board and acrylic sheet base (5 mm)	Perforated boards containing circuits mounted on to octagonal acrylic disks (10 cm diameter, 5 mm thick).	Circuit boards attached to frame via light adhesive and screws.
Probe Shell and Frame	Plywood and balsa wood	Houses all of the components inside the probe.	Attached to Heat Shield by a motor screw mechanism. Internal components attached with adhesive and screws.

Mechanical Sub-System Requirements

18:45

TITION

No.	Requirement
1	Total mass of the CanSat (probe) shall be 500 grams +/- grams.
2	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.
6	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.
7	The probe shall hold a large hen's egg and protect it from damage until landing.
8	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 50 mm and length up to 70 mm.
10	The aero-braking heat shield shall be a florescent colour; pink or orange.
11	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.
12	The rocket airframe shall not be used as a part of the CanSat operations.
16	All descent control device attachment components (aero-braking heat shield and parachute) shall survive 30 Gs of shock.
17	All descent control devices (aero-braking heat shield and parachute) shall survive 30 Gs of shock.
19	All structures shall be built to survive 15 Gs of launch acceleration.
20	All structures shall be build to survive 30 Gs of shock.
22	All mechanisms shall be capable of maintaining their configuration or states under all forces.
23	Mechanisms shall not use pyrotechnics or chemicals.

Mechanical Sub-System Requirements

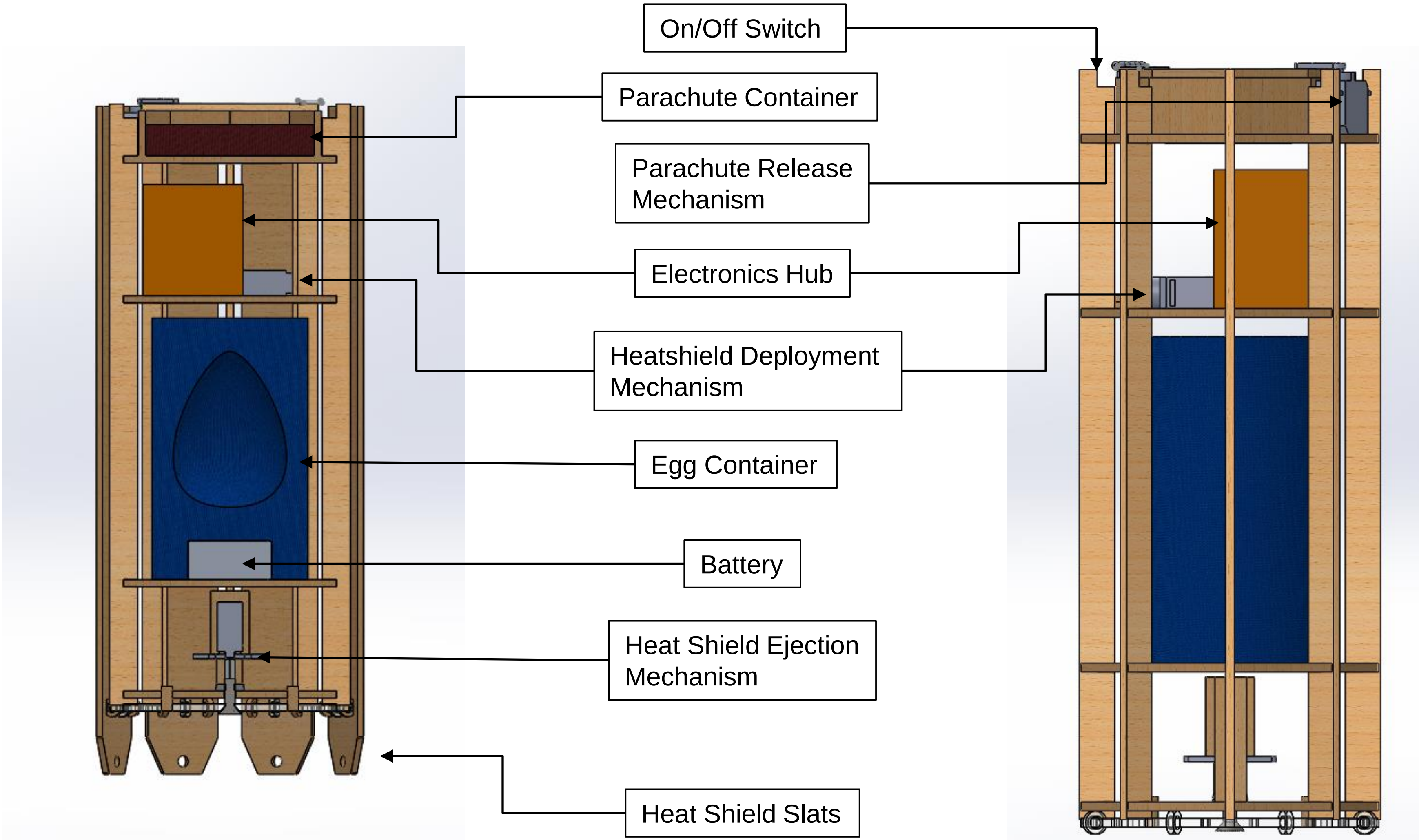
18:45

No.	Requirement
24	Mechanisms that use heat (eg. Nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.
38	Both the heat shield and probe shall be labelled with team contact information including email address.

- **Key trade issues related to mechanical layout and component selection**
  - Electronic interface
    - Placement of sensors relative to each other
    - Placement of electronics relative to high magnetic field induction actuators (DC motors, servos)
  - Wireless signal directionality
    - Location of patch antenna to optimize signal strength and minimize packet loss
  - Weight distribution
    - To ensure the probe is steady during descent the centre of gravity needs to be located accordingly to assist in passive stabilization

Probe Mechanical Layout of Components Trade & Selection

18:45



With Heat Shield Slats

Without Heat Shield Slats

Probe Mechanical Layout of Components Trade & Selection

18:45

- **MATERIAL PROPERTIES OVERVIEW**

Criteria or Metric	Thick CardStock	Carbon Fiber	Plywood	Foam	Balsa Wood
Fabrication Complexity	Easy to cut and glue into required shape.	Requires the use of molds or interior structure for manufacturing. Can be drilled or machined if needed.	Can be laser cut and mated together easily.	Can be formed into basic shapes with relative ease. Easy to cut and glue.	Can be laser cut and glued together easily.
Mass	Lightweight	Lightweight	Higher weight	Lightweight	Lightweight
Cost	Low Cost	Higher Cost	Low Cost	Varies based on type of foam but generally low.	Low Cost
Strength	Structurally weak	Strong and durable	Structurally strong and rigid, but susceptible to some cracks.	Varies based on type of foam and can be rigid or soft.	Structurally weak

Good	Average	Bad

Probe Mechanical Layout of Components Trade & Selection

- **MATERIAL SELECTION OVERVIEW**

Area of Application	Material	Justification
Probe Frame and Shell	Plywood and balsa wood	Although plywood has a higher relative weight but is structurally significantly stronger, it is a suitable material to be used in many of the structurally demanding components of the probe frame. It can also be easily manufactured and assembled into the required geometries. The balsa wood is more lightweight than plywood but is not suitable for a load bearing component. As a result it can be used on non structural areas of the probe to reduce the overall mass.
Egg Containment	Foam of varying firmness	Foam is a good material to protect the egg as softer foam can be used to provide sufficient shock absorption with firmer foam for more rigid support. It is also easy to cut into the desired geometries and is able to deform and provide a secure fit to eggs of slightly varying sizes.

Payload Pre Deployment Configuration Trade & Selection

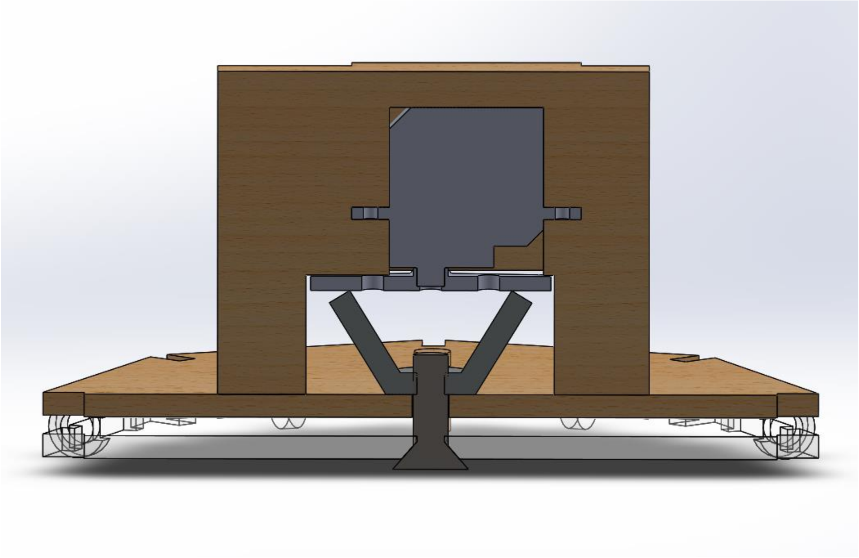
18:45

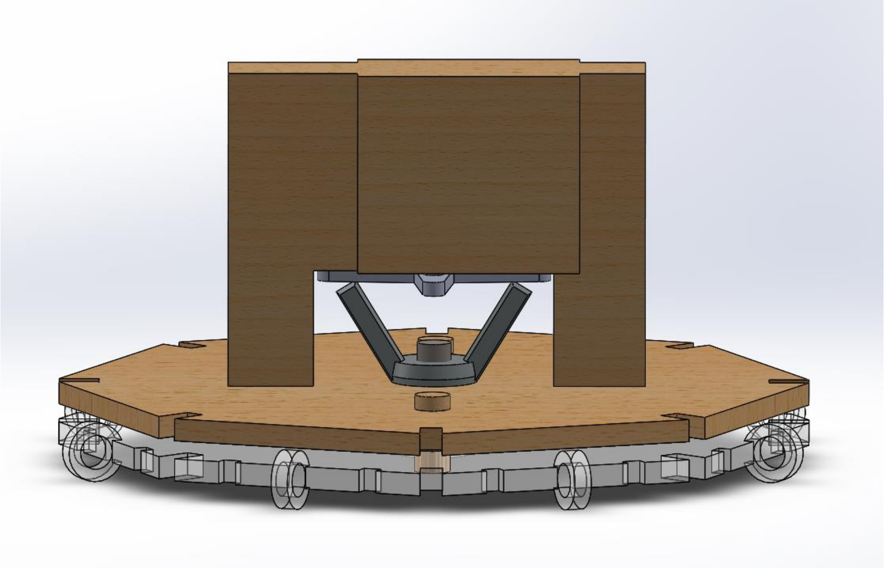
Criterion Metric	Solenoid	Pivot Latch	Motorized Screw in	Magnets
Mass	Solenoids can have high mass when using multiple.	Low mass due to use of servos.	Low mass due to use of a continuous servo.	Magnets typically have a high mass.
Volume	Low volume.	Low volume.	Low volume.	Low volume.
Power Required	Power needed to release pin.	Power needed to activate latch.	Power needed to release screws	Significant power for magnets.
Manufacturability	Simple to make a release pin system.	Simple to make a twist latch.	Servo can easily produce the screw out motion.	Requires additional circuitry.
Reliability & Stability	Very reliable stable due to servos.	Twist latch could be less stable but still generally reliable.	Screw connection is very stable and reliable.	Should be a strong connection with reliable results.
Deployment time	Near instantaneous.	Near instantaneous.	Slower due to screwing out.	Near instantaneous
Chosen Solution: Motorized Screw in	Chosen due to its low mass and volume design which is able to form a very strong and reliable connection between the payload and heat shield. The slower release is not an issue as the parachute should release first.			

Good	Average	Bad

Payload Pre Deployment Configuration Trade & Selection

18:45





Heat shield Deployment Configuration Trade & Selection

18:45

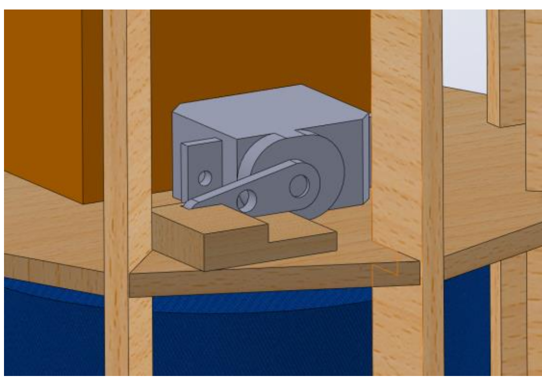
Criterion Metric	Circular/Translational Latch	String & Servo	Magnets	Gears
Mass	Low mass due to simple latch design and one actuator.	String and Servo have low mass.	Magnets are generally high mass.	Complex mechanics has higher mass.
Volume	Higher volume due to large latch connected to each fin.	Low volume, string fed through pins in heat shield fins.	Low volume, as large magnets not required.	Higher volume due to gearing system.
Power Required	Requires some power for release.	Requires some power for release.	Significant power for magnets.	Need to continually actuate gears.
Manufacturability	Latch mechanism easy to manufacture.	Servo latch easy to manufacture.	Mechanically simple.	Difficult due to complex gearing.
Reliability	Reliable and easily repeatable.	Some risk of failure at the string release.	Magnets are usually reliable.	Reliable and easily repeatable.
Deployment time	Release is near instantaneous.	Release is near instantaneous.	Release is near instantaneous.	Release would be slow.
Chosen Solution: String/Rope	The string & servo system has been selected due to its low mass, low volume and the fact that requires only simple manufacturing. The one potential issue of failure at string release can be remedied by a properly chosen latching mechanism.			

Good	Average	Bad

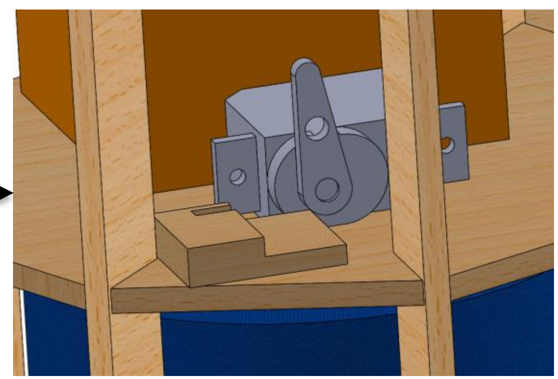
Heat shield Deployment Configuration Trade & Selection

18:45

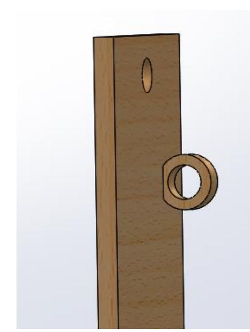
- A rope will be fed through hoops in all of the heatshield slats and will then be clamped in a latch to keeps the slats in stowed configuration.
- When the latch is actuated it will release the tension in the rope and the slats will be able to release into deployed configuration due to spring loading.



Servo in Stowed Configuration



Servo in Deployed Configuration



Example of a hoop on the heatshield slat. Likely to be implemented as a small bracket attached to the slat.

Heat shield Mechanical Layout of Components Trade & Selection

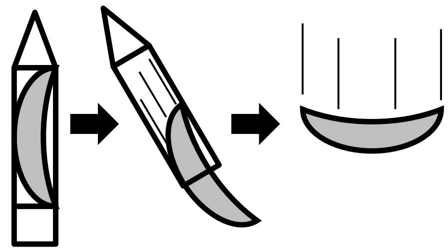
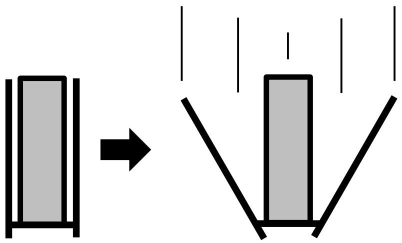
18:45

TITION

- **Key trade issues related to mechanical layout and component selection**
  - Electronic Interface
    - Ensuring that there are no electrical components on the heat shield to interfere with ejection.
  - Weight Distribution
    - To ensure that the probe is steady during descent the centre of gravity needs to be located accordingly to assist in passive stabilization
  - Aerodynamics for Descent
    - The shape of the heat shield and position of the payload in it must be so that the probe does not tumble during the descent.

Heat shield Mechanical Layout of Components Trade & Selection

18:45

Criteria/Metric	Horizontal (Boat) Layout	Vertical Cylinder Layout
Design Structure		
Stability	Vulnerable to longer period of tumbling prior to stabilization.	More resistant to tumbling and will stabilize more rapidly.
Deployment Speed	No active deployment necessary.	Depends on deployment mechanism.
Reliability	Consistent performance due to no active deployment but may not reliably stabilize the probe due to possible tumbling.	Can reliably stop tumbling, however it depends on the reliability of deployment mechanism.
Manufacturability	More complex geometrically but lack of movement is simple.	Simple geometrically but movement adds some complexity.
Chosen Solution: Vertical Cylinder Layout	This layout was chosen primarily due to the fact that it will be able to stabilize the probe and prevent tumbling much more reliably.	

Good	Average	Bad

Heat shield Mechanical Layout of Components Trade & Selection

- **MATERIAL PROPERTIES OVERVIEW**

Criteria or Metric	Thick CardStock	Carbon Fiber	Plywood	Foam	Balsa Wood
Fabrication Complexity	Easy to cut and glue into required shape.	Requires the use of molds or interior structure for manufacturing. Can be drilled or machined if needed.	Can be laser cut and mated together easily.	Can be formed into basic shapes with relative ease. Easy to cut and glue.	Can be laser cut and glued together easily.
Mass	Lightweight	Lightweight	Higher weight	Lightweight	Lightweight
Cost	Low Cost	Higher Cost	Low Cost	Varies based on type of foam but generally low.	Low Cost
Strength	Structurally weak	Strong and durable	Structurally strong and rigid, but susceptible to some cracks.	Varies based on type of foam and can be rigid or soft.	Structurally weak

Good	Average	Bad

Heat shield Mechanical Layout of Components Trade & Selection

18:45

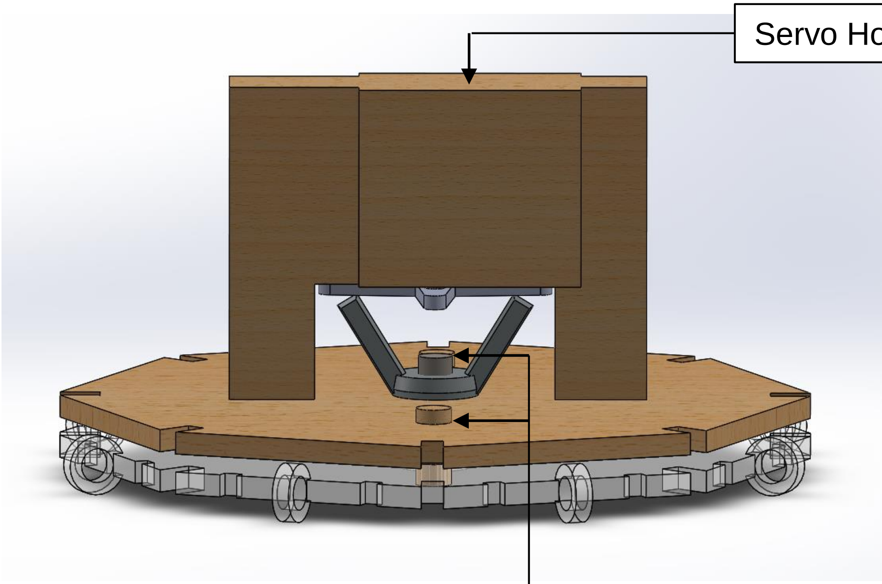
- **MATERIAL SELECTION OVERVIEW**

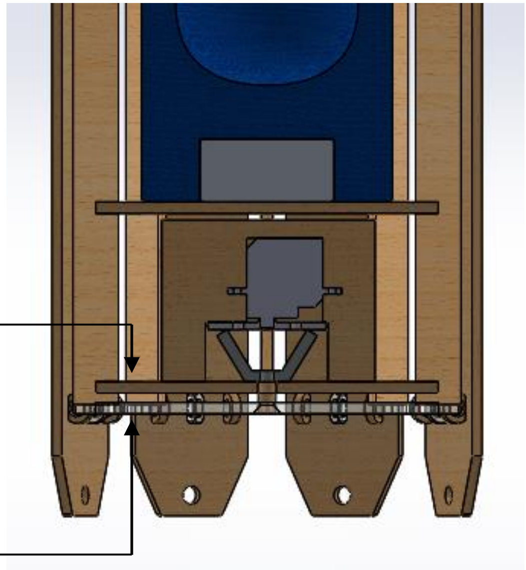
Area of Application	Material	Justification
Heat Shield	Balsa wood with carbon fibre reinforcement as necessary.	It is desirable to keep the heat shield as light weight as possible and as a result balsa wood is a good material choice. However to help it meet the structural demands it will be necessary to use carbon fibre as reinforcement on the fins. That will greatly improve the strength of the fins while maintaining a low mass.

Heat shield Release Mechanism

18:45

- A servo turns a wing nut which allows the heatshield base plate (attached to the heatshield slats) to separate from the probe base plate.
- To prevent the heatshield from twisting two dowels are used as pins.



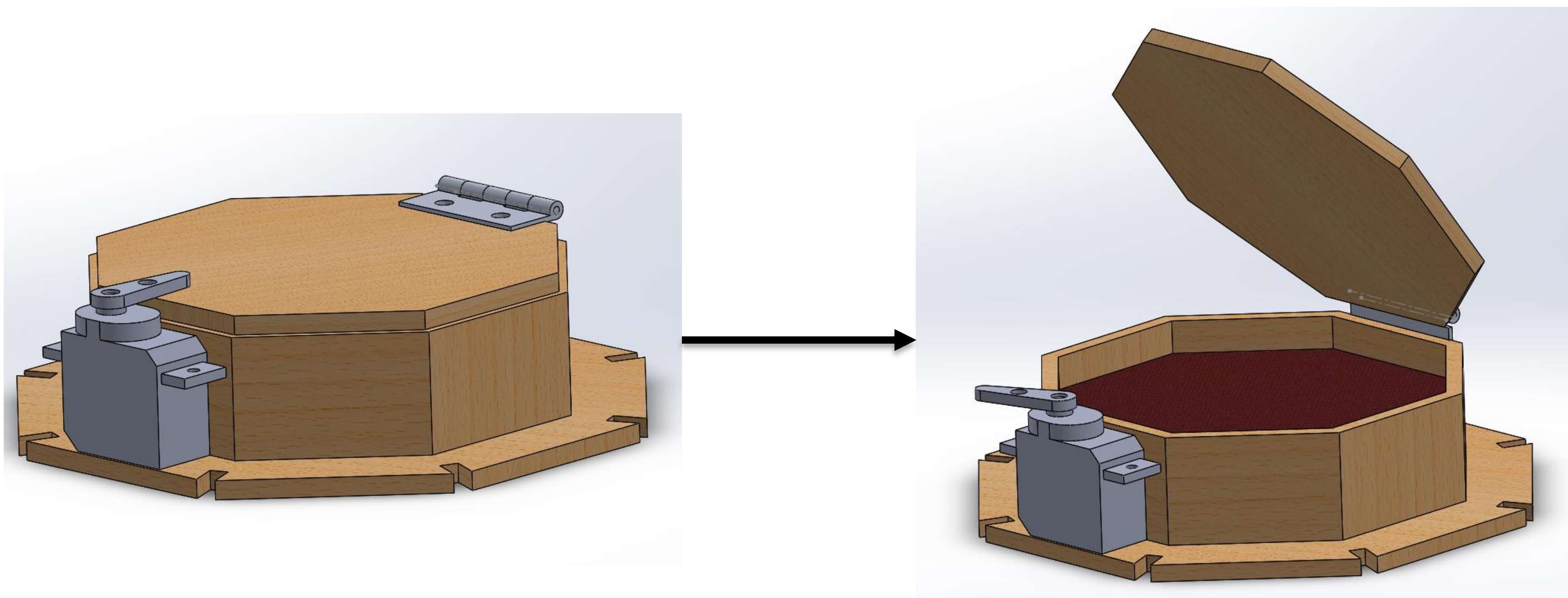


Probe Parachute Release Mechanis

18:45

TITION

- The parachute employs a spring and cap mechanism.
- When the servo is actuated it frees the lid which is opened by a spring loaded system.
- The parachute is then ejected out of the container by a spring allowing it to deploy.

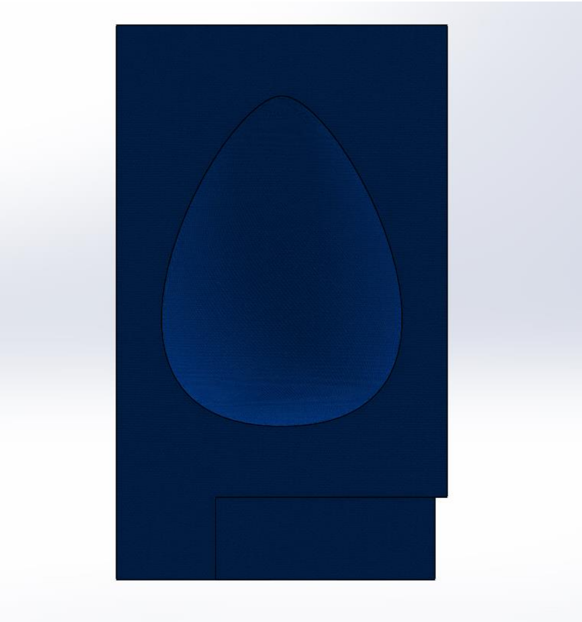


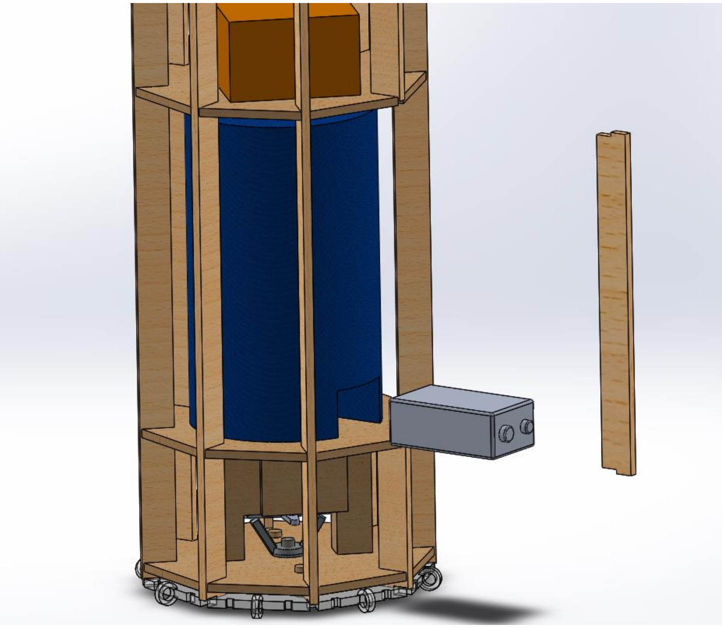
Egg Protection Structure

Criteria/Metric	Air Bags	Foam Casing	Bubble Wrap
Cost	Balloons and container to hold egg are low cost.	Foam can vary in price but is generally low cost.	Bubble wrap is easily attainable at a low cost.
Mass	Low mass due to the use of air to absorb shock.	Relatively low mass but more than air cushions.	Low mass due to the use of air bubbles.
Reliability	Has a risk of popping or pressure loss which could cause failure.	Very reliable and the outcome should be consistent.	Risk of some bubbles popping although many would need to pop before failure.
Manufacturability	Easily made by creating a holding case for the balloons.	Foam can easily be cut into the required shape to hold the egg.	Easily made by wrapping the egg in the required amount of bubble wrap.
Chosen Solution: Foam Casing	Due to low cost, relatively low mass, and reliable performance with minimal risk of failure a foam casing was chosen.		

Good	Average	Bad

Egg Protection Structure





- The foam case will be stored above the heat shield interface near the bottom of the probe.
- It can be removed through the side of the frame after part of one of the beams (which clips into place) is removed.

- The egg can be inserted into the foam casing by removing as section of the foam as shown above.
- The battery is also housed in the egg compartment and is accessed in the same way.

Electronics Structural Integrity

- Mounting
  - All electrical components will be mounted via stand-offs
    - It has been shown in previous years that they were able to withstand impacts as expected
  - Batteries will be additionally secured with duck tape to minimize risk of ejection upon impact.
- Enclosures
  - Probe frame will act as an enclosure for the electronics
  - Makes the electronics easier to access as opposed to their own dedicated enclosure inside the frame.
- Electrical Connections
  - Hot glue will be used to ensure electrical connections do not separate

Mass Budget

18:45

Component/Structural Element	Quantity	Mass/Unit (g)	Margin (g)	Total Mass (g)	Source
PB: Frame Beams	8	8	1.2	73.6	Estimate
PB: Frame Plates	4	19	2.85	87.4	Estimate
PB: Parachute	1	45	2.25	47.25	Data Sheet
PB: Parachute Release Mech	1	15	2.25	17.25	Estimate
PB: Patch Antenna	1	1.5	0.075	1.575	Data Sheet
PB: Electrical Wires	N/A	20	3	23	Estimate
PB: Fasteners	N/A	15	2.25	17.25	Estimate
PB: Battery	1	33.9	1.7	35.6	Data Sheet
PB: Heatshield Release Mech	1	15	2.25	17.25	Estimate
PB: Egg	1	68	10.2	78.2	Estimate
PB: Egg Foam Container	1	15	2.25	17.25	
HS: Slats	8	5	0.75	46	Estimate
HS: Fabic	1	10	1.5	11.5	Estimate
HS: Base Plate	1	20	3	23	Estimate
Total Mass				**496.125**	

- Total estimated mass is 496.125 g (Mass will be adjusted as the design alters to meet mass req.)
- Probe mass: 415.625 g
- Heatshield mass: 80.5 g
- 15% error margin is applied to estimated values
- 5% error applied to values from data sheet

Communication and Data Handling (CDH) Subsystem Design

Eric Boszin

CDH Overview

21:15

- Payload Controller: Arduino Nano
  - Queries sensors, flight state control, compiles communication packets and sends packets to transceiver
- Real-Time Clock : DS3231 Chip (I2C)
  - Possesses battery backup capabilities
- RF Transceiver: XBee-Pro 900HP
- Antenna: Taoglas FXP290
  - Omnidirectional, decent gain, linearly polarized
  - range testing needed

CDH Requirements

21:15

No.	Requirement
6	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.
18	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.
21	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.
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.
26	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.
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.
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.
29	XBEE radios shall have their NETID/PANID set to their team number.
30	XBEE radios shall not use broadcast mode.

Probe Processor & Memory Trade & Selection

Criterion [Metric]	Raspberry Pi 3	Arduino Nano	Arduino Pro Mini
Communication Connections	40 GPIO pins 4 USB ports UART, CSI Sufficient pins but not cost-effective for the redundant pins	22 Digital Pins (6 PWM) 8 Analog Pins UART, I2C, SPI Sufficient pins to work with	14 Digital Pins (6 PWM) 6 Analog Pins UART, I2C, SPI Not enough pins
Memory	1GB RAM 8GB MicroSD Sufficient memory but not cost-effective for the redundant memory	32KB Flash 2KB SRAM 1KB EEPROM Enough memory	32KB Flash 2KB SRAM 1KB EPROM Enough memory
Processor	ARM Cortex-A53 (1.2GHz) High processing speed, full support to all tasks	ATmega328 (16MHz) Acceptable speed, enough to support most related tasks	ATmega328 (16MHz) Acceptable speed, enough to support most related tasks
Power	250mA baseline (1.2W) consume too much power for a power critical project	50mA@5V (0.25W) Decent power consumption	40mA@5V (0.2W) Decent power consumption

Good	Average	Bad

Probe Processor & Memory Trade & Selection

21:15

Criterion [Metric]	Raspberry 3	Arduino Nano	Arduino Pro Mini
Size/Weight	85.6x56.5mm/45g Size is too large for a compact space	45x18mm/5g Acceptable size	33x18mm/2g Relatively small size, good fit for a compact container
Programming	Python, no external computer required Ease of use Ease for debugging Abundant and easily accessible modules	Arduino IDE, requires external computer Abundant online support Ease of use Limited functionalities	Arduino IDE, requires external computer Abundant online support Ease of use Limited functionalities
Price	$35	$25-35	$10-15
Chosen Solution: Side of Cylinder	Candidate 2 is chosen due to its good overall performance including sufficient D I/O pins, memory and processing speed to manage various tasks with a relatively low overhead in power consumption and programming development		

sufficient pins and memory and processing speed, with low overhead in in power consumption and programming development

Good	Average	Bad

Probe Real-Time Clock

21:15

TITION

Criterion [Metric]	DS1307	DS3231
Operating voltage [V]	5	3.3
Operating current [mA]	1.5	0.3
Cost [$USD]	7.50	13.95
Size [mm]	25.8*21.7*5	23*17.6*7.2
Interface	I2C	I2C
Backup battery	Yes	Yes
Mass [g]	Due to extremely small size, mass is ignored	
Chosen Solution: DS3231	DS3231 was chosen because the “operating voltage and current” criterion were given the highest priority due to power distribution concerns.	

Good	Average	Bad

Probe Antenna Trade & Selection

- **Antenna selection criteria:**
  - –omnidirectional pattern
  - –900 MHz and maximum range
  - –high gain
- **Antenna range and patterns**
  - –2 km maximum range
  - –Line of sight (LOS) coupling
  - –Linear polarization for better range
- **Module: XBee-PRO 900HP**
  - –up to 5 km range with 1.5 dBi dipole antenna
  - –156 kbps data rate
  - –RPSMA connector

Probe Antenna Trade & Selection

21:15

Criterion [Metric]	Taoglas FXP290	A09-HASM-675	APAE915R2540ABDB1-T
Cost [USD]	24.76	31.24	25.70
Type	PCB Patch	Whip	Ceramic Patch
Gain	1.5 dBi	2.15 dBi	4.5 dBic
VSWR	≤2:1	1.9:1	1.5:1
Frequency [Range]	915 (902-928) MHz	915 (902-928) MHz	915 (902-928) MHz
Polarization	Linear	Linear	Right Hand Circular
Dimensions	75mm x 45mm x 0.1 mm	171 mm x 7 mm x 10 mm	25 mm x 25 mm x 4.6 mm
Weight	1.5 g	25 g	N/A
Connector	U.FL (need adapter)	RPSMA	RPSMA
Chosen Solution: Taoglas FXP290	The Taoglas is chosen over the whip antenna because it has a more reliable radiation pattern and is cheaper, lighter, with similar gain and VSWR.		

Good	Average	Bad

Probe Radio Configuration

- **Communication with module is done through serial UART**
  - Requires modules to operate using same format (ie. baud rate)
- **Configuration:**
  - Transparent mode: since we are only communicating between two Xbees (may compare with API once testing begins)
  - HP and ID set to team number
  - Unicast: DH:DL of each radio will be set to the SH:SL of the other
  - Point to Point/Multipoint (P2MP) mode (TO = 0x40)
  - Cansat radio will be in Asynchronous Pin Sleep Mode and wake on transmission (SM=1), Ground station radio will not sleep (SM=0)
  - Other params: PL=4, RR=to be determined, CM=0x00FFFFFFFFFFFFFF (all channels, but may use ED to disable channels on competition date)
- **Transmission control:**
  - Initialize at parachute stabilization stage
  - Begin transmission at deployment
  - Put Cansat radio to sleep on ground impact and terminate transmission

Probe Telemetry Format

21:15

- **Format of packets:**

<TEAM_ID>, <MISSION_TIME>, <PACKECT_CNT>, <ALTITUDE>, <PRESSURE>, <TEMP>, <VOLTAGE>, <GPS TIME>, <GPS LATITUDE>, <GPS LONGITUDE>, <GPS ALTITUDE>, <GPS SATS>, <TILT X>, <TILT Y>, <TILT Z>, <SOFTWARE STATE>

In terms of ASCII characters (each character is a placeholder):

tmID,hh.mm.ss,pac#,altd.#,Psi.xx,To,Vi,GPSTIME###,-##.latitu,-##.longitu,-alt.##,S#,Tlx,Tly,Tlz,#\n

- –100 ASCII characters (8 bits each) = 800 bits per packet excluding overhead

- **With overhead and repeat requests, data transmission rate should still only be in the range of 1-10 kbps assuming 1 Hz sample rate**
- **Burst transmission**
- **Testing will yield an appropriate data rate and hence sample rate**

Electrical Power Subsystem (EPS) Design

Shahin Jafari

EPS Overview

22:55

Main Power
(battery)

Interface Elements
(switches, light indicators)

Regulation
Regulate voltage level to requirements of certain electronics

Measurement of battery level

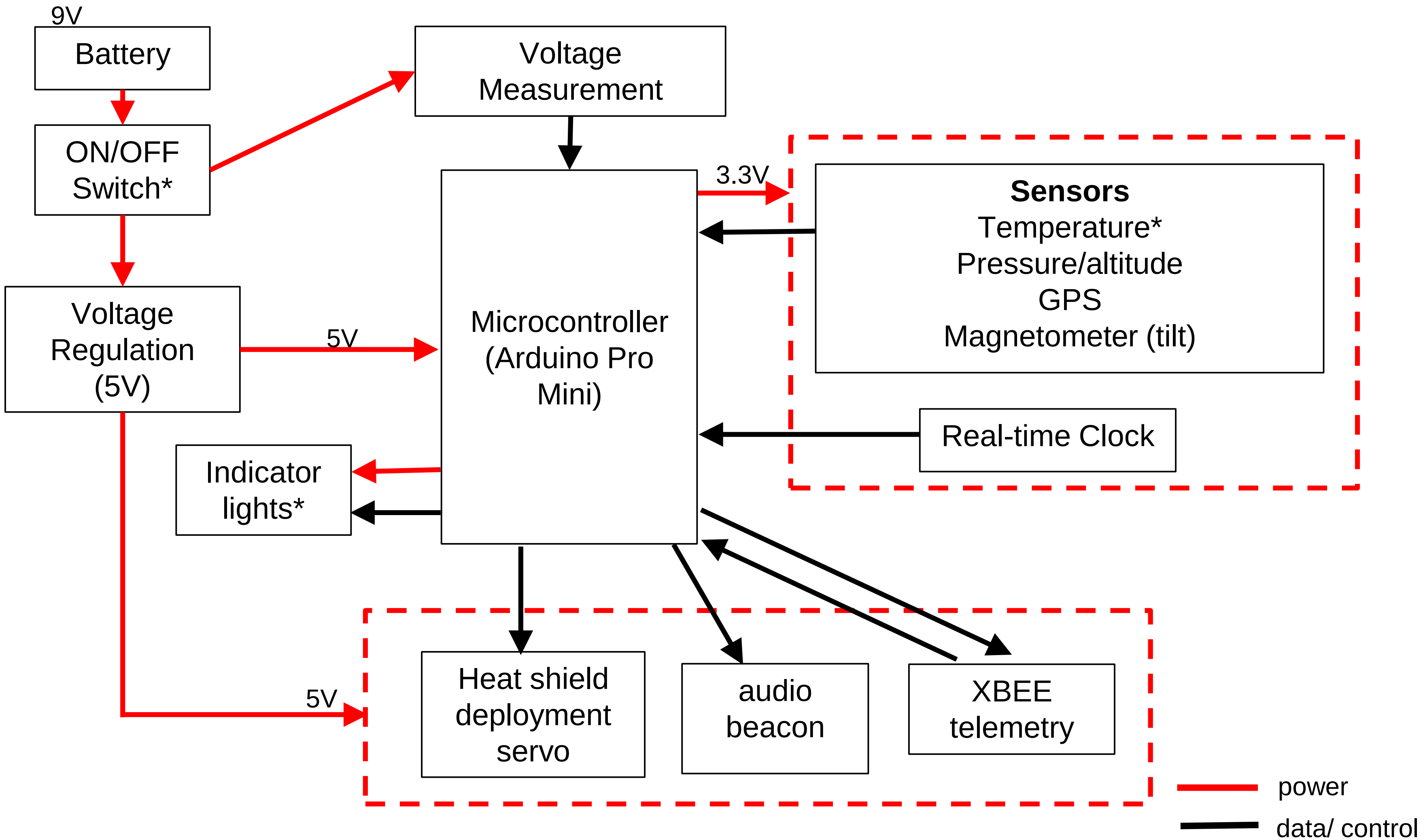
Probe System
(microcontrollers, heatshield deployment, sensors, telemetry, audio beacon, etc.)

EPS Requirements

22:55

No.	Requirement
6	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.
18	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.
21	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.
40	No lasers allowed.
41	The probe must include an easily accessible power switch.
42	The probe must include a power indicator such as an LED or sound generating device.
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.
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.
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.
48	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.

Probe Electrical Block Diagram



*These components are externally accessible and/or visible

RSX Robotics for Space Xploration

Probe Power Trade & Selection

22:55

Criterion [Metric]	AA x3	AAA x3	9V
Nominal voltage [V]	1.5 x 3 = 4.5	1.5 x 3 = 4.5	9
Cost	low	low	medium
Size	large	medium	medium
Chosen Solution: 9V	Candidate 3 was chosen because of high nominal voltage and operating time under 1W of power.		

Good	Average	Bad

Probe Power Trade & Selection

22:55

TITION

Criterion [Metric]	Nickel-Cadmium (NiCd)	Nickel-Metal-Hydride (NiMH)	Lithium Ion
Energy Density	low	medium	high
Cost	low	low	medium
Robustness	high	medium	high
Compactness	medium	medium	high
Chosen Solution: Lithium Ion	Candidate 3 was chosen because of high energy density, robustness and compactness		

Good	Average	Bad

Probe Power Budget

22:55

Component	Duty Cycle	Power (mW)	Time (min)	Uncertainty (%)	Total (mWh)	Source
Microcontroller	>100	250	60	20	300	testing
Pressure/Altitide	>300	0.7	60	15	0.805	data sheet
Temperature	>300	1.25	60	20	1.5	data sheet
GPS	>300	66	60	10	73	data sheet
Magnetometer	>300	0.36	60	20	0.432	data sheet
Audio	>300	40	60	20	48	data sheet
Indicator Lights	>300	50	60	10	55	data sheet
Voltage Regulation	>300	10	60	30	13	data sheet
XBEE	>300	7.7	60	20	9.24	data sheet
Deployment Servos (x3)	>100	3750	0.08	30	390	Data sheet
				Total	**891**	**mWh**

Probe Power Budget

Choose the Energizer L522:

- **750mAh of power @ 200mA discharge rate**
- **750mAh ~= 5400mWh (@ ~7V average)**
- **9V Lithium Ion with metal casing**

Available Power	Power Required
5400mWh	891mWh

- **Battery clips will be used to secure connection**
- **Source for specifications: http://data.energizer.com/pdfs/l522.pdf**

Flight Software (FSW) Design

Eric Boszin

FSW Overview

- **Basic FSW architecture**
  - Initialize daemons and backend scripts
  - Initialize sensors, report/log status
  - Perform system checks (CPU, memory, signal, battery)
  - Create new directories and logging files for new mission profile
- **Development language(s): C/C++**
- **Development environment(s): Sublime, Arduino IDE**

FSW Overview

- **Major tasks to perform:**
  - Configure and poll sensors
  - Collect and transmit data
  - Monitor system status and log errors
  - Determine different fight stages and actions
  - Command actuators for deployment
  - Count data packets
  - (optional bonus; not pursued) Command color video camera to capture image data for the final 300m of descent
  - (optional bonus; pursued if time permits) Custom radio transmitter to indicate wind speeds during mission

RSX Robotics for Space Xploration

FSW Requirements

25:00

No.	Requirement
14	The aero-braking heat shield shall be released from the probe at 300 meters.
15	The probe shall deploy a parachute at 300m.
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.
26	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts
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.
29	XBEE radios shall have their NETID/PANID set to their team number.
30	XBEE radios shall not use broadcast mode.
32	Each team shall develop their own ground station.
33	All telemetry shall be displayed in real time during descent.
34	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)
35	Teams shall plot each telemetry data field in real time during flight.
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.

FSW Requirements

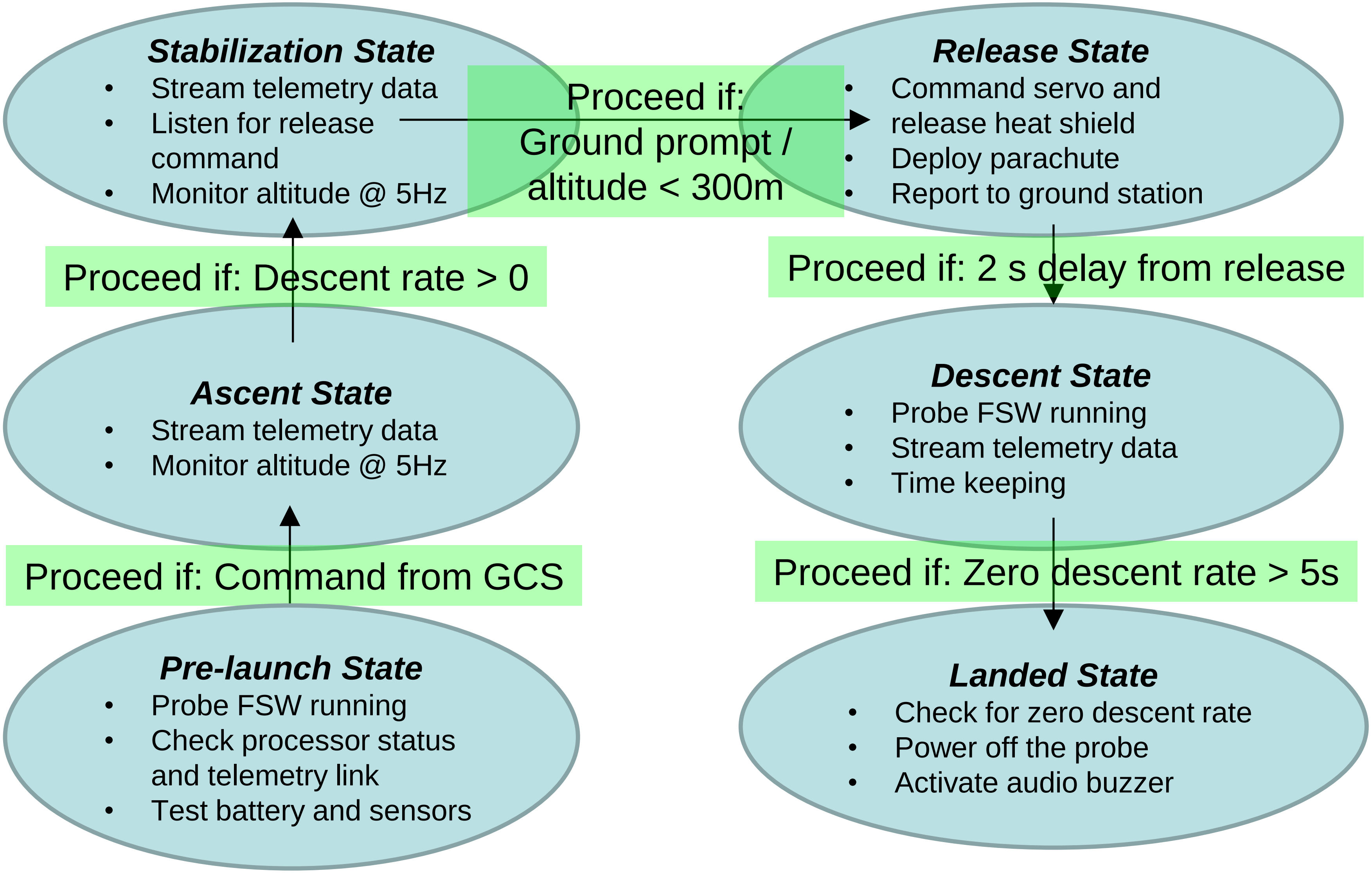
25:00

TITION

No.	Requirement
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.
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.

Probe FSW State Diagram

25:00



Probe FSW State Diagram

RESET LOGIC

FSW recovery to correct state after processor reset during flight:

State = Ascent state

If (Descent rate > 0 & altitude > 300)
  State = Stabilization State
Elseif (Descent rate > 0 & altitude <= 300)
 State = Release State
Elseif (Zero descent rate > 5s)
  State = Landed State
end

% descent state is entered from release state only (not directly on reset) to ensure the probe is released regardless of a processor reset

Software Development Plan

25:00

- **Subsystem development (21 Feb. – 28 Mar.)**
  - Modularity: divide system codes into different modules to enable parallel development
  - Encapsulation: define module interfaces, black box module implementation to reduce mutual dependencies
- **Testing methodologies (30 Mar. – 6 May)**
  - Unit tests: used to debug and refine sub-modules
  - Simulated environment: used to examine codes in the absence of actual input
  - Benchmarks: used to evaluate software performances
  - Quick and dirty implementations, frequent and early testing

Software Development Plan

- **Development team (Johnny, Eric, Shahin)**
  - Early stage (21 Feb. – 29 Feb.): sub-modules will be distributed to avionics subteam members, working independently to work out the basic functionalities
  - Middle stage (1 Mar. – 20 Mar.): combine modules, test and refine their performances
  - Final stage (21 Mar. - 28 Mar.): finalize the codes and documentations

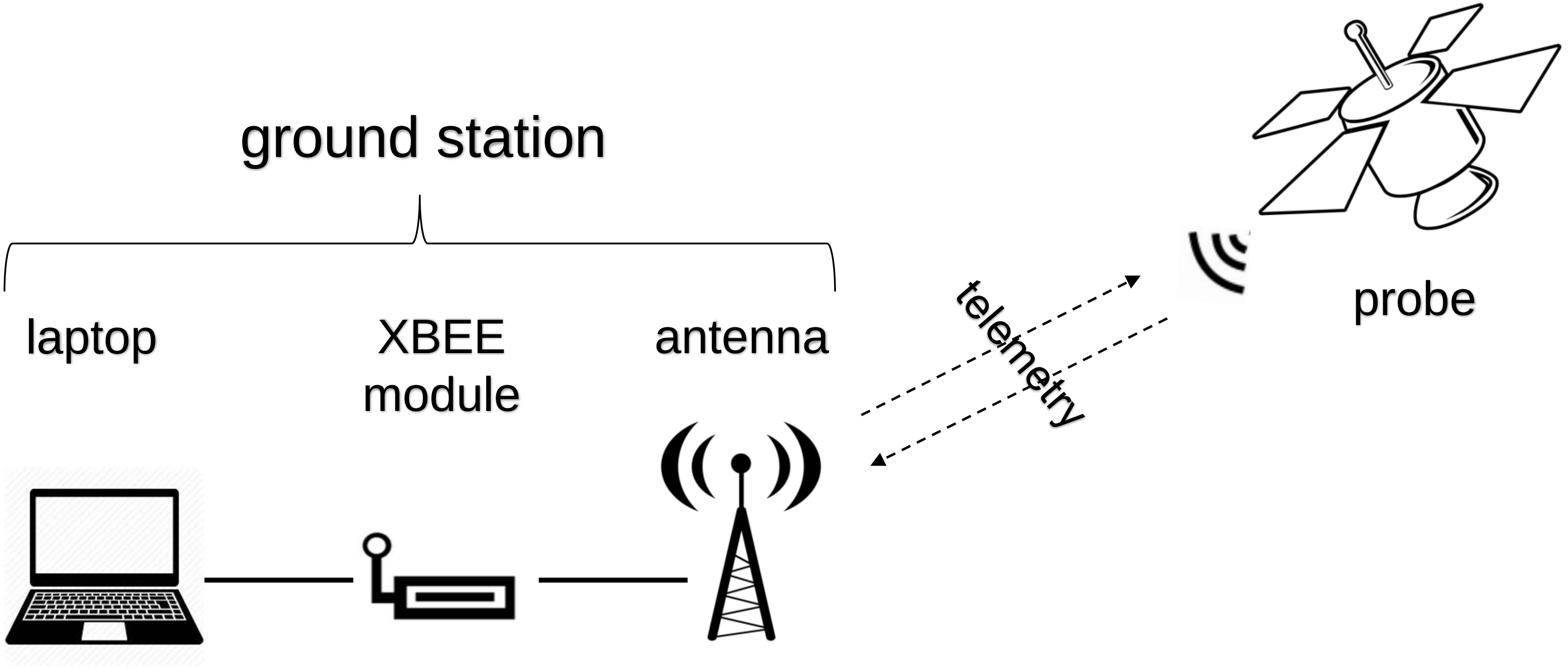
- **Prototyping environment**
  - Using the same Sublime & Eclipse IDEs
  - Test function and reliability of individual modules
  - Integrate with all functional modules

Ground Control System (GCS) Design

Johnny Wang

GCS Overview

- The antenna detects and collects the telemetry from the probe, transmits it to the laptop through the XBEE module.
- The base laptop processes the signal, extracts data and displays it in the specified format.



GCS Requirements

26:40

No.	Requirement
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.
29	XBEE radios shall have their NETID/PANID set to their team number.
30	XBEE radios shall not use broadcast mode.
32	Each team shall develop their own ground station.
33	All telemetry shall be displayed in real time during descent.
34	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)
35	Teams shall plot each telemetry data field in real time during flight.
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.
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.

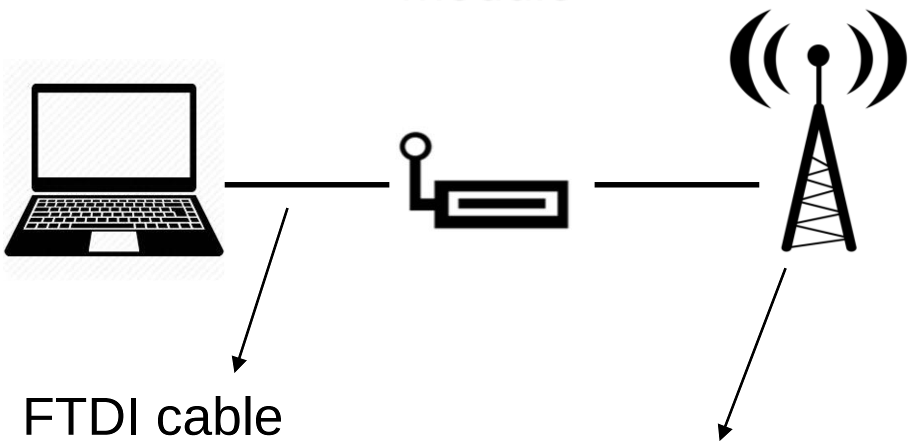
GCS Design

26:40

laptop

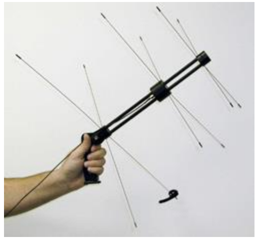
XBEE module

antenna



FTDI cable

Hand-held



- Base laptop and the XBEE radio module are connected by a FTDI cable.

- To allow a dynamic and accurate detection, the antenna will be hand-held instead of being fixed to the ground

- **Laptop has a minimum of 2 hours battery and an average of 4 hours battery when fully functioning.**
- **Covers will be used to prevent laptop from exposing in the open sun. Laptop cooling pad can help mitigate heating effect.**
- **Ubuntu Linux will be used to run the GCS to avoid auto-updates.**

GCS Antenna Trade & Selection

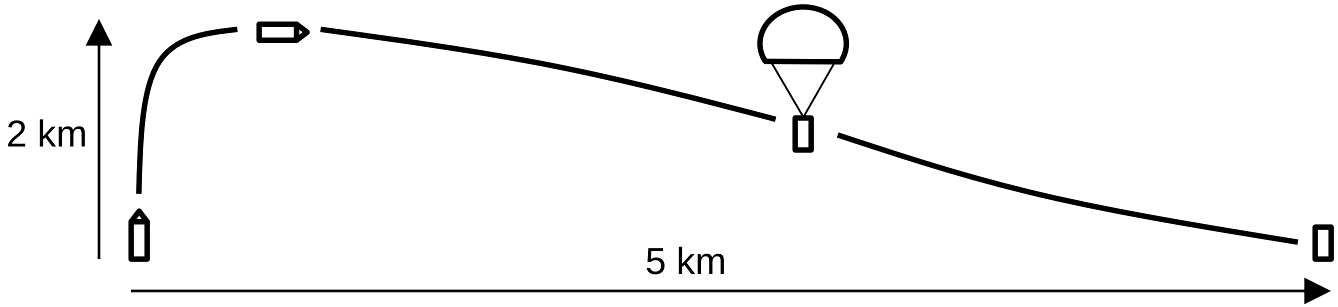
26:40

Criterion [Metric]	Half-wave dipole	Grid antenna
Mass & Volume [g]	Light & small (~15cm long)	Large & bulky due to parabolic shape
Gain	2 dBi gain at broadside	~70dBi
Propagation	Omni-directional	Directional
Chosen Solution: Grid antenna	Due to past experiences of poor connection using a Half-wave dipole antenna, a grid antenna will be used for higher gain and directional tracking. This solution will require manual hand-held tracking.	

Good	Average	Bad

GCS Antenna Trade & Selection

- Maximum expected distance from GCS to Cansat is ~ 5km with Line of Sight (LOS):

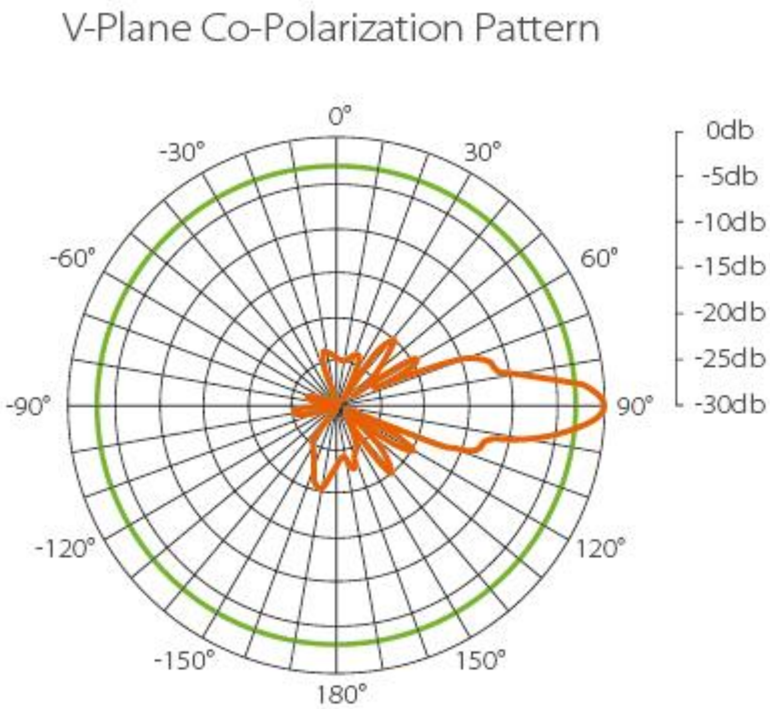


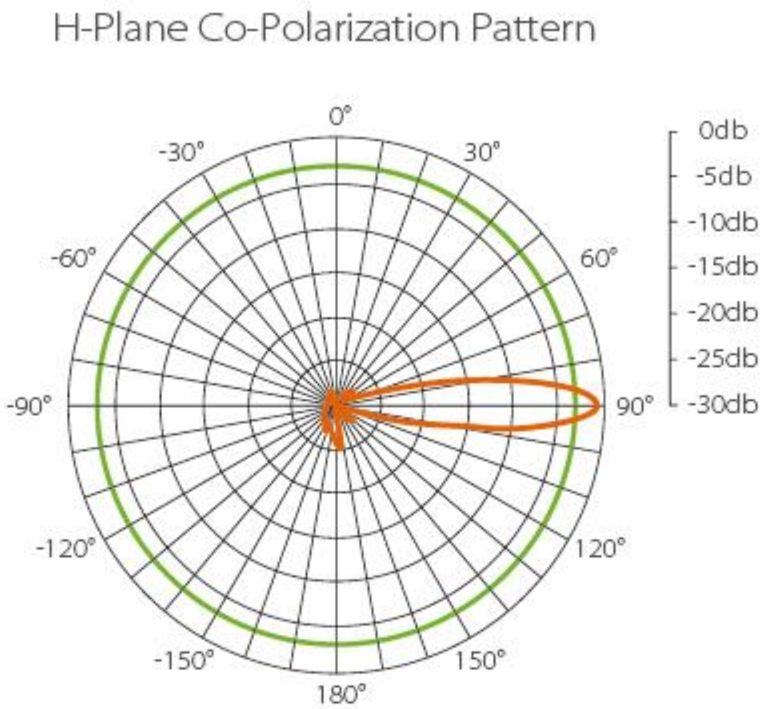
- Link budget:

Term	P_t	G_t	FSPL	G_r	Wire Loss	P_r	RX Sensitivity	Margin
Value [dBm]	24	2	105.5	2	1	-78.5	-101	22.5

- Since the link is LOS and not exceptionally far, high gain antennas are not needed
- To avoid Cansat tracking issues, a directional antenna will be used for high gain
- Choose grid antenna:
  - ~70dBi gain
  - Provides sufficient directional beam propagation
  - Does not require highly accurate hand tracking
  - Available sizes to be hand-held

Antenna Radiation Pattern

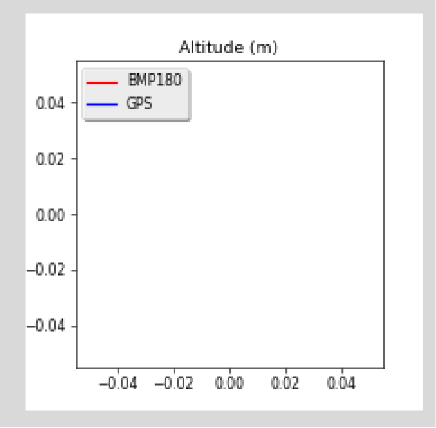




GCS Software

- Development language(s): Python
- Tkinter library: design the user interface
- Matplotlib: render 2D real time data plotting

- GUI includes control commands, settings and data display
- The display support auto-scaling for dimension changes
- No COTS software packages are used



26:40

TITION

GCS Telemetry Display

Probe configuration

Telemetry plots

Control commands

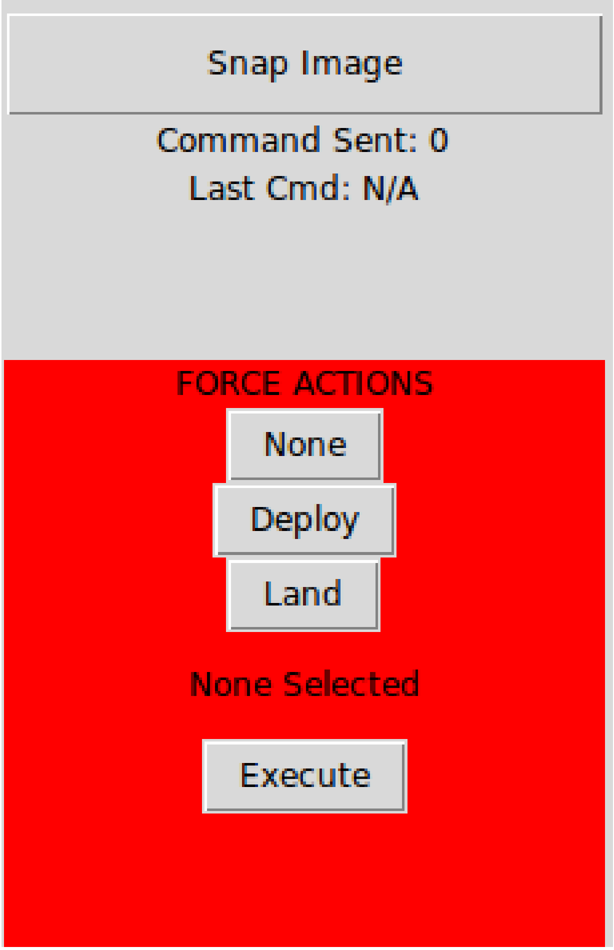
Telemetry data stream

GCS Software

26:40

GCS Interface & Commands

- GCS commands include:
  - Force commands
    - force probe actions if anomaly occurs
  - Function commands
    - Control probe to perform specific functions during data collection



Telemetry Data Format

- **During transmission, telemetry data complies with the format:**

  <TEAM_ID>, <MISSION_TIME>, <PACKECT_CNT>, <ALTITUDE>, <PRESSURE>, <TEMP>, <VOLTAGE>, <GPS TIME>, <GPS LATITUDE>, <GPS LONGITUDE>, <GPS ALTITUDE>, <GPS SATS>, <TILT X>, <TILT Y>, <TILT Z>, <SOFTWARE STATE>

- **GCS creates a comma separated value file (.csv) named: "CANSAT2018_TLM_1138_RSX.csv"**

- **GCS automatically appends processed data stream**

- **First line of the output file identifies each column**

- **All data displayed in engineering units (m, m/s, degrees, Celsius, etc)**

GCS Bonus Wind Sensor

- **The wind sensor bonus will be pursued if time permits**
  - This will be an add-on to the ground station
  - No significant changes needs to be made to the core design if we decide to use the remaining time to pursue this bonus

CanSat Integration and Test

Johnny Wang

CanSat Integration and Test Overview

27:05

- **Subsystem level testing plans (1 April – 6 May):**
  - Perform tests before CanSat integration to assess individual subsystems (details on slide 107)
- **CanSat Integration Deadline (6 May):**
  - Probe (Heat shield + payload structures) components are integrated with avionics (PCB's, radio, antennas)
- **FULLY integrated system functional testing plans (6 – 20 May):**
  - Integrated CanSat system is tested on the ground to ensure individual subsystems meet performance requirements when functioning together (details on slide 108)
  - Mission is simulated from payload release stage using a quadcopter to perform a drop test (details on slide 108)
- **Environmental testing plans (20 – 27 May):**
  - Drop, thermal, and vibration tests performed as per the Environmental Testing Requirements document(details on slide 109)

Subsystem Level Testing Plan

27:05

TIMELINE: 1 April – 6 May (Following tests are performed before CanSat integration to test individual subsystems)

- **Sensors:** use breadboard to assess if sensors provide accurate readings
- **CDH:** use microcontroller board to verify microcontroller output signals
- **EPS:** place 9V battery under simulated load to assess power supply duration. Ensure all onboard electronics are robustly powered and no power dips causing system reset.
- **Radio communications:** test range of radio and antenna on the ground to validate if required performance and range is met
- **FSW:** feed simulated sensor data to FSW to ensure GUI works as planned
- **Mechanical:** Perform probe drop test with dummy masses before integration of circuits to test structural integrity
- **Descent Control:** Perform heat shield and parachute mockup tests before integration with dummy masses to assess performance

TIMELINE: 6 – 20 May (performed after FULL CanSat integration)

- **Communications**
  - Data transmission range will be tested on the ground for the probe to ensure interference from structures is minimal
- **Mechanisms**
  - Moving mechanisms will be tested on the ground to inspect for full range of motion after integration to ensure no parts clash
- **Deployment**
  - Heat shield deployment will be inspected for any part clashes
  - HS ejection mechanisms will be run with the HS extended to test for successful ejection
  - Parachute deployment will be tested for successful deployment of parachute
- **On-board System testing**
  - Mission simulation will be performed by deploying the probe from >300m using a quadcopter

Environmental Test Plan

27:05

TITION

TIMELINE: 20 -27 May

- **Drop test**
  - The probe with heat shield inside it will be dropped 80cm when suspended by the parachute line as per the Environmental Testing Requirements document
- **Thermal test**
  - Thermal chamber fabricated for 2016 competition will be used to test the CanSat at high temperatures (55-60°C) as per the Environmental Testing Requirements document
- **Vibration test**
  - Orbit sander will be used as a “shake table” for the CanSat system as per the Environmental Testing Requirements document

27:05

ITION

Mission Operations & Analysis

Johnny Wang

Overview of Mission Sequence of Events

27:05

1. Arrival at launch site (All members)
2. Construction and mounting of antenna (Johnny & Shahin)
3. Set up and test ground station (Johnny & Eric)
4. Set up and assemble CanSat (MC, Ryan, Ali, Andrew)
5. Power on CanSat and conduct subsystem tests (MC, Ryan, Johnny)
6. Walk through CanSat preflight checklist (All members)
7. Load CanSat in container, ensure CanSat is securely latched (MC, Ryan)
8. Final telemetry tests (Johnny, Eric)
9. Load container into rocket (MC)
10. CanSat is launched and continues autonomously through flight states
11. Tracking and retrieval of CanSat upon touchdown (Johnny, Ali, Shahin)
12. Retrieval of data stored onboard for further analysis (Johnny, Eric)

Mission Operations Manual Development Plan

- **Primary components of Mission Operations Manual**
  - Preparation and readiness of CanSat
  - Testing of subsystem functionalities and nominal operations
  - Pre-flight checklist

- **Development**
  - Each subteam will create their own documents summarizing key checkpoints and important details of components
    - Allows for isolated testing and debugging
  - Members involved in subsystem integration will summarize key aspects of integration and update documents accordingly
  - GitHub version controlled wiki will be used to curate and share notes across subteams

CanSat Location and Recovery

27:05

- CanSat will be visually tracked from launch until touchdown by all members
  - Some members will be equipped with binoculars
- CanSat can be audibly tracked using piezo beacon signal after landing
- Heat shield will be fluorescent pink in order to have a colour contrast with the field
- In the event that the CanSat drifts too far and is lost or unreachable, our return address, phone number and email will be written on the probe and heatshield to ensure its return
- Latest GPS coordinates received indicates the approximate region

27:30

Requirements Compliance

Johnny Wang

Requirements Compliance Overview

27:30

Current design complies with most stated requirements.

No serious issues due to non-compliance.

Requirements which require further testing to confirm compliance:

- 16: All descent control device attachment components shall survive 30 Gs of shock.
- 17: All descent control devices shall survive 30 Gs of shock.
- 19: All structures shall be built to survive 15 Gs acceleration.
- 20: All structures shall be built to survive 30 Gs of shock.

Requirements Compliance

27:30

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
1	Total mass of the CanSat (probe) shall be 500 grams +/- 10 grams.	Comply	61	
2	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	10, 51	
3	The heat shield must not have any openings	Comply	51	
4	The probe must maintain its heat shield orientation in the direction of descent.	Comply	10	
5	The probe shall not tumble during any portion of descent. Tumbling is rotating end-over-end.	Comply	10	
6	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	12	
7	The probe shall hold a large hen's egg and protect it from damage from launch until landing.	Comply	59	
8	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	59	
9	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	12, 45, 51	

Requirements Compliance

27:30

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
10	The aero-braking heat shield shall be a florescent color; pink or orange.	Comply	110	
11	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	16	
12	The rocket airframe shall not be used as part of the CanSat operations.	Comply	16	
13	The CanSat, probe with heat shield attached shall deploy from the rocket payload section.	Comply	16	
14	The aero-braking heat shield shall be released from the probe at 300 meters.	Comply	85	
15	The probe shall deploy a parachute at 300 meters.	Comply	85	
16	All descent control device attachment components (aero-braking heat shield and parachute) shall survive 30 Gs of shock.	Partial	47,55	Requires testing
17	All descent control devices (aero-braking heat shield and parachute) shall survive 30 Gs of shock.	Partial	47,55	Requires testing
18	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	60	
19	All structures shall be built to survive 15 Gs of launch acceleration.	Partial	47,55	Requires testing
20	All structures shall be built to survive 30 Gs of shock	Partial	47,55	Requires testing
21	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	60	
22	All mechanisms shall be capable of maintaining their configuration or states under all forces	Comply	47,55,59	

Requirements Compliance

27:30

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
23	Mechanisms shall not use pyrotechnics or chemicals.	Comply	N/A	
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	N/A	
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.	Comply	17-23	
26	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.	Comply	71	
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	71	
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	68	
29	XBEE radios shall have their NETID/PANID set to their team number.	Comply	70	
30	XBEE radios shall not use broadcast mode.	Comply	70	
31	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	119-120	
32	Each team shall develop their own ground station.	Comply	89-101	
33	All telemetry shall be displayed in real time during descent	Comply	98-100	
34	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	98,100	

Requirements Compliance

27:30

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
35	Teams shall plot each telemetry data field in real time during flight.	Comply	98	
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	93	
37	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.	Comply	93	
38	Both the heat shield and probe shall be labeled with team contact information including email address.	Comply	110	
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	82	
40	No lasers allowed.	Comply	N/A	
41	The probe must include an easily accessible power switch.	Comply	45	
42	The probe must include a power indicator such as an LED or sound generating device.	Comply	75	
43	The descent rate of the probe with the heat shield deployed shall be between 10 and 30 meters/second.	Comply	39	
44	The descent rate of the probe with the heat shield released and parachute deployed shall be 5 meters/second.	Comply	39	
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Comply	110	

Requirements Compliance

27:30

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
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	79	
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	45	
48	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	79	
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	18, 24	

Management

Johnny Wang

CanSat Budget – Hardware (1/2)

28:20

Subsystem	Component	Quantity	Unit Price (USD)	Total Price (USD)	Source
CDH	Arduino Nano	1	24.00	24.00	Newark
CDH	DS3231 RTC Module	1	5.99	5.99	Amazon.com
CDH	Taoglas FXP290 Antenna	1	19.00	19.00	Digikey.ca
CDH	RTC coin battery	1	4.00	4.00	Amazon.ca
CDH	XBEE Pro 900HP	1	55.00	55.00	Sparkfun
Sensor	MPU-9250 Magnemometer	1	14.95	14.95	Sparkfun
Sensor	Bosch BMP180	1	9.00	9.00	Ebay
Sensor	NEO-7M-C	1	20.99	20.99	RobotShop
Sensor	10kΩ resistor	2	0.20	0.40	Home Hardware
EPS	Buzzer	1	2.50	2.50	Digikey
Power	9V Battery	1	3.00	3.00	Canadian Tire
Mech	PAR-24 24” Parachute	1	11.05	11.05	Top Flight Recovery
Mech	Plywood	1	70.00	70.00	Hobby shop
Mech	Balsa Wood	1	15.00	15.00	Hobby shop
Mech	Insulation Foam	1	20.00	20.00	Hobby shop
CDH	XBEE Pro 900 HP	2	55.00	110.00	Digikey

CanSat Budget – Hardware (2/2)

28:20

Ground Station Costs

Subsystem	Component	Quantity	Unit Price (USD)	Total Price (USD)	Source
CDH/GCS	Grid Antenna	1	20.00	20.00	Equipment from past year
GCS	Mast Hardware	1	30.00	30.00	Equipment from past year
Mech	Mechanical Attachments	1	50.00	50.00	Equipment from last year
GCS	Laptop	1	900.00*	900.00*	Equipment from last year
	Subtotal			**$490**	

*excluded from Subtotal price

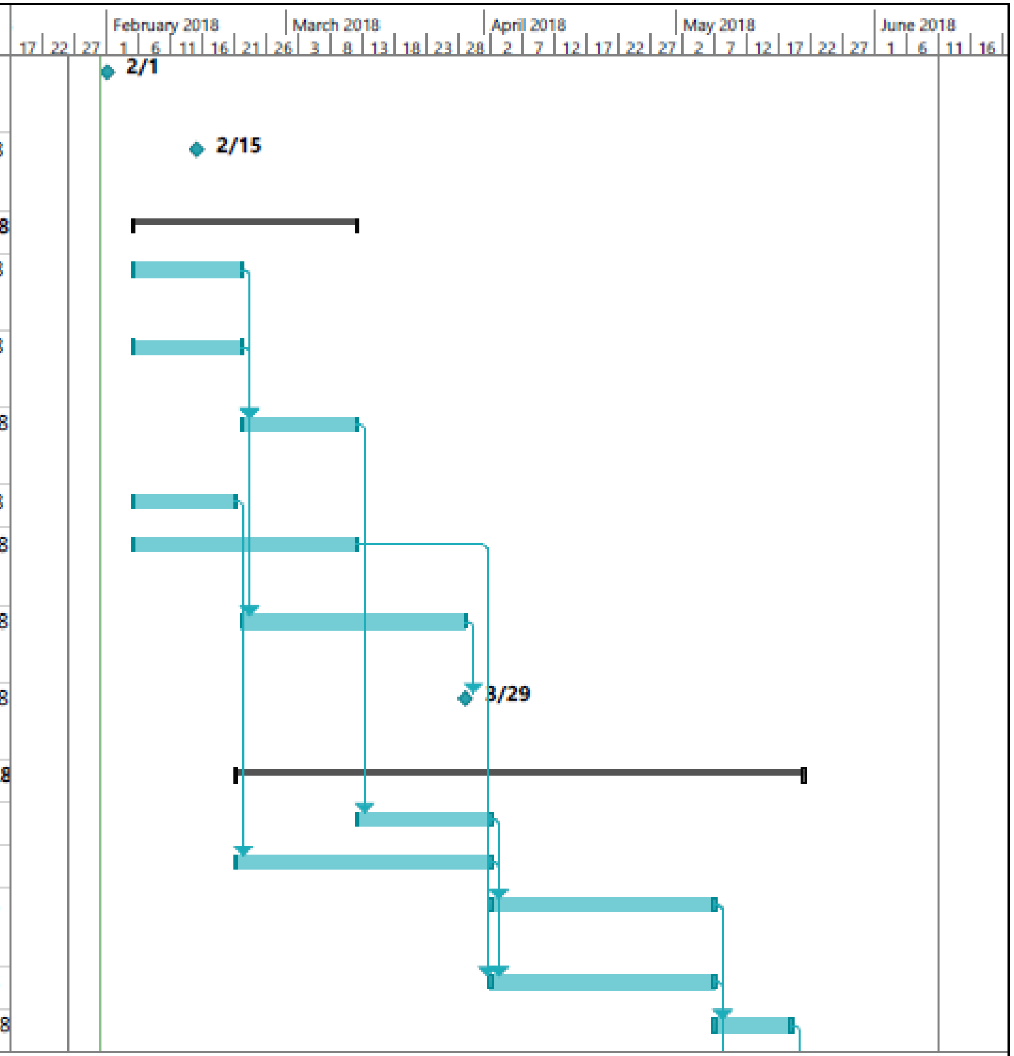
CanSat Budget – Other Costs

Travel Costs

Item	Description	Cost (USD)
Hotel	Super 8 Stephenville: USD 60/night x 4 nights x 2 rooms	480.00
Car Rental	Fullsize SUV: USD 72.45 x 4 days	189.80
Gas	~600 miles @ 20mpg x $2.25/gal	67.50
Flights	YYZ-DFW USD420 x 8 pax	3360.00
Food	USD30/day x 4 days x 8 members	960.00
Subtotal		**$5057.30**

Program Schedule (1/2)

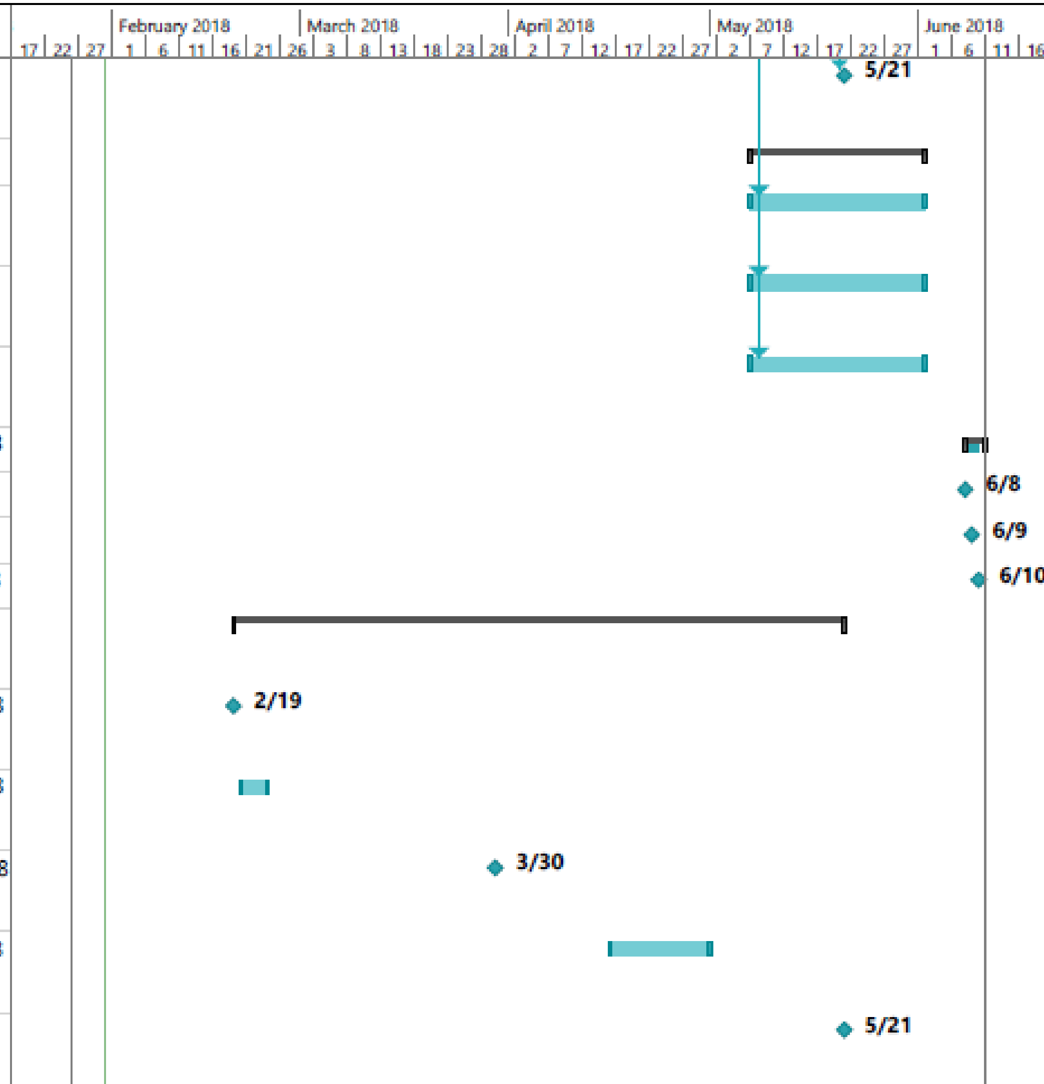
ID	Task Name	Start	Finish
1	Submit Preliminary Design Review slide package	Feb 1 '18	Feb 1 '18
2	Preliminary Design Review Presentation	Feb 15 '18	Feb 15 '18
3	**Detailed Design**	**Feb 5 '18**	**Mar 11 '18**
4	Aerodynamic Optimization	Feb 5 '18	Feb 21 '18
5	Structural Detailed Design	Feb 5 '18	Feb 21 '18
6	Internal Detailed Layout Design	Feb 22 '18	Mar 11 '18
7	PCB Design	Feb 5 '18	Feb 20 '18
8	Software Module Development	Feb 5 '18	Mar 11 '18
9	Create Critical Design Review slide package	Feb 22 '18	Mar 28 '18
10	Submit Critical Design Review slide package	Mar 29 '18	Mar 29 '18
11	**Fabrication**	**Feb 21 '18**	**May 21 '18**
12	Airframe Fabrication	Mar 12 '18	Apr 1 '18
13	PCB Fabrication	Feb 21 '18	Apr 1 '18
14	Integration of airframe and circuits	Apr 2 '18	May 6 '18
15	Software Integration	Apr 2 '18	May 6 '18
16	Simulated Data Testing	May 7 '18	May 18 '18



Program Schedule (2/2)

28:20

ID	Task Name	Start	Finish
17	Fabrication Completion Deadline	May 21 '18	May 21 '18
18	**Testing**	**May 7 '18**	**Jun 1 '18**
19	Descent Control Flight Testing	May 7 '18	Jun 1 '18
20	Mission Simulation Drop Tests	May 7 '18	Jun 1 '18
21	Environmental Testing Requirements	May 7 '18	Jun 1 '18
22	**2018 CanSat Competition**	**Jun 8 '18**	**Jun 10 '18**
23	CanSat Inspection	Jun 8 '18	Jun 8 '18
24	CanSat Launch	Jun 9 '18	Jun 9 '18
25	Post Flight Review	Jun 10 '18	Jun 10 '18
26	**Important Dates and Holidays**	**Feb 19 '18**	**May 21 '18**
27	Family day (Statutory Holiday)	Feb 19 '18	Feb 19 '18
28	University of Toronto Reading Week	Feb 20 '18	Feb 23 '18
29	Good Friday (Statutory Holiday)	Mar 30 '18	Mar 30 '18
30	University of Toronto Examinations	Apr 16 '18	Apr 30 '18
31	Victoria Day (Statutory Holiday)	May 21 '18	May 21 '18



Conclusions

28:45

- Major accomplishments
  - Avionics and power subsystem components have been evaluated and selected
  - Structural layout of CanSat is complete and modeled in CAD, fabrication materials have been evaluated and selected
  - Descent control for CanSat and payload have been evaluated and selected to successfully meet flight requirements
- Major unfinished work
  - Finalize structural fabrication techniques
  - Design PCB to integrate avionics efficiently
  - Subsystem construction and integration
  - System testing
- Proceeding to next stage of development
  - Schedule has been developed to allow for timely construction and testing
  - Effective preliminary decisions will smoothen the detailed design process
  - Component sourcing has begun, equipment needed for subsystem and system-level testing have been prepared