Level 3 Certification Project – May 22, 2024
Ryan C. Greenblatt – NAR 107963, TRA 29944

Project name: Seven To Eternity

Advisor: Howard Druckerman (L3CC)

Concept:

This Level 3 certification project consists of a 4-inch diameter G10 fiberglass airframe, capable of accommodating up to 75mm M-impulse+ motors. It is based on a 3-fin booster design by Wildman Rocketry with lower and upper payload sections for drogue and main chute recovery gear. The rocket is topped with a 6:1 filament wound aluminum tipped Von Karmen (VK) conical nose cone, giving the rocket an overall length of 103.25 inches and a **fineness ratio of 25.7:1**. Dry weight, including recovery gear and electronics, rounds out at ~237 ounces (14.81 lbs.).

Certification motor: Aerotech M1780NT
Projected Max Alt: 15,069 ft. AGL (simulated)
Drogue deployment: Apogee
Main deployment: 600 ft. AGL

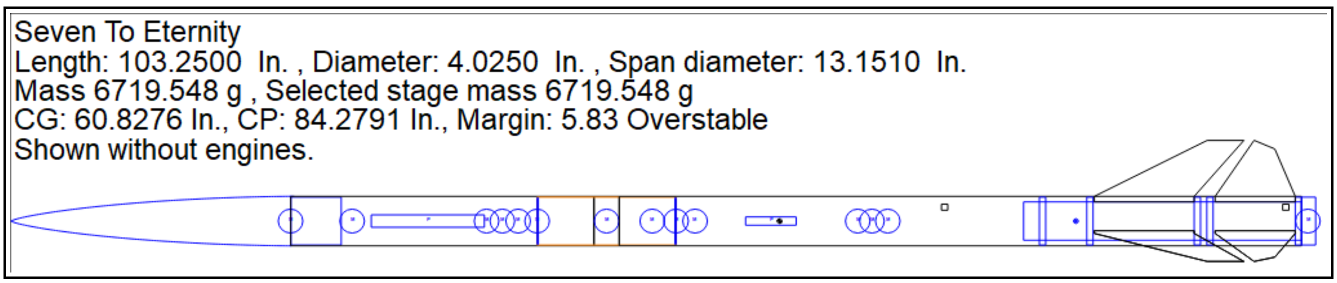


Fig. 1 – Dry Weight

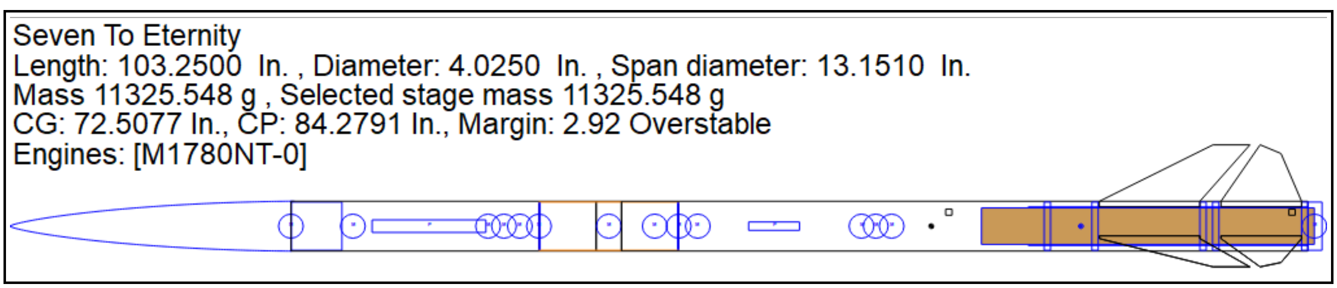


Fig. 2 – Loaded Weight (M1780NT)

Preliminary flight simulation data:

Center of pressure: 84.2791 inches from nose (Rocksim V10.5.0f0)
Center of gravity: 72.5077 inches from nose (Rocksim V10.5.0f0) [Loaded with motor]
Mass at liftoff: 24.96 lbs. (Rocksim V10.5.0f01)
Total impulse: 5783N-Sec.
Burn Time: 3.05 Sec.
Est Drag Coefficient: 0.627747N

Fig. 3 – Flight Profile

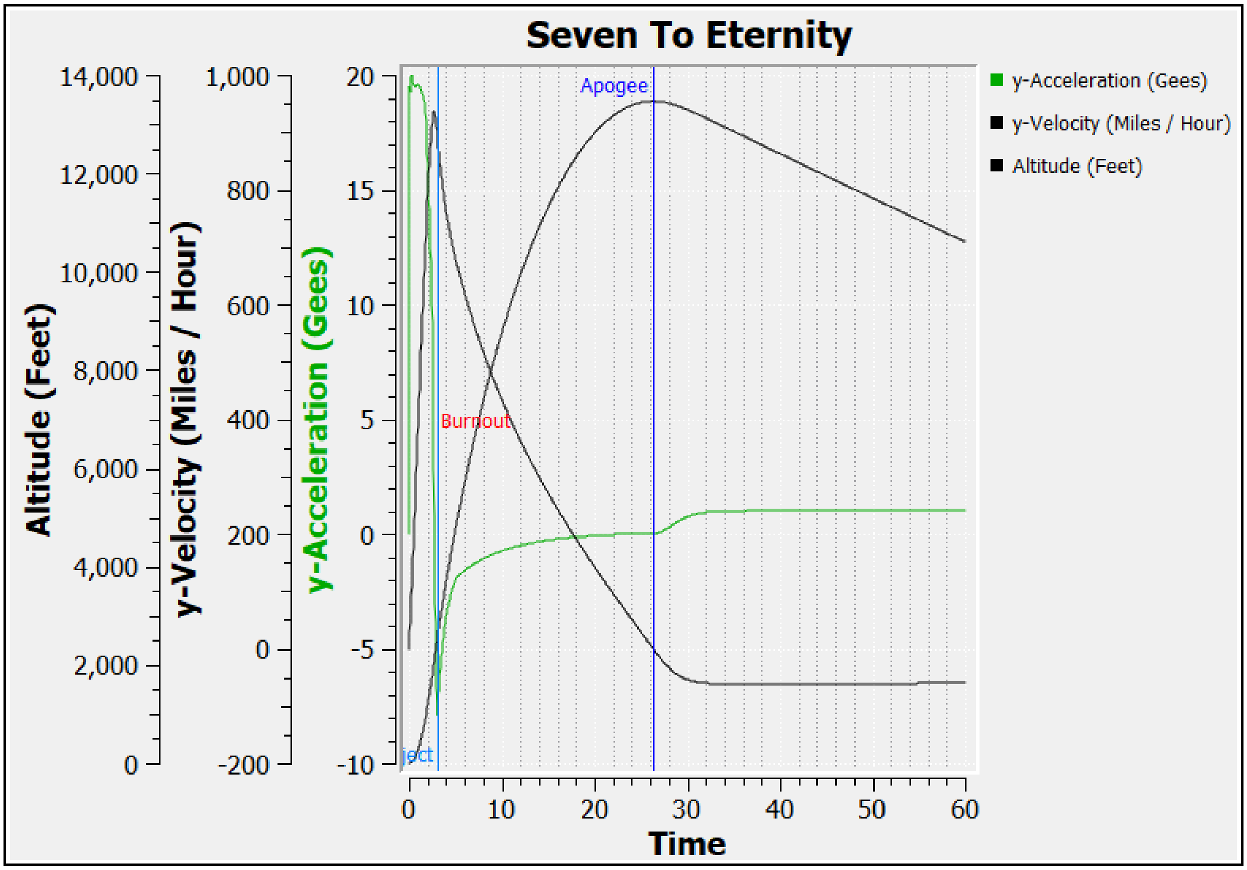


Fig. 4 – Flight Sim Graph

Launch guide data:

- Launch guide length: 120.0000 In.
- Velocity at launch guide departure: 73.9251 MPH
- The launch guide was cleared at : 0.194 Seconds
- User specified minimum velocity for stable flight: 29.9996 MPH
- Minimum velocity for stable flight reached at: 20.3710 In.

Max data values:

- Maximum acceleration:Vertical (y): 19.151 gee, Horizontal (x): 0.389 gee, Magnitude: 19.151 gee
- Maximum velocity:Vertical (y): 937.3072 MPH, Horizontal (x): 14.9000 MPH, Magnitude: 938.3835 MPH
- Maximum range from launch site: 2141.12594 Ft.
- Maximum altitude: 13469.19592 Ft.

Landing data:

- Successful landing
- Time to landing: 206.522 Sec.
- Range at landing: 2141.12594
- Velocity at landing: Vertical: -16.4346MPH , Horizontal: 12.5101 MPH , Magnitude: 20.6543 MPH

Component Descriptions:

Nose Cone

VK 6 to 1 w Aluminum Tip
Material: FWFG
Nose shape: Hollow Sears-Haack series, 6 to 1
Len: 22.1380 In., Dia: 4.0250 In., Wall thickness: 0.1000 In.
Body insert (shoulder): OD: 3.9000 In., Len: 4.0000 In.
CG: 16.1527 In., Mass: 603.887 g

GPS Recovery System/Tracking

Featherweight GPS Tracker + Base Station
Labrat Tracker Sled: Pro grade PETG plastic with a high Tg (Glass transition) of 76 deg C (169 deg F). All parts are solid (100% infill), so no internal voids or honeycombs.
MAC Nosecone Bay: ABS Plastic + Cardboard

Upper Airframe/Payload Section

Material: G10 Fiberglass
OD: 4.0250 In. , ID: 3.9000 In. , Len: 24.0000 In.
CG: 12.0000 In. , Mass: 563.362 g

Main Recovery [Head-End]

Chute type: Wildman Recon 60
Chute size: 60.000 inches
Main Harness: OneBadHawk 3/8” tubular Kevlar 25'

Avionics Bay

Type: G10 fiberglass
OD: 3.9000 In., ID: 3.7750 In., Len: 11.0000 In
Bulkheads: G10 fiberglass, OD: 3.7750 In., Len: 0.0930 In.
Ventband: G10 fiberglass, OD: 4.0250 In. , ID: 3.9000 In., Len: 2.0000 In.

Flight computers:

Primary: Featherweight Blue Raven 1
Backup: Featherweight Blue Raven 2

Switches:

Flight computers: Featherweight Magnetic Switch x2

Sled:

Additive Aerospace 98mm PET Smart Sled 5" long x 3.4" wide x 2.25" deep

BP Charge Wells:

Firebird 3[gram] x2 – for primary charges
Firebird 6[gram] x2 – for backup charges

Camera:

NA

Lower Airframe/Booster Section

Type: G10 fiberglass
OD: 4.0250 In. , ID: 3.9000 In. , Len: 54.0000 In.
CG: 27.0000 In. , Mass: 1268.360 g

Drogue recovery [Booster]

Chute type: Pro Experimental Drogue
Chute size: 24.000 In.
Drogue Harness: OneBadHawk 3/8” tubular kevlar 30'
Motor Mount Bridal: 3/8” tubular kevlar

Motor mount

Type: G10 Fiberglass
OD: 3.1250 In. , ID: 3.0000 In. , Len: 22.0000 In.
CG: 11.0000 In. , Mass: 399.343 g

Fins (3 total)

Planform: trapezoidal
Root chord: 7.9060 In., Tip chord: 2.9050 In., Semi-span: 4.5590 In.,
Sweep: 8.9364 In., Mid-Chord: 7.8871 In.
Thickness: 0.1875 In.
Profile: airfoil
CG: 6.3314 In. , Mass: 496.487 g
Semi-span to thickness ratio: 24.3 to 1 or **4%**

Motor Retention

Aero Pack 75mm Flange Style
MAC 3.9” 75mm Performance Aluminum Thrust Plate

Misc - Zipper Protection

Type: Giant Leap Fireball (large) x2
Material: Kevlar, Nomex, High Density Foam

Overall Dimensional drawing:

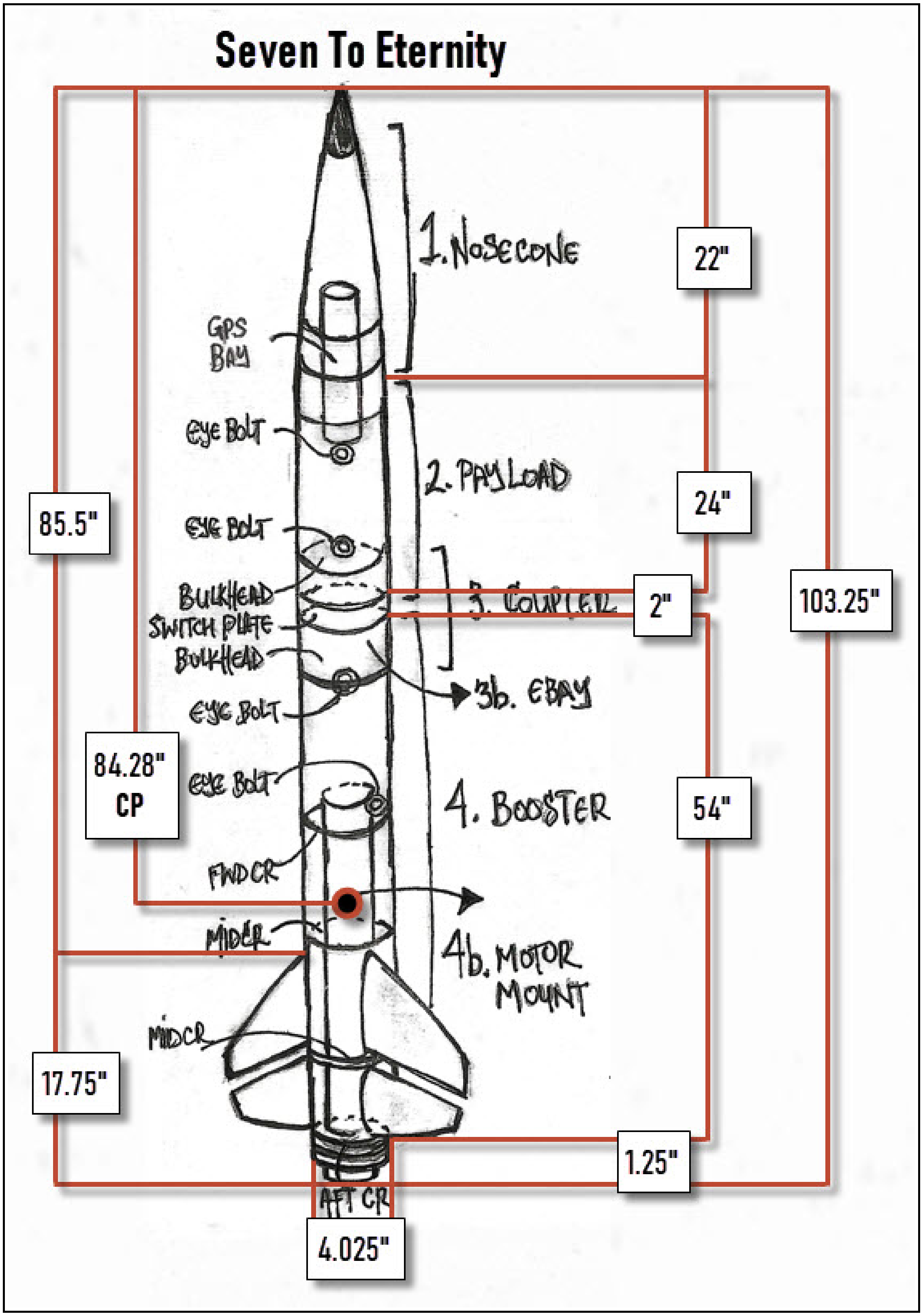


Fig. 5 – Overall dimensional drawing

Component sketch:

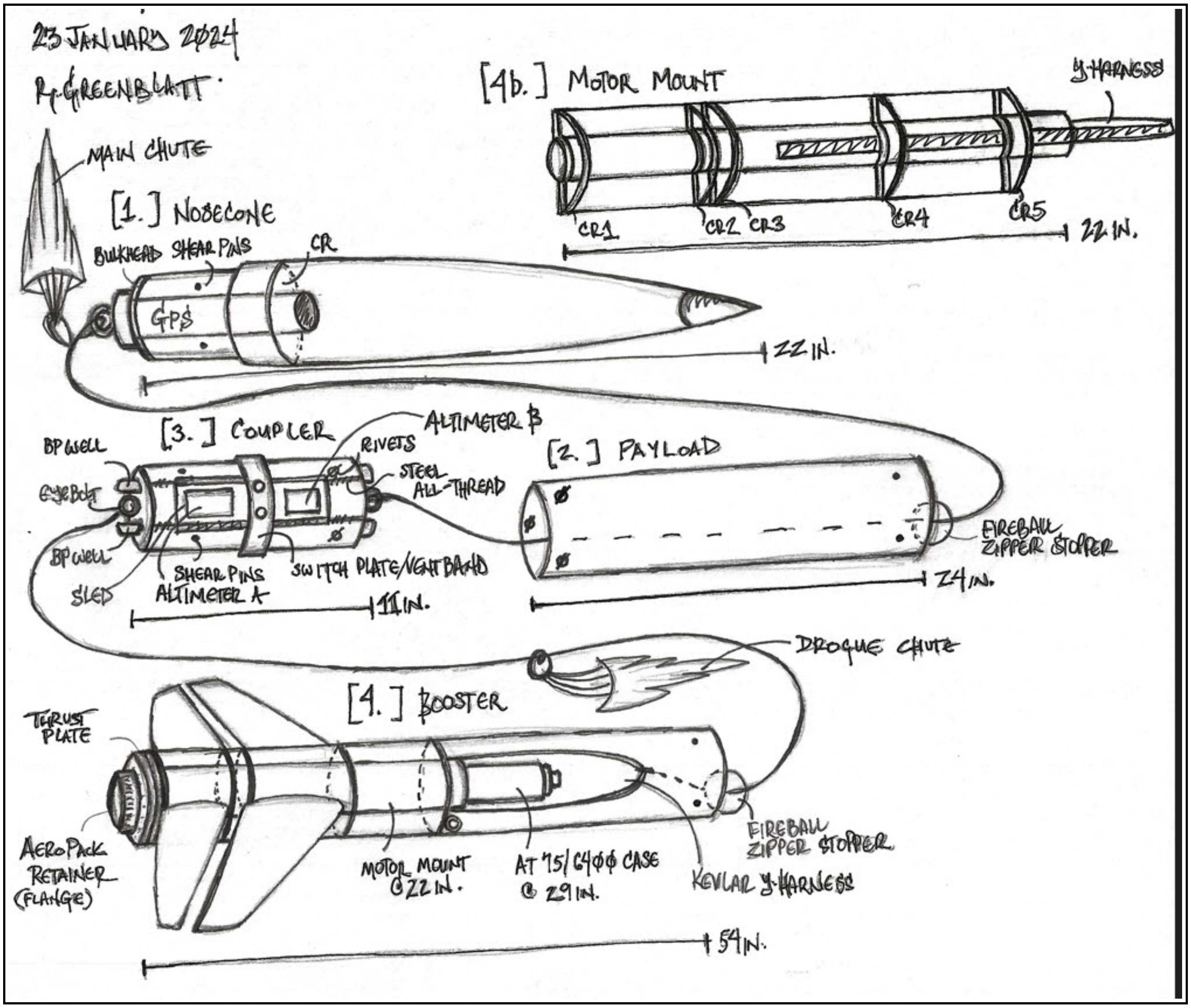


Fig. 6 – Component sketch

Avionics wiring design (front):

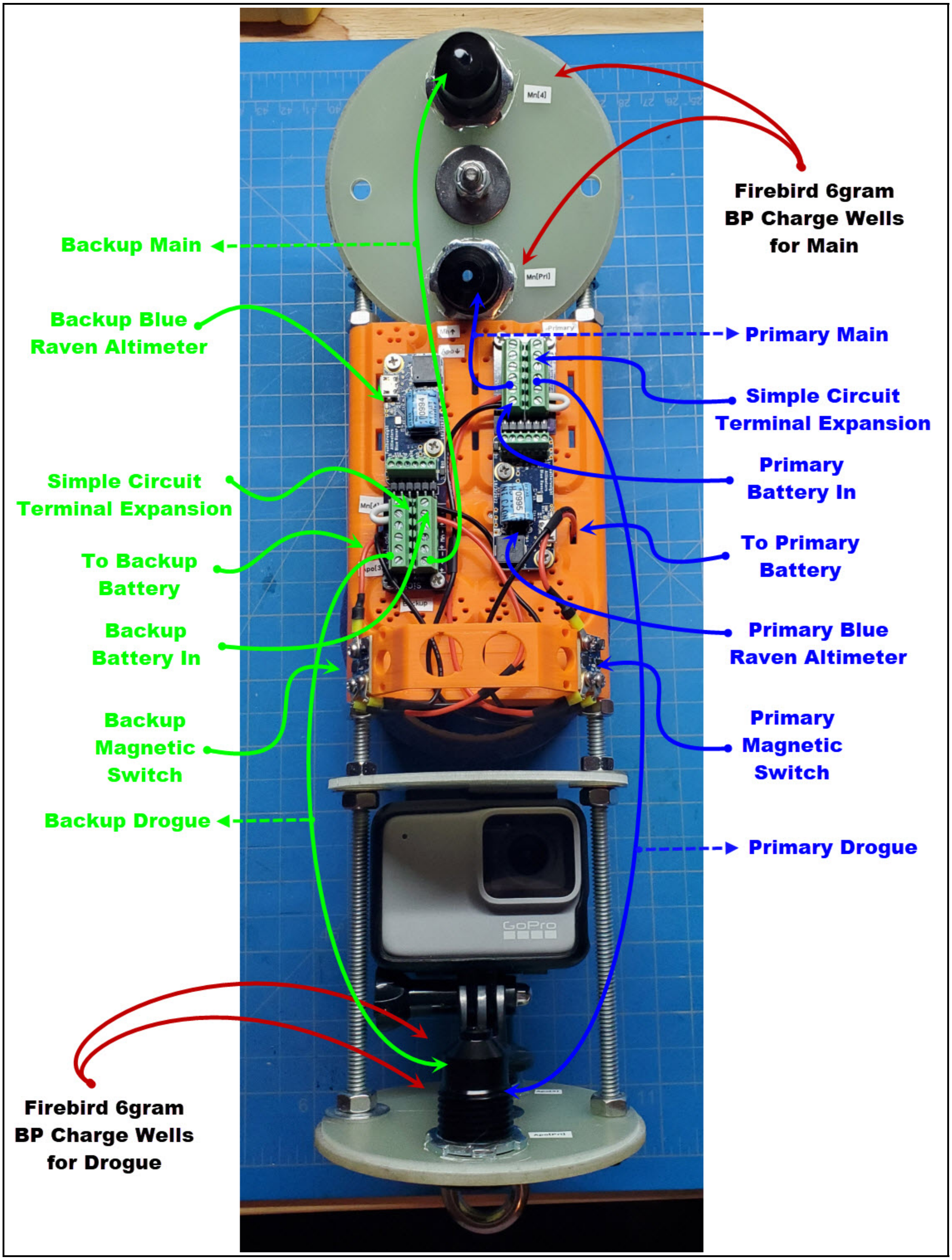


Fig. 7 – Flight Computers Front View

Avionics wiring design (rear):

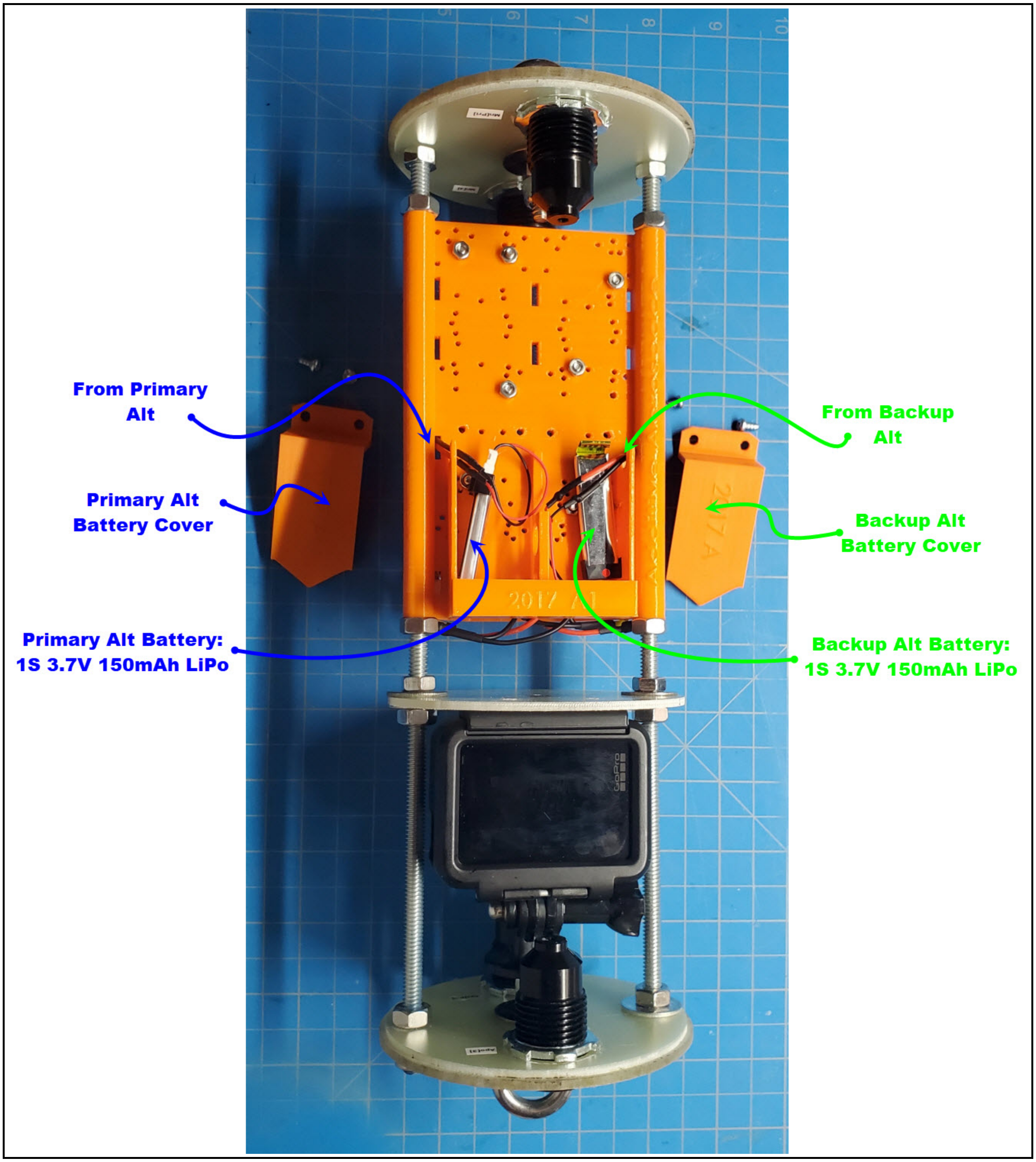


Fig. 8 – Flight Computers Rear View

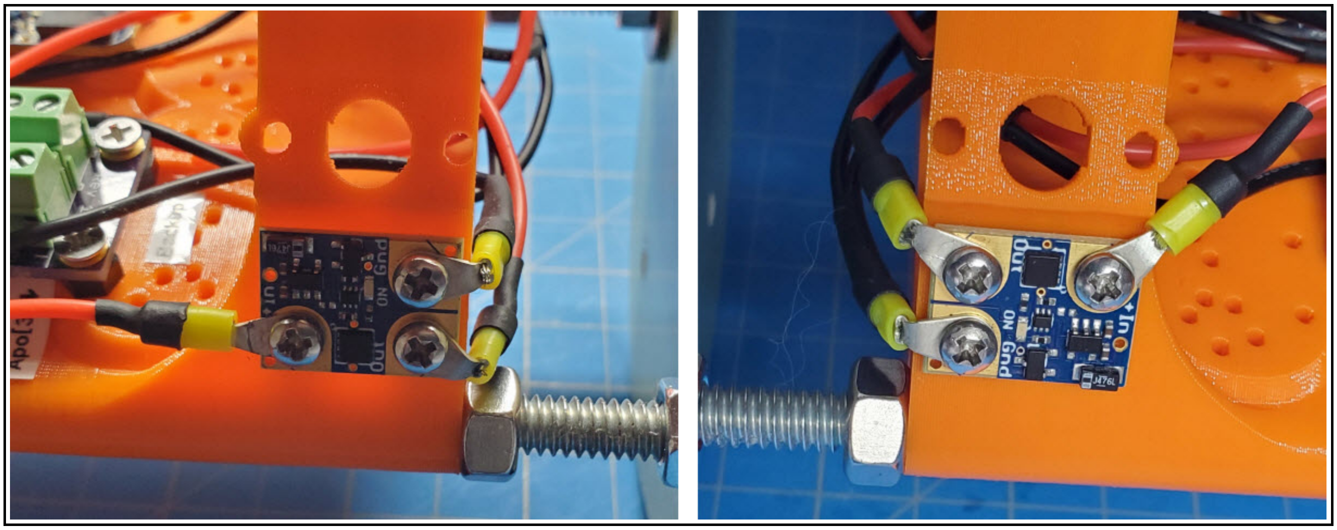


Fig. 9 – Mag Switch Detail (Backup left, Primary right)

Construction Details:

The entire airframe is comprised of 4.0250" DIA. G10 fiberglass tubing, with a wall thickness of 0.12 inches.

The **nose cone** is a VK, 6:1 conical shape, filament wound fiberglass design, with an aluminum tip.

The **GPS system** is comprised of a Featherweight GPS, screwed into a Labrat Rocketry 3D printed sled that is screwed in a MAC Performance Nosecone bay. See GPS System Detail for pictures and additional information.

Fig. 10 – Nose cone

The **fins** are 3/16" G10 beveled fiberglass from Wildman.

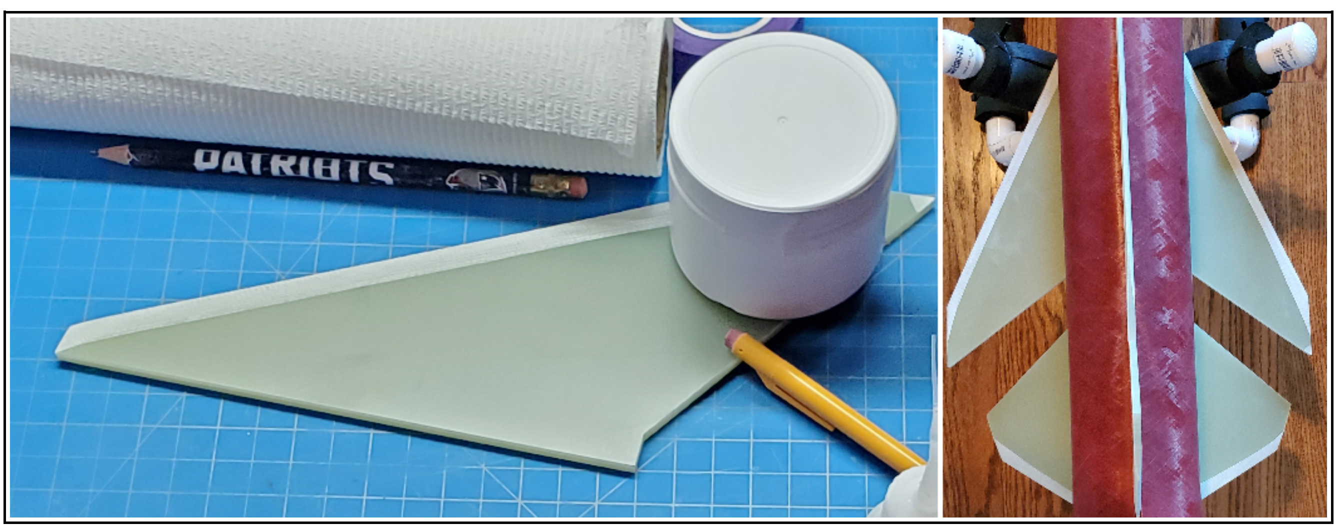


Fig. 11 – Fin Set

The **avionics bay** is comprised of a G10 fiberglass coupler, switchplate, two bulkheads (avionics bay lids) and one coupler bulk plate that separates the altimeter section from the camera section. A 95mm Additive Aerospace 3D printed sled is secured via two 11” sections of stainless steel (SS) all-thread, SS wing nuts, hex nuts and washers. A pair of Featherweight Blue Raven altimeters are screwed into the sled and wired to Featherweight magnetic switches. The lower steel shoulder eye bolt serves as a connection point for the lower Kevlar harness. A pair of Firebird 3(gram) BP charge wells are installed into each bulkhead for the primary charges and a pair of Firebird 6(gram) BP charge wells are installed into each bulkhead for the backup charges. A steel shoulder eye bolt is also bolted to upper bulkhead to serve as connection point for the upper Kevlar harness. See Fig. 7 for Avionics layout.

Motor retention is achieved through the use of an aluminum thrust plate seated and epoxied into the aft end of the airframe. An Aero Pack flanged motor retainer is then screwed down through the thrust plate and into the aft most G10 fiberglass bulkhead. This aft bulkhead is epoxied onto the motor mount so the entire sub-assembly becomes nearly monolithic. All motor mount internals, including the retention sub-assembly were bonded using J-B Weld High Heat Epoxy.

Fig. 12 – Motor Retention Detail

Zipper prevention for both the booster and payload sections is achieved through the use of (2) Kevlar, Nomex and high density foam Fireball kits, designed by Giant Leap.

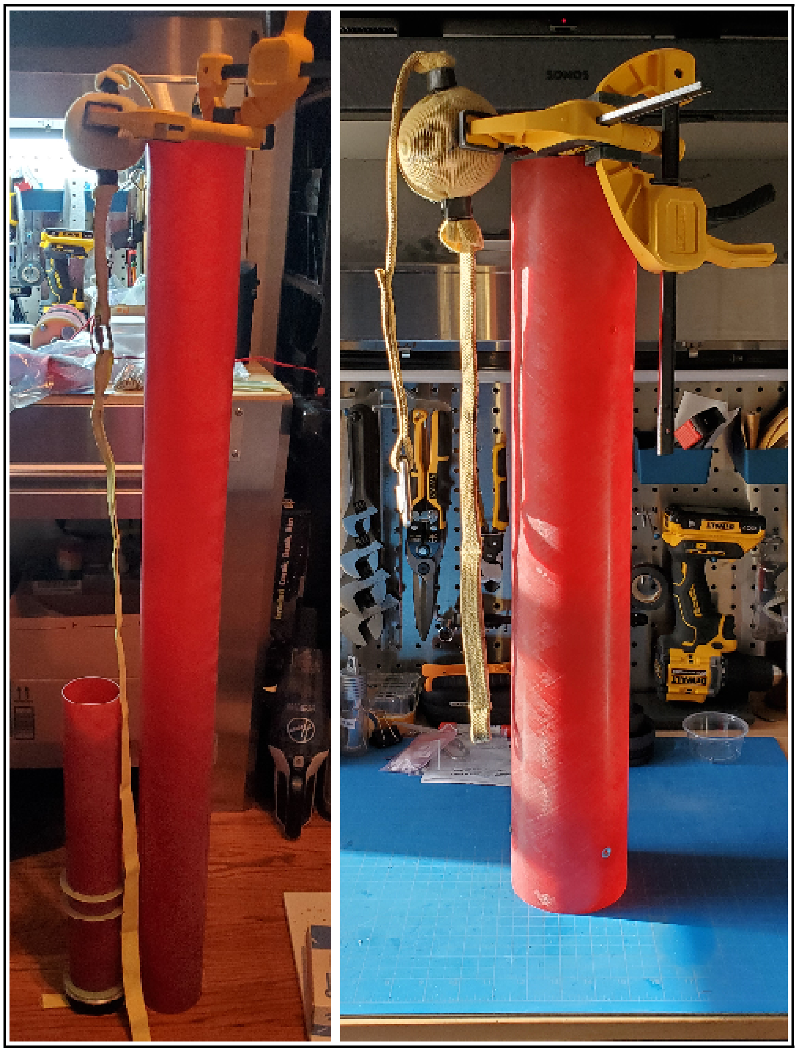


Fig. 13 – Zipper Prevention Detail (Booster Left, Payload Right)

Construction Sub-Assembly Pictures

Motor Mount + Fin Detail

The mount mount (MM) is comprised of G10 fiberglass as specified above, the motor retention sub-assembly (including 2 centering rings), 4 additional centering rings and a Kevlar bridal. The 2 centering rings nearest the top of the MM were modified (filed) to accommodate the width and depth of the Kevlar bridal as it passes through them on either side of the MM. The Kevlar bridal was mounted to the MM tube using J-B Weld High Heat (HH) Epoxy. All centering rings were tacked using CA glue and then permanently bonded to the MM using J-B Weld HH Epoxy. The area between the middle centering rings that separates the forward fin set from the aft fin set was covered in J-B Weld HH Epoxy, creating a strong and rigid structure for the subsequent fin installation. Any ares where fins would contact the MM were taped off using black vinyl tape.

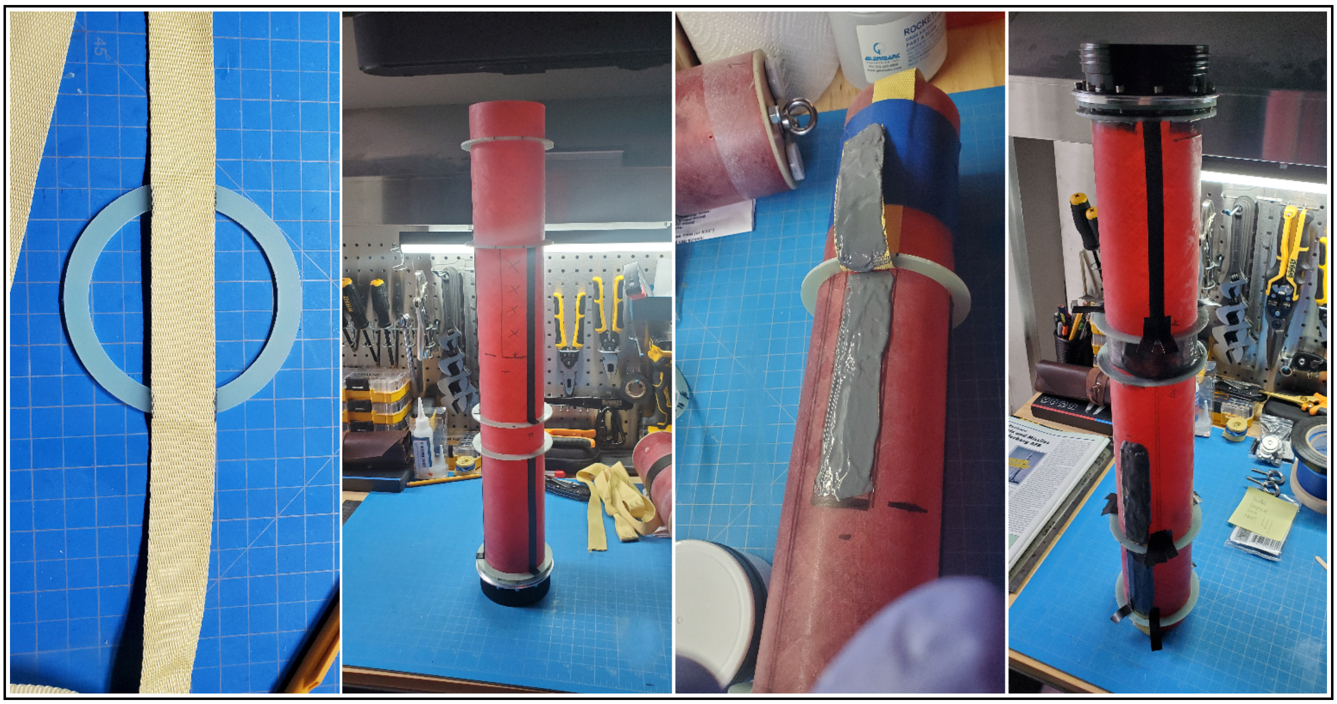


Fig. 14 – Left to right (Centering ring prep, centering ring mounting, y-harness threading and mounting, centering ring fillets laid down)

Fin slots were sanded using 120grit and a full round file was used to create injection ports for the internal fillet applicator. After body tube prep was completed, all fins were dry fit using metal clips and a printed 4” Badass Build Guide (fin alignment jig) from Mach 1 Rocketry.

Root edges for each fore and aft fin set were covered with RocketPoxy G5000, installed and aligned using the fin alignment jig, popsicle sticks and metal binder clips. Each fin set was allowed to fully cure before the next fin set was installed.

After all fin sets were installed, West 105 was mixed with shredded carbon fiber and internal fillets were injected via plastic syringe in the amount of 15ml per fin, per side or 5ml per section.

Next, each fin was taped off to prevent overflow of epoxy during the external fillet layment. RocketPoxy G5000 and a steel ball (cake decorating tool) was used to build up 3/8" fillets.

Finally, the external fillets were sanded using 120grit. Bondo Glaze and Spot Filler was applied to smooth all transitions and the Bondo was then sanded with 180grit until all transitions were sufficiently uniform.

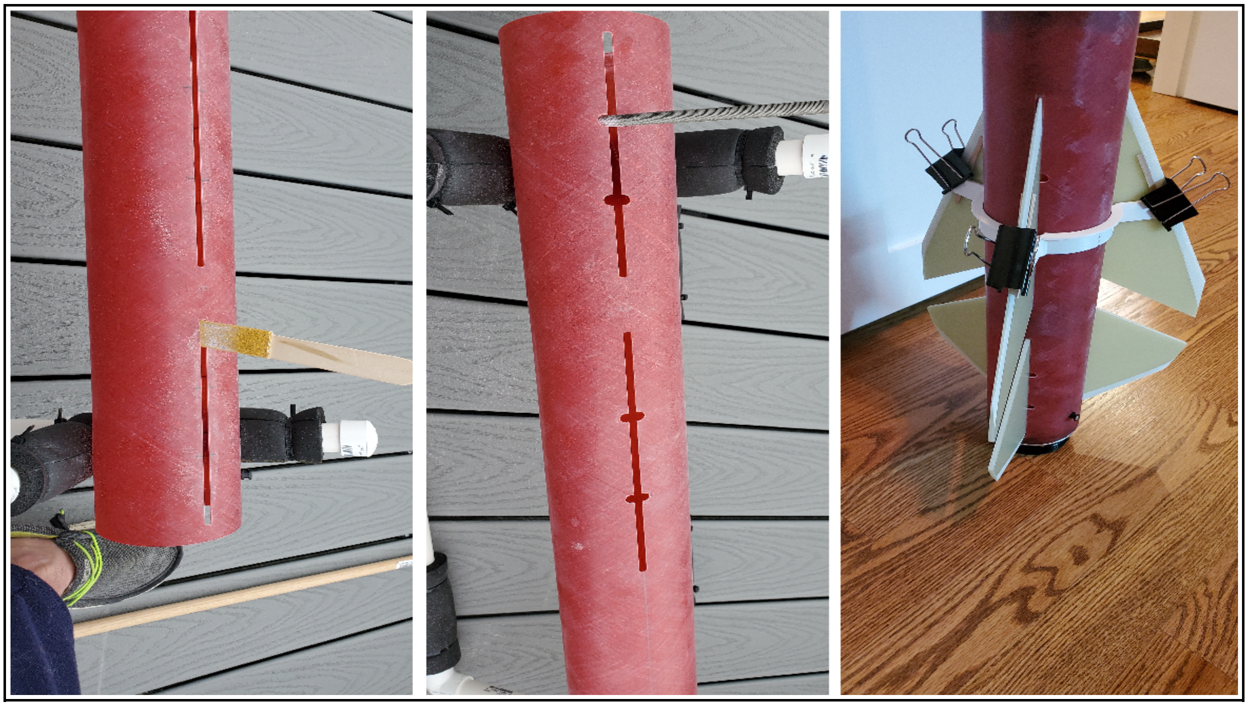


Fig. 15 – Fin slot sanding, internal fillet applicator clearances filed out, dry fit fin sets

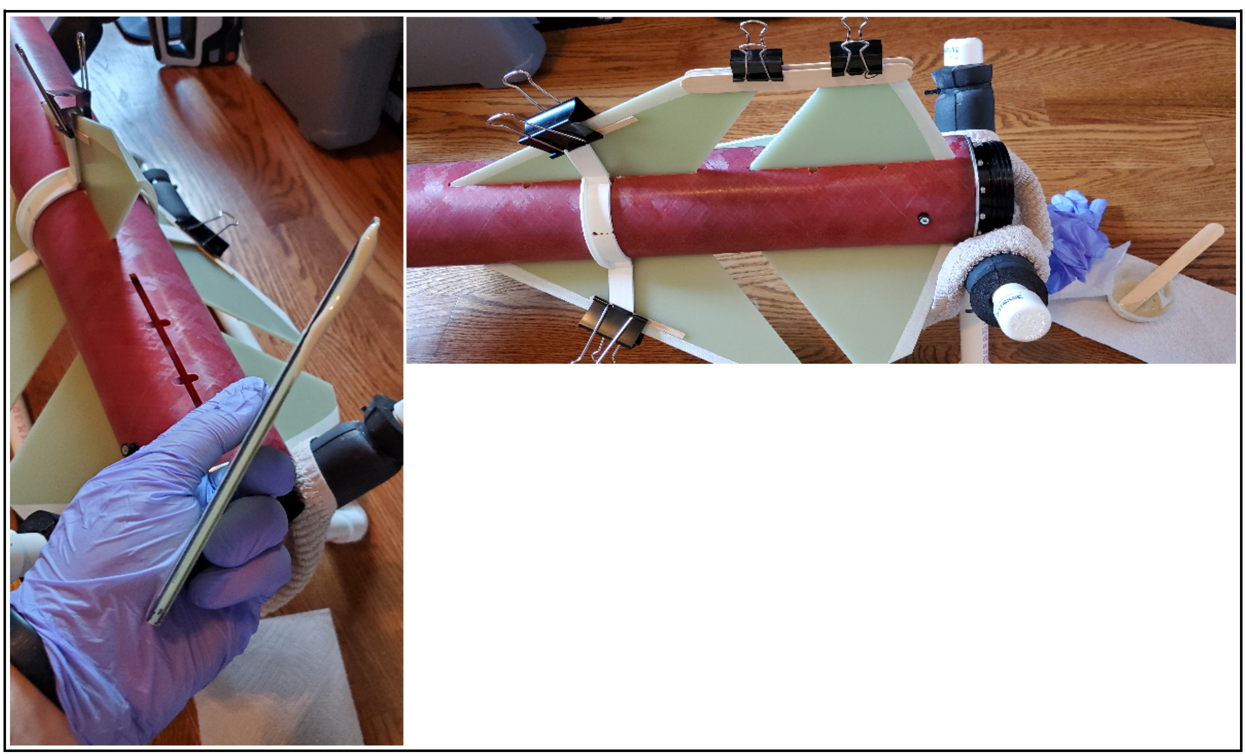


Fig. 16 – Root edge glue-up, fin alignment

Fig. 17 – West 105 mixed w cut carbon fiber, internal fillet injection (5ml/slot)

Fig. 18 – External fillet prep, finished external fillets (RocketPoxy G5000)

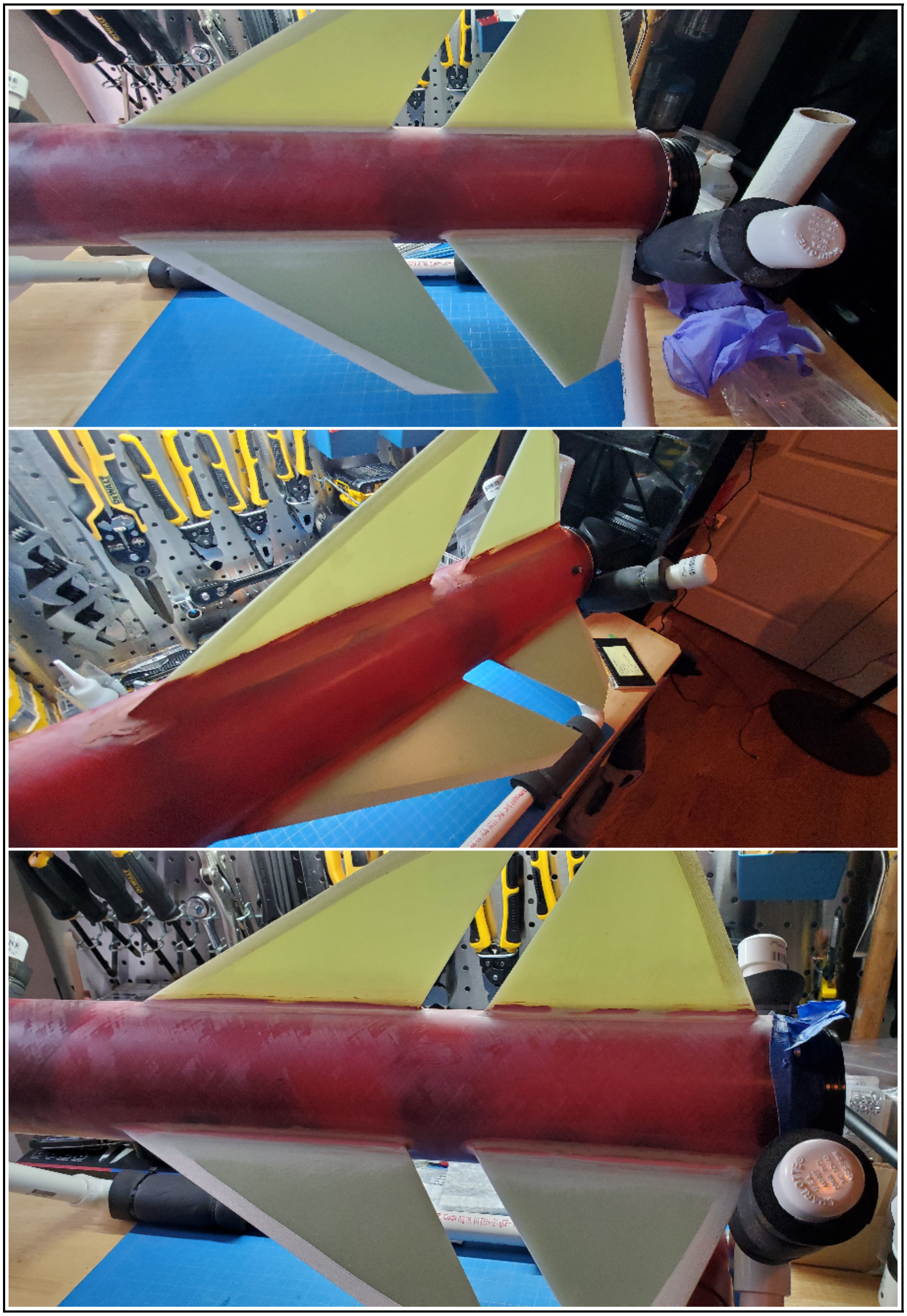


Fig. 19 – External fillet sanding, Bondo spot filler applied, sanded

GPS System Detail

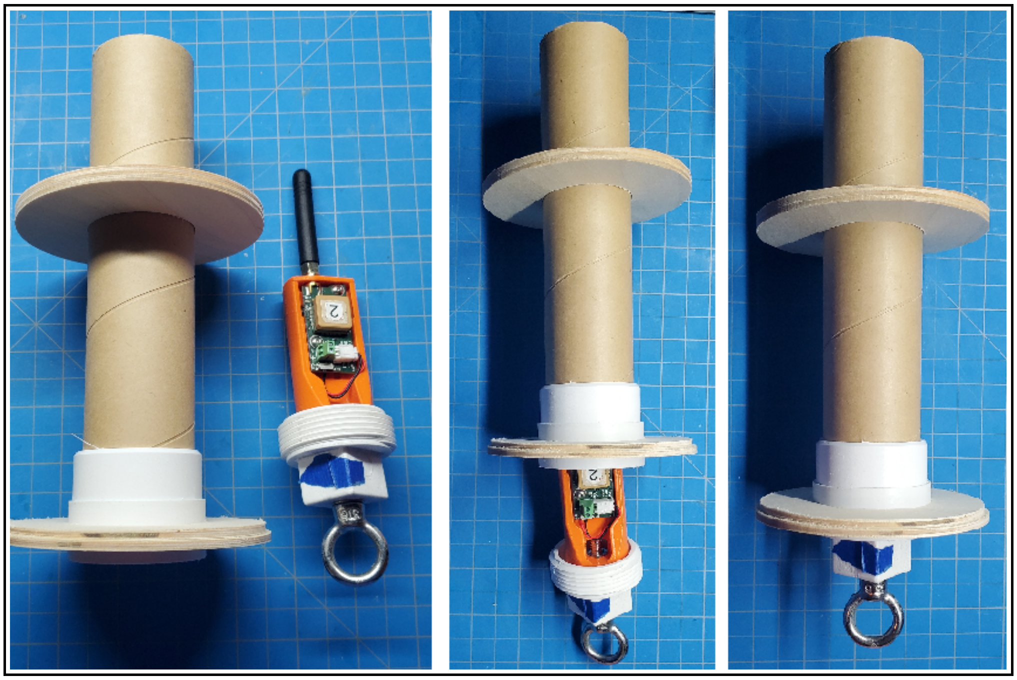


Fig. 20 – Nose cone bay sub-assembly, prior to mounting

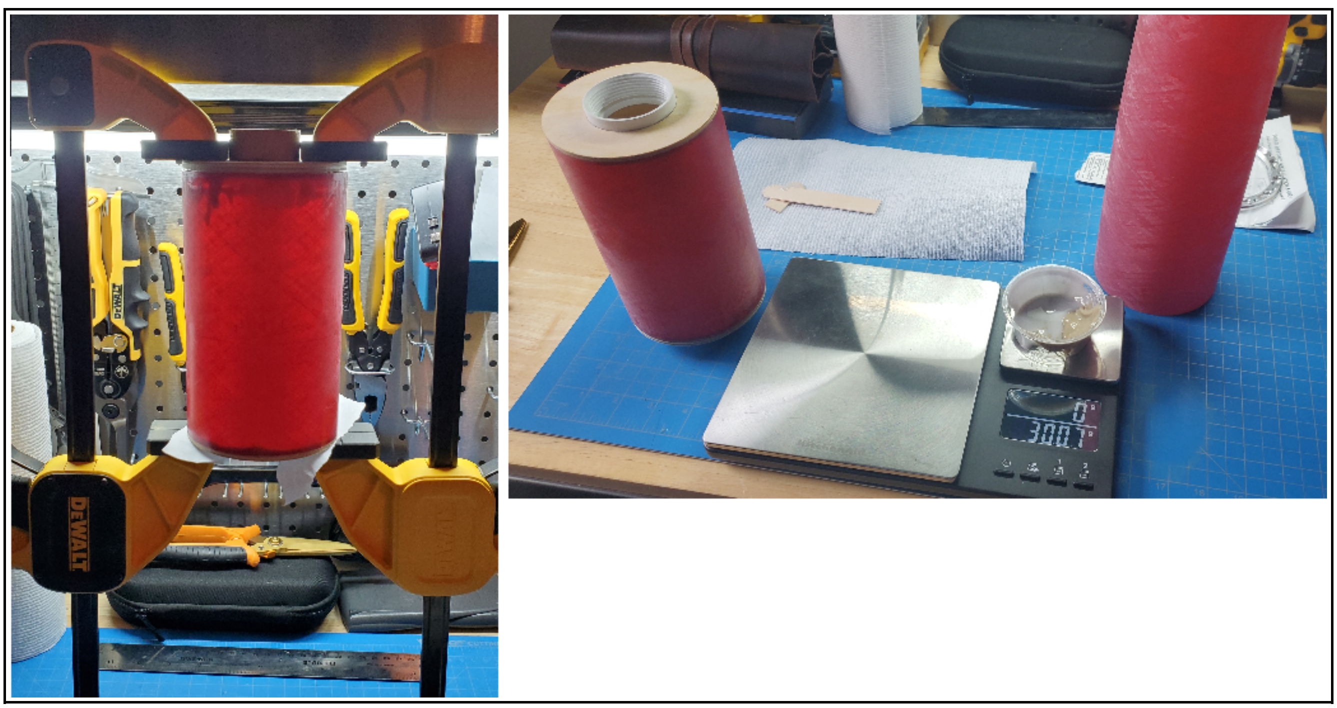


Fig. 21 – Nose cone bay sub-assembly glue up, nose cone mounting prep

Sheer Pin & Aluminum Fastener Detail

I have installed three (3) 4-40 nylon shear screws to temporarily fasten the nose cone to the payload bay (main deployment section). Each nylon screw should require ~38lbs of force to shear, this means that a total of ~114lbs of force should be required to shear all 3 nylon screws. With a primary charge of **3.0g** BP and a backup charge of **4.0g** BP, a force of between 358lbs and 477lbs should be exerted on each bulkhead, more than sufficient to shear all 3 screws (see Deployment Details below for calculation details).

Three (3) 2-56 nylon shear screws are also installed between the lower section of the avionics bay and the booster section (drogue deployment section). Each nylon screw should require ~21lbs of force to shear, this means that a total of ~63lbs of force should be required to shear all 3 nylon screws. With a primary charge of **3.0g** BP and a backup charge of **4.0g** BP, a force of between 197lbs and 263lbs should be exerted on each bulkhead, more than sufficient to shear all 3 screws.

Three (3) 4-40 Vindicoat aluminum fastener inserts are installed between the upper section of the avionics bay and the payload section. These fasteners are epoxied into the inner and outer airframe and are not meant to break away during flight. The estimated shear strength of each 4-40 304 stainless steel machine screw that locks each fastener in place is ~248lbs, this should withstand up to ~748lbs of loading.

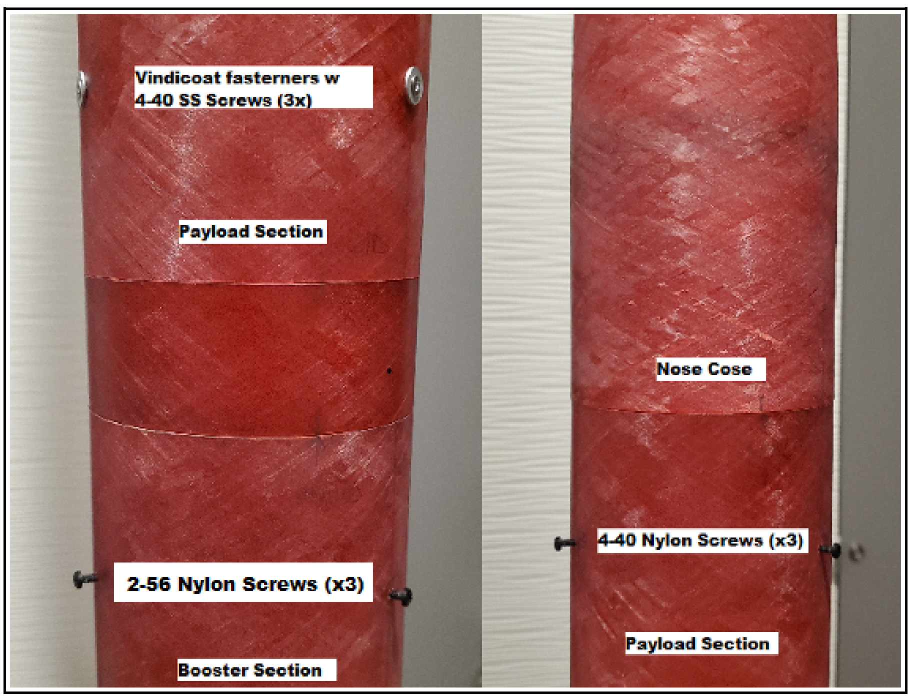


Fig. 22 – Nylon screws and Vindicoat Fasteners

Finished Assembly

Fig. 23 – Finished assembly

Recovery System Package

Deployment Details

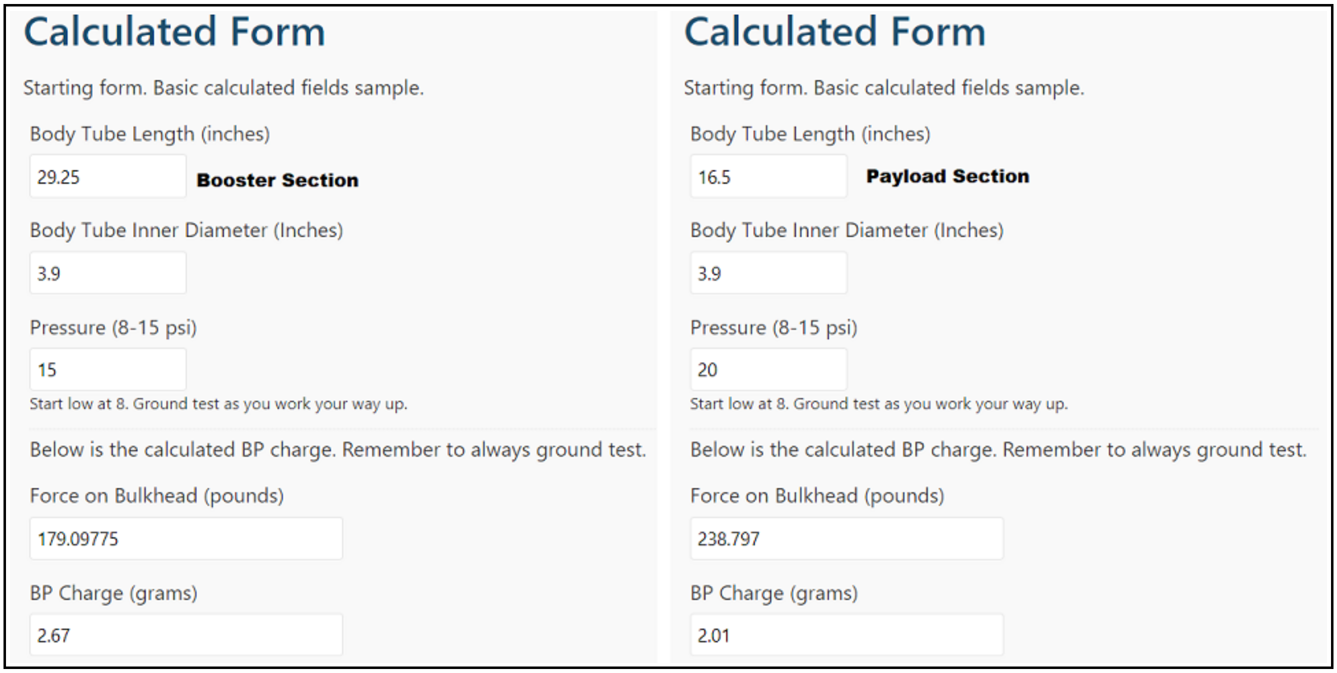
Courtesy of https://rocketrycalculator.com/rocketry-calculator/bp-estimator/

$$Pressure(psi) = \frac{Force(lbs)}{Area(inch^2)}$$

$$volume(inches^3) = \frac{\pi \times (diameter(inches))^2 \times Length(inches)}{4}$$

$$Grams(BP) = \frac{454grams}{1lbf} \times \frac{Pressure(psi) \times Volume(inches^3)}{266\frac{inches\bullet lbf}{lbm} \times 3307 \circ R}$$

Fig. 24 – BP Charge Estimation Formula



Calculated Form

Starting form. Basic calculated fields sample.

Body Tube Length (inches)

29.25 **Booster Section**

Body Tube Inner Diameter (Inches)

3.9

Pressure (8-15 psi)

15

Start low at 8. Ground test as you work your way up.

Below is the calculated BP charge. Remember to always ground test.

Force on Bulkhead (pounds)

179.09775

BP Charge (grams)

2.67

Calculated Form

Starting form. Basic calculated fields sample.

Body Tube Length (inches)

16.5 **Payload Section**

Body Tube Inner Diameter (Inches)

3.9

Pressure (8-15 psi)

20

Start low at 8. Ground test as you work your way up.

Below is the calculated BP charge. Remember to always ground test.

Force on Bulkhead (pounds)

238.797

BP Charge (grams)

2.01

Fig. 25 – BP Charge Estimations

Description of the recovery system components

Drogue Deployment Charge (**Booster Section**):

- Drogue Bay volume: 29.25” L x 3.9” DIA.
- Primary charge set to fire @ apogee, backup charge @ apogee +2s
- **Estimates:**
  - Yields 2.7g BP (**Primary, rounding to 3.0g**) + 50% safety factor = **4.0g BP (Backup)**
  - (3) 4-40 nylon shear screws
  - Pressure @ 15psi equals ~180lbs loading on bulkhead for Primary
  - Pressure @ 22.5psi equals ~ 269lbs loading on bulkhead for Backup
- **Ground Test Actuals (using 3x 2-56 nylon shear screws):**
  - 3.0g separated and fully removed drogue
  - 4.0g separated, fully removed drogue and fully extended harness
  - **Based on test results, setting primary to 3.0g and backup to 4.0g**
  - **3.0g pressure @ 16.5psi ~197lbs loading on bulkhead for Primary**
  - **4.0g pressure @ 22psi ~262lbs loading on bulkhead for Backup**

Main Deployment Charge (**Payload Section**):

- Main Bay volume: 16.5” L x 3.9” DIA.
- Primary charge set to fire @ 625ft, backup charge @ 525ft
- **Estimates:**
  - Yields **2.0g BP (Primary)** + 50% safety factor = **3.0g BP (Backup)**
  - (3) 4-40 nylon shear screws
  - Pressure @ 20psi equals ~239bs loading on bulkhead for Primary
  - Pressure @ 30psi equals ~358lbs loading on bulkhead for Backup
- **Ground Test Actuals:**
  - 2.0g failed to separate
  - 3.0g separated and fully removed drogue minimally extended harness
  - 4.0g separated, fully removed drogue and moderately extended harness

- **Based on test results, setting primary to 3.0g and backup to 4.0g**
- **3.0g pressure @ 30psi ~358lbs loading on bulkhead for Primary**
- **4.0g pressure @ 40psi ~477lbs loading on bulkhead for Backup**

Shock Cords (3,600lb rated):
- Both shock cords (drogue and main) are 3/8" tubular Kevlar
- Payload/MM Bridal is 3/8" tubular Kevlar

Main Chute:
- Wildman Recon 60"
- Rated for a 22lb rocket
- Verified by Mark Rose TRA #11717
- Projected velocity @ deployment: 86fps
- Projected decent rate under main: **29fps**
- Estimates determined by RockSim see Fig 26

Drogue Chute:
- Pro Experimental Drogue 24"
- Drag coeff .97
- Projected velocity @ deployment: 32fps
- Projected decent rate under drogue: **88fps**
- Estimates determined by RockSim see Fig 26

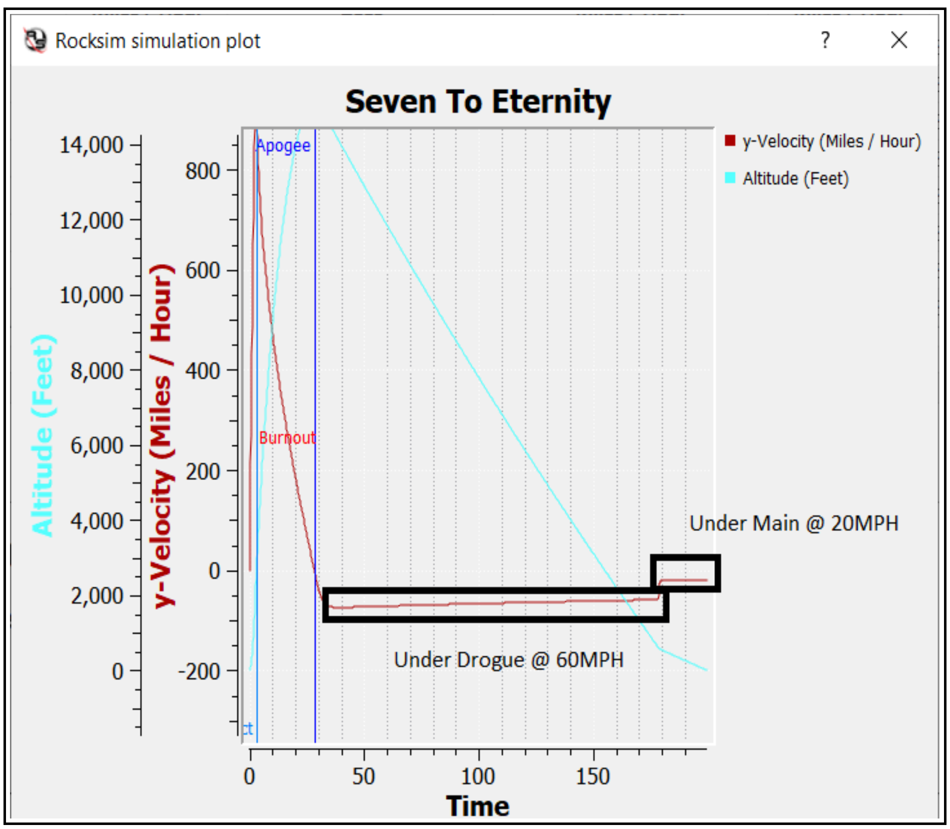
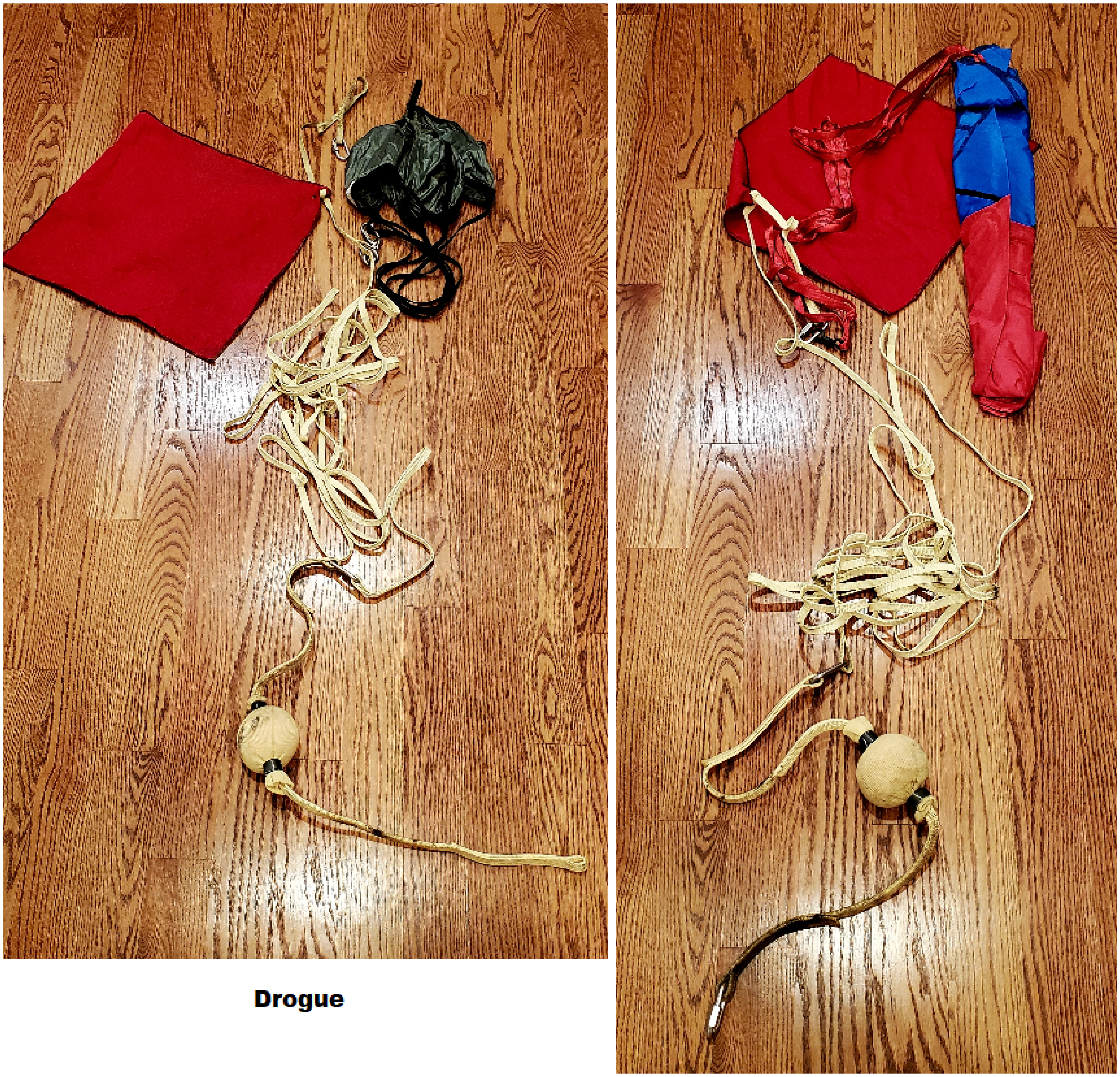


Fig. 26 – Velocity under drogue and main



Drogue

Main

Fig. 27 – Recovery gear

Description of recovery initiation control components

1. Logic and controls modules
   - Black powder charges are controlled via a primary Blue Raven altimeter and a secondary or backup Blue Raven altimeter.
   - Redundancy is achieved by configuring the primary Blue Raven to control primary drogue and primary main while the backup Blue Raven controls the backup main and the backup drogue.
   - Each altimeter is powered by it's own 3.7V LiPo battery, switched via it's own high-g rated magnetic switch and is capable of initiating both the drogue and main events independently.

2. Power Sources
    - Each altimeter is powered by it's own 3.7V 150mAh Li-Polymer battery, as recommended by the manufacturer and as tested during several prior high-power flights.
    - Each battery has been ground tested to ensure consistent and sufficient power is available and delivered.
3. Safe and Arm Provisions
    - Each altimeter is controlled by an independent magnetic switch and the internal circuitry of the Blue Raven is designed and configured to prevent power surges to the terminal block on startup.
    - The altimeter can be configured prior to launch or at the launchpad and each individual event channel can be armed and disarmed independently from a safe distance away from the rocket.
    - The Blue Raven app allows a user to see the status (arm/disarm, continuity with voltage and event description/configuration settings) of each channel in real-time while within Bluetooth range of the altimeters.
4. Output Devices
    - Each channel is wired to a pair of Firewire Electric Matches and seated in an anodized Firebird Charge Well. Using a pair of matches per well is recommended by Tinder Rocketry and in my experience is a configuration that has performed well in the field.
    - Each Firewire has a recommended min firing current of .75amp, and the Blue Raven delivers 4amps for each event (to each wire).
    - For continuity checking, the Blue Raven delivers 1 milliamp, the Firewire can handle up to 40 milliamps.
    - Each wire in the pair has the positive ends twisted together and the negative ends twisted together and these wire sets are then connected to the appropriate port on the Blue Raven input section based on polarity.
5. Schematic/Wiring Diagram
    - Please see the Avionics Wiring Design section as well as figures 7 and 8.
6. Mounting Structure/access features
    - Please see the section below figure 11 (page 11) that describes the avionics bay in detail.
7. Pyrotechnics Devices
    - 4F black powder is loaded into each charge well and ignited via the Firewire Electric Matches as described above.
    - Please see the Deployment Details section above for additional information on how quantity, volume/weight were calculated and tested.