Apogee Components

PEAK OF FLIGHT

NEWSLETTER

In This Issue

Explorations in Modular Tube Fin Rocket Design

Cover Photo: DFR Technologies Delta IV Medium 5+4 rocket kit.
http://www.apogeerockets.com/Rocket_Kits/Skill_Level_4_Kits/Delta_IV_Medium_5_4

Apogee Components, Inc. — Your Source For Rocket Supplies That Will Take You To The “Peak-of-Flight”
3355 Fillmore Ridge Heights
Colorado Springs, Colorado 80907-9024 USA
www.ApogeeRockets.com e-mail: orders@apogeerockets.com
Phone: 719-535-9335 Fax: 719-534-9050

ISSUE 335 MARCH 26, 2013

Exporations In Modular Tube Fin Rocket Design

By Bruce Fette

Introduction

A wise vendor suggested that the LOC Cyclotron [2] was a good choice for a level 1 rocket, because the fins were unlikely to break upon landing – and thus could improve the chances of successfully landing a Level 1 Certification. And that was true.

Figure 1: LOC Cyclotron uses 6 tube fins for stability.

I gradually decided that the hobby needs some creative new designs besides flat fins and a nose cone. So I decided to explore what is possible with tube fins. In section 1 of this article I am going to explore how to make stable designs with tube fins, and compare these with flat fin design. In section 2, I will cover how to enter tube fin designs into Rocksim V9, and assess the stability of your favorite tube fin design. A number of articles have been written about tube fin designs, and I summarize the essentials of these articles in section 3.

How Much Tube Is Needed for Stability?

One of the early methods for understanding how much fin area is required for stability is called the cardboard cutout method. In this method, projecting the shadow of the rocket onto cardboard will project the area of the nose cone, body tube and fins, and we want the effective center of the area of the shadow (called the *Center of Pressure* - CP) to be near the tail, and we want the *center of gravity* (CG), even with the motor installed to be closer to the nose cone. The usual criteria for stability is that the CG should be two body diameters (calibers) closer to the nose cone than the CP; this criteria can provide sufficient stability margin for the dynamic changes of angle of attack due to wind gusts. The interesting property of tube fins is that no matter what angle you project a shadow each tube fin projects almost the same surface for the airflow to wash over the fins in the proper direction(s) to restore straight flight. Each tube fin projects the same equivalent surface area in every radial orientation. Advanced analysis by Barrowman [3] has refined the calculation of CP, but the principles remain based on the surface area washed by the airflow.

However, to get started, we can calculate the surface area of a tube fin by the traditional equation:

A=2*pi*Diameter*Length (notice we count both sides of the tube)

So immediately we notice that a tube fin that sticks up from the rocket body by a body diameter is 3.14 times more area than a flat fin that sticks up by the same amount. We typically discount the tube fin area to 80% of this, to account for the part of the tube that is glued against the rocket body, where it adds little value.

Section 1: Some Unique Tube Fin Configurations

To explore a variety of tube fin designs, I bought an Aerotech HV Arcas [4] kit, with a plan to “kit bash” the rocket using the kit parts to build a few tube fin rockets to get a sense of what constitutes stable tube fin designs above and beyond the traditional 6 tube fin designs of the LOC Cyclotron, and similar designs (Big Dumb Rocket [26], and others).

Section 1 of this article addresses different tube fin designs, all of which explore variations in tube fins with the basic principles of 1) projecting a stable fin shadow implemented with tube fins, and 2) a modular design enabling direct performance comparison of design stability. Rocket

Continued on page 3

About this Newsletter

You can subscribe to receive this e-zine FREE at the Apogee Components web site (www.ApogeeRockets.com), or by sending an e-mail to: ezine@apogeeRockets.com with “SUBSCRIBE” as the subject line of the message.

Newsletter Staff

Writer: Tim Van Milligan
Layout / Cover Artist: Tim Van Milligan
Proofreader: Michelle Mason

Continued from page 2

Explorations In Modular Tube Fin Design

designers know that the design is stable if the Center of Gravity (CP) is at least two calibers (two body diameters) closer to the nose cone than the Center of Pressure (CP). In general the fin surface area and the distance of this surface area from the rocket CG create a torque to stabilize the angle of attack in line with the rocket's long axis. Studying the fin design of the HV Arcas, we see 4 fins; each fin is approximately 10.3 square inches on one side, and four fins are 82.4 square inches when counting both sides of each fin. In contrast, the Cyclotron is also a 2.6 inch diameter rocket with 6 fins with a total area of approximately 400 square inches. So it is likely to be more stable, and since the fins are cardboard, they are unlikely to break upon landing. But this extra fin area also represents more surface area to experience more drag, and therefore balances stability against maximum velocity and maximum altitude.

One more point about fin design. You will notice that most flat fin rockets have a swept-back leading or trailing edge. One reason for this is to minimize the resonant flutter of the fin at high speed, which can break off the fins or cause other surprises during flight. It is slightly less common for tube fins to have a swept-back cut. For low speed flights, we see less resonant behavior. However, even a tube fin may experience flutter, so some better tube fin designs may also choose to sweep one or both edges to minimize any resonance.

So, I set out to explore a wide variety of tube fin designs and get some real experience with tube fin design stability under real flight conditions, while holding all other design properties identical. Since 6 tube fin designs are already well validated by the LOC Cyclotron, I have not included that design in this collection.

My designs were built with a modular concept in mind, so that I could reuse as much as possible. I wanted to grow from simple designs to complex, and then to whimsical.

I adopted a technique to make all parts serviceable by extensive use of #8-32 T nuts and #8-32 x1/2" machine screws to assemble all the parts. With this modular construction technique, a motor mounting shell is designed to slide into the body tube of any of these designs and be attached with two machine screws, and then to be reused in every other tube fin experimental design.

Beginning with a kit Bash – 4 Tube Fins with Modular Design

For my first design, I built a 4 tube fin rocket, cutting the tube fins to provide the same average length as the Arcas fins, and the same diameter (caliber) as the body tube – 2.6 inch (Figure 2). The objective of this design is to show that

Figure 2: Four tube fin design bottom (left), and completed rocket on the pad at Novaar – Great Meadow

Continued on page 4

Continued from page 3

Explorations In Modular Tube Fin Design

a simple translation to tube fins produces a stable design.

The 4 fins must be carefully aligned with the axis of the rocket body and evenly spaced around the body. Be sure to make a line inside the tube with a small piece of aluminum angle extrusion so that the tube can be axially aligned with the rocket body for exact airflow alignment. Even minor misalignment can cause spin or worse, can cause it to arc over. I recommend use of a Fin Jig [5] to hold the axial alignment accurately while the attachment epoxy cures.

3, 2 and 1 Tube Fins

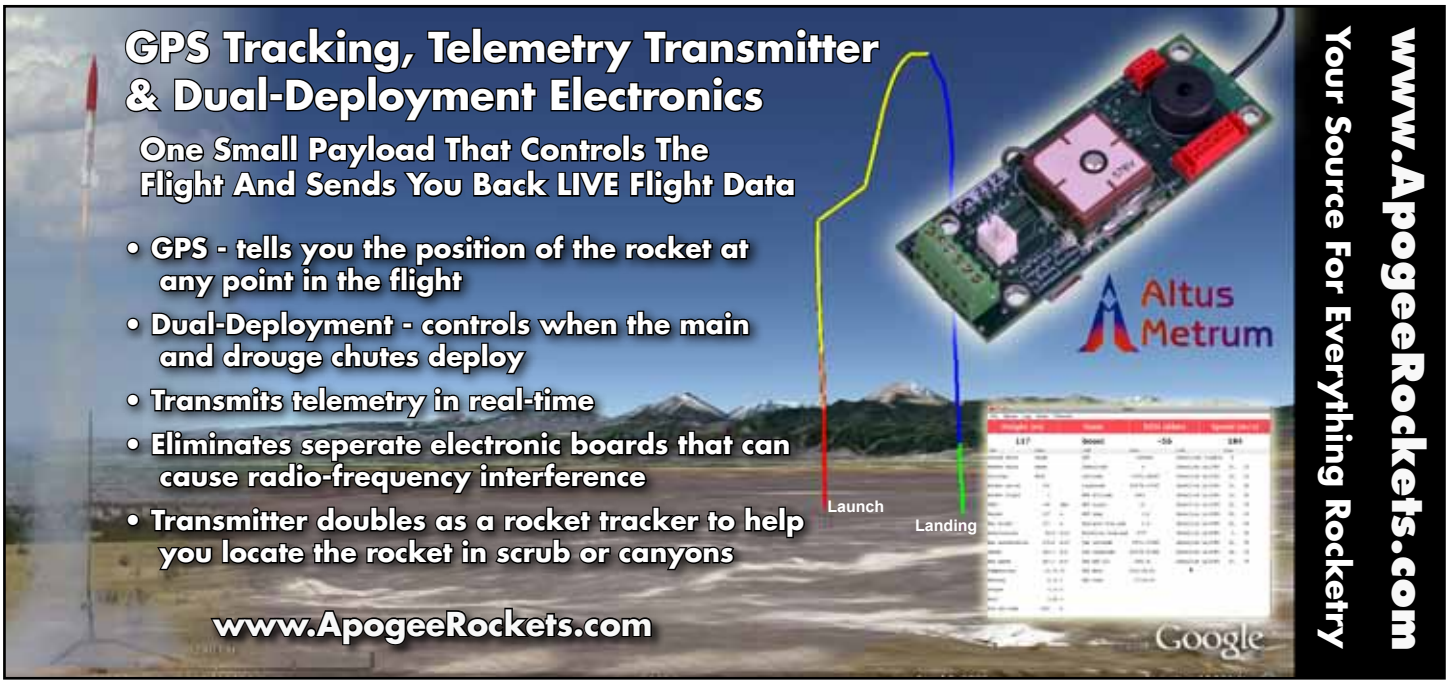
After building the 4-tube finned rocket, I subsequently built lower bodies (fin cans) with 3 tube fins, 2 tube fins, and one ring-tail fin, each with the same 24 inch length body tube as the HV Arcas, all shown in Figure 4.

Since the motor shell mount and shock cord mounts are all identical, the only differences are the fin designs, providing the opportunity to get a reasonable understanding of the impact introduced by any differences in the tube fin design.

The 1 fin, ring fin, design was done using tube fins to support the ring, so that no one could complain that the rocket had flat fins inside the ring fin. However, the exten-

Figure 3 (right): This is a rear view of what I call the motor shell. As you can see, I built two sizes for either 29 mm or 38 mm motors. Either one is slid into the tube-fin "can" and held in place with two #8-32 x ½" machine screws. Motor retention clips are seen at the base of the 29 mm motor shell (leftmost tube). The shock cord attachment is a short tube (seen on the right), made to fit inside the body tube. A ½" nylon strap loop is epoxied inside the tube. It is also secured into the tube-fin can by machine screws.

Continued on page 5



Continued from page 4

Explorations In Modular Tube Fin Design

Figure 4: Tube fin designs with 3 tubes, 2 tubes (Big Ears) and 1 ring-tail fin.

sive amount of epoxy used to make standoff tubes and to glue all the standoff tubes to the ring tube made the ring fin rocket a somewhat sluggish flyer.

All designs were stable when flown with G77-7R rocket motors. They also used the same motor shell, forward body and nose cone (since that was interchangable).

Variations in Tube Fins – Half Tubes, Spread Tubes & Pieces

I then decided to see what other variations would also provide reasonable stability. So, I cut a ring fin tube in half, and swept-rearward the leading edge. I mounted each half outward facing. Yes, it does bear an interesting resemblance to a 4 fin rocket, but it's all tube fin, (Figure 5).

Figure 5: An interesting variation with swept fins.

This "Two Halves" design was a real crowd pleaser due to its unusual design, and the spin it developed on the way up; it was as perfectly straight up as anyone could hope.

Another variation is expanding the size of the tubes of the tube fin rocket. By slicing two 4 inch body tubes lengthwise on one side, and then putting a plywood spreader into the 4 inch tube to open the spacing to exactly line up with where 4 flat fins would normally be attached, and then epoxying these two large tubes with

Continued on page 6

Looking For A Fun Rocket Kit?

Roam In Our Forest of Over 190 Different Types

- Unique and exotic kits from over 20 different manufacturers
- Skill Levels range from "easy" to "fiendish"
- Sizes from 1/4A motor to level-2-high-power
- We build & fly them to find out what they're like, saving you grief
- More new ones arriving all the time
- Educational bulk packs available too

www.ApogeeRockets.com

www.ApogeeRockets.com/Rockets_By_Manufacturers

Continued from page 5

Explorations In Modular Tube Fin Design

Figure 6: Big Ears (left) and Six Easy Pieces (center). Six Easy Pieces at the MDRA Sod Farm (right).

a "butt joint" to the body tube on the 90 degree axial lines, I created a two tube fin design that I call "Big Ears". Red is the perfect color for 2 tube fins.

For my next design, I took three 2.6 inch tubes and cut them exactly in half down both sides, and then epoxied them together at the 60 degree points of their arcs. I then epoxied three such structures to the body tube uniformly at 120 degree spacings. This fin can was called "Six Easy Pieces".

Both Big Ears and Six Easy Pieces flew successfully with MDRA at Maryland Sod Farm.

Lucky 7

It just seemed right to keep exploring other creative tube fin designs. Mr. Larry Brand exhaustively explored the coefficient of drag of tube fin designs, and he found that 7 tube fin designs had the lowest drag [8,9,10]. So it seemed fully appropriate to build a 7 tube fin design. To make 7 tube fins with the proper surface area such that they line up properly around the body tube, each tube must be mounted to the body at 51.5 degree spacing, and each tube must be a 2.1 inch diameter for a 2.6 inch body tube.

Such tubes are available from Kinkos/FedX as mailing tubes. However, because I have been using launch rods, the launch rod lug must be carefully planned relative to the last tube.

In this design, I first epoxied 6 of the tubes into 3 pairs on a flat table so that they are perfectly aligned. Then each pair is epoxied to the rocket body, again taking care to achieve perfect axial alignment with tick marks on the rocket body at 51.5 degree steps and axial alignment guidelines. The launch lug is then centered into the hole

Continued on page 7

Continued from page 6

Explorations In Modular Tube Fin Design

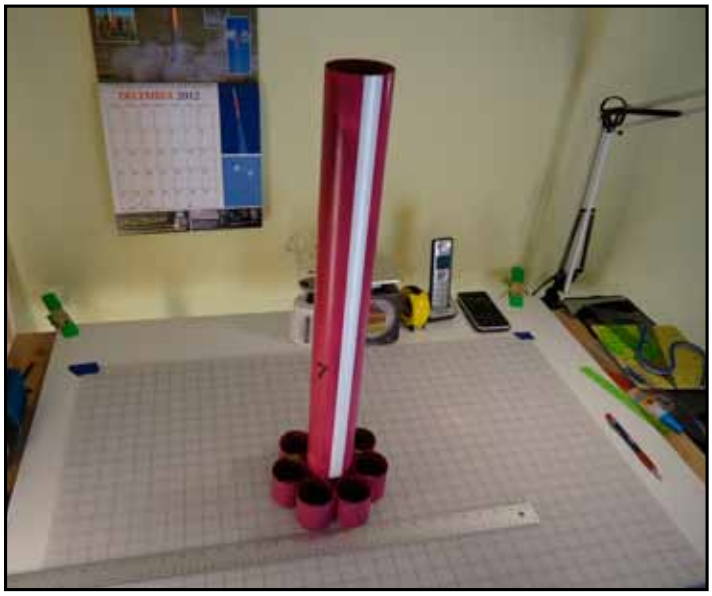


Figure 7: "The Lucky 7" fin can. Plain looking, but according to theory, it has the lowest drag.

remaining where the last tube fin will go. Finally the last tube fin is cut lengthwise, trimmed to fit around the launch lug, and then epoxied to the launch lug and to the tubes on either side. See Figure 7.

8, 9, and 10 – Tubes in Tubes and Stacked Tubes

Running out of real-estate on the outside of the rocket, I decided to explore tubes inside of tubes. It works nicely to do 3 sets of tubes such that we end up with 9 tubes organized as 3 sets of 3. I also decided to bevel the leading edges – just for looks. As always, all the tubes must be carefully aligned with the rocket body axis. See Figure 8.

Perfect 10

After considering many possible ways to do a "Perfect

Figure 8: "9 is the Number" (left), "Perfect 10" (center), and "8 Hot" (right).

10", I decided to stack them so that there is an inner and outer tube in five sets of two. By cutting a 29 mm motor tube in half, epoxying the two tubes together on a flat table, and then cutting the leading edge with a 50 degree bevel such that the longest edge was 4.5 inch long and the shortest edge is 2.125 inch long, and being careful to get 5 sets, I then used a fin jig to hold each fin pair in place as I epoxied each pair to the body tube.

8-HOT

So then I needed to add an 8 tube fin rocket to the collection. So again, I explored many possible designs, but ended with a design to show that much of the tube fin surface area can be placed farther away from the main rocket body, and may be connected to the rocket body at 180 degree spacing and can still be stable. The "8 HOT" rocket fins were cut from a few pieces of 38 and 29 mm motor tubes.

Continued on page 8

Continued from page 7

Explorations In Modular Tube Fin Design

Split Fins

There are popular split-fin designs for flat finned rockets, so I thought that there needs to be an equivalent in tube fin designs. I decided on 5 tube fins in a split tube fin configuration. This design uses a 54 mm motor tube cut to 5 pieces each 4 inch long. Then each 4 inch piece is further cut with a 75 degree bevel such that the shortest edge is 1" long and the longest edge is 3" long. The rocket body is tic marked at 72 degree spacing, and axial guide lines drawn. The split tube fin pieces are then axially aligned and epoxied to the rocket body with a 1" gap between the long and short tubes (see Figure 9).

Figure 9: "Split 5" rocket fin can.

8-HOT, 9s the Number, Perfect 10, and Split 5 all flew stably and successfully at MDRA in Maryland.

Eleven Dimensions?

I found a challenge somewhere to design a rocket that in some way had some feature that was 11. So I decided to build an 11 tube fin rocket, and to make it whimsical. My son and I tried a lot of designs before I found one that I felt was properly capricious. Shown in Figure 10, the "11 Dimensions" rocket has 11 tube fins mounted on 10 flat fins.

When mounting the tubes to the stand-offs, it is important that the butt joints have excellent fillets on both sides to minimize breakage upon takeoff and landing. I found that it is preferable to use ¼" square lengths of balsa on each side of the plywood at the body joint to get a stronger butt joint fillet.

Figure 10: The "11 Dimensions" rocket fin can (left), and what it looks like on the PAD at MDRA.

And remember, you must ask the launch control officer (LCO) to count backwards from 11 to zero.

Tube fin Area

OK, I admit that I designed these first and foremost to look good as rockets. But I also calculated the tube fin area to see how they all compare with the HV Arcas and the Cyclotron. Aerotech's HV Arcas has the smallest total fin area of 82.4 sq inches (counting both sides of all 4 fins), and LOC Cyclotron has the largest at 407 sq in (both sides of all 6 tubes). My tube fin experiments range from a low of 131 for "11 Dimensions" and a high of 279 for "9 Is The

Continued on page 9

Continued from page 8

Explorations In Modular Tube Fin Design

Number".

	Area in Sq In
HV Arcas	82.4
11 Dimensions	131
Lucky 7	149
8 HOT	153
2 Halves	165
6 Easy Pieces	186
Perfect 10	193
3 Tubes	195
4 Tubes	197
Ring Fin	207
Big Ears	216
Split 5	240
9s the Number	279
Cyclotron	407

As I said before, Larry Brand found that a 7 tube fin rocket had the lowest drag, and possibly a small total surface area is the reason. I wish I had flown all of the rocket designs with the same altimeter so I could accurately report the drag impact, but alas, too many motors to repeat the work.

Modeling Tube Fin Designs in Rocksim V9

Rocksim V9 has the ability to do standard 6 tube, tube fin designs as well as ring fin, and other numbers of tubes. In Figure 11, you can see the example of the 3 tube fin design analyzed below, as well as its calculated location of CP and CG.

Rocksim V9 does not have the ability to model swept leading or trailing edges. When I used Rocksim to calculate CP, I was astonished that no matter how large the tubes were, and corresponding surface area, Rocksim's estimate of CP seemed to be closer to Cg than expected with 4 or fewer tube fins. Tim VanMilligan suggested that for designs with fewer than 6 tubes, that it might be better to use the pods capability of Rocksim to assemble flat fins into a tubular shape. With this method I found realistic calculation

Figure 11: Rocksim V9 Design was used to analyze the CP of 3 tube fin design. Side view (top) base view (bottom).

Continued on page 10

Wanted: Your Rocket Products

If you're a manufacturer of rocketry products, like kits, electronic payloads, parts, construction tools, motors, launch equipment, or something totally cool, we're interested in talking to you. We're always looking for new products to sell.

So why have Apogee sell your products?

- *We have the best customers that are looking for something new.*
- *We provide the product support for the customers, so you don't have to.*
- *We take care of all of the hassles, so you can focus on what you do best.*
- *We are a volume seller - Our web traffic means buyers will find you easier.*
- *Our endorsement means you sell more and make more money!*

APOGEE COMPONENTS

www.ApogeeRockets.com

If you're not getting enough sales, let's talk.

Continued from page 9

Explorations In Modular Tube Fin Design

of CP. It also allows for modeling of tube fin bevel if you are willing to put in enough effort. I believe that there is now a Rocksim V9 patch that corrects the calculation of CP for tube fin designs.

So one method to model unusual tube fin designs is to create a replacement for a round tube by creating a square tube, such that the height of each edge is 70% of the diameter of the intended round tube, and the length is the same as the length of the round tube. With this process, the result is a square tube that would just fit inside the round tube. Regarding CP, this is a conservative analysis.

The first two edges are attached to a pod at the location where the tube would attach to the rocket body, and of course they are attached with 90 degrees difference in their attachment angle. A second pod is used at the other end of each of these flat fin pieces, and a second flat fin attached to the pod at such an angle that it forms the other two sides of a square. These second two sides should be able to exactly touch or to come very close to touching. With this method, one is able to validate the CG to CP separation when the motor is in place and assure two or more calibers. The method appears to be tedious and time consuming but provides improved accuracy about CP and flexibility to model more complex fin structures.

Using the square tube approximation method, as well as the built-in tube fin model, I analyzed the interaction of CG and CP for stability as I varied the length of the 3 tube, tube fin design, ranging from a very short 1" length to a very long 8" length for each tube, all mounted at the same location. Doing so, I found that while CG moved farther from the nose cone the longer the tube fins get, that CP moved very rapidly away from CG up to the point of 4 inch length, and then not much more after that.

Stability margin, in calibers, is maximum at tube fin lengths between 4 and 6 inches, and then begins to decline again as the fins get very long for the 3 tube fin rocket.

I also studied the coefficient of drag of the overall rocket, and of the fins, and the percentage of drag attributed to the fins as I scaled the tube fin length from 1" to 8" all using the 3 tube fin design. Since I have been testing this design with a G77-7R motor, I chose to make the simulation measurements at 390 ft/s, which is just slightly higher than the maximum speed attained by this series of rocket designs. Fin drag (C_d) increases 2% from 47% to 49% of the overall drag of the rocket as the tube length increases from 1" to 8". Furthermore, the 2% change in drag of the tube fins has a 10% effect on maximum velocity slowing from 384 ft/s on 1 inch long tubes, to 341 ft/s on 8 inch tubes. Correspondingly, the drag also has a 10% impact on maximum altitude decreasing from 1332 ft for 1" long tubes to 1204 ft for 8 inch tubes. Maximum altitude and maximum speed occur with 4" long tube fin design.

I also compared this with the 4 HV Arcas polystyrene fins mounted to the same rocket body using Rocksim V9. For 4 HV Arcas fins, CG is 42.8, CP is 52.8, Max V is 346 ft/s, and Max Alt is 1371 ft. You can see this is a relatively small difference in CG and CP. I find that fin drag is reduced to 25% of the total rocket drag vs 48% for the 4 inch long tube fins, and the over all C_d is 0.454 vs 0.653 for the 3 tube fin design.

From this, we can conclude that those seeking altitude should stick with flat fins, and those seeking minimal breakage on landing or novel design should consider tube fins.

Publications in Tube Fin Rocket Design

Tim Van Milligan pointed me to three issues of *Sport Rocketry Magazine* that address tube fin design [9,10,11]. These articles by Larry Brand address the coefficient of drag (C_d) of the fin design of tube fin rockets, as well as

Continued on page 11

Continued from page 10

Explorations In Modular Tube Fin Design

the ratio of the rocket length (L_{eff}) to body diameter (D) (ratio=L_{eff}/D) (where L_{eff} is measured from the tip of nose cone to leading edge of the tube fins). In these three articles Larry explores 6, 7 and 8 tube fin designs, body length to width ratio, various improvised nose cones, and compares these designs with corresponding flat fin design. He calculates the C_d of the tube fins by adjusting C_d until the predicted apogee matches that of his altimeter using his simulation tool [12]. In the first issue, he finds that tube fin C_d is not constant with max velocity, and eventually concludes that short stubby rockets with L_{eff}/D at approximately 5.5 minimize tube fin drag.

In the second issue, Larry uses his analysis data to predict performance of 3, 4 and 5.5 inch body tubes, using stubby body tube design principles and tube fin designs to see if his data accurately predicts new rocket builds. In addition a significant amount of building advice for higher power rockets is provided.

In the third article, Larry concludes the sequence with the conclusion that L_{eff}/D of 5.2 is about optimum, and provides the equation for the coefficient of drag, C_d=[(5.0/stubbiness_ratio) + 0.31]^-1. Larry then explores C_d vs max velocity for 2.1, 3, 4, and 5.5 inch stubby designs, and finds that the 7 tube fin design always has the lower drag than 6 tube fins at all max velocities, and that the C_d is largely flat vs Max velocity. Again, Larry provides a considerable amount of construction guidance about how to pack big motors into stubby rockets, and also touches on the fact that fin flutter can also occur for a tube fin rocket.

Larry has a wealth of construction information for all these tube fin designs on the web site in [13].

I have also found a wealth of tube fin rocket design background on the Apogee *Peak of Flight Newsletter.*

In *Peak of Flight Newsletter #119* [14], Bruce Levinson explores how to use the Rocksim V7 simulator to model tube fins. While the V7 simulator apparently had the ability to graphically model 6 tube fins or a ring fin design, Bruce explored how to get the Center of Pressure (CP) to match expectations. Bruce has a lengthy discussion that the surface area of the tube fin, washed by the airflow, can be modeled with the equivalent of 3 flat fins with a total of the same surface area as the corresponding tube fins. In the article he applies this to both 6 tube fin and ring fin designs, showing both tubes and an overlay of the equivalent flat fins. He explains how to use the side-pod feature of Rocksim to enable either tube fins or side pods that behave like tube fins, and can be mounted like tube fins with an optional offset from the rocket body. Of course side pods that have nose cones only experience air washing the outside surface of the tube.

Bruce Levinson reports more about managing CP in short fat rockets in [15,16,17]. While this is not about tube fin rockets, it does address accurately modeling CP on stubby rockets using Rocksim V8. This series of articles discusses rocket design where the short fat rocket with no boat-tail experiences excessive drag due to its blunt end. Bruce describes fabrication of a synthetic conical section to

Continued on page 12

Continued from page 11

Explorations In Modular Tube Fin Design

more accurately position the CP to match that of real short fat rockets.

Tim Van Milligan's article [18] discusses how to use pods to create polyhedral wings. This article provides excellent detail on how to make use of pods to create wings of arbitrary shape. The term pod is used by the RockSim program to define a point at which other things may be attached, and multiple things may be attached at various angles. While the article is focused on modeling polyhedral of wings, the same methods can be used to create wings that are essentially tubular. I have included it into this list, because I have used this method to create tube fins that are modeled as a square tube of nearly equivalent surface area to a round tube. Clearly it can also create tubes with more than 4 sides, so that it even more closely resembles a round tube. This method can also be used to create an approximation to beveled shape tubes.

Tim Van Milligan's article [19] discusses the Barrowman equations. The focus of this article is on very long skinny rockets and why they go unstable even if the Barrowman equations imply sufficient stability in the distance between the CG and the CP. Again, I have included this article in this anthology because it addresses some issues not entirely obvious in the use of standard Barrowman equations for analyzing stability.

In Dan Moss's letter [20], he discusses how Falls Church High School calculated Coefficient of Drag (C_d) during ascent after motor burnout. The method is expected to be more accurate than the method of matching apogee by tuning the C_d, since it does not include the variability of motor performance. It does however, require download of deceleration, velocity and altitude data from a recording altimeter, in order to match the deceleration rate. While it does not separate the individual components of C_d, as Rocksim does, this article and the referenced research it describes, does explain a methodology to explore the individual contribution of various rocket components by flying a modular design (like that of my article), and experimentally substituting parts to observe the contribution differences and how they impact C_d in conjunction with your favorite altimeter and holding other design parameters fixed.

Tim Van Milligan's article [21] is a thought piece on the possibility of a 2 fin rocket. He discusses dynamic stability versus angle of attack and versus motor weight shift during flight. This article concludes that a two tube rocket might be possible, and even a one tube rocket that is similar to a ring fin design.

Summary

There is a lot of opportunity to explore new rocket designs avoiding the 3FNC and 4FNC designs typical of current commercial offerings. This article should provide sufficient background for those interested in creating novel designs. I would very much like to see recording altimeter drag races between these designs to see the C_d relationship to the fin area, preferably all with the same motors, and using the coasting method described by Dan Moses [20]. If I receive multiple reports, I would be interested in aggregating the data.

Additional Tube Fin Rocket Designs on the Web

LOC Cyclotron [2] was my Level 1 rocket, and I upscaled this design to my Level 2 and Level 3

I have not tested any of the following designs:

Super Neon and Razor [22]

Oddl Rockets Corkscrew [23]

Final Notes: Yes I know that if a ring fin is held on to the

Continued on page 13

We're Paying Cash

For Great Articles for This Newsletter

Are you a writer looking for some serious pocket change? We're paying up to $350 for good how-to articles for this newsletter. If you're interested, see our submission guidelines on the Apogee web site.

www.ApogeeRockets.com/Newsletter/Newsletter_Guidelines

Continued from page 12

Explorations In Modular Tube Fin Design

body with more than 1 tube then it really doesn't count as a 1 tube design. Yes I know that the Split 5 design really has 10 tubes, although I count it as 5. Yes I know that the 11 dimensions design has not only 11 tube fins plus 10 flat fins and therefore could be considered a 21 fin design.

References:

[1] Aerotech Mirage: http://www.apogeerockets.com/Rocket_Kits/Skill_Level_3_Kits/Mirage

[2] Loc Cyclotron: http://shop.locprecision.com/product.sc?productId=120&categoryId=14

[3] J.Barrowman, "*Aerodynamics of Sounding-Rocket Geometries",* NASA Technical Reports Server (NTRS), Sep 1, 1982

[4] HV Arcas: http://www.apogeerockets.com/Rocket_Kits/Skill_Level_3_Kits/HV_Arcas

[5] http://www.apogeerockets.com/Building_Supplies/Tools/Guillotine_Fin_Jig

[6] http://en.wikipedia.org/wiki/Resistor_color_code

[7] http://www.youtube.com/watch?v=hC6evC1N05c

[8] http://www.adeptrocketry.com/SB40ds.htm

[9] Larry Brand, "Tube Fin Rocket Aerodynamics Revisited", *Sport Rocketry,* January-February 2008

[10] Larry Brand, "Tube Fin Rocket Aerodynamics Revisited Part 2", *Sport Rocketry,* March-April 2008

[11] Larry Brand, "Tube Fin Rockets – Seven Beats Six Part 3", *Sport Rocketry,* March-April 2010

[12] Larry Brand's Simulator: http://webalt.markworld.com/webalt.html

[13] Larry Brands Tube Fin Construction Articles: http://www.rocketreviews.com/larry-brand-page.html

[14] Bruce Levinson, "Simulation of side pods Using Rocksim V7", Apogee *Peak of Flight Newsletter #119* (www.ApogeeRockets.com/Education/Downloads/Newsletter119.pdf), Jan 27, 2003

[15] Bruce Levinson, "Simulating Short Wide Rockets in Rocksim 8", Apogee *Peak of Flight Newsletter* #154 (www.ApogeeRockets.com/Education/Downloads/Newsletter154.pdf), Dec 30, 2005

[16] Bruce Levinson, "Simulating Short Wide Rockets Part 2", Apogee *Peak of Flight Newsletter* #157, (www.ApogeeRockets.com/Education/Downloads/Newsletter157.pdf) March 14, 2006

[17] Bruce Levinson, "Simulating Short Wide Rockets in Rocksim 8.0 Part 3", Apogee *Peak of Flight Newsletter* #162 (www.ApogeeRockets.com/Education/Downloads/Newsletter162.pdf), June 15, 2006

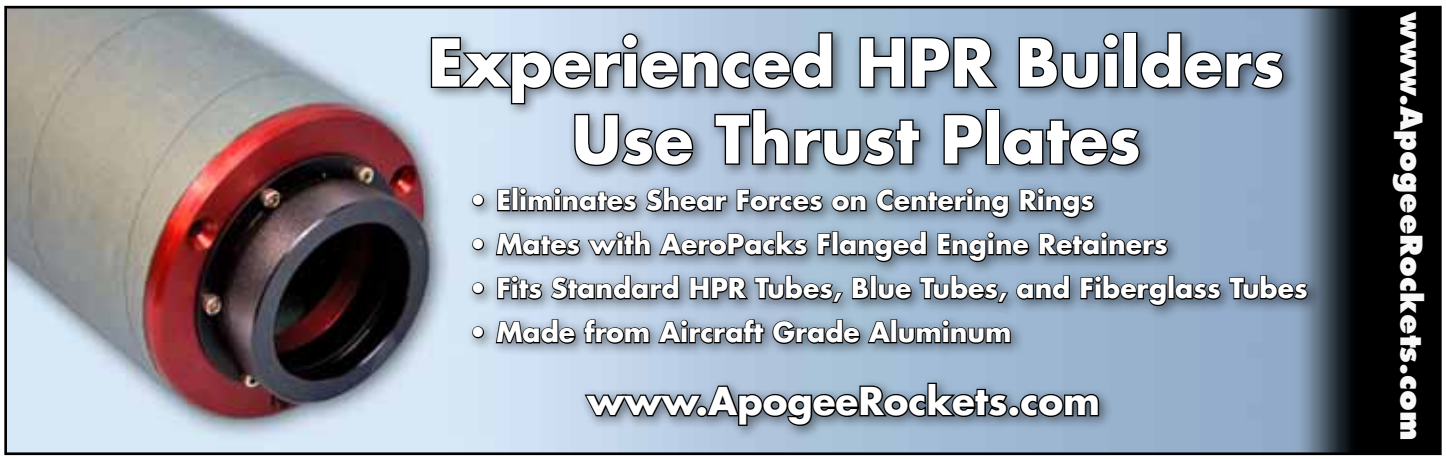
[18] Tim Van Milligan, "How to create Polyhedral Wings in Rocksim V9", Apogee *Peak of Flight Newsletter* #232 (www.ApogeeRockets.com/Education/Downloads/Newsletter232.pdf), April 7, 2009

[19] Tim Van Milligan, "Why Do Tall Skinny Rockets Go Unstable", Apogee *Peak of Flight Newsletter* #239 (www.ApogeeRockets.com/Education/Downloads/Newsletter239.pdf), July 14, 2009

[20] Dan Moses,"Calculating A Rocket's Cd", Apogee *Peak of Flight Newsletter* #315 (www.ApogeeRockets.com/Education/Downloads/Newsletter315.pdf), June 19,2012

[21] Tim VanMilligan, "Can you design a 2 Fin Rocket?", Apogee *Peak of Flight Newsletter*, #220 (www.ApogeeRockets.com/Education/Downloads/Newsletter220.pdf), Oct 21, 2008

[22] Estes Super Neon and Razor: http://www.estesrockets.com

[23] Oddl Rockets Corkscrew: http://www.apogeerockets.com/Rocket_Kits/Skill_Level_1_Kits/Corkscrew_Powered_Flics_Combo_Pack

[24] http://www.rocketreviews.com/scratch-cheap-dumb-rocket-cdr-by-larry-brand.html