NAR Level 3 Certification Package

Project Name: Scaleless Rogue

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Contents

1. INTRODUCTION

I began high power rocketry in 2011 during college and then fell out of the hobby until recently. Starting back up in 2021, I obtained my L2 in 2022 and have a dozen flights in the H-L impulse range including many redundant dual-deploy flights up to 6,990 feet AGL. Low and mid-power activities number somewhere around 60-70 flights in the A-G impulse range. I also have my own FAA Waiver for Jordan Bay in Sebago Lake during the winters.

I've documented most of my recent projects and flights on youtube (including my Doorknob on an L1090, and two flights of this L3 Rocket on a K1050 and K1275 at CRMRC): https://www.youtube.com/@pathtouch1

While planning for my L3 rocket build, the follow initial criteria were personal requirements:

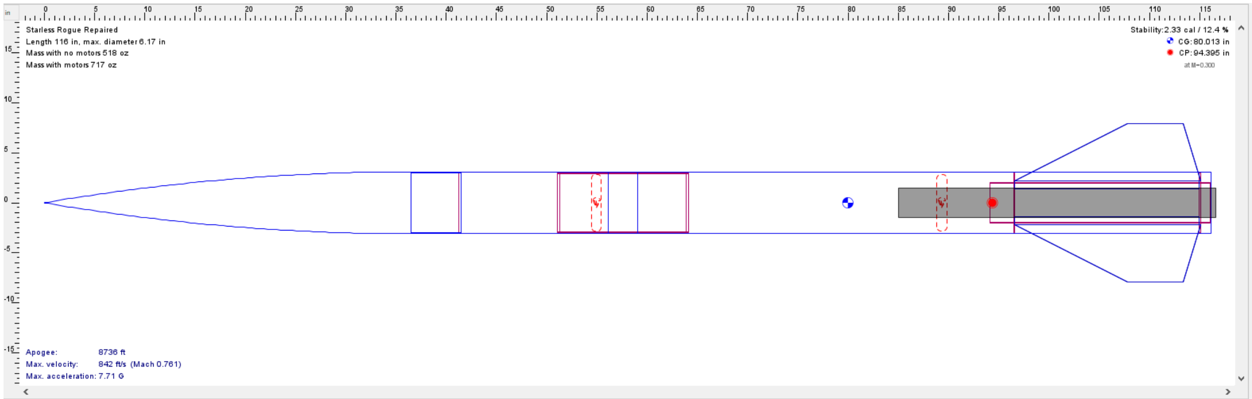
- Fiberglass airframe, as I occasionally launch on frozen lakes and they don't treat cardboard well.
- 98mm motor mount adapted to an AT M1315 in 75mm hardware to allow for flexibility.
- Apogee under 10,000ft to be east coast waiver friendly.
- Four fin design for added drag and better stability.
- Capable of flying on an K-impulse shake down flight

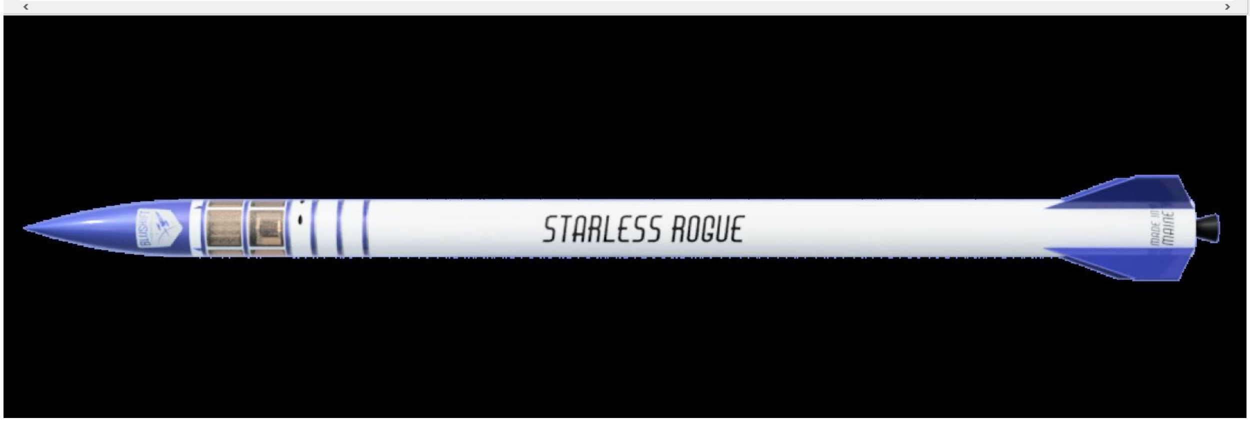
I decided I would like to create a loosely quartered scale model of the "Starless Rogue". This is the proposed sub-orbital vehicle being developed by BluShift Aerospace. They are a Maine based company working on developing the first commercial rocket powered by carbon-neutral biofuel. After Pricing out options with several vendors the most economic source for airframe materials would be to start with an Ultimate Widman Kit from Wildman Rocketry. Tim Lehr was able to provide me with an additional fin, and slotted the airframe for a four-fin setup versus the standard three-fin offering. The overall length, nose cone profile, and fin shapes aren't exact matches. This is mostly due to a zipper shortening the length 16-inches during the first test flight. As the rocket hasn't reached production yet I am satisfied with the look, and I will name this the "Scaleless Rogue".

L3 Project Overview

Dimensions	6" Diameter x 116" Length
Weight On the Pad & at Burnout	44.8 lb / 32.4 lb
Planned Motor	Aerotech M1315 in 75/6400 hardware
Expected Altitude	8,736 feet AGL
Recovery system operation	Traditional Redundant Dual Deploy with Drogue and Main Chutes
Fins	Four Clipped Deltas
Software for Simulating Values in Report	OpenRocket 22.02

2. SCALE DRAWING





3. CONSTRUCTION MATERIALS AND TECHNIQUES

3.1 Materials

A summary of Airframe materials is given below and their weights within the OpenRocket model were updated based on actual measurements throughout construction.

Airframe Materials

Body tubes or fuselage	6” Diameter Filament Wound Fiberglass
Nosecone	5:1 Von Karman with Aluminum Tip
Fins	3/16” thick G10
Centering Rings	1/8” thick G10
Launch Pad Interface	1515 Rail Buttons
Reinforcement materials	Epoxy thickened with colloidal silica
Adhesives	Total Boat Epoxy
Motor Retention	Aero Pack 98mm flanged retainer and 75mm motor adapter

3.2 Fin Flutter Analysis

An analysis was done based on Apogee Rocket’s Peak of Flight article 291 by Zachary Howard[1]. There has been some commentary on this approach but AeroRocket AeroFinSim is no longer available, and this was the most relevant reference found. As this is project is based on a commercially available kit used regularly, fin flutter is not a major concern but the exercise was performed to increase comfort level. Based on fin dimensions and materials, expected flutter boundary velocity would be 1,024 fps. The anticipated maximum velocity is approximately 82% of this value therefore the fins should be fine with no additional reinforcement beyond a typical epoxy fillet at the root chord.

3.3 Shear Pin Sizing

Maximum negative acceleration after motor burnout is expected to be near -3.0Gs. Conservatively assuming the fin can was fully restrained, the weight of the rocket including and beyond the AV Bay is 23 lb. Multiplied by 3.0Gs, requires shear pins capable of withstanding 69 lb of drag separation. The combined shear strength of two #4-40 nylon shear pins ranges from 100-152lb based on RocketryCalculator.com and those will be

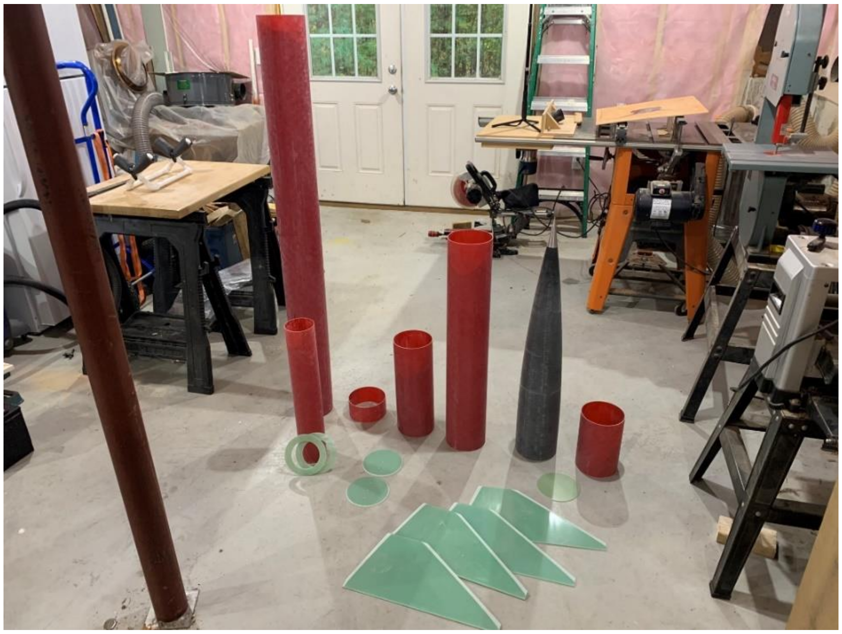
[1] https://www.apogeerockets.com/education/downloads/Newsletter615.pdf

used at connection of the fin can to the avionics bay. Nosecone weight is approximately 5.3lb. Assuming a maximum acceleration of 50Gs occurs due to some abnormal deployment of the drogue (discussed below), the maximum force nose cone shear pins should be able to withstand is 265lb. The combined shear strength of four #4-40 nylon shear pins ranges from 200-304lb and will be used at the nose cone.

3.4 Techniques

Naturally as soon as my box of goodies arrived I had to tape it all together and stack it up to get a sense of scale. I'll file this under large.

Aside from my extra fin, below is what you get with the Ultimate Wildman kit. The only exception is I cut myself an extra 1/8" G10 bulkhead for the nosecone. You'll see later on I used this to create a stepped bulkhead so I'll be able to maintain access to the nose cone for GPS trackers and other payloads.



I did the usual parts cleaning with warm soapy water to get rid of any stray dust/fibers and mold release. All surface preparation for bonding fiberglass components will be based on advice from Rocketry Forum and consist of sanding with 220 grit and cleaning with either acetone or denatured alcohol until a good water break surface is achieved. This 6" Bosch sander has been worth its weight in gold for prep on large diameter rockets and will continue to do so for this build. Hooking it up to a shop vacuum also greatly reduces the fiberglass dust let loose in the shop. My epoxy of choice is Total Boat 5:1 thickened with West 406 colloidal silica when needed. I've recently tested this product combo on a K2050 flight in a 4" bird @ 44Gs, and then proceeded to cut that fin can loose and drop it out of a 60-foot pine tree and not a single fillet was cracked.

Nose cone construction started by bonding the shoulder. I decided I wanted this epoxied in place. I have done Wildman kits where you leave this loose and rely on threaded rod and a larger bulkhead to hold everything together, but I feel like that can distort the nose cone shape.

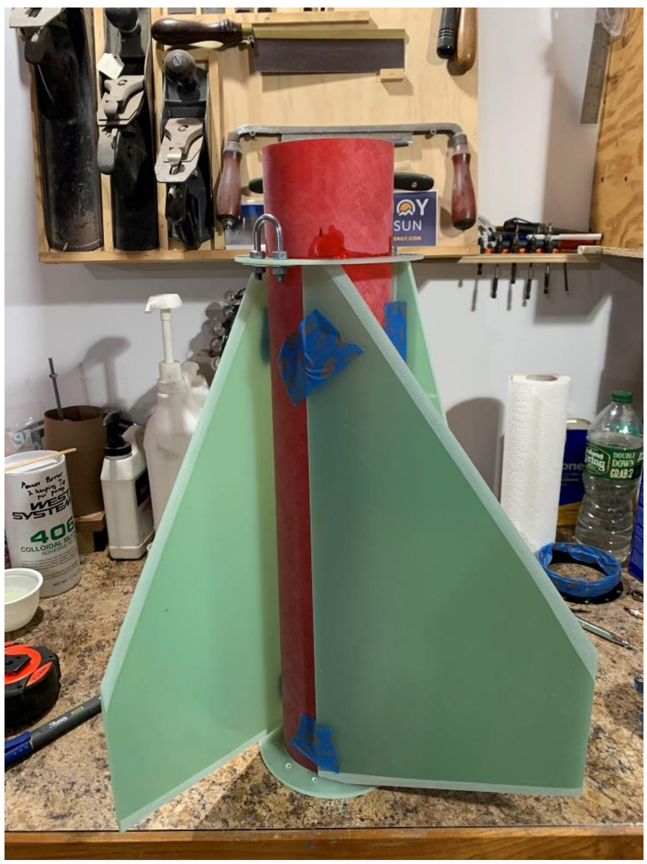
Speaking of that bulkhead. I didn't think ahead to order, or ask for this to be swapped out to one that matches the OD of the shoulder. The stock kit comes with one matching the ID and the intent is for you to epoxy it in place. Luckily, I had a sheet of 1/8" G10 and just cut my own extra bulkhead out, and bonded this to the stock bulkhead to create a super beefy stepped bulkhead. I attached a 1/4" u-bolt here with blue locktite, and drilled a hole to accept a long 1/4-20 rod from the aluminum tip.

Here you can see the 1/4-20 rod double nutted and locktited. This is essentially the nose cone ready for paint! I'll drill shear pins last after running some calcs.

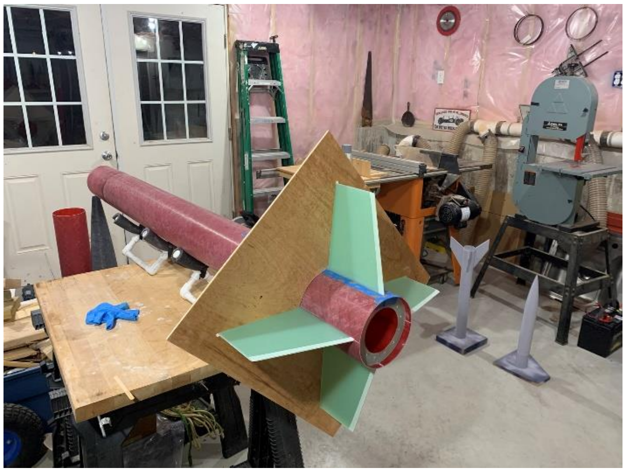
The weakest component here hardware wise is the 1/4-20 rod, and that's rated to 1,900 lb ultimate strength. This nose cone is about 5lb, so unless a 380G deployment event happens nothing should fail.
Steady progress in the rocket lab.

Moving onto the motor mount. I squared up the tubes on a flat piece of tile with some 120 grit sand paper. I also did this for all the body tubes but didn't get a photo of that. Next, I predrilled the centering rings for the Aeropack and my two 1/4" u-bolts for recovery gear. Each u-bolt is rated for 2,822lbs so the two of them can handle over 5,600 lbs.

I tacked the centering rings in place with thick CA using the fins as spacers. **Make sure u-bolts and fins don't conflict!**

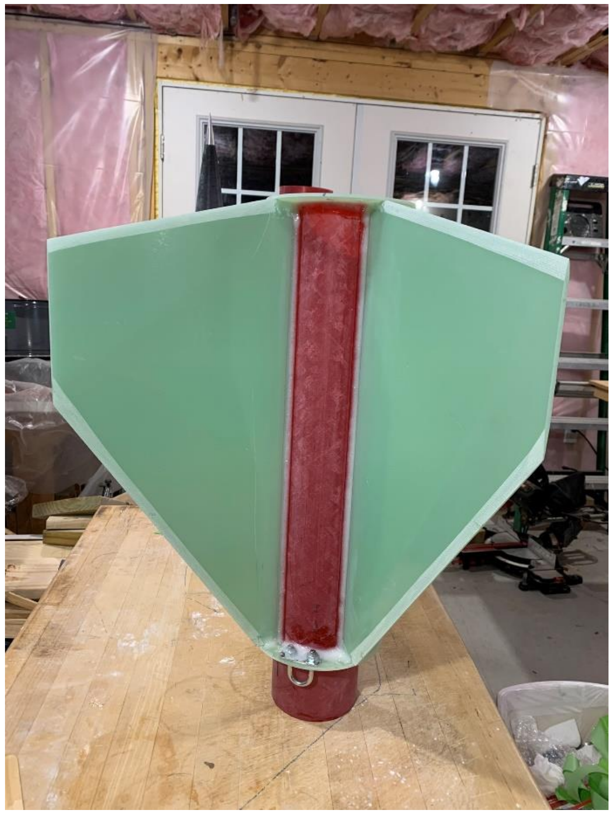


Using a 1/4" luan template, I tacked the fins in place with 5 minute epoxy. I like this approach as its easy to square things up and you can use the airframe to ensure fins are straight as well. Over an 18" long fin, if there is only a 1/32" of slop in the air frame you can't be more than 0.1 degrees mis-aligned axially. **Also get that first fin centered between Aeropack mounting holes or you'll have a conflict with hardware.** I slid it all back out through slits in in the air frame behind the fin slots and prepped it for internal fillets.



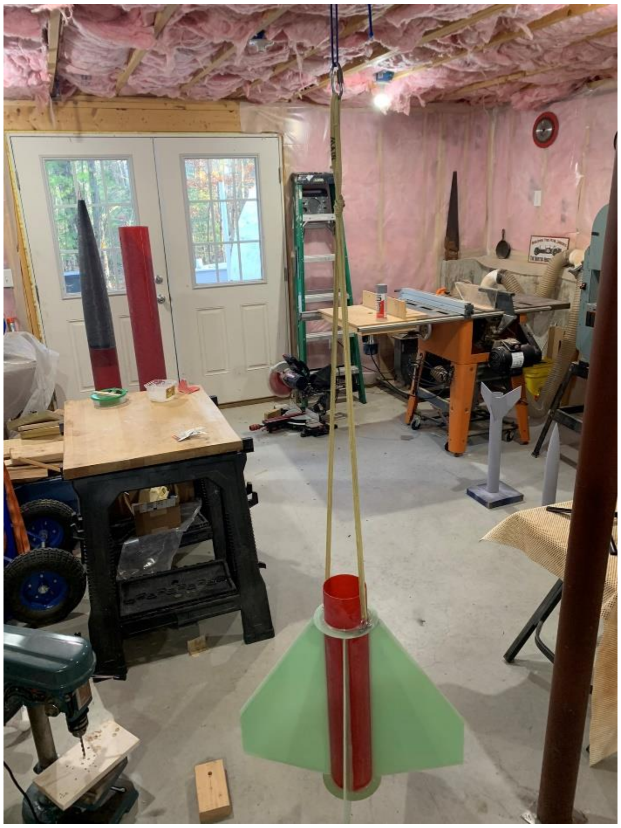
Weapons of choice here. The popsicle stick mixer is key. Each pair of fins needs about a full pump which is around 25 grams of resin. Noting quantities for my future self when I'm doing the next big rocket. Taped things off because I'm not a savage. Also note I taped over the Aeropack mounting holes so they weren't filled in accidently.

What's nice about the thickened epoxy is that you can do more than one fillet at a time. Note I epoxied backing nuts for u-bolts in place so they are now permanent.



Made a decision on my Y-harness. I had a 3/8" One Bad Hawk harness from another rocket and I had to cut both sections of it out of a tree. I end-to-end spliced it like you would sailing dyneema (burying at least 47 rope diameters each side!). This shortened the cord about 5 feet so it was perfect length for a y-harness. Looks like Kip Daugirdas did some testing thinks less may be necessary but I don't have a good pull test rig and am used to sailing rigging.... so more is better.

I rigged the harness like a semi equalizing but redundant rock-climbing anchor. One strand is rated for 3,600 lb breaking, so using four strands shown below would be 14,400 lbs x 90% for the splice = 12,960 lb breaking. I've seen some dire numbers from Marlow Ropes that knotting aramid (kevlar) fibers can reduce strength to 30%! However if I didn't knot below the quicklink, a failure in any one strand would let the y-harness completely unravel. so I'll take the hit, especially at such high factors of safety. 30% of 12,960lb is still 3,888 lb, and that would mean a 15 lb fin can has to experience a 260 G deployment event, which will probably fail a lot of other components first. So any one of the four strands could get severed and I'd still maintain half the capacity. Also later on a test flight of this rocket, a main chute deployed at 300 fps and zippered a 12-inch section of fin can. Despite those massive forces all hardware and harnesses remained intact.

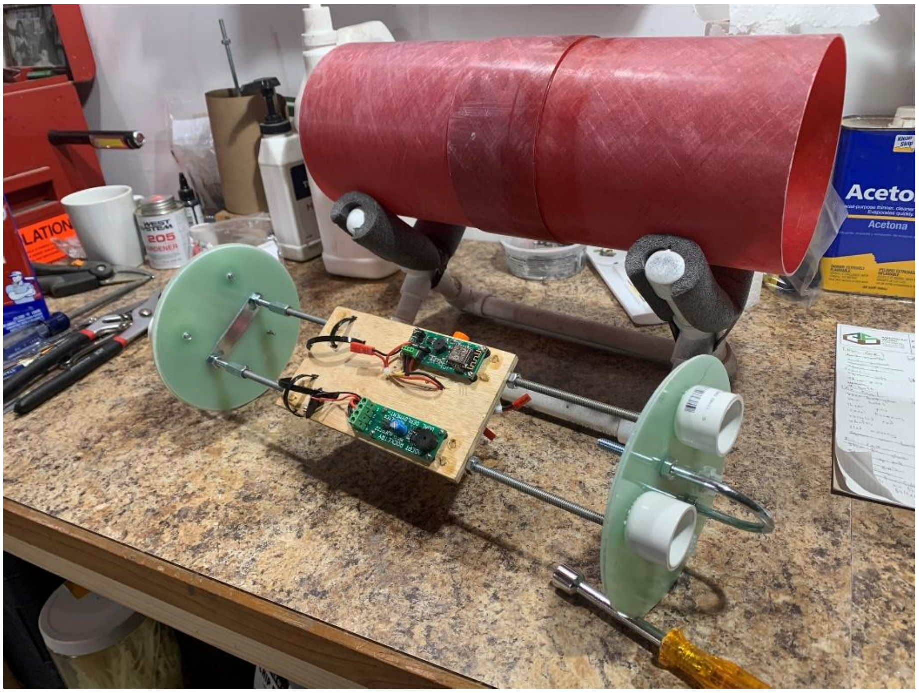


Also made progress on the AV Bay. I masking taped the two bulkheads together back to back and drilled all the mounting holes out so they'll be symmetrical.

Then I tapped some holes for the charge wells.

For this rocket I'm going to have the U-bolt for the drogue side attached directly to the two all thread going through the AV bay. This way the highest deployment forces aren't transferred into the rear bulkhead. Yes they'll in theory be applied to the front bulkhead, but that will be a force pulling it against the AV bay coupler, much more evenly distributed around the circumference, and shared with the hardware holding the payload section to the AV bay.

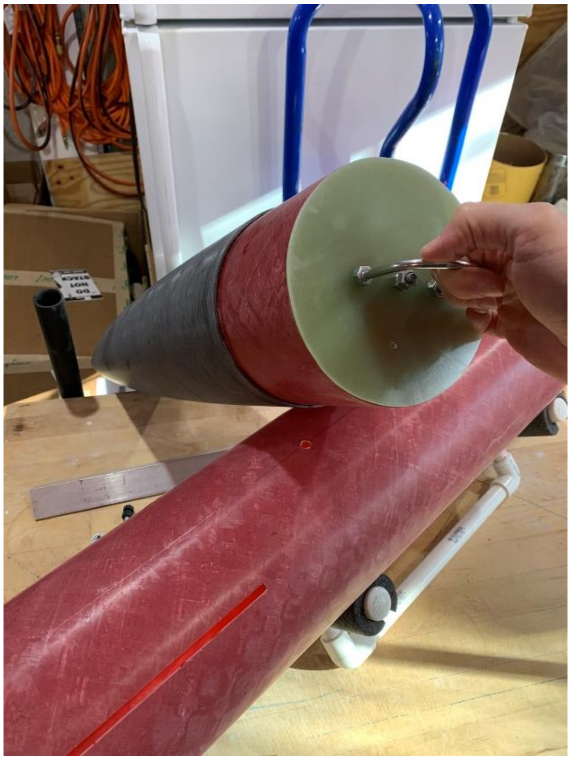
Also got the switch band epoxied into the center of the coupler.
This electronics sled is shared between all my rockets 4" diameter or larger. I just have to make the threaded rod spacing similar between rockets and it slides right in. Big cost savings! I may finally upgrade it to a G10 sled, but that cheap plywood has survived a K2050 at 42Gs. I wonder if the less rigid material helps lower impact on the components?



Decent backing plates and fender washers at all u-bolts too.

Charge wells are Schedule 40 PVC 3/4" pressure caps. This is what 5grams of powder looks like in them. When I ground test next week we'll see if they survive....

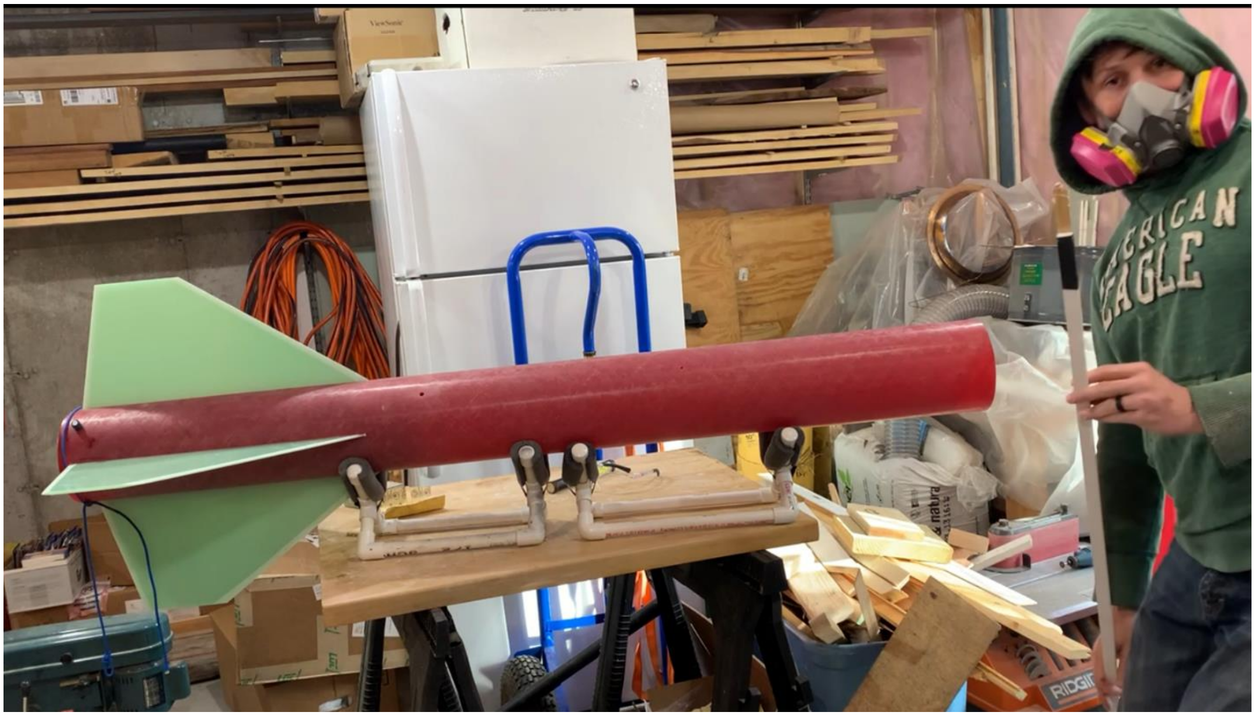
I also drilled a hole in the nose cone bulkhead to vent that to the interior of the payload bay. As far as static port sizes I used the usual guidance of a 1/4" diameter per 100 cubic inches of interior volume. My AV bay is 6"x16"=452 cubic inches and required (3) 0.307" holes so I rounded up to 5/16 (0.3.125") and drilled three of those spaced equally around the switch band.
I used the same 5/16" diameter to make a vent hole in the fin can at the calculated center of pressure. I like locating it there on my rockets so I always have a reference for COP without using a sticker or marker.
I made another vent in the payload bay an arbitrary distance from the nose cone.



Then it was time to prepare and epoxy the fin can into the airframe. Before I slid this all the way in I epoxied in a weld nut for the aft rail guide. Notice how I taped all the kevlar harness up. This not only protects it from epoxy, but also any future ejection charges. Getting epoxy on the harness will concentrate forces and could be reduce overall strength.

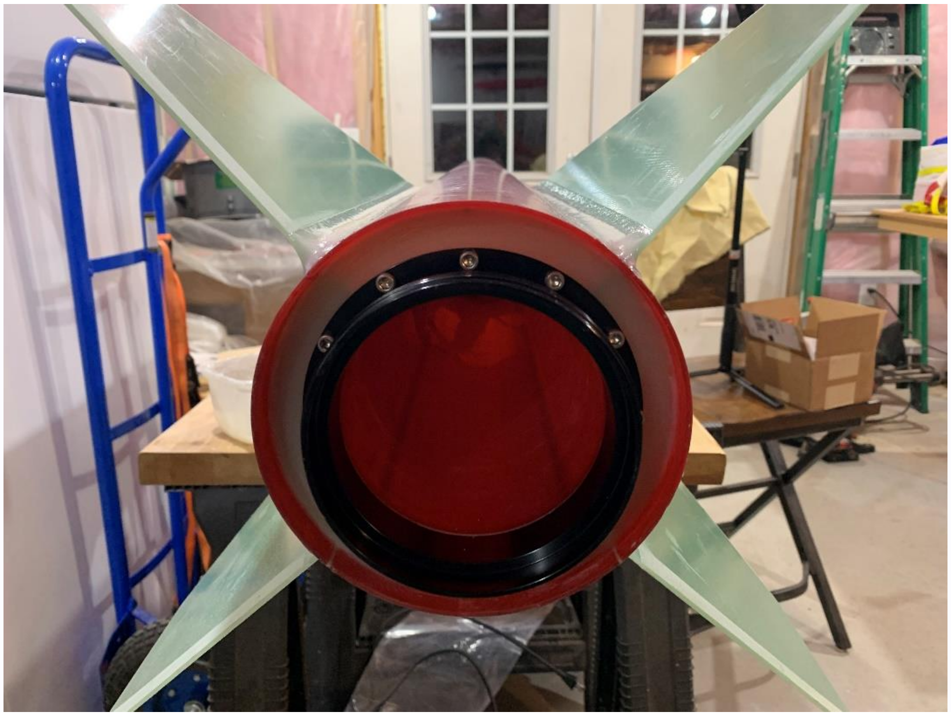
Got the fin can all the way in, tourniqueted the back of the airframe to clamp it around the aft centering ring, and epoxied the forward rail guide in with another weld nut.

Also sometimes you have to tape a popsicle stick to a piece of scrap to get that top centering ring fillet into ship shape.



While that cured, I got around to epoxying some #6-32 hardware into the AV bay to secure the Payload tube to it. This is just so much easier to source parts for and cheaper than PEM nuts it's my go to method still. I just slather Super Lube in the threads to keep the epoxy out and epoxy a nut to the interior.

Started external fillets today. Total Boat Epoxy and West 406 Colloidal Silica per usual. Decided to follow the typical guidance of fillet radius = 4% fin root chord length. With an 18″ chord this comes to about 3/4″. Found a socket in the toolbox with an 1.5″ OD and went to town. Did the usual sanding and acetone prep. I got the Aeropack all mounted up. This completes major construction of the rocket.



4. RECOVERY SYSTEM

4.1 Anticipated Loads

Based on past experience, typical maximum forces during recovery events range from 10-30Gs. To incorporate some additional factor of safety for non-nominal deployments a 50G event will be assumed.

4.1.1 Descent Rates and Parachute Selection

The drogue and main parachutes are sized based on their published data to achieve the following descent rates.

Parachute Descent Rates

Parachute	Drogue	Main
Manufacturer	Recon	Skyangle Cert-3 XLarge
Size	24”	89.0 sq ft
Published Cd	1.55	2.59
Calculated Descent Rate	80 fps	12 fps
Observed Descent Rates	60 fps	21 fps
Flame Protection	24” x 24” Nomex	24” x 24” Nomex

4.2 Recovery Bill of Materials

The table below summarizes all components of the recovery system, their rated capacities, calculated demands, and associated factor of safety against failure during a 50G deployment. Calculated demand assumes the heaviest attached assembly weight undergoes 50Gs of acceleration. For example, the fin can with motor casing is the heaviest component (16 lb) attached to a harness, therefore the maximum force on the harnesses would be 16 lb x 50G = 800 lb.

Recovery System Components

Item	Rated Capacity (ultimate)	Calculated Demand (heaviest attached assembly weight x 50G)	Factor of Safety
Drogue Chute Swivel	1,500 lb	800 lb	1.875

Main Chute Swivel / Suspension Lines	1,500 lb / 2,250 lb	800 lb	1.875/2.81
35′ x 7/16″ Kevlar Drogue Harness	5,300 lb	800 lb	6.63
25′ x 7/16″ Kevlar Main Harness	5,300 lb	800 lb	6.63
¼″ Quicklinks (880lb Working Load limit 5:1 factor of safety)	4,400 lb	800 lb	5.5
AV Bay Bulkhead ¼″ U-bolts	2,822 lb	800 lb	3.53
(2) AV Bay ¼-20 Rods	1,900 lb x2 = 3,800 lb	800 lb	4.75
Centering Ring ¼″ U-Bolts	2,822 lb x2 = 5,644 lb	800 lb	7.06
Nose Cone ¼″ U-bolt	2,822 lb	750 lb	3.76
Nose Cone ¼-20 Rod	1,900 lb	750 lb	2.53

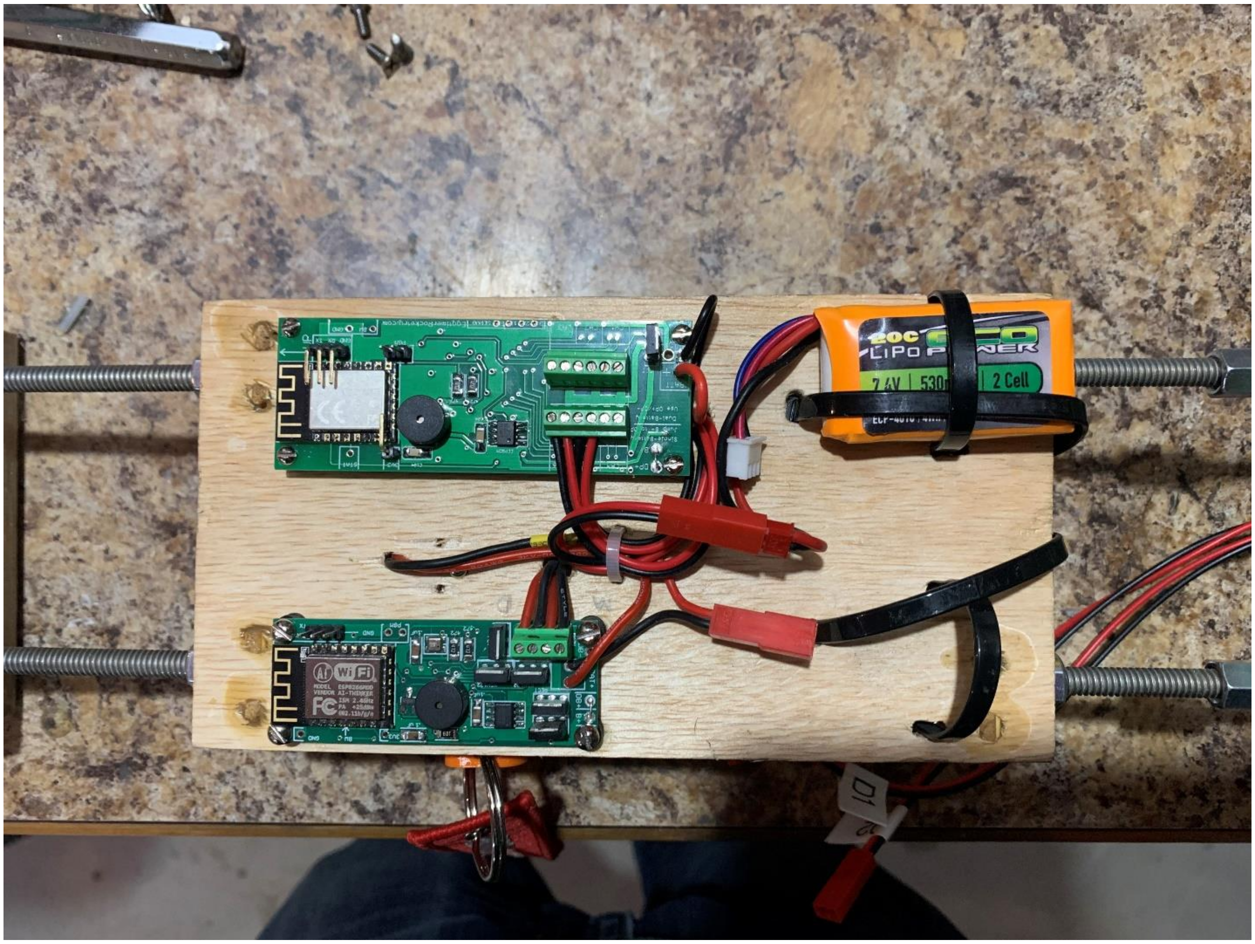
4.3 Electronics and Deployment Sequence

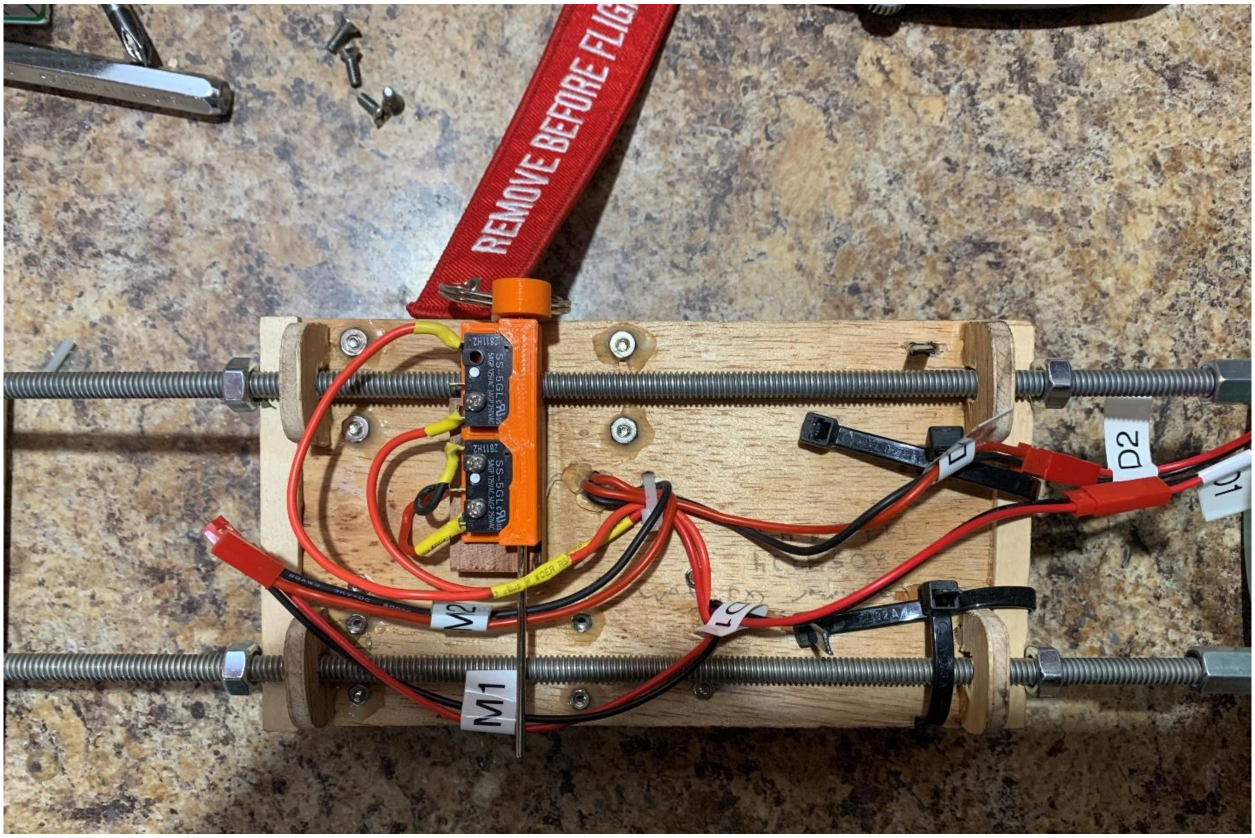
Electronics have been flight proven over a range of altitudes and motor configurations ranging 600-7,000 feet and from I through L motors.

Recovery Electronics

Device	Main: Eggtimer Proton	Backup: Eggtimer Quantum
Power Source	2s 530mAh LiPo	2s 530mAh LiPo
Switching	Additive Engineering Double Pull Pin Switch	
Drogue Chute Deployment	Apogee	Apogee +2 Seconds
Main Chute Deployment	700 feet	600 feet
Black Powder Charge Size	6.0 g drogue 4.5 g main	7.2 g drogue 5.4 g main

Black Powder ignition source	MJG Firewire Initiators
GPS Tracking in Nosecone	Featherweight GPS System





4.4 AV Bay Static Port Sizing

Static port sizing is based on guidance from Tom Billings, developer of the Adept Altimeters[2]. He advised three or four vent holes within the avionics (AV) bay with an area equal to a ¼" hole for every 100 cubic inches of AV bay volume. After having had an experience on a windy day with an AV bay with four holes prematurely firing on the launch pad, my preference is for three holes per advice received on the Rocketry Forum. The 6" diameter x 16" long AV bay has 452 cubic inches of volume so **three 0.3125" diameter vent holes** will be provided.

4.5 Black Powder Charges and Ground Testing

Online black powder calculators indicate the combined shear strength of four #4-40 nylon shear pins ranges from 200-304 lb[3]. To develop this force on a 6" bulkhead 11psi is required and should be achievable with 5.7 grams of FFFFg black powder within a 6" diameter by 36" long empty airframe. Similar builds on The Rocketry Forum averaged 5.0-6.0 grams, which is logical once accounting for the volume of the recovery gear. Ground testing confirmed 4.5 grams of FFFFG black powder achieved sufficient separation of the main compartment, and 6.0 grams for the drogue compartment. Backup charges will be upsized 20% to 5.4 and 7.2 grams.

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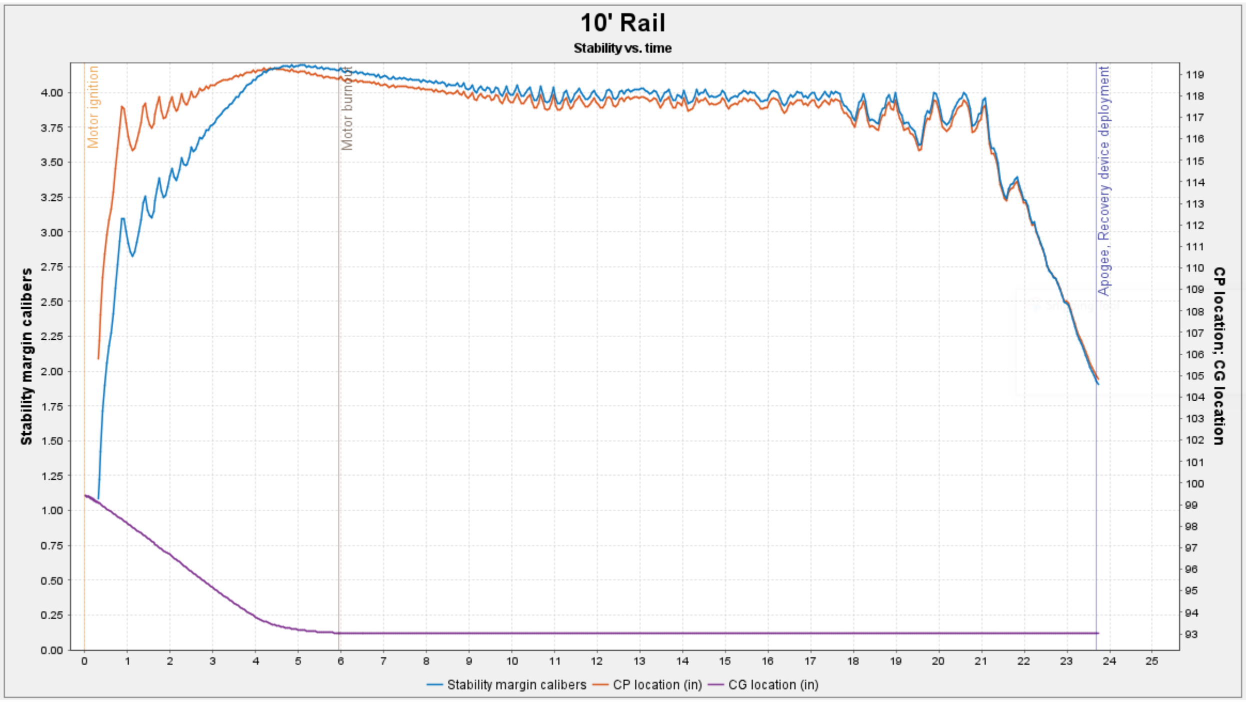
[2] https://ke7fiv.com/images/stories/edocs/manuals/adept22.pdf

[3] https://rocketrycalculator.com/rocketry-calculator/bp-estimator/

5. STABILITY EVALUATION

To ensure a stable flight the center of gravity of a rocket must remain ahead of the center of pressure. A general guideline is to keep them a minimum of on airframe caliber apart. The OpenRocket plot below summarizes this relationship throughout the entire flight from launch to apogee.



Stability immediately above the launch rail was further investigated. An angle of attack beyond 15 degrees is usually considered the limit on rocket fins before they lose lift and restoring forces. MIT wind tunnel testing also indicated this angle of attack is also associated with forward shift in the center of pressure of about one airframe caliber. A 15 degree angle of attack occurs when vertical velocity is only 4x the horizontal wind speeds. Off the rail velocity was calculated assuming a 10 and 12-foot long launch rail, subtracting the distance between rail buttons. The results are given in the table below to maintain 4x wind speed off the to limit apparent angle of attack.

Other guidelines are to have 4-5 times thrust-to-weight ratio at lift off, or per NFPA 1127, maximum lift off weight shall not exceed 1/3 the average motor thrust. The table below and motor label summarize anticipated thrust to weight ratios and that the above guidelines are met.

Thrust to Weight Ratios

Velocity off 10' Rail	57.7 fps (39mph)
Velocity off 12' Rail	65.0 fps (44mph)
Max allowable Horizontal Windspeed (10'/12')	10 mph/11mph

Launch Weight	44.8 lb
Initial Peak Thrust	450 lb
Initial Thrust to Weight Ratio	10.0:1
Average Thrust	296 lb (1315 N)
Average Thrust to Weight Ratio	6.6:1

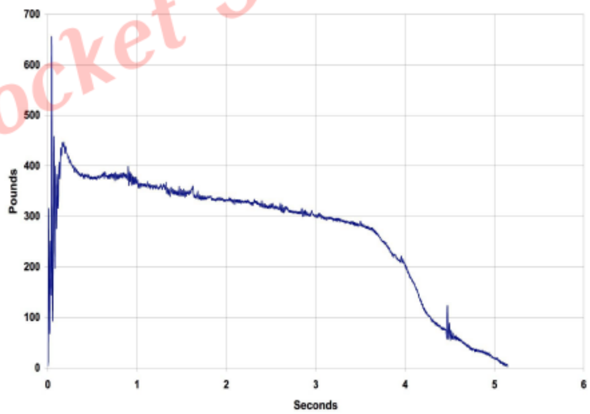
M1315W-PS *White Lightning*™

RMS hardware required: 75mm aft closure, 75mm forward closure, 75mm forward seal disk, 75/6400 case.

Also requires separately packaged 1 x P/N 03035-5 phenolic liner and 5 x 03617 propellant grains.

Motor Specifications

Total impulse:	6,714 N-sec (1,509 lb-sec)
Burn time:	5.4 sec
Peak thrust:	450 lbs (2,002 N)
Delay time:	Plugged with smoke
Propellant wt.:	3,351 grams (7.38 lb.)
Loaded wt.:	5,675 grams (12.50 lb.)

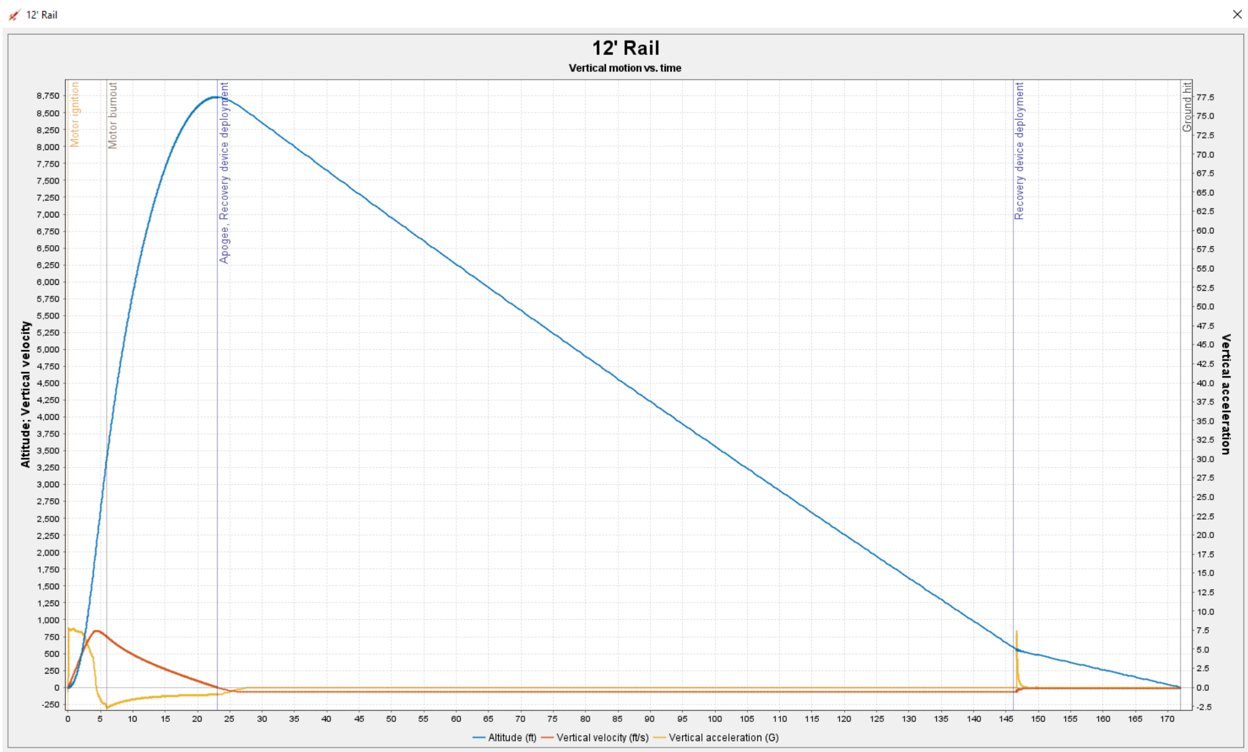


6. FLIGHT PROFILE

Flight Profile

Launch Weight	44.8 lb
Recovery Weight at Motor Burnout	32.4 lb
Motor Type & **Total Impulse**	Aerotech M1315 in 75/6400 hardware 6,714 N-Sec of White Lightning
Estimated Drag Coefficient **Flight Test Calibrated Drag Coefficient**	0.417 0.420
Maximum Expected Velocity	842 fps (0.76 Mach)
Maximum Expected Altitude	8,736 ft @ 17.1 Seconds
Drogue Chute Deployment	Apogee & 2 sec backup
Main Chute Deployment Altitude	700ft / 600ft backup @ 146 Seconds
Maximum Expected Acceleration	7.71 G
Total Flight Time	172 Seconds

The rocket was test flown twice prior to LDRS. The first flight on a K1050 approximated the maximum acceleration the certification motor will apply to the airframe, just at a shorter duration. This shakedown flight revealed that four shear pins on the drogue side of the AV bay were excessive. A second flight on a K1275 went flawlessly. Below is a typical flight profile graph from OpenRocket for the rocket with updated geometries, weights, and parachute drag coefficients based on data from the two test flights.


12' Rail
12' Rail
Vertical motion vs. time
Altitude; Vertical velocity
Vertical acceleration
Motor ignition
Motor burnout
Apogee, Recovery device deployment
Recovery device deployment
Ground hit
Altitude (ft)
Vertical velocity (ft/s)
Vertical acceleration (G)

7. EQUIPMENT PACKING LIST

- ☐ Screwdrivers
  - o Small Flathead
  - o Regular Flathead
  - o Small Phillips
  - o Regular Phillips
- ☐ Drill & Drill bits
- ☐ Masking Tape
- ☐ Electrical Tape
- ☐ Wire strippers
- ☐ Multimeter
- ☐ Shear pins and thread tap
- ☐ 11/32” ,7/16”, 1/4", & 3/16” nut driver
- ☐ Adjustable, 7/16”, & 10mm wrench
- ☐ Thread locker
- ☐ Zip Ties
- ☐ Channel Locks
- ☐ Needle Nose Pliers
- ☐ Triple 7 and Scale
- ☐ Initiators
- ☐ Dog Barf
- ☐ Throwline
- ☐ Wet wipes
- ☐ Blanket for ground
- ☐ Motors and Igniters
- ☐ Motor adapters if need
- ☐ Motor Case & spacers if needed
- ☐ Delay Tool
- ☐ Motor Retention hardware
- ☐ Rocket stands
- ☐ Cell phone battery
- ☐ Featherweight, Jolly Logic Chute Release Go-pro, Run Cam
- ☐ Run cam & gopro & Batteries
- ☐ Camera Stand
- ☐ Clipboard and pens
- ☐ Simulation printouts – rail speed 4x wind?
- ☐ Compass
- ☐ 2ft level
- ☐ NAR paperwork/Card
- ☐ Trash Bag
- ☐ Lawn Chair
- ☐ Headlamp
- ☐ Sandpaper
- ☐ Fire Extinguisher
- ☐ First Aid Kit
- ☐ Shovel

-----Summer-----

- ☐ Sunblock & Bug Spray

-----Winter--------

- ☐ Cooler with heat source
- ☐ Ice Auger & Drill & Batteries
- ☐ Ice cleats
- ☐ Snow Suit, hat, gloves, sunglasses
- ☐ Handwarmers
- ☐ Sled & Rope

8. PRE-LAUNCH CHECKLIST

- ☐ Assemble motor per manufacturer’s recommendations
- ☐ Pack Charges w/ igniters, 4 layers masking tape, igniters not in terminals
  - 4.5g Main & 6.0g Drogue (Starless Rogue)
  - 3g & 3.5g (Doorknob)
  - 1.25g Main & 2g Drogue (PL)
  - 1.5g (Darkstar Junior)
- ☐ Attach Batteries to sleds & Tape
- ☐ Adept no pins for 600 foot main
- ☐ Sled in AV bay, drogue side first
- ☐ Tape sled to rails
- ☐ Plug in Quantum
  - 200 ft LDA
  - Appogee plus 2 seconds
  - Main @ 500
- ☐ Install and tighten payload bay bulkhead
- ☐ Install pull pin (turns off electronics)
- ☐ Attach Igniter leads to terminal blocks
- ☐ Tape Terminal blocks
- ☐ Tighten and tape quicklinks
- ☐ Bundle drogue laundry
- ☐ Turn on and mount Featherweight GPS
- ☐ Install AV bay to booster w/ shearpins
- ☐ Install payload bay to AV bay w/ machine screws
- ☐ Bundle main laundry
- ☐ Keep webbing on opposite side of charges
- ☐ Install nosecone with shear pins
- ☐ Install runcam
- ☐ Install Motor, including positive retention
- ☐ Strip igniter, tape to side of rocket

9. LAUNCH CHECKLIST

AT PAD:

- ☐ Turn on Runcam
    - Default pass: 1234567890
    - Long press power to turn on/off
    - Button glows blue at standby
    - Press to record, blinks blue
- ☐ Start gopro
- ☐ Arm Adept, long pulsating beep, beeps last altitude twice, after 10 seconds, four beeps, Tape to upper section
    - 1 beep = no charges
    - 2 beeps apogee only
    - 3 beeps main only
- ☐ Arm Quantum
    - 192.168.4.1
    - 192.168.4.1/test
    - 192.168.4.1/hsetup
    - Pass: 52054324 or 21311775
- ☐ Close Quantum page after arming
- ☐ Install igniter
- ☐ Sandpaper leads and spark test, clip to igniter
- ☐ Start cellphone video

10. POST FLIGHT CHECKLIST

- ☐ Verify all pyrotechnics are discharged
- ☐ Safe the pyrotechnic systems if live devices are present
    - Attempt to identify the reason for the unfired pyrotechnic
- ☐ Record or save any flight data indicates that will be lost after power removal
- ☐ Remove power from electronic systems

11. CONTINGENCY CHECKLIST

For misfires, launch aborts, or crashes:

- ☐ Disconnect and remove motor igniter(s)
- ☐ Safe pyrotechnic systems to allow safe handling and/or disassembly
- ☐ Note operating time to determine if flight batteries need charging or replacement