

# PEAK OF FLIGHT

## NEWSLETTER

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# PEAK OF FLIGHT

## How Windy is Too Windy for a Launch?

By Ion Voss

### Introduction

You've driven all the way to the launch site, probably in a bit of a rush (an early start is a good start), you start setting up and then... you notice how windy it is. To launch or not to launch – that is the question. To make an informed decision, you need to quantify what is 'windy' and whether or not it is safe to launch. Safety is the key concern here. Rocketry has a very good safety record and enthusiasts would very much like to keep it that way. Experienced modelers may find this article a bit basic but a little revision never hurts. For those who are relatively new to the hobby, read on (and take notes!).

### Simulation and Information

If you're an enthusiastic, switched-on rocket enthusiast, then by the time you're at the range you will have already done the following;

1. Designed/built a rocket/s and dry fitted all the components for practice.
2. Measured the CG and total mass of the finished, ready to fly rocket and entered all the required information accurately into a simulator.
3. Run numerous simulations allowing for (here it comes) various wind conditions. This step will give you some idea what to expect for a given range of conditions including how far you may have to walk to retrieve your rocket (hopefully the dreaded cornfield is further away than the predicted landing zone).
4. Check the weather report for local conditions either the night before or on the morning of the launch.

Beginners, by now you're hopefully gaining an appreciation of how challenging the hobby of rocketry is. Challenging, but also very rewarding – if you do your 'homework'.

For those who are not as 'switched-on' (i.e. prepared), there's no need to despair. If you're at a club launch, it's highly likely that the more experienced modelers will be able (and happy) to help you decide whether to launch or not (some models will be given a definite no if they fall outside a safe range of values, especially with more powerful motors – this should be seen as an opportunity to improve your knowledge/skills and try again). A lot of modelers will have more than one rocket to fly – some will be a better option on windy days. Keep those simulation results handy.

Below are a number of tools/'rules of thumb' that one may use where step 3 and/or step 4 is not accessible. They will hopefully help you develop a sense of what should be ok and what is definitely not safe. If you have any doubts, please seek advice from someone with experience.

### The Beaufort Scale

The Beaufort scale was developed by Francis Beaufort in an effort to quantify conditions at sea for mariners (see chart below).

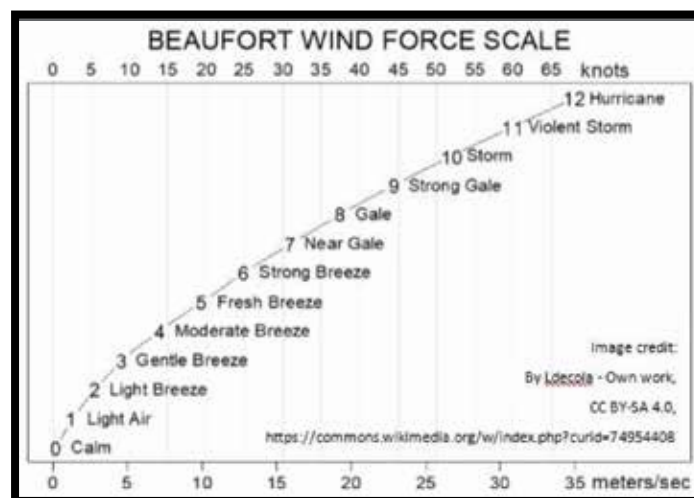


Figure 1: Beaufort Wind Force Scale

Seafarers in sailboats were (not surprisingly) interested in whether there was enough wind to propel their vessel (1 or more on the scale) or whether the sails would be ripped apart (7 or more). For perspective, it's interesting to note that at 5, the use of an umbrella is a viable proposition. Around 6 you would need to be careful. At 7 you would leave the umbrella at home. The upper limit for 6 is 13.8 meters per second – remember this value. This is the speed above which the effects of flowing air become significant (for us rocket modelers at least). As a side note, for fuel economy, most cars are best operated in the range of 22 m/s or less (the upper limit of 8 – about 80km/h or 50mph). Above this speed, air resistance becomes great enough to increase fuel consumption significantly.

Note that wind speed is not always constant. Imagine a river rapid. Now stack those river rapids and have them flowing in different directions and you're approximating what the air can be like in our sometimes unstable atmosphere. Anyone who has flown in turbulence can appreciate this. Luckily, for us modelers the air near the ground is usually more consistent in its direction and intensity on a given day.

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Also note that wind direction changes at different altitudes. Hot air balloon pilots exploit this to navigate to their chosen landing site. Obviously, this involves careful planning while consulting the latest weather information.

### Estimating wind speed

Estimating wind speed is relatively easy - the chart and directions below provide one method. Note that I haven't verified the accuracy of this method - perhaps the reader would like to take some measurements (in the name of science, of course!).

Estimating wind-speed			
height at point of release (m)	2		
time to hit ground (s)	2		
terminal velocity (m/s)	1		
distance from point of release (m)	0	2	4
wind velocity (m/s)	0	1	2

Figure 2: Estimating wind-speed chart

If you take a small piece of paper (about the size of your fingernail) and drop it, it will quickly reach terminal velocity. We will use this as a gauge to measure the difference between how long the paper takes to reach the ground vs. how far it will drift with the wind. If we drop the paper from a height of around 2 meters (about 6'), it should take about 2 seconds to reach the ground. We're not looking for decimal accuracy here - just a count of 1 Mississippi, 2 Mississippi. From the chart we can see that with zero wind speed, the (lateral) distance from the point of release will be zero (no surprises there). Now imagine the paper landing 2m away. The falling paper will be travelling more or less at the same lateral speed as the air in which it is falling. It will take 2s to travel those 2m so, the wind velocity will be 1m/s. Note that this method does not allow for 'ground effect'. The top of the launch rod is around 2m or less from the ground (for Low Power launches) so this method will do. If the paper

lands 4m away, then the wind speed will be 2m/s and so on. If you can't find the paper after it lands, then it's probably best to get the anemometer out (if you're lucky enough to own one). The moral here is that you can estimate the wind speed in mild conditions with something approaching reasonable accuracy. Which brings us to that value I mentioned earlier. Read on.

### Minimum Velocity off the Launch Rod

One 'rule of thumb' for launching is that we want the rocket to have a minimum velocity of around 13.8 m/s (around 30 mph) as it leaves the launch rod. The theoretical speed of the rocket can be calculated for a given rocket/motor combination. An option for this would be to launch off of a longer rod, if one is available. The usual approach is to simulate again with the next more powerful motor.

Why this magic value of 13.8 m/s? Because that is the speed at which the effect of the moving air becomes significant. In other words, that is the speed at which the air will push hard enough on the fins to keep the rocket pointed in the direction you want it to go (which hopefully is straight up or near to it).

### Maximum launch mass

Manufacturers of rocket motors want us to launch safely (again, safety!), so they provide us with some information that enables us to make informed decisions about what motors to use in what rockets. Below is a scatter plot showing another 'rule of thumb' (the 5 to 1 rule).

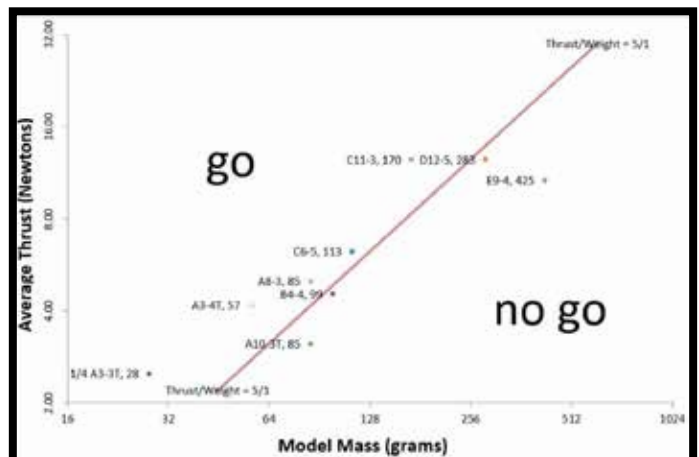


Figure 3: Scatter plot showing how Model Mass and Average Thrust are calculated for a safe launch.

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It's interesting to note that for the respective rocket/motor combinations, at their maximum recommended mass, some of them fail the 5 to 1 rule. Without an accurate simulation to go by, we might think that it's not safe to launch those combinations. In reality, the initial thrust of the motor is much greater and so a heavier rocket may still be launched safely provided it does not exceed the maximum mass as recommended by the manufacturer. With accurate simulations, the '5 to 1' rule becomes redundant.

If you don't have access to a simulator, then to err on the side of safety, so the weight of the finished rocket would need to be less than the specified maximum. It would then fall to the left of the go/no go boundary. Note that **Figure 3** does not tell us anything about the optimum delay period. For that you need either some experience and/or simulated results. As yet, we haven't considered what effect the wind will have on our launch.

### Angle of attack

Normally, when we talk about angle of attack, we're imagining the rocket in flight. As the rocket oscillates, the angle of attack (and the air pressure on the fins) is increasing and decreasing repeatedly while the rocket maintains a stable flight. (The magnitude and frequency of that oscillation is determined by many factors and is referred to as dynamic stability. There are other articles that cover this subject far better than I can – see the end of this article for references.) For this article, imagine that the rocket is stationary on the launch rod. Any wind that is blowing will be at 90 deg. to the fins. (This 90 deg. angle of attack isn't relevant because the rocket is held straight by the launch rod.) Now imagine the same rocket leaving the launch rod at our magic figure of 13.8 m/s. That same wind will now (hopefully) have a much lower velocity relative to the speed of the rocket. When we compare these speeds and break them down into vector components, we can use trigonometry to calculate the angle of attack.

Note: Jim Barrowman kindly gave us a very nice method to calculate a rocket's center of pressure. (There

is a link to this at the end of this article.) One of the assumptions of this method is that the angle of attack is less than 10 deg. Why less than ten degrees? Because as the angle of attack increases, the center of pressure moves forward which reduces our static margin and could potentially turn our nicely made (but now unstable) rocket into a "lawn dart". It is worth viewing this information purely to be aware of the assumptions that ensure the accuracy of this method. If your rocket's attributes violate any of these assumptions then caution is advised. Again, with a simulator, manual calculations of this nature are not required and simulation results may be relied on.



**Figure 4:** The A4 (or V2 as it came to be known) violates more than one of the assumptions for the Barrowman method of calculating the centre of pressure. This model is right on the maximum weight for a D12-5. It has a static margin of 0.6 and has a lot of nose weight to achieve that. Definitely not one to launch on a windy day. No pics of this one in flight but I recall seeing it oscillating noticeably in light winds.

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For rockets where the static margin is approaching the minimum, wind, or the lack of it becomes a critical factor in deciding whether or not to proceed with a launch. As you'll see on the chart below, it's possible to have an angle of attack that is greater than ten degrees at the moment that the rocket leaves the launch rod. All it takes is a gust of wind of sufficient magnitude.

To rationalize what we've looked at so far, I've cooked up a chart which will hopefully give you some food for thought (pun intended). The actual values may be slightly off (depending on the method used to calculate this very dynamic event) but of more interest is the comparison of values for the rocket/motor combinations and the resulting speed of the rocket at a given height vs. the prevailing wind conditions.

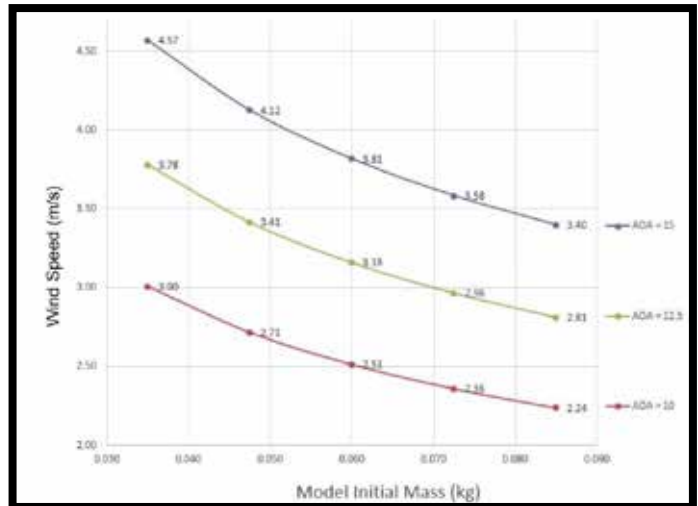
### The Nitty Gritty

The speed of a rocket may be calculated for the moment that it leaves the launch rod (for a 1 meter launch rod, the rocket will have traveled about 900mm because the launch lug is already higher than the bottom of the rod). At the moment that the rocket leaves the rod, it will have a certain angle of attack (AOA) which is relative to the speed of the rocket and a given wind speed. Obviously, a heavier rocket will have less acceleration and less speed when it leaves the launch rod. All of the derived values below assume the use of an A8 single use motor (neglecting the delay period). Please refer to the chart and see the numbered examples below;

1. If we limit the AOA to 10 degrees or less, and we launch a rocket of mass 0.035kg, the wind speed would need to be 3 m/s or less. (You may think this is a very light rocket. It is an extreme example but it is achievable.)
2. With the same rocket, leaving the launch rod at the same speed, if we increase the wind speed to 4.5 m/s, our AOA would be approaching 15 degrees. (In practice, it's likely the rocket would pitch slightly at the end of the launch rod. The AOA would immediately be reduced. The rocket would still be accelerating so provided it regains a stable attitude, the flight would continue – the

peak altitude would obviously be reduced. Remember that at a wind speed of 4.5 m/s, our dropped piece of paper would drift about 9 meters.)

3. With a model of around 0.085kg (the limit for an A8-3), to maintain the same limits for AOA, the allowable wind speeds are reduced.



**Figure 5: A chart created to compare the calculations of the degree of the angle of attack, the mass of the rocket, and the wind speed.**

Keep in mind that just because the chart says a launch lies outside a given range, the actual launch may be safe in that the rocket may (optimistically) experience a brief moment where it pitches, regains a stable attitude and continues its flight (if it doesn't rip the fins off – now we start thinking about structural integrity and fillets). On the other hand, if it pitches and fails to regain a stable attitude (we call this sky-writing – it's what your E.C.G. might look like if they could capture it while you watch your expensive hardware pitching violently) it will crash. Possibly damaging someone or some thing in the process. What we're concerned with here is the more extreme combinations – short launch rod, heavy rocket, narrow static margin, gusty winds (would you be comfortable using an umbrella?), any or all of the above. Educate yourself and use discretion. All jokes aside, safety is no joke. Be safe.

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With regard to 'weather-cocking', this is not always a bad thing as the rocket that weather-cocks up-range will result in less walking down-range for retrieval. So, having a static margin of at least 2 (3 to 4 is possibly a bit of over-kill?) starts to look like an attractive proposition for a more launch friendly rocket. It also allows some margin for error and reduces uncertainty on the more windy days. The worst-case scenario here (assuming a stable flight) is wind (and weather-cocking) at launch followed by opposite wind at deployment (and a very long walk). Timing becomes an issue when there is instability in the weather and it is very much a lottery where the rocket will land.

### References

[https://www.apogeerockets.com/downloads/PDFs/barrowman\\_report.pdf](https://www.apogeerockets.com/downloads/PDFs/barrowman_report.pdf)



**Figure 6:** Even after making an informed decision on whether to launch, there are still mishaps that can throw you off your game. If you look closely, you'll notice that three of the six motors in this cluster didn't ignite. This rocket was poorly designed and didn't fare well during deployment – but that is another story.



**Figure 7:** This rocket – the Estes Astron Sprint XL (junior rocket modeler provided for scale) satisfies all of the assumptions for the Barrowman method for calculating the centre of pressure (except for the rounded edges on the fins). Note the CP mark (black dot) – this helps alleviate the Range Safety Officers' stress levels. On its maiden flight, this rocket flew to 987' on a D12-7 in calm weather.



**Figure 8:** Ian Voss

### About the author

Ian Voss lives in Queensland, Australia and hopes to achieve his L1 certification "one day". Although he is not currently a member of the Queensland Rocketry Society, he looks forward to returning when his work/life balance allows it. Ian firmly believes in the benefits of getting involved in the hobby of model rocketry. "As a tool to promote learning, rocketry is hard to beat. It's exciting and fun and captures the imagination like few other things can."