A Quick Start Guide to Flying Micro and Mini-hybrid Motors

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Introduction

The purpose of this publication is to show interested persons how to fly small hybrid rocket motors as quickly and safely as possible. Micro and mini-hybrids offer the sport and experimental rocketeer more varied and interesting challenges along with less expensive flights compared to equivalent solid motors like those marketed by *Estes* (black powder) and *Aerotech/Quest* (APCP). These motors are unique in that they are powered by small whipped cream "chargers" filled with nitrous oxide used in combination with almost any solid combustible material like paper, wood, wax, PVC pipe, 3D printed ABS etc. This cartridge-based hybrid approach was originally conceived of by Dave Oback, worked on by Bill Colburn, and brought to a flight capable configuration (Figure 1) by Rene Caldera in the mid 1990s (as shown in Figures 30 and 31). These small hybrids are in the D (micro) and E (mini) power class. They are reasonably easy to operate and safe to fly on your own (where local and state regulations do not prohibit). But, because they are experimental and not certified, you may not be able to fly them at organized club launches unless that club supports "research" launches (usually Tripoli Rocketry Association prefectures); check with your local launch Range Safety Officer.

Figure 1. A standard-cased micro-hybrid machined from an original Rene Caldera kit (ca. 1998).

How do Micro and Mini-hybrid Motors Work?

Following assembly as per the instructions described later, the motor is armed by turning an *initiating* or *charging screw.* The screw pushes the N_2O cartridge against a small *piercing cone* with a very small *injector hole* drilled through its center. A thin plastic *burst disk* sealed with an O-ring sits under the piercing cone constraining the self-pressurized liquid oxidizer prior to ignition. Directly below the burst disk is a chamber containing a small piece of solid propellant called a *pre-heater grain* thus creating a "pyro valve" in concert with the burst disk. Upon launch, the standard 12 volt hobby rocketry igniter lights the pre-heater grain which; 1) melts the burst disk freeing the flow of N_2O, 2) creates an ambient temperature above 600 ^{o}F (316 ^{o}C) allowing liberation of oxygen from the N_2O in the *combustion chamber* below, and 3) ignites the main solid fuel grain in this oxygen rich environment and the motor begins its burn.

Why Fly Micro and Mini-hybrids?

1) Low cost flights; typically $1.00 to $2.00 per flight considering all consumables plus shipping and handling. This is about 1/4 to 1/3 the list price of flying an Estes D single–use or Aerotech D reloadable motor. Mini-hybrids cost a bit more, about $1.50 to $3.00 per flight.

2) Single stage rockets powered by micro-hybrids are able to reach 500 to 1000' (152 to 304 m) altitudes and mini-hybrids are able to reach 1000 to 2000' (304 to 609 m) altitudes.

3) Relatively inert propellant components and one of the safest real rocket motors available! The main hazard comes from handling N_2O cartridges under 860 psi (5930 kPa) pressure.

4) Can be clean burning and less messy clean-up than most solid reloadables.

5) Allows for substantial experimentation with propellants (especially the fuel).

6) Easy to use. Unlike many larger hybrids, no complicated and expensive ground support equipment is needed.

7) An excellent choice for experienced rocketeers who can build small, lightweight but strong rockets, are comfortable with electronic deployment, and enjoy experimenting with unique propulsion methods. There is certainly a lot going on here!

8) Arguably the most elegant hobby rocket motor of its size ever designed.

What is Needed to Fly Micro and Mini-hybrid Powered Rockets?

1) Reusable micro or mini-hybrid motor hardware (see Figure 2).

2) Whipped cream dispenser cartridges containing either 8 (micro) or 16 (mini) grams of nitrous oxide.

3) Homemade fuel as simple as rolled-up paper bag material.

4) A few small replaceable items including O-rings, burst disk and pre-heater grain.

5) A typical C, D, or E class rocket kit (or scratch-built) at least 24 mm in diameter modified to take the motor and a deployment device. Note: we will make our own alternative airframe later in this paper.

6) A lightweight parachute and electronic deployment system (either an altimeter, timer or Magnetic Apogee Detector) along with an electric match and black powder ejection charge. Note: in this paper we will apply a flight method that does not require any of this.

7) A standard hobby rocketry 12 Volt launch system with 1/8” (3.2 mm), 3/16” (4.8 mm), and 1/4" (6.4 mm) launch rods or micro-rail as needed and a standard solid fuel igniter.

Reusable Parts for a Dexter Labs Micro-hybrid or Mini-hybrid (see figure 2 below):

1) Aluminum motor casing
2) Nozzle retaining (snap) ring
3) Aluminum or stainless steel chafing washer - rear closure
4) Graphite nozzle
5) Aluminum injector body
6) Brass piercing / injector unit
7) Stainless steel T-nut forward closure
8) Stainless steel charging (initiating) screw
9) Forward retaining (snap) ring

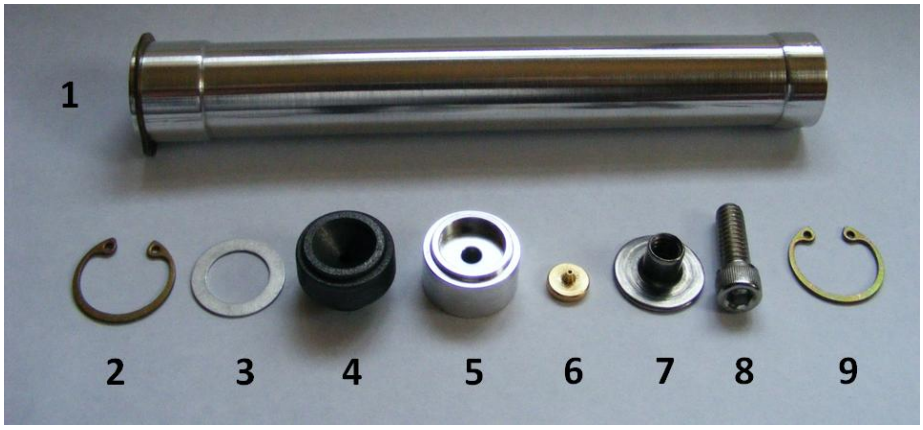

Figure 2. Parts for a *Dexter Labs* Micro-hybrid motor, lightweight case version.

Consumable Parts Needed for Each Firing:

1) N_2O cartridge (8 gr. for the micro, 16 gr. for the mini)
2) Fuel grain (0.75” dia x nominal 2” long (micro), 0.88” dia x nominal 3” long (mini))
3) 2 “large” O-rings (“dash 016” for the micro, “dash 018” for the mini)
4) 1 “small” O-ring (“dash 009” for either motor)
5) 1 pre-heater grain (0.15” thick x 0.50” diameter with a 3/32” central hole)
6) 1 plastic burst disk (0.011” thick x 0.340” diameter)
7) Krytox nitrous safe O-ring lubricant
8) 1 standard rocket motor igniter (must be thin enough to fit through the 0.10” nozzle)

Purchasing Nitrous Oxide Cartridges. Resembling CO_2 cartridges in appearance, these are often sold as “chargers” for whipped cream or iced coffee dispensers (Figure 3). You may be able to find them at local cooking supply stores or order them online from numerous suppliers.

Figure 3. N_2O whip cream chargers.

Making Paper Fuel Grains. Shopping bag (aka kraft) paper is the simplest material from which to make fuel grains. You will need a ruler, a pair of scissors, a 3/8" (9.5 mm) diameter rod about a foot long (aluminum works best), a can of *3M Formula 77* spray glue and some masking tape. Cut several strips of bag paper about 7" (18 cm) wide by as long as you can get from your bag. You will need a total length about 46-50" (117 – 127 cm) for the micro and 60-64" (152 – 163 cm) for the mini. Cover the first 2" (5 cm) of the first paper strip with masking tape. Spray the entire face of one side of the paper lightly with 3M 77 glue. Working on a firm surface like a sturdy table remove the tape and center the rod at the very end of the dry area of the paper strip. Begin rolling the paper tightly onto the rod until your first strip is glued down. Spray the next strip of paper with 3M glue, no need to protect the first part with tape this time. Carefully line up the paper with the rod and continue to roll on the glued paper. If the roll drifts off of alignment just stop rolling, cut the rest of the strip off, re-align and resume rolling. Don't worry about the uneven edges. Repeat as necessary until you have achieved the proper OD to fit your hybrid's case (Figure 4).

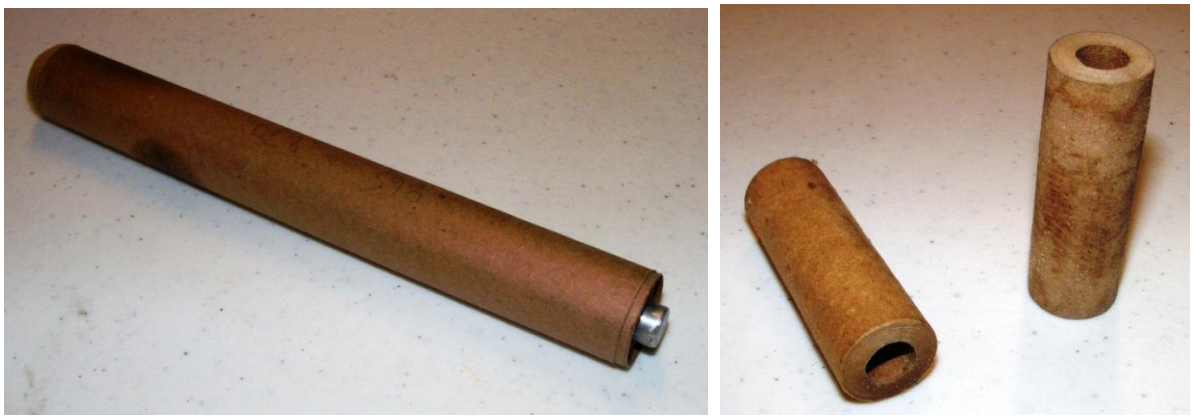

Figure 4a. (left) Bag paper rolled onto a 3/8" (9.5 mm) aluminum rod. 4b (right) Finished grains.

Remove the rod and let this paper roll dry overnight. Using a table saw or hand "draw saw" and miter box cut the roll into lengths that fit your specific hybrid (2" – 5.1 cm for micros and 3" – 7.6 cm for minis). The grain ends must be cut square, even and smooth.

Purchasing O-rings. Properly sized O-rings may sometimes be found locally at hardware or auto parts stores but most assuredly from large on-line hardware supply stores like *McMaster Carr* or *Grainger* where they will be much more economically priced in batches of 50 to 100.

Making Pre-heater Grains. There are several ways to make pre-heater grains as explained in the full *User's Manual*. Crude but simple, just cut disks from almost any APCP propellant reload kit (like those sold by *Aerotech*[tm]) and shape with a hobby knife to fit the pre-heater well.
To minimize waste use the 18 mm D24T Blue Thunder (most effective) reload grain. Peel off the outer cardboard liner, sharpen one end of a ½" (12.7 mm) ID thin wall brass tube and trim the slug diameter to size. Use a hobby knife to cut the slug into about 1/8" (3.2 mm) thick disks. This yields about a dozen disks with very little waste (Figure 5). Rely on the C-slot if your grain has it (Figure 5) or drill a 1/16 to 3/32" (1.6 to 2.4 mm) hole in the center of the grain.

Figure 5. Pre-heater grains cut from a D24T load.

Making Burst Disks. The quick way to make burst disks is to punch or cut them from 2 liter soft drink bottles (Figure 6a). The disk should be as close to 0.340" (8.6 mm) in diameter and as round as possible. Very neat burst disks can be fashioned with a punch specifically made for the task (Figure 6b). Standard spring handle paper hole-punches are too small. Specialty spring handled hole punches 11/32" (8.7 mm) in diameter can be purchased but are quite pricey.

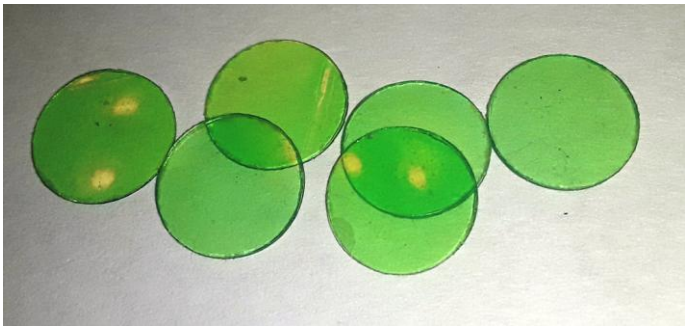

Figure 6a (left). Burst disks made from 2 liter pop bottles.6b (right) A simple punch and die offered by Dexter Labs specially to produce burst disks.

In the following motor loading and launch procedures be sure to observe these safety precautions:

Safety Precautions:

Do not use the motor if any part appears to be damaged.
An improperly assembled motor can disassemble violently during arming sending parts ricocheting everywhere. Speaking from experience, I cannot emphasize this hazard enough!
Avoid dropping or jarring the motor after assembly.
To minimize leak potential, do not arm the motor until just before launch.
Use gloves and safety glasses and even arm the motor covered by a folded tarp. Keep your hands away from the ends of the motor as much as possible while arming.
Make sure you are pointing the ends of the motor in safe directions during arming.
Keep ignition sources away from the arming operation.
Never apply heat to a loaded N_20 cartridge.
This is an experimental motor, launch following Tripoli guidelines www.tripoli.org

Micro and Mini-hybrid Assembly and Launch Instructions (refer to figure 2 above):

The following is an abbreviated assembly procedure. See the full *User's Manual* for complete instructions. Once mastered it takes only a minute or two to prepare these small hybrids for launch:

1) As described earlier, purchase appropriate N_2O cartridges and O-rings, fabricate by the methods of your choice (or purchase) fuel grains, pre-heater grains, burst disks and igniters. Make sure there is a 1/16" to 3/32" (1.6 to 2.4 mm) hole through the center of the pre-heater grain. Also have on hand a pair of snap ring pliers and a 3/16" (4.8 mm) hex key (aka Allen wrench) and a foot or two length of ½" to ¾" (8 mm – 19 mm) wooden dowel.

2) Working from the bottom of the casing insert the fuel grain into the casing and slide it down toward the front about ¾" to 1" (19 to 25 mm) past the rear end of the case.

3) Place the nozzle O-ring in the casing and tamp it lightly against the bottom of the fuel grain with a ½" to ¾" (12 to 19 mm) dowel. Visually inspect the resulting placement.

4) Place the nozzle into the rear end of the casing and push it down against the fuel grain and O-ring.

5) Insert the chafing washer (rear closure) on top of the nozzle.

6) Clip in the nozzle-end inner retaining ring.

7) Turn the case upright and tamp all the installed parts firmly against the lower snap ring.

8) Place the upper O-ring for the injector body into the casing and tamp it flat against the top of the fuel grain with the ¾" dowel. Visually inspect the resulting placement using a flashlight if necessary

9) Prepare the piercing unit / injector and injector body as follows:

   a) Place a pre-heater grain in the pre-heater well (the shallow but larger diameter well). Make sure the hole in the middle of the grain is visible through the port in the injector body.

   b) Into the piercing unit well of the injector body insert; 1) a burst disk, followed by 2) a small O-ring, and then 3) the piercer/injector. If the burst disk is dish-shaped from the punching operation, place the concave side up. The piercer should be positioned with the flat side against the O-ring and the point facing out.

10) Holding the casing angled a bit off-vertical, place the prepared injector body unit, pre-heater end first, into the motor casing and let it slide down on to the top of the fuel grain and upper O-ring. Tamp lightly but be careful not to dislodge the piercer and its O-ring.

11) Slowly slide the cartridge, nozzle end first, in until it rests at the top of the piercing unit.

12) If it is still screwed into the T-nut, temporarily remove the charging screw and place the T-nut / forward closure (flange side down, threaded tube pointing out) on top of the cartridge.

13) Clip in the forward retaining ring.

14) Replace the charging screw and lightly snug it up against the top of the cartridge but do not tighten it any further until ready to arm.

15) Just before you are ready to take your rocket to the pad; alert bystanders, keep your hands away from the casing ends and, using the 3/16" (4.8 mm) hex key, initiate the nitrous cartridge by twisting the motor while holding the wrench still.

Remember: wear gloves plus safety glasses, point the motor in a safe direction, cover the motor with a blanket and keep ignition sources away while arming – see Figures 7a and 7b below.

Figures 7a and 7b. Safely arming micro and mini-hybrids.

My arming technique starts by twisting the motor slowly to allow all the parts to settle in. Usually (but not always) I get a satisfying "click" or "thunk" sensation as the cartridge punctures; then I speed up the last 2-3 twists. Ideally, there will be no trace of leakage but if a small amount of nitrous does escape the hiss should stop as you finalize tightening the charging screw. If no puncture is felt, or the hiss continues, tighten the screw as much as is reasonable and try to launch. Do not tighten the charging screw too much or you may damage Buna-N type O-rings and completely crush silicone type O-rings.

16) Load the motor in the rocket and establish positive retention. Generally you will need to apply layers of masking tape, or use an adapter tube, to fit the motor snugly in the mount.

17) Take your rocket to the pad and install it on the rod/rail.

18) Insert an igniter through the nozzle so that it touches the pre-heater grain and secure in place. Good contact between the head of the igniter and the base of the pre-heater grain is crucial to avoid misfires; poor contact is the most common reason launches fail!

19) If you are using electronics, start the unit, make sure it is responding properly and launch ASAP to benefit from maximum cartridge pressure! There will be a second or two delay after the button is pressed as the ignition process proceeds.

20) After a successful firing, the rear of the motor casing will be hot while the front will be cold.

21) If you have a misfire that cannot be resolved by simply replacing the igniter, hold the motor at arm's length (**wear suitable gloves**) then loosen the arming screw slowly until the nitrous begins to escape. The motor will cool significantly as the nitrous oxide expands. After the cartridge empties completely, continue to disassemble the motor.

Static Firing Your Micro or Mini-hybrid

It certainly pays to static fire your small hybrid a couple times before actually attempting to fly it. At the most basic level, if you don't have a test stand at your disposal, just anchor the motor securely and fire it…maybe with a video camera aimed at it for slow motion review! Be careful not to deform the casing when clamping the motor down. For such simple static firings I use short sections of pipe capped off and clamped to the stand or support. I then insert and secure the motor inside the pipe. A wooden firing stand along these lines can be made without too much effort (Figure 8).

Figure 8. A simple wooden firing stand in use with a mini-hybrid.

For more details on test stands of various levels of sophistication first see the *Static Testing* section in my full *User's Manual* then follow up with the *Test Stand Paper*.

Disassembly of Your Micro and Mini-hybrid

Disassemble the motor in reverse order of assembly. While the spent cartridge is sliding out, keep track of the brass injector as it is easily lost.

Finally, use a ¾" (19 mm) dowel to force the burned fuel grain out. If you find the spent motor has "frozen up"; a light heating with a propane torch usually frees the internal components enough to allow removal with the aid of the dowel (never heat a motor containing a full and undischarged N_2O cartridge).

Care of Your Micro and Mini-hybrid

The motors I produce are un-anodized and need some TLC to keep them stain free. The important maintenance step is prompt clean-up. Combustion deposits left on aluminum for long periods can lead to the "gritty grays". Try to clean the motor within a day or two of firing. I use a mixture of *409* and *Simple Green* but other types of non-petroleum based cleaning solvents can be used. Soak all components in the cleaning solution of your choice but note that staining can occur if the parts are soaked too long. For cleaning the case, a tall *Gatorade*® 24 oz "Thirst Quencher" bottle makes a great shaker; then finish off by scrubbing the ID with a bottle brush. Pay attention to the snap ring grooves and make sure they are clean. The *Perio-aid* ® dental toothpick holder, or similar, works well for this. Use a toothbrush to scour the remaining parts. A dull blade-like tool can be used to carefully scrape deposits off the nozzle but very few oxide deposits remain after a typical small hybrid burn. Dry the parts and spray the metal ones with a very light coating of *WD-40*. The bright polished finish can be maintained by rubbing with a *Cadie*™ polishing cloth. The metal parts can be contained in a plastic baggie and the nozzle kept in a separate one for extra padding. Graphite is brittle and chips easily so handle with care.

Rocket Airframes to use With Your Small Hybrid

One disadvantage of hybrid rocket motors is the lack of a simple delay and ejection system for parachute recovery. The most versatile solution to this problem is to use some kind of electronic device to trigger a small black powder charge to eject the parachute. These techniques require some experience and skill to employ successfully. We will cover the basics of this approach a bit later but there are a couple of more simple alternatives. Given that this publication is intended to be a quick-start guide to flying small hybrids we will give primary attention to the simplest method to get your motor into the air and that is *Art Applewhite Rockets* Priority Stealth saucer!

Art ApplewhiteRockets Priority Stealth. For many years Art Applewhite has been designing very creative and easy to build rocket powered craft for model through high-power motors. The Priority Stealth© saucer is one of his creations and it is absolutely brilliant! This airframe is a perfect "first flight" vehicle for your small hybrid (Figure 9).

Figures 9a, 9b, and 9c. Flight of an *Art Applewhite Rockets* Priority Stealth airframe powered by a *Dexter Labs* Mini-hybrid; the launch with a slow roll (a), under power but approaching apogee (b), and auto-rotate on descent (c).

A 50% speed version of the full flight can be seen here:

https://www.youtube.com/shorts/yBKtc3hlG48?feature=share

These little saucers are about as low cost as you can get (virtually free), very easy to assemble, can be launched in small areas, are easy to fly and require no special deployment techniques or equipment, not even a parachute! Begin by navigating to Art's website :

www.artapplewhite.com

Which opens with a simple link menu (Figure 10), followed by a "conditions of use" page (Figure 11) and then the "free stuff" page (Figure 12)(figures used with permission):

Figure 10. Opening page for *Art Applewhite Rockets* web site. select FREE STUFF!

Figure 11. Before accessing the material please accept the terms of using his web site and designs.

Figure 12. *Art Applewhite's* free designs page and the Priority Stealth© link specifically.

Download the *29 mm Priority Stealth* template sheet and the associated *Instructions* document. Because the stock Priority Stealth is sized for 29 mm diameter motors you should set your template print scale settings at 77% for the micro-hybrid or 88% for the mini-hybrid. The airframe itself is constructed from an approximately 6" x 6" x 6" (15.2 cm x 15.2 cm x 15.2 cm), or larger, unfolded mailing box trimmed to match the configuration shown in Figure 13a. Alternatively, a flat sheet of plain corrugated cardboard larger than about 13" to 14" (33 cm to 36 cm) square works fine (Figure 13b).

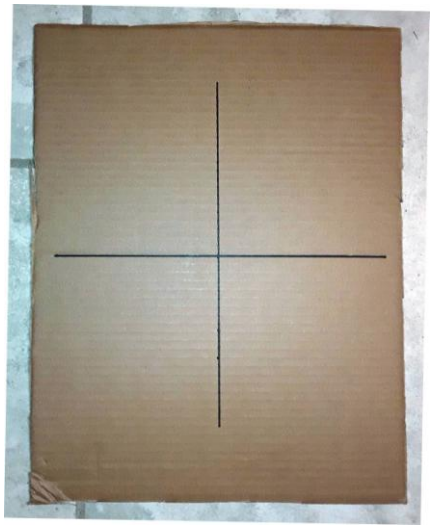

Figure 13a (left) and b (right). a) A section of generic unfolded box useful for a Priority Stealth airframe. b) A flat piece of regular corrugated cardboard (in this case a pizza box lid) with a cross marked for later folding can be used instead.

The following few figures summarize Art's procedure; but be sure to follow his complete instructions to achieve the best possible build. Begin the layout on the flattened box using the side pattern as a template to mark the three main body panels (Figure 14a). If you are starting with a plain sheet of cardboard, begin by laying out a 13" perpendicular cross to mark out fold lines then mark the side panels (Figure 14b):

Figure 14a (left) and 14b (right). a) The side pattern positioned on the unfolded box. b) The side pattern placed against the cross drawing on a flat sheet of cardboard.

Cut out along the outline of the body panels (Figure 15a and 15b). If you use a sheet of plain cardboard in place of an unfolded box you can create neat folding scores by following the cross mark using the tip of a dull butter knife pressed and guided alongside a rigid ruler (Figure 16b).

Figure 15a (left) and 15b (right). a) Marked layout of the three body panels and the glue tab. b) The cut out body panels.

Fold the panels into shape and glue the seam (Figure 16a and 16b):

Figure 16a (left) and 16b (right). a) The folded and cemented body. b) A body folded from scores made by pressing a knife tip along a ruler in a flat piece of cardboard.

Next, cut out the lower centering triangle (Figure 17). Cement the triangle into place in the bottom of the body (Figure 18):

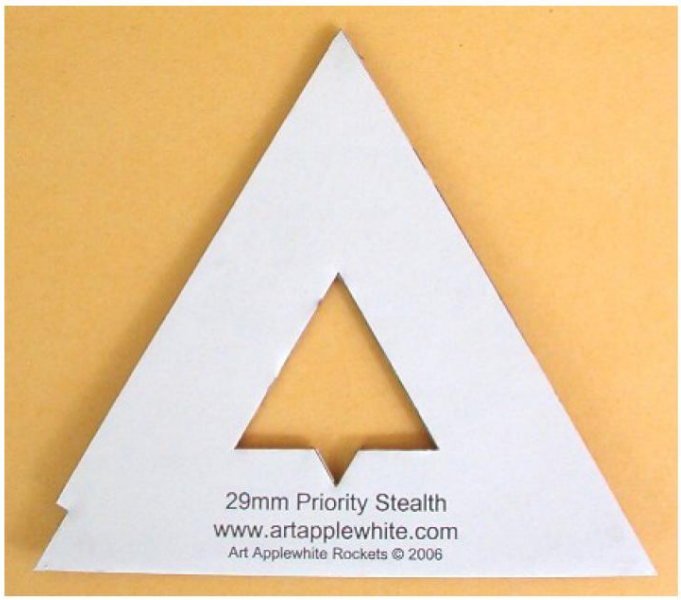

Figure 17. The lower centering triangle.

Figure 18. The lower centering triangle glued in.

Finally, cut out and fold the motor “tube” (Figure 19). Cement it into place in the body (Figure 20):

Figure 19. The folded motor tube.

Figure 20. *Art Applewhite’s* completed Priority Stealth!

You will end up with a great “saucer- type” airframe perfect for a micro or mini-hybrid with no need for an altimeter or even a parachute (Figure 21). You may need to adjust the fit of your hybrid case by adding some extra cardboard strips glued inside the triangular motor mount or extra tubing etc. These little saucers will slowly roll on ascent, invert at burnout and auto-rotate back down to the ground. Since the Priority Stealth lands motor first avoid hard landing sites like parking lots. Due to the high drag of this craft do not expect much altitude (50 to 150’ or 15 to 24 m). For your small hybrid motor these are the perfect first flight vehicles, test vehicles or even just for routine flying in tight fields. Also, this may be of interest to international rocketeers who have a difficult time obtaining pyrotechnics for deployment devices.

Figure 21. Two of my builds of the Priority Stealth. One build is sized for a mini-hybrid (left) and the other for a micro-hybrid (right).

I am including some photos and videos by Gordon Strodel using one of my micro-hybrid motors along with the Priority Stealth airframe. Figure 22a shows his so-called “Prime Stealth” (since he is a “millennial” he made it from an Amazon Prime [tm] box of course!) and Figure 22b shows Gordon preparing it for a flight.

Figure 22a (left) The Prime Stealth and 22b (right) Gordon Strodel preparing his micro powered Stealth for launch.

To see some flights of Gordon’s millennial version Prime Stealth navigate to these videos on his YouTube channel:

Launch prep: https://youtu.be/jF3lRQkkD-8

Full speed: https://youtu.be/N_EqXeNXf_E

Slow motion: https://youtu.be/lNEBvxhqVxo

While the Priority Stealth has all the attributes needed to safely fly and recover your small hybrid motor, there are a couple of additional rockets that can be used without the need for any special recovery system. Also these rockets will give you a bit more altitude but, because they return ballistically, they are not permitted at sanctioned launches. These rockets should be flown only in wide open areas away from people, animals, automobiles, houses etc. Always fly these with “all heads-up” rules!

Ankyo Boink Rocket. This clever rocket is the creation of Dick Stafford (author of the Original Rocket Dungeon Blog). This is another way to fly small hybrids without the need for any deployment system. He has modified an *Ankyo* foam pool noodle rocket by removing the forward canard fins and added 1.5 oz (42.5 g) of nose weight to help with stability. The rocket itself weighs 3.5 oz (99 g) while the complete rocket will weigh in at 7 oz (198 g) on-the-pad. The mass of the motor will reside at the rear of the rocket so there is plenty of foam to absorb the impact (Figure 23).

Figure 23. An *Ankyo* foam pool noodle rocket and micro-hybrid motor (photo from Dick Stafford).

Dexter Labs Boink Rockets. Following Dick Stafford's lead, I created another version of boink rocket for these small hybrids from plain swimming pool noodles (2 1/4" – 57 mm and 3" – 76 mm diameter) (Figure 24). For nose cones use various toy rubber or foam balls cut up as needed and for fins use 3/16" foam board. These rockets give a bit better altitude (300' – 91 m to 700'-213 m) than the Priority Stealth but don't expect real high flyers and be ready for more arcing flights due to the flexibility and slight curve inherent in pool noodles (select the straightest you can find or use a lengthened motor tube for rigidity).

Figure 24. *Dexter Labs* boink rockets for these small hybrids.

While not approved for sanctioned launches, these rockets are fun to fly on your own for novelty, useful for learning/training, great for experimentation where you don't want to risk an altimeter; and, I guess, if you want to fly near water they will float! Also they are quite inexpensive at less than $5 each for materials. Please see my Rocket Construction Manual for more details. Note: these foam-based airframes commonly suffer some amount of damage when hitting hard surfaces like dry lake beds so soft grassy landing spots are preferred.

Congratulations!

If you have successfully completed the steps presented above and launched your first cartridge-based hybrid then welcome to this fascinating little corner at the intersection of model and experimental rocketry!!

What's Next?

Commercial Kits Modified for Small Hybrids. The next step up in sophistication, versatility and higher altitude flights is to begin building commercial rocket kits adapted to fly with these motors. Many suitable kits are available from manufacturers like *Estes*, *Quest*, *Semroc*, *FlisKits* and others. But, this also brings in the added complexity of needing to work with some kind of electronic event detector and controller like an altimeter, timer or MAD. This section is intended to give you a brief preview of some of the factors to consider when working in this arena. If this interests you refer to the more in depth manuals and papers from Dexter Labs discussed in the final section of this guide.

In general you should look for kits with the following characteristics:

1. Airframes over 0.98" (24 mm) in diameter (designated BT-50) for micros and over 1.05" (27 mm) in diameter (the old ST-10 designation) for minis.
2. Airframes should be on the long side; preferably at least 18" or 46 cm (micro) to 24" or 60 cm (mini) in length) to insure a stable flight with the relatively heavy hybrid.
3. The best motor mount tube material for these small hybrids comes from Balsa Machine Service (www.balsamachining.com) and includes their BT50 coupler stock (# C50-34) for the micro and ST-10 body tube (# T104-34) for the mini. Dexter Labs supplies a custom 1" to 29 mm heavy wall adapter tube that is useful for mini-hybrid motor mounts as well.

4. You will most likely need an extra airframe coupler and a small bit of thin sheet plywood or luan about 1” square from which to make the electronics bay and bulkhead to hold your deployment controller.

5. Plastic fins and fin cans are generally more robust than the typical balsa wood glue-on fin however building techniques exist (like skinning the fins) that can strengthen balsa fins to survive hybrid-powered flights.

6. For highest performance flights and safest launches, try to keep the finished airframe weight under 100 grams (3.5 oz) for the micro and under 200 grams (7 oz) for the mini.

7. I recommend epoxy cements for all kit builds to be used with these small hybrids.

8. Step up to nylon parachutes. Plastic parachutes typically supplied with such low power kits will not cut it. Also these rockets are heavier than they look so size your parachutes accordingly. Most common sizes are between 12” (30 cm) for the lighter micro-hybrid powered airframes and 18” (45 cm) for the heavier mini-hybrid powered airframes.

These kits can be modified fairly easily as in the example shown in Figure 25.

Figure 25. An *Estes* Sky Hawker with small altimeter ready for a micro-hybrid.

Comments on electronics for use with these rockets. The most straightforward and effective electronic deployment controller is a small altimeter possessing at least one apogee-firing output channel. The venerable *Perfectflite Stratologger CF* (www.perfectflite.com) at 10 g (0.35 oz) (Figure 26) and the *Altus Metrum Easy Mini* (https://altusmetrum.org) at 6.5 g (0.23 oz) (Figure 27) are excellent candidates.

For minimum weight, choose batteries that are often characterized as the “Ultra Micro” version of the 1S 3.7 V lithium polymer type. These batteries are used in very small RC planes and helicopters. Often they are branded with names like “*E-flite*” and “*Parkzone*”; but over the years this type of battery has also been made by *Venom*, *Tenergy* and *G-force* (as seen in Figure 26). They have been made in a number of mAh ratings (and hence different physical sizes) from 75 to 250 or more. I have successfully connected these Ultra Micro type batteries to an altimeter using a Parkzone^{tm} connector plug and cable (part # PKZ3052). Employing these components I have kept the total weight for a deployment-capable altimeter to only about 12-14 grams with a bay length requirement of about 76.2 mm (3”)!

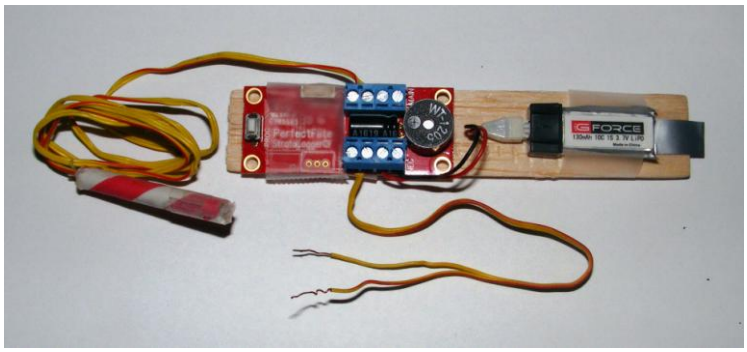

Figure 26. A *Stratologger CF* altimeter set up for a small hybrid flight.

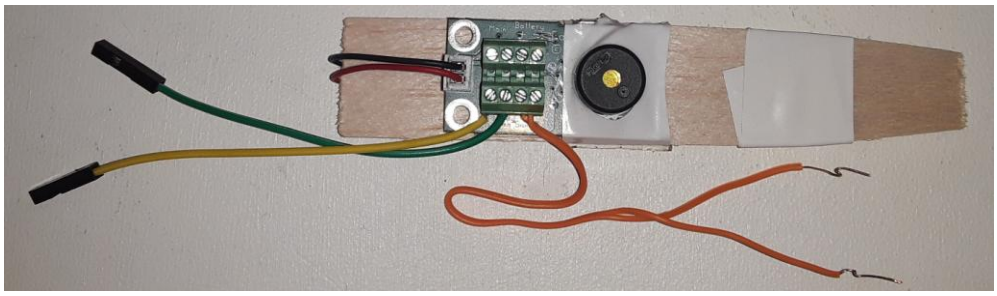

Figure 27. An *Altus Metrum* Easy Mini altimeter (the battery is under the sled).

For those of you who can assemble your own electronics kits, *Eggtimer Rocketry* www.eggtimerrocketry.com offers the *Apogee* (single deployment) and *Quark* (dual deployment) controller kits for only $15 and $20 respectively and these units also report peak altitude! The *Apogee* is especially easy to build using mostly “through the board” components! The assembly and user’s manuals for these kits are thorough and well written. All of these altimeters/controllers will fit in a 24 mm (0.95”) body tube and function superbly with these small hybrids.

In the early 2000s Robert Galejs released his design for a *magnetic apogee detector* (aka MAD) that used the relationship between a rocket's orientation and the Earth's magnetic field to detect apogee and fire an ejection charge. Rene used a Galejs magnetic apogee detector in some of his early micro-hybrid test flights and was enthusiastic about its light weight and lack of a required minimum arming altitude. Galejs and others produced kits and completed units for sale but I have not seen them available lately. Finally lightweight timers like the *Altus Metrum Easy Timer*, *Perfectflite Microtimer2* at 0.12 oz (3.5 g) or *Minitimer4* at 0.25 oz (7 g) less battery can also be used for deployment. Like MADs, timers do not report altitude and unlike altimeters and MADs you must estimate your time to apogee in order to program your timer.

Once the electronics have been obtained the rest of the deployment system revolves around selecting a parachute (see item #8 above) and fabricating an ejection charge. I have had good luck with e-matches from China found on eBay (almost always made with orange shooting wire and supplied with red plastic protective caps) or from *MJG Technologies* (*Firewire* ^{tm}). I use these almost exclusively in conjunction with a small section of paper soda straw filled with 4Fg black powder. Typically around 5 to 10 grains (1/3 to 2/3 gram) of BP works well for these size rockets (see the soda straw charge attached to the SLCF altimeter shown in Figure 26).

Moving Onward and Upward

Once you have mastered electronically controlled deployment the world opens up and you can try your hand at designing original air frames and scratch-building them, explore flight photography/videography with very small spy-sized video cameras, formulate and test more exotic fuels including HTPB formulations, 3D printed grains or bi-hybrid dual burn grains, attempt piston launches, attempt higher altitude flights with superlight airframes, dual-deployment recovery, multi-staging, etc. etc. See Figures 28 through 47 for some flight examples.

For far more information on these motors, along with details of these advanced small hybrid projects, see the complete

Dexter Labs Micro and Mini-hybrid User's Manual

for additional details of the rocket airframes just alluded to, along with many others, see the companion manual

Dexter Labs Micro and Mini-hybrid Rocket Construction Techniques and Examples

and for suggestions on methods to formally static test your motor first refer to the *Static Testing* section of my User's Manual for general comments then see my full

Dexter Labs Test Stand Paper

for specific details on my version of an electronic test stand.

All are available from **Micro Nitro Rocketry** by emailing me at nmrockets@yahoo.com.

Good flying and enjoy working with your small hybrid!

Lee Dexter
TRA 8306 L2
NAR 90581 L2

Some Other Rockets and Some Flight Examples:

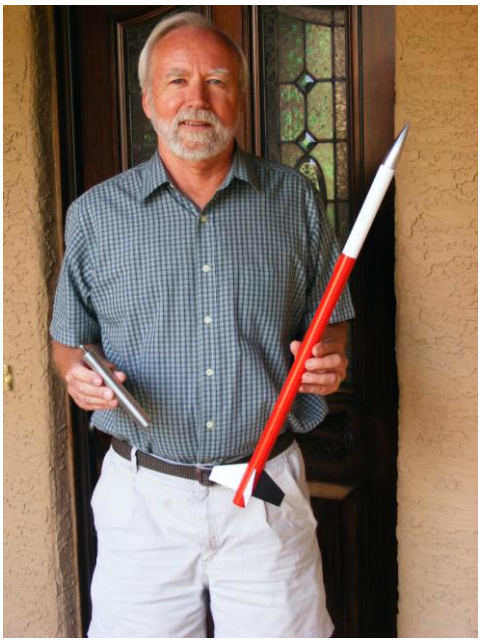

Figure 28a and b. A *Dexter Labs Whippet* prototype kit (left) for the mini-hybrid and a *WhipperSnapper* prototype kit (right) for the micro-hybrid. These rockets are very typical examples of the type and size you will be able to fly with these small cartridge-based hybrid motors. They both employ small electronic altimeters for apogee parachute deployment.

Figure 29a and b. Matt Rolley's (Alexandra Hills, QLD, Australia) Mayfly II airframe lifts off (left) on a *Dexter Labs* long case micro-hybrid motor burning a 3D printed finocyl-cored ABS grain (right).

Figure 30a and b. Rene Caldera (left) and one of his original *Quest Icarus* kit builds (right) from the early 2000s (photos courtesy Rene Caldera).

Figure 31a and b. Rene Caldera's very first micro-hybrid flight 3/26/2000 (photo and image captured from a video courtesy Rene Caldera).

Figure 32. A more recent liftoff of my *Quest Icarus* powered by a 3D printed ABS grain burning in a mini-hybrid motor.

Figure 33. A *Dexter Labs Whippet* rocket heads toward the clouds on a mini-hybrid burning plain old PVC plumbing pipe for fuel.

Figure 34. A *Dexter Labs* video-cam carrying *Whippet* ascends on a paper fueled mini.

Figure 35. The view from a *Dexter Labs Whippet* near apogee looking north-east from above the SMRA launch site. The towns of north Alamogordo and La Luz New Mexico, along with the Sacramento Mountains, are seen in the distance. Our neighbors at the Joe Weidner model airplane field appear in the foreground below.

Figure 36. A *Dexter Labs Whippet* flies on HTPB/ aluminum fuel.

Figure 37. A *Dexter Labs Boink Rocket* during a dusk flight on a grain made from a wax fireplace log.

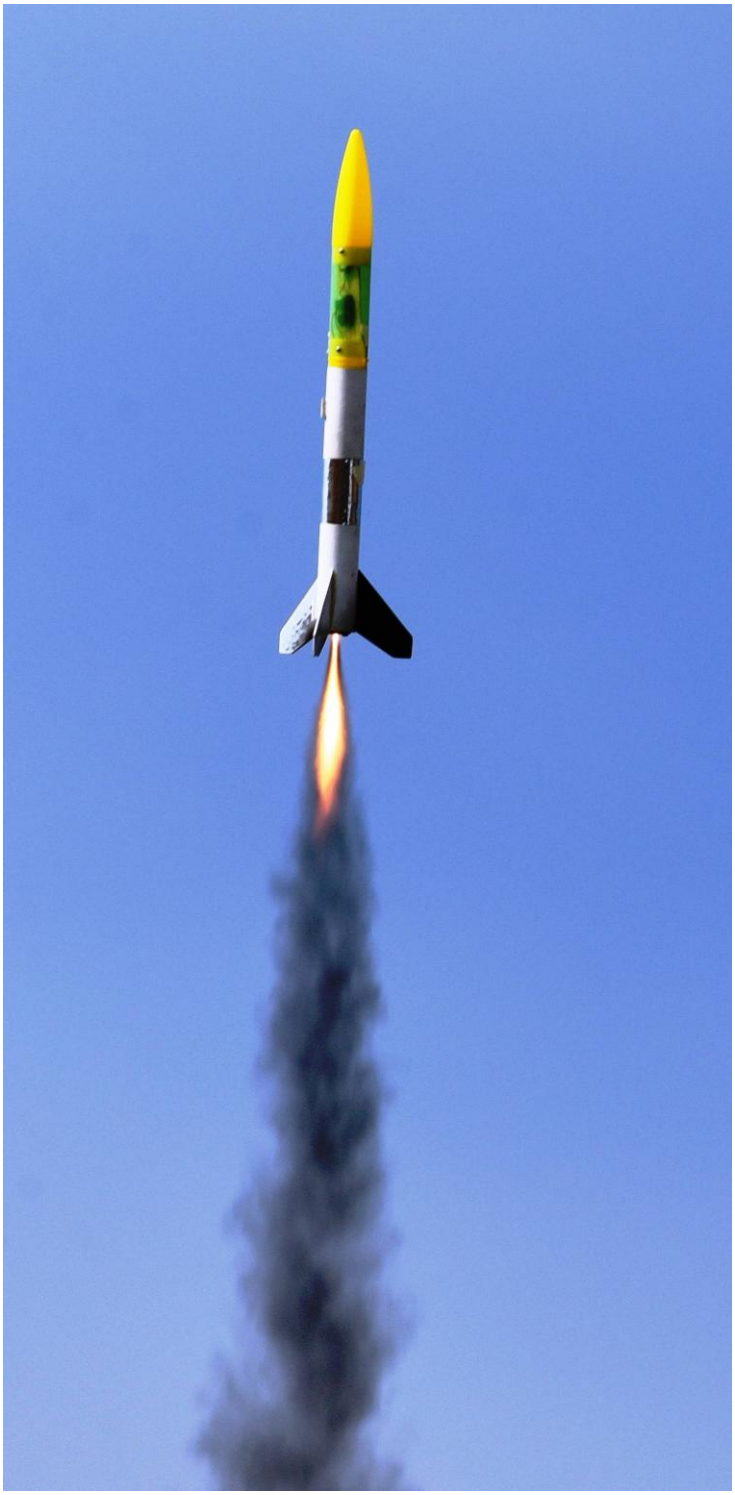

Figure 38. A modified *Estes Green Eggs* kit with an *Altus Metrum Easy Mini* altimeter that can be seen in the tansparent bay, flying on a *Dexter Labs* mini-hybrid burning a *Matt Rolley* designed 3D printed ABS fuel grain. Photograph courtesy Allen Webb.

Figure 39. A *Dexter Labs Superlight* powered by a 29 mm mini-max motor. This flight illustrates what is called a *2-burn by 1 stage (2x1)* type bi-hybrid burn. In this image a typical black powder grain contained inside the hybrid combustion chamber is almost at the end of its burn (burn #1). Next the pre-heater will be ignited by the last bits of black powder (identical to what is called "direct staging") and that will start the hybrid (burn #2) which consumes the leftover paper case for fuel and greatly accelerates the rocket…clever no?

The next series of 5 images shows the ascent portion of a “3x2” (three burns in two physical stages) type boosted mini bi-hybird flight. The airframe is a modified Estes Firestorm with a Booster 60 two stage rocket. The images are clipped from a video taken by a *Fuvision micro spy camera* using a down-looking mirror to capture the major phases of the burn.

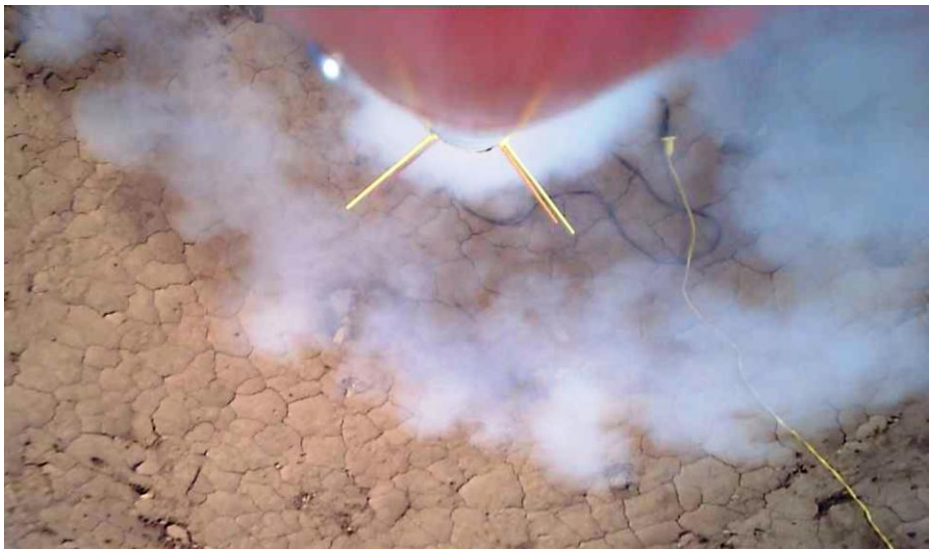

Figure 40. Launch of a *Firestorm* on a 3x2 boosted mini bi-hybrid motor. The D12-0 booster motor (burn #1) has just come to life!

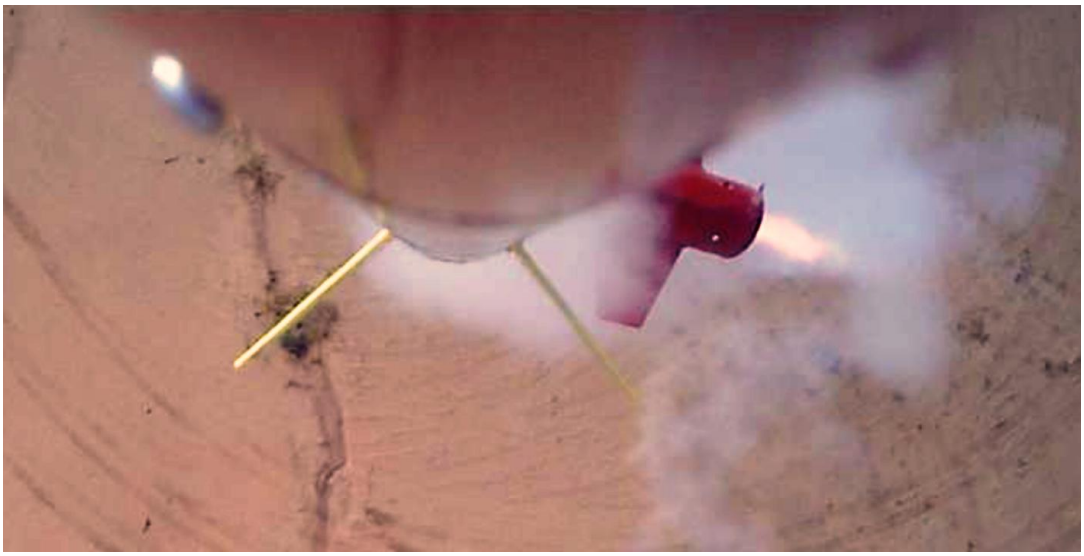

Figure 41. Separation of a *Firestorm* 3x2 boosted mini bi-hybrid. The D12-0 burns out as the booster separates and tumbles away. The black powder of the modified C6-0 contained in the mini-hybrid motor has just lit by direct staging (burn #2).

Figure 42. Middle of the powered *Firestorm* flight on a bi-hybrid mini (3x2) motor. The booster separation shown in Figure 41 occurred at the puff of smoke that can still be seen below. Currently the modified C6-0 (burn #2) is nearing the end of its black powder burn within in the hybrid case and soon power will transition to the hybrid itself, again by direct staging, consuming the remaining case of the C6-0.

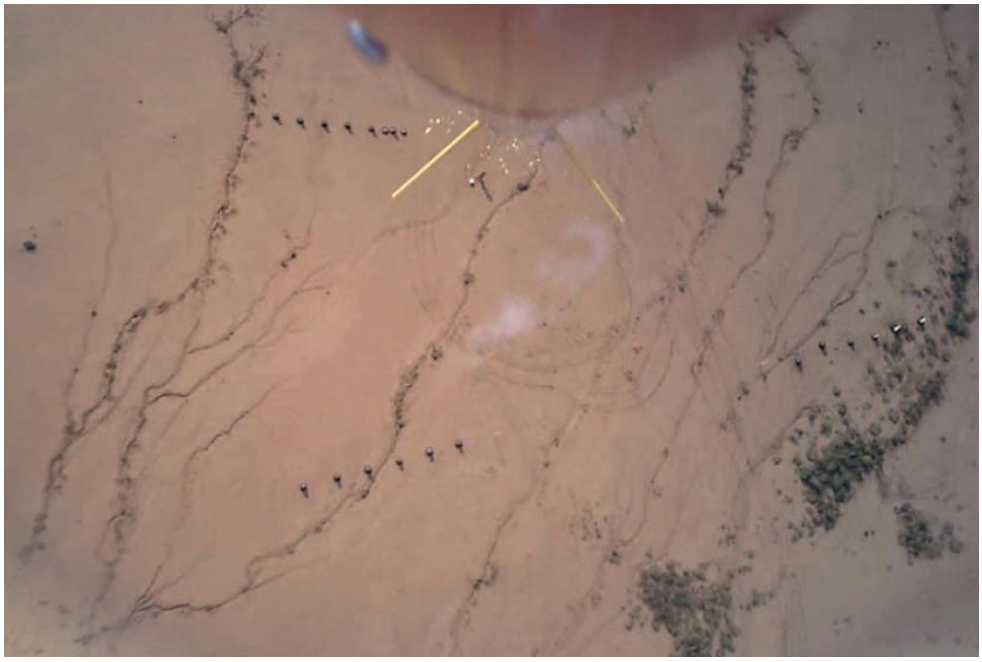

Figure 43. Now under full hybrid power (burn #3) a few sparks are the only evidence of the spent C6-0 paper case being burned.

Figure 44. The sustainer arcs over and the parachute deploys at apogee triggered by an *Altus Metrum Easy Mini* altimeter.

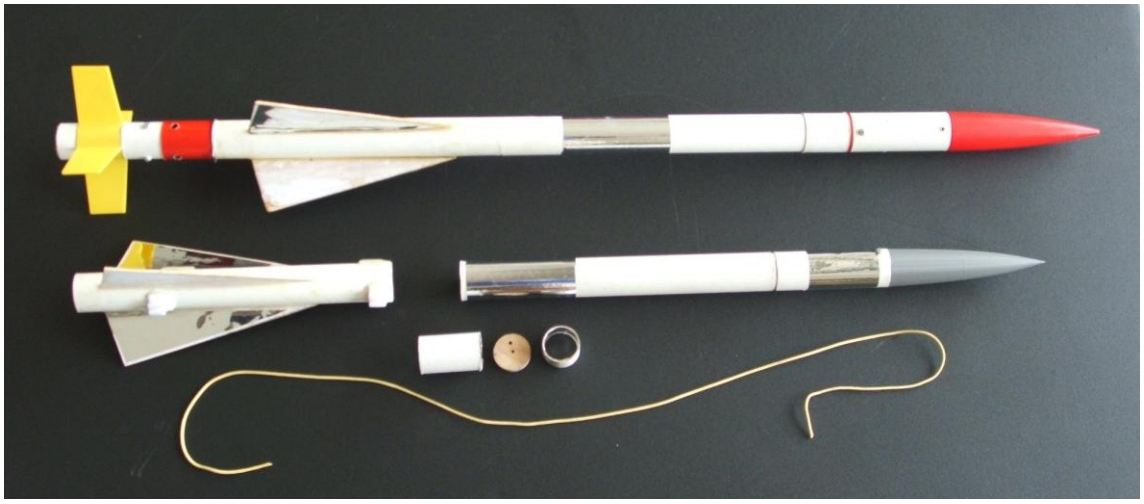

Figure 45. A dual-deployment two-stage mini bi-hybrid powered scratch build.

Figure 46. A dual-deploy two-stage 3x2 mini bi-hybrid, as shown in Figure 45 above, launching with piston assistance on its way to 2,845' (867 m). This rocket actually delivers four separate thrust phases during the course of its ascent.

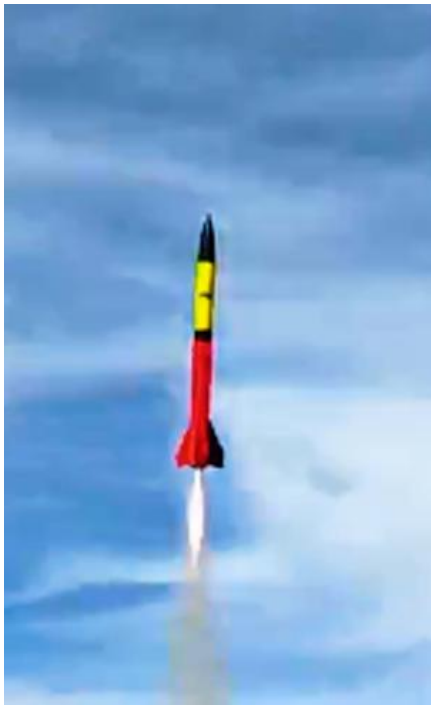

Figure 47. *Mad Cow Discovery* flying on a *Dexter Labs "Turbo"* 1x1 bi-hybrid motor. Here an *AeroTech* G-54 White Lightning grain is flushed with N_2O "turbo-charging" the burn.