PEAK OF FLIGHT NEWSLETTER

Issue 620 / February 27th, 2024

APOGEE COMPONENTS
www.ApogeeRockets.com
4960 Northpark Dr, Colorado Springs CO 80918
Ph# 719-535-9335

In This Issue:

Launch Rod Whip and Solutions

https://www.apogeerockets.com/Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/EggTosser

PEAK OF FLIGHT NEWSLETTER

Issue 620 / February 27th, 2024

Launch Rod Whip and Solutions

By Jack Haggerty

There is a part of model rocket flight that is often overlooked in rocket educational books, probably because it is over in less than a second (often much less), but it still has an influence over the entire flight.

When you look at the dynamics of a rocket during launch [Fig. 1], the thrust of the motor is aimed directly up the centerline while the drag from the launch lug rubbing on the rod is offset to one side by half the body diameter. Even though these two forces are parallel, that offset is a problem. Analyzing how the forces interact [Fig. 2], we see that the portion of thrust from the motor that is overcoming the launch rod drag works like a little lever. Two forces acting in opposition a distance apart is what engineers call a "couple" and it causes a torque (twisting force). This torque does not cause rotation at the rocket's center of gravity, like in free flight, but rather at the launch lug since the rocket is being constrained by the launch rod. In addition to stressing the glue joint holding the lug to the rocket, this torque will bend the launch rod.

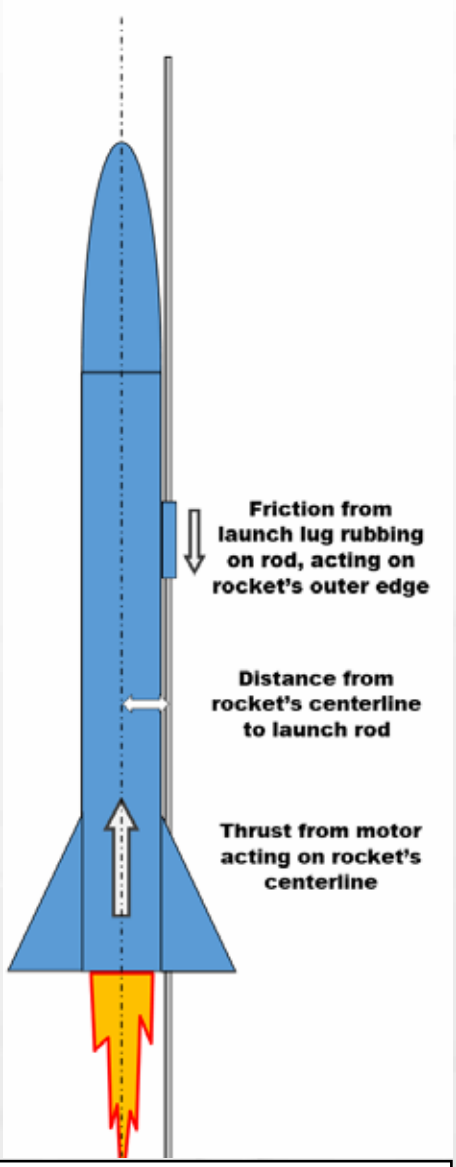


Fig-1: Launch Forces / Credit: ARA Press

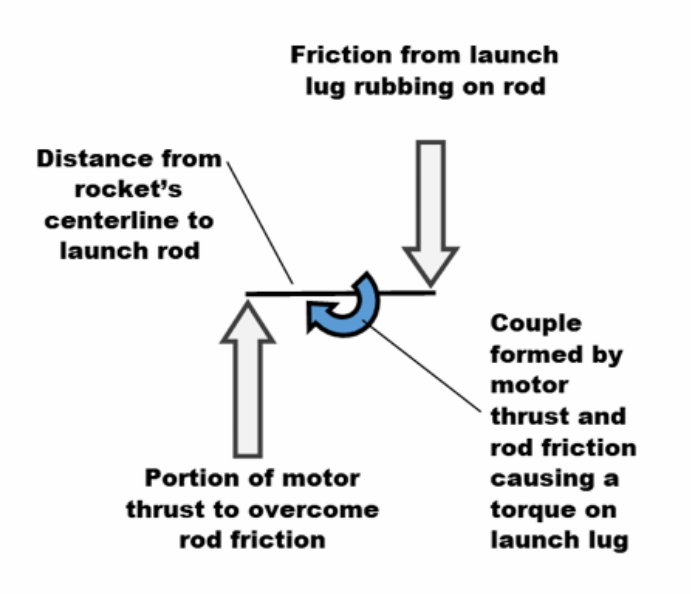


Fig-2: Rod-whip Dynamics / credit: ARA Press

Whether this causes a problem depends on several factors such as the amount of launch rod drag, the diameter of the body (which controls how long the lever arm is), and the stiffness of the rod.

In a small rocket, the thrust is low and the body is small so there isn't much force from the lever, and even a 1/8" launch rod is able to keep things going straight. If, however, you still need convincing of the reality of rod whip, notice that even after the smallest rocket cleanly leaves the pad, you will see the tip of the launch rod wavering side-to-side.

If you're not careful, as you advance to higher thrust levels and larger rockets, things can get out of hand until you wind up with the situation seen in Fig. 3.

In this launch of Jim Bassham's up-scaled Estes Alpha, the 3/16" rod was too small for the wide body combined with a higher powered "G" motor, and the rod was severely bent over. This points out another aspect of rod whip other than just pointing the rocket off vertical. The bending metal rod is a spring, storing the energy imparted to it by the rocket motor through the launch lug. You can see in this picture that

About this Newsletter

You can subscribe to recieve this e-zine FREE at the Apogee Components website www.ApogeeComponents.com, or by clicking the link here Newsletter Sign-Up

Newsletter Staff

Writer: Jack Haggerty
Editor: Tim Van Milligan
Layout: Ryan Conway

Fig-3: Extreme Rod Whip
credit: Jim Bassham

the bent rod is already imparting a torque to the launch pad itself, causing it to tip over to the left. Finally, once the launch lug clears the tip of the rod, it (the rod) is no longer constrained and the "spring" will start to straighten out. If you are unlucky enough, this fast-moving tip can "slap" the bottom edge of the rocket turning it completely sideways and causing it to fly in "cruise missile mode" or, even worse, down towards the ground.

So, what can be done to minimize rod whip? Well, you have the three factors mentioned above to play with: the distance from the center of the rocket to the launch lug, the friction of the launch lug on the rod, and the stiffness of the launch rod.

To minimize the distance to the rod, sometimes you can move the launch lugs from the outside of the rocket body to the inside, such as with this model of a Titan IIIB booster [Fig. 4], to get them closer to the centerline. While the outer body tube in this model is scaled to match the prototype booster, the working bits inside are a smaller diameter "stuffer tube" which has some launch lugs on it. The launch rod can be guided into and out of the inner launch lugs by some discreetly placed guides. Of course, the main reason the launch lugs were placed inside this particular model was to eliminate the non-scale appearance of the lugs when placed on

Fig-4: Internal Launch Lug / credit: ARA Press

the outside (for which you lose points in competition) with the reduced rod whip being a side benefit. But what if you can't run the lugs inside, like with this PMC (Plastic Model Conversion) entry that Gary Miller[1]

entered in NARAM 53? [Fig. 5] This very wide model had no place to run the guides closer to the center, so Gary instead modified a different one of the variables: rod drag.

Fig-5: Launch Rings / Credit: ARA Press

Launch lugs on model rockets consist of a very thin-walled paper tube with a plastic coating. Compared to the metal launch rod, they are very soft and deform when pressed. As the thrust rotates the rocket into the launch rod due to the offset, the lug will deform slightly, causing it to conform to the rod at the points of contact as seen in Fig. 6, left side. This gives two large contact patches that rub on the rod causing a lot of drag which increases the couple making the rod bend. This can be greatly reduced by using launch rings rather than a cylindrical lug. Launch rings are generally made of heavy wire formed into loops and attached in pairs. Fig. 6, right side, shows the rings sliding up the same launch rod, and since both the rod and the ring are made of metal, the deformation is almost zero. Thanks to Pythagoras, we know that when two cylinders (the launch rod and the ring[2]) touch, they have to meet at a single point which reduces the drag to an absolute minimum.

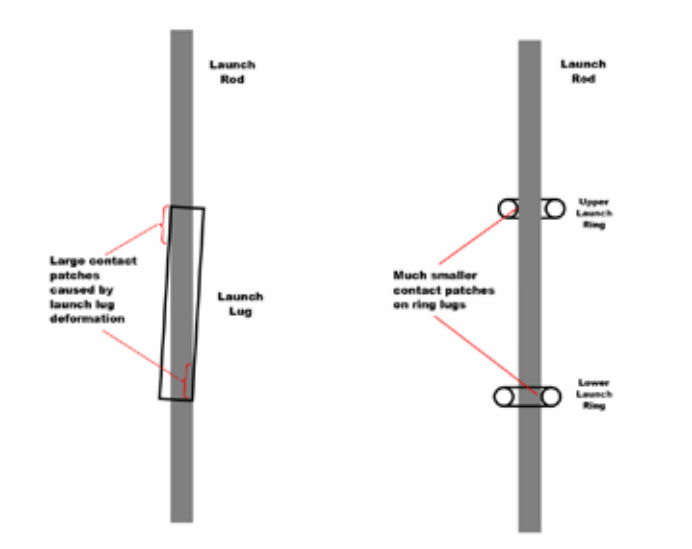


Fig-6: Launch Lugs vs. Launch Rings / Credit: ARA Press

You may ask why, if rings are so great, aren't they used on all model rockets? Well, they have their own issues dealing with craftsmanship. They can be difficult to form accurately, anchoring them to the body is not easy, and they must be carefully aligned to not impose their own rotation to the rocket as it rides up the rod. Gary Miller could do these things in his sleep, but they can be a challenge to ordinary modelers like you and me. Probably the easiest way to reduce rod friction is just to wipe your launch rod clean before every launch.

The final variable, rod stiffness, is easier to deal with today, but the road getting here was not an easy one. Stiffness goes up with the area of the material, so to get a stiffer rod, all you need to do is go up in size. A 3/16" diameter rod is more than twice as stiff as a 1/8" diameter, so just put bigger launch lugs on your model and you're set. That said, though, the hobby today never uses rods more than 1/4" diameter since there's something better.

Early on, Estes recognized the necessity for something stiffer than a small cylindrical rod to guide the ever-larger rockets hobbyists were building. In the 1968 catalog they introduced the "C Rail." This was a

3/8" square, hollow aluminum extrusion that had a 1/8"wide slot in one face. The idea was that rather than the launch lug riding on the outside of a small, flexible rod, it would ride inside a larger, much stiffer[3] square guide. The part that wasn't completely thought-through was how to make the guiding part attached to the rocket. Whatever it was, the part inside the rail had to be larger than the slot so it wouldn't pull through while guiding the rocket, but attached to the rocket by something smaller than the slot that wouldn't rub on the slot edges. As the blue box in Fig. 7 shows, they had several suggestions for doing this, all of which had problems.

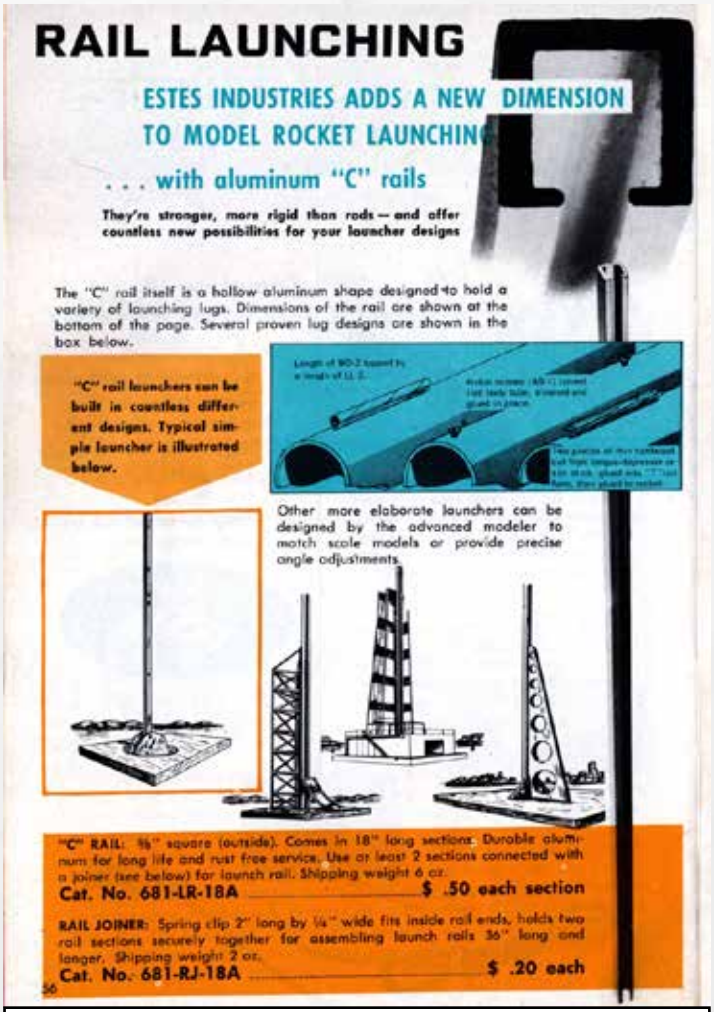


Fig-7: Estes C Rail / Credit: Estes Industries

The first was a regular launch lug mounted on a thin piece of dowel to stand it off from the body [Fig. 7a]. While this had the added bonus of letting the rocket also be launched from a standard launch rod, the problem is one of tolerances. If the little standoff dowel was too small, the launch lug wouldn't fit into the slot far enough and would rub on the inside of the rail. If it were too big, the standoff itself would rub on the edges of the slot. Even if it were exactly right, the launch lug/standoff and the standoff/body adhesive contact patches would be very small, leading to weak joints.

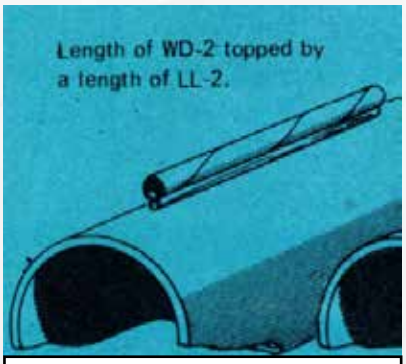


Fig-7a: Standoff Launch Lug / Credit: Estes Industries

The second method was to use nylon screws twisted through the body tube and "trimmed and glued in place" [Fig. 7b]. With the standard body tube thickness being only 0.012" (0.3mm), there is only 1/2 thread (assuming the screw is a 10-32 thread) holding the screw in place while it's being trimmed and glued. This gives very little support to the screws, even after they are glued. And if you built up a fillet around the screw, you're limited to 1/8" wide where it travels in the slot.

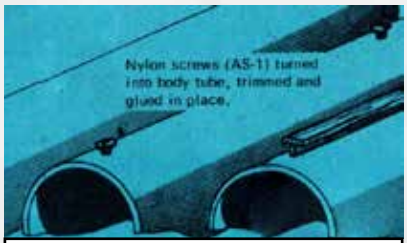


Fig-7b: Nylon Screws / Credit: Estes Industries

The last method was to fabricate a "T" lug out of some pieces of wood harder than balsa [Fig. 7c]. While this is basically a good idea, it has the same issue of very narrow glue footprints on both the rocket body and at the "T" joint, plus the craftsmanship needed to

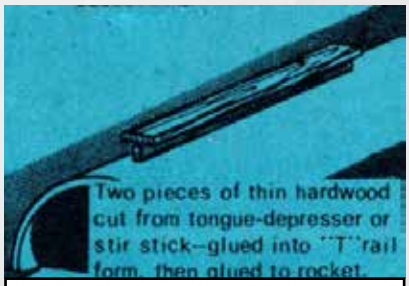


Fig-7c: "T" Lug / Credit: Estes Industries

build the two lugs straight and square and keep them aligned. These last two methods also had the problem of guiding using a flat surface rubbing on the inner flat surface of the rail, leading to greatly increased friction.

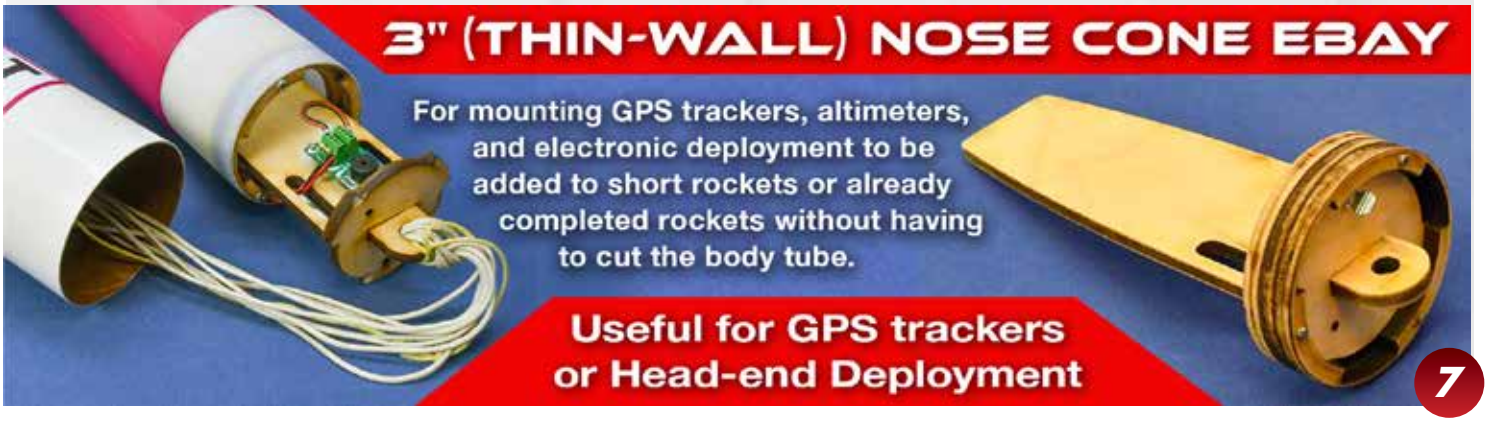
The final issue is with the rail itself. Estes sold launch rods in short, 18" lengths that plugged together to make the standard 36" rod. This was done so they would fit in the average high school rocketeer's range box. The C-Rail was likewise sold in 18" lengths with an internal spring clip to hold the segments together. Being on the inside, your guide, whichever you decided to use, could potentially snag on this clip and strip off.

Fig-8: PortPad C Rail Mount / Credit: ARA Press

Despite these shortcomings, the C-Rail was a major step forward in reliable, solid launch guidance, and it remained in the Estes catalog for 11 years. While it was gone by the 1979 edition, the new plastic PortPad was introduced during this time and, to this day the rod clamp/pivot assembly snaps into a 3/8" square hole that was put there to hold the C-Rail [Fig. 8].

This brings us up to current techniques. In the 1990's, companies started developing systems of aluminum extrusion to allow the rapid building of precision fixtures for industry. Led by Bosch in Germany, other companies world-wide have come up with their own versions, and the one embraced by the rocket hobby is made by the 80/20 Company in the US. Fig. 9 shows the fully engineered solution for guiding medium and large model rockets. This is a piece of 1010 extrusion[4]

Fig-9: Launch Rail with Rail Button / Credit: Apogee Components



with a "rail button" riding in it. It is the precision manufacture of both the extruded rail and the rail buttons that make this system work. The simple, robust method of attaching the buttons to the rocket can be seen in Fig. 10. This particular image is from an Apogee Components training video (thanks, Tim!), but all manufacturers use a similar technique. A "T-nut" has its internally threaded shaft passed from the inside through a hole drilled in the body. The button mounts on this shaft and is retained by a flat-head screw. This type of screw not only anchors the button to the nut, but also presents a flush face to the air stream, reducing drag.

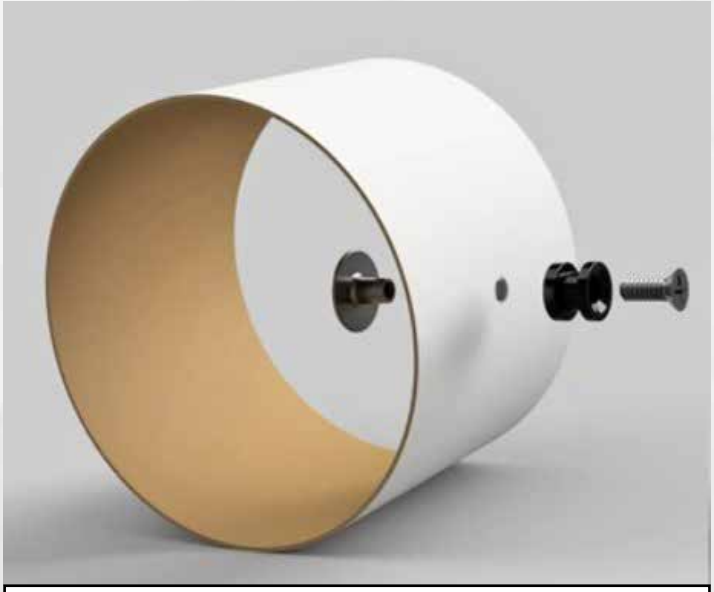


Fig-10: Rail Button assembly / Credit: Apogee Components

The buttons are always used in pairs, one placed in front of the rocket's CG and the other behind. Since the dimensions of both the extrusion and the buttons are held to better than 0.01" (0.25mm), the position of the rocket is similarly tightly controlled. The cylindrical center of the button fits in the rail slot and prevents movement side-to-side. The two conical faces control movement in and out.

In Fig. 11 we see the dynamics of the buttons riding in the rail during guided flight. The thrust offset causes the rocket to rotate into the rail at the top, which is shown on the left side of Fig. 11. The rocket's inward travel is stopped by the outer conical face when it encounters the rounded outer edges of the rail slot (red arrows). This gives, theoretically, only two points of contact, although there will always be a tiny bit of deformation in the button. At the bottom end [Fig. 12, right side], the outward travel is arrested by the inner conical surface on the inner edge of the slot (red arrows again). On a typical large model, the off-vertical angles during launch are controlled to better than 1° both side-to-side and in-and-out. Additionally, the very minimal contact area at the four points is between low-friction materials, so very little energy is lost due to friction.

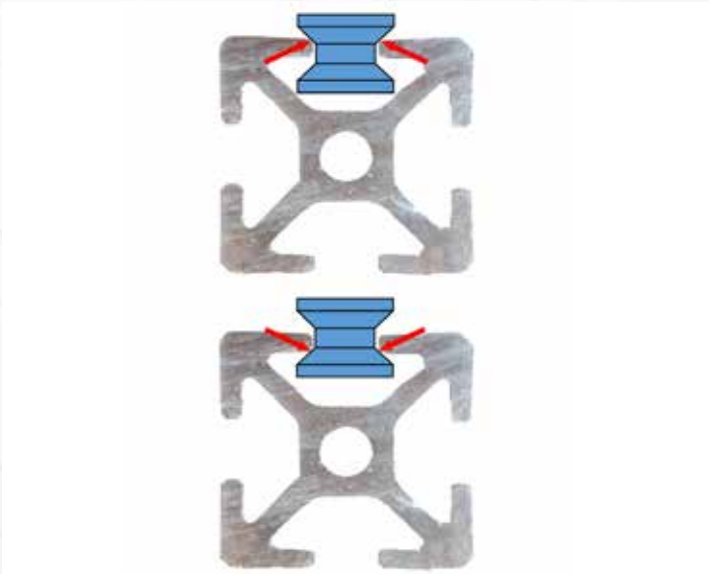


Fig-11: Rail Button Operation Under Thrust / Credit: ARA Press

As for rod whip, you can put that concern to rest. A 1010 rail is some 3,300 times stiffer than a 1/8" rod!

END NOTES

1. I had just picked this photo as an illustration and was about to write to Gary for permission to use it when I learned of his untimely death due to lung cancer. With his passing, the hobby lost a spectacular craftsman, not surprising with his "day job" being an ENT surgeon. In my more than two decades of judging Scale at NARAM this particular model was the only one to which I've given a perfect 300 point Craftsmanship score. RIP, Dr. Miller. You are missed.
2. Technically, the ring is a cylinder wrapped into a circle, which is called a torus.
3. A quick calculation shows the Estes C-Rail to be 55 times stiffer than a 1/8" diameter rod.
4. This is 80/20's name for an extrusion that is 1.0 inch on a side. Other sizes used in the hobby are 1515 (1.5 inches on side) and 2020 (2.0 inches per side). These latter two have different slot widths so would require different rail buttons when used on Level 2 and 3 projects.

ABOUT THE AUTHOR

Jack is a Mechanical Engineer working in the Medical Device and Automation/Robotics industries. He is the co-founder of LUNAR, the Livermore Unit of the National Association of Rocketry, the largest rocket club in the country (and, possibly, the world).