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NEWSLETTER

How to Excelerate Your Complex Rocketry Project

Tips for TARC teams to jump-start their rocket program

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ISSUE 224 DECEMBER 16, 2008

How to Accelerate Your Complex Rocketry Project

By Tim Van Milligan

There is a university just a few miles up the road from us here at the Apogee Components World Headquarters, where a team of students are working on a significant rocket project. The goal of the rocket is to reach 100 Km (330,000 feet), which is what NASA defines as "space." It is a lot like many of the high power projects that many of our readers are also working on. It also has a lot of similarities to the TARC project that is now in full swing with middle and high school students.

The only difference is that this university is the United States Air Force Academy, and the students are called "cadets." Other than that one little fact, it is so close to what we hobbyists are doing, that I thought I'd write about it in this issue. It is my goal that we can learn something from them that will make your own projects more successful and get them off the ground a lot faster.

Before I get too far into this though, I'd like to say that the cadets (and hence the military) are learning a LOT from us hobbyists. I was shocked to find this out. But when I saw their rocket and started looking at the components they were using, I saw a lot of familiar names that you would recognize too. It seems like the cadets got a hold of one of the rocketry magazines and started ordering their components based on the advertisers. Without naming names (because they aren't advertising in this newsletter – *HINT, HINT*), they were buying the same off-the-shelf components that you would buy for your high power flights. This includes things like: flight computers, sensors, igniters, tracking electronics, shear pins, recovery devices, airframe tubes, and of course our own RockSim (www.RockSim.com) and RS-PRO software (www.ApogeeRcokets.com/RS-PRO.asp).

It makes sense that the Air Force cadets would use consumer products, because they have been tested by you and other hobbyists in thousands and thousands of launches and are proven to work great!

For my part, I got word of their project early this fall, when Tony O'Shea, one of the Senior cadets, had some questions about running RS-PRO simulations. I got grilled about everything dealing with high-power launches. I could tell he had a good case of the "rocketry bug" and that he was eager to learn as much about rocketry as he could. Like many of our customers, he found a lot of good information on the Apogee Components web site. But I pointed him to a few other web sites where he could further his education.

Figure 1: Mission patch created by the Air Force Academy cadets.

About a month ago, the astronautics instructor invited me to attend the Critical Design Review for the cadets, which occurred on December 10. A Critical Design Review (CDR) is a meeting where the rocket design is critiqued by knowledgeable outsiders. They try to determine if the rocket has a good chance of meeting all of its performance objectives, and will do so safely and within the allowable budget.

If the rocket design passes muster, the students are given the go-ahead to actually build the rocket. If it fails, they head back to the drawing board.

I think the concept of a critical design review is something that we as rocketeers might adopt for our own complex projects. And I think that teachers involved in the TARC program should look at it too. It is a "test" that could be used to help determine a student's grade.

I'll use TARC as an example to explain the design process.

1. First, the students are given the mission objective. In the case of TARC 2009, it is to launch a single-stage rocket carrying a raw egg (laying on its side) to 750 feet, and to get it back down to earth in 45 seconds without cracking

Continued on page 3

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Continued from page 2

Accelerate Your Complex Rocketry Project

the egg. In the case of the Air Force cadets, it is to launch a simple payload that measures 3-axis rotation to 100 Km and then recover the payload on the ground.

2. Now the students are told to do their research and come up with a design that can meet these objectives. Research is a big part of the design process. For both TARC and Air Force Academy students, just learning about rocketry is a huge part of that task. Everyone needs to know the rudimentary principles of rocketry, so both groups usually end up building some simple rockets.

3. At this point, the students make a BIG realization. *Rocketry is complex.* It encompasses a lot of different disciplines. It looks deceptively simple, but in reality there is a lot that has to be taken into account. There is not only propulsion, but also the design of the airframe, the payload, onboard electronics, flight simulations, ground support equipment, recovery systems, logistics in ordering the components, securing the launch field, interfacing with government agencies, and finding out the safety ramifications of the launch. It is really because of this complexity that rocketry is such a great teaching tool.

The tasks of launching the rocket have to be broken down into compartments, where someone becomes responsible for completing that section of the work. Now the overall objective has become a team project instead of an individual's task (that is why teachers love rocketry). The students break themselves up into sub-groups that go about tackling these obstacles that stand in their way. Again, "research" plays a huge role in the process.

In the case of the Air Force Academy cadets, they started by finding out what the prior year's class had done. That is pretty smart. Why reinvent the wheel? They simply looked to see how they divided the tasks up, and then copied what they did.

For the TARC participants, there is also plenty of data available. If you are the first group to build a TARC rocket at your school, your first step should be to contact one of the NAR mentors in your area. They are a goldmine of information.

Then start contacting some of the vendors (like Apogee Components). That is what Cadet Tony O'Shea did, and it probably saved him hours and hours of work.

4. The team leader is also chosen, and it is their job to make a schedule and budget and then make sure everyone sticks to it. It may sound fun to be the leader, but many times it is an unpleasant task of being a disciplinarian who's job it is to light a fire under the other team members. A lot of tension starts to take place in the group, and a lot of anger can be directed at the leader. So my suggestion is to choose your leader well, and from the first meeting decide as a group what punishments should be handed out if team members aren't pulling their own weight. Again, don't try to reinvent the wheel, find out what strategies teams used in the past to overcome personal conflicts within the group.

5. The critical design review should be one of the steps

Figure 2: General layout of the Falcon 7 launch vehicle.

Continued on page 4

Continued from page 3

Accelerate Your Complex Rocketry Project

before building the rocket. Most people in TARC don't realize it, but this step will help save them time. If you haven't scheduled a CDR yet, I highly recommend that you put it into your schedule as soon as possible. I guarantee it will accelerate your progress to light-speed velocity.

At the Air Force Academy Critical Design Review that I attended, the group of cadets made a power-point presentation describing their project. Each individual got to stand up and talk about their part on the team.

On the other side of the table sat a group of teachers, mentors, and industry experts. Most were Air Force officers of the rank of Major or higher. I would estimate there were approximately 65 people in the room to grill the team of 25 students.

Realize this important fact. The teachers, mentors, and experts in the room wanted to see the students succeed. They weren't there to tear down their work. They know that the overall objective isn't the rocket or the mission, it is the learning experience (i.e., how to tackle a complex problem while working as a team). For the United States Air Force, launching a rocket to 100 Km is simple stuff. The mission of the Air Force Academy is to produce "leaders." I see the mission of TARC to be very similar, and I'm pretty sure all the TARC mentors realize this too.

As I arrived at the Air Force Academy for the Critical Design Review, I was a little in awe of the atmosphere. There I was sitting next to a bunch of extremely intelligent

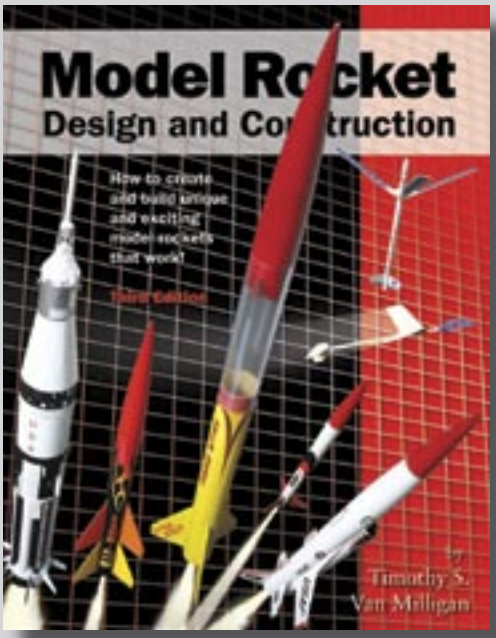
Figure 3: The upper portion of the Falcon 7 rocket is unpowered. That makes it a "boosted dart."

and accomplished Officers. I didn't know their procedures or protocol, so I just sat and watched for a while.

Then I realized what was going on. As I mentioned, they weren't there to grade the students, they were there to help them. The first way they helped was by quizzing them on their knowledge of all the sub-systems involved in the project. They wanted to see if the students had done their homework, which consisted of book-work and doing historical comparisons against prior rockets. This may not seem like "helping," but it is. You have to have a knowledge foundation upon which you can move forward. Otherwise you'll spend your time trying to reinvent the wheel.

To me, it seemed just like the examination a rocketeer

Continued on page 5



Model Rocket Design and Construction

By Timothy S. Van Milligan

New 3rd Edition Now Shipping!

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.

For more information, and to order this hefty book, visit the Apogee web site at: www.ApogeeRockets.com/design_book.asp

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Continued from page 4

Accelerate Your Complex Rocketry Project

would experience when going for their level 3 high-power certification. The questions were very similar. I started writing them down, because I wanted to know what the military experts thought was important. Here are some of them:

- How do you know your fins will stay on during the high speed flight?
- What is the burnout velocity of the rocket?
- When you did your sims, did you use nominal (best case), or conservative uncertainties (worst case situation)? Why?
- How do you know that data you have is going to be realistic? In other words, how did you verify as accurate your simulation software?
- In what way is your rocket different from what has been flown in the past?
- How are the flight events in your rocket triggered?
- What redundancy systems do you have?

When the reviewers spotted a potential flaw in the design – and I say "potential" because there is no way for them in such a short time to know for absolute certainty if it is a flaw – they would ask them additional questions about it. By asking a few non-threatening questions about a specific area of the rocket, they were pointing out to the cadets that this is an important area where they should pay some extra attention to. I suppose that is why they were promoted in rank, because they had some smarts about them.

I think my readers are smart (you wouldn't be reading this if you weren't smart, would you?) and you probably are already doing this kind of questioning for TARC participants. If so, keep it up.

One question in particular would really highlight to the students that you think this may be a design flaw without trying to redesign their rocket for them. That question is: *"Can you think of a way to test this prior to building the rocket?"*

The Air Force Academy cadets had planned on a lot of sub-system tests to confirm all their assumptions about how they expected things to work. This included things like

Continued on page 6

Continued from page 5

Accelerate Your Complex Rocketry Project

telemetry tests to make sure they could receive data back from the rocket, and an ignition and static firing test of the rocket motor to make sure their new igniter design was going to work properly. They were even planning a series of wind tunnel tests to make sure their predictions on drag coefficients were accurate.

Part of the Critical Design Review process was for the testing schedule to be scrutinized too. The military officers knew from their own experience that things often don't work the way you planned. Tests often get delayed because of bad weather or late arriving parts. What they were looking for was how the students were going to adapt to these unforeseen difficulties.

The Officers also helped the students by suggesting a test or two to confirm that the design decisions that the students made were sufficient. They didn't suggest a redesign, but they did request that a test be performed. I'm not sure who had the authority to mandate a test, but I'm pretty sure that it was the department heads or the actual class instructor. The cadets were given a lot of freedom to set their own tests, and I suspect that other than for safety aspects, they could ignore a request that they perform a test.

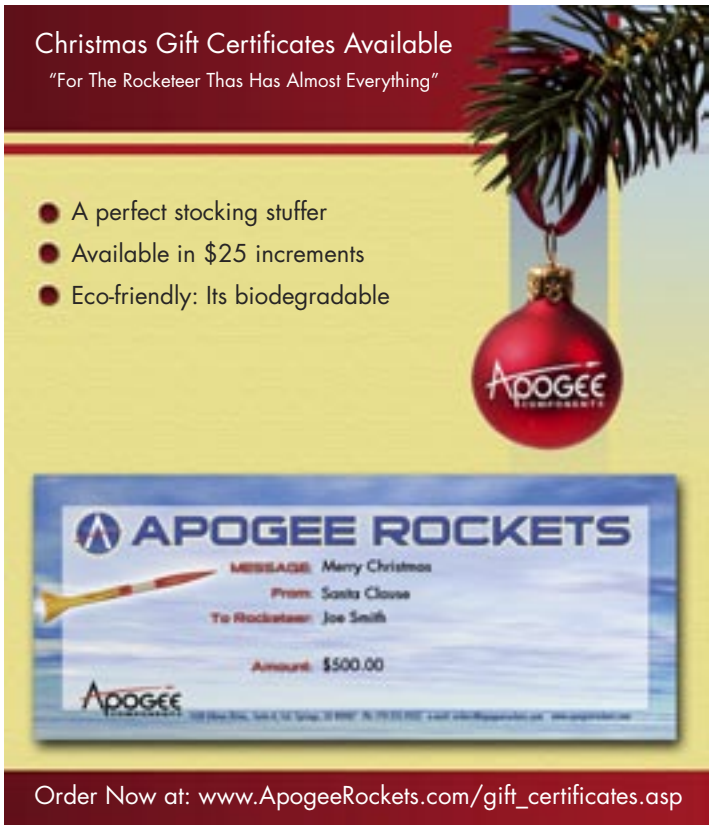
I know many TARC teams do some rudimentary tests, such as testing the padding on their egg capsule to make sure the egg will survive a hard landing. If you are in TARC, you might want to diagram out the sequence of events in your rocket's flight to see where you might perform some sub-system tests. For example, you might want to test several different techniques of folding your parachute to find the one that is most reliable for your rocket.

But before you go out and do these tests, make a schedule to be sure you have enough time to get all your tests accomplished before you do your qualification flight. You don't want to head into that last flight with some untested aspects of your rocket.

6. After the Critical Design Review, the students are allowed to start building their rocket. As mentioned previously, they still have some tests to perform, but they are far enough along that they can start building hardware.

7. Up until now, the students have not launched a fully equipped rocket. They may have launched some test flights, but not what is called a "full-up" rocket. That is a rocket with the actual payload mated to the rocket. They may have flown a rocket to test the recovery device, but not with all the parts that are expected to fly on the actual mission.

Continued on page 6



Continued from page 6

Accelerate Your Complex Rocketry Project

That is the goal, to work to that point where everything is put into the rocket for a real full-up test.

In TARC, you probably should not fly the expensive altimeter until you have verified that your egg capsule works properly. Kinda makes sense, doesn't it?

8. If the sub-system tests are progressing well, the students enter the next phase. That is the Flight Readiness Review.

A Flight Readiness Review (FRR) is similar to the Critical Design Review. A group of outsiders will come in and look over all the test data to verify that the students have a good chance of succeeding with their actual launch.

The students will again present all their data from their subs-system tests to show how it matches the predictions that made previously.

Again, there will be some amount of time devoted to looking at the student's schedule. How well have they used their time, and do they still have enough time to complete the final launches?

At this point, the observers will also ask to see the final written countdown procedure. It is unlikely that they will be able to point out tiny flaws. But by seeing the procedures the students have made, they will have some peace of mind that the students are looking deep at the problem. The contingency plans they come up with will receive a lot of attention. They'll be asked things like: "What will you do if the rocket doesn't launch when you push the button?" By doing this, they'll make sure that the students are prepared for the worst case situation.

I suppose that one question that will be asked of the students is: *"What have your learned so far?"*

That is the big and final question. If the student doesn't have a good answer, the "real mission," which if you recall is to educate the pupil, may have been a failure.

9. After the Flight Readiness Review, the students are given the go ahead to finish out their plan to launch the full-up rocket.

For the Air Force Academy cadets, that means they can crate up their rocket and ship it to the launch facility at White Sands, New Mexico. For TARC, this is the go-ahead to perform the last series of tests to prepare for the qualification attempt.

Any mishap at this point will jeopardize the success of the launch. Last year, the prior cadets discovered that their rocket engine had a crack in the rocket propellant after they shipped it to the launch site. This was something that they had not planned for, and they had no choice but the scrub their launch.

For TARC, a major mishap would be something like cracking the altimeter in a test flight. Unless you have a back-up device, it would add a major time-hit to the schedule to have to order a new one..

Conclusion

Continued on page 8

Aligning Multiple Fins

As found on EMRR, contributed by Geoffrey Kerbel:

This is a featured tip for holding and aligning multiple fins on a rocket body that makes sure they are parallel to each other and aligned straight with each other and the body tube they are on. It can be used for flush mounted fins as well as TTW fins.

The following pieces are needed:

Small and large paint stir sticks (they can be had at Wal-Mart in the paint department. The small ones are free and the large ones are only about .40. Get the straightest ones you can find.)

Clothpins or spring clamps (Sears has a really nice set of plastic ones that have flexible ends and light clamping pressure for $10.)

The most important part is that one set of fins has to be on the rocket and firmly set up before using this method. It doesn't matter if the front fins or the back fins are on first, only that the ones you clamp onto are set up and firm. Take extra care on the first sets alignment to the body and themselves and the others will be dead on for nice straight flights.

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Continued from page 7

Accelerate Your Complex Rocketry Project

The purpose of this article was to show how professional groups run a complex rocket launch. While the purpose of the extra meetings may not seem apparent and a waste of time, they will actually help you be more successful and get things done quicker. Hopefully, we can all learn a little bit that will help us to make our own launches more successful.

TARC Tips

For more information on how to succeed at the TARC competition, check out Peak of Flight Newsletter #209 (www.ApogeeRockets.com/Education/Downloads/Newsletter209.pdf).

We also have an exclusive tip sheet called "TARC Tactics" that goes more in depth. You can read about it and get the information to request your free copy at: www.apogeerockets.com/team_america_challenge.asp

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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