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APOGEE PEAK OF FLIGHT NEWSLETTER

Maximum Simulation Accuracy for RockSim

By Tim Van Milligan

One question I get often about RockSim is: *"How come the actual measured altitude of my flight is different from RockSim's prediction? I know I input everything with extra care and precision -- so why the difference?"*

This is an easy question for me to answer. The blame goes to that mystical parameter know as the "Coefficient-of-Drag." No matter what computer software you use to predict the altitude and performance of your model; the Coefficient-of-Drag (abbreviated: C_d) is that last bit of information that is still somewhat of a estimation.

The C_d of the model takes into account many different but related components. These include:

1. Shape of the rocket -- known as "Form Drag." This also must include changes to the C_d when the model flies at some angle-of-attack.
2. "Skin Friction Drag" which is determined by the relative smoothness of the model.
3. Induced Drag, which occurs whenever the fins have to create lift to restore the rocket to a straight path.
4. Interference Drag -- which occurs because parts cause the airflow to behave in erratic patterns.

All these play an important role in determining the overall drag of the model. And I would recommend that you read the third chapter in the book: *"Model Rocket Design And Construction."* You can order the book on my web site at: http://www.apogeerockets.com/design_book.asp

That chapter (called: *"Drag Reduction and Aerodynamics"*), explains the different components of the drag, and how you can minimize them. By doing so, you can make your model fly higher and faster. Hopefully, you'll come to realize how complex this C_d number really is.

The big problem for our computer simulations is that the C_d of the model is not a constant number. We often treat it like it is static and unchanging; and give it a fixed value. Traditionally, we start with C_d = .75, but sometimes it is higher, and sometimes it is lower.

Overall, the C_d is dynamic, and constantly changing throughout the flight. As listed in the first component (Form Drag), the C_d changes whenever the model changes angle-of-attack. The "Induced Drag" component also changes as the rocket changes angle-of-attack. Similarly, the "Interference Drag" changes too.

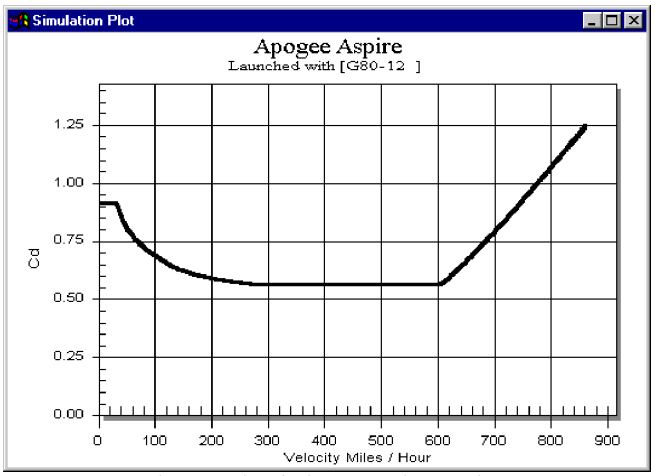

Figure 1: The Cd of the rocket changes as the speed of the rocket changes.

But that is not the end to the problem. To compound the situation, the Coefficient-of-Drag changes as the velocity of the model changes. That makes it speed dependent too. Since our models are constantly changing speed: speeding up on the launch rod, and slowing down after motor burnout; the C_d is going through some pretty wild fluctuations.

But it is much more complicated than this. If there is any cross-wind as the rocket flies, it makes the rocket travel at an angle of attack. This changes the drag on the rocket too, as can be seen in Figure 2.

The way we try to predict the C_d value(s) is with a procedure called the "DATCOM" method. If you ever read the Estes

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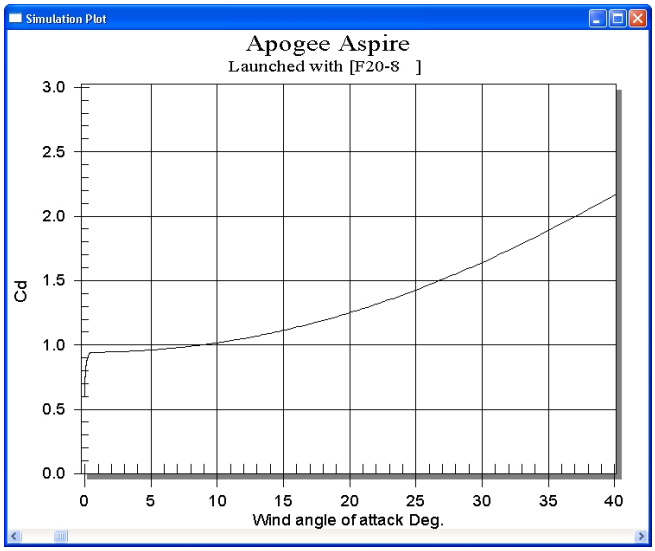

Figure 2: The C_d changes with angle of attack.

booklet TR-11, *"Aerodynamic Drag of Model Rockets"* by Dr. Gerald Gregorek, you'll get a feel for the types of procedures that are involved in using this complicated method.

RockSim uses this method, and it was further enhanced by the data available from MIL-HDBK-762, *"DESIGN OF AERODYNAMICALLY STABILIZED FREE ROCKETS."*

RockSim also uses additional data presented in the book *"Fluid Dynamic Drag."* You can find a link to order that classic book from:
http://www.apogeerockets.com/education/rocket_aerodynamics.asp

Basically what computer programs like RockSim have to do is several things. First, they must compute the basic C_d value of the various components of the model that affect form drag. Then it adds in the interference drag and skin friction drag. It has to do this at each different velocity the rocket is traveling at. Finally, if the rocket is hit by any wind, it is flying at an angle-of-attack, so it must try to calculate the additional drag component.

RockSim, in my opinion, being one of the best programs; has to perform these calculations hundreds of times per each second the model is flying. It is a difficult task. There are several places where it starts to break down though...

The worst case would be for really odd-ball designs. Things like asymmetric configurations (more fins on one side than the other); and any projections sticking off the side of the model. Also in this category are strap-on pods, tube fins, ring tails, and drag fins (like the Zoom Broom configuration models). This is one reason we've had a hard time trying to allow these types of configurations into RockSim. The data for these types of configurations is pretty scarce; and we're not sure how accurate it is anyway.

Another problem occurs at very low speeds. Here, determining the C_d is pretty much a real guessing game. Under 30 miles per hour, the classical DATACOM method of determining the C_d value are mostly useless. Fortunately, the model doesn't typically spend a lot of time flying at low speeds. But RockSim has to do something, particularly just as the rocket clears the launch rod (an important point in the flight). So it uses a fixed value at low speeds. Otherwise, it could be using a C_d value so high, that the rocket may not leave the launch pad.

You may have seen the user defined parameter on the "simulation" tab of the Application Settings controls called "Minimum C_d Prediction Velocity." This value controls how RockSim predicts C_d's at low speeds. At speeds lower than this value, RockSim uses a constant value for the C_d. That value is whatever it calculates at the minimum velocity. For example, assume the minimum C_d Prediction Velocity is set at 30 miles per hour. If the C_d predicted by RockSim is .315 at 30 miles per hour, then this is the same value it will use at speeds below 30 miles per hour.

The alternative to this complicated method is to use a static number throughout the entire flight of the rocket. A lot of other simulation softwares do. But you know what; that ain't bad. It is better to use something than nothing at all.

Using the DATCOM method is always going to have its drawbacks. But it is a very good starting point. As you can see, predicting the C_d of the model is as much "artistic technique" as it is hardcore "science."

Are there ways to increase the simulation accuracy? Yes. There are three techniques you can use.

The first way is to build the model, and put it into a wind tunnel. Then you can measure the actual forces acting on the model. This is the best and most accurate way.

In a wind tunnel, you can run it through many angles-of-

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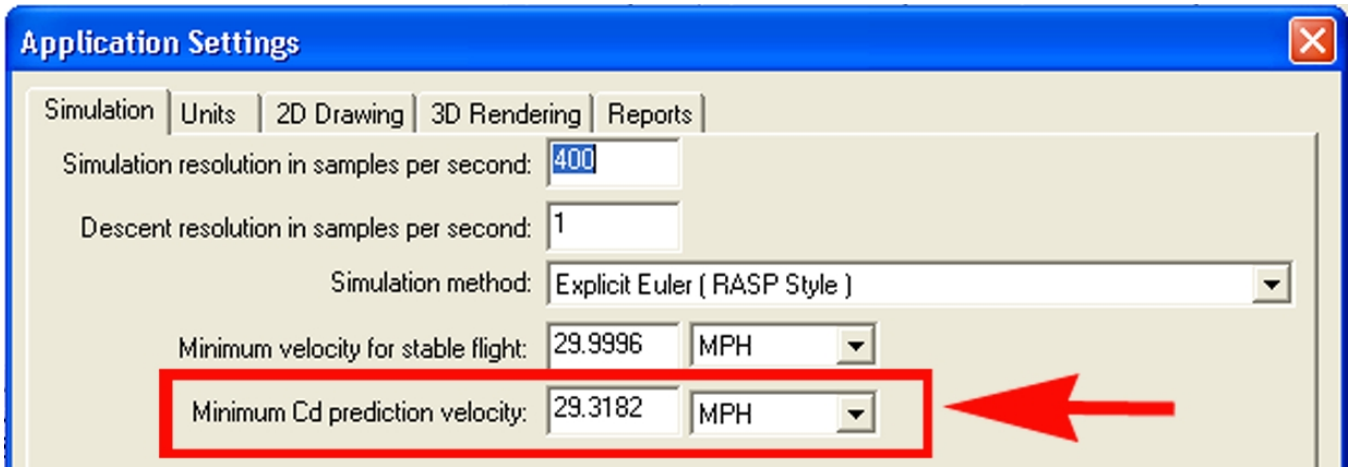

Figure 3: Since Cd at low values can be misleading, RockSim uses a minimum speed to calculate the number.

attack, and see how the C_d changes. The drawback of this method is that it is slow and expensive. We can't make too many changes to the configuration of the rocket without causing a lot of delays in building the final model.

The second method is similar; but this time, we'll actually fly the prototype design and use instrumentation or tracking techniques to try to 'back out' the forces acting on the model. A lot of folks are using accelerometers and altimeters in an attempt to do just this. From this flight data, you can theoretically go back into the simulation software and predict how the rocket will fly on other motors.

Again, the drawback is that it is a slow and expensive method; which doesn't allow for massive changes in configuration of the rocket. It can be a lot more expensive than wind tunnel testing, because you have to burn up a lot of motors to get enough data. Hopefully, you don't crash the rocket, and lose your instrumentation equipment.

The final method is called "Computational Fluid Dynamics." This a branch of aeronautics that tries to use a computer to find the actual flight forces acting on the rocket. I'm sure you've seen those colorful pictures created by NASA of the Space Shuttle flying at different speeds. The nifty colors represent the velocity or pressure patterns of the air flowing around the rocket. In this way, you can see the air as it flows past the rocket.

In conclusion, the limiting factor on the accuracy of the flight simulations comes down to the Coefficient-of-Drag of the rocket. It is a complicated problem, but it is simple for us to point the finger at it. But you probably knew that...

About the Author:

Tim Van Milligan 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 the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.