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# Selecting Motors: A Step-by-Step Proceedure

## How to use RockSim to pick the BEST rocket engine for your models

By Tim Van Milligan

In issues #38, #39, and #40 of the *Peak-of-Flight Newsletter*, I gave some general hints on selecting rocket motors. I now want to take this a step further and show you step-by-step how to use the RockSim software to make the perfect selection based on actual flying conditions. Getting that perfect flight is every modeler's dream and goal. With the motor selection method described here, you'll have a nearly fool-proof way of achieving that goal.

But before we start, let me say that if you don't have RockSim, don't fret. You can use the FREE Rocksim demo version to perform motor selection too. Go ahead and download it from the Apogee Components web site: http://www.ApogeeRockets.com/rocksim_demo.asp

### *Create the Rocket Design First*

To start off, I have to assume that you have already inputted your rocket design into RockSim. The purpose of this article is to select the proper rocket motor. So take a little time to get familiar with RockSim and how to use it. The time you spend now is really an investment. It will pay huge you dividends in the time saved down the road when you're designing hundreds of rockets. People are constantly telling me how addicting RockSim is, and once you get to know the layout of the program, you just can't stop creating neat looking models.

The process of selecting the "right" rocket motor for your rocket is shown in the flow chart. That is basically the process, and you should keep a copy of this chart in a folder where you store your design printouts.

In the rest of this article, I'll go through this chart to flesh out the details that might need a bit of explaining. Every step in the process is important, and I hope this becomes apparent as I try to explain each decision you'll need to make based on what RockSim tells you.

As you can see from the flow-chart, I've divided the process into 22 steps. I want to point out that there may be several motors that would work for the conditions you plan to launch in. With so many motors available these days, it's no wonder that there will be a lot of choices. The process will help you weed out the motors that shouldn't be used in your rocket.

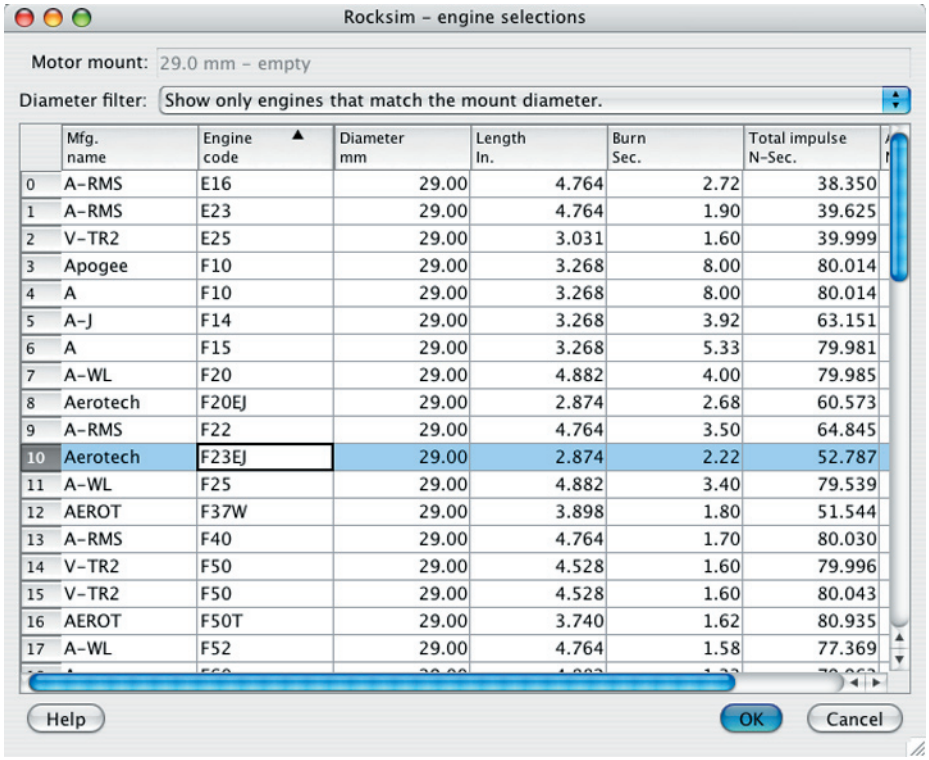
### *Getting Started*

#### Step 1. Install A Rocket Motor Into The Design.

In this first step, you'll need to make an initial guess. I really hate guessing, don't you? So I suggest that you start with the largest rocket motor that will fit into the engine mount. Most people want to know what is the biggest motor the rocket can use anyway. We might as well start from big and work our way to the smallest. And this will save you some time.

However, as you know from reading my previous articles, there is this little voice in the back of your mind saying something else, "lower thrust motors will make the rocket fly higher." That is competely true, of course. If you want to start with smaller motors, go right ahead. This is a weeding out process, so it doesn't matter if you start with a big or a small motor.

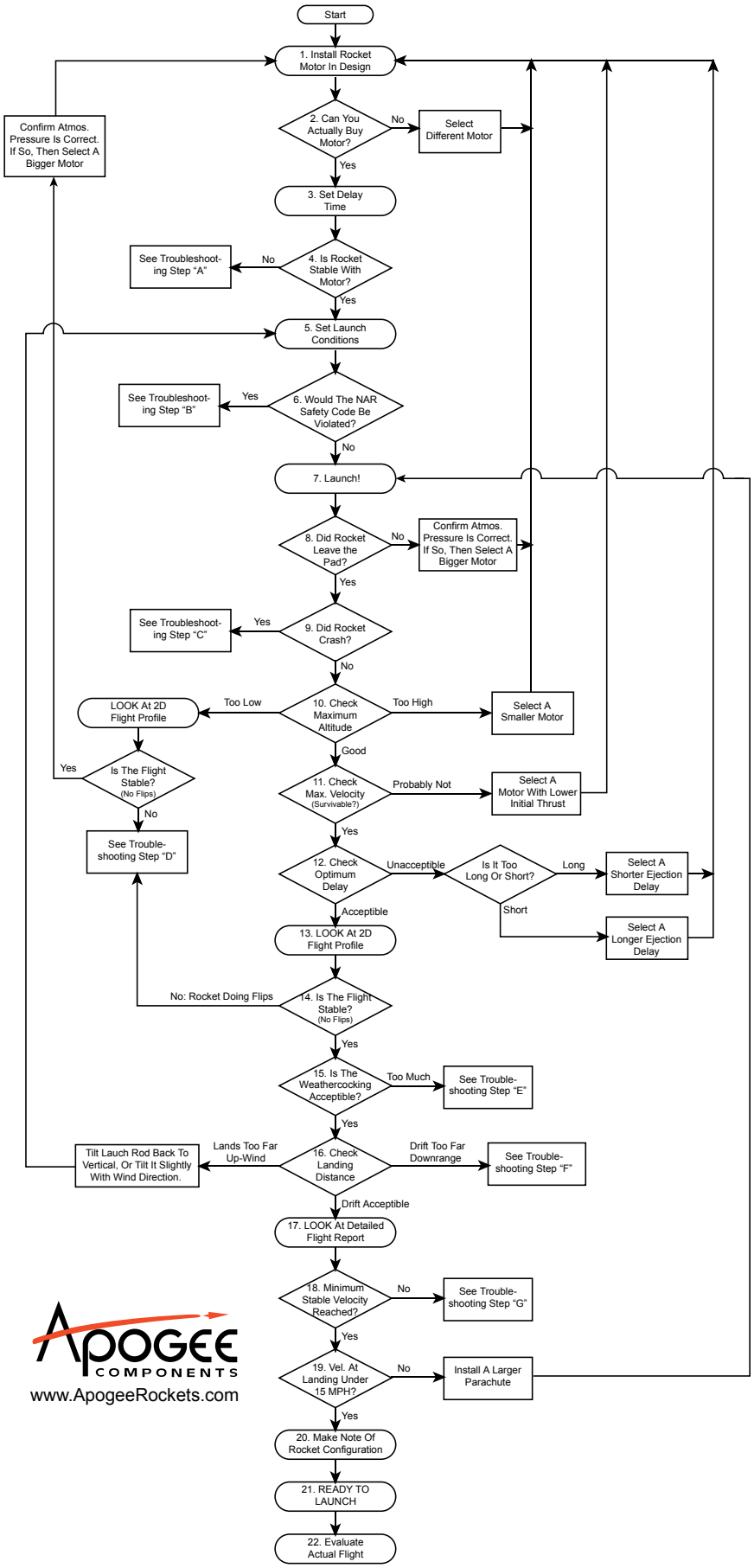
After you've gone through this motor selection process a number of times for different models, you will intuitively know which motors won't work. This is where




| | Mfg. name | Engine code | Diameter mm | Length In. | Burn Sec. | Total impulse N-Sec. |
|---|---|---|---|---|---|---|
| 0 | A-RMS | E16 | 29.00 | 4.764 | 2.72 | 38.350 |
| 1 | A-RMS | E23 | 29.00 | 4.764 | 1.90 | 39.625 |
| 2 | V-TR2 | E25 | 29.00 | 3.031 | 1.60 | 39.999 |
| 3 | Apogee | F10 | 29.00 | 3.268 | 8.00 | 80.014 |
| 4 | A | F10 | 29.00 | 3.268 | 8.00 | 80.014 |
| 5 | A-J | F14 | 29.00 | 3.268 | 3.92 | 63.151 |
| 6 | A | F15 | 29.00 | 3.268 | 5.33 | 79.981 |
| 7 | A-WL | F20 | 29.00 | 4.882 | 4.00 | 79.985 |
| 8 | Aerotech | F20EJ | 29.00 | 2.874 | 2.68 | 60.573 |
| 9 | A-RMS | F22 | 29.00 | 4.764 | 3.50 | 64.845 |
| 10 | Aerotech | F23EJ | 29.00 | 2.874 | 2.22 | 52.787 |
| 11 | A-WL | F25 | 29.00 | 4.882 | 3.40 | 79.539 |
| 12 | AEROT | F37W | 29.00 | 3.898 | 1.80 | 51.544 |
| 13 | A-RMS | F40 | 29.00 | 4.764 | 1.70 | 80.030 |
| 14 | V-TR2 | F50 | 29.00 | 4.528 | 1.60 | 79.996 |
| 15 | V-TR2 | F50 | 29.00 | 4.528 | 1.60 | 80.043 |
| 16 | AEROT | F50T | 29.00 | 3.740 | 1.62 | 80.935 |
| 17 | A-WL | F52 | 29.00 | 4.764 | 1.58 | 77.369 |

**Figure 1: From the list, choose the motor you want installed.**

Selecting The "RIGHT" Rocket Motor For Your Model Using RockSim




knowledge based on past experience will kick in. At that point, your initial selection will be better, and the weeding-out process will go quicker. In other words, RockSim is paying you back in the currancy of "knowledge gained" in exchange of the time you spent using it.

## Step 2. Can I Actually Buy The Motor I Selected In Step 1?

This one step will eliminate a lot of motor choices. But most people that are new users of RockSim (like contestants in high-school challenges, such as the Team America Challenge that were popular in the early 2000's) completely gloss over this step. They get frustrated when they discover that the "perfect" motor isn't available any more.

There are a lot of legacy motors in the RockSim database. They are there because someone might have one buried in their motor collection and suddenly they have the urge to fly it in a rocket. So before you get too far into the selection process, take a look at different manufacturers to make sure you can obtain that perfect motor.

If the motor isn't available, you must return to step 1 and pick a new motor from RockSim's list.

Note: If you note a new motor available that isn't in the RockSim database, you can easily add it yourself. See the article in *Peak-of-Flight Newsletter* #11. It explains the process of putting the motor into RockSim's database. You'll find that article at: http://www.ApogeeRockets.com/education/newsletter11.asp

## Step 3. Set the delay time.

With the motor selected, you can choose from the available delay times listed in RockSim. For most small rockets, this step is straight forward. You don't have to guess: start by picking the longest delay of the available choices.

If you are flying a high power rocket, you'll note that the delay choices are somewhat limited, if there are any choices at all. The reason is that high power rockets often use electronic devices to control when the ejection charge fires.

In this case, since we are just starting, you can physically "type in" a number of seconds into the delay field. Yes! Just type in a number. I suggest a high number, such as 20 seconds. Most times, this will cause the rocket simulation to crash. But that can and will be adjusted later.

Whatever size rocket you are flying, it is better to be too long for the initial guess. It will actually speed up the selection process

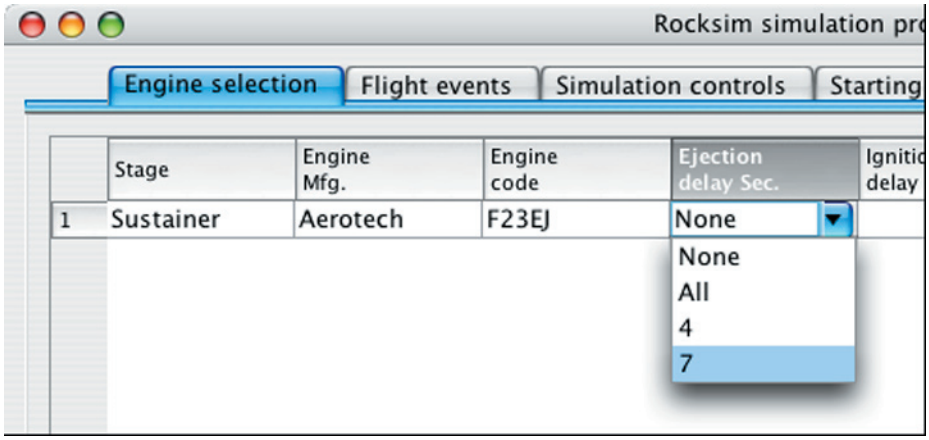



**Figure 2: Pick a delay from the available choices. If you're using electronics to deploy the parachute, then pick "None."**

because you'll narrow in on the optimum delay faster; especially if you are using an older version of RockSim (the software has an easier time of finding the optimum delay when the initial guess is long, rather than too short. See the related article in *Peak-of-Flight Newsletter* #59 at http://www.ApogeeRockets.com/education/newsletter59.asp)

### Step 4: Is the Rocket Statically Stable With Motors Installed?

You can click back to the main screen to check the static stability of the rocket. You'll find it on the 2D image of the rocket. RockSim makes this easy, as it will tell you specifically if the model is stable, marginally stable or unstable.

If the static stability of the rocket is "Unstable," you'll need to correct this first. See troubleshooting Step "A."

If the rocket is "marginally stable," you may have to correct this to make it "stable." You'll make that determination later in the motor selection process, after you see how

## Standard Delay Choices and What They Mean

Just in case you are new to rocketry, here are some definitions of the available delay choices listed in RockSim:

**None:** Plugged Motor. It acts as if the motor has an infinite delay. Parachute will NEVER be ejected by the motor. RockSim will always put NONE as one of the choices in the list. It does this because there is no way to designate a plugged motor in the WRASP engine format. The WRASP motor format was created by Harry Stine, long before RockSim was created.

**0:** Typically zero is a booster motor. That means the ejection charge occurs immediately at engine burnout. There is usually a "0" as one of the choices. This is a result of the WRASP engine format requires something in the delay field. If the motor is plugged, usually the unknowing person that created the motor file, will just put a zero. It does not mean "plugged." It will fire out the parachute every time.

Numbers (i.e., 3): This is the delay time, measured in seconds, from when the motor burns out until when the ejection charge fires.

**All:** Selecting this is the same as selecting the longest delay that is currently in the list. For example, on a Estes C6 motor, which comes in available delays of; 0,3,5, and 7 seconds, it will eject the parachute at 7 seconds after burnout. The purpose of this to mark points on the GRAPHS to indicate where each delay will occur in the trajectory. This "ALL" choice is specific to RockSim, as it was requested by many users.

Many HIGH POWER get confused by the "ALL" choice in the list. Why? Because a lot of high power motors are plugged and require electronics to control the ejection of the parachute. Because of this, you won't see any numbers in the list (just the default of "None" and probably a "0"). So they mistakenly pick "ALL" from the list. Since "0" is the biggest number in the list (NONE is NOT a number), the motor will eject at zero seconds. This means the rocket is only a couple hundred feet in the air at deployment, when they expected ejection to occur at several thousand feet.

In RockSim version 6, we added a way to use electronic staging without having it controlled by the motor delay field. So it is less confusing for people using version 6 or newer. But if you are using the free demo (which is version 5), you have to be aware of this.

Finally, RockSim does allow the user to override the delay choices in the list. You simply type in the delay number you want (whole numbers only).

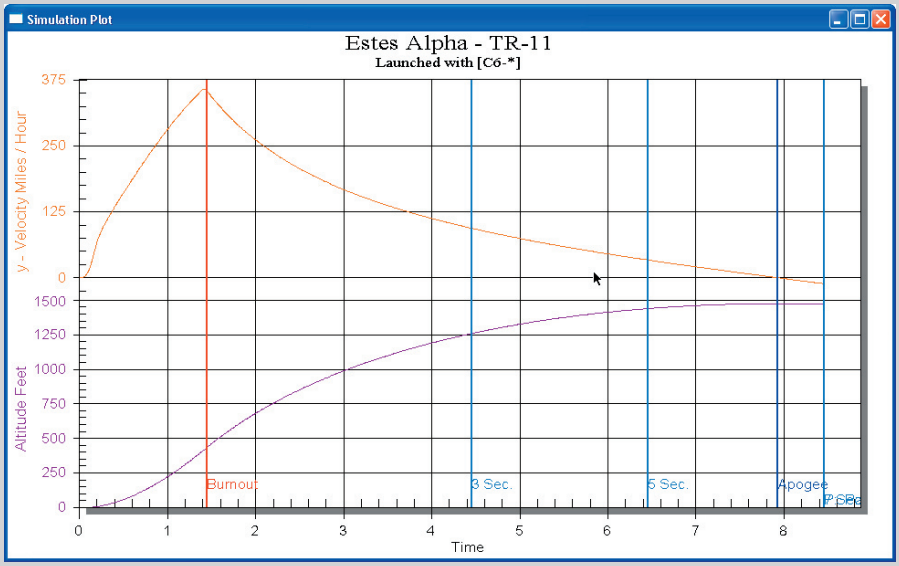



**Figure 3: When you choose "ALL" , you will see see how each delay affects the rocket on the graphs. That is all it does.**

dynamically stable the rocket is in flight. You can proceed on to the next step.

## Step 5. Set The Launch Conditions

The actual launch conditions play a major role in selecting the best motor(s) for the rocket. You'll find that one motor will be acceptible for some weather conditions, and completely terrible for others. So terrible in fact, that it would be unsafe to use that motor for the rocket if you encounter those conditions on the day of the real launch.

It is very important to realize the impact that launch conditions have on the motor selection process. When people ask me what are the motor choices for generic rocket XYZ, I always ask them, "what conditions are you launching in?" Without that information, it could be certain doom for their flight.

Since we are just estimating at this point, what launch conditions should we input into RockSim? Great question!

I like to set these initial values because they are a bit conservative. In other words, they're not worst case, but they are fairly poor flying conditions. They are:

### Initial Launch Condition Settings

**Launch Angle:** 0°
**Launch Guide Length:**
36" for small rockets
48" for E, F, or G powered rockets
60" for H or bigger rockets
**Wind:** Set at "Slightly Breezy," with "Some Variability."
**Thermals:** Set it at "No Thermals."
**Deploy Recovery Device:** "At Maximum Engine Ejection."
**End Simulation:** When the rocket reaches the ground.

## Step 6. Would the NAR Safety Code Be Violated?

Why would I insert this step in the process? Because safety is of utmost importance!

Since we're using a computer simulation, we lose the perspective of "danger" associated with rocketry. It isn't real on a computer, so we easily set up simulations that would violate the NAR safety code. I find myself doing this all the time.

The most common violation of the safety code that I find my self doing in RockSim, is setting the launch angle greater than 30 from vertical. It is fun to see how far downrange we can make a rocket go. But remember, when you go out to a real launch, you are obligated to non-participants to follow the safety code. Even if no one is around, you are obligated to your fellow rocketeers to follow the safety code. It will only take one person doing one stupid thing that will outlaw rocketry for EVERYONE. That is why we all MUST follow the safety code at every launch. My suggestion is to

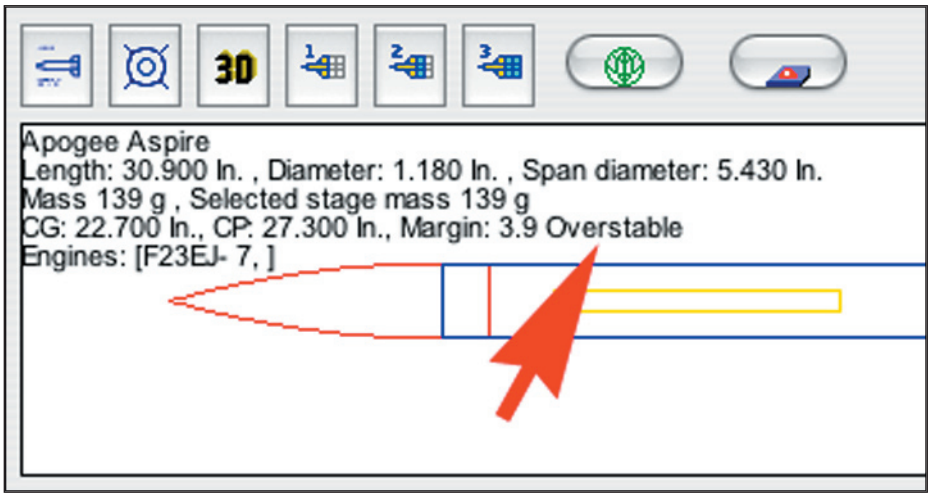



**Figure 4: RockSim will tell you the static stability of the rocket. Be sure to have the engine installed, so the CG moves to its lift-off position.**

### *Troubleshooting Step "A": Fixing An Unstable Rocket*

You have two choices to make the rocket stable: either move the CG forward, or the CP aft. Moving the CG forward can be done by adding nose weight. Generally, I'm not in favor of adding weight unless it's a last resort. Additional mass is going to slow the rocket down and limit its performance. It will also reduce the number of motor options we'll have to pick from. But if the rocket is already built, you may have to do this for your rocket.

I recommend running simulations on rockets long before you start building them, so you have more choices on how to fix problems. For example, there are a number of methods of moving the CP aft. Such as larger fins, moving them further back, or lengthening the rocket. You can find out more techniques in the book *Model Rocket Design and Construction* at http://www.ApogeeRockets.com/design_book.asp.

### *Troubleshooting Step "B": How To Keep The Pointy End UP?*

If you need to tilt the launch rod into the wind more than 30° to achieve close-to-the-pad recovery, you have one of two choices. First, you can use a smaller parachute so the rocket descends quicker. That way, you don't have to tilt the pad so much. If that is not an option, as it would cause the rocket to land too hard, you have only one option: "resign yourself to the fact that you'll be walking a long way to retreive your rocket."

If you need to tilt the launch rod with the wind more than 30° from vertical to get the highest altitude possible:

**Option 1:** Use a longer launch rod. Most weathercocking occurs at slow speeds, which is when the rocket just leaves the launch rod. You can increase the speed of the rocket leaving the pad by using a longer rod.

**Option 2:** Use a motor with higher initial thrust. This is the other way to increase the speed of the rocket as it leaves the pad.

**Option 3:** Add spin tabs to the model to get it to spin. This reduces weathercocking of the model, so you don't have to tilt the pad as much to achieve a higher flight. See the book *Model Rocket Design and Construction* at: http://www.ApogeeRockets.com/design_book.asp

**Option 4:** Your rocket is probably significantly overstable. While generally, I don't think overstable is a bad thing (See *Peak-of-Flight Newsletter* #5 at: http://www.ApogeeRockets.com/education/newsletter05.asp), in this case, you might consider making the rocket less over-stable. That way, you won't have to tilt it so far to get a higher flight.

### *Safety Note To Teachers:*

I get teachers telling me (all the time) how they are trying to show how launch angle affects distance travelled — which is a common trajectory problem in physics. To do this, they glue the nose cone on the rocket, and launch it across the athletic field. PLEASE DON'T BE THIS STUPID! Even experts have accidents, where fins can pop off a model unexpectedly. Your disregard for safety will mean that future generations of students will not get to use rocketry at all. That would be a shame, because rocketry is such a powerful education tool. Besides, with a great tool like RockSim, you can perform this demonstration safely with your computer.

refresh your memory of the NAR safety code before you go any further.

If you need to set up conditions in RockSim, that violate the NAR Safety Code, just to make your selected motor work, see Troubleshooting Step "B".

## Step 7. Launch!

## Step 8. Did the Rocket Launch?

Look at the "Results" column for the Flight Simulation. It will show one of three basic kinds of icons:

Rocket on Launch Pad
Rocket Crash
Parachute Deployed

If the rocket never left the pad (Rocket on Launch Pad icon), you should check two things. First, check the barometric pressure (found in the launch conditions tab when

**Figure 5: Summary icons used by RockSim to display final results.**

you load the rocket motor). I've seen people change the pressure to an unbelievable amount competely by accident. Basically, their rocket is trying to fly through thick soup, and it doesn't have enough power to rise up on the launch rod. The default setting is 1.013 bars, or 29.914 inches of mercury. If it is close to that, you're OK.

If the barometric pressure is fine, then the reason it left the pad is that the rocket is under-powered. You need a much bigger motor for the model. If you have a "B" motor installed, you should probably switch to a "D" size. You need a lot more thrust! Go back and start over at step 1. If you get a parachute icon, that means the recovery device deployed, which is good. This is what we want, and so we can now go to Step 10 to evaluate whether or not the motor we selected is best for this model and the launch conditions.

## Step 9: Did the Rocket Crash?

The "Rocket Crashed" icon always means the rocket touched down to the ground prior to the recovery device being deployed. So let's find out why that happened by going to Troubleshooting Step "C".

## Step 10: Check Maximum Altitude

The next thing I look at after RockSim is done running a simulation is the rocket's "Maximum Altitude." We have to decide whether or not the rocket motor we selected has allowed the model to reach it's objective.

When you're starting out in rocketry, I know it's difficult to come up with some rule-of-thumb as to how high a given rocket should fly. If this is the case, don't worry. The remaining steps will walk you through the proceedure of determining if it is high enough or too low.

But if you do have an idea that the rocket went too high, such as if you know the actual launch will have a FAA waiver of 5000 feet, and RockSim predicts 6000 feet, then you're flying too high. In that case, you'll need to select a smaller rocket engine. For example, if you were using a "J" size motor, you should replace it with something smaller, like an "H" or and "I" size engine. Go back to Step 1.

If the rocket didn't achieve the altitude you expected, then something strange is going on. As listed before in Step 8, I would first check to see if the barometric

### *Troubleshooting Step "C": Did The Rocket Crash?*

First, check to see if a parachute or streamer is installed in the rocket. Without one, you'll always get the "rocket crashed" icon. So it may not be the motor's fault at all.

Next, check the settings in the "Flight Events" (when you are prepping the rocket for flight). You may have it set to deploy at a certain number of seconds after apogee, or "Time after Ejection". These are settings used by people trying to simulate electronics on the rocket that control deployment. In either case, the setting number is too long, and you'll need to reduce it to a smaller number. Go back to Step 7 after making changes.

Likewise, if your Flight Event is set to "Deploy at Max. Ejection Delay" and the icon shows crash, then you need to choose a shorter delay from the list available when you load the motor. For example, if you choose a C6-7 for the model, you should back it down to a C6-5 motor.

pressure is properly set in the "Launch Conditions." If this is wrong and is set too high, the rocket won't travel too far. I've seen this occasionally on rocket files that people have sent to me to troubleshoot. It's rare, but it can happen.

If the barometric pressure is properly set, how do we figure out what is the "Strange" thing is that is causing the low altitude? Easy — you look at the 2D flight profile. This is what makes RockSim the best program for selecting motors, because it's 2D flight profile takes into account how the rocket behaves in the wind. NO OTHER PROGRAM has this feature! Without it, you really can't make the best motor selection.

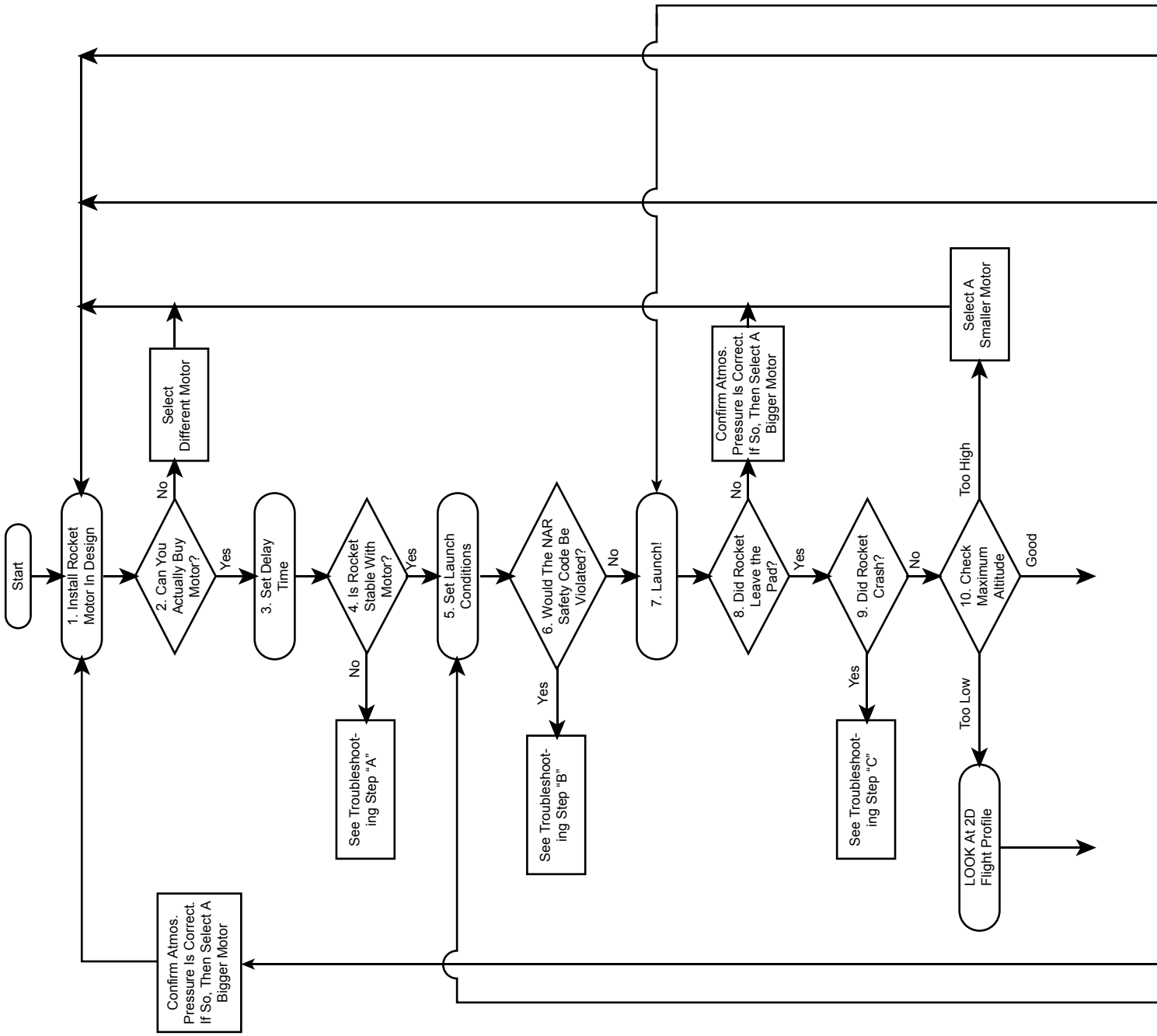
I'll talk about this screen a little bit later in step 14.

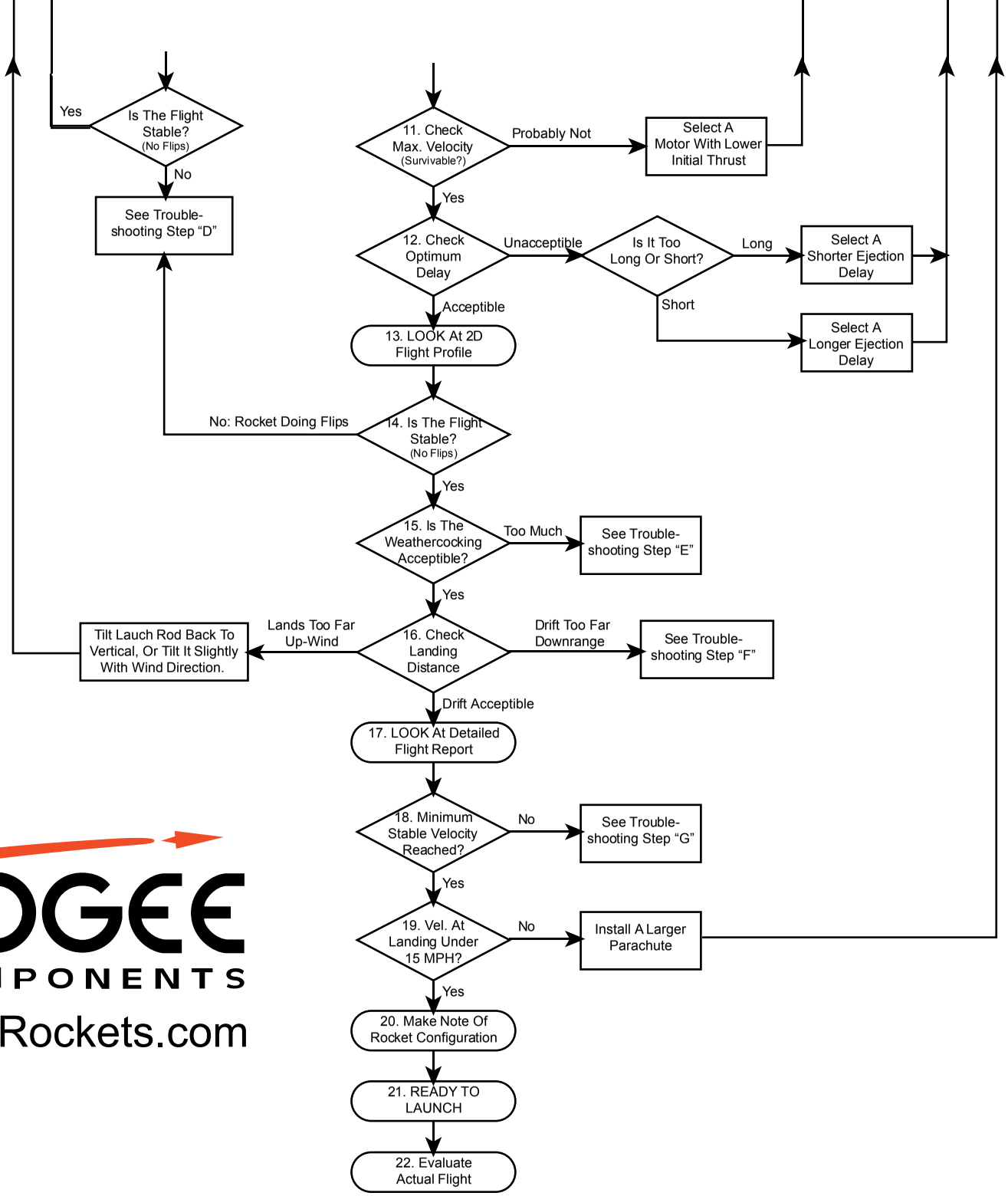
## Step 11. Check the Maximum Velocity

Again, unless you have some reference point in the back of your mind, it's hard to make a determination of the speed being too slow, just right, or too fast.

But what I wanted to get across is that there is a speed for every rocket that is too fast. For most small model rockets, and especially starter kits, you don't have to worry about it. The available motors won't get the rocket moving too fast above the structural limit of the rocket.

# Selecting The "RIGHT" Rocket Motor For Your Model Using RockSim



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But there are some cases, such as supersonic rockets, when the fins will shred off. Or if you have a rocket with very long and narrow fins, where they will start to flutter. If that happens, eventually they will shred from the rocket too. So at this point, I just want you to keep it in the back of your mind that you have to make sure your rocket is built strong. This is why we always do a safety inspection of the rocket to make sure all the fins are glued on properly — NO TAPE ALLOWED!

If you worry about the rocket coming apart, your only option here is to select a rocket motor with a lower initial thrust level. While this is hard to determine without looking at all the different thrust curves, you can generally assume that a rocket with a lower average thrust will have a lower initial thrust. For example, a B4 motor will make the rocket fly slower than B6 motor. This is why competition style boost gliders will use the B4 instead of the B6. It lowers the chances of the wings shreding off on the way up.

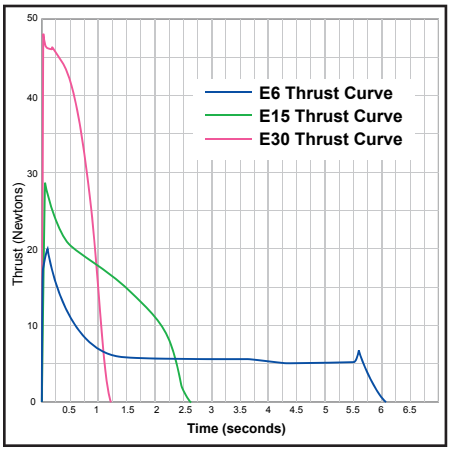


**Figure 6: A motor with a high initial thrust level will take off faster. You can look at Thrust Curves to find this information.**

## Step 12. Check Optimum Delay

As we talked about before in Step 8, there should be a little parachute icon in the RockSim summary chart. This icon actually tells you if the optimum delay you selected is OK for the flight. It does this with a little arrow.

If the arrow inside the parachute is pointing upward, the rocket is deploying the recovery device too soon, while the rocket is still rising.

If the arrow inside the parachute icon is pointing downward, then the rocket is arching too far when the recovery device is deployed. This may or may not be of concern, but it does depend on the strength of your rocket and the parachute. To be on the safe side, your goal should be to deploy very near the peak altitude of the flight. This is when the forces trying to shred the parachute are at their lowest.

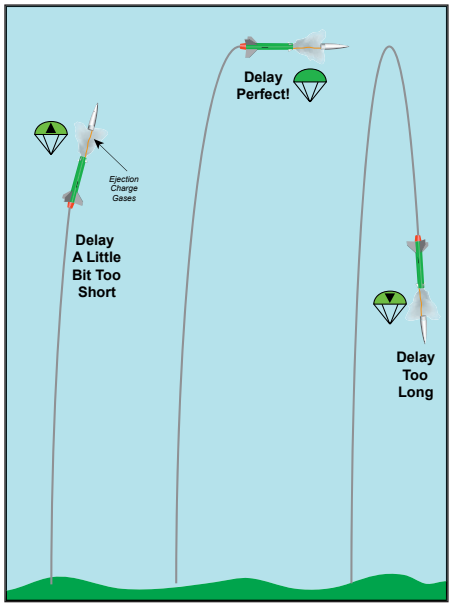


**Figure 7: You can tell where the parachute deployed by looking at the summary icon.**

If you get a parachute icon without any arrow, you have selected a good delay based on the flying conditions you've set. The flying conditions will always dictate the delay, which is why RockSim is so useful at picking the right motor. You can check several different flying conditions, and have the right motors with you at the launch.

It is nearly impossible to get a motor that will match the value shown in the "optimal Delay" column of the flight summary. The best we can hope for is to be 'close-enough.' But what is close enough? RockSim defines close-enough as being within 1 second of that optimal delay number. So the rocket could eject a little early, or a little late, but as long as it is within 1 second of peak, then you'll get the parachute icon without any arrow in it. That is acceptible.

As far as motor selection goes, if your rocket is deploying the parachute too early, you should select a delay that has a longer value. Such as a C6-5 in place of a C6-3.

Or if the model is arcing over too much, you'll need a shorter delay. If you selected a C6-7, you'll want to swap it out with a C6-5 and rerun the launch simulation again.

For more information on optimal delay, see *Peak-of-Flight Newsletter* #59 at ApogeeRockets.com/education/downloads/newsletter86.pdf)

### *Troubleshooting Step "D": Fixing Unstable Rockets*

The most common reason rockets go unstable is that they started out as statically unstable. This is why you should check the stability of the model, WITH THE MOTOR INSTALLED (See Step 4). The addition of the motor into the rocket shifts the CG rearward, making the model less stable. Before we launch the rocket, we want to make sure that the rocket remains "Statically Stable."

Sometimes, even a statically stable rocket can go unstable because of the wind at launch. Usually, these rockets started out being **Marginally Stable.**

If RockSim indicates the rocket is Marginally Stable, that means the distance between the CG and the CP of the rocket is less than one body tube diameter apart. For some rockets, this can be OK. An example would be short-squat rockets like the Estes Fat Boy and Big Daddy. They are so fat, that you'd have to put a ton of noseweight in the nose to get them even close to one-calibler stable. (See related article on "short-squat" rockets in *Peak-of-Flight Newsletter* #86 at: http://www.

Being marginally stable means we really need to look hard at the launch conditions. Sometimes the flight may be OK, while other times, it may go astray. RockSim will give you a good indication of the flight, which is why it is so valuable to the rocketeer.

If the rocket does go unstable, the culprit is almost always the wind. The rocket just isn't designed for moderate to high winds. You'll have to wait until the wind is dead calm before you launch it. In step 20, you'll see that you need to make good notes on the model to track things like this. You'll want to make sure that you don't launch this model in high winds, or it will give you a screwy flight.

If possible, add some nose weight to the model. This moves the CG forward, making the model more stable. While this will lower the performance of the model, the model will fly straighter, and therefore be safer to launch.

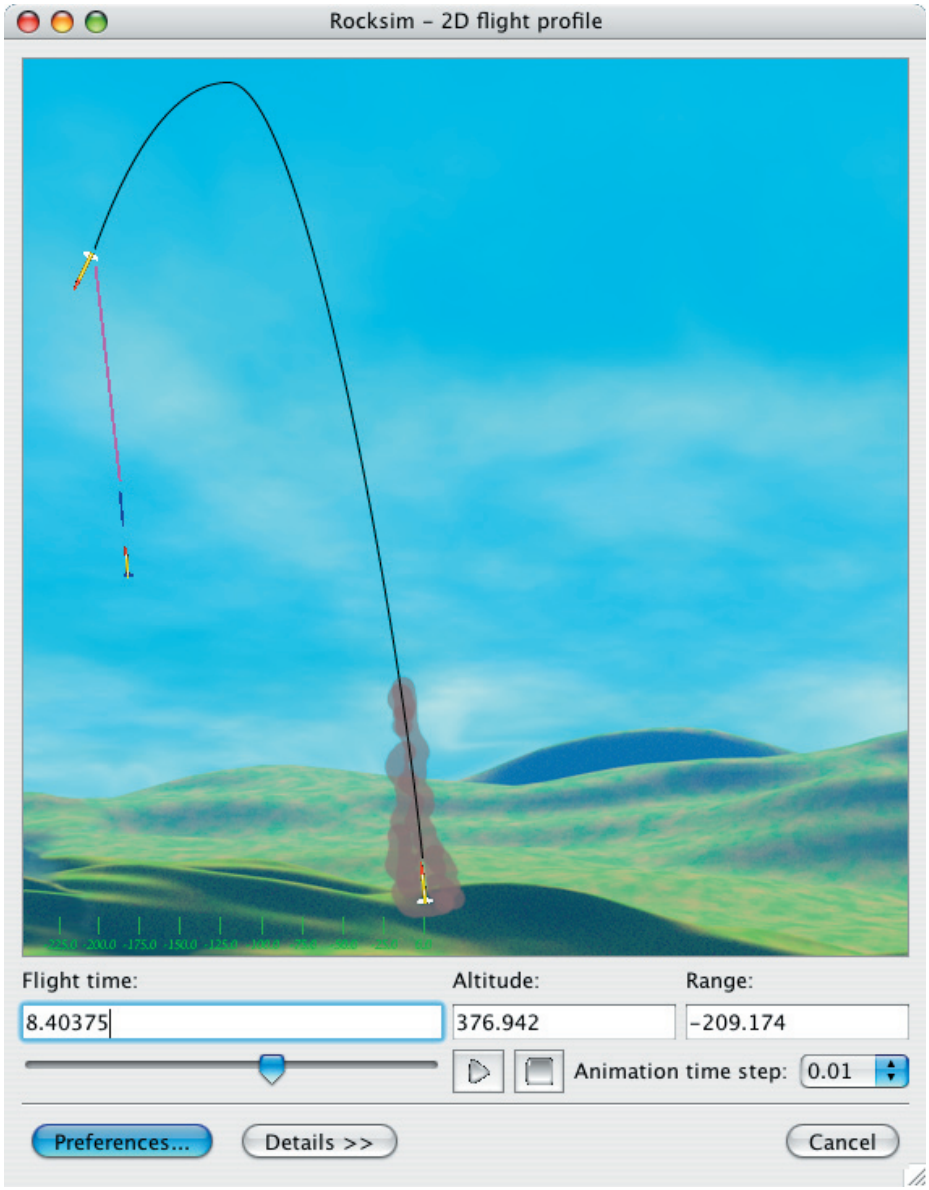


**Figure 8: The "2D Flight Profile" shows you how the flight will look.**

http://www.ApogeeRockets.com/Education/newsletter59.asp

## Step 13. LOOK At The 2D Flight Profile

Even if all the indicators up to now are showing that you've got a good motor selected for the rocket, you can't really be sure until you look at the **Flight Profile.** It shows an incredible amount of information.

This past week, I ran a flight simulation on a rocket, and I thought everything was fine. The parachute ejected near peak altitude, and the altitude was somewhat low – which didn't concern me, because the rocket was very heavy at liftoff. But the 2D Flight Profile told me a completely different story. The reason the altitude was low was not because the rocket was heavy, but because the model went unstable! It was doing flips all over the sky. I would have never picked this up unless I looked at the 2D Flight Profile.

ALWAYS, ALWAYS, ALWAYS look at the 2D flight profile before you actually go out and launch the real rocket.

## Step 14. Is the Flight Stable?

When looking at the 2D Flight profile, this is the first thing you should look for. If it is stable, and the trajectory of the rocket doesn't shift suddenly, then you can go on to the next step.

If the rocket flight is unstable, you'll have to do some troubleshooting to find out why. See Troubleshooting Step "D".

Note: If the rocket goes unstable on it real flight — after you've checked it in RockSim, you have to do some additional troubleshooting. This is discussed in length in the article Why Rockets Go Unstable which appeared in *Peak-of-Flight Newsletter* #42. This can be found at: http://www.ApogeeRockets.com/education/newsletter42.asp

It lists 27 reasons why rockets can still go unstable, even after you've checked them in RockSim.

## Step 15. Is the Weathercocking Acceptible?

Excessive weathercocking only affects Over Stable rockets flown int breezy conditions. These rockets are going to point into the wind and travel horizontal for long distances.

What is too much weathercocking? As we saw in *Peak-of-Flight Newsletter* issue #34, (http://www.ApogeeRockets.com/education/newsletter34.asp), if the rocket arcs over and ejects outside an imaginary cone of 20°, then we have too much weathercocking.

This is fairly simple to compute. From RockSim, 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 doesn't have too much weathercocking. It is OK to fly.

If weathercocking is excessive, we have to perform troubleshooting step "E" to see if we can correct the problem.

## Step 16: Check the Landing Distance

How far can you allow the rocket to drift and still get it back? Will it land in the trees downrange from your pad, or will it just

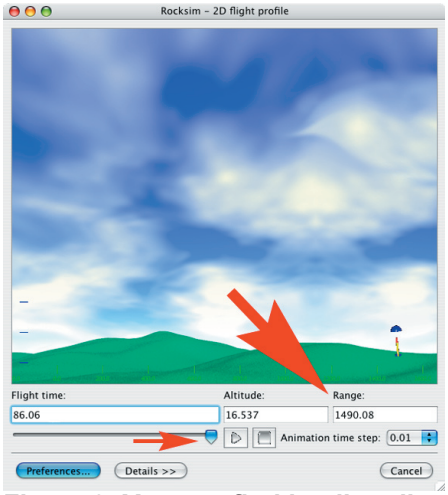


**Figure 9: You can find landing distance on the 2D Flight Profile.**

### *Toubleshooting Step "E" Correcting Excessive Weathercocking*

**Option 1:** I would first start by using a longer launch rod. The faster the rocket leaves the pad, the less susceptible it is to weathercocking. A longer launch rod is the the rocketeer's best friend. That is why launch rails are making great headway into the hobby, since they can be made extremely long.

**Option 2:** Use a higher thrust motor. Again, the purpose is to have the rocket leave the pad at a higher speed so weathercocking is less pronounced.

**Option 3:** Try angling the launch rod "WITH" the wind direction. This will make the rocket fly more up than sideways. It is still weathercocking, but with a proper launch angle, you can take advantage of the weathercocking.

**Option 4:** If the rocket isn't built yet, you can reduce the size of the rear fins to make it less overly stable.

**Option 5:** Spin the rocket with spin tabs or canted. Either method makes the rocket fly straighter. Unfortunately, it isn't possible to tell RockSim that the model is flying straighter because it is spinning.

sail so far that you won't have a chance of finding it?

You have to make a decision right now, before you actually launch the rocket and determine how far downrange you want your rocket to land.

If It Lands Upwind...

I'm assuming that you read Step 15 and have corrected the weathercocking problems. That way, weathercocking isn't that cause of the rocket landing too far uprange.

The cause is probably that you're angling the rod into the wind too much. Bring it back toward vertical.

If the rocket is drifting too far downrange look at the suggestions in Toubleshooting Step "F"

## Step 17: Look at the Detailed Flight Report.

RockSim has several ways to extract information about the flight. The "Detailed" *Simulation Results* report is one of the fastest. In RockSim version 7, you can double-click on the line in the summary screen. This will bring up the report. In earlier versions, you may have to find it from the "Simulation" menu.

### *Troubleshooting Step "F" Landing Too Far Downrange*

**Option 1:** Use a lower power rocket motor. The rocket won't go as high, so it won't drift so far in the wind. Then go back to step 1.

**Option 2:** Try angling the launch rod into the wind a little bit (see Step 5). But be sure you don't violate the NAR Safety Code by going more than 30° from vertical.

**Option 3:** Add ballast weight to the rocket. This will decrease the altitude of the rocket by making it a little heavier. Use tracking powder for the ballast. It will eject, making the rocket lighter (i.e., safer) as it descends.

**Option 4:** Use a smaller parachute or cut a spill hole into it. Another option is to switch to a streamer. Either method has the same effect: to make the model descend quicker. However, you shouldn't have it descend to fast that it could be unsafe. You'll check this in Step 19.

**Option 5:** Use a slightly longer delay. The rocket will arc over more and will be lower to the ground when the parachute is ejected. Be careful though... It might arc over too much and coming down too fast when the parachute ejects. Can you say "shred?" This is always the last option.

## Step 18: Is the "Minimum Stable Velocity" reached before the rocket leaves the launch rod?

This height will be found on the detailed flight report under the Launch Guide Data heading.

If the rocket reaches this speed before it reaches the end of the launch rod, you can go on to step 19.

If the rocket is traveling too slowly by the time it reaches the end of the launch rod, you've got a major problem. The fins won't be very effective at providing a restoring force to keep the rocket pointed up. The model could immediately go unstable as it leaves the launch pad.

### *Troubleshooting Step "G" Increasing the Lift-off Speed*

**Option 1:** Use a longer launch rod, or switch to a rail launcher if you have access to one. Proceed back to Step 7.

**Option 2:** Use a higher thrust rocket motor. After switching it out, go back to step 1.

**Option 3:** If you haven't actually built the rocket yet, try some building techniques that will lighten the rocket. See the book *Model Rocket Design and Construction* for ideas and tips (http://www.ApogeeRockets.com/design_book.asp).

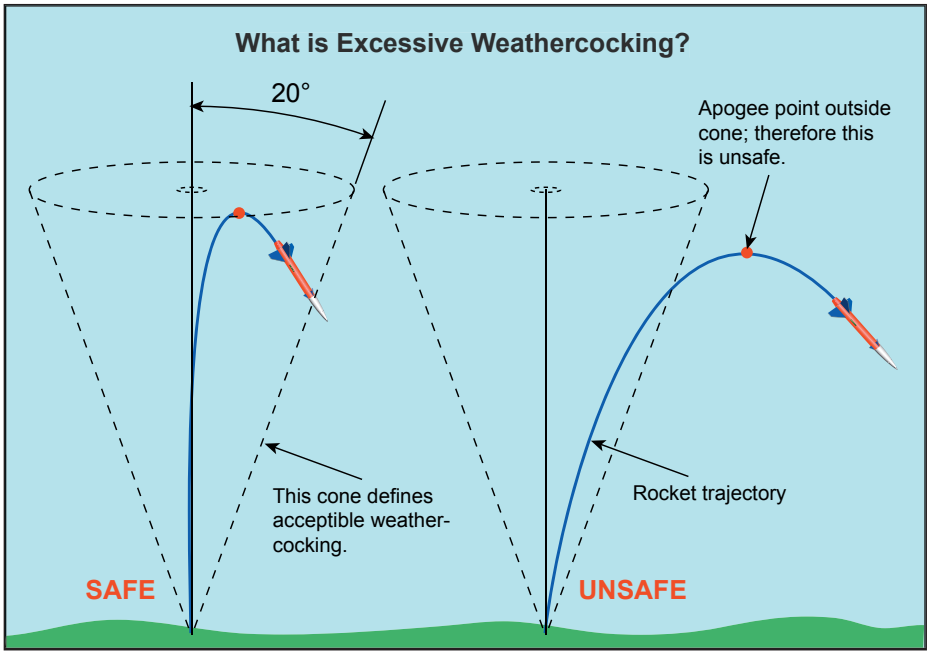


**Figure 10: Definition of acceptible and excessive weathercocking.**

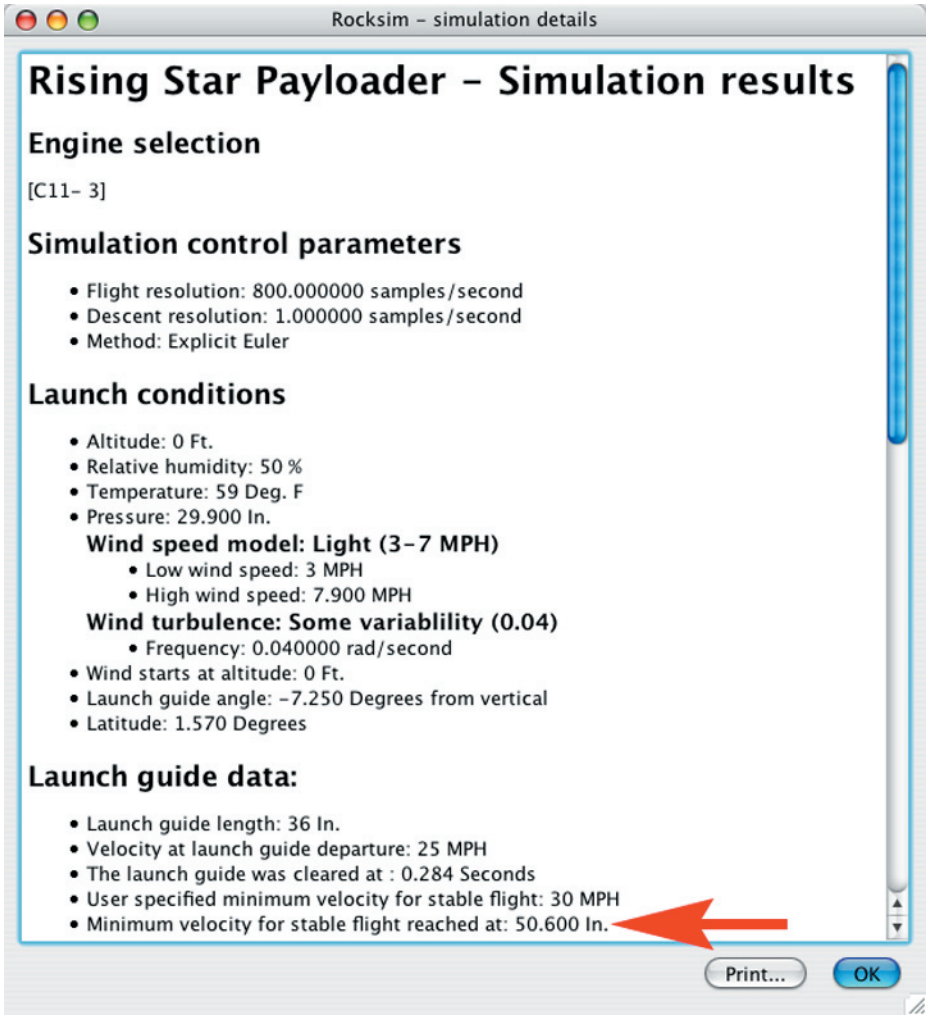


**Figure 11: The detailed Simulation Results is a report that gives extensive information about the flight.**

## Step 19: Velocity at Landing Under 15 MPH?

At this point, we've got our motor dialed in. Great job! The last thing we need to check is to make sure it will land safely. Our threshold for this is 15mph.

From the detailed simulation results report, scroll down to the bottom and find the "Velocity at Landing" line. You need to look at the both the vertical velocity, and the magnitude. The vertical velocity is the most important. But the Magnitude tells us that wind will make the rocket feel like it is hitting harder. I've seen a lot of egg capsules that come down slow, but the horizontal speed is pretty high and it whacks the eggs pretty hard when it hits the ground or against a fence. Splat!

If the rocket is descending too quickly, you'll need to put a larger diameter parachute in it. Then re-run your simulation one last time to make sure the added weight doesn't affect the motor and delay selection.

## Step 20: Make Note of Rocket Configuration

As you noticed, the motor selection depends heavily on the launch conditions (wind), and the launch rod angle. You need to jot these things down and have them with you at the launch site.

If your launch conditions change, it will affect the motor selection. That is why we want to write this information down.

You might find it easier to print out the detailed flight report, which has all the information. But I'll leave it up to you.

## Step 21: READY TO LAUNCH

With your notes about the rocket from Step 17, you're now ready to go out and launch the rocket!

## Step 22: Evaluate the Actual Flight

This step is as important as any of the previous steps. When you launch your rocket, you're still looking for any flight characteristics that can help you make a better motor selection the next time around.

For example, the rocket might have a natural tendancy to spin on the way up. This makes the rocket less suseptible to weathercocking and fly straighter than RockSim might predict. You probably won't have to aim it downwind as much to get a more vertical flight.

There are other flight factors to watch out for too. These are listed in the *Apogee Flight Record* sheet. It gives you a lot of little things to look at during the flight that will make your next flight even better. I heartily recommend it on any launch, and particularly the first launch of any new design.

There are three places you can find the *Apogee Flight Record* on the Apogee Components web site. First, It is part of

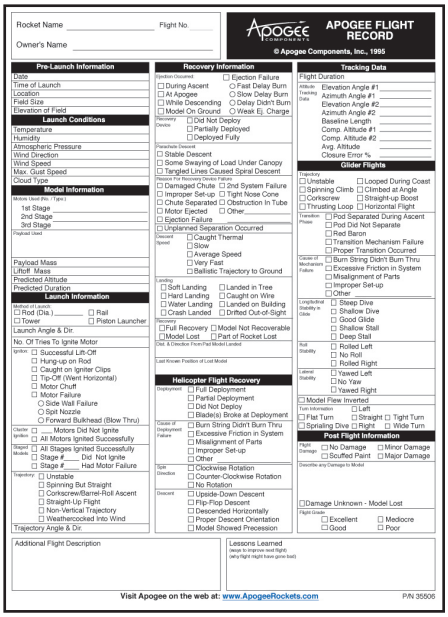


**Figure 12: The *Apogee Flight Record* is a good tool to use to confirm the RockSim results. You use the data to make the next flight even better.**

the "Data Sheet Collection" at http://www.ApogeeRockets.com/data_sheets.asp. A more descriptive narration of how to use it can be found in *Technical Publication #9* which is at: http://www.ApogeeRockets.com/technical_publications.asp. Finally, this same technical publication is now a chapter called Flight Testing in the book *Model Rocket Design and Construction* (http://www.ApogeeRockets.com/design_book.asp).

## Conclusion

Picking rocket motors was always difficult in the past. It took a lot of practice and trial-and-error to build up a storehouse of knowledge inside the modeler's head. RockSim has made that somewhat easier by showing us what the flight of the model would look like with each motor. With it, the expense of flying actual rockets could be eliminated by running quick computer simulatinos. But without knowing what to specifically look for, you may still not get the best motor in the rocket.

Now, with this step-by-step outline, I believe most anyone can pick the "best" motors with great precision. What once took a lot of skill based on perceptions of past flights, is now just a matter of following a cookbook-like proceedure.

While RockSim has a hefty sticker price, I hope you can see that it is an investment in your rocketry hobby. It pays you back in knowledge gained about rocketry. It also allows you to avoid the expense of wasting hundreds of dollars in rocket engines testing different motor combinations. Plus, by pre-flying your rockets on the computer, it prevents you from making really poor decisions which would make your rocket crash. That is extremely expensive, which makes RockSim the best bargain in all of rocketry.

## 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 the 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.