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PEAK OF FLIGHT

NEWSLETTER

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Cover Photo: Long March 3 Rocket Kit. Get one at:
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ISSUE 319 AUGUST 14, 2012

Shaving Weight For Super Sonic Flight

By Annette Sostarich

Last year, while browsing the Apogee rockets website, I came across the LOC Nuke Pro Maxx (www.ApogeeRockets.com/Rocket_Kits/Skill_Level_3_Kits/Nuke_Pro_Maxx_Payloader). I don't usually build too many kits, but the performance caught my eye: Over 800 miles per hour on a J285 motor! And over 1 mile altitude! And a chance for Level 2 certification! Suddenly I was bitten, hard, by the supersonic flight bug. The kit was very affordable for the promised performance, so I bought it.

I then proceeded to do a great deal of research into the aerodynamics of supersonic flight, available tracking options, and avionics.

Supersonic flight puts many stresses on an airframe. The shock-wave coming off the nose can cause the airframe to kink or crumple. The fins, if not rigid enough, can succumb to flutter. The coefficient of drag goes way up as the speed approaches Mach 1, further increasing stress on the vehicle and requiring yet more thrust to overcome. Technically, this will be a transonic flight, because the airflow on the vehicle will probably not be supersonic everywhere on the airframe. This also increases airframe stress.

Photo 1. The LOC Nuke Pro Maxx rocket kit.

The Nuke Pro Maxx lends itself very well to this type of endeavor, since it comes with through-the-wall, stubby fins less likely to have a flutter problem, an upper payload compartment (easily converted for avionics use), and a 38mm motor mount. It also has a very heavy duty, albeit paper, body tube.

On the Road to Mach 1

Let's look at the many mods made to the rocket, with 5 objectives in mind: First, it obviously needs to be strong enough to survive a supersonic flight, but, second, it needs to be light enough to actually go that fast with the chosen motor. I highly recommend using the Rocksim software to predict the maximum velocity with various weights.

It may seem counter intuitive at first, but (up to a point) the lighter the rocket is, the faster it goes, and the heavier it is, the higher it goes. The reason for this is that weight, coefficient of drag and total thrust are the main things that limit top speed, but inertia (or the lack thereof), and coefficient of drag limit altitude. Altitude is all about the coast phase, so a little extra weight here will give a higher coast. According to Rocksim, I needed to keep the weight down to about 32 ounces in order to get at least 800 mph. The kit weighs in at 19.7 ounces, so I had about 12 ounces to work with. The avionics bay, tracking unit, fiberglass, epoxy, and everything else could not add more than that if I was to be successful.

In dry air at 68 °F, the speed of sound is 768 mph, but that figure goes up with increasing temperature, and I fly in Arizona. In the Summer, at 90 degrees, the speed is 783 mph, so it pays to fly in Winter. ("Speed of sound at sea level" is a common misconception; the speed is actually only dependent on temperature and humidity.)

Third, it's important to make the vehicle as aerodynamically "slick" as possible (low coefficient of drag). The Nuke Pro Maxx is already a very sleek design, and I made a few changes to make it even sleeker.

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Fourth, some kind of instrumentation is required, otherwise you can't tell if your flight goals were reached. I chose the Entacore USB for its light weight, low cost, programmable dual deploy capability, and easy USB downloading of flight profiles.

The final objective is being able to find the rocket after its flight, since it's fairly small. I installed a radio tracking beacon in the nose cone to improve my chances.

Modifying The Nose Cone

I probably could have scrounged up a nose cone that would have performed better aerodynamically in the transonic region; the standard Ogive shape is less than perfect, so you could substitute a Von Karman shape nose cone (www.ApogeeRockets.com/Building_Supplies/Nose_Cones/High_Power_Nose_Cones/2.56in_Fiberglass_Nose_Cone_FNC-2.56in) if you want. But remember that the vehicle is going to spend maybe two tenths of a second in the transonic region, and all the rest subsonic. There is no known design that performs equally well in all flight envelopes, so the stock Ogive nose cone is an OK compromise.

It's best, if you need a radio transmitter, to mount it as far away from the flight electronics as possible. Radio energy can play all kinds of tricks on other electronics, causing them to do weird things, or completely cease to function. For this reason, the nose cone interior is a very useful place for such items. It's also the best place to put added weight, since I had to be careful of CG with my planned big motor. *{If you have a TeleMetrum GPS payload (www.ApogeeRockets.com/Electronics_Payloads/Altimeters/TeleMetrum_Starter_Set), you don't need a seperate transmitter}*

It's quite easy to cut a hatch in the shoulder of the nose cone for a tracking payload if it's the soft and thick plastic

Photo 2: A hatch cut into the shoulder of the nose cone to allow electronics to be placed inside.

that LOC uses. Lay out a square or rectangular area on the shoulder, and outline it with tape. Using a new X-acto knife blade and a strong stroke, cut a beveled incision. If you bevel your cut toward the inside of your square hatch, the cut out lid will be bigger than the hole, and won't fall into the nose cone. You can use a piece of tape as a hinge and hold the hatch closed with another piece of tape once you've installed the payload. A few pieces of soft foam padding prevent the payload from shifting (See Photo 2).

A 10 foot length of 1500 lb. Kevlar was attached to the eyelet in the nose cone for the upper parachute in my dual-deploy setup.

The nose cone is prevented from separating in flight by a pair of removable plastic rivets (www.ApogeeRockets.com/Building_Supplies/Misc._Hardware/Removable_Plastic_Rivets), allowing access to the nose cone payload

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Photo 3: Plastic rivets hold the nose on the tube.

compartment (see Photo 3).

Many folks have found it difficult to get a finish to stick to the (Polyethylene?) nose cones that LOC and other high-power manufacturers use. Here's one way: sand the entire cone thoroughly with 150 sandpaper, using a power (orbital) sander if possible. This is the key step. Sand off all the mold marks at this point. Use a heavy coat of "plastic primer" (Krylon and RustOleum both make this), and wet sand with 320 till most of the primer is sanded off. Fill any holes at this point. Prime again with the plastic primer as necessary, sanding between coats. Wet sand the final coat of primer with 400 grit. Now the finish coat will actually stick!

Fiberglassing the Tube

Before any major assembly, I fiberglassed the front and rear body tubes with 2 layers of .5 oz. (the lightest you can get, it looks like a wedding veil) fiberglass and epoxy resin

Photo 4: A simple work stand made from scrap wood.

(which doesn't smell nearly as bad as polyester resin). This added about 1.7 ounces. Since it's a small rocket and I didn't want to make it my life's work, I threw together a very simple "rotisserie" from some scrap 2 X 4 and PVC pipe, allowing me to rotate the tube as I laid on the glass (see Photo 4). Two Saran Wrapped couplers inserted halfway into the ends of the body tubes kept the resin out and let me remove them easily.

Motor Mount Modification

Even though light weight was a near obsession in this build, (my digital scale became my constant companion!) I extended the motor mount tube from its original 10 inches to 14 (the length of my motor), and added a third centering ring (.4 oz.), since I was going to be hitting it with 25+ Gs. A ten foot length of 1500 lb. Kevlar rope was epoxied to the motor mount tube and through the forward centering ring. Epoxy is very heavy stuff, so I used just enough to produce good fillets on each ring. 30 minute epoxy was used throughout the structure, both for strength and working time. This allowed me to epoxy each of the 2 top centering rings individually as I slid the motor mount into place. The bottom centering ring was installed later.

Fin Airfoils

The fin edges were sanded to as precise a 15 de-

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gree knife-edge bevel as I could manage, to reduce drag. Many supersonic rocket designs use a sharp edge on both leading and trailing edges, rather than the traditional airfoil shape. The air piles up and compresses on rounded shapes (nosecones and fin leading edges) and it takes energy to compress air, which creates drag. I also visited http://www.payloadbay.com/page-Tools.html and made a fin positioning jig from corrugated cardboard to ensure the fins were at exactly 90 degrees to the fuselage. Any variation from symmetry will probably cause the rocket to spin, which also creates drag. After filleting with epoxy putty, I covered the fin can with 3 oz. Fiberglass (.5 oz added). I filled the spaces between the fin tabs inside the body tube with 2 part expanding foam (weight: negligible) to add some extra rigidity.

Add A Tailcone

Rocksim said I could get a little more speed with a tailcone, so I made one from paper covered with fiberglass, using Rocksim's template printing feature (.25 oz.). This was done by printing out 2 tailcone templates on card stock, gluing them into shape, then slipping them one inside the other and saturating with low-viscosity epoxy, such as the stuff used for fiberglassing. After the epoxy set, two pieces of lightweight fiberglass were cut to the same template and laid onto the cone, one layer at a time. The tailcone was slipped over a Saran-Wrapped tube and centering ring so it would be perfectly round when it set. This gave me a very light, very strong part that fit perfectly after trimming and sanding. I also managed an Aeropack motor retainer (.8 oz.), reasoning it was worth the weight for foolproof motor retention that would work with the tailcone (see Photo 5).

Photo 5: A boattail reduces base drag on the rocket.

Avionics Bay Weight Reduction

The Nuke Pro Maxx was designed as a payloader, with the payload bay being about half the total length. I re-purposed the coupler from the kit as an avionics bay, converting the upper fuselage into a secondary parachute compartment. Commercial avionics bays of this size weigh about 8 ounces. I needed mine to weigh 3 ounces, so I challenged some assumptions: Does it really need 1/4" plywood bulkheads? Do we really need 2 or more lengths of #10 allthread? What about all those super-strong space age materials...?

A traditional avbay needs to absorb all the tension and punishment of the shock cord during ejection. That means thick bulkheads, big screw eyes, and heavy duty all-thread. But what if the bay didn't need to stand up to all that shock cord tension? Aha! If we run the shock cord THROUGH the bay, then the bay just needs to be strong enough to hold ITSELF together.

The answer was to run a short piece of heavy Kevlar rope with looped ends all the way through the bay, slightly off-center. The upper and lower shock cords were connected to the center rope with aluminum quick links (weight saved over steel: .25 oz.) One piece of 6-32 all-thread, through the center, holds the bay together. The end caps were made of 1/8 inch plywood cut to the outside diameter

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of the coupler, and laminated with rings cut to the inside diameter. The Kevlar was sleeved where it went through the bay with heat-shrink tubing, because Kevlar, while very strong, has little abrasion resistance, the holes it goes through need to be snug to seal against ejection gases, and the bulkheads need to slide on the Kevlar in order to open the bay (see Photo 6). The ejection charge canisters, in case they look familiar, are made from .38 caliber cartridge cases, which are just the right size to hold a half-gram of powder. A couple of knots in the Kevlar just inside the bulkheads, to prevent it from sliding out of place, completes the basic bay.

Photo 6: Instead of heavy "all-thread," Kevlar® was used to hold the e-bay together.

An alternate to the Kevlar approach is to replace the Kevlar rope with 10-24 all-thread, coupling nuts, and 10-24 screw eyes. This makes opening the bay a bit more convenient but adds about 3/4 ounce of weight. I changed to this approach after the Supersonic flight (see Photo 7).

Photo 7: Conventional all-thread with coupling nuts and screw-eyes adds more weight.

The electronics sled is conventional construction for dual deploy, except for the switch, which is made from a 1/8" headphone jack, available at Radio Shack. This is of the "closed circuit" variety. This means it has a set of contacts that are normally closed, but open when something is plugged into it. These are very common in portable radios and such, where the jack cuts off the speaker when headphones are plugged in. In this case, the switch is attached to the sled and only requires a 1/8" hole in the bay for the

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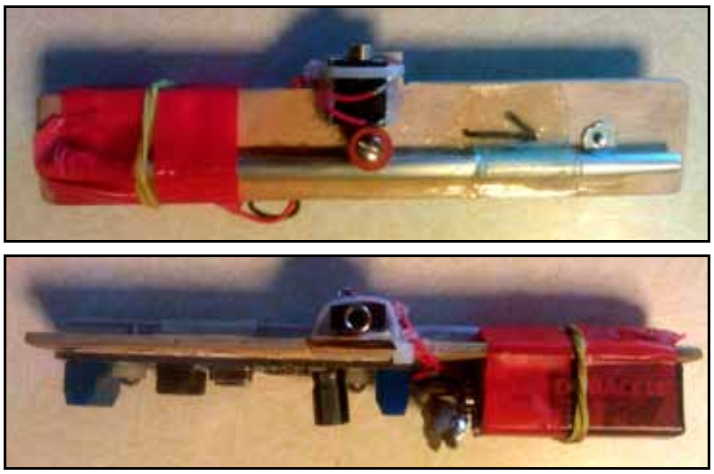

Photo 8 & 9: A head-phone jack serves as an arming switch for the electronics.

pin to be inserted (see Photos 8 & 9). I made a pin out of 1/8" brass rod and attached a "Remove Before Flight" flag to it.

Finishing The Rocket

I used streamlined rail guides instead of the 1/4" launch lug in the kit, rounding them off and polishing the burrs they had from the factory. I'm not sure if this reduced drag or not, but I've seen launch lugs torn off by rod whip and that would definitely slow the rocket down.

An aerodynamic finish also helps with speed, so I put considerable effort into making the paint as smooth as possible. The fiberglass needed a lot of smoothing, so after the rough sanding, (don't do this in the house!) which included reshaping the fin bevels, I applied several coats of Kilz spray primer (available at WalMart) , which goes on quite thick and can be either dry or wet sanded. The final primer coat was wet-sanded with 400 grit paper, and the finish coat was worth the effort. The final product weighs about 32 ounces, exactly my target weight.

Plan Your Flight, Fly Your Plan

I made several test flights, starting with F motors and working up. The only surprise was the vehicle was going a lot higher than Rocksim predicted. I worked the problem backwards and determined the drag coefficient to be .47, way lower than Rocksim's default .75. I got my "mile high" flight on an I motor, meaning I had to use a different field with an 8500 foot waiver for my J motor attempt.

Photo 10: Launch of the Nuke Pro Maxx rocket.

My chosen flight day had iffy winds, but after driving 150 miles, I didn't want to come back again. The ground wind was over 10 mph, and if I hadn't had two redundant tracking devices I never

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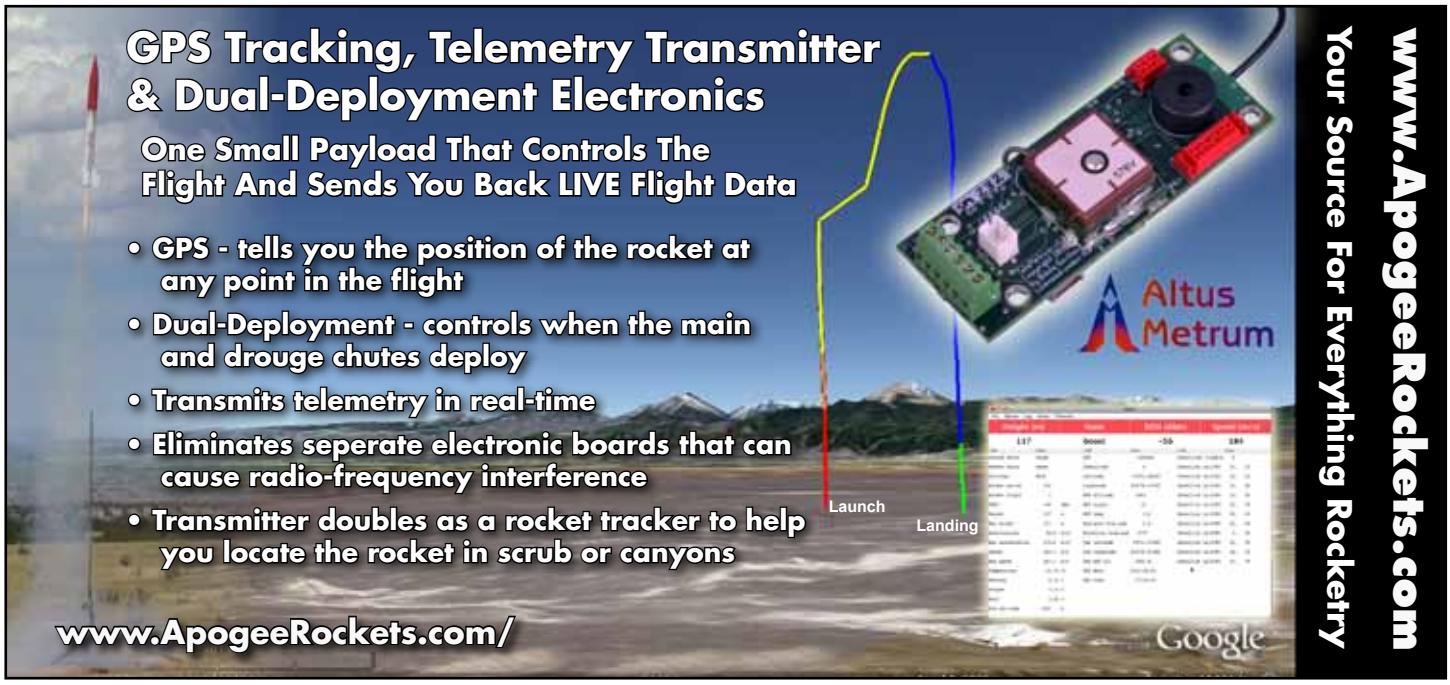
would have chanced it. I lost the rocket in the clouds right after burnout, but I knew it hadn't come apart, and the reassuring beeps from my tracker proved that somewhere, WAY up there, the parachute had worked.

Good thing I had redundancy. The last signal from my on-board GPS device said it was 1.8 miles away and moving 16 mph, so I had to extrapolate the wind line further out, till I finally picked up the "beep" again. Final score: 8178 feet, Mach 1.07 (801 mph), Level 2 Certification, a 4.6 mile walk, and the satisfaction of having built a "great rocket" by Homer Hickam's definition: *one that does exactly what you planned for it to do!*

About the Author

Ever since she can remember, Annette Sostarich has been fascinated with two subjects - electronics and aviation. From watching planes take off as a kid on Saturday mornings to over 450 parachute jumps, designing and building numerous kites, volunteer work at Tucson, Arizona's Pima Air & Space Museum in their restoration hangar, and now designing unusual rockets, there have been a lot of adventures.

Her electronics background began with picking up a soldering iron by the wrong end at the age of 12, and has since been parlayed into a part-time computer repair business. She is just beginning to apply electronics to rocketry with subcompact video cameras as payloads. She met her husband of 28 years while skydiving, and they jumped into their own wedding. Her husband is an aircraft mechanic who is currently building an airplane in their garage.