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PEAK OF FLIGHT

NEWSLETTER

What Went Wrong With My Flight?

Using altimeter data to decipher why a flight didn't achieve its objective.

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EMRR Corner

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ISSUE 208 MAY 6, 2008

Playing Sherlock Holmes With Altimeter Data

By Tim Van Milligan

I got a letter a few weeks back, and I asked the person if I could share it with you in this newsletter because there is a good opportunity to learn some new things, to play Sherlock Holmes, and interpret altimeter data. First, here is a short paraphrase of the letter:

> *"Yesterday, our middle school TARC team launched three flights of our competition rocket using the F39-6 reloadable motor. The final two flights were witnessed by a senior NAR member, who was officially scoring us for the competition.*
>
> *To our dismay, all the flights performed far worse that any previous flights we have flown using the exact same motors. I believe the problem is that the wrong ejection charge delay was packed with the motors we purchased. The NAR representative said that he agrees with this, as it is what the data seems to indicate. He is willing to give us another opportunity to launch our rocket and rescore the flight if you will concur that our flight data was more than likely the result of a packaging or labeling error made by the manufacturer. We are not asking for anything other than your willingness to look over the data and your support."*

Along with the letter, the writer also included printouts of the data recorded by the Perfectflite altimeter (http://www.apogeerockets.com/altimeter.asp) for both the practice flights and the qualification flights.

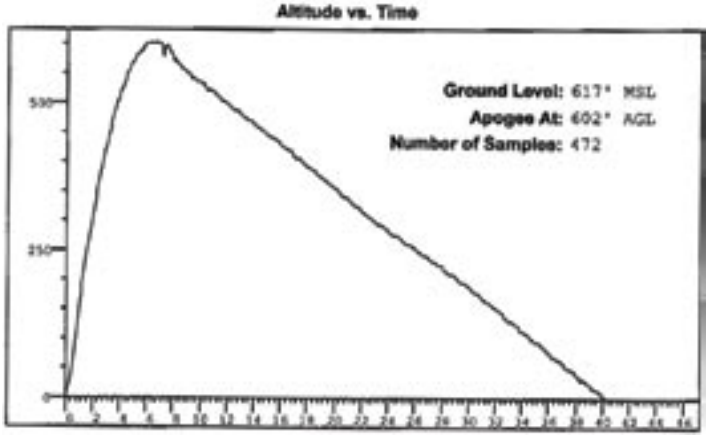
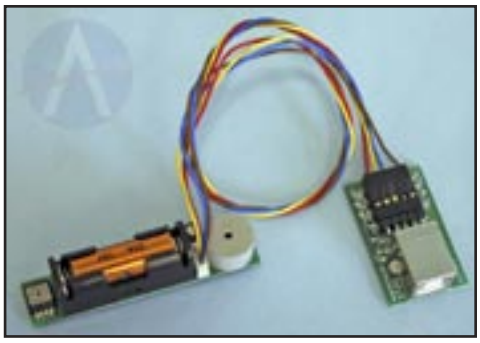


Figure 1: Altimeter data from one of the test launches. Apogee is at 602 feet. Duration aloft is 40 seconds.

The Detective Work Begins



First off, I would like to praise the TARC team for downloading the altimeter data from all of their flights. This shows that the students had a real willingness to learn. Without the flight data, I wouldn't have had anything to look at, and I would not have been able to judge the validity of their hypothesis.

Figures 1 and 2 compare two flights; the first is a practice flight that was a few days before the team's qualification attempt. The second shows the altimeter data from one of the two qualification attempts.

The team was obviously concerned with the time aloft, which went from exactly 40 seconds in the practice flights to 34 seconds in the qualification flight. In the TARC competition, there is a double time-penalty compared to the altitude being off. This puts a greater emphasis on having a perfect duration aloft (in this case, 40 seconds).

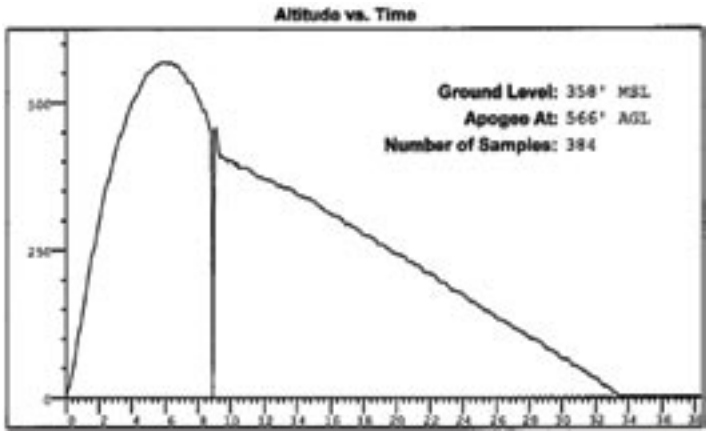


Figure 2: Altimeter data from one of the TARC qualification launches. Apogee is at 566 feet. Duration aloft is 34 seconds.

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Sherlock Holmes Using Altimeter Data

But what I noticed right away wasn't the "time aloft." The practice launch hit an altitude of 602 feet, while the qualification flight only got to 566 feet.

When I see this altitude difference, the first question is "why?" What changed? Because I sold the person the motors, my thoughts automatically gravitated to this question: "Were the motors somehow different?" I'd hate to think that we were the reason that they didn't get a successful qualification flight.

I really wanted to give the customer the benefit of any doubt that I might have had. While the customer was thinking that he got long delays, my initial reaction was that he got a motor that had lower total impulse because the rocket didn't go as high as the practice flights.

At this point, I said to myself that I better dig into this a bit more. I better start from the beginning and see if the customer was correct about the delay time being too long. If that was the case, what would happen to the flight? I started playing a picture in my mind of a rocket with a long delay.

The mental picture showed a rocket that arced over in the sky and was coming down when the parachute opened (see Figure 3). Since it was lower in the sky at ejection,

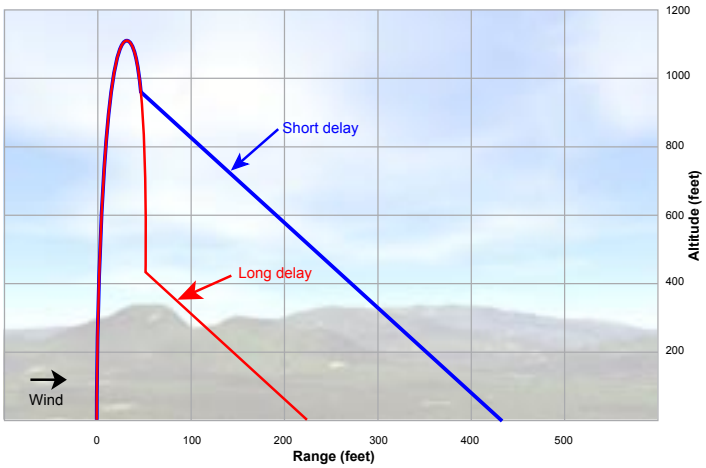

Figure 3: A rocket with a longer delay will arc over more and will be back down on the ground quicker.

it would stand to reason that it wouldn't have as much hang-time in the air. This would be consistent with what the customer had reported, since the team's total duration aloft was lower.

Do we have the necessary data to check this hypothesis? Fortunately yes. The altimeter data can be used to check the delay time.

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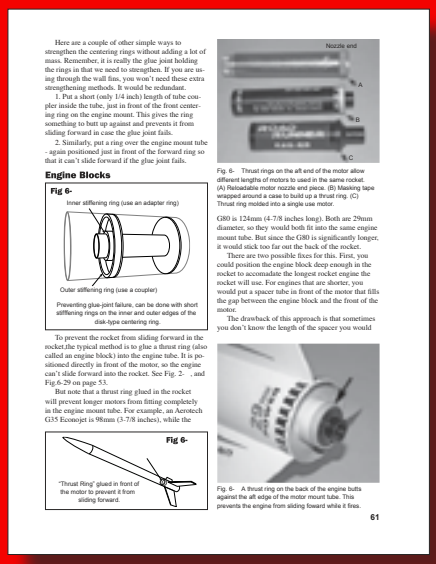
Model Rocket Design And Construction



Here are a couple of other simple ways to strengthen the centering rings without adding a lot of mass. Remember, it is really the glue joint holding the rings in that we need to strengthen. If you are using through the wall fins, you won't need these extra strengthening methods. It would be redundant.

1. Put a short (only 1/4 inch) length of tube coupler inside the tube, just in front of the front centering ring on the engine mount. This gives the ring something to butt up against and prevents it from sliding forward in case the glue joint fails.

2. Similarly, put a ring over the engine mount tube - again positioned just in front of the forward ring so that it can't slide forward if the glue joint fails.

Engine Blocks

Fig 6-

Inner stiffening ring (use an adapter ring)

Outer stiffening ring (use a coupler)

Preventing glue-joint failure, can be done with short stiffening rings on the inner and outer edges of the disk-type centering ring.

To prevent the rocket from sliding forward in the rocket,the typical method is to glue a thrust ring (also called an engine block) into the engine tube. It is positioned directly in front of the motor, so the engine can't slide forward into the rocket. See Fig. 2- , and Fig.6-29 on page 53.

But note that a thrust ring glued in the rocket will prevent longer motors from fitting completely in the engine mount tube. For example, an Aerotech G35 Econojet is 98mm (3-7/8 inches), while the

Fig 6-

"Thrust Ring" glued in front of the motor to prevent it from sliding forward.

Nozzle end

A

B

C

Fig. 6- Thrust rings on the aft end of the motor allow different lengths of motors to used in the same rocket. (A) Reloadable motor nozzle end piece. (B) Masking tape wrapped around a case to build up a thrust ring. (C) Thrust ring molded into a single use motor.

G80 is 124mm (4-7/8 inches long). Both are 29mm diameter, so they would both fit into the same engine mount tube. But since the G80 is significantly longer, it would stick too far out the back of the rocket.

There are two possible fixes for this. First, you could position the engine block deep enough in the rocket to accomodate the longest rocket engine the rocket will use. For engines that are shorter, you would put a spacer tube in front of the motor that fills the gap between the engine block and the front of the motor.

The drawback of this approach is that sometimes you don't know the length of the spacer you would

Fig. 6- A thrust ring on the back of the engine butts against the aft edge of the motor mount tube. This prevents the engine from sliding foward while it fires.

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Sherlock Holmes Using Altimeter Data

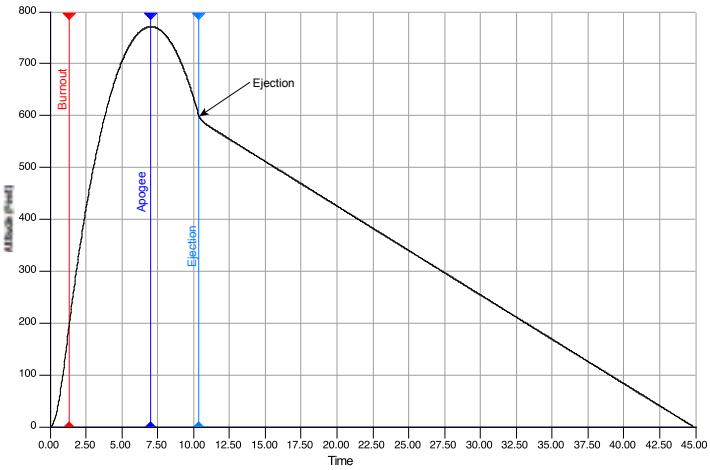

Figure 4: RockSim plot of a rocket that uses the F39-9 engine. Note that ejection occurs a little bit after 10 seconds.

Since I'm so familiar with RockSim, the altimeter data plot reminds me of the type of plots from RockSim (see Figure 4). By comparing these two types of plots, maybe they can help us to pick off when the ejection occurred during the real flights.

From Figure 4, you can see that the slope of the line makes an abrupt change when the parachute is deployed (at ejection). Compare this to Figures 1 and 2. You can also see this same abrupt change in the slope of the line. So we can easily tell exactly when during the flight the ejection charge deployed.

Now just compare Figures 1 and 2. Find when the ejection occurs on those two charts. I can see that ejection, in both cases, occurred a little after 8 seconds. What does this mean?

The fact that both motors fired their ejection charges at approximately the same time tells me conclusively that the "delay" is not the problem with the qualification flight. In other words, the flight shown in Figure 1 does not use a longer (nor a shorter) delay then the official qualification flight shown in Figure 2.

What else could cause the shorter amount of time-aloft?

My first guess was that the TARC team changed parachute sizes between flights. But there was no reason to do this. They had a perfect time-score the first time, so why would they change it?

In case you're interested, it is easy to check by looking at the altimeter data. We talked about this before in *Peak-of-Flight Newsletter #187* (http://www.ApogeeRockets.com/education/newsletter187.pdf). When you read it, you'll see how to calculate the rate of descent of the rocket by calculating the slope of the line after the ejection charge fires. I haven't done it for these flights, but it looks like it will be fairly close. That indicates that the same diameter parachute was used in both flights.

We've eliminated the delay as being the difference in the two flights, as well as the parachute size. That gets me back to my first thought. Was the total impulse lower?

I don't think that this is likely. For one thing, they are composite propellant motors, and these are usually very consistent from a performance standpoint. The F39 motor as tested by the NAR has a very low standard deviation of 0.49 (to see what this means, see: http://en.wikipedia.org/wiki/Standard_deviation).

The F39 is also a 24mm diameter reloadable motor. If the grain was shorter than it was supposed to be, you'd know it when you went to assemble the motor. Additionally, I don't think it was likely that a wrong motor was substituted in the plastic bag containing the reload kit. Why? There are only two other "F" size motors that fit the RMS 24/40 case,

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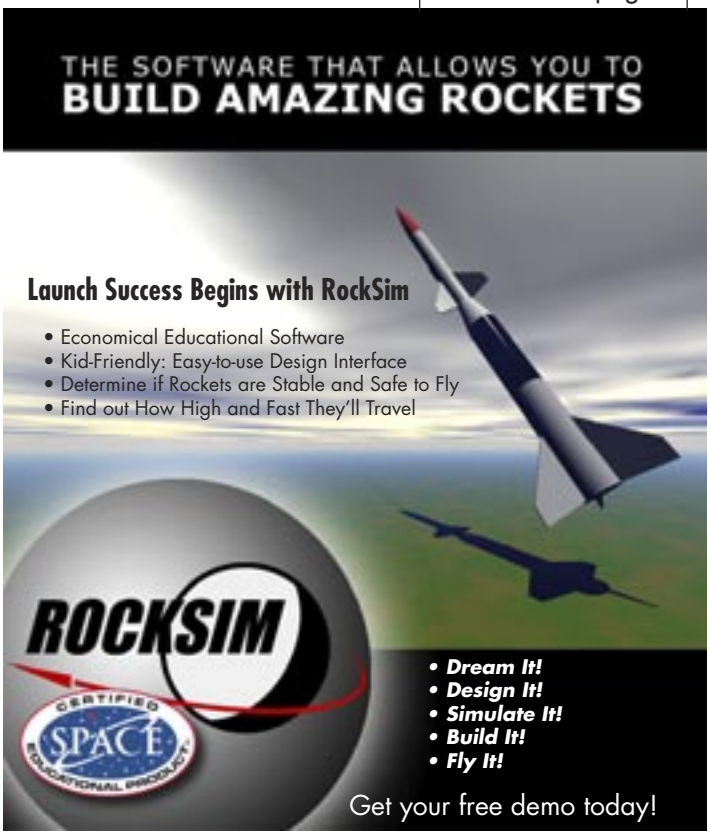

Continued from page 4

Sherlock Holmes Using Altimeter Data

and they are the F24W, and the F12J. The white lightening and the black-jack propellants are vastly different from the blue thunder propellant of the F39T. The user would definitely know that something was wrong when they saw either a bright white flame or a lot of black smoke coming from the motor. This was not reported in the customer's email.

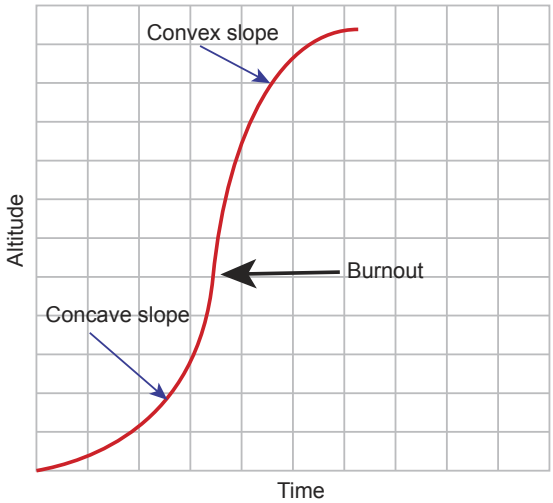

Figure 5: In this exaggerated view, you can tell when burnout occurs by finding the inflexion point on the altitude graph.

Although I don't have the raw altimeter data to run through Excel to generate an acceleration curve for the motor, I think it is possible to use the altitude curve from the altimeter to get an approximation of the burn time of the motor.

You can sort of pick off the burn time of the rocket motor by finding the point on the curve where it changes from a concave slope to a convex slope. Figure 5 shows an exaggerated version of what this looks like.

From the NAR data, burnout for the F39 should be around 1.33 seconds. We publish this on the Apogee Components web site too at: http://www.ApogeeRockets.com/Aerotech_Reload_Motors.asp. It is hard to pick off the exact point on the graph, but it is somewhere under two seconds. The F12 and the F24 motors have burn times that are both greater than two seconds.

Since we know the burn time, we can check to see which delay we have installed in the motor. The delay time is measured from engine burnout to when the ejection charge fires. We said previously that the ejection charge fired around 8 seconds. Subtracting the burn time of 1.33 seconds, we estimate that the delay is 6.66 seconds. That is within tolerances of the NAR for a 6 second delay. All this information confirms that we have a F39-6 motor installed in the rocket on each of the flights.

The one thing that can really affect the altitude of the rocket is the trajectory. The key piece of information that we don't have is what path the rocket took as it ascended upward. My opinion is that the qualification flight weathercocked much more into the wind than the practice flight. If everything else was the same (same motor, same launch angle, same weight, etc.), then it is logical that it didn't go *straight up.*

We can see from Figure 2 that the rocket was heading downward when the parachute deployed. This is consistent with a rocket that is weathercocking strongly into the wind. Figure 6 shows what weathercocking looks like, which is what I think may have happened on the qualification flight.

I believe this is the most likely scenario that explains the data, and why the flight was lower and landed sooner. Once I reached this conclusion, I emailed the teacher and explained what I had found. He was very cool about it, and said that he also thought this was a good learning experience for his students.

Incidentally, how do you correct weathercocking? My favorite suggestion is to impart a spin to the rocket. If you are interested in this or other techniques, see the book Model Rocket Design and Construction (http://www.ApogeeRockets.com/design_book.asp), or search the back issues of the Peak-of-Flight newsletters at: http://www.apogeerockets.com/Peak-of-Flight_index.asp.

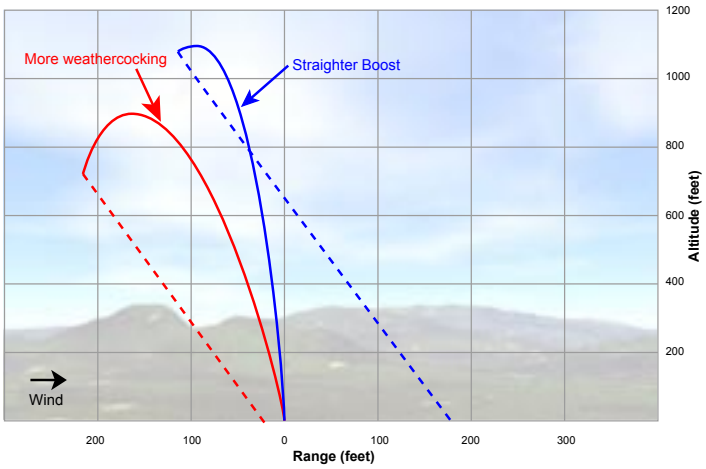

Figure 6: With more wind, the rocket will weathercock more and the altitude will be lower.

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Sherlock Holmes Using Altimeter Data

More Data Please...

If you talk to an engineer, they always want to see more data. In this case we were fortunate to have the altimeter data. As you saw, we gleaned a lot of information about the flight without ever having seen it.

If it were a perfect world, I would have like to have seen some other pieces of information. I'll mention them to you, in case you are a teacher and would like to do a similar type of detective game with your students. I would have like to have seen:

1. The RockSim design (http://www.ApogeeRockets.com/rocksim.asp) file for the model. From this you can see the general layout of the rocket and what flight simulations the flyer has already run. I want to know where the fins are on the rocket, so I can get an idea of how stable it will be.

I can also get an idea of the level of expertise of the modeler by looking at the RockSim file and the flight simulations. An expert modeler really understands the importance of running simulations and making sure the RockSim file contains good information. Experienced modelers are also going to put more effort into achieving quality construction of the rocket. Therefore, just by looking at the RockSim file, I can infer about the construction quality of the model itself based on the modeler's attention to detail in the design.

2. I'd like to see a copy of the *Apogee Flight Record* that the modeler used to record information about the flight itself. The *Apogee Flight Record* is used to remind the modeler which are the important things about the flight that should be written down. It contains things like weather conditions and launch angles. I urge every modeler to use it. The *Apogee Flight Record* is part of our free *Rocketry Reservoir for teachers*. It can be downloaded from: http://www.apogeerockets.com/Education_Pack.asp

3. A video tape of the rocket launch would also be helpful, but not the ordinary kind that most people take of a rocket launch. When people hold the video camera in their hands and follow the trajectory of the rocket, the video loses all of the background information. For flight testing, the video camera needs to be placed far back from the launch and should sit on a tripod. Once the camera is set up, don't move it. Leave it alone. The rocket will fly out of the picture frame very quickly, but that is OK. I only want to see how straight the rocket takes off, and at what speed. There are clues in the background (such as trees) that can give a point of reference when looking at the trajectory.

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With these three extra pieces of information and the altimeter data, I feel that I could diagnose with a high level of certainty what caused the problems with any rocket flight. I think you can and should develop this skill too.

Conclusion

I wanted to show in this article that there is a lot of information that can be found out about a flight by digging into the altimeter data from the PerfectFlite altimeter. No flight is 100% perfect, and we need to find out what prevented it from being perfect. That is our goal! You have to learn something from each flight if you want to be a better modeler. Building a quality rocket is only half of the qualification of being an expert; you must work on your flying skills too. See Newsletter #1 (http://www.ApogeeRockets.com/education/downoads/Newsletter01.pdf) which I wrote eight years ago. It is still relevent today!

While the TARC team who wrote me the letter didn't qualify for the TARC finals, I think they learned a lot of information that will make them a formidable competitor next year. I know that I'll be watching their progress.

Additional References:

To test your skills on how to interpret flight data, take the RockSim Challenge. It is a series of graphs that show different charts generated by RockSim. Your task is to determine which rocket and flight situation would create each kind of data. Download it at: http://www.ApogeeRockets.com/education/downoads/Newsletter23.pdf

It is important to also understand the thrust curves and motor certification paperwork. You can download NAR certifications at: http://www.NAR.org/SandT/NARenglist.shtml

About The Author:

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.

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EMRR REVIEW CORNER

Who's Who In Rocketry?

(Are you in the database?)

Angelo Castellano (Toronto, ON Canada)

Club Member of: NAR CAR TRA

Favorite Rocket: Sunward SkyBender

"I currently live in Toronto with my family.

"The bug got me into the hobby of model rocketry after watching the film October Sky with my 2 children. That led to a launch and further involvement in the hobby. I tend to make and fly model rockets. To me there in more enjoyment in building kits and flying. I personally don't like spending hours building a scale kit only to lose it on a flight.

"I am the Owner of Sunward Aerospace Group Limited which is a maker of high quality model rockets based in Canada. Sunward also makes a line of products for the Rocketeer and Hobby Stores.

"Other hobbies and interests include photography (35mm film kind), gardening, and many things on the geek side."

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Building Some Rockets To Celebrate The Completion of A Big Project

By Tim Van Milligan

The 3rd edition of the book *Model Rocket Design and Construction* is undergoing proof-reading right now. It is a big load off my mind that my part is complete. Writing and illustrating it was such big task that I have put everything else aside since January 1st so that I could get it done. I have to admit that I've been celebrating a little bit for the past couple of weeks by building a lot of rockets!

Actually it is work related, but it is the enjoyable portion that I rarely get to do. I'm currently building several models that we'll be selling in the Apogee Components web store. It is rare when I don't build at least one kit of every rocket that we sell. I want to know what kind of experience our customers will have when they build the rocket. Why? So that I can provide some advice that will make construction easier or more enjoyable. It is another thing that is unique about Apogee Components compared to other vendors.

My list of projects includes the Cosmodrome Rocketry Aerobee Hi (http://www.apogeerockets.com/Cosmodrome_Aerobee-Hi.asp) and Black Brant II (http://www.apogeerockets.com/Cosmodrome_Black_Brant_2.asp). These kits have a lot of hardware you'd find on hi-power kits, like quick links for attaching the parachutes. We do have these models in stock, along with the Cosmodrome Nike Smoke kit which you can see on the cover page.

Also on my "build" list is two kits from Mad Cow Rocketry: the 4-inch diameter Patriot Missile, and the 2.6 inch diameter Bomarc. The Patriot is going to be the first truly high-power kit that we'll have at Apogee, as it uses 38mm diameter high-power motors. Both these models are in the paint booth right now, and hopefully I'll be able to finish them up by the end of next week.

We're also now stocking the PerfectFlite Staging Electronics timer (http://www.apogeerockets.com/Staging_Timer.asp). It is extremely useful for staging composite-propellant motors. And personally, I really like the simplicity of the unit.

Right: Cosmodrome Aerobee-Hi kit with an electronics bay added so the rocket can be flown in two-stage configuration using composite propellant motors.