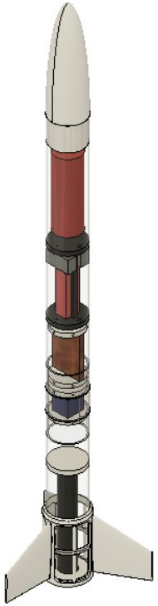
ICLR A.P.O.G.E.E

Design Review no.1



Airframe and Recovery Team

Date: 20/02/2019

Mission summary

The airframe and recovery subteams of the Imperial College London Rocketry (ICLR) team are designing, building and launching a rocket during the Spring term in order to get useful data and experience for the 2020 SA Cup competition.

The two teams have joined ICLR with little knowledge, guidance or experience but have quickly developed a good understanding of their assigned parts and been working on developing a conceptual design for the competition rocket.

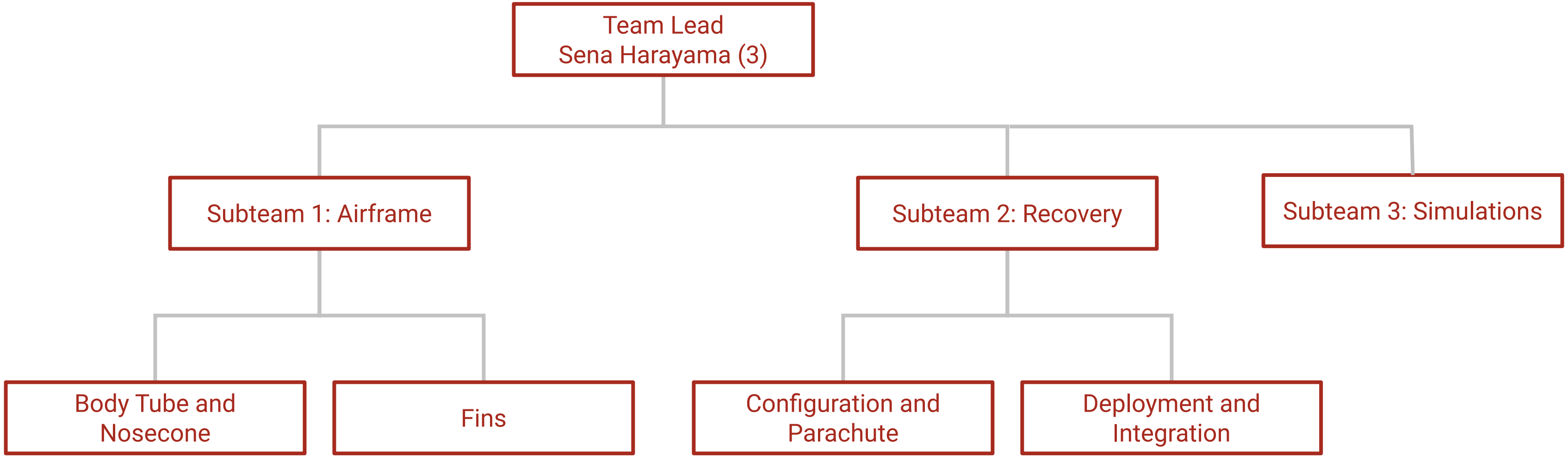
In order to get some hands-on experience and apply the theoretical knowledge they gained while consulting their engineering intuition, the two teams have been tasked to fully design and build a test rocket to be launched in Spring 2019 at one of the monthly East Anglia Rocketry Society (EARS) launch events.

This DR summarises the main strategies adopted into developing this rocket as well as the main details of the design proposed here.

Objectives

1. Primary objectives: To test...
   a. Competition components (electronics, sensors)
   b. Accuracy of simulations (open rocket vs real flight data)
   c. Concepts (e.g. dual recovery, integrated fincan and fin geometry, spinning of rocket, mounting mechanism)
2. Secondary objectives: To explore....
   a. Manufacturing and Assembly techniques
   b. Material choices

Team Organisation



Acronyms

- ICLR: Imperial College London Rocketry
- EARS: East Anglian Rocketry Society
- OR: OpenRocket

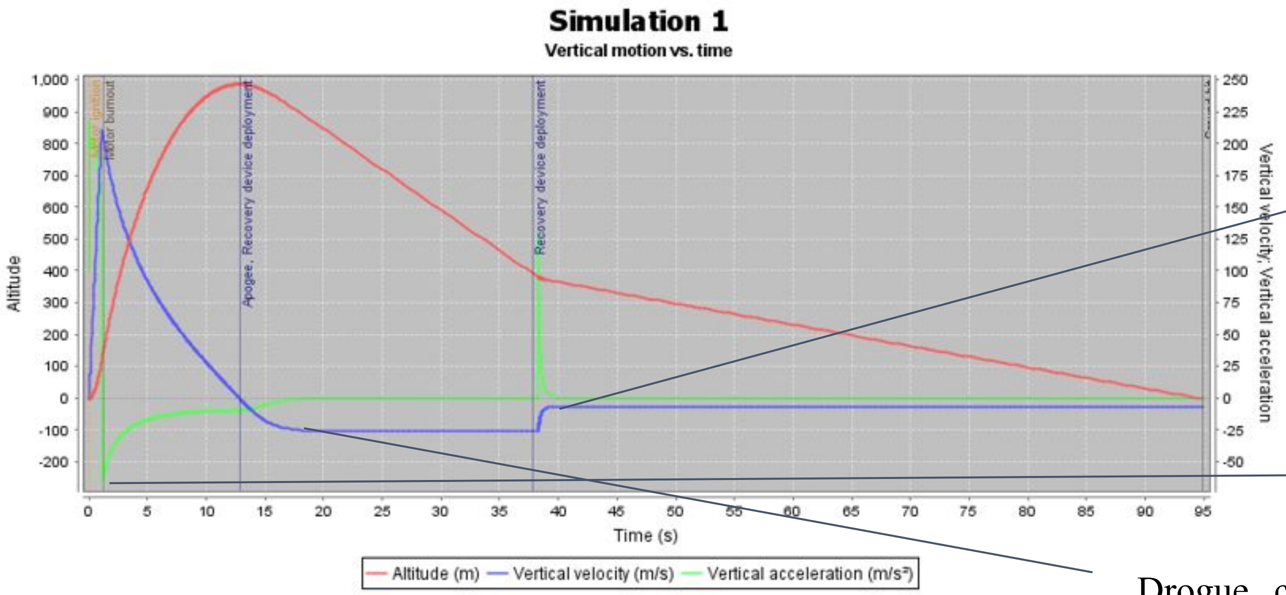
System Level overview

OpenRocket Simulation

Aim of this test flight : can we trust OR's simulations in anticipation of the final rocket flight ?

- How ?
  1. Collect the data from the OpenRocket simulation.
  2. Equip the model rocket with devices measuring this data.
  3. Compare.

Apogee	Altimeter	Same device used for the recovery system. Graph obtained by interpolation (collects data every second).
Maximum velocity	Accelerometer	**To be discussed.**



Main chute reaches terminal velocity

No upwards thrust, only resultant air resistance massively decelerate the rocket

Drogue chute reaches terminal velocity

APOGEE : 986 m

MAX VELOCITY : 210 m/s (M .61)

TIME TO APOGEE : 12.8 s

LANDING VELOCITY : 6.62 m/s (better if improved)

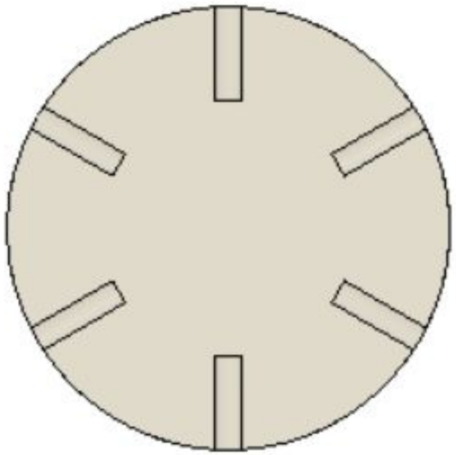
Subsystem overview
Airframe

Names

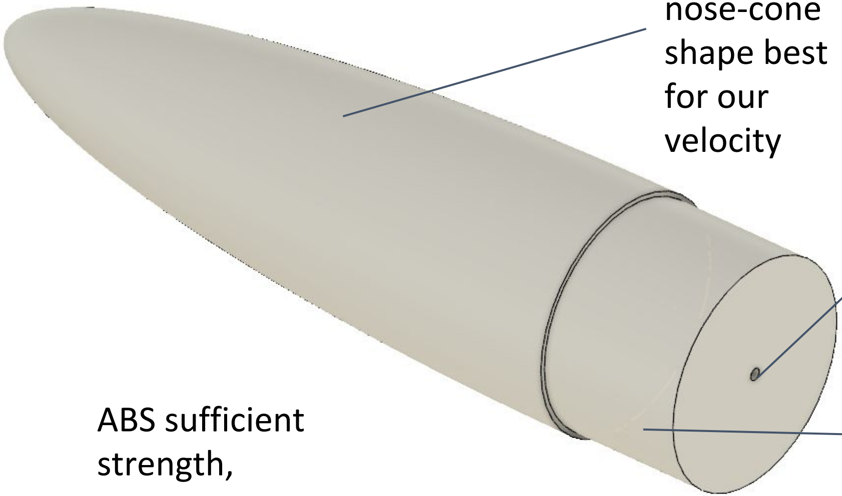
Body Tube

Cardboard Phenolics
Around 90cm
3.002 Inch Diameter
0.0062 inch thickness

See image

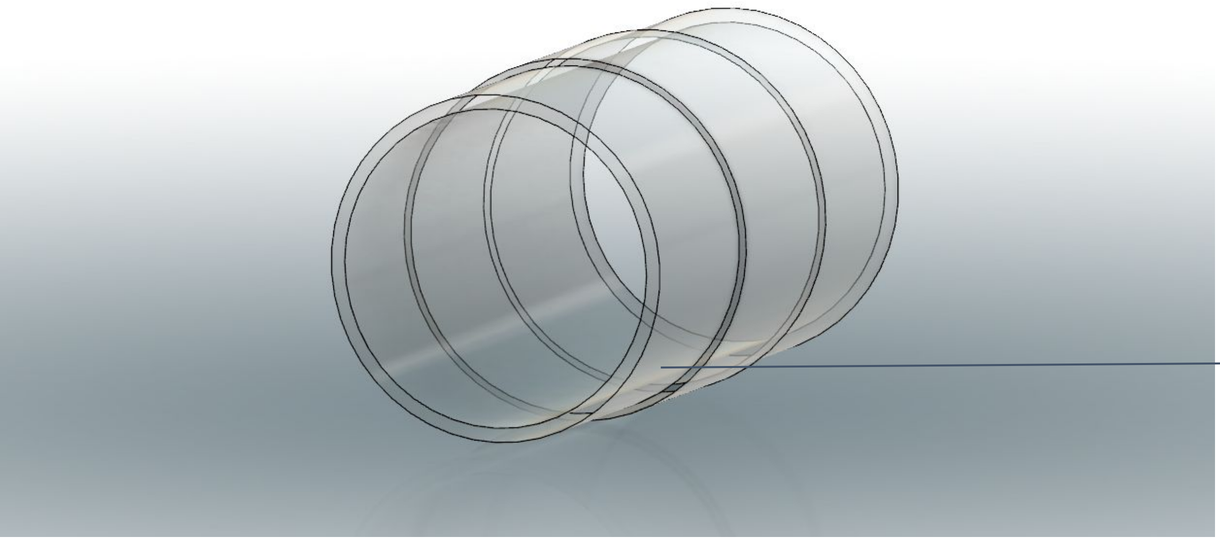


Airframe : Nose Cone



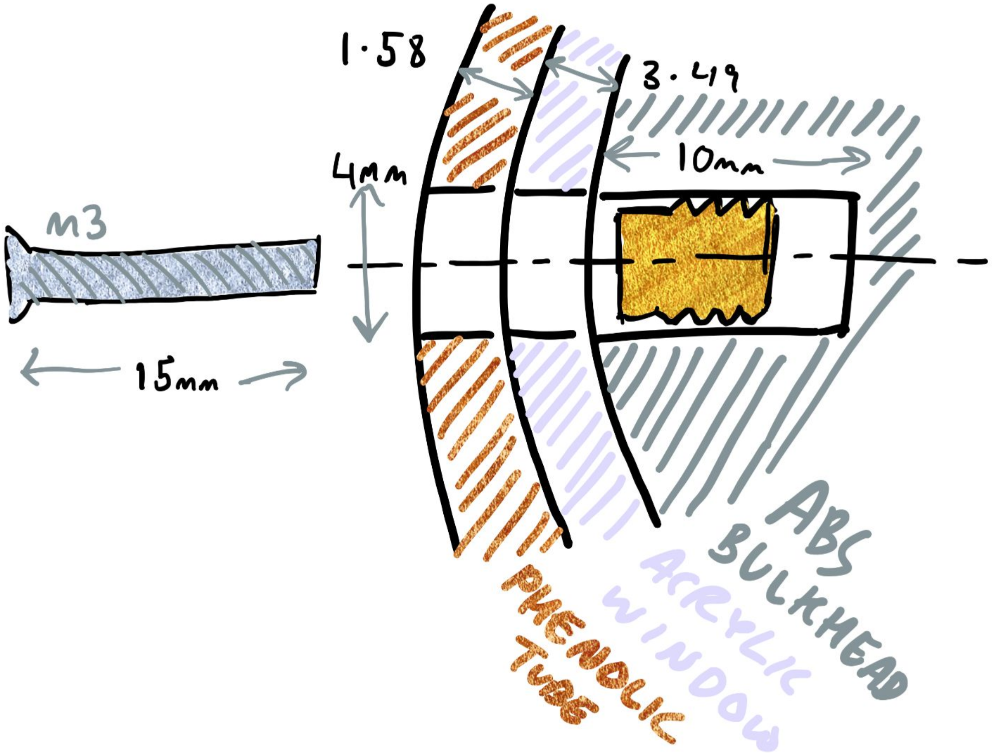
Payload Integration : Acrylic Window

One part, manufactured with CNC



Built-in coupler so that there is no discontinuity on the outer diameter of the rocket

Coupler Systems



Payload: GoPro camera

Purpose of this is to test if the resolution of the footage we obtain is sufficient for a ‘cool’

Fins

- Purpose of fin: Correct for any unintended perturbations that affect our intended flight path (Basically where the rocket is pointed at) Eg: Wind
- Ideal stability between 1.5 and 2 cal (distance between Cg and Cp/body diameter). Stability more than 2 increases drag significantly
- Operating Mechanism: Fins should create low drag when freestream velocity is aligned to body axes, and a resultant force (lift & drag) as soon as it tilts to correct the path

Fins

- Don’t want to have lift when rocket is on it’s intended path → 0 lift at 0 degrees AoA
- Symmetric airfoil that gives high C_L/C_D ratio at intended AoA range (0~15 degrees)

NACA 0012

Fins

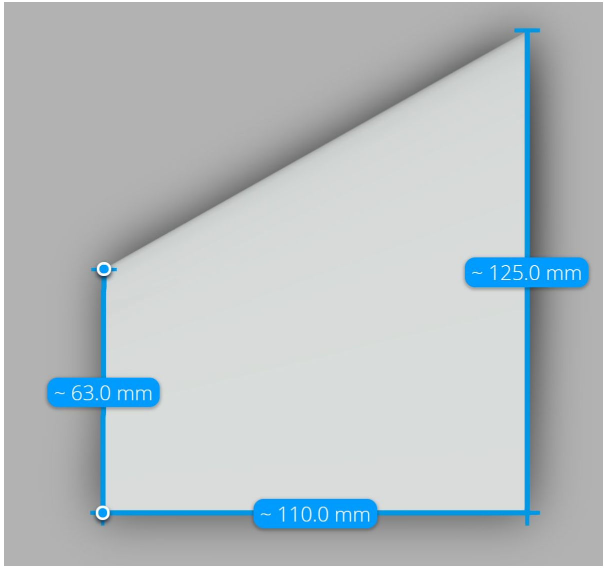


Figure 1: Top view of fin

Manufacturing specifications

- Material: ABS plastic
- Aerofoil cross-section: NACA 0012
- Manufacturing method: 3D printing
- Mass of 3 fins: 249.0270g
- Area= 103cm^2

Fin features

- Trapezoidal
- Stability=2.15cal
- C_D per fin (using OpenRocket) = 0.02

Design criteria

- Minimise surface area to minimise drag
- Stability greater than 1.5 cal (ideally around 2 cal)
- Minimise Height/Chord to reduce chance of breaking fin, however if this is too low, rocket will have poor stability characteristics
- A=((d+0.5)xL)/6 was used initially, however this gave a much greater stability than needed

Fins

$$V_f = a\sqrt{\frac{G}{\frac{1.337AR^3P(\lambda+1)}{2(AR+2)(\frac{t}{c})^3}}}$$

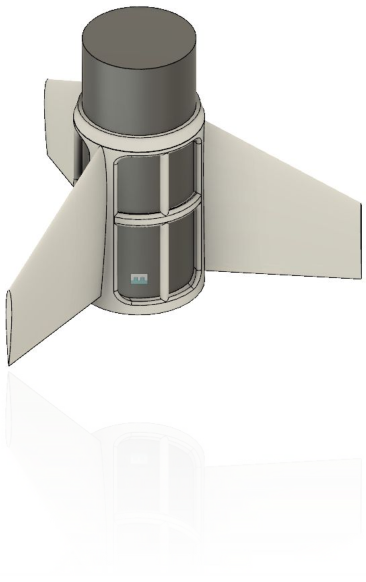
Equation 1. Flutter Boundary Equation

- Fin flutter is not expected to be a problem:
  Flutter critical M= 1.456, max expected flight M=0.5

Questions:

1. How could we measure spin on the test rocket? Accelerometers on the fins?
2. How should we measure bending stresses and deflections on fin? Strain gauges?

Fin Can



Manufacturing Specifications

- Material: ABS Plastic (M30)
- One-Set 3D print with fins attached
- Expected total mass with fins: 280g
- Print size with fins: ~27cm*27cm*15cm

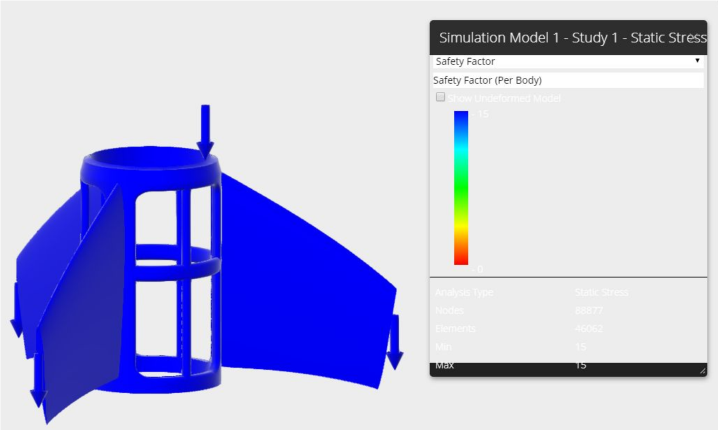
Fin Can Features

- Safety Factor > 15 under Launch conditions
  a. Ratio of Maximum allowable stress to equivalent stress (von-Mises)

Design Criteria

- Withstand forces from Launch and Flight with the minimal amount of material
- Serve as a cheap and easy to manufacture platform for Test Launch

Fins Can



Fusion 360 was utilized in simulating stress tests.

1. No plastic deformations and breakages observed under launch conditions
2. Slightly over-engineered, but deemed sufficient in weight

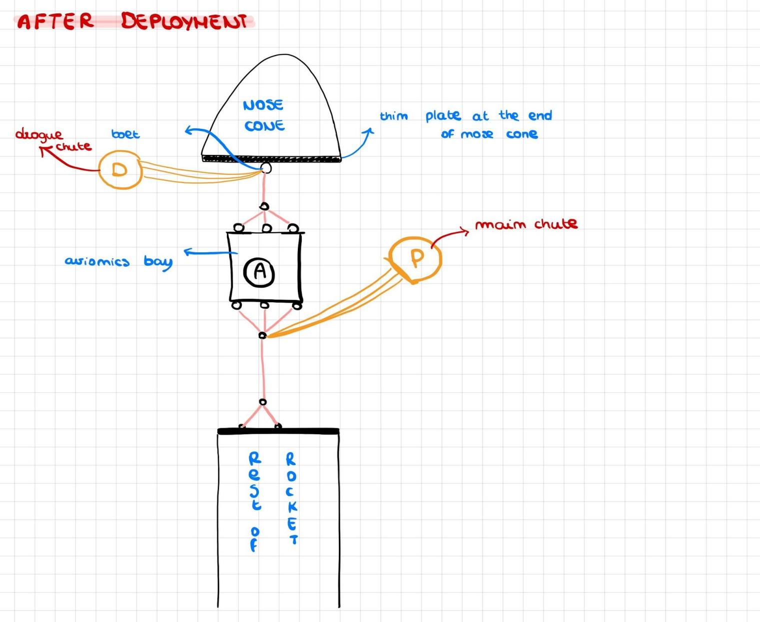
Questions:

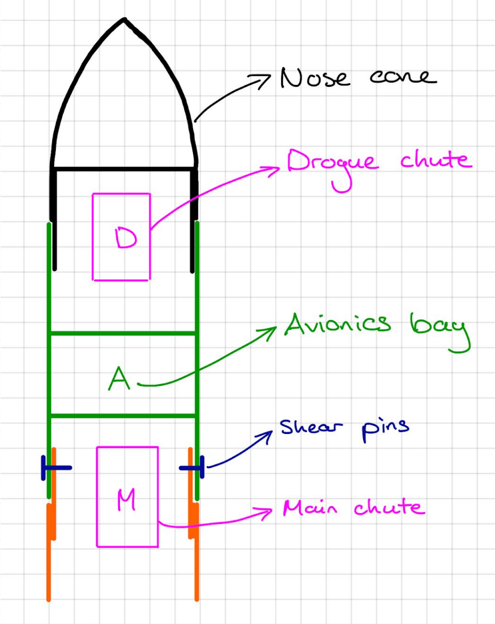
What factors should we look into to measure the shear forces between the can and rocket body in launch & flight, considering it will be attached to the body via epoxy.

Subsystem overview
Recovery

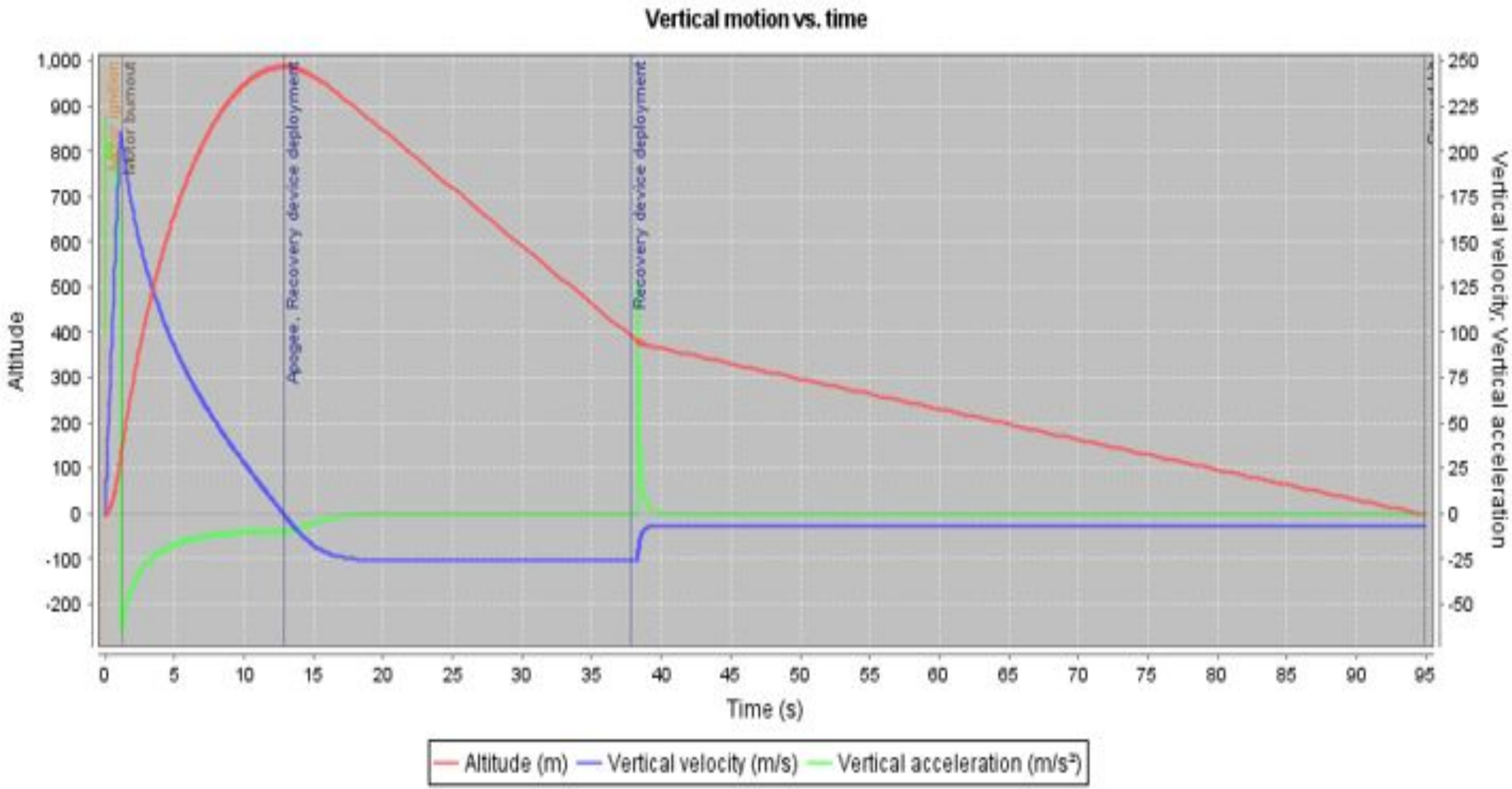
Names

Recovery


AFTER DEPLOYMENT
NOSE CONE
thin plate at the end of nose cone
drogue chute
bolt
D
main chute
P
avionics bay
A
REST OF ROCKET


Nose cone
Drogue chute
D
Avionics bay
A
Shear pins
M
Main chute

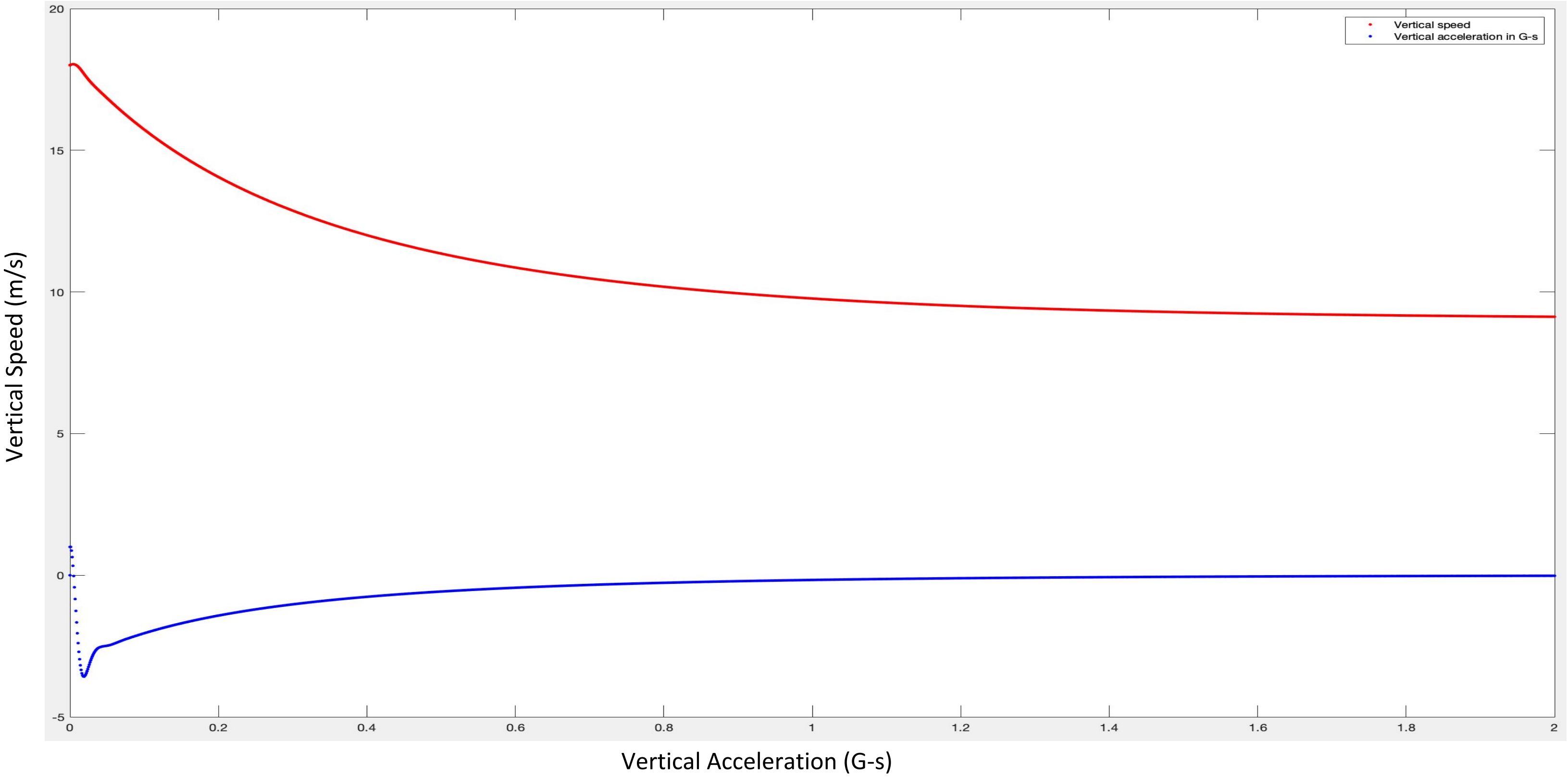
Simulation 1



Simulation 1 summary

- Drogue chute deployment at apogee (986m)
- Main chute deployment at 370m
- Max velocity: 210 m/s
- Time to apogee: 12.8 s
- Landing velocity: 6.62 m/s

Simulation 2



Simulation 2 summary

- Largest G-loading: -3.5779 (G)

- Force per shear pin (for 4 shear pins): 14.9171 (N)

Assumptions:

- Drogue parachute fully deploys 2 seconds after deployment

- Vertical velocity of main rocket body is 18 m/s at full deployment

Shock cords:

Material: Nylon

Length: 3m & 5m

- Length should be 3-5x the length of the rocket

Why Nylon over Kevlar:

- Cheaper
- Stretches more than Kevlar, decreasing peak load

Connecting ropes to bodies

M6 eye-bolt: attached to body

Carabiner: connects eye-bolt to swivel link

Swivel link: attached to reduce torsion on ropes

Rules for competition:

“ Launch vehicles shall implement redundant recovery system electronics, including sensors/flight computers and “electric initiators” --- assuring initiation by a backup system; with a separate power supply”

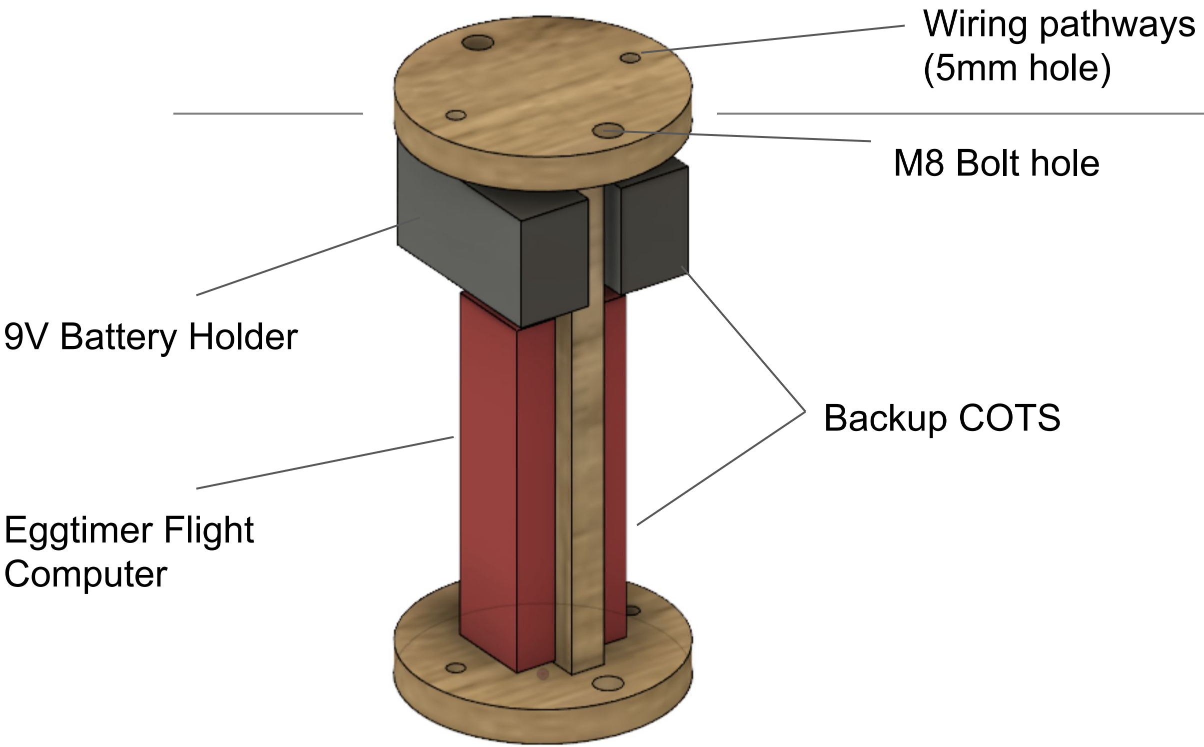
“At least one redundant recovery system electronics subsystem shall implement a COTS flight computer.

Parachute configuration decision:

- We decided to place both parachutes and avionics bay in the upper part of the rocket in order to do not affect camera recording of payload.

- The drogue chute is going to be just behind the nose cone because it is easier to make the nose cone pop up and we will, therefore, need a smaller ejection charge.

Avionics Bay



Only thing missing in the design the eyebolt screw hole.

Flight computer is screwed into the board while the battery holder can use velcro along with tape or other adhesives.

To be programmed and configured with laptop.

Drogue deployment at apogee and main at set height.

Backup system set on delayed timer (like +3s).

Ejection System

- Recovery Parachutes will be ejected out of the rocket using Black Powder. When this Black Powder burns, it will produce a sudden release of gas creating enough pressure to break the shear pins allowing deployment of the parachute.
- Black Powder was chosen over CO2 Ejection as the altitude is not high enough for black powder to burn inconsistently and it's cheaper!
- Black Powder obtained from motor (Solid Fuel, Reloadable 3- Grain White Thunder)

Deployment

1. Black Powder will be used in two stages. Once to deploy the drogue chute and once to deploy the main chute.
2. Black Powder will either be placed in ejection charge canister caps and these caps will be secured to the bulkhead/plates.
3. Altimeter connected via electrical wires to an igniter.
4. The igniter will be placed in the caps holding the black powder and will flare up burning the black powder
5. Pressure from sudden release of gas will lift the nose cone allowing deployment of the drogue chute and shear pins will also break during descent to allow main chute to deploy.
6. To prevent the Parachutes from melting, wadding will be used to prevent parachutes from melting/burning before deployment (Quest Tissue Wadding)

Parachute

1. Main Chute:
   a. BCC-36
   b. Manufactured by Blackcat Chutes
   c. Light weight rip stop nylon
   d. 170 grams , 36 inches
   e. Landing speed: 6.62m/s
2. Drogue Chute
   a. Premium Edition Para-sheet Chutes 10”
   b. Manufactured by Blackcat Chutes
   c. Materials include: rip-stop, nylon shroud lines, swivel
   d. 10 inches
   e. terminal speed: 25m/s

Next Steps

Names