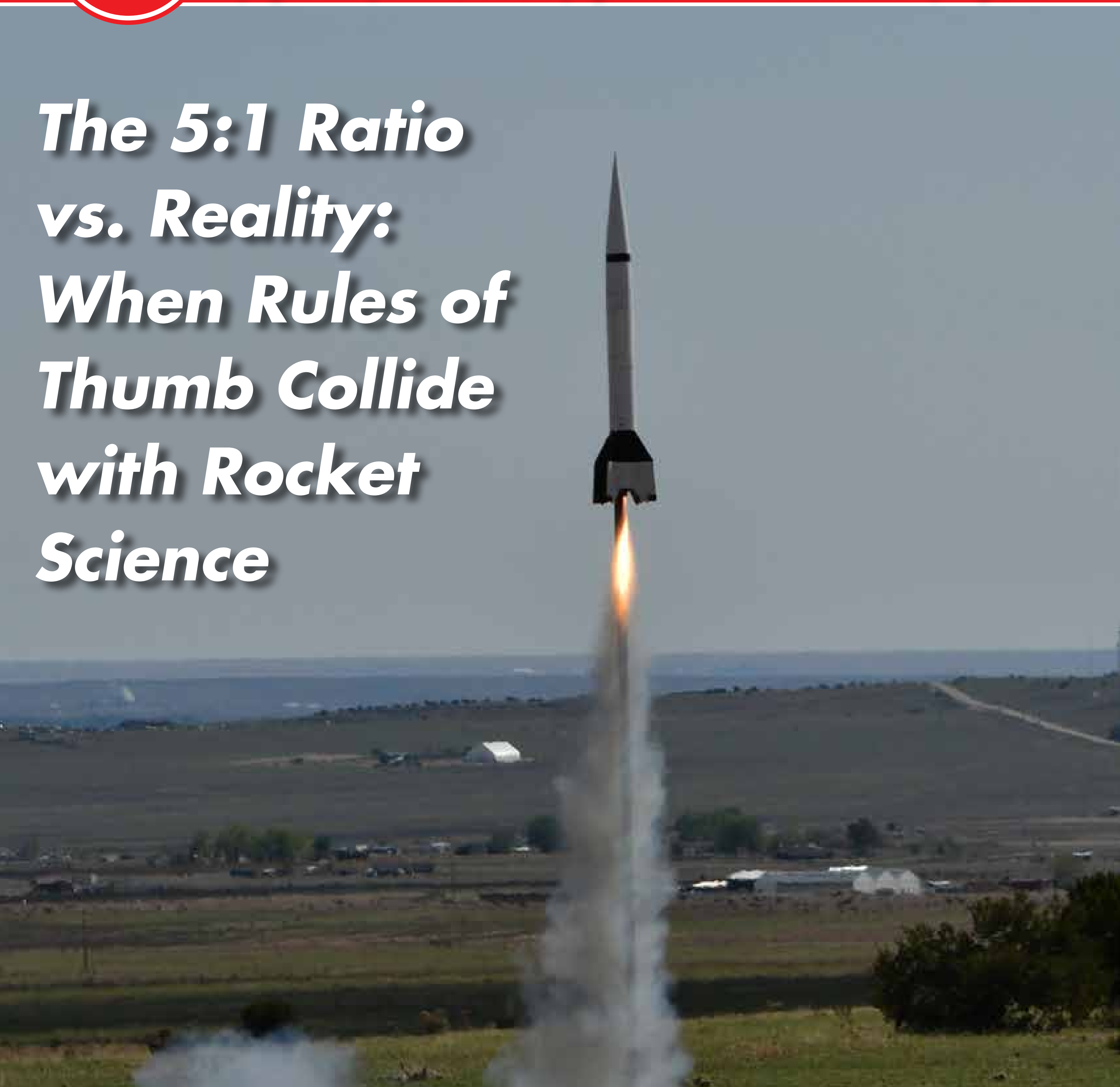
Issue 671 / February 10th, 2026

PEAK OF FLIGHT NEWSLETTER

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

The 5:1 Ratio vs. Reality: When Rules of Thumb Collide with Rocket Science



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COVER PHOTO

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The 1/10th scale model of the Convair MX-774 Hiroc lifts off. It was a pioneering rocket that laid the groundwork for future advancements in American ICBM technology. Click here for more information.

FEATURED ARTICLES

The 5:1 Ratio vs. Reality

It's a good rule-of-thumb, but sometimes your rocket won't get the RSO's blessing to launch your rocket because of it - even though your rocket is stable in other regards.

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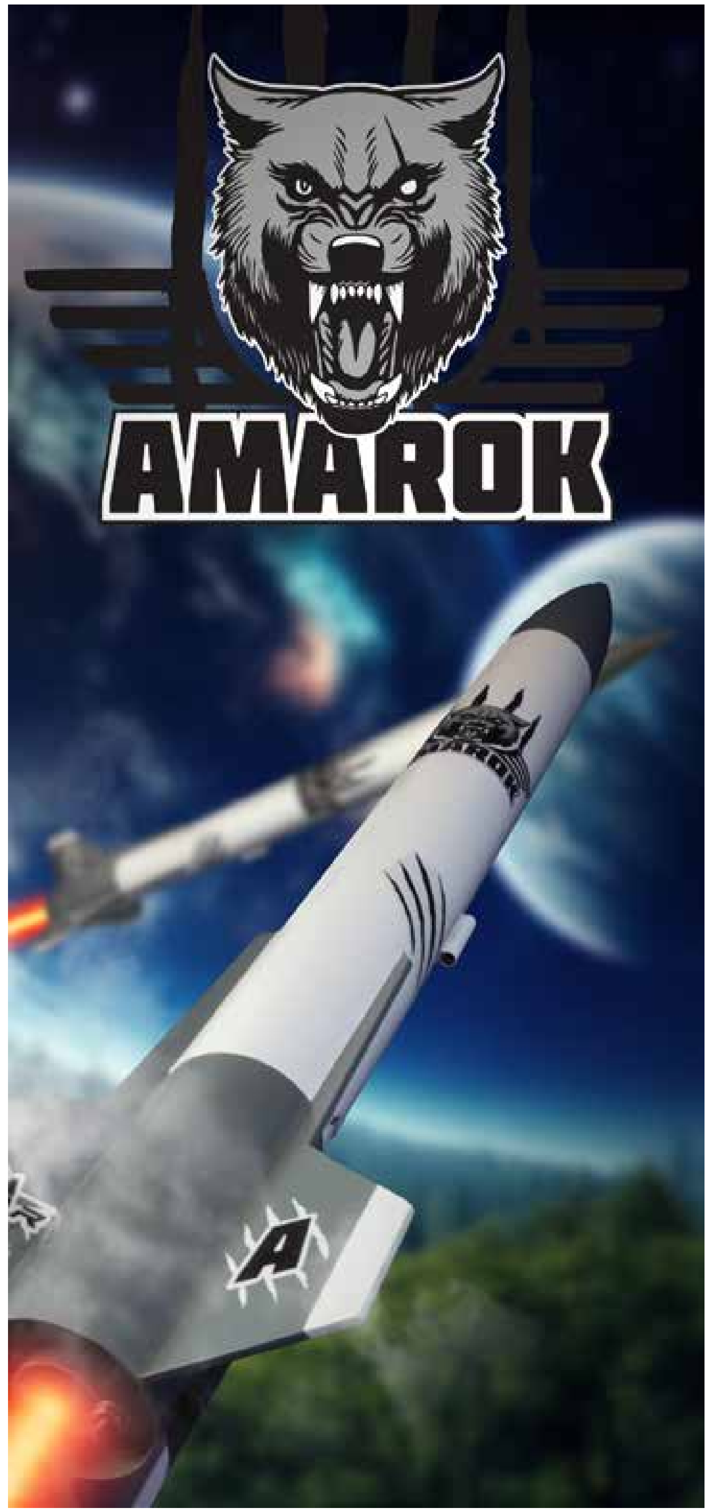

The 5:1 Ratio vs. Reality: When Rules of Thumb Collide with Rocket Science

By Tim Van Milligan

We have all been there. You have spent weeks building a new rocket. You have sanded the fins until they are glassy smooth, applied a paint job that gleams in the sun, and carefully packed the parachute. You approach the check-in table at the launch range, your heart beating a little faster with anticipation. You hand your flight card to the Range Safety Officer (RSO). They look at the rocket. They look at the motor you have selected. They punch a few numbers into a calculator.

And then, they shake their head.

“I can’t let you fly this,” they say. “The motor doesn’t have enough thrust for this weight.”

You are stunned. You ran the simulations at home! You used RockSim. You checked the weathercocking cone. You know it’s safe. But the RSO is pointing to a simple rule of thumb: The 5:1 Thrust-to-Weight Ratio.

This exact scenario happened recently to a customer named Mark S. He sent me an email that really got me thinking about the intersection of old-school rules, modern simulation technology, and the human element of keeping our hobby safe.

Figure 1 - RSO checking rocket before flight

Mark wrote:

“The other weekend I was questioned by the RSO about my motor and that it did not comply with the 5/1 ratio? I said I ran it in Rocksim several times and even at 15 mph wind it said safe and it was inside the cone. So what parameters does Rocksim use? … You will see my sim had 5.5 both wind conditions… I questioned the RSO as I stated well the

day before You passed it to fly what is the difference? and both flights were perfect?????"

Mark was flying a heavy rocket (about 3.3kg) on an AeroTech I140 motor. The RSO did the math and decided the I140 was too weak for that heavy of a rocket. Mark knew from his software that the flight would be fine.

So, who was right? And more importantly, how do we navigate this gap between a "Rule of Thumb" and complex physics?

The First Commandment: The RSO is Always Right

Before we dive into the math and the physics of thrust curves, we have to establish the most important rule of rocketry, one that supersedes aerodynamics and propulsion.

Do not argue with the Range Safety Officer.

I want to be very clear about this. Even if you have a PhD in "unexpected rapid disassembly" and a supercomputer strapped to your back, if the RSO says the rocket doesn't fly, the rocket doesn't fly.

Why am I so hard-line on this? Because the RSO is the person whose name is on the line. If a rocket goes unstable, arcs over, and hits a car (or worse, a person), the RSO is the one who has to answer for it. They are the guardians of our hobby. Their conservatism is the reason model rocketry has such an incredible safety record compared to almost any other outdoor hobby.

There is an old saying in aviation that applies perfectly here: "It is better to be on the ground wishing you were in the air, than in the air wishing you were on the ground."

When an RSO flags your rocket, they aren't trying to ruin your day. They are trying to ensure that everyone goes home with the same number of fingers and toes they arrived with. They are making a judgment call based on the data they have available in that moment.

In Mark's case, he mentioned that he questioned the RSO because they had allowed the flight the day before. While it is human nature to point out a discrepancy, it puts the RSO in a defensive position. It is always better to approach these situations as a collaboration on safety, rather than a debate on physics.

However, understanding why the RSO flagged the flight—and why Mark's simulation said it was safe—is a fascinating dive into how rocket motors actually work.

Deconstructing the 5:1 Rule of Thumb

To understand the conflict, we have to look at the math the RSO was using. It is known as the 5:1 Thrust-to-Weight Ratio (TWR).

This is one of the oldest and most reliable rules in model rocketry. It states that the thrust of the motor should be at least five times the weight of the rocket.

The Formula:

- Rocket Weight (in Newtons) x 5 = Minimum Required Thrust (in Newtons).

Why the number 5?

- **1G (Gravity):** You need 1G of thrust just to counteract gravity and hover. If your thrust equals your weight, the rocket sits on the pad and burns.
- **4Gs (Acceleration):** The remaining thrust is used to accelerate the rocket. We need the rocket to get moving fast. Stability comes from air flowing over the fins. If the rocket moves too slowly off the launch rod, the fins have no "grip" on the air. If a wind gust hits a slow-moving rocket, it will weathercock (turn into the wind) severely, or worse, become unstable.

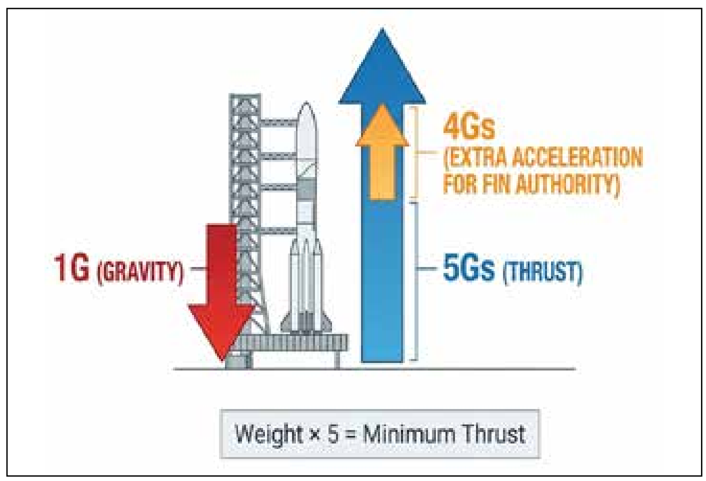

Figure 2 -The 5:1 thrust ratio makes sure the rocket accelerates at least 4G's coming off the pad.

The 5:1 ratio is a "blunt instrument." It is designed to be calculated in your head or on a scratchpad at the launch site. It provides a wide safety margin to account for wind, imperfect motor performance, and drag.

Let's look at Mark's Rocket:

- **Rocket Mass:** 3.308 kg.
- **Gravity:** 9.81 m/s².
- **Rocket Weight:** 3.308 x 9.81 = 32.45 Newtons.

Now, apply the 5:1 Rule:

- 32.45 Newtons (Weight) x 5 = **162.25 Newtons.**

According to the rule, Mark needed a motor that produces at least 162.25 Newtons of thrust to fly safely.

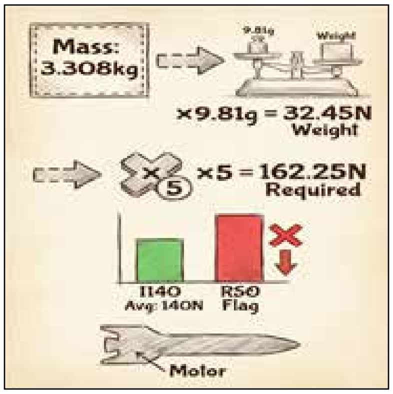

Figure 3 - the 5-to-1 Rule allows for quick math calculations

The Motor:

Mark was using an AeroTech **I140**.

In rocketry nomenclature, the letter (I) tells us the total impulse (total power), and the number (140) tells us the **Average Thrust** in Newtons.

Do you see the problem?

The RSO looked at the motor designation: **140**.

The RSO looked at the requirement: **162**.

140 is less than 162. Therefore, according to the strict application of the 5:1 rule, the motor is underpowered.

Case closed? Not quite.

The Problem with "Average"

The discrepancy here lies in a single word: Average.

The number printed on the side of a rocket motor (like the 140 in I140) is the average thrust over the entire duration of the burn.

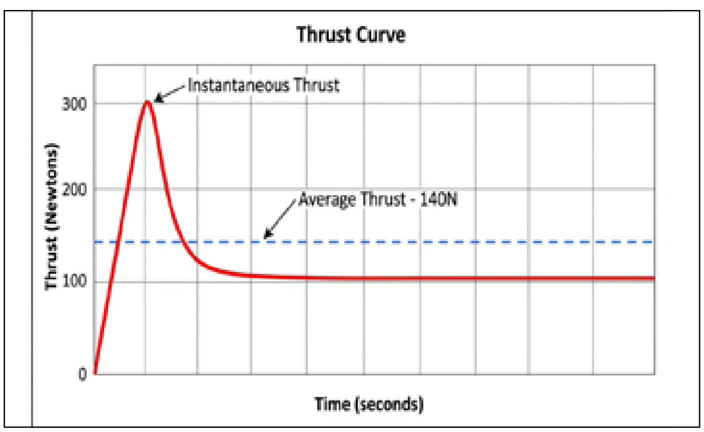

Figure 4 - The average thrust can be misleading to the performance of the rocket because it doesn't tell the full story of the thrust level throughout the flight.

But rocket motors rarely burn at a constant rate.

Imagine you are driving a car on a trip. You start by flooring the gas pedal to get onto the highway, hitting 75mph. Then you cruise at 60mph. Then you hit traffic and crawl at 20mph. Your average speed might be 50mph. But if I asked, "Did you have enough power to merge onto the highway?" looking at your average speed of 50mph doesn't tell the whole story. You need to know your speed

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at that specific moment.

Rocket motors are similar. They have a "Thrust Curve"—a graph showing how much force they produce at every split second of the burn.

The Simulation Difference

When the RSO did the math, they used the **Average Thrust (140N).** This averages the high initial thrust spike with the lower sustain. It smooths out the data.

When Mark ran RockSim, the software didn't care about the average. RockSim looks at the **Instantaneous Thrust** at the exact moment the rocket leaves the launch rail.

The I140 motor has an initial thrust that is close to 180 Newtons for that first critical second.

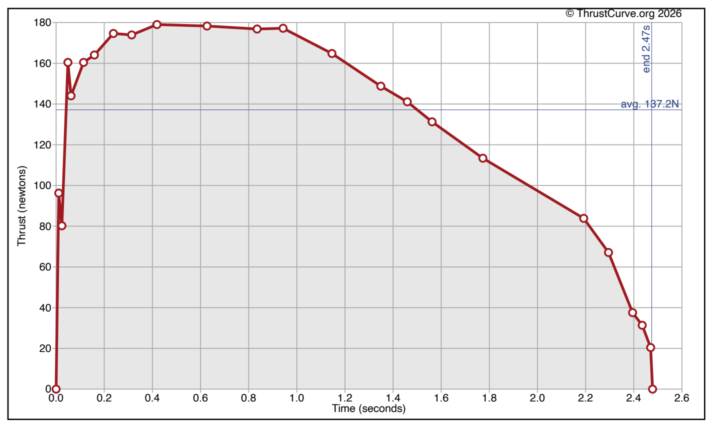

Figure 5 - The I140 Thrust profile (source: Thrustcurve.org)

If the rocket weighs 32 Newtons...

And the motor is pushing with 200 Newtons at liftoff...

That is a ratio of **5.62:1**.

That is why RockSim said "Safe." The software saw the spike because the rocket got up to speed quickly. The RSO's calculator saw the average.

This is a classic case where the "Rule of Thumb" fails to capture the nuance of the physics, and your rocket is penalized for it. The 5:1 rule assumes the motor pushes with the same force the whole time. But in reality, what we care about most is that first half-second. We need that kick to get the rocket up to speed.

Moving Beyond Weight: Velocity is King

This brings us to a concept I discussed in *Peak-of-Flight Newsletter #625: The "Maximum Recommended Lift Off Weight"* (https://www.apogeerockets.com/education/downloads/Newsletter625.pdf) is actually a flawed metric.

For decades, manufacturers published charts saying "Maximum Lift Off Weight" for a motor. I stopped using those charts in 1996 when RockSim came out. Why? Because the weight of the rocket isn't actually what makes it stable or unstable. **Speed is.**

The fins on your rocket are essentially wings. Wings need air flowing over them to generate lift. In the case of a rocket, "lift" is the restoring force that corrects the rocket if it starts to tip over.

- If the rocket is sitting still, the fins do nothing.
- If the rocket is moving slowly, the fins are only making a very weak force.
- If the rocket is moving fast, the fins are providing sufficient force and snap the rocket straight.

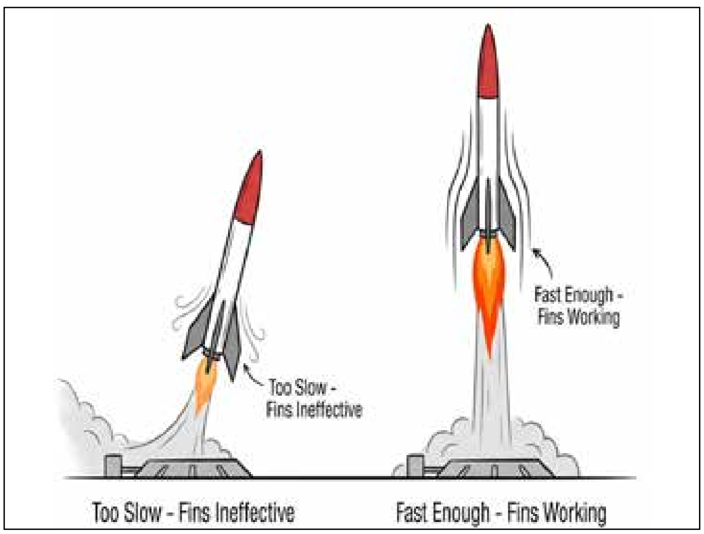

Figure 6 - Low thrust motors make the rocket fly slower, so the fins are less effective at producing forces to correct disturbances.

We don't really care how heavy the rocket is; we care if the motor can get that specific rocket to a safe speed before it leaves the guidance of the launch rod.

The "Slow Realistic Liftoff" Trap

In Newsletter #625, I wrote about why manufacturers created those weight limits. It was because modelers wanted "Slow, Realistic Liftoffs." They grew up watching the Saturn V launch on TV. It looked majestic and slow. They didn't realize the TV footage was often in slow motion!

To mimic this, modelers would load their rockets with weight. The rocket would lift off painfully slowly. But because it was slow, the fins weren't working yet. If a breeze hit the rocket, it would tilt.

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The motor would then push the rocket in that tilted direction—often right over the heads of the spectators.

The Golden Number: Rail Exit Velocity

So, if the 5:1 ratio is a guess, what is the real number we should look for?

In my opinion, it is the **Rail Exit Velocity.**

General consensus in the high-power community (and verified by RockSim) is that a rocket needs to be moving at roughly 30 to 50 feet per second (approx. 9 to 15 meters per second) by the time the launch button leaves the rail.

- Under 30 ft/s: The fins may not have enough authority to fight the wind.
- Over 50 ft/s: You are definitely safe (aerodynamically), though you might rip a fin off if you aren't careful with construction!

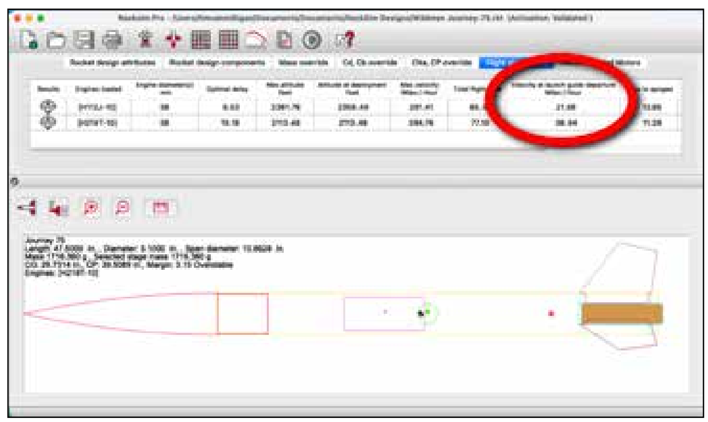

Figure 7 - RockSim will list the speed at which the rocket exits the launch rail.

When Mark ran his simulation, RockSim wasn't just checking the 5:1 ratio. It was calculating the drag, the mass, and the instantaneous thrust to see if the rocket hit that safe velocity.

The Weathercocking Cone

Another safety check Mark mentioned was the "Cone." This refers to the **Weathercocking Cone**.

When a rocket leaves the pad, it will naturally turn into the wind. This is good! It means the rocket is stable. But if it turns too much, it becomes dangerous because it flies horizontal rather than vertical.

RockSim projects an imaginary 40-degree cone extending up from the launch pad. If the simulation shows the rocket's apogee (peak height) stays inside that cone, the flight is considered safe.

Figure 8 - RockSim-Pro will display an imaginary 40° cone rising up from the launch pad. If the apogee point of the rocket stays inside that cone, the rocket is generally said to be "safe."

If the rocket is too heavy or too slow off the pad, the wind will push it over too far, and the apogee will fall outside the cone.

Mark's simulation showed the rocket staying inside the cone. This confirms that even if the Average thrust was low, the Actual thrust was enough to get the rocket moving fast enough to resist the wind.

The Wind Variable

There is one more variable that complicates the 5:1 rule. But this time it is on the opposite side where the 5:1 ratio is not enough thrust. This variable that complicates things is: **The Wind.**

Mark mentioned the wind was **15 mph**. That is a significant wind for model rocketry.

In the case of when wind is significant, you would use a different rule-of-thumb. In *Newsletter #625*, I mentioned what some people call the "20% Rule." This rule of thumb states:

- **The wind speed should be less than 20% of the rocket's lift-off speed.**

The purpose of this rule is to make sure the fins don't stall because they are flying at a high angle of attack (see Figure 9).

The 20% wind rule further states that the lift-off speed of the rocket must be greater than 5 times the wind speed to keep the fin airfoils from hitting their stall angle. Typically this is around 12° for most airfoils. It works out that the sine of the angle of 12° is around .2, which is where the 20% comes in.

Let's do the math on Mark's 15 mph wind:

- 15 mph / 0.20 = **75 mph**.

This suggests that to be truly safe in a 15 mph wind, the rocket needs to leave the rail at **75 mph (110 feet per second)**.

That is incredibly fast. Most model rockets leave the rail between 30 and 50 fps. To hit 110 fps, you would need a massive

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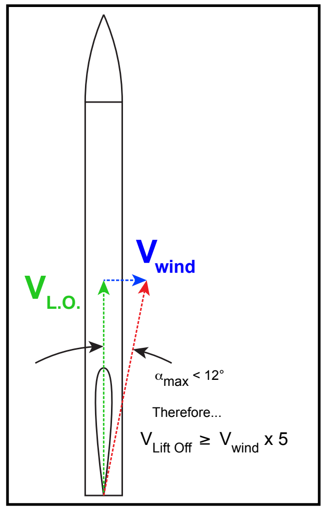

Figure 9 - The lift-off velocity should be 5 times greater than the wind speed to keep the fins from stalling.

motor—way more than a 5:1 ratio.

This highlights a limitation of the 5:1 rule. The 5:1 rule assumes "normal" calm conditions. It does not account for high winds.

- In relatively calm air, a 5:1 ratio is plenty.
- In 15 mph winds, a 5:1 ratio might actually be unsafe, because the rocket won't be fast enough to resist that strong crosswind.

This could be why another RSO might also be hesitant. Even if they didn't articulate the "20% rule" for windy conditions, experienced RSOs develop a "gut feeling." They see a heavy rocket, a medium motor, and a flag whipping in the wind, and their internal alarm bells go off. They were likely right to be cautious, even if Mark's simulation (which accounts for wind) said it was marginally okay.

Bridging the Gap: Preparation and Backups

So, what do you do? You have the simulation data that says "Go," but you are facing an RSO using a rule of thumb that says "No."

First, go back to the First Commandment: **Don't argue.** But, you *can* present data.

1. The Data Package

If you are flying a complex rocket or pushing the limits of weight, don't just bring the rocket to the pads. Bring your "Flight Data Package." Print out your RockSim results.

Specifically, show them:

- **The Thrust Curve Graph:** Show them the spike! Point to the graph and say, "I know it's an I140, but look here—it kicks 180 Newtons for the first 0.8 seconds."
- **Rail Exit Velocity:** Circle this number *(velocity at launch guide departure)*. If it is over 40-50 ft/s, most RSOs will be reassured, especially if the fins look reasonably sized (not itty-bitty fins).
- **Stability Margin:** Show that the rocket is stable.
- **Prior launch history:** You probably have a video of a previous launch on your phone, so you can show that as well.

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Figure 10 - Rocketeer checking in with a data packet.

RSOs love data. If you show them you have done the homework, they are more likely to trust your build and motor choice.

2. The "Plan B" Motor (Thinking Ahead)

This is the most practical advice I can give you. If you are going to a launch with a rocket that is heavy for its motor class, bring a backup motor.

You should always be thinking ahead. "What if the wind picks up? What if the RSO is strict about the 5:1 rule?"

In Mark's case, he was flying an I140. If he had a "Plan B" motor in his range box—perhaps a high-thrust I-motor (like a I280DM AeroTech Dark Matter propellant) or a small J-motor—he could have simply swapped it out.

Scenario: RSO says, "The I140 is too weak."

You say: "I understand your concern. I actually have an I280 in the car. That gives me a 10:1 thrust ratio. Would you prefer I fly that?"

RSO: "Absolutely. That sounds great."

Problem solved. You get to fly, the RSO feels their safety concerns were respected, and everyone is happy.

3. Check the Rail Length

Remember that rail exit velocity depends on the rail length. A 8-foot rail gives the rocket more time to speed up than a 6-foot rail. If your sim says you are safe on a 8-foot rail, make sure the club actually has a 8-foot rail available! If you put that rocket on a 6-foot rail, you might leave the pad too slow, and suddenly the RSO's fears come true. Longer rails, or a 20-foot tower is even better!

Conclusion

It is easy to look at the 5:1 Thrust-to-Weight ratio and call it "old school" or "outdated." But I don't think that is fair, nor is it helpful.

The 5:1 rule exists for a very good reason: Simplicity.

We want model rocketry to be open to everyone. We want the 12-year-old student, the school teacher, and the casual hobbyist to be able to go to a field and fly safely without needing a degree in aerospace engineering or a laptop on the flight line. The 5:1 rule is easy to remember, easy to calculate, and 95% of the time, it keeps rockets safe. It is a useful tool for accessibility.

However, as we get into larger rockets, high-power motors, and complex weather conditions, we have to understand the physics behind the rule. We have to understand that "Average Thrust" can be misleading. And we also have to understand that wind changes the math.

The goal of this article isn't to prove the RSO wrong. It is to help you understand the invisible forces at play.

Use the 5:1 rule for your quick checks.

Use RockSim to find the truth about your specific motor's thrust curve.

Use your judgment to bring a backup motor just in case.

And most of all, respect the people who volunteer their time to keep the range safe. They are the reason we can keep looking up.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (https://www.apogeerockets.com) and also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE ezine newsletter about model rockets. You can email him by using the contact form at https://www.apogeerockets.com/Contact.

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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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