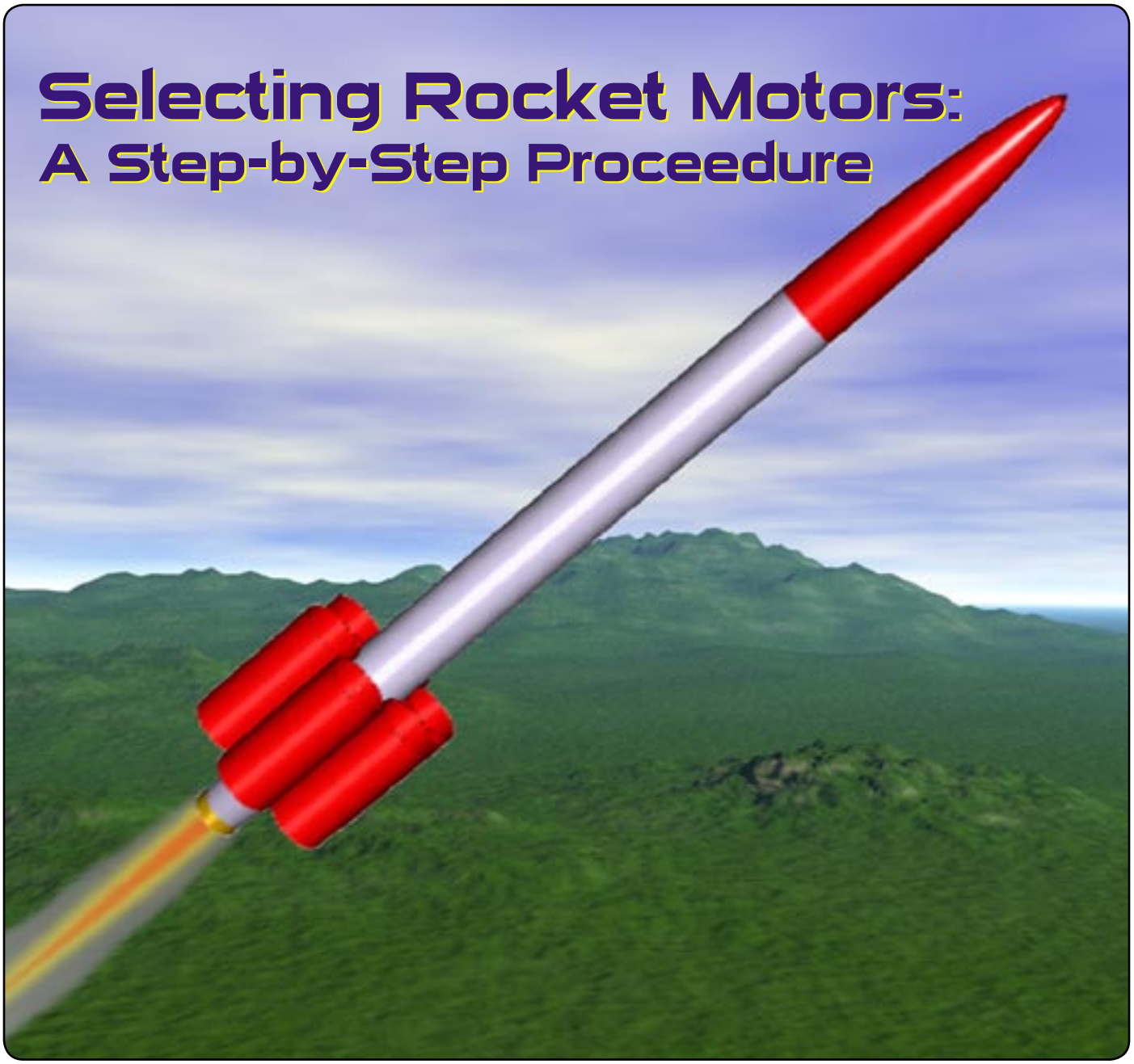
ISSUE 132, SEPT. 28, 2004

APOGEE PEAK OF FLIGHT NEWSLETTER

Selecting Rocket Motors:
A Step-by-Step Proceedure



Apogee Components
1130 Elkton Drive, Suite A
Colorado Springs, Colorado 80907 USA
www.ApogeeRockets.com email: orders@ApogeeRockets.com
phone: 719-535-9335 fax: 719-534-9050

ISSUE 132 - SEPT. 28, 2004

APOGEE

PEAK OF FLIGHT

Selecting Rocket Motors: Step-by-Step

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 knowledge

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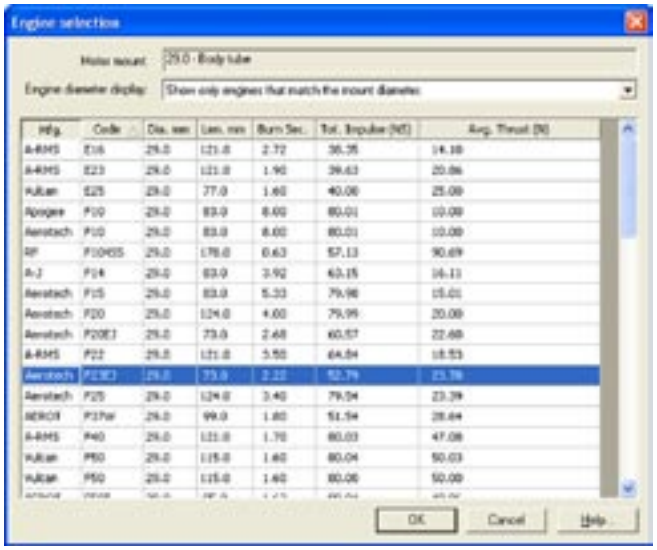

Figure 1: From the list, choose the motor you want installed. Start with a fairly big one.

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Selecting Rocket Motors

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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 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

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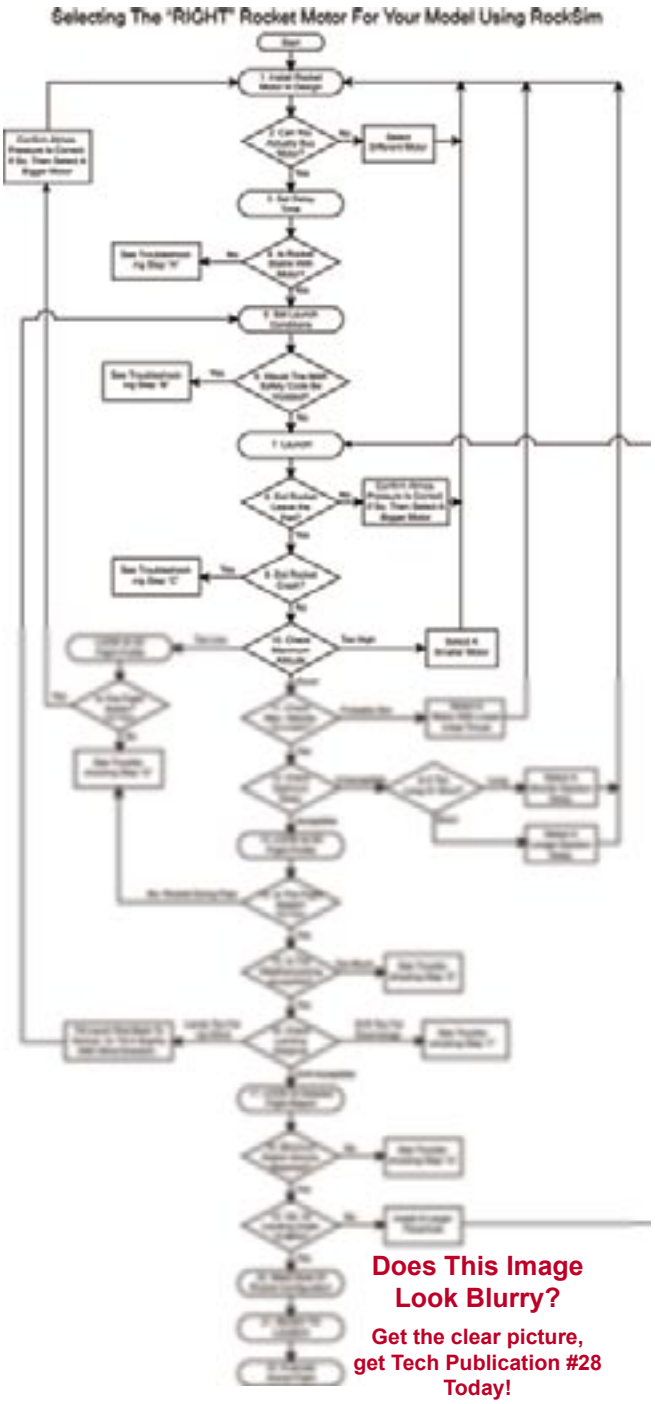

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Selecting Rocket Motors

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

related article in *Peak-of-Flight Newsletter* #59 at http://www.ApogeeRockets.com/education/newsletter59.asp)

Step 4: Is the Rocket Statically Stable?

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

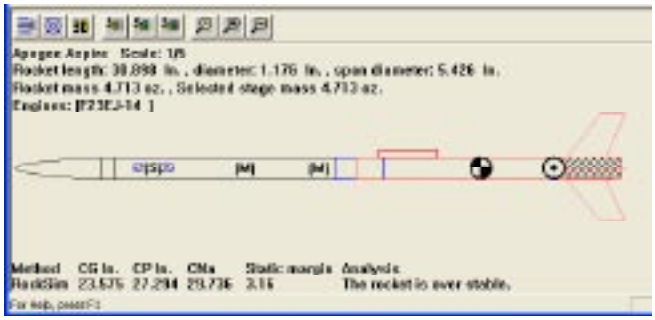

Figure 3: RockSim tells you the static stability of the rocket. Make sure the engine is installed.

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.

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.

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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 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".

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.

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 you load

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Rocket never left the pad.

Recovery system ejected before apogee.

Recovery system ejected at apogee.

Recovery system ejected after apogee.

Rocket impacted with ground prior to deployment of recovery device.

{BLANK} If you see a blank field, this means the simulation was set to "end at apogee." You'll need to change it to end when rocket reaches ground.

Figure 4: Summary icons used by RockSim to display what happened with the flight.

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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 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.

Article Continued...

In Steps 11 to Step 22, we'll look at the results computed by RockSim, and determine what we have to do to get the perfect flight. The remainder of this article is continued in Apogee Technical Publication #28. http://www.apogeerockets.com/technical_publications.asp

In the 12 pages of Technical Publication #28, you'll get crystal-clear drawings and illustrations, and lots of little extra details to help you pick that perfect motor for your rocket. It is very educational, thereby making it great for teachers to help them show students the process of picking a rocket motor.

You can order this important report on CD-ROM, or as a pdf that will be emailed to you after you placed your order.

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.

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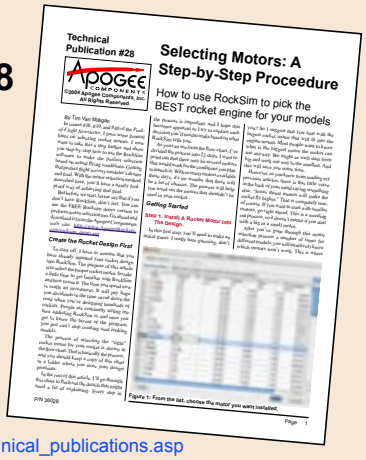

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