NAR Level 3 Certification Project

(proposal 11/24/2020, then updated spring/summer 2021 during the building process)

Project Name: *Failure Is Not An Option!*

Rocketeer: James Stanford, NAR #103765

L3CC Adviser: Rick Comshaw

Mentor/Club President: Howard Druckerman (L3)

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Rocket Brand and Model

Wildman Rocketry "Ultimate Wildman", fiberglass, 6 inches diameter, 132 inches tall (11 feet)
Loaded weight 51 lbs with 5-grain CTI M1810-RL motor

This kit is a sturdy, three-fin, fiberglass Wildman Rocketry model that has been used for many other rocketeers' L3 certifications. For my own build of the Ultimate Wildman, I will be following a standard Wildman kit approach except that I will be adding a redundant harness attached to the forward centering ring (via U-bolts), and also using the nosecone coupler as a small secondary av-bay with the lids functioning as bulkheads, so that the nosecone will be accessible for later configurations if desired (rather than epoxied shut).

Wildman Main Airframe Parts

60" fiberglass booster
37" nosecone, 5-to-1 ogive shape, filament-wound fiberglass, with aluminum tip
30" fiberglass payload section
3 G10 thick fiberglass pre-beveled fins (3/16")
98mm fiberglass motor mount tube (MMT)
3 fiberglass centering rings (6" outer dia., 98mm inner dia.)
16.5" fiberglass avionics bay (primary av-bay)
3" fiberglass switchband
6" dia. black anodized aluminum stepped lids for primary av-bay
9" fiberglass coupler (to be used as a small secondary av-bay/coupler for NC)

Other Materials

Adhesives:	RocketPoxy G5000 (2 pints resin + 2 pints hardener) and JB Weld
Quick links:	1/4" steel (True Value Hardware and MAC Performance Rocketry)
U-bolts:	1/4" steel (True Value Hardware and MAC Performance Rocketry)
Swivels:	5/8" steel (MAC Performance Rocketry) and SkyAngle XL swivel
Av-bay board:	MAC 3D-printed sled with two enclosed 9-volt battery chambers
Av-bay charge wells:	8-gram anodized cylindrical wells from Rocket Junkies, two aft, two fore
Av-bay sled rods:	1/4" threaded steel rods (McMaster-Carr)
Lids for secondary av-bay:	6" heavy-duty MAC canvas phenolic stepped lids with U-bolts
Ejection igniters:	Firewire Brand Initiator (Apogee Components)
Motor igniter:	standard CTI
Rail buttons:	standard 1515 buttons with T-nuts (Delrin RG15A, Animal Motor Works) and standard Unistrut buttons (Aerocon Systems)

Shear pins:	standard plastic 4-40 threaded shear pins (4 pins at the apogee separation point and 4 pins at the main separation point)
MMT adapter:	AeroPack 98-75 (aluminum)
Motor retainer:	AeroPack RA98 flange-mounted threaded retainer (aluminum)
Motor casing:	CTI 75mm 5G casing (Gen 2) with two spacers for 3G motors
Av-bay switches:	Twist-and-tape

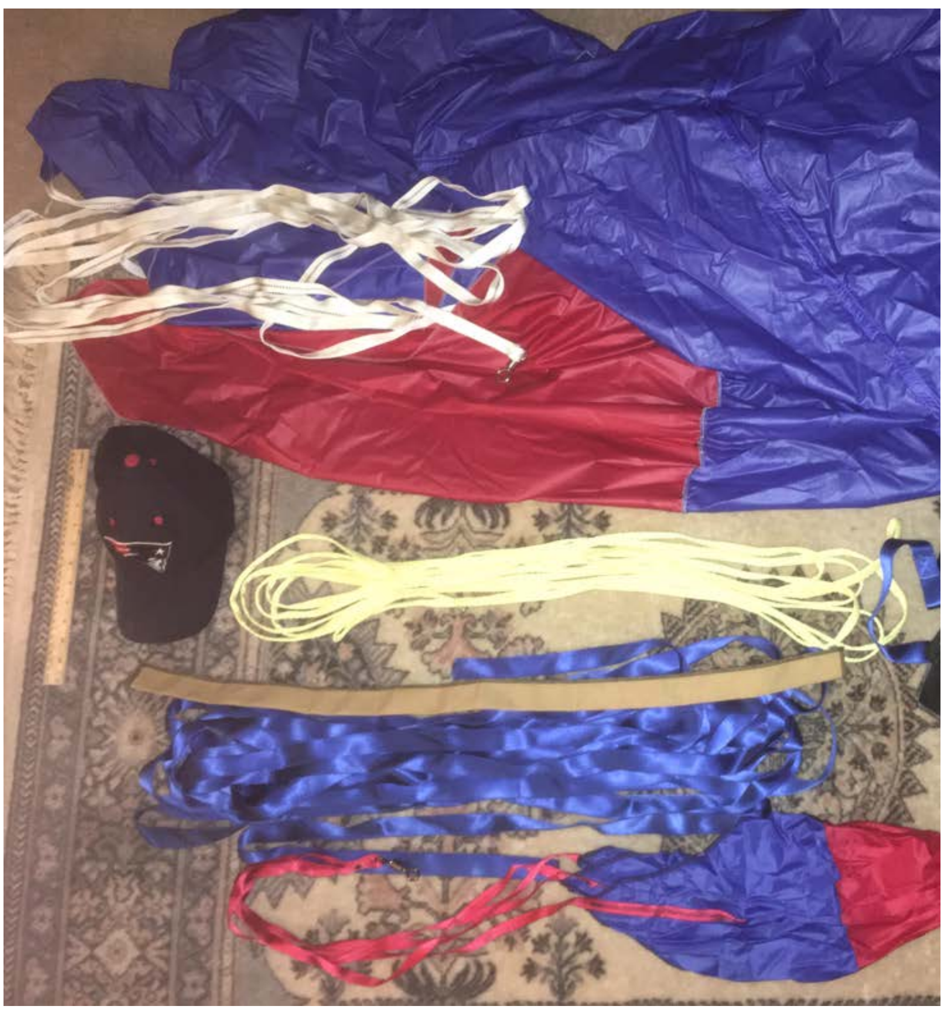
Airframe parts. Photo includes 12-inch ruler and baseball cap for visual scaling. Photo 11-16-2020.

Electronics

Primary flight computer:	Altus Metrum Easy-Mini v2
Backup flight computer:	MissileWorks RRC2L
Second backup flight computer:	MissileWorks RRC2+
Additional ride-along altimeters:	Jolly Logic Altimeter III FlightSketch Altimeter
GPS system:	Jiobit

Author wearing hat for visual scaling. Photo 11-16-2020.

Recovery Materials



-SkyAngle Cert-3 XL, main parachute, 10.6 feet diameter, surface area 89.0 sq. ft., 100" suspension line length, 2.59 drag coefficient measured by SkyAngle, net weight 45.0 oz. Rated for 32.6-70.6 lbs by SkyAngle

-60 feet of 1" nylon shock cord from SkyAngle, and then MAC Performance Rocketry sewed sturdy loops for each end of the shock cord. MAC sewed using Kevlar thread, and covered the stitches with double-wall shrink tube for additional protection. One looped end of the shock cord attaches to the MMT harness with a quick link and swivel. The other end attaches to the U-bolt on the aft end of the main av-bay, and the av-bay end of the shock cord is protected with Nomex 1" wide shock cord protectors (48" total).

-Recon drogue parachute (24") attached to a swivel that is quick-linked to an overhand loop in the 1" nylon shock cord, positioned approx. 12 feet from the top of the booster

-Shock cord bumper (Dino Chutes, size large) to protect the contact point near the top of the booster

- 30-foot Kevlar harness set (3 loops, as produced by One Bad Hawk via Wildman site). One loop attaches to a quick link and swivel on the U-bolt on the fore end of the main av-bay. The second loop attaches to a quick link and swivel on the main parachute. The third loop attaches to the nosecone coupler system via a U-bolt and quick link.

-Two 18" x 18" Nomex protectors: One attached to the shock cord in the booster to protect the drogue during ejection, and one attached to the harness in the payload section to protect the main parachute during ejection.

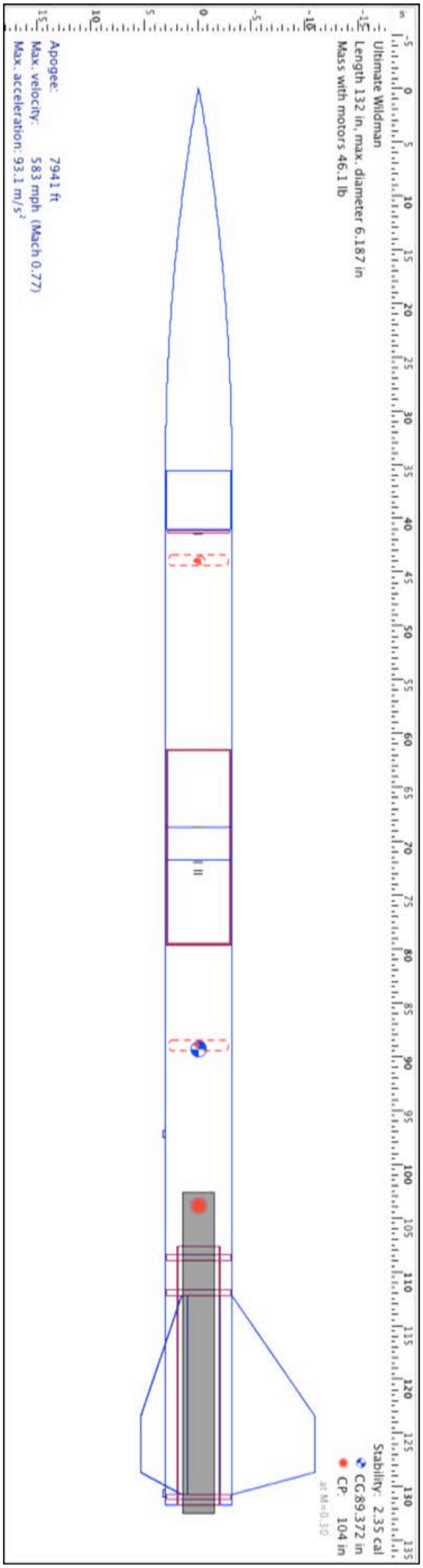
-Shock cords, parachute harnesses, and parachute shroud lines will be zigzag-folded and organized into small piles. Each pile is wrapped in one light layer of masking tape to prevent tangling before ejection.

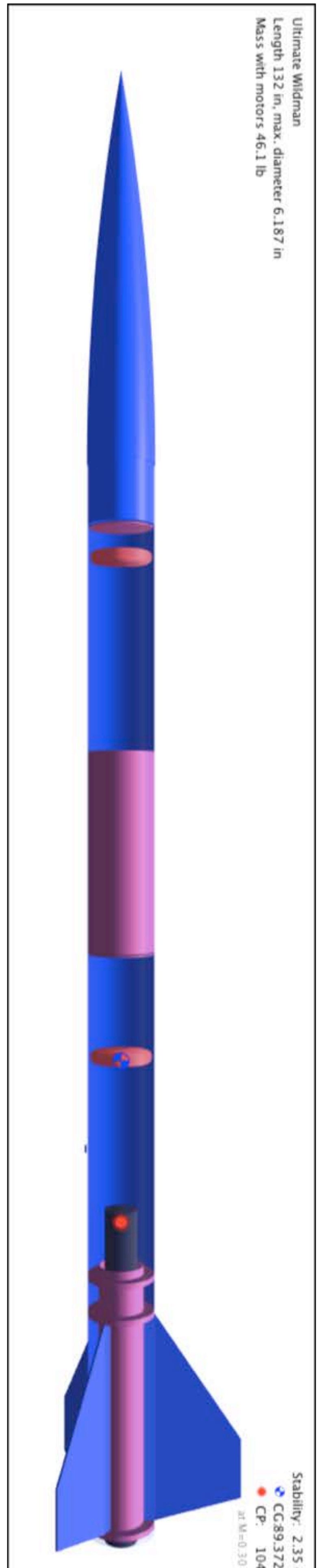
-Booster harnesses: standard Wildman Kevlar Y-harness (flat, 1 inch wide) plus redundant MAC Kevlar harness (tubular, 1/2 inch wide). As discussed later in this document, the Wildman Y-harness is glued to the MMT under the centering rings, and the redundant MAC harness is attached to U-bolts on the forward centering ring.

Motors

-Test flight: 3-grain CTI 4263-L1350-CS
-Certification flight: 5-grain CTI 6128-M1810-RL

The photo below shows the 5 grains of Red Lightning propellant in their boxes, the CTI phenolic liner with disposable nozzle and O-ring kit, the CTI smoke module/igniter kit, the CTI 75mm 5-grain aluminum casing along with CTI aluminum aft retaining ring, nozzle holder, forward closure and forward retaining ring, a CTI 75mm hand wrench (for tightening the retaining rings), and finally the AeroPack 98-to-75mm adapter rings (three black anodized aluminum rings).


Ultimate Wildman
Length 132 in, max. diameter 6.187 in
Mass with motors 46.1 lb
Stability: 2.35 cal
CG:89.372 in
CP: 104 in
at M=0.30
Apogee: 7941 ft
Max. velocity: 583 mph (Mach 0.77)
Max. acceleration: 93.1 m/s²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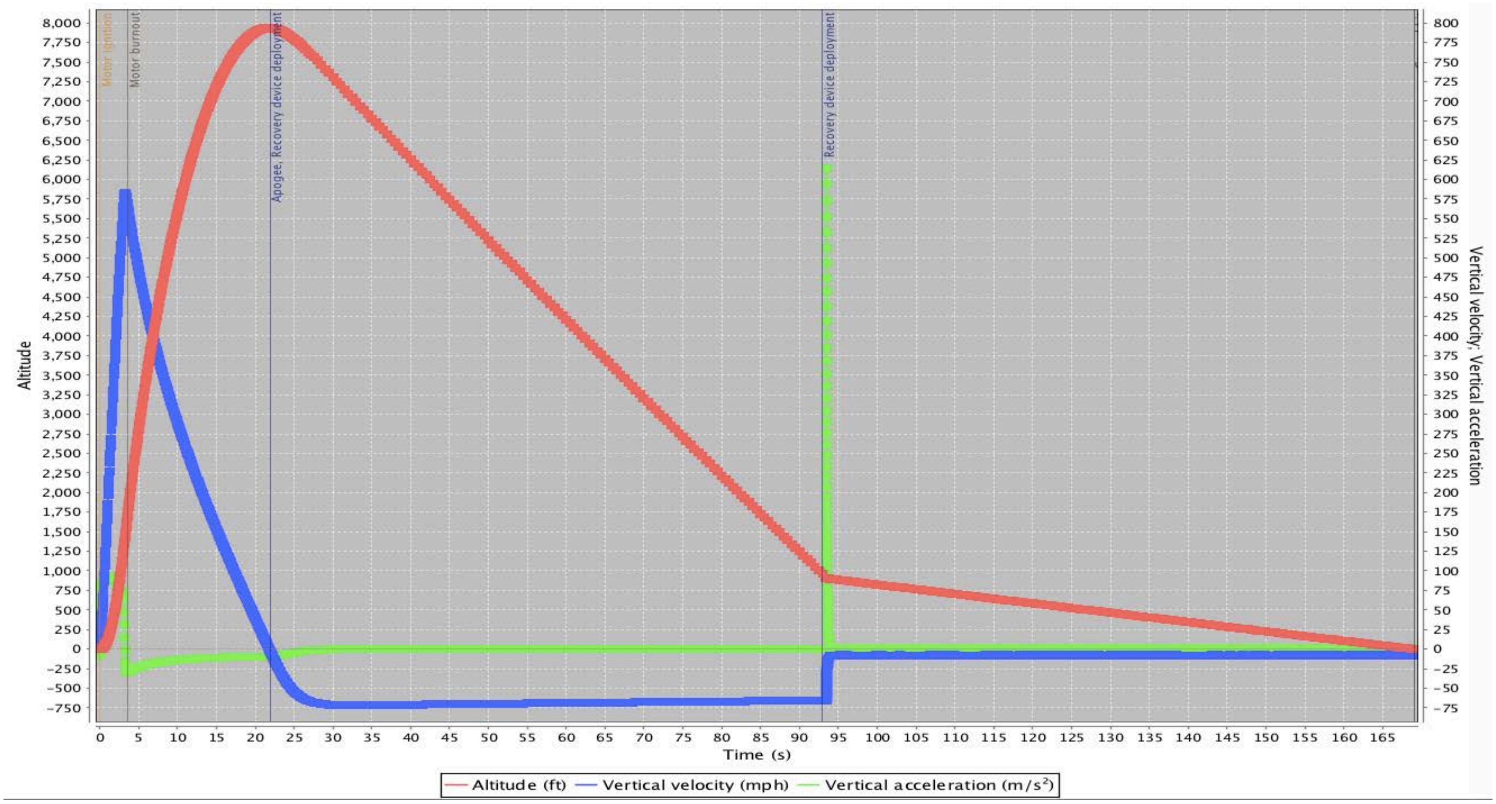
Open Rocket Simulation of the L3 Certification Attempt on M1810RL

(See below for stability margin, CG, CP, and landing velocity)



Stability: 2.35 cal

CG: 89.372 in

CP: 104 in

M1810-RL-P

Altitude	7937 ft
Flight Time	169 s
Time to Apogee	21.8 s
Optimum Delay	18.3 s
Velocity off Pad	45.2 mph
Max Velocity	583 mph
Velocity at Deployment	65.6 mph
Landing Velocity	7.59 mph

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
M1810-RL	1818 N	3.37 s	2085 N	6128 Ns	8.86:1	7.27 lb	75/757 mm

Maximum vertical acceleration 93 m/s^2 (9.5 g) at T+1.24 sec

Maximum vertical speed 583 mph at T+3.3 sec

Fineness ratio (length to diameter) is 132 inches to 6 inches = 22:1 ratio

Ratio of semi-span (chord) to fin thickness is 9 inches to 3/16 in. = 48:1 ratio, so the fin thickness to semi-span ratio is 1:48, or 2% of semi-span

Construction Procedures

<u>1. Preparation</u>
-Wash all fiberglass parts in warm soapy water

-Lightly sand all fiberglass parts with fine sandpaper (400-grit) and wipe with a cloth

-Sand every place where epoxy is to be applied (80-grit), including all connecting surfaces for fins and fin tangs, airframe-to-coupler connections, MMT, centering rings, and so on

-Dry-fit the fins in their airframe slots, and dry-fit couplers and all other connecting surfaces. As needed, apply more sandpaper until each part fits properly

-Drill vent holes: (a) three 1/8" holes in nosecone, (b) three 1/8" holes in payload bay, (c) three 1/8" holes in booster, in order to allow pressure equalization during flight:

-To ensure that the aluminum tip of the nosecone is securely fastened: Unscrew the aluminum tip, put epoxy on the screw threads and other surfaces, return the aluminum tip to the nosecone and securely tighten with screwdriver:

-Mark the aft centering ring with 12 dots that align with the 12 holes in the AeroPack 98mm retainer's circular flange mount. Use a #29 (9/64") drill bit and then 8-32 tap (McMaster-Carr) to create the 12 mounting holes in the fiberglass forward CR. Use 9/64" hex-driver to attach the screws, adding JB Weld to each screw's threads to keep them in place permanently in the CR. Ensure that the retainer fits properly by dry-fitting it to the MMT, and then remove this retainer/aft CR assembly until the rest of the MMT construction is complete.

-Redundant harness: drill two 1/4" holes in the forward CR, attach U-bolts (put some epoxy on the screw threads), attach the redundant Kevlar harness to each of the two U-bolts (1/2" tubular Kevlar harness with a loop on each end). Make an overhand loop in the middle of the 1/2" harness, which will later be attached via quick-link to the shock cord along with the regular Wildman Y-harness.

2. Gluing the MMT and attaching the shock cord

-Draw lines on the MMT showing where the fins will contact the surface

-Using the Kevlar Y-harness ribbon from Wildman with a loop in the top, align it along the MMT, put notches in the middle and forward CR so that the ribbon can slide under. Use a permanent marker to mark the desired locations of the CRs. Dry-fit the fins to make sure everything fits. Remove fins. Put masking tape over the areas of the MMT that will not be epoxied. Generously apply epoxy where the CRs meet the MMT, and all over the area below the Kevlar ribbons, and then all over the top of the ribbons (this stage is probably the hardest part of the whole build project -- definitely the messiest!). During this process, I checked the middle CR's placement multiple times by dry-fitting a fin between the middle CR and the aft retainer, which I had dry-fitted temporarily onto the aft end of the MMT. This fin-check ensures that the distance from the middle CR to the aft retainer will be correct, for each of the three fins. Always keep the fin and aft retainer clear of epoxy drips by rubbing them down with isopropyl alcohol. Also, keep the outside rims of the CRs and the interior of the MMT clear from epoxy by rubbing them with isopropyl alcohol whenever there are any drips. Finally, add another generous layer of epoxy on top of the Kevlar ribbons and also add thicker fillets to the CRs. Carefully clean all leftover epoxy from the rest of the MMT and the CR rims when finished. Remove the aft retainer.

First layer of expoxy:

Second layer of epoxy (and fillets for the CRs):

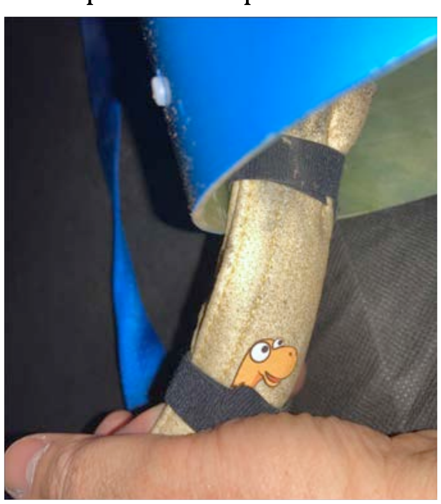
Then find a creative way to suspend it horizontally for drying while keeping the wet epoxy off the floor (in the absence of a workbench or vise equipment):

Let this whole MMT system dry until the epoxy is firmed up but still malleable, remove the masking tape, then let dry overnight. Add the redundant (backup) harness: Use quick links to attach the two Kevlar loops to the U-bolts that I already installed in the top CR (add some JB Weld to the quick-link threads).

Finalized MMT, after removing the masking tape:

Knot the two harness systems together so that the weight will be evenly distributed, then add quick links and a rotating swivel.

-Before flight, wrap a shock cord bumper (Dino Chutes, size large) at the top of the booster harness, in order to protect the point of contact at the top of the fiberglass booster.

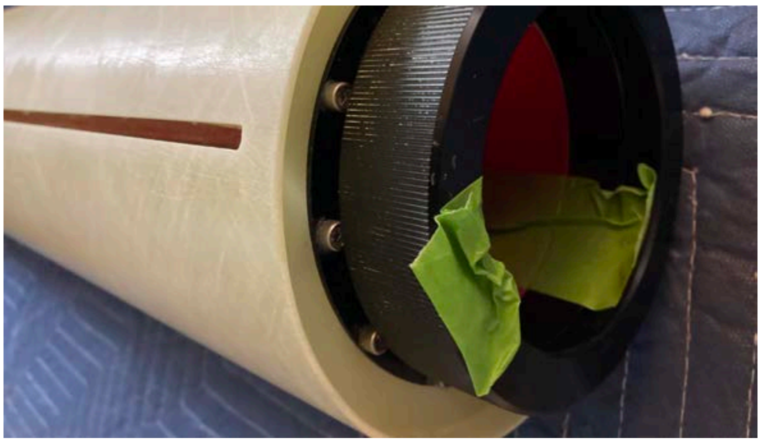


-Switchband: Epoxy the switchband onto the middle of the av-bay and carefully remove any stray drips with rubbing alcohol.

-Rail buttons: Before installing the MMT in the airframe, it is first necessary to prepare the rail button holes because the interior of the lower booster tube won't be accessible later. Drill one T-nut hole (1/4") in the main airframe 2" forward of the aft CR. This hole will be for the lowest rail button. Do not install this lowest T-nut and button yet since the MMT/CRs still need to be inserted here. Now draw a very straight pencil line from this aft hole all the way to the top of the booster tube (use a long angle iron to draw it). Find a good location just above the forward CR, drill a 1/4" hole there, and *immediately install* the second 1515 rail button in a T-nut there (this location will not be accessible after the MMT is glued in). Finally drill a third hole and install the third 1515 rail button in a T-nut just aft of the av-bay. Secure each 1515 button with a 10-32 x 3/4" screw in the T-nut. Use JB Weld to securely attach the T-nut to the fiber-glass hole, but no JB Weld on the screw threads (the screw needs to be removable to exchange 1515 for Unistrut buttons). If Unistrut buttons are needed on the field, switch out the 1515 buttons and install the Unistrut buttons using the same three holes and same T-nuts, but with longer screws for the Unistrut buttons (10-32 x 1" screws for Unistrut). I have checked the fit of the T-nuts with 1515 versus Unistrut buttons and their corresponding screw lengths, and the system works fine with either 1515 or Unistrut buttons.

Reach into the airframe and stick on several layers of plastic smiley stickers onto the T-nut to smooth it over and seal the area (and also add a small layer of duct tape), so that the T-nut will not interfere with harnesses. These layers of stickers also help to keep the T-nut in place in the event it becomes dislodged when changing buttons. (When installing the aft button, I neglected to put these stickers over the T-nut, and later the T-nut slipped down inside the sealed fincan where I couldn't reach it! I had to manually pull a strong magnet across the exterior of the airframe to grab the T-nut and gradually drag it back to its hole, and then carefully thread the screw back into it.)

-Mix some Rocketpoxy and wait a few minutes so that it won't drip too much, then reach into the airframe to apply the epoxy in the area forward of the fin slots, i.e. apply epoxy where the centering rings will contact the airframe. Then push the whole MMT into the rocket. Before the epoxy sets, dry-fit the aft CR to check the fit and to secure the MMT in the correct position in relation to the fin slots, but make sure the aft CR is free of epoxy so that you can later re-move the aft CR to allow access for internal fillets. Also dry-fit each fin in its slot to make sure the alignment is correct between the aft CR and the middle CR. During this brief dry-fitting of the fins, confirm that each fin slot is directly above its corresponding dark permanent marker line previously drawn onto the MMT (i.e. directly above bare MMT fiberglass without any interference from the dried epoxy areas on the MMT where the Kevlar straps are already glued in). Let dry overnight.



3. Installing the fins and fillets

-Take one fin and put epoxy on all the contact areas, then insert the fin through the slot until it contacts the MMT. Secure it with a wooden fin jig (6-inch MAC wooden fin jig leftover from another project which had slots for 5 fins, but the same jig works here since I am just in-stalling one fin at a time). Maintain a sharp 90-degree angle between fin and airframe tangent. Carefully apply internal fillets with a wooden dowel through the open end of the booster. Spread generous amounts of epoxy all over the areas where the fin and fin tangs meet the interior of the booster and where the fin meets the exterior of the MMT. Use isopropyl rubbing alcohol to clean any epoxy from MMT areas where another fin will be inserted later.

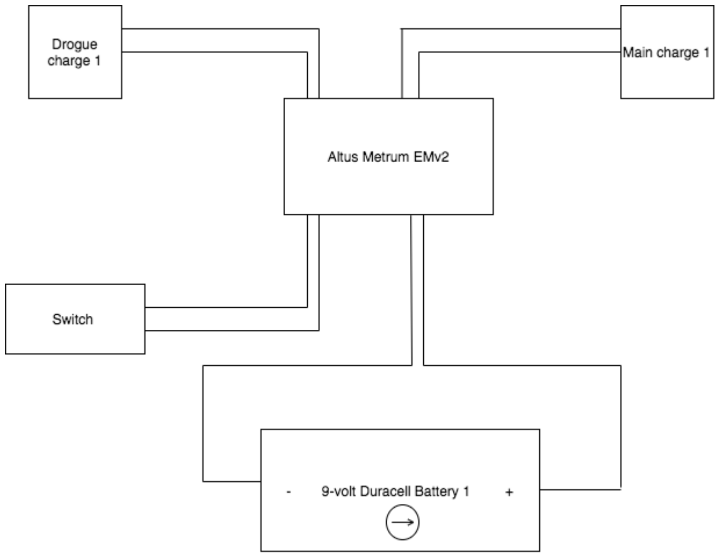
-External fillets: First, put long lines of masking tape along the fillet area of the fin and air-frame, leaving open a long thin groove along the junction of the fin and the airframe. Then mix Rocketpoxy in a bowl and wait about 15 minutes until it is becoming slightly firm but still able to be poured easily. Pour/spread the epoxy into the fillet grooves. Wait a few minutes as it spreads itself evenly into the groove, and then use a fillet tool (small piece of PVC tube or similar) to smooth over the fillets within the groove and remove excess epoxy. Do this a few times as needed (sometimes it helps to dip the fillet tool in rubbing alcohol occasionally). After about 15 more minutes, when the epoxy has become relatively firm but not yet hard-ened, carefully remove masking tape. These curing times are not exact, and it is important to keep an eye on how firm the epoxy is getting at each stage. There's nothing worse than trying to smooth out epoxy that hardened much faster than expected!

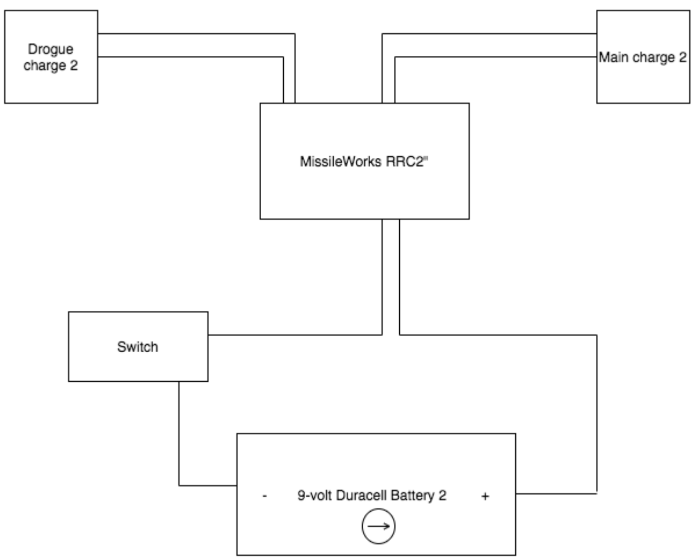

-Let dry overnight, then rotate the rocket and repeat these methods with the next fin on the second day, then on a third day for the final fin.
-Finally, using the long wooden dowel again, generously spread another layer of thick epoxy inside the fincan all over the places where each fin, centering ring, and/or airframe come into contact. Be very careful not to get any epoxy inside the MMT, nor on the outer rim of the MMT and inner rim of the airframe, i.e. where the aft retainer will be installed later. If any epoxy drops land in those areas, quickly apply generous amounts of rubbing alcohol to clean it.

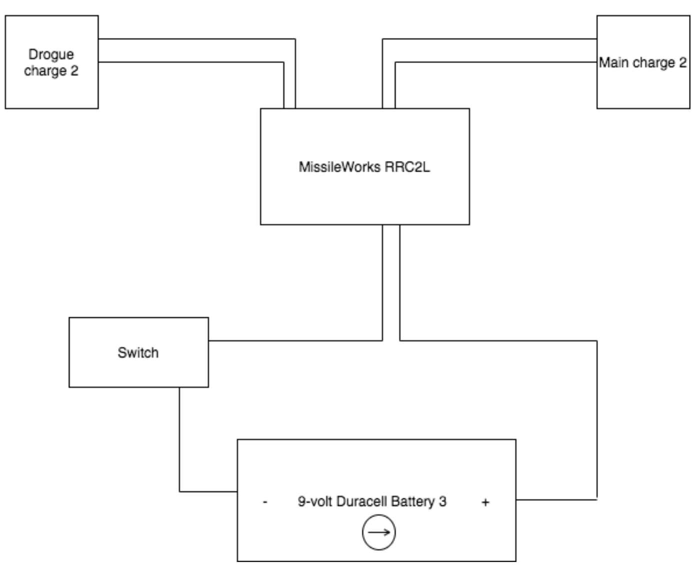
-Install the aft rail button and T-nut (*before* gluing in the aft retainer!). Then epoxy the aft CR onto the MMT (including the motor retainer which is already attached to the aft CR). Let dry overnight.

4. Assembling the dual-deploy system and two fully redundant backup DD systems

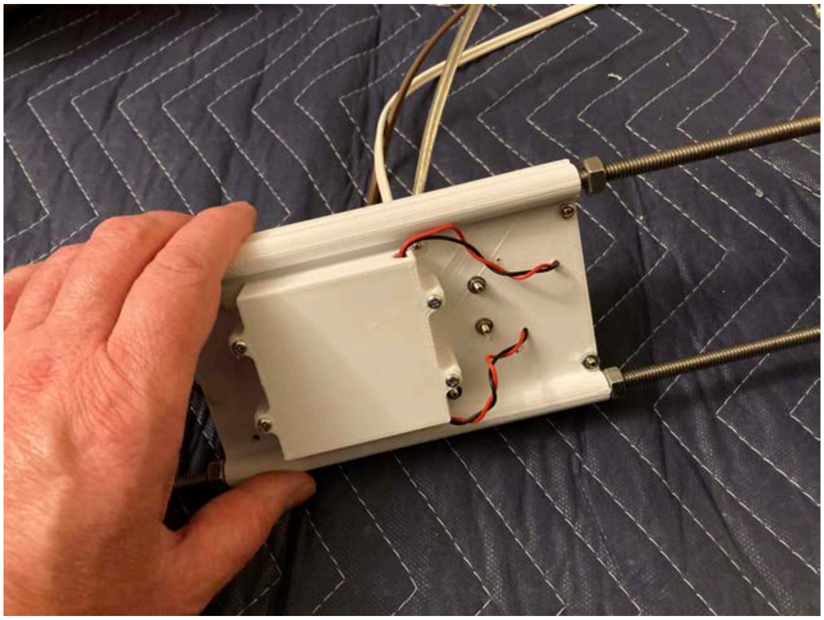
-Set up three fully independent circuits for the three altimeters (RRC2+, RRC2L, Altus Metrum) each with a switch and battery, and each with e-matches connected to their respective charge wells. The circuits are schematized below. Note: Altus Metrum has built-in contacts for the switch, whereas the RRC2+ and RRC2L both require putting the switch in series with the battery, as shown on next page.


Drogue charge 1
Main charge 1
Altus Metrum EMv2
Switch
- 9-volt Duracell Battery 1 +

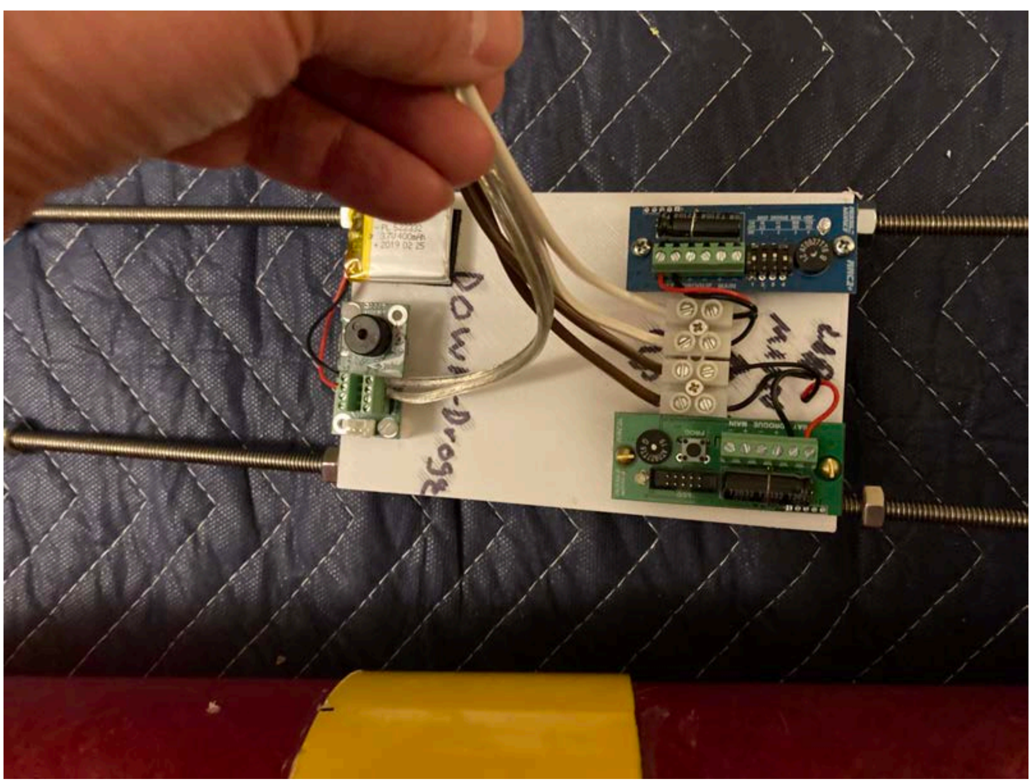

Drogue charge 2
Main charge 2
MissileWorks RRC2"
Switch
- 9-volt Duracell Battery 2 +

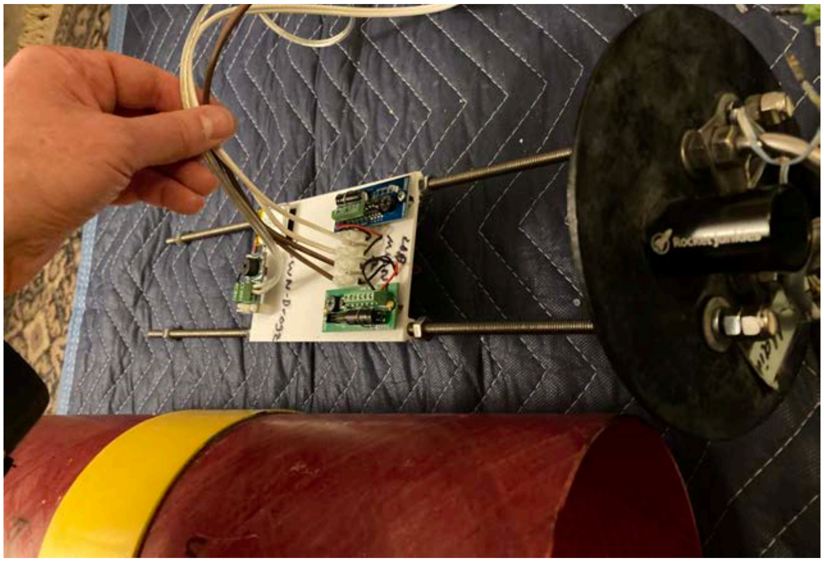

Drogue charge 2
Main charge 2
MissileWorks RRC2L
Switch
- 9-volt Duracell Battery 3 +

-Install two 9-volt Duracell or Energizer batteries in the two enclosed battery holders on the MAC 3D-printed sled, and install a lightweight Lipo battery on the top of the sled (velcro).



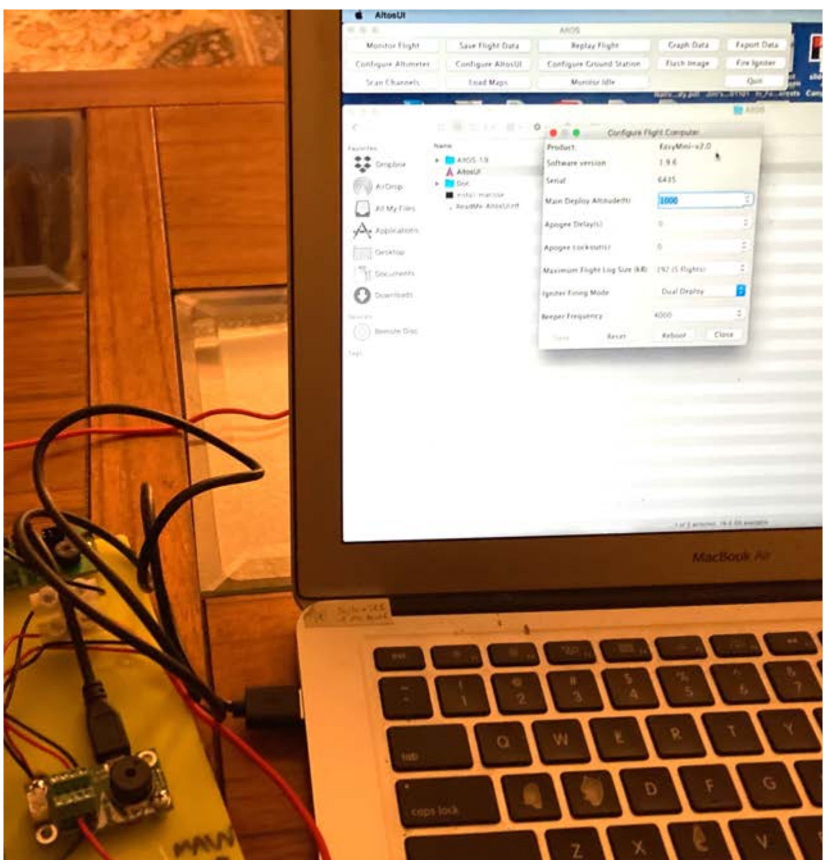
-On the MAC 3D-printed av-bay sled, drill holes for mounting RRC2, RRC2L, and Altus Metrum EM. Mount each altimeter on standard standoff posts (3/8" posts). Run wiring from altimeters to their respective switches and batteries.
Note: I have two other ride-along altimeters that will simply attach to the parachute shroud lines (Jolly Logic Altimeter3 and FlightSketch altimeter).



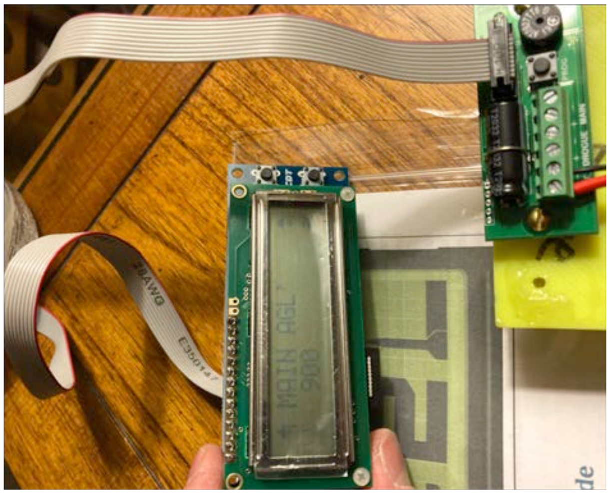


Note: I tested this av-bay board and altimeter system in a 6-inch MAC Super Black Fly on CTI L820SK to 5062 feet (11-20-2021 St Albans, VT), and all deployments worked as planned, including backups. YouTube flight video here: https://youtu.be/n3j_lj4LirA

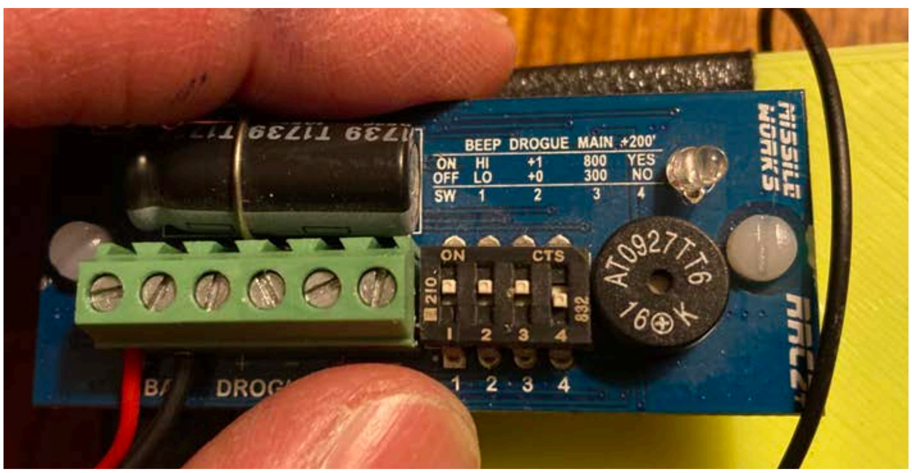
-Set the Altus Metrum EM altimeter to dual deploy at 1000 feet for main chute, and drogue at apogee, using USB cable to a Mac computer running AltusUI/Altos software:



-Set the primary backup altimeter (RRC2L) to 900 feet for main deploy, and drogue at apogee, using external LCD terminal connected via IDC ribbon cable to the device:

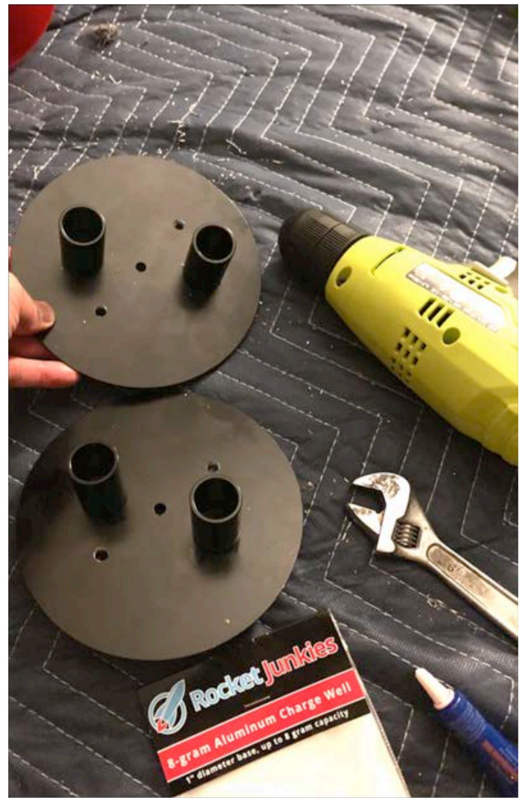


-Set the secondary backup altimeter (RRC2) to 800 feet for main deploy, and drogue at apogee+1 second, using DIP switches on the device:



-In the aft and forward bulkplates (black anodized aluminum plates from Wildman), drill two 1/4" holes for the av-bay's two long threaded rods, drill 3/16" holes for mounting screws for the charge wells and 5/16" holes for the MissileWorks bulkhead-sealing well nuts (2 aft, 2 forward). Then two 5/16" holes for the U-bolts. (The central hole in each plate will be used for the MissileWorks well nut which secures the e-match wires, as discussed below.)

-Tip: Before drilling into the aluminum plates, use a center punch or a nail to create a small indentation at the desired location of the hole. These Wildman anodized aluminum plates are quite strong and smooth, and so the drill bit can slide around on the surface. The small indentation helps to keep the bit in the right location while drilling.



-On each bulkplate, drill two 5/16" holes for the U-bolts. Mount them with 5/16" nuts as shown in the photos below.

-Mount the MissileWorks bulkhead-sealing well nut in the center hole. The well nut needs a 5/16"hole, and the Wildman bulkplate comes with a 1/4" hole in the center, so I just expanded that hole to 5/16" for the MissileWorks sealing well nut. The rubber well nut has a metal screw that I will tighten to secure the igniter wires in place in the bulkhead. I have used MissileWorks well nuts successfully on many prior DD flights. Also, on the U-bolt side of the bulkplate, note that the U-bolt's horizontal washer protects the well nut and igniter wires from being inadvertently hit by shock cords or metal quick links attached to the U-bolt. To get the igniter wires to fit just right, it may be helpful to widen the well nut's hole with a slight groove on one side. I create this groove on the side of the existing hole using a 1/4" drill bit, but just a little at a time, widening the hole a bit, testing the wires in the hole each time until it's a good fit.

-Drill three vent holes in the switchband. First, calculate the hole diameter: For this 6-inch dia. 16-inch long av-bay, the minimum appropriate diameter for three vent holes is 1/4" for each hole, according to the Missile Works RRC2 instruction booklet, or between 1/4" - 3/8" as calculated from the book *Make: High Power Rockets* (Westerfield 2018, p. 146). However, I will make the holes slightly larger (4/8" = 1/2" for each hole) for easier access in the twist-and-tape switch method. After drilling the three holes, be sure to sand them so that they are smooth, both the exterior and interior.

-Calculate charge needed for drogue separation and main separation, based on the deployment charge equation attributed to Vern Knowles on the NAR website in Denny Smith's L3 certification package (2008, p. 11): *n=0.00052 x F x L* where n = grams of FFFFg
F = desired separation force (lbs), and L = Length of chamber (inches)

For my 6-inch rocket, I will set F to 350 lbs as recommended by Westerfield for a 6-inch rocket (p. 155). The same value of 350 lbs is used in Denny Smith's L3 certification package (p. 11) on the NAR website. Using Knowles' equation, I find that 6 grams is a reasonable amount for my drogue charge (L=35 inches), and 5 grams for my main charge (L=26 inches).[1]

<u>Drogue</u>
Primary charge well: 6 grams
Second backup's charge well: Add 5% safety factor for a total of 6.3 g
(the first backup system will share the same charge well as the primary)

<u>Main</u>
Primary charge well: calculated 5 grams, but I rounded up to 6 grams to be on the safe side
Second backup's charge well: 6 grams
(the first backup system will share the same charge well as the primary)

<u>5. Assembling the small forward av-bay/nosecone coupler</u>

Rather than gluing a bulkhead into the nosecone, I will use a small av-bay as the coupler. This small forward av-bay will be attached to the nosecone by three 1/4" metal screws. I prefer this method since the nosecone will remain accessible for future configurations, such as the possibility of adding nosecone electronics in future flights.

-Insert two 12"-long threaded metal rods (1/4" steel) in the av-bay lids, along with the sled and U-bolts. Tighten the screws and nuts securely.

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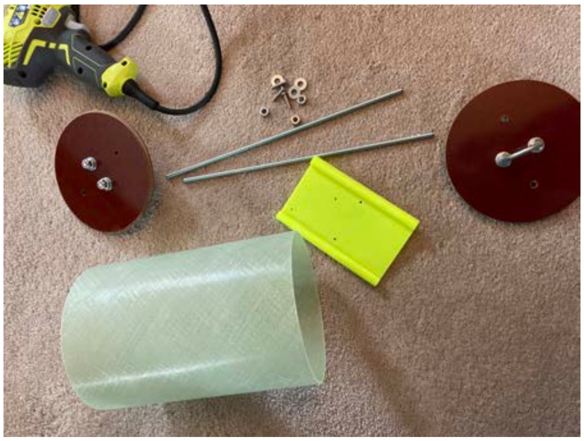
[1] Knowles' equation n = 0.00052 x F x L can be derived from PV=nRT, where n is the amount of charge in grams. According to Westerfield's *Make: High-Power Rockets* (2018, p 154), the constant R is 266 for FFFFg charge, and the temperature T is 3307 for this kind of charge.
n = PV/RT = [PV/(3307*266)] * (454 g/lb) = [(F/A)*V / 3307*266] * (454 g/lb)
= [(F/A) * A*L / 3307*266] * (454 g/lb) = [F * L / 3307*266] * (454 g/lb)
= (F * L) * 0.00052
n = 0.00052 x F x L

-Insert the forward end of the av-bay into the nosecone.
-Now secure this secondary av-bay/coupler to the nosecone: Drill three 1/4" holes through the nosecone and av-bay/coupler, and install three 1/4" sets of metal screws, washers, and nuts. Now attach the aft lid of the av-bay, and tighten it down. Finally, drill three 1/8" vent holes near the top of this secondary av-bay/coupler where it connects to the nosecone (drill the vent holes all the way through both the nosecone and the av-bay/coupler so that that the sealed coupler can vent to the outside air).



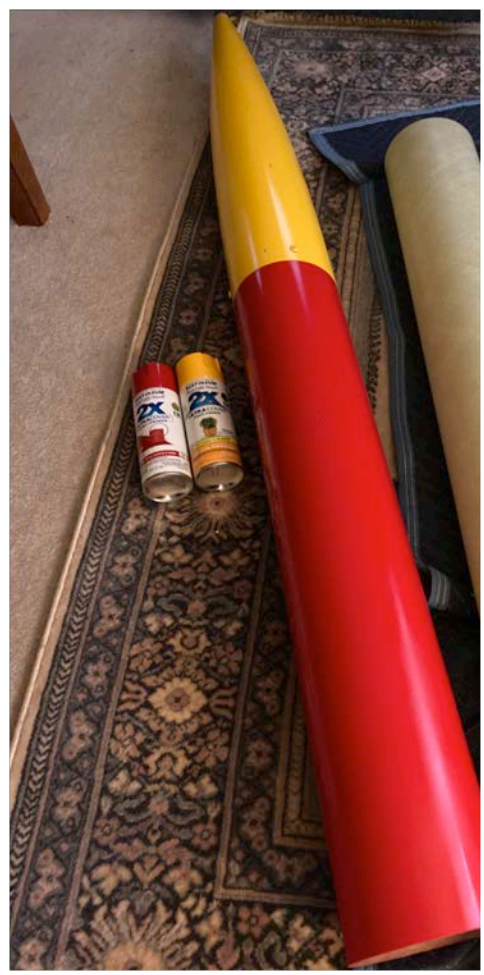
6. Exterior finishing and flight preparation

-Lightly sand the rocket with 400-grit wet sandpaper (and 220-grit where needed)

-Paint the rocket with multiple coats of Rustoleum Painter's Touch 2X spray paint, and lightly sand with 400-grit wet sandpaper between coats of spray paint:
(1) Nosecone and switchband:
3 cans of 12 oz. gloss "Golden Sunset" color, and 1-2 cans of 12 oz. gray primer
(2) Payload section (upper airframe):
3 cans of 12 oz. gloss "Apple Red" color

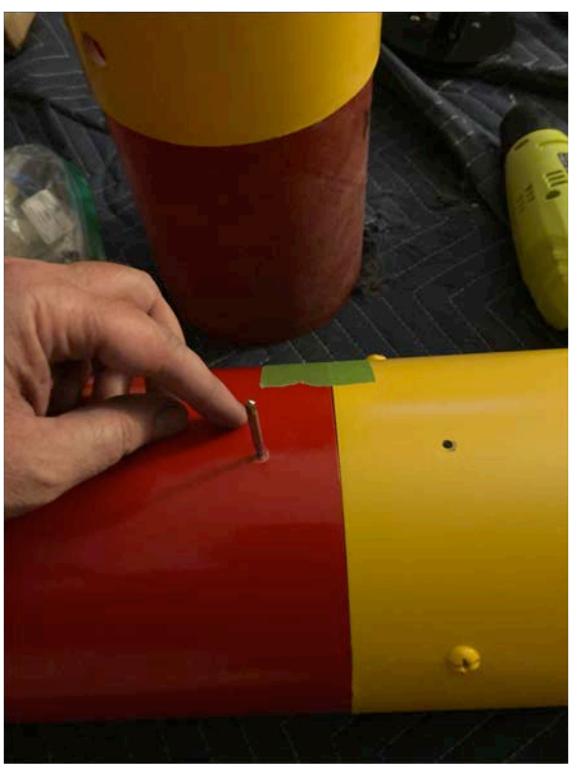
(3) Fins and booster section:

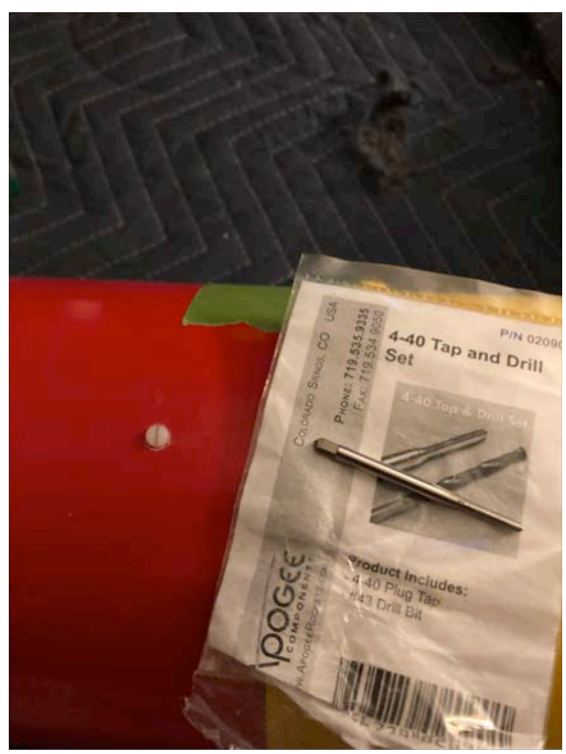
7-8 cans of 12 oz. gloss "Brilliant Blue" color (also add a decal from StickerShock)




ULTIMATE

-Using a 4-40 bit and tap set, install four evenly spaced 4-40 shear pins where the forward end of the payload section (upper airframe) connects to the nosecone coupler, drill shallow half-moons to mark the position for later alignment. Similarly, install four evenly spaced 4-40 shear pins where the booster section connects to the aft end of the payload section, drill shallow half-moons to mark the position for later alignment. Note: Rather than using a wrench, I turn the tap gently by hand because this helps keep it slow and gentle, reducing the chance of breaking the tap while tapping through the two fiberglass walls.





-Secure the av-bay to the aft end of the payload section by drilling three 1/4" holes and inserting 1/4" screws, nuts, and washers.

-Fold the SkyAngle XL Cert3 parachute according to the company website instructions www.b2rocketry.com -- spread the chute on the ground, fold lengthwise back and forth (zig-zag fold) until it is about 6 inches wide. Then fold the chute vertically in 6-8 inch sections, following a zig-zag pattern until it is a narrow pod about 6 inches wide and about 6-8 inches tall. Fold the shroud lines in a zigzag pattern at the base of the chute, and insert it all into the compartment, all above the Nomex cloth (with shroud lines aft of the chute).

<u>7. Test flight on CTI 4263-L1350-CS</u>: St. Albans, Vermont, CRMRC monthly club launch 8-21-2021, supervised by Club President Howie Druckerman (NAR-L3)

-Ground test the charges, and begin preparing the rocket for loading onto 12-foot 1515 rail

-Load the 3-grain CTI L1350 into the 5-grain CTI casing with 2 spacers. Tighten with the CTI 75mm wrench. Install the AeroPack 98-to-75mm adapter rings onto the CTI casing, then load the casing into the 98mm MMT and fasten the 98mm AeroPack retainer.

-Install the igniter wires in the av-bay using the MissileWorks bulkhead-sealing well nuts in the aft and forward bulkplates. Tighten with screwdriver until the wires are firmly secure. Place the igniter heads in the charge wells with the igniter heads close to the bottom of the well, pour in the appropriate amounts of charge, and then fill the rest of the well with wadding, then tape over the top of the well securely with masking tape.

-Load the rocket onto the rail at 300 feet from the launch table (ask some friends to help carry this heavy rocket!), climb a small stepladder to arm the altimeters in the av-bay, insert the igniter into the motor (using the long thin straw supplied by CTI) and secure it with plastic cap (CTI), connect the two electric leads to the igniter, confirm that the sky and range are clear, then launch!

YouTube full video of the L1350 test flight available here: https://youtu.be/udtWbwcnQWA

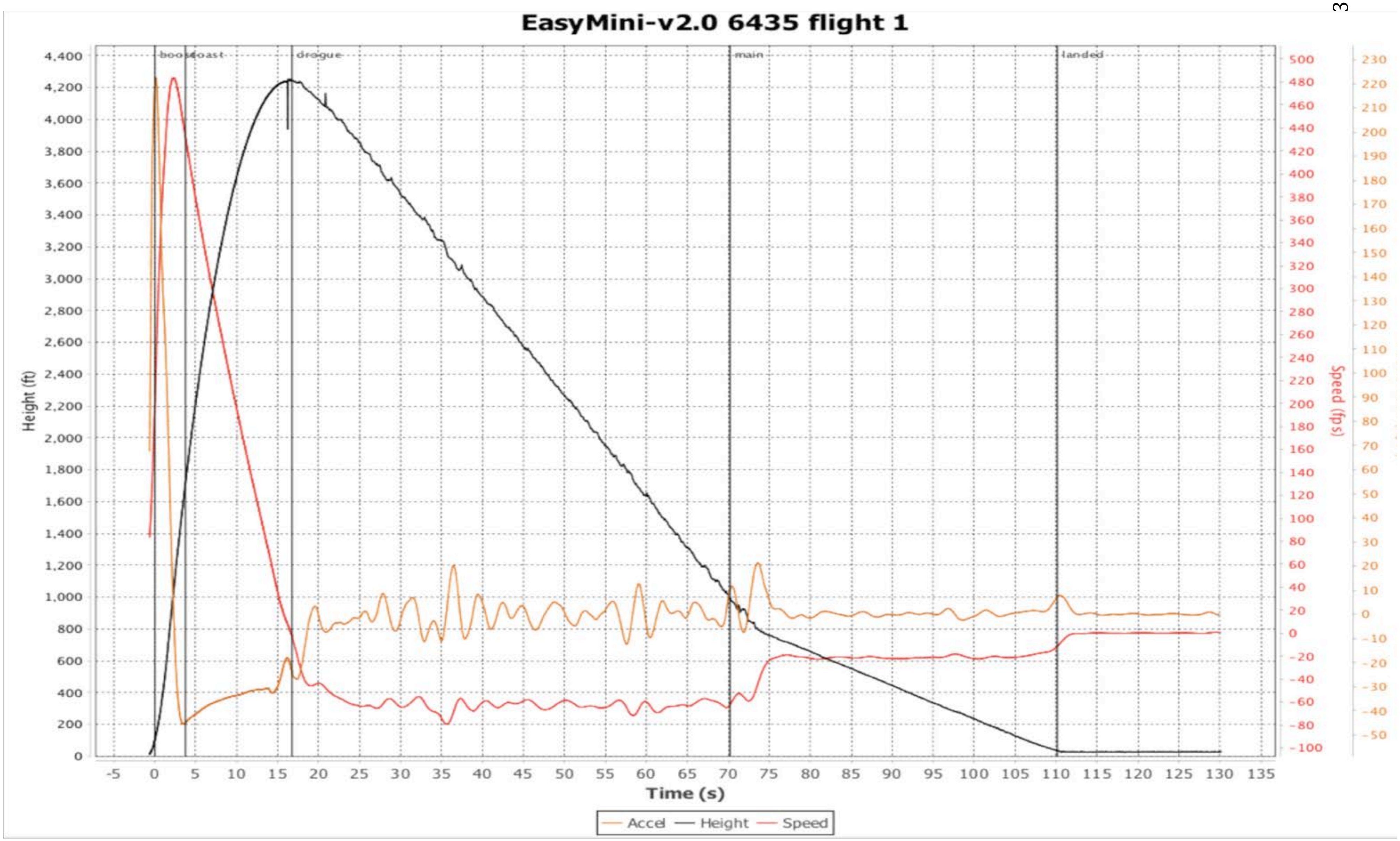
Result of test flight: PERFECT FLIGHT AND RECOVERY!
47 pounds loaded weight with the L1350 motor, launched from a 12-foot rail (1515) angled 5 degrees west. Good smooth launch, good drogue deployment at apogee, good main deployment at 1000 feet as planned. All of the charges deployed as planned, including backups. Drogue and main chute both deployed properly at the planned altitudes. The rocket landed safely about a half mile to the northwest. See photos below.

-After the test flight, carefully examine all components for any possible damage or anomalous behavior, including nosecone, airframe, fins, U-bolts, quick-links, swivels, shock cords, parachutes, and all dual-deploy systems and charges. <u>Result: All good</u>

<u>Test flight (L1350) results summary:</u>
1. Altus Metrum altimeter:
Apogee 4252 feet, max speed 330 mph. The graph below shows that the apogee (drogue) charge fired at apogee as planned, followed by backup charge 1 second later. The main chute's charge was fired at 1000 feet as planned (backup altimeters at 900 and 800 feet). The main chute itself was fully unfurled within about 2-3 seconds after its charge fired. Descent rate under drogue was 61 fps. Under the main chute, Altus Metrum reports average descent rate as 24 fps, but actually the Altus Metrum's own graph shows that the descent speed stays below 20 fps for the whole time while under the main chute. The Altus Metrum's reported number for average descent rate seems to be calculated a bit too early, i.e. from a point before the main chute had fully deployed.

2. Jolly Logic Altimeter3 output:
Apogee 4312 feet, max speed 386 mph, drogue descent rate 63 fps, and main chute descent rate 20 fps.

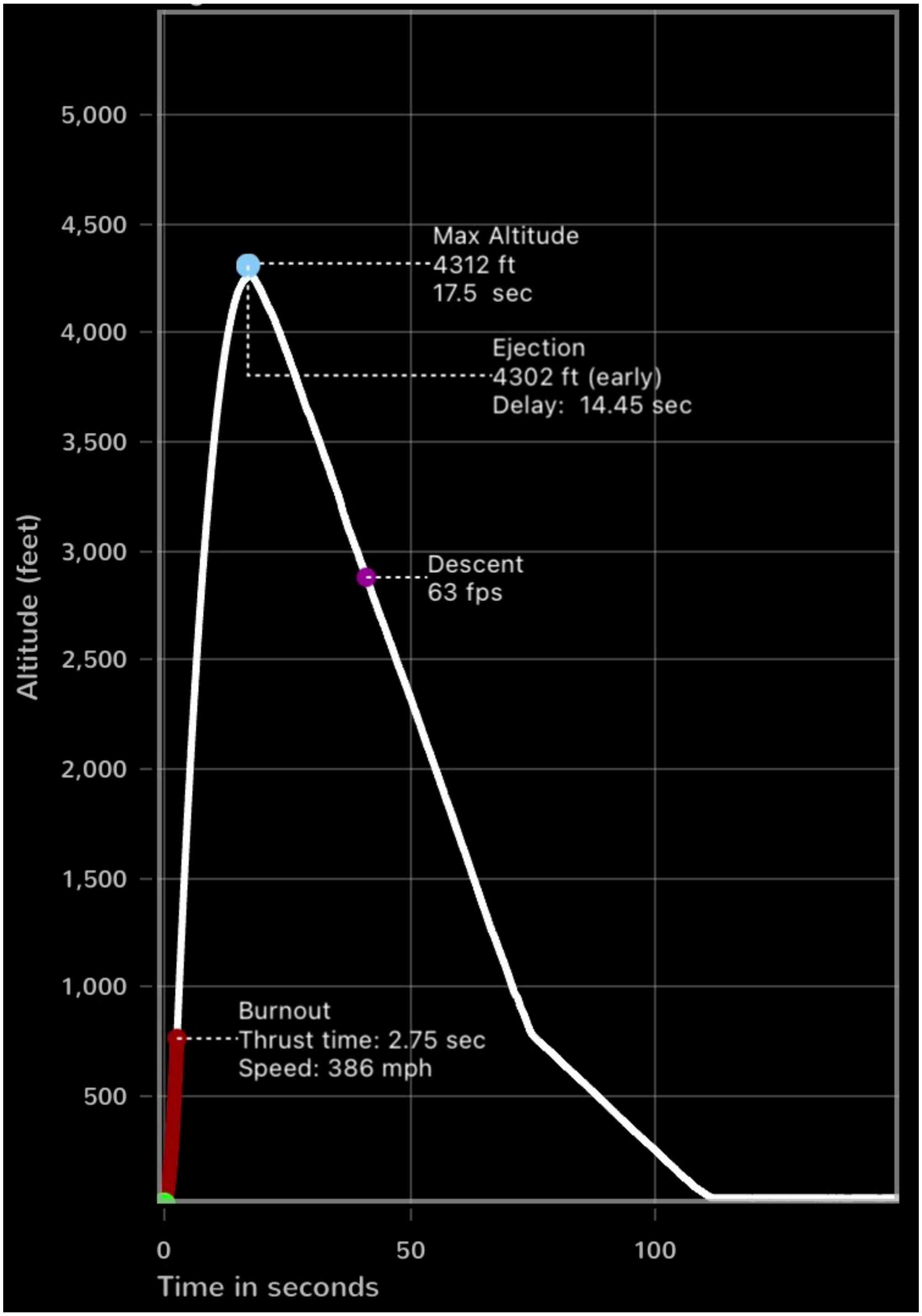
See below for flight graph and statistics from Altus Metrum altimeter, and then the flight graph from Jolly Logic Alt3.


EasyMini-v2.0 6435 flight 1
boost
coast
drogue
main
landed
Height (ft)
Speed (fps)
Time (s)
Accel
Height
Speed

Flight statistics from Altus Metrum (test flight on L1350):

Device	EasyMini-v2.0	version 1.9.6	serial 6435
Flight	1		
Maximum height	1296.1 m	4252 ft	
Maximum speed	147.4 m/s	484 fps	Mach 0.4
Maximum boost acceleration	67.8 m/s^2	222 ft/s^2	6.91 G
Average boost acceleration	18.6 m/s^2	61 ft/s^2	1.89 G
Ascent time	3.7 s boost	13.0 s coast	
Drogue descent rate	18.5 m/s	61 ft/s	
Main descent rate	7.3 m/s	24 ft/s	
Descent time	53.5 s drogue	40.0 s main	
Flight time	110.1 s		

Flight graph from Jolly Logic Alt3 (test fight on L1350):



8. Planned Certification flight

(a) Assemble the 5-grain CTI 6132-M1810-RL into the 5-grain CTI casing.
Shown below: 5 grains of the M1810 motor, the phenolic liner and disposable nozzle, CTI igniter and smoke kit, aluminum 5-grain casing, 98-75mm adapter rings, forward assembly and forward retaining ring, nozzle holder and aft retaining ring, CTI 75mm wrench.

Assembly:
First, put the tracking smoke element into the forward closure assembly: Lightly coat the interior of the forward closure bay with Super Lube, then coat one surface of the smoke element with lubricant and insert the smoke element into the forward closure with the lubricated face first.

Next, find the CTI 75mm O-ring kit, which consists of three O-rings in a small plastic bag. Put the smaller (red) O-ring into the internal slot of the nozzle holder. Then put a large O-ring into the external slot of the nozzle holder, and another large O-ring into the external slot on the forward closure assembly. Note that these rings are pre-lubricated and do not require any additional lubricant. In fact, none of the O-rings in the CTI motor kit require any additional lubricant. Now push the nozzle holder onto the nozzle until it snaps into place, and then insert this nozzle assembly into the aft end of the phenolic liner, with the shoulder firmly up against the aft end of the liner.

Inserting the 5 grains: Position the phenolic liner horizontally on a flat surface. Line up the 5 grains with one O-ring separating each one (one such O-ring is found inside each bag for each of the 5 grains). From the forward end of the phenolic liner, insert the grains one at a time into the phenolic liner, placing an O-ring on top of each grain so that there is an O-ring separating each grain from the next one. According to the CTI 75mm instructions, the last O-ring (highest grain on the forward end) can be omitted if the fit is too tight, that is, if the O-ring would extend more than 1/3 of its width beyond the top of the phenolic liner. This is the only O-ring that can be omitted, and only if it is a tight fit!

Now that all of the 5 grains are installed inside the phenolic liner and the nozzle is also installed, place the phenolic liner vertically on a hard surface, and cover the outside surface of the liner with a smooth layer of lubricant, being careful not to spill any lubricant onto any grains inside the liner. Here comes the tricky part: Carefully pull the aluminum casing down over the slippery lubricated phenolic liner, starting at the forward end of the tube and ending at the aft end. Remove excess lubricant as the casing slides down over the phenolic liner. Put the aft retaining ring (threaded ring) into the aft end of the casing, and tighten it a few turns to get it started, but not all the way yet.

On the forward end of the casing, insert the plastic seal disk (black) on top of the last (most forward) grain. Then above that seal disk, add a thin layer of lubricant onto the inside of the walls of the aluminum casing (only in the small area above the plastic seal disk). Insert the forward assembly into the casing, and then install the forward retainer (threaded ring). Tighten with the CTI 75mm wrench until this forward threaded ring is flush or slightly submerged inside the casing.

Now go to the aft end of the casing and securely tighten the aft closure, using the CTI wrench.

The photo below shows the completed M1810 assembly secured inside the CTI 5-grain casing (along with a 98-75mm adapter ring).

Note: Here's a link to a YouTube video showing all my steps in assembling this motor: https://youtu.be/kgERES12gHc

Finally, in order to reduce oxidation of the grains during storage, seal the whole casing within its original plastic packing tube, using duct tape to form an airtight seal as much as possible. Add a note to identify the motor (M1810), so that later we don't forget which motor it is!

(b) Pre-Flight Checklist for Certification Flight:

-Install a new battery for each altimeter and confirm voltage levels on the altimeters
-Confirm that there are no obstructions inside the MMT or airframe tubes
-Fold the drogue and install it, following the procedures described above
-Fold the main parachute and install it, following the procedures described above
-Install the two Nomex protectors: One on the shock cord above the av-bay, and one on the shock cord below the av-bay
-Confirm that quick links are attached at each necessary point: Booster harness to shock cord and drogue; shock cord to aft end of av-bay, nosecone to shock cord, main parachute, and forward end of av-bay
-Wire the e-matches from each altimeter to its respective charge well
-Make sure that the connection wires on the altimeters are correctly wired as Drogue versus Main charges: Compare the wire connections on each altimeter with the corresponding charge wells. The av-bay bulkhead plates are marked "Drogue - Up" and "Main - Down" to make sure it is oriented correctly.
-Install the plastic shear pins at the two separation points, and install the metal screws to secure the aft end of the av-bay, and to secure the nosecone
-Prepare the three switches (paired wires ready for twist-and-tape), and keep them open/separated (not armed at this point)
-Install 98-to75mm adapter rings, load the motor casing into the MMT, and securely install the aft retainer
-Confirm that the actual CG of the fully loaded rocket matches the expected location of the CG from Open Rocket simulation
-Fill out flight card and L3 certification forms, then get the rocket inspected for flight
-Load the rocket on the rail, arm the three altimeters controlling recovery, and also arm the ride-along altimeters
-Insert the igniter, ask the LCO to check continuity, then follow standard launch procedures and launch it!

(c) Post-recovery checklist:
-Remove and inspect av-bay, and disarm altimeters
-Check for any unfired e-matches or charges, and remove if needed
-Confirm that the motor has been correctly retained by the aft retainer
-Confirm that all segments of the rocket remain linked together by harnesses/shock cords
-Confirm that fins, MMT, airframe, nosecone all have maintained integrity without damage

Appendix: Prior Rocketry Experience

Background: I flew Estes rockets as a child in Iowa, and then rejoined rocketry as a middle-aged adult in New England. I am an active member of Howard Druckerman's NAR club (CRMRC) in St. Albans, Vermont. For the past four years, I have driven 4 hours round-trip from western New Hampshire to St. Albans, Vermont, for almost every monthly CRMRC launch. Club president Howard Druckerman (L3) has been mentoring me in rocketry (special thanks to Howie for all of his help and advice for many years). Our club flies 12 months a year when flying conditions allow. Since September 2019, I have written our club's launch reports that we post online each month, including technical details documenting each club member's flights. During 2021, I have also been producing our monthly video of club launches that we post on YouTube. On CRMRC launch days, I help with transportation of a club member to the field and then help set up our club launch equipment. I video-record the launches throughout the day and then edit them into our monthly club video. I also occasionally serve as RSO or LCO.

NAR club memberships: I have flown with clubs in four different states: Vermont, Maine, New Hampshire, and Maryland. In addition to my primary club membership with CRMRC in Vermont, I am also a member of the Lake Winnipesaukee HPR Club (New Hampshire), and I flew with them on their frozen lake launch site in February 2021. I am also a member of MDRA and flew with them at Red Glare 2021. I also flew in Maine twice with the MMMS/CMASS clubs, before their Maine farm launch site was closed.

Previous flights and motors used: During the past four years, I have flown a total of 48 high-power flights and 25 mid-power flights, averaging 17 flights per year. I flew my L2 certification flight in St Albans with CRMRC in February 2018 (100% on written exam), and I have tackled numerous other rocketry challenges since then. I have flown six L motors:

(1) CTI 3618-L995 (75mm 3G) on 7.5-inch x 12-foot LOC Bruiser to 4249 ft (July 2019)
(2) CTI 3147-L935 on 2.6-inch ARR Predator (Blue Tube airframe shredded during Mach transition) (Feb. 2021)
(3) CTI 3727-L1050 (75mm 3G) on 6-inch x 7-foot MAC SuperBlackFly to 6937 ft (March 2021)
(4) CTI 2833-L805 (54mm 6XL) on 6-inch x 7-foot MAC SuperBlackFly to 5100 feet (April 2021)
(5) CTI 4263-L1350 (75mm 3G) on 6-inch Ultimate Wildman to 4252 feet (Aug 2021; this was the test flight of the current project, as described in this document)
(6) CTI 2946-L820 (75mm 3G) on 6-inch x 7-foot MAC SuperBlackFly to 5062 feet (Nov. 2021)

I have also flown five K motors and eleven J motors, including a CTI 2377-K711 in an ARR Predator at Mach 1.2 to 10,000 feet, and a 7.5-inch LOC Bruiser with CTI 2108-K780 and then a flight with CTI 2010-K675 with the same rocket. I have also flown three flights in the range of 5100-6200 feet on a Madcow Super DX3, including the extra-long Loki 1519-K627 (two flights on the K627). I also flew a 54mm MAC Hyper54 at Mach 1.1 to 6400 ft. I have experience assembling motors from three major manufacturers (Cesaroni, AeroTech, Loki).

Dual deploy experience: I have been flying dual-deploy for over three years, including standard mid-rocket separation and also head-end deploy. I have built dual-deploy systems for a wide range of rockets and airframe diameters: 7.5-inch, 6-inch, 4-inch, 75-mm (min. dia.

rocket), 2.6-inch, and 54-mm (min. dia.). I have used four different types of av-bay construction materials: fiberglass, Blue Tube, MAC canvas phenolic, and cardboard/wood. I include redundant DD systems on all DD flights (2 or 3 flight computers mounted on each flight). In these DD systems, my altimeter arming mechanisms have included push buttons, screwdriver switches, pull-chain switches, magnetic switches (Featherweight), and twist-and-tape method.

Rocketry electronics experience: I have used six kinds of altimeters/flight computers (Missile Works RRC2, Missile Works RRC2L, Altus Metrum EM, Jolly Logic Altimeter3, PerfectFlite APRA, and FlightSketch), three GPS tracker systems (Featherweight, Eggfinder, Jiobit), beeping locators (Tatako beeper and PerfectFlite APRA), a weather logger (Senonics Minnow), and the Jolly Logic Chute Release (JLCR).

Building experience: I have built a wide variety of high-power rockets and mid-power rockets, including fiberglass airframes (Wildman, Madcow, MAC), canvas phenolic airframes (MAC), Blue Tube airframes (ARR), cardboard/wood rockets (LOC/Precision and Madcow), cardboard/plastic rockets (Estes), and a rocket that I built from clear plastic tubing (custom). Nosecone assemblies on these rockets have included Von Karman filament-wound fiberglass nosecones (aluminum tipped) as well as polypropylene nosecones. Additional airframe building experience (custom work): I extended the airframe of my fiberglass 4-inch Madcow SuperDX3 from 78 to 102 inches tall, and I extended my cardboard 4-inch Madcow SuperDX3 from 67 to 79 inches. I also extended my 7.5-inch LOC Bruiser from 112 to 142 inches tall.

In addition, I have experience with the following rocketry equipment: multiple types of retainers (flange-mounted AeroPack retainers, JB Weld-mounted AeroPack retainers, MAC FastBack with snap rings, AeroPack aluminum tailcone retainer), all major sizes of MMT adapters (98mm-to-75mm, 75mm-to-54mm, 75mm-to-38mm, 54mm-to-38mm, 38mm-to-29mm, 29mm-to-24mm), multiple types of fin assemblies (Binder MaxQ aluminum riveted fins in 54mm and 75mm sizes, Additive Aerospace 3D-print fincan, Acme/ARR injection-molded fincan, as well as standard thru-the-wall fin mounts), polyurethane expanding foam (Pour-N-Fill Poly), experience building minimum diameter rockets (54mm and 75mm), grain-gluing of Loki extra-long motors, installing steel rods to reinforce a 6-inch diameter 3D-printed MAC tailcone, and building a custom nosecone av-bay. I am also experienced with flyaway rail guides (Additive Aerospace, both 54mm and 75mm) and two-stage Estes boosters.