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A design challenge that teaches stability and aerodynamics

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Is It Possible To Make A 2-Fin Rocket?

By Tim Van Milligan

While browsing the rocketry forums this past week, I came across an interesting subject line: “Two fin rocket.” “What an interesting concept,” I said to myself. Then I began wondering, is it possible? That’s how I got the idea for this article. Can we design a stable 2-finned rocket?

The first thing I want to show you is that a two-fin rocket is statically stable in RockSim. It is simple to create a 2-fin rocket design in RockSim, so I did. And it showed that the rocket is indeed statically stable because the CG is forward of the CP.

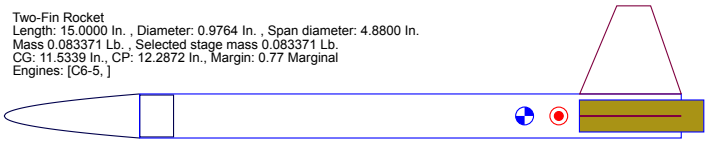

Figure 1: A 2-fin rocket shows to be statically stable in RockSim

How can this be?

First it’s important to understand how RockSim locates the CP of an asymmetrical rocket like the one shown in Figure 1. What RockSim does is find the CP of the rocket at every side view of the rocket. Think of it as finding the cardboard cut-out CP location. You look at the silhouette of the side view of the rocket while spinning it on its roll axis like shown if Figure 2.

There is one difference from a traditional cardboard cut-out method. We are not balancing the silhouette on a ruler to find the balance point -- which is the CP point of the cardboard cut-out method. Instead, we’re letting Rocksim calculate the aerodynamic CP for each side view based on the Barrowman equations. The difference is that RockSim (and the Barrowman method) places the CP much further back on the rocket.

Obviously, as can be seen from Figure 2, the CP location shifts around on us depending on which side view we’re looking it. So which is the correct one? That is a great question.

We always err on the side of safety, so we’ll always use the CP location that will give us the least stable rocket. That is where the CP is the furthest forward toward the nose.

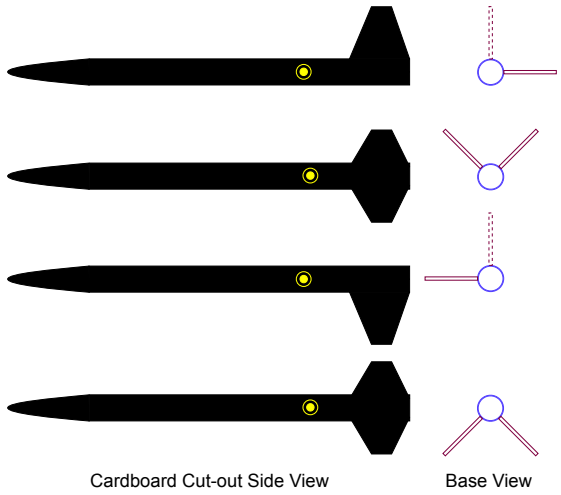

Figure 2: Cardboard cut-out of the 2-fin rocket in different orientations. For example, in the top image, you’re looking down at the rocket where one fin sticks out to the side, and one fin is pointed up at you.

That is exactly what RockSim does. It will always report this CP location on the 2D image of the rocket on the main screen of the software. For an unsymmetrical rocket like this one, there are CP locations that are further back (which is good for stability), but it will tell us the CP location that is the furthest forward.

If you would like more information on determining the CP locations of other view angles of the rocket, see Peak-of-Flight Newsletter #105 (www.ApogeeRockets.com/education/downloads/Newsletter105.pdf). It explains where this information can be found in RockSim.

Getting back to our 2-finned rocket, RockSim is telling us the CP is always behind the CG. That means the model will always turn into the wind, no matter what side we balance the silhouette on. This balance point defines a pivot axis. So no matter what direction the rocket is oriented to with respect to the pivot axis, it will always rotate the nose toward the on-coming wind.

This is what is seen in Figure 3 through 6. The pivot point, which always runs through the CG of the rocket, can

Continued on page 3

About this Newsletter

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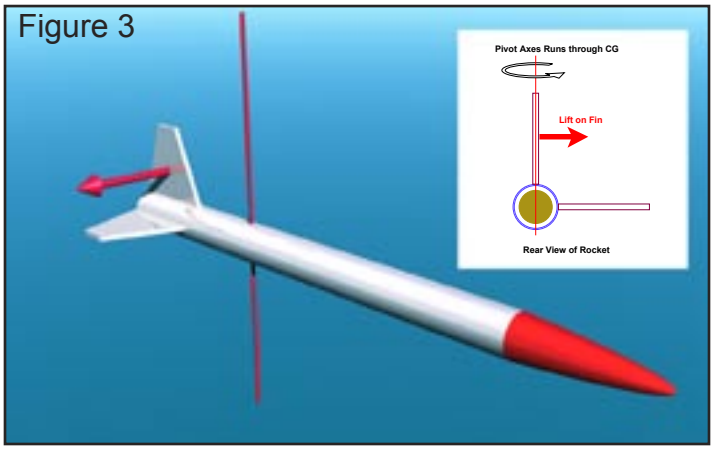
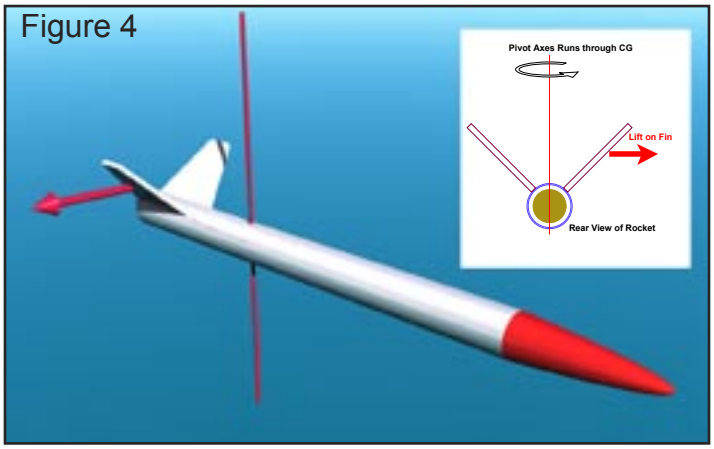
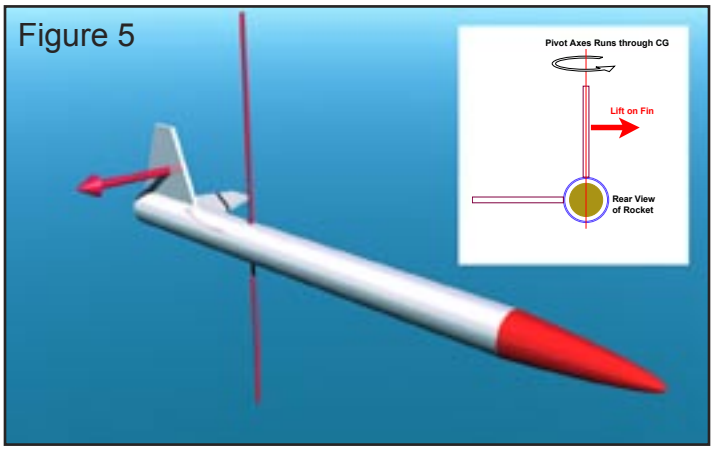
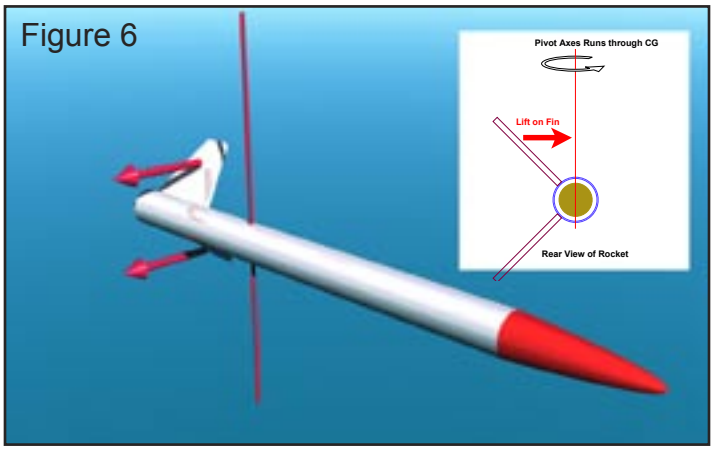
Continued from page 2

Is It Possible To Make A 2-Fin Rocket?









Figures 3-6: No matter what the orientation of the axis relative to the fins, there is always a side force that will cause the 2-finned rocket to rotate.

Model Rocket Design and Construction

By Timothy S. Van Milligan

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This new 328 page guidebook for serious rocket designers contains the most up-to-date information on creating unique and exciting models that really work. With 566 illustrations and 175 photos, it is the ultimate resource if you want to make rockets that will push the edge of the performance envelope. Because of the number of pictures, it is also a great gift to give to beginners to start them on their rocketry future.

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Continued from page 3

Is It Possible To Make A 2-Fin Rocket?

be oriented differently, but the model is statically stable.

At this point it seems that we could actually build and fly a two-finned rocket. But unfortunately, we don't have all the information we need. As anyone that has been in rocketry a while will tell you, a 2-finned rocket as shown in Figures 1 through 6 is NOT stable.

Well, why not? RockSim is telling us that it is, so is the software wrong?

What RockSim is reporting is the "STATIC" stability location. Unfortunately, things aren't static when you actually launch the rocket. They are "dynamic." That means things are constantly changing on us.

One thing that is changing on us is that the CG is shifting forward as the back end of the rocket becomes lighter weight. This happens because the propellant is being consumed and expelled out the nozzle of the motor. Having the CG move forward during the flight is actually a good thing, as it makes the model more stable.

Another thing that is changing on us is the CP location. It moves forward as the rocket flies at an angle-of-attack. That is very bad. The further forward the CP moves, the less stable the model is. If the CP moves so that it is ahead of the CG, then the rocket will be unstable.

You can get the information on the CP shift from RockSim by plotting the CP versus angle-of-attack after running a simulation with high wind speeds (see Peak-of-Flight Newsletter #86 for more information at: www.ApogeeRockets.com/education/downloads/Newsletter86.pdf).

This is a critical piece of information, so we added a special graphic to RS-PRO to show how far the CP moves

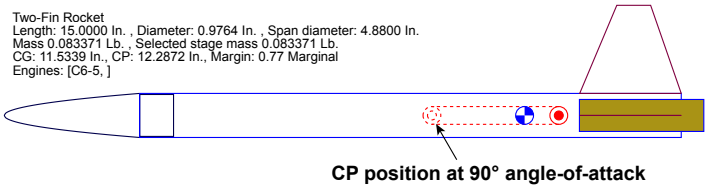

Figure 7: RS-PRO contains an extra graphic that shows how far the CP will move forward with angle-of-attack. Notice that it can move far enough forward that this design will become unstable.

forward with angle-of-attack (see Figure 7).

If you notice in Figure 7, at some angle-of-attack, the CP will have moved ahead of the CG and the rocket will become unstable. What is this critical angle-of-attack? That information is found on another graphic from RS-PRO. It is shown in Figure 8.

Continued on page 5

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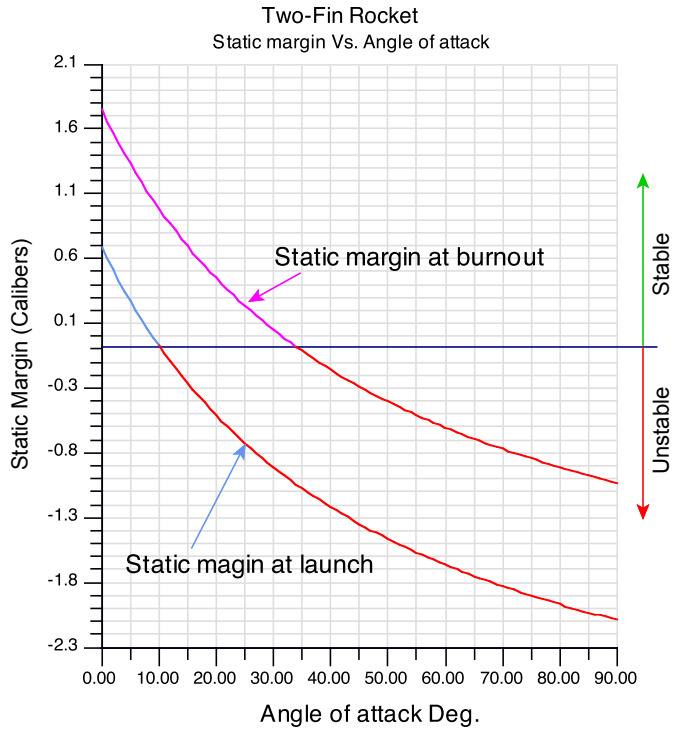

Figure 8: This graphic shows that as the rocket increases its angle-of-attack, the static margin decreases because the CP moves forward.

In Figure 8, you see that the static margin drops with angle-of-attack. Recall that Static Margin is the distance between the CG location and the CP location divided by the maximum diameter of the rocket. What this means is that for the static margin to become a smaller number, the distance between the CG and the CP must be decreasing. This happens because the CP is shifting forward with angle-of-attack.

There are two lines in Figure 8, because the CG of the rocket also shifts. When a new motor is installed, the weight of the propellant moves the CG toward the back end of the rocket (closer to the CP). As the propellant burns, the back end of the rocket gets lighter in weight and the CG shifts forward. It moves its furthest forward when the propellant is totally consumed (at burnout).

To err on the side of safety, you should only look at the line that defines the rocket with a new motor in it (Static Margin at launch). This gives you the worst-case situation. In this design, we can see from Figure 8 that at 10 degrees angle-of-attack the rocket will be totally unstable.

Even at lower angles-of-attack, the rocket is "marginally stable." Ideally, we want a Static Margin with a value of at least 1.0. Under that value, the CG and the CP are too

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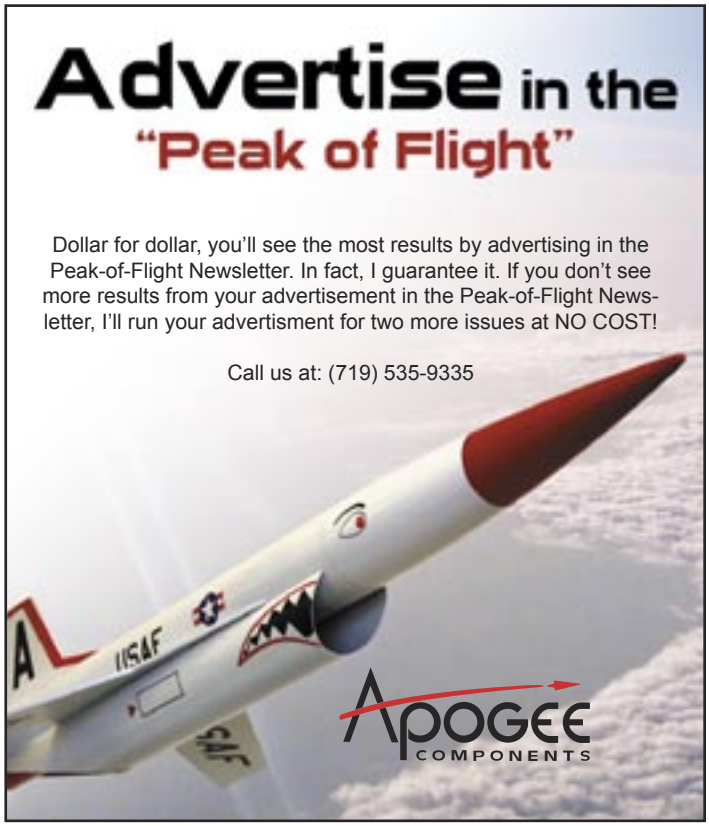

Continued from page 5

Is It Possible To Make A 2-Fin Rocket?

close together and we don't have any room for error.

Another thing that is happening that RockSim does not take into account is that there is a difference in fin drag on one side of the rocket compared to another.

In Figure 9 we see the drag forces acting on the two fins. The fin that is vertical has a drag vector that is indicated by the blue arrow. The fin that is horizontal in the picture has a drag vector force that is indicated by the red arrow.

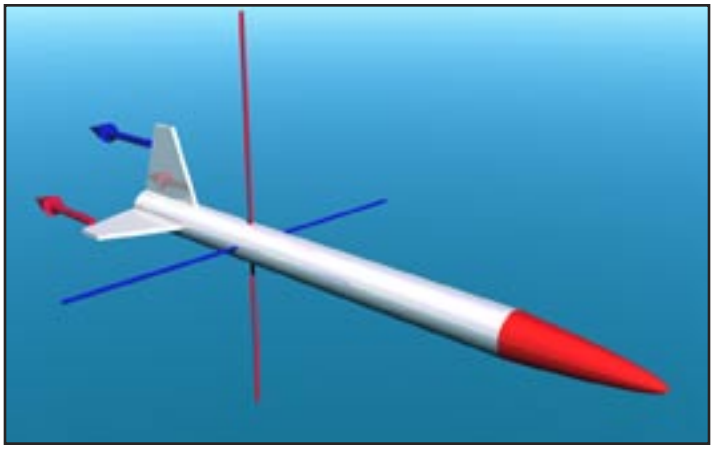

Figure 9: Drag pulls backward on each fin.

Let's ignore the red arrow for the time being, and concentrate on what happens because of the drag force on the vertical fin. The blue arrow force is going to cause the rocket to pivot along the "blue" line (called the pitch axis) because there is no drag force on the bottom to counteract that force. Do you see that?

When the nose starts to pitch upward, that puts the horizontal fin at a positive angle of attack. Since it is at a positive angle-of-attack, the fin starts to produce lift to counteract the pitch of the nose. This is good, since we want to force the nose back down.

But another thing happens too. That lift force is only on one side of the rocket, so it is going to also rotate the rocket along the long axis (roll axis) of the rocket (Figure 10).

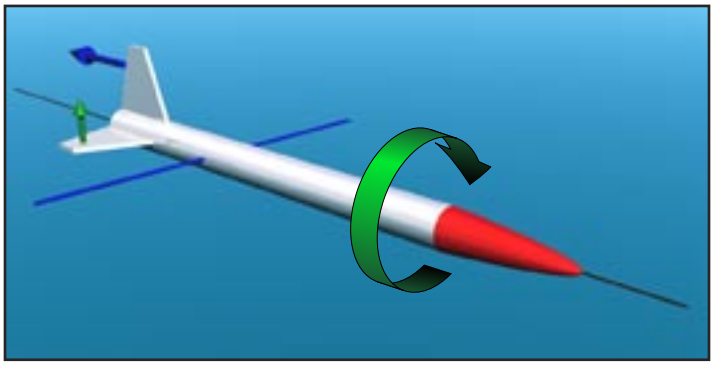

Figure 10: Drag on the vertical fin (blue arrow) causes the 2-fin rocket to pitch upward (blue axis). This puts the horizontal fin at an angle-of-attack, and it produces a lift force (green arrow). This lift force causes the rocket to roll to the left.

Continued on page 6

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Continued from page 6

Is It Possible To Make A 2-Fin Rocket?

What we have happen is the rocket pitches upward and then starts to roll left. It starts to cone pretty bad, and gets out of hand very quickly. Our rocket will exceed the critical angle of attack and will go unstable. It is a very bad situation indeed.

Unfortunately, RockSim does not take all this into account because it is a 3-degree-of-freedom program and will not roll or yaw the rocket. For this reason you shouldn't design rockets that are extremely asymmetric with a lot of fin area on one side and not on the other.

Basically, what we've proved is that with flat fins, we cannot design a stable rocket.

But let's think outside the box. First, what if we spun the rocket like a bullet to create stability? This can be done with spin tabs on the base of the fins. But first we must put the fins on the opposite side of the rocket so that the drag force produced by each fin is equalized and it doesn't pitch over. The resulting rocket will look something like shown in Figure 11.

The downside of such a rocket is that causing the rocket to spin takes energy. You have to get that energy to spin the rocket from somewhere, and it will come from the kinetic energy of the moving rocket. In other words, it will act like it is draggy, and it won't go as high as we might want it to.

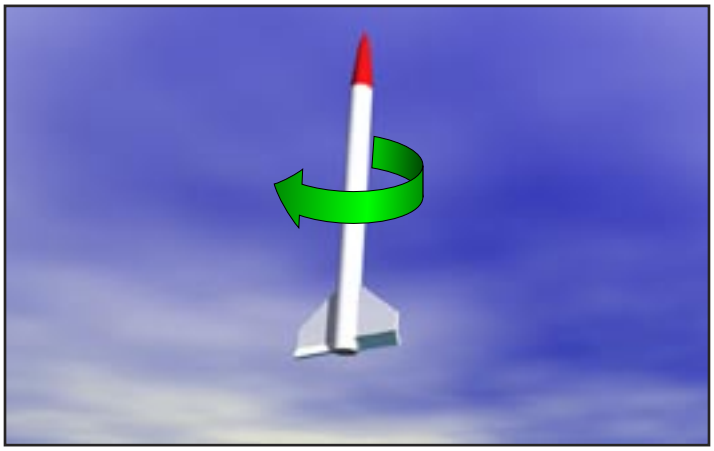

Figure 11: Spin tabs added to the base of the fins can be used to induce a roll in the rocket, and create a stable flight. The downside is extra drag.

Here's a thought... What if we used curved fins? That changes the situation because we can get more creative. In Figure 12, we see a two-finned rocket that should actually work fine. The only thing to watch out for is that the fins must be very stiff and rigid. If they are flexible, the fins themself will warp under the lift and drag forces created.

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Continued from page 7

Is It Possible To Make A 2-Fin Rocket?

Unfortunately, I can't simulate either of these complex rocket in RockSim…

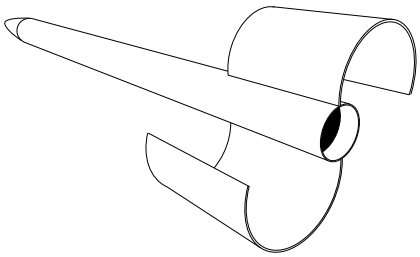

Figure 12: A two finned rocket that is actually stable!

Come to think of it, I think it is also possible to make a single-fin rocket. Again, you have to use a rigid and curved fin. We're getting real close to a ring tail rocket at this point though (see Figure 13).

Conclusion

I hope you learned a little bit about aerodynamics in this article. This started out as a logic exercise was to show you that a two fin rocket, while statically stable in RockSim, is not dynamically stable. It will cause there rocket to quickly go unstable. But then as I started to play with concepts in my mind, I did figure out that a two-fin rocket is actually possible. But the only way to make a two finned rocket stable is to use curved fins.

About The Author:

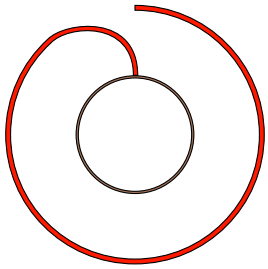

Figure 13: Base view a single-fin rocket.

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. Before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education/. He is also the author of the books: *"Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics"* and publisher of a FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site or by sending an e-mail to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

Apogee News

A Busy Summer Leads To The Release Of Model Rocket Design and Construction

By Tim Van Milligan

It has been over five months since I last gave you an update on the things that are going on around here at Apogee Components. The last update was on May 6, 2008.

I write these news articles for my own benefit, as well as for your's. If I don't document the history of Apogee Components, I know I'll forget what happened. By putting it down in these newsletters, I know that it will be out of my mind and in the newsletter archive where I can find it again.

A lot has happened since May.

The third edition of my book *Model Rocket Design and Construction* arrived and was released last week. The book actually went to the printer in early September, even though we anticipated it would be out of here in July or August. There were several reasons for this. The first was proof-reading the text. A bigger time hit was creating the last four pages of the book: the index. Before we started the index, we were assured by Adobe, the makers of the InDesign page-layout software we used, that creating the index would be a piece of cake. It was all supposed to be automated during the process; just feed it a list of words, and it would spit out the index. Yeah, right...

Every time we input in a word, it would spend a few hours chugging and whiring away as it tried to digest the word into the index. For a technical manual like this book, that process literally took weeks. It would have been faster to do it the old fashioned way of highlighting the words on each page of the book and creating the index that way.

By the time the index was complete, it was late summer. Unfortunately, summer is our slow season, and then we had another cash-flow hiccup. I had a big balloon payment on a piece of equipment that we were leasing. I completely forgot that the lease was about to expire, or I would have exercised an option in the contract to extend the lease. But the money (which I had saved up for the printing of the book) was yanked out of my bank account. It was my own fault, and I fully take responsibility for it.

The end result was that the book was ready to print, but I didn't have the cash on hand to pay the printer to print it. The solution was to do a special pre-release sale offer on the book to raise some extra money. It worked! Our customers came through, and we were able to raise the necessary money.

Now we are literally hours away from having the official launch of the book with a party for our customers. It is exciting, and I can't wait to get all of them shipped out to our customers that have been waiting so patiently.

Tim signs his signature in the new 3rd edition of "Model Rocket Design and Construction" for those customers that pre-ordered it.

Also this summer we have been adding a lot of new rocket kits from other manufacturers to our offerings. Why carry other people's rockets when we make some of the best ones on the market? That is a great question.

The biggest reason is that customers want a lot of variety. I cannot satisfy all that desire for different rockets at the current time, because it would cost too much to try to stock all the individual parts for every new kit. To keep from going broke by having too much inventory in parts, I asked myself, "why not just find kits from other vendors?" That way, my money is not tied up in parts inventory, it is in kit inventory that moves a bit faster. While profit margins are not as high as making our own kits, it gives our customers the variety that they want.

Over the summer and early fall I've added to our line-up kits by Mad Cow Rocketry, Semroc, Dr. Zooch, Red River Rocketry, Cosmodrome, Mercury Engineering, and Sunward Aerospace. We are also stocking more products by PerfectFlite, Aeropack, and Transolve.

While we have a lot more kits here at Apogee, we are still distinctive from other vendors that sell kits. We actually build and fly the products that we stock, where they don't. Can you imagine getting paid to build model rockets? I'm telling you, life is great here at Apogee Components!

But besides the fun, I'm sure you realize that building

Continued on page 10

Continued from page 9

Apogee News

A photo of our front entry at Apogee's World Headquarters in Colorado Springs. We build each model we sell so that we know how the rockets will work for you and our other customers.

all these kits and putting motors into them to fly them is very time consuming and expensive. I do have help though. I'm now having some of our staff build some of the simpler models to personally save me some time.

However, I still inspect all the built models and the kits in their raw unassembled-form with my engineering-eye. I want to know as much about the products we carry as possible. In some cases, I think we know more about the items than the manufacturers that make them. This benefits our customers because they can come to us for detailed information. More importantly, they won't be buying a kit that doesn't meet their needs.

There will be some new kits from DynaStar (which is our brand of mid-power kits). I did most all the development work on the new DynaStar LexxJet kit. See Newsletter #215 (www.ApogeeRockets.com/Educations/downloads/Newsletter215.pdf) for a sneak peek at what it looks like. The only thing left to do is start ordering the new parts that we don't currently stock and then bagging it up. But because of cash-flow issues, it may be another couple of weeks before that happens. I don't know if it will be released by the end of the year, but that is my goal.

In other news, we will be getting another load of the Sky kits in time for Christmas. Because we have to order such large quantities to get reasonable shipping rates, we have to deplete our inventory to very low levels before it gets economical to place a re-order. Some of the kits, like the Shenzou, have been out of stock since early Spring. So it will be nice to get those back in stock again. By the way, we have the same problem with the Noris kits from Germany.

I have gone to Virginia twice since May. The first was for the TARC competition, and the second was for NARAM-50. I enjoyed both events, but with the price of oil so high, I'd probably reconsider flying to both events next time. I also drove to Kansas for LDRS. That was a fun event too. And since I drove, I was able to take kits and things to sell at the field.

It has been a busy summer here at Apogee. In addition to all the projects I mentioned, there was one other little teensy-weensy project that I've been working on too. That project was the next revision to our design and simulation software: RockSim. I've probably put as much time working on RockSim v9 as I have all the other projects combined. I've been working with the programmer (Paul Fossey) to make sure the project moves along with the features that you've been asking for. The effort we've put into it will be worth it to you. I guarantee that it will blow your socks off. As hard as it is to imagine, it is a million times better than RockSim version 8. Stay tuned for more information.

Throughout this article, I mentioned cash-flow issues a number of times. I hope you don't get the impression that things are looking bleak for Apogee Components. It's not. Actually we're in much better shape this year than we were in 2007. In March of 2007 we made the big move to our current 6,000 square-foot facility. That move was expensive and I had to borrow a lot of money to make ends meet. But I've been steadily paying down that debt to the point where it should be gone in a few months. I look forward to being debt-free again, as I was before the move of 2007. That means we can take on even more new projects starting next year.

Additionally, I no longer have the hefty lease payments on the equipment, and our inventory levels are at the highest point in company history. When I mentioned the cash-flow situations, it was to point out a brief event in Apogee's timeline. And despite the ups and downs of the current economy, we're in a great place right now. I can't control the economy, but I still see exciting times ahead not only for Apogee Components, but for you and our other customers too. I can't wait to see what tomorrow brings for you!

Wanted! Article Ideas.

If you have a question about rocketry, send it in to us. Other people are probably wondering the same thing.