ISSUE 34

APOGEE

PEAK OF FLIGHT

NEWSLETTER

What's the Maximum Weight a Motor Can Lift? Part 1 of 2

By Tim Van Milligan

In the last issue, we talked about some of the factors that make it hard to determine the maximum liftoff weight that a rocket motor can launch. This time, we'll discuss some of the many different guidelines that modelers have used to solve this problem.

I've seen 5 different methods. They all seem to work OK. So I'll let you decide for yourself which method you'd like to use.

Probably the oldest guideline I've come across is a simple one. It is to divide the maximum thrust of the motor by 4.

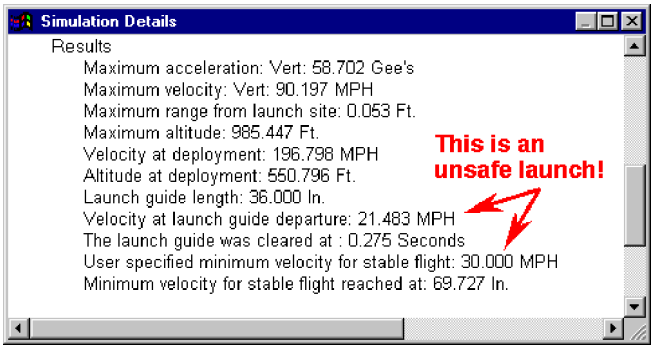
The advantage of this proceedure, and the next one is that you can somewhat predict the maximum lift-off mass prior to running any simulations.

Method 2, from Bob Dahlquist, is similar to the first method. But this time, you don't use the maximum thrust. You use the average thrust produced during the first part of the burn -- while the rocket is still accelerating on the launch rod. Once you know this, the max lift-off weight is at least 10 times less than this average initial thrust. The proceedure for finding this maximum lift-off mass can be found in Bob's article called *Wind Caused Instability* at: http://www.apogeerockets.com/education/instability.asp

In the next three methods, you'll need to perform multiple simulations to find the maximum lift-off weight. That is, you perform a simulation, and if it works, you add more weight. Then continue this routine until you reach the point where the simulation fails.

If you follow the discussions on r.m.r. you'll recognize method number 3. It is posted by long-time modeler Leonard Fehskens. In this method, the maximum liftoff mass is determined by the minimum lift-off velocity. Basically, the rocket must leave the launch rod with sufficient speed for stable flight.

This method is easy to perform using a program like RockSim; because it will compute the liftoff speed as the rocket clears the launcher. It compares it to the minimum lift-off speed input by the user. If it does not meet the minimum speed, the program will automatically tell you something is wrong (see the detailed flight report for the simulation).



The simulation details from RockSim can give you the results you need to see if the rocket is leaving the launch pad fast enough to be stable.

The main drawback of these first three methods is that none of them take into account the delay of the motor. For example, they don't differentiate between a D12-3 and a D12-7. But we should all know that the shorter delay can (and should) be used in higher weight rockets. The next two methods do take into account the delay of the motor.

The fourth method I've used many times. It has been around a long, long time. You've probably used it too. It is the brute force computer simulation method. Basically, you perform the computer simulation and see if the rocket is still going up when the ejection charge fires. If it the rocket is still traveling upward, you add some weight and repeat the simulation. This continues until the rocket deploys at or within one second of apogee. It can take numerous simulations if you didn't pick a good starting point. But eventually, by running

APOGEE COMPONENTS
1130 Elkton Drive, Suite A
Colorado Springs, CO 80907 USA
www.ApogeeRockets.com
orders @ApogeeRockets.com
phone 719-535-9335 fax 719-534-9050

enough simulations, you'll get an answer.

The drawback to this is that it does not take into account the speed at which the rocket leaves the launcher. On low thrust rockets, it could very well be traveling below the minimum safe speed when it leaves the launcher. This becomes a major concern if there is any wind in the simulation. Then the rocket will weathercock, and could actually go horizontal.

This is where RockSim really comes in handy. You can add wind to the simulation, and still perform this brute-force method. With wind, we know the rocket is going to weathercock, and therefore shorten the delay required. Eventually, we'll find the maximum weight the motor can lift in the rocket for the particular delay.

The fifth and final method is another brute-force proceedure, and is basically similar to the forth method. But this time, we're given some additional guidelines.

The guidelines will define what is a safe flight.

Long-time rocketeer; Trip Barber, came up with a simple analytical criteria for evaluating potential safety of a motor/rocket combination. He was attempting to find out if motor manufacturers were giving good guidelines in their "Maximum Recommended Lift-Off Weights" (M.R.L.O.W.). The proceedure comes from his report: *"REPORT TO THE CHAIMAN, NAR STANDARDS & TESTING COMITTEE ON A SAFETY ANALYSIS OF MANUFACTURERS' RECOMMENDED LIFTOFF WIEGHTS FOR MODEL ROCKETS,"* By Trip Barber, NAR 4322 (January 9, 1996).

In his report, he defines two safety guidelines:

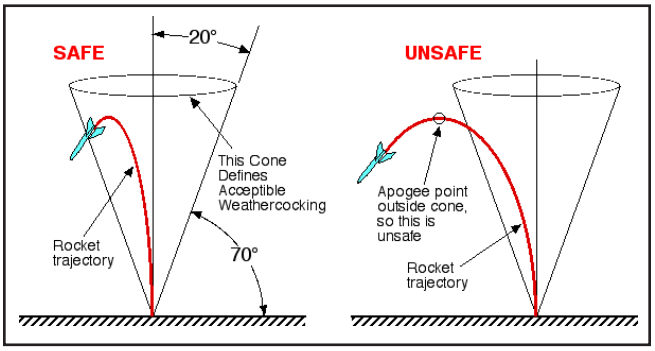
First:: "Ejection Altitude as a percentage of apogee altitude. Rockets which go 'over the top' and fall to below about 50% of apogee or 10 meters of altitude (whichever is lower) before ejecting are too heavy or too draggy for the motor/delay combination used." ... "Rockets ejecting prior to reaching peak altitude could possibly lift a heavier rocket, if weathercocking is not a problem."

Second: "Weathercocking as a function of windspeed. The elevation angle from the launcher to which the rocket flies by apogee depends on the ratio of its early thrust (not necessarily average thrust) to its weight. Underpowered models move at low velocities and weathercock more severely in wind than those with a thrust-weight ratio sufficient to give them an adequate velocity at launcher exit. Rockets which weathercock to apogee elevation angles below 70 degrees (as measured from the horizontal) in a 10 mph wind, or rockets that "prang" with ground impact prior to ejection in a 20 mph wind, probably have an MRLOW that is too high."

The first guideline is pretty obvious. If you perform your simulation, and the rocket flies past apogee (peak altitude) and descends more than 10 meters prior to deploying its recovery device, then the weight of the rocket is too high for that motor/delay combination. The reasoning is probably that if the rocket is coming down fast, it is probably going to strip its parachute; leading to an unsafe condition.

It isn't obvious, but the second guideline is profound in its meaning. This is the first time that I've seen where we're given criteria to determine how much weathercocking is too excessive.

Trip Barber defines an inverted cone, with the point at the launch site. The half-angle of the cone is 20 degrees.



Trip Barber's guidelines are probably the best, because it clearly defines acceptible weathercocking.

As long as the apogee point of the trajectory stays within this cone, it is a safe ascent. If it also meets the first criteria, it would be a safe flight.

This method also works very well with dynamic stability features of RockSim. Just run the simulation, and find the range and altitude of the rocket at apogee (not deployment). If the range distance divided by the altitude is less than or equal to 0.363, then the flight falls within Trip's guideline.

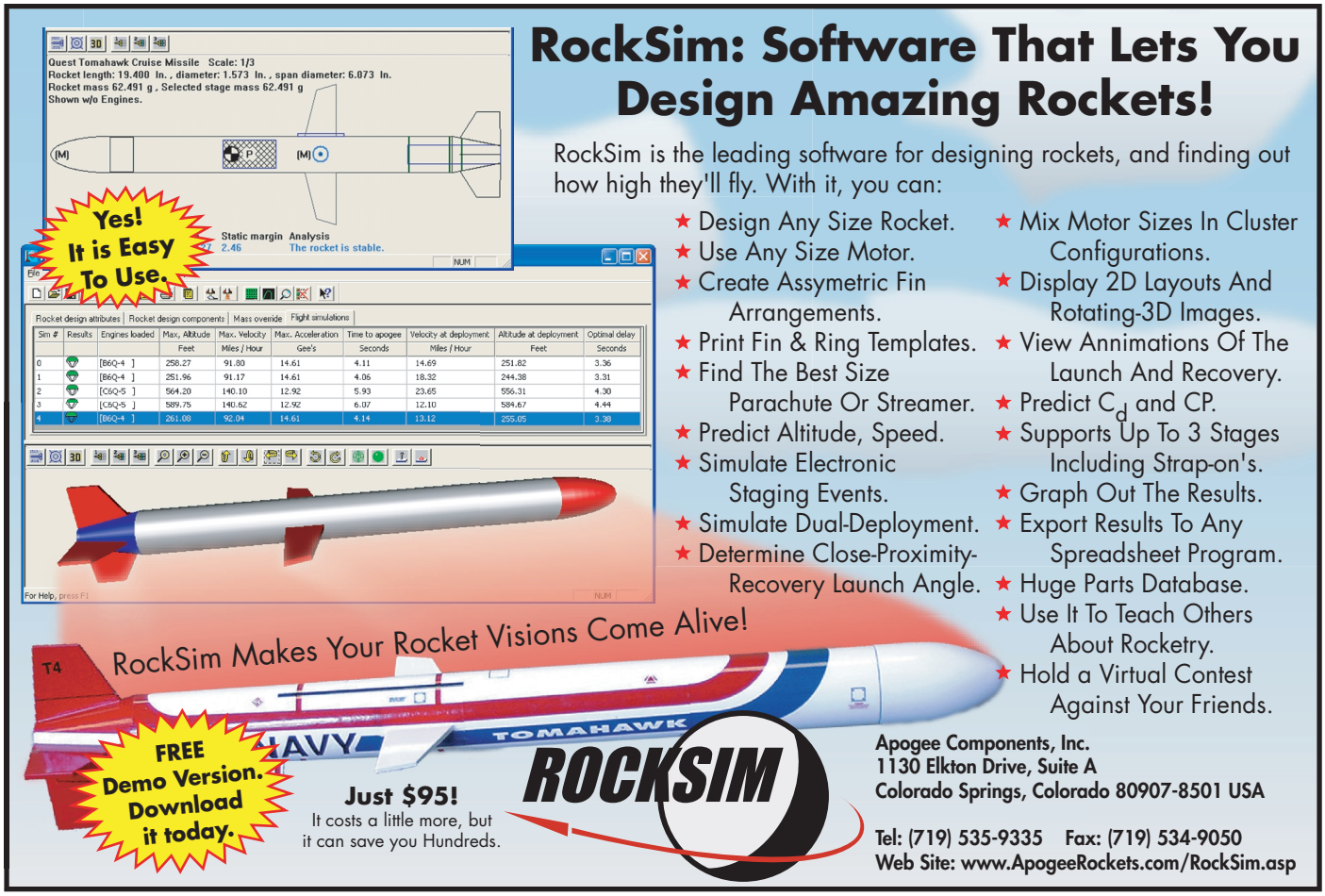
Even though I like this method a lot, I would still keep an eye on the liftoff velocity as the model leaves the launch rod. You'll find this in the detailed report of the simulation.

In conclusion, all of the five methods have their good and bad points. All of them are a little bit subjective. That is, they

About this Newsletter

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

can be vigorously debated whether or not they are the "end all," or if their basic assumptions are valid. But they are all better than a guess -- which is what the MRLOW tables supplied by motor manufacturers are likely to be. So pick your favorite method, and use it. Just be able to explain which method you used when you seek permission from the RSO to launch your next rocket.

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.