

# Level 3 Certification Project - October 2025

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Project Name: - Black Brant 6" Scale  
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## Design

Project consists of a 6-inch diameter Madcow fiberglass airframe with a 98mm motor mount intended for K-N motors. It is intended to be a sport scale version of the classic Canadian sounding rocket, the Black Brant II.

The booster design is a 3-fin model, with large swept-back G10 fins. There is a 12" payload section with a 1" switch band between the booster and the main Madcow G10 body tube. The nose cone is a 5:1 conical Madcow fiberglass nose cone, which will contain GPS tracking electronics. Recovery systems will be deployed via classic two-break dual deploy. The overall weight of the rocket without motor is approximately 14.0kg. Pad mass including motors & propellant varies between 18.7kg (5120 case) and 19.7kg (6400 case).

## Projected Altitudes

Given the current availability of Aerotech motors, several different scenarios have been simulated in OpenRocket 23.09.

Motor Designation	Total Impulse	Casing	Projected Altitude
M1297	5414.6Ns	75/5120	2391m
M1500	5220Ns	75/5120	2234m
M2225	5228Ns	75/5120	2258m
M1780	5783Ns	75/5120	2355m
M1550*	5600Ns	75/6400	2370m

\*denotes preferred choice.

# Electronics

To ensure safe deployment of parachutes, we will use redundant dual deployment with different manufacturers of electronics to minimize risk of correlated failures.

## Primary (MissileWorks RRC3):

- Drogue deployment: Apogee.
- Main deployment: 315m.
- Arming switch: Missileworks 2 pole rotary switch
- Battery: Varta 9V Alkaline
- Brownout protection: Brownout capacitor as part of device.

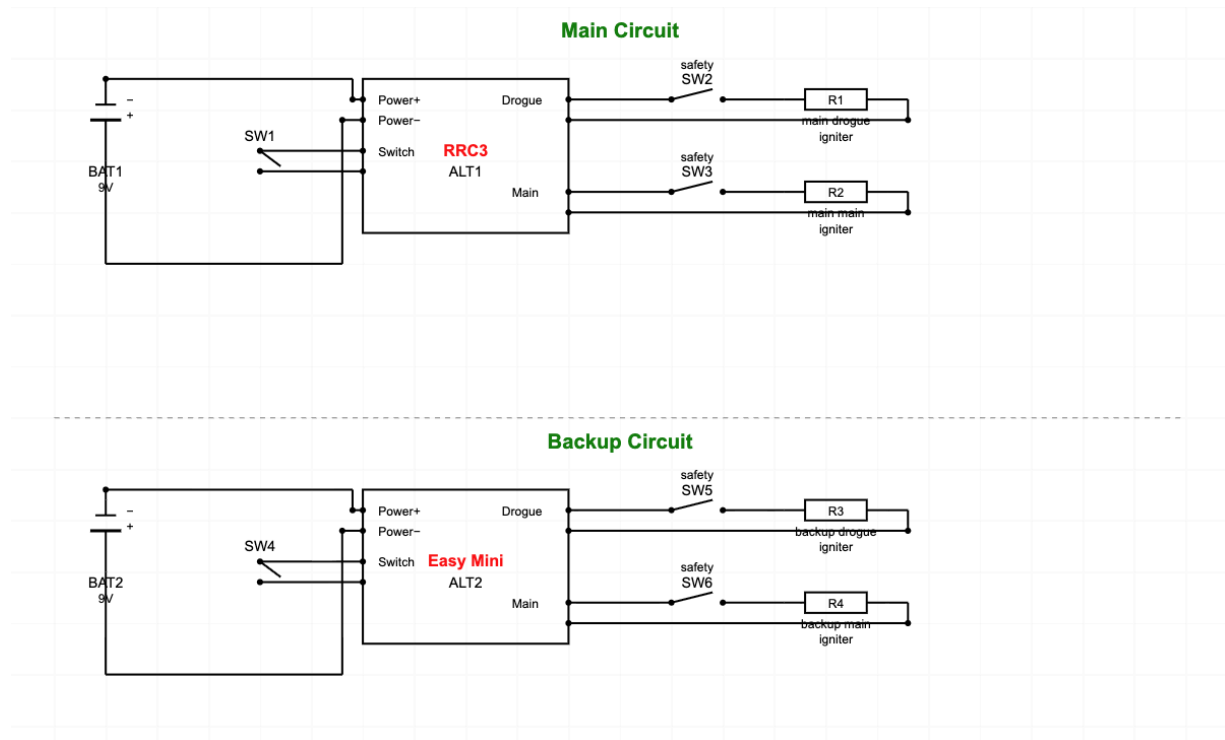
## Backup (Telemetrum EasyMini):

- Drogue deployment: Apogee + 1sec.
- Main deployment: 280m.
- Arming switch: Missileworks 2 pole rotary switch
- Battery: Varta 9V Alkaline
- Brownout protection: Brownout comparator as part of device (schematic here: <https://altusmetrum.org/EasyTimer/v1/easytimer-sch.pdf> - same comparator for easymini).

## GPS and flight monitoring (Silicdyne Fluctus):

- No deployment capabilities.
- Ride along in nose cone to provide real-time tracking.
- Arming switch: Slide switch on bulkplate.
- Battery: Varta 9V Alkaline

# Wiring Diagram



## Recovery devices

Redundant dual deployment of parachutes at apogee and at 315m above ground level is intended to safely bring the rocket back to earth. Our chosen parachutes are:

### Main Parachute

The main parachute will be contained in a 6" fruity chutes deployment bag, with a 24" pilot chute to pull it out of the bag. The whole setup will be protected with a 18" diameter nomex protector.

- Type: Fruity Chutes 120" Iris Standard Parachute.
- CD: 2.2
- Mass: 1020.6g
- Descent rate: 3.98m/s

### Drogue Parachute

The drogue parachute will be protected with a 18" diameter nomex protector.

- Type: Fruity Chutes 36" Iris Standard Parachute.
- CD: 2.2
- Mass: 141.7g

- Descent rate: 14.6m/s

## Parachute deployment flow:



## Attachment Points & Harnesses.

There are three distinct points in flight where force is exerted on the harnesses and attachment points:

1. Airframe separation.
2. Drogue parachute opening.
3. Main parachute opening.

### 1. Airframe separation.

Airframe separation is caused by pressurization of the body chambers by a pyrotechnic charge. This pressurization creates a force on both components of the rocket body. This force continues to do work on the rocket parts until they separate, and the pressure can be released. The total work done by the charge on the rocket components is:

$$W = F L_{\text{coupler}}$$

We know that the components of the rocket then continue to separate at a constant speed until they reach the extent of the shock cord holding them together. We treat this shock cord as an extensible material with an elastic constant  $k$ , which can be calculated from its material properties as:

$$k = \frac{EA}{L}$$

Where E is the Young's modulus of the woven nylon (around 0.6-1.0 GPa), A is the cross sectional area of the material, and L is the length.

We can then compute the force on the bulkhead from the shock cord bringing the rocket parts to rest. We use conservation of energy (assuming that the effect of air resistance on the two parts of the rocket is negligible):

$$F L_{coupler} = \frac{1}{2} k x^2$$

Which means that the maximum extension of the shock cord is:

$$x_{max} = \sqrt{\frac{2 F L_{coupler}}{k}}$$

So that the maximum force on the ends of the shock cord is:

$$F_{max} = \sqrt{2kFL_{coupler}}$$

Calculating some real numbers to put into this equation, we will have a 15cm shoulder on the coupler, we work with a pressurization of 10psi, our shock cords have an area of 1.6cm\*0.2cm and a length of 9m. We assume a high-end Young's modulus of 1.0GPa. This gives us a k of:

$$k = \frac{10^{-9} \times 0.016 \times 0.002}{9} = 3555.6 \text{ N/m}$$

Similarly, we find that the force F on the bulkplate is (10psi = 68948n/m2):

$$F = \pi(0.157/2)^2 \times 68948 = 1335 \text{ N}$$

Substituting in our equation for F, we find

$$F_{max} = \sqrt{2 \times 3555.6 \times 1335 \times 0.15} = 1193 \text{ N} = 121 \text{ kg} \times 9.81 \text{ m/s}^2$$

## 2. Drogue parachute opening.

Through the simulation, the maximum acceleration we see from the main chute opening is 20.46m/s<sup>2</sup> (calculated by OpenRocket assuming instantaneous opening of the chute, likely an overestimate). The peak force on the rocket is (F=ma) 20.46 x mass. Rocket mass at burnout, which is 15.5kg for the 75/5120 casing. For the complete rocket, this gives us a maximum force of 317N = 32.3kg x 9.81m/s<sup>2</sup>.

## 3. Main parachute opening.

Through the simulation, the maximum acceleration we see from the main chute opening is 109m/s<sup>2</sup> (calculated by OpenRocket assuming instantaneous opening of the chute, which is in a deployment bag with a pilot chute, so an overestimate). The peak force on the rocket is (F=ma) 109 x mass. Rocket mass at burnout, which is 15.5kg for the 75/5120 casing. For the complete rocket, this gives us a maximum force of 1689.5N = 172kg x 9.81m/s<sup>2</sup>.

Of these three shocks, the harshest comes from the main parachute opening - which exerts a maximum estimated force of 1700N on the attachment points.

## Fireproof kevlar harnesses (2):

- Type: Fruity chutes kevlar
- Width: 1.27cm
- Length: 1.5m
- Breaking force (peak): 2700kg

## Booster kevlar Y-harness:

- Type: Fruity chutes kevlar
- Width: 1.27cm
- Length: 0.7m
- Breaking force (peak): 2700kg

## Shock cords (2):

- Type: Fruity chutes tubular nylon
- Width: 1.43cm
- Length: 9m
- Breaking force (peak): 1350kg

## Quick links (2 booster, 2 ebay, 1 nose):

- Type: Fruity chutes stainless steel.
- Diameter: 6.35mm
- Breaking force (peak): 1800kg

## Attachment points:

### Booster.

Type: 2x U-bolts, 16mm steel washers.

Attach into: 3mm G10 centering ring

Bolt breaking force (peak): 4000kg

Centering ring breaking force: 5800kg (on one washer).

### Nose Cone.

Type: 1/4" threaded rod

Attach into: 2 1/4" stainless steel locking nuts, locked to 3mm G10 centering ring.

Centering ring breaking force: 5800kg (on one washer).

Bolt breaking force: minimum tensile strength can range from 860kg to 1440kg.

Threaded rod breaking force: 988kg

### Electronics Bay.

Type: 2x U-bolt, 16mm steel washers.

Attach into: G10 bulk plate.

Bolt breaking force (peak): 4000kg

Bulk plate breaking force (peak): 5800kg (one washer)

## Physical Properties (Assuming M1297)

- Overall Length: 300cm
- Diameter: 15.7cm
- Centre of Pressure: 246cm from nose tip.
- Centre of Gravity: 200cm from nose tip.
- Stability Margin: 2.99 calibers
- Burn time: 4.2s
- Time to apogee: 21.9s
- Total mass: 18665g

## Flight Maxima

- Max Acceleration:  $93.6\text{m/s}^2$
- Max Velocity: 242m/s (0.725 mach)
- Max Altitude: 2391m

## Launch Rail Data

- Rail length: 3m
- Velocity at rail end: 23.2m/s
- Number of rail buttons: 3

## Landing Data

- Total flight time: 238s
- Distance at landing (5m/s wind): 600m
- Vertical velocity at landing: 3.94m/s

## Components

### Booster

#### Booster body tube

- Length: 122cm
- Diameter: 15.5cm
- Wall thickness: 2.23mm
- Material: G10 Fibreglass (Madcow)
- Mass: 2572g

#### Booster motor tube

- Length: 55.9cm
- Diameter: 10.2cm
- Wall thickness: 1.65mm

- Material: G10 Fibreglass (Madcow)
- Mass: 595g

#### Fins

- Length (tip to tip): 55cm
- Span: 26.7cm
- Thickness: 5mm
- Material: G10 Fibreglass plate
- Mass: 2693g

#### Centering rings (\*3)

- OD/ID: 15.2cm/10.2cm
- Thickness: 3mm
- Material: G10 fibreglass plate
- Mass: 68g

#### Tailcone, Retainer, centering ring

- Base diameter/aft diameter: 15.5cm/12.3cm
- Length: 9.52cm
- Coupler: 3.82cm long, 2.16mm thick G10 fibreglass
- Centering ring in tailcone: OD 12.5cm, ID 10.2cm, 3mm G10 fibreglass
- Retainer: 98mm aeropack, mounted to centering ring
- Total mass: 741g

## Electronics Bay

#### Coupler tube:

- Length: 33.0cm
- Diameter: 10.2cm
- Wall thickness: 2.16mm
- Material: G10 Fibreglass (Madcow)
- Mass: 850g

#### Bulkheads & U bolts (x2):

- Diameter: 10.2cm
- Thickness 4mm
- Material: G10 Fibreglass
- Total Mass: 277g with U-bolt & washers.

#### Sled, batteries, threaded rods:

- ABS 3d printed sled
- M6 threaded rod x 2
- 2 x 9v Li-ion batteries & 3d printed holders.
- Wiring harness, pull-pin switches
- Total mass: 650g

## Payload

#### Payload body tube:

- Length: 71.7cm

- Diameter 15.5cm
- Wall thickness: 2.23mm
- Material: G10 Fibreglass (Madcow)
- Mass: 1531g

#### Nose Cone

- Length 80cm:
- Base diameter: 15.5cm
- Wall thickness: 2.54mm
- Material: G10 Fibreglass, Aluminium tip.
- Mass: 1091g

#### Nose Cone Coupler

- Length: 20.3cm
- Outer diameter: 15.0cm
- Wall thickness: 2.3mm
- Material: G10 Fibreglass (Madcow)
- Mass: 494g

#### Nose Cone Tracker Bay + bulkheads

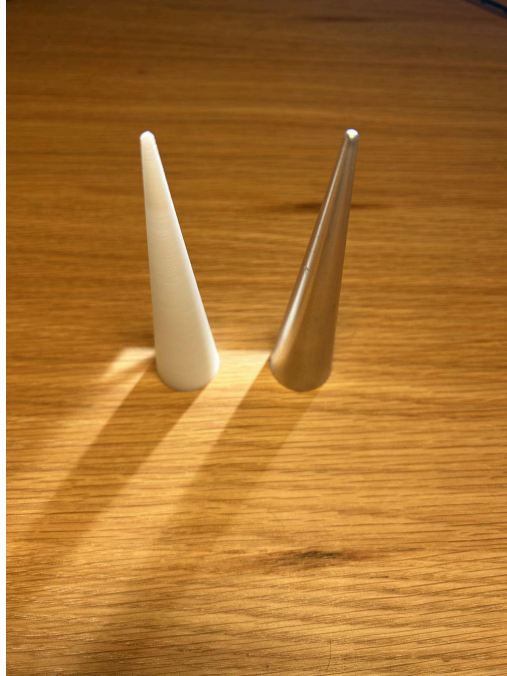
- Bay: Length: 20.3cm, Outer diameter: 75mm, Wall thickness 2.5mm (244g)
- Bulkheads: diameter 14.8cm, thickness 3.12mm (109g)
- 1/4" threaded rod \* 92cm (150g)
- 1/4" U bolt (50g)
- GPS tracker, sled, wiring harness (200g)
- Total mass: 862g

## Modifications from stock kit

The stock Black Brant kit comes with an aluminium nose tip, which can be flown at the prefect's discretion under Tripoli rules, but can cause some worries. In order to mitigate this, a 3d-printed, fibreglass laminated alternative can be fabricated.

Two 3mm thick g10 fibreglass discs form the mounting points for the 1/4" threaded rod to hold the rest of the nose together. These plates mount inside and outside of the nose cone, and are secured with steel washers and 1/4" locking nuts. The 3d printed nose tip is printed in ABS and undersized such that 2 layers of 150g/m<sup>2</sup> fibreglass can be laid up on top of it to bring it up to the correct size.

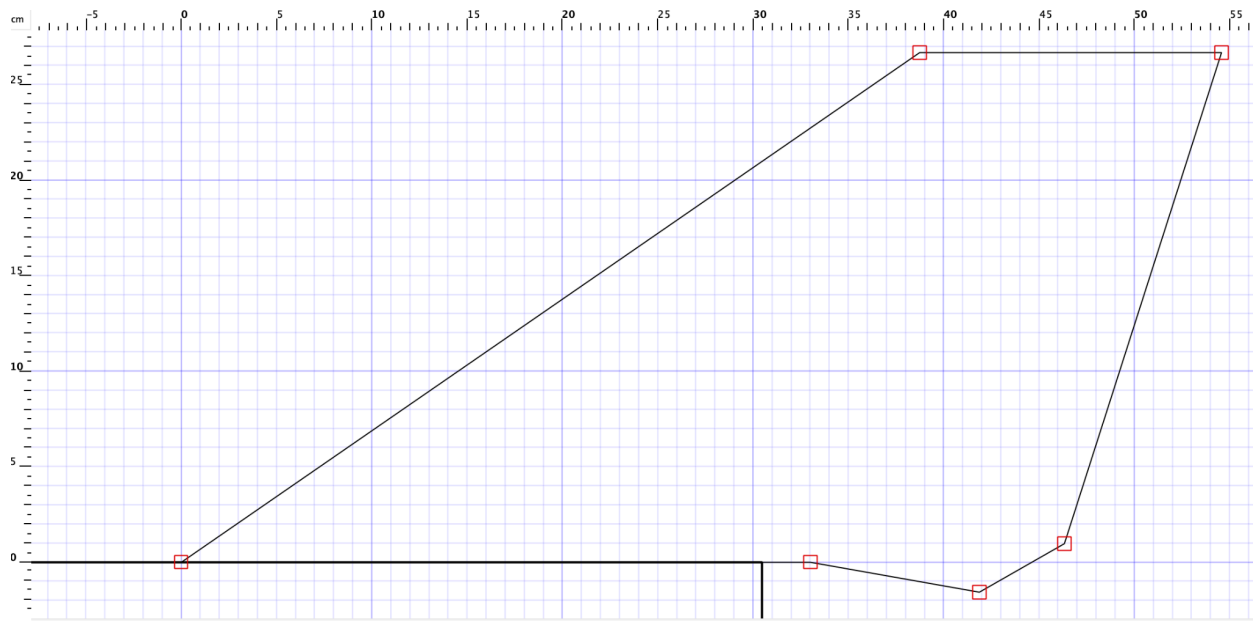
A test version has been fabricated in ABS for validation, photos below.



# Simulations & Designs

## Fins

Keeping with the semi-scale design, the fins are copies of the Black Brant II sounding rocket fins, including a dropped section to follow the contour of the tail cone.



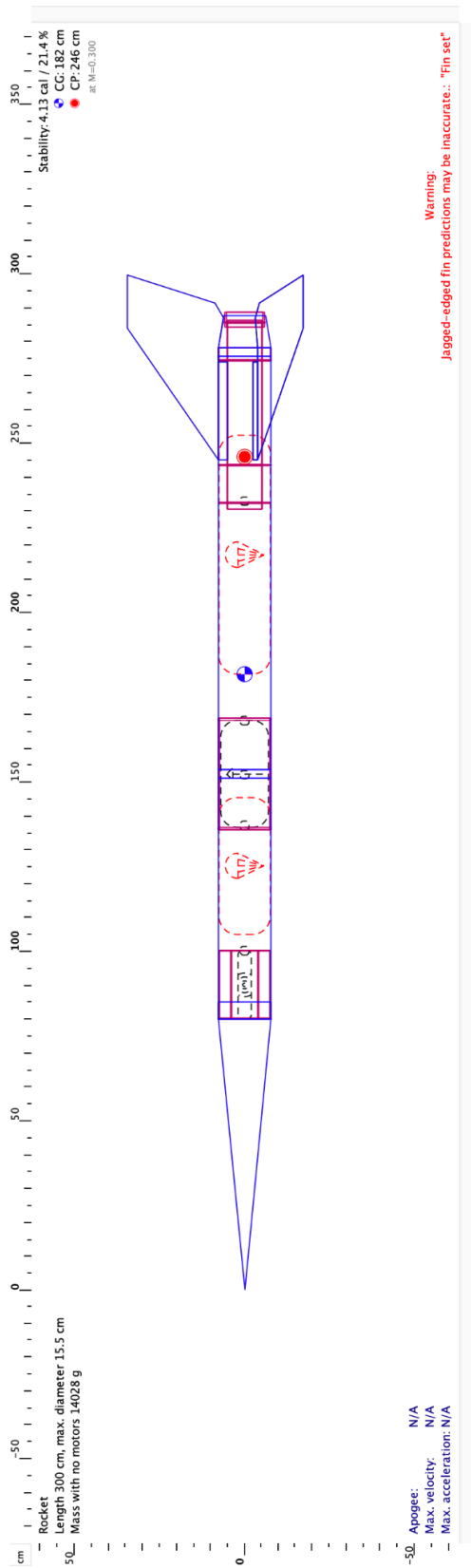
Because of the backswept shape of the fins, which places them behind the tailcone, they are exposed to the landing force of the rocket at impact. The fins themselves are 5mm thick G10 fibreglass, and so comfortably able to survive this impact, and similarly, if the force of the landing is transferred to the body tube by sufficiently large-radius fin fillets, it will be adequately dissipated. The weak link in this setup is the fin fillets themselves, which are subject to torsional forces which may crack them if they are not sufficiently strong.

In order to mitigate the risk of cracked fillets, three main approaches will be used:

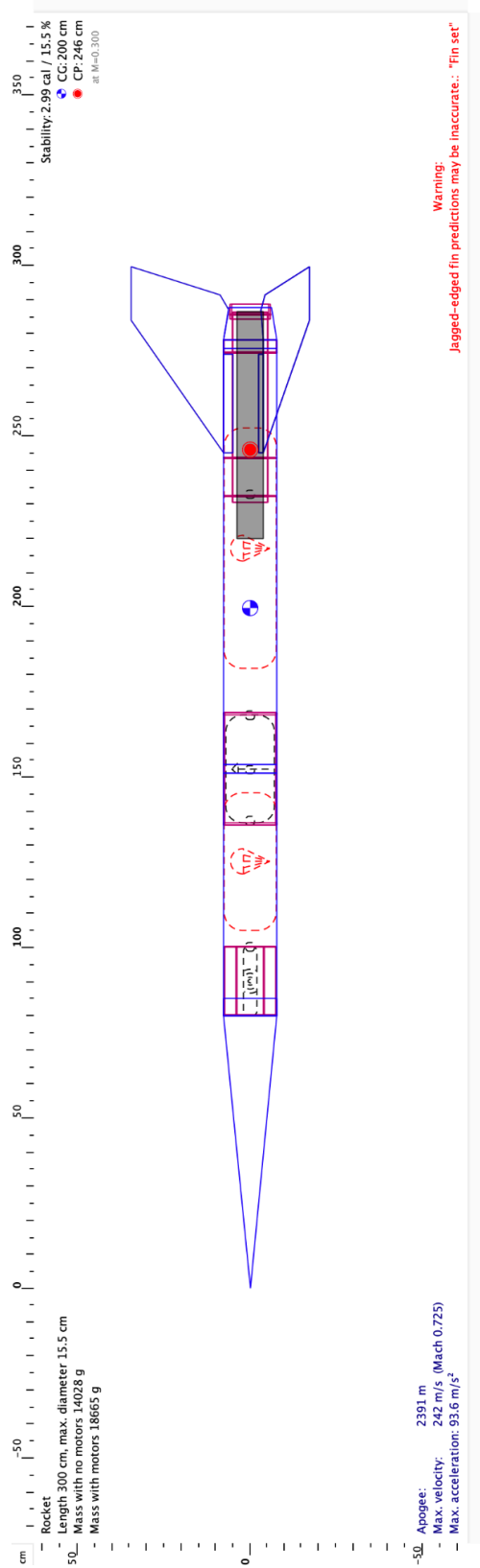
1. We will build the motor assembly / tailcone assembly outside of the booster body tube. This will allow for solid attachment of the fins to the motor tube using a 3d printed jig to ensure alignment. Once the fins are attached, the bond joint will be strengthened with laminated strips of kevlar, and then filleted (Kevlar is incorporated for its [energy dissipative properties](#)).
2. In order to obtain a perfect fit between the fin cutouts and the tail cone, we will build up any space between the fin and cone with thin strips of 150g/m<sup>2</sup> fibreglass to ensure a better bond (the kit comes with some space between the tailcone and the fins when dry-fitting).
3. Once the motor assembly has been attached inside of the booster body tube, the outer joint between the booster body tube and the fin will be secured using laminated strips of

kevlar (we choose Kevlar for this because it is good at dissipating energy over a wide area when laminated), and then filleted over with a 2.5cm radius filleting tool (3d printed).

Full rocket (no motor)



Full rocket (with motor)



# Flight Profiles

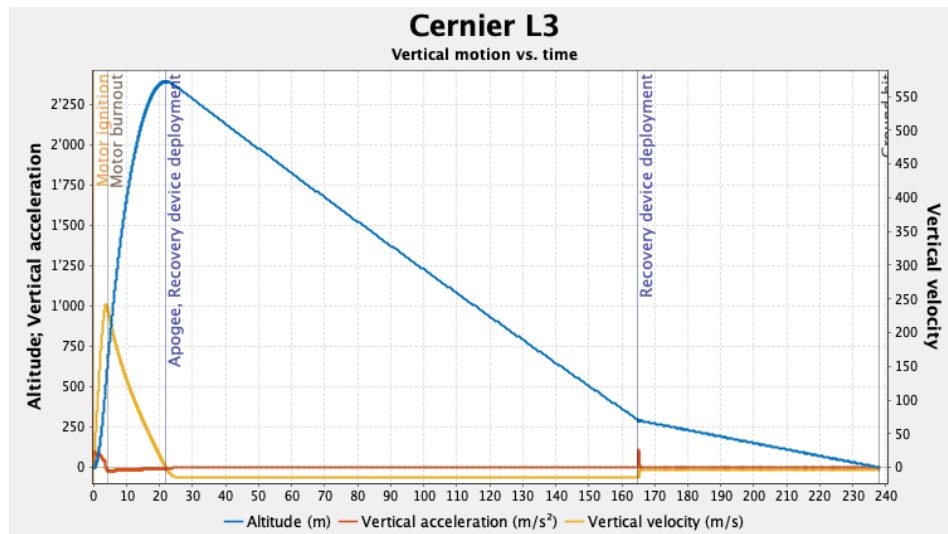
All simulations were carried out assuming:

- 5m/s wind velocity
- 10% variability in wind velocity
- Easterly direction

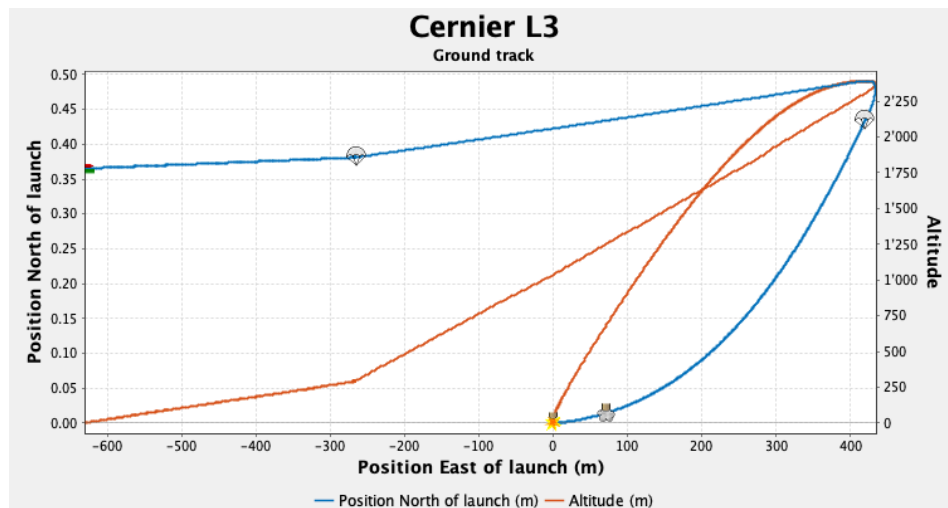
Cernier is at:

- Longitude: 47.1degrees
- Latitude: 6.9 degrees
- Altitude: 820m

## Vertical motion



## Ground Track



# Ejection Charges

## Drogue

The drogue section of the airframe has a diameter of 15.2cm, and a length of 65cm. This section will be secured using 3 M3 shear pins (force is sufficient to shear 6). In order to generate  $6.9\text{N/cm}^2$  (10psi) of pressure, we need a theoretical charge size of: 3.65g

### **[TO BE COMPLETED ONCE ASSEMBLED]**

From ground testing, we find that a charge size of: g is sufficient.

Primary: g

Backup: g

## Main

The drogue section of the airframe has a diameter of 15.2cm, and a length of 35cm. This section will be secured using 3 M3 shear pins (force is sufficient to shear 6). In order to generate  $6.9\text{N/cm}^2$  (10psi) of pressure, we need a theoretical charge size of: 1.75g

### **[TO BE COMPLETED ONCE ASSEMBLED]**

From ground testing, we find that a charge size of: g is sufficient.

Primary: g

Backup: g