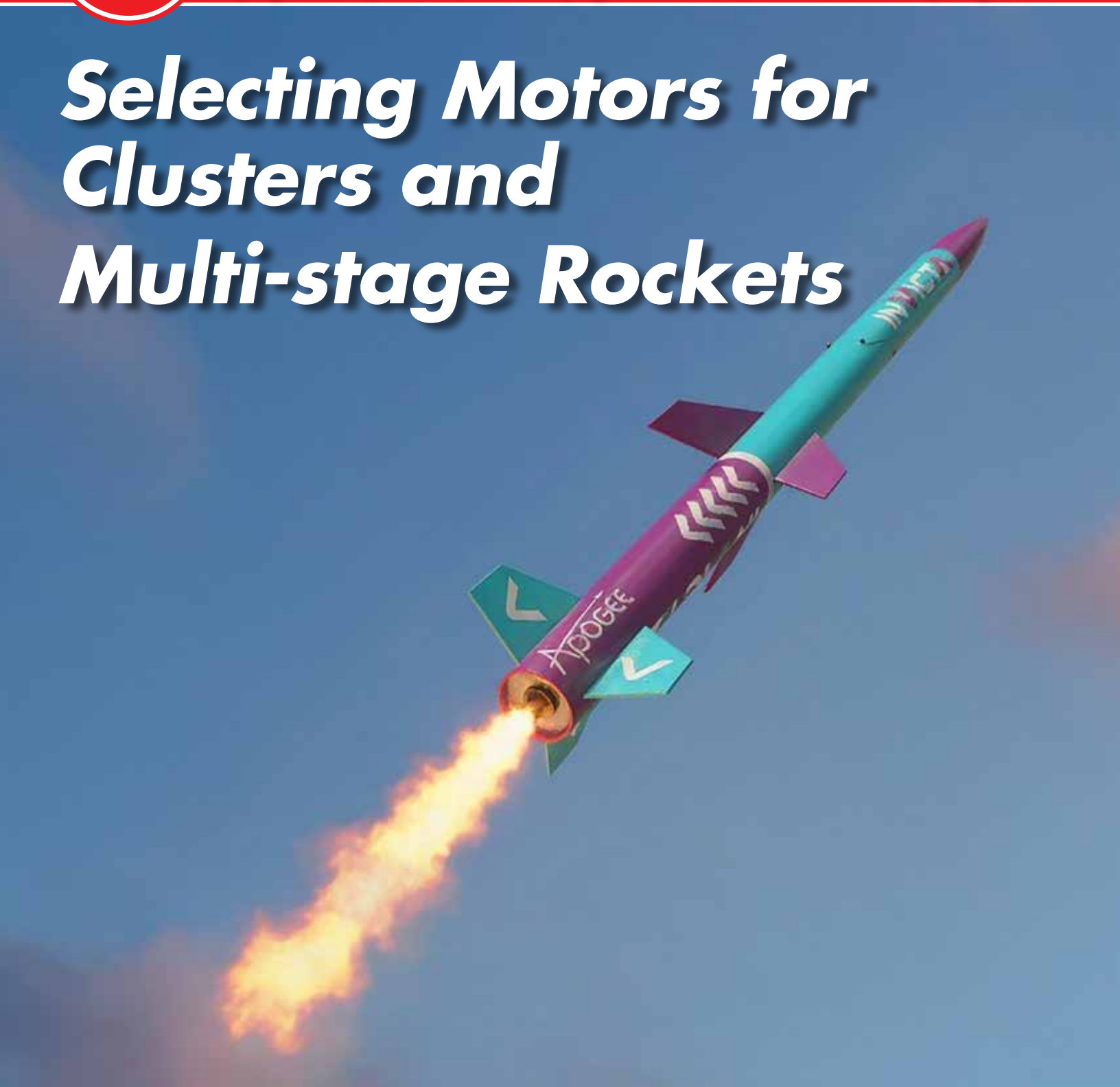
Issue 657 / July 29th, 2025

PEAK OF FLIGHT NEWSLETTER

Apogee Components, Inc. / ApogeeRockets.com / Colorado Springs, CO

Selecting Motors for Clusters and Multi-stage Rockets



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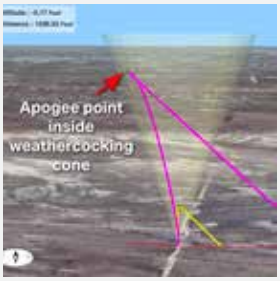
COVER PHOTO

The 2-stage Invicta roars into a cloudless sky.

FEATURED ARTICLES



Selecting Motors for Clusters and Multi-Stage Rockets

by Tim Van Milligan

Since we can't use RockSim's Recommend Motor feature for clusters and multi-stage rockets, we need a simple process for picking motors. That is what this article is about.

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About this Newsletter

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Successful launch of the Apogee Nike Hercules Rocket on four F15 motors.

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By Tim Van Milligan

Model rocketry becomes especially thrilling when you move beyond single-motor designs into the realm of clustered and multi-stage rockets. These configurations offer more dramatic launches, complex flight paths, and greater altitude potential. However, they also introduce more complexity—particularly when it comes to choosing safe and appropriate rocket motors.

If you've used RockSim before, you've likely appreciated how easy it is to select motors for single-stage rockets. In fact, RockSim includes a built-in "Recommend Motors" feature that automatically generates a list of safe motor options for your design. With just three clicks, you can view a list of motors that meet critical safety criteria, such as minimum launch speed, stability, and deployment velocity. You can see this process demonstrated in our

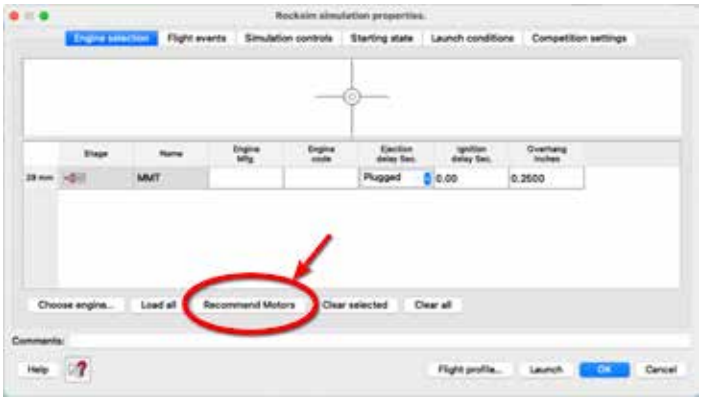

Figure 1: The "Recommend Motors" button allows you to generate an extensive list of potential motors with just a simple click of your mouse

video tutorial (https://www.youtube.com/watch?v=iwrjTgStOLM&-feature=youtu.be) or Newsletter #624 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter624).

But when it comes to rockets that have more than one motor mount—either in a cluster or across multiple stages—RockSim disables the Recommend Motors feature. Why is that?

The answer is simple: combinatorics. When you move from one motor to two, three, or more, the number of possible combinations increases exponentially. Each motor mount can potentially hold any motor of the same diameter, and each motor may come

with multiple ejection delays. Add in the possibility of adapters, mixed motor types, or varying thrust levels, and the total number of combinations becomes massive. For example, as explained in Newsletter #583 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter583), a four-motor cluster using 69 available 24mm motors can result in over 1 million potential motor combinations.

Running simulations for each of those combinations would take hours—or even days—on a typical computer. That's why RockSim disables the Recommend Motors feature when multiple motor mounts are detected. Instead, the process must be done manually, one combination at a time.

Fortunately, there is a structured and efficient way to do this. In this article, I'll walk you through a step-by-step method for selecting motors for clustered and multi-stage rockets. You'll learn how to:

- Use RockSim to simulate worst-case scenarios (e.g., motor failure in clusters)
- Identify safe motor combinations based on velocity, stability, and recovery conditions
- Build and test your own motor lists
- Adapt RockSim files (e.g., converting two-stage rockets to single-stage for testing)
- Use RockSim-Pro's 3D visualizations to verify safe trajectories
- And ultimately, build confidence in your ability to fly complex rockets safely

We'll include two real-world examples:

- A three-motor clustered version of the Mako rocket, using our Triple 29mm Adapter Kit (https://www.apogeerockets.com/Building-Supplies/Motor-Mount-Kits-Adapters/Motor-Mount-Kits-for-Body-Tubes-56mm-and-Up/Triple-Motor-Mount-Adapter-Kit-29-74)
- A two-stage high-power flight with the Invicta rocket, featuring electronic staging using the Simple Timer (https://www.apogeerockets.com/Electronics-Payloads/Staging/Simple-Timer-for Staging)

The approach we'll use is focused on safety first. We're not searching for the absolute highest altitude or maximum speed. Instead, we want to generate a safe, reliable, and visually satisfying experience, ideally using rocket motors you already have in your collection.

Let's begin by reviewing the key safety criteria that RockSim uses to determine whether a flight is acceptable. These will serve as our benchmarks as we simulate clustered and staged motor combinations manually.

Key Safety Criteria for Motor Selection

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Before we examine the processes specific to cluster and multi-stage rockets, it is important to understand the criteria RockSim uses to evaluate flight safety. These same principles will guide our manual simulations for more complex designs.

1. Static Stability (Static Margin):

The Center of Gravity (CG) must be ahead of the Center of Pressure (CP) to ensure the rocket is stable at lift-off. Clusters and multi-stage configurations often shift the CG rearward, so this must be carefully monitored.

2. Minimum Lift-Off Speed (Velocity at Launch Guide Departure):

The rocket must reach at least 30 feet per second by the time it leaves the launch guide. This ensures aerodynamic control surfaces (i.e., fins) are effective. See Newsletter #625 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter625) for more on this criterion.

Figure 2 - The Mako rocket with an optional 3-engine cluster mount.

3. Weathercocking Cone:

The apogee of the flight must fall within a 20° half-angle cone extending upward from the launch pad. A trajectory outside this cone indicates excessive weathercocking and increased risk. This concept is explained in detail in Technical Publication #28 (https://www.apogeerockets.com/downloads/PDFs/Tech_Pub_28.pdf).

4. Maximum Angle of Attack:

The rocket must not exceed a 90° angle of attack at any point during flight, to prevent instability. Recovery from instability may occur later in flight, but RockSim flags this as a safety issue.

5. Parachute Deployment Speed:

The recovery system (e.g., parachute) should deploy at less than 50 mph to avoid damage. This is primarily relevant for selecting ejection delay times, especially for single-use motors with fixed delays. See Newsletter #520 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter520) for further guidance.

Motor Selection for Cluster Rockets

Cluster configurations involve multiple motors igniting simultaneously. The primary challenge is not just selecting motors that work together, but ensuring that the rocket will still fly safely if one or more motors fail to ignite—a realistic concern in clustered launches.

For this example, we will use the Mako Rocket Kit from Apogee Components. The Mako (https://www.apogeerockets.com/Model-Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/Mako) is a 3-inch diameter, 42-inch tall rocket designed for mid-power motors. When outfitted with the Triple Motor Mount Adapter Kit 29/74 (https://www.apogeerockets.com/Building-Supplies/Motor-Mount-Kits-Adapters/Motor-Mount-Kits-for-Body-Tubes-56mm-and-Up/Triple-Motor-Mount-Adapter-Kit-29-74), it becomes a highly capable clustered launch platform.

Step-by-Step Process

1. Prepare the RockSim File

Begin by opening the Mako design file in RockSim. We've got the 3-engine design file that you can download here (Mako with Longtail Fins and a cluster of three 29mm motors - https://www.apogeerockets.com/downloads/rocksim_files/Mako-long-tail_3x29.rkt)

2. Simulate a Motor Failure

To simulate the failure of one motor in a three-motor cluster, leave one motor mount empty and instead insert a mass object with the equivalent weight of the motor. This represents the unlit motor as dead weight. For most motors (up to 54mm in diameter), the mass can be found on the Apogee website.

3. Begin with Lower-Thrust Motors

Start by loading lower average thrust motors into the two active mounts. If a pair of low-thrust motors provide sufficient lift-off speed (30 mph), then higher-thrust combinations will also pass.

Figure 3 - The mass of the rocket motors are listed on the Apogee website.

For example, let's see if two AeroTech F20W motors with one dead motor may provide adequate lift.

In our simulation shown in Figure 4 and Figure 5, the clustered Mako reached 52.9 mph at lift-off with two F20Ws and a 80g mass object. The trajectory remained within the weathercocking cone with winds at 8mph, and the rocket attained 2053 feet of altitude.

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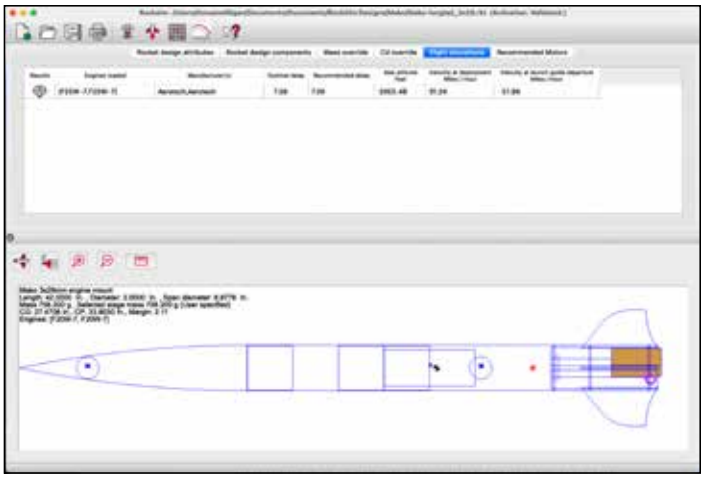

Figure 4 - Simulation results of the clustered version of the Mako with two F20W-4 motors, plus a mass object of 80 grams to simulate the motor that didn't ignite.

Figure 5 - The apogee of the flight stayed inside the weathercocking cone (black lines), indicating a nice straight-up flight.

Static margin was 2.11 calibers—well within the safe range.

4. Repeat and Build Your List

Repeat the simulation using different motor combinations. Increase the average thrust incrementally—e.g., simulate with G40Ws, then G80Ts. You can export out the simulation summary screen (Figure 6) when you are done so you have a list that you can use to plan your future flights of the rocket.

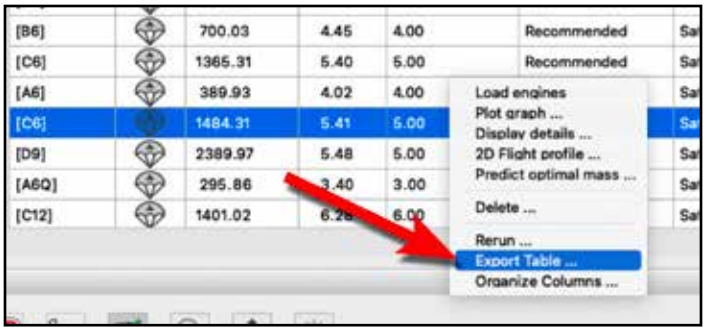

Figure 6 - To export the simulation summary screen, right-click on the chart and select "Export Table."

This is the step that will take you the longest, and as mentioned, the potential motor combinations could run to over 1 million. So you probably want a cheat to save yourself some time.

It is wise to start with the motors you might already have in your range box so that you can save money by not having to purchase more. Also concentrate on those motors that have the flame effects that you find most visually appealing. There is an explanation of the flame effects for the different propellant types on our website at: https://www.apogeerockets.com/Peak-of-Flight/Newsletter624. Once you know the smallest motors that will work in your cluster rocket, you can assume that the larger ones will also work; so you don't have to do everything. Narrow your focus to what motors you can actually acquire.

5. Cant Motors for Thrust Balance

If your rocket isn't already constructed, to further enhance safety and stability, especially in the case of uneven ignition, consider canting the motors slightly toward the center of gravity. This helps prevent the rocket from veering if one motor fails. The technique is discussed in Newsletter #654 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter654). RockSim Pro allows you to simulate canted motors via the "axis error" fields under motor configuration. But don't get too concerned if the motors aren't canted, this is just a suggestion, rather than a rule. Straight motors in the rock-

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et will still give a good stable ascent, which is the important part.

6. Consider Motor Adapters

Motor adapters (e.g., 24mm-to-29mm) expand your options and may reduce cost per flight. Simulate these configurations by assigning the appropriate mass to the motor and adapter combination. You can find various motor adapters on the Apogee website at: https://www.apogeerockets.com/Building_Supplies/Motor_Mount_Kits_Adapters/Motor_Mount_Adapter_Kits

7. Visual Preferences

Once you've identified a safe list, you may filter for visual appeal. For example, Black Max™ motors produce dark smoke trails, while White Lightning™ offers a bright flame. See Newsletter #624 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter654) for a thorough guide to visual effects by propellant type.

Motor Selection for Multi-Stage Rockets

Multi-stage rockets carry their own set of challenges: CG shifts due to extra motors, timing concerns for staging, and the need to simulate each stage's performance. The good news is that RockSim can be adapted to generate motor lists for both booster and upper stages, using a few creative adjustments. So unlike the cluster configuration, we can use some tricks that will allow us to use the Recommend Motor feature in RockSim to generate separate lists of potential motors for the upper and lower stages. Then we can pick and choose from the two lists to come up with our final motor choices.

For this section, we will use the Invicta Rocket Kit (https://www.apogeerockets.com/Model-Rocket-Kits/Skill-Level-4-Model-Rocket-Kits/Invicta), a 2-stage high-power rocket designed for electronic staging and capable of using 29mm motors in both stages.

Step-by-Step Process

1. Isolate the Booster Stage

Duplicate the Invicta design file. In this new version:

- Copy all components of the booster stage and attach them to the bottom of the sustainer.
- Delete the original booster stage section.
- Add a mass object to simulate the sustainer motor (e.g., ~127.9g for a G80T). Also uncheck the box on the tube that designates it as a “motor mount tube.” We only want a single tube in the rocket to be a motor mount tube

Figure 7 - The parts tree of the 2-stage Invicta (left side), and after the booster stages' parts were attached to the sustainer to make a single-stage version of the rocket.

Now you have a single-stage design representing the booster plus the payload. This allows you to use RockSim's “Recommend Motors” feature.

2. Generate a Booster Motor List

Run the simulation with the default conditions (e.g., 5-8 mph wind, 96" launch guide). RockSim will recommend motors that meet the safety criteria. Export this list for reference.

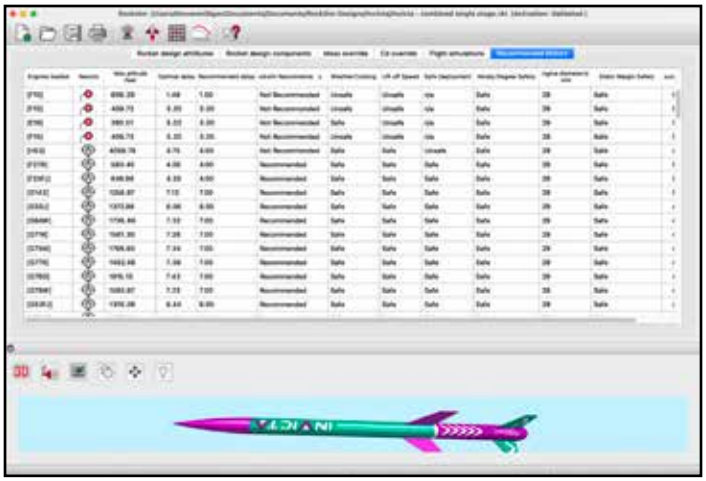

Figure 8 - After running the recommend motors feature, you'll have a giant list of motors that will work in the booster stage to safely lift the rocket off the launch pad.

3. Determine Appropriate Delay

The safest delay for the booster is **zero seconds**—the upper-stage ignites as soon as the booster burns out, while velocity is still high. This ensures stability and keeps the probability high that the upper stage will have its apogee point inside the weather-cocking cone.

However, you may experiment with longer delays for efficiency (coasting reduces drag) and to create a more exciting "air start" type flight. But be sure to check the apogee remains inside the weathercocking cone if you do experiment with a delay in the booster stage.

For optimal staging, especially for altitude goals, consider using electronics like the Blue Raven altimeter. Its "Three Seconds in the Future" feature, described in *Peak-of-Flight Newsletter #635* (https://www.apogeerockets.com/Peak-of-Flight/Newsletter635), helps determine the ideal ignition point based on predictive trajectory data.

4. Isolate the Upper Stage

To evaluate upper-stage motors:

- Duplicate the original Invicta file again.
- Delete the booster stage entirely.
- Simulate the sustainer as a single-stage rocket.

RockSim assumes zero starting velocity, but RockSim Pro allows you to set a custom initial speed and altitude, replicating realistic conditions post-staging. Even with RockSim and starting at zero velocity, the list of recommended motors is useful for the initial selection. The only thing that will be wrong is the exact ejection delay - normally, it will need to be a little longer because the rocket has a high starting velocity because it was staged.

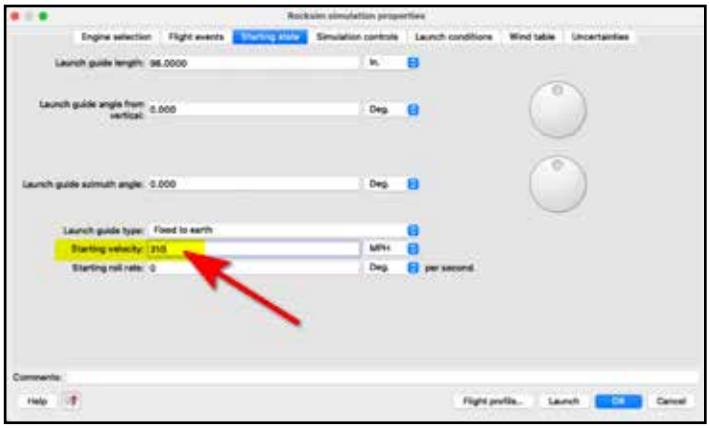

Figure 9 - In RS-Pro, you can change the starting velocity of the rocket to account for staging speed. This will help you find the optimal delay time for parachute deployment.

5. Generate a Sustainer Motor List

Use the Recommend Motors feature to generate a list of upper-stage options. Export these and cross-reference with your booster motor list to make your final pairs.

6. Combine and Simulate

Now that you have viable booster and sustainer motor lists, simulate full two-stage flights by pairing them in the original Invicta file.

Example: F67C-0 booster with a F20W-7 sustainer. Simulated apogee: ~1855 feet. All safety criteria passed.

Use RockSim's 2D profile or the 3D Launch Visualizer in RS-PRO (see Figure 11) to verify the apogee remains within the

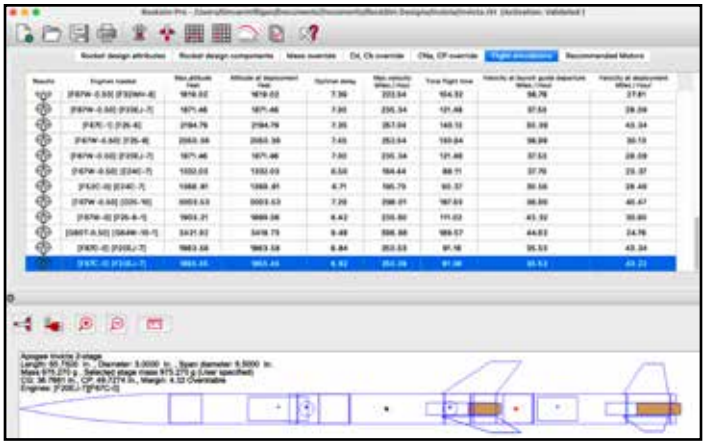

Figure 10 - Final summary screen shows the results (highlighted blue) with the F67C-0 and a F20-7 in the upper stage.

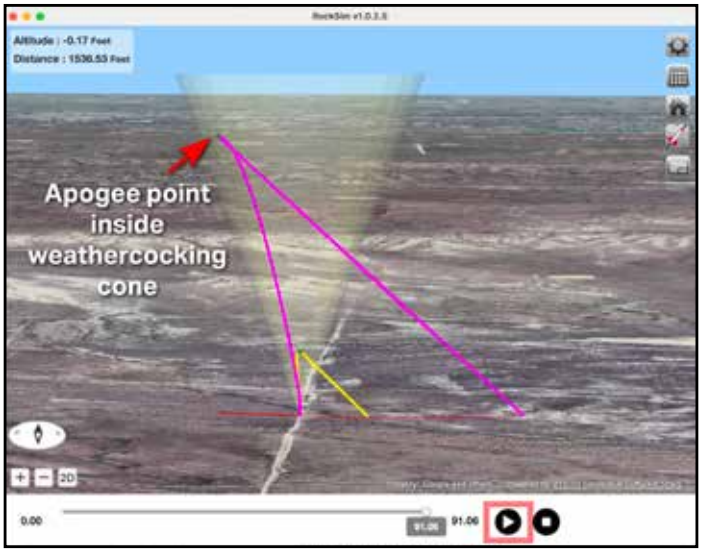

Figure 11 - 3D Launch Visualizer view from RS-PRO shows the trajectory of the 2-stage Invicta. The pink is the upper stage, and the yellow is the booster stage. Note the apogee point of the rocket is inside the weathercocking cone, indicating a good flight.

weathercocking cone and that stability is maintained throughout.

Summary and Final Recommendations

Selecting motors for clustered and multi-stage rockets requires more diligence than for single-motor designs. However, with a methodical approach and tools like RockSim, the process becomes manageable—and even enjoyable.

Key Takeaways

- Use RockSim to simulate worst-case scenarios for clusters (e.g., one motor fails).
- Focus on minimum lift-off velocity as your primary safety criterion.
- Isolate stages in multi-stage rockets to use RockSim's Recommend Motors feature.
- Use motor adapters to expand your list of options.
- Consider canting motors for improved stability in cluster configurations.
- Filter your final motor list based on visual preferences and availability.
- Use RockSim Pro for more advanced simulations, such as setting initial conditions post-staging.
- Reference key Apogee resources and newsletters for deeper learning.

Calls to Action

If you found this article helpful, here are ways to take your next step:

- **Download RockSim:** Try the free 30-day trial and see how easy it is to simulate your own designs.
- **Upgrade to RockSim Pro:** For advanced users, RockSim Pro offers 3D trajectory visualization and is ideal for cluster and multi-stage work.
- **Subscribe to the Peak-of-Flight Newsletter**: Get weekly tips, design ideas, and technical insights delivered to your inbox.

- **Share this article:** Forward it to your rocketry club or friends. Help others learn the process and build better rockets.

We hope this guide has empowered you to confidently explore more complex and exciting rocket designs. With the right tools and a thoughtful approach, your clustered and staged rockets will fly safely—and impressively.

About the Author

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who enjoys helping fellow rocketeers. He is Level 3 high-power certified, an experienced educator, and the founder of Apogee Components. Formerly involved in the Delta II rocket program, Tim holds a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University and has worked toward an M.S. in Space Technology from the Florida Institute of Technology. He is also the author of Model Rocket Design and Construction and 69 Simple Science Fair Projects with Model Rockets: Aeronautics, and publisher of the *Peak-of-Flight newsletter.*

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Article Submission Guidelines

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SUBMITTING ARTICLES TO APOGEE

We are always looking for quality articles to publish in the *Peak-of-Flight* newsletter. Please submit the "idea" first before you write your article. It will need to be approved first.

When you have an idea for an article you'd like to submit, please use our contact form at **https://www.apogeerockets.com/Contact**. After review, we will be able to tell you if your article idea will be appropriate for our publication.

Always include your name, address, and contact information with all submissions. Including best contact information allows us to conduct correspondence faster. If you have questions about the current disposition of a submission, contact the editor via email or phone.

CONTENT WE ARE LOOKING FOR

We prefer articles that have at least one photo or diagram for every 500 words of text. Total article length should be between 2000-4000 words and no shorter than 1750 words. Articles of a "how-to" nature are preferred (though other types of articles will be considered) and can be on any rocketry topic: design, construction, manufacture, decoration, contest organization, etc. Both model rocket and high-power rocket articles are accepted.

CONTENT WE ARE NOT LOOKING FOR

We don't publish articles like "launch reports." They are nice to read, but if you don't learn anything new from them, then they can get boring pretty quick... Example: "Bob flew a blue rocket on a H120 motor for his certification flight." As mentioned above, we're looking for articles that have an educational component to them, which is why we like "how-to" articles.

You can see what articles and topics we've published before at: **https://www.apogeerockets.com/Peak-of-Flight?pof_list=archives&m=education**. You might use this list to give you an idea or two for your topic.

Here are some of the common articles that we reject all the time, because we've published on these topics before:

- How to get a L1, L2, or L3 Cert
- Building cheap rockets and equipment (pads & controllers)
- How to 3D print parts, or a Rocket Kit
- How to Build a cheap Rocket Kit
- Getting Back Into Rocketry After a Long Hiatus

ARTICLE & IMAGES SUBMISSION

Articles may be submitted by emailing them to the editor. Article text can be provided in any standard word processor format, or as plain-text. Graphics should be sent in either a vector format (Adobe Illustrator, SVG, etc.) or a raster format (such as jpg or png) with a width of at least 600 pixels for single column images or 1200 pixels for two-column images. It is preferable for images to be simple enough to be readable in a two-column layout, but special layouts can be used.

Send the images separately via email as well as show where they go by placing them in the word processor document.

ACCEPTANCE

Submitted articles will be evaluated against a rubric (available here on our website). All articles will be evaluated and the results will be sent to the author. In the evaluation process, our goal is to ensure the quality of the content in *Peak-of-Flight*, but we want to publish your article! Resubmission of articles that do not meet the required standard are heavily encouraged.

ORIGINALITY

All articles submitted to Peak-of-Flight must not run in another publication before inclusion in the *POF* newsletter, but it may be based on another work such as a prior article, R&D report, etc. After we have published and paid for an article, you are free to submit them to other publications.

RATES

Apogee Components offers **$300** for a quality-written article over 2,000 words in length. Payment is pro-rated for shorter articles.

WHERE WILL IT APPEAR?

These articles will mainly be published in our free newsletter, *Peak-of-Flight*. Occasionally some of the higher-quality articles could potentially appear in one of Tim Van Milligan's books that he publishes from time to time.

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