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PEAK OF FLIGHT

NEWSLETTER

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What Are the Best Launch Conditions For A High Altitude Flight?

By Joel L. Schiff & Martin Aspell

Not all rocket launch sites are created equal. Some are better than others for a variety of reasons including a lack of power poles nearby, but our specific interest here will be weather and geography.

What we wish to investigate is how some of these factors can affect the performance of your rocket. For performance, we will use the maximum altitude and the tool for our experiments will be RockSim (www.ApogeeRockets.com/rocksim.asp) which is ideally suited for this sort of investigation.

The rocket will be a 54mm fiberglass KestreL kit. In each case except one, the rocket will be simulated on an Aerotech K250 motor. This gives us a reasonably high altitude for certain effects to become appreciable.

Figure 1: The Kestrel rocket fully assembled.

Air Temperature

Our first weather variable is temperature (see Figure 2). At one extreme we will consider 50 degrees F, and the other extreme, 90 degrees F. All other variables will be held constant. What should we expect? When air is heated, the air molecules move further apart and so the air becomes less dense. Thus we would expect our rocket to go higher on a hotter day than on a colder one, assuming all other factors such as humidity are the same. Indeed this turns out to be the case.

In this instance, the difference resulted in 598 ft higher altitude, which is a considerable amount (nearly 3%), especially if you are going for an altitude record. The moral here: Hotter is better, all other things being equal.

Relative Humidity

Let us next consider (relative) humidity, since it is often related to temperature. It is a common misconception that humid air is more dense than dry air. In fact, it is just the opposite. Humid air is less dense than dry air! Let me explain.

A water molecule (H_2O) consists of two atoms of hydrogen and one atom of oxygen. Using what are called 'unified atomic mass units' (u) which is just a way of comparing the weight of different atoms and molecules, a water molecule weighs in at just over 18u, essentially 2u for the two hydrogen atoms and 16u for the oxygen atom. On the other hand, the gases in our atmosphere are almost entirely composed of nitrogen (78%) and oxygen (21%). The remaining 1% are gases composed of a mixture of argon, carbon dioxide, neon, helium, methane, etc. The latter can safely be ignored.

The nitrogen in our atmosphere comes in the form of the molecule, N2, that is, two atoms that weigh in at 28u. The oxygen molecule (O2), weighs in at 32u. Since the density of the air is just its weight per given volume, comparing the weight of 18u of a water molecule to that of either the 28u of nitrogen or 32u of oxygen gives us the explanation as to why damp air is less dense than dry air, (for a given temperature). *{Editor's comment: this is why clouds float in the air.}*

This now being the case, we would expect our rocket

	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deploy Feet / Sec	Altitude at deploy Feet
1	0		[K250W-24]	21401.35	1549.96	343.47	33.12	35.18	21381.95
2	1		[K250W-24]	21999.84	1575.45	345.23	33.58	20.32	21993.37

Figure 2: A higher air temperature will lower the density of air, allowing for a higher flight. Top row shows a rocket at 50°F and the bottom row shows the same rocket when launched in 90°F air. The difference is 598 feet.

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Best Conditions For High Altitude Flights

	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deploy Feet / Sec	Altitude at deploy Feet
1	0		[K250W-24]	21681.40	1561.81	344.30	33.34	28.18	21668.98
2	1		[K250W-24]	21732.41	1563.58	344.43	33.38	26.82	21721.15

Figure 3: A higher humidity level will lower the density of air, allowing for a higher flight.

to go higher in air that has a higher relative humidity than a lower one. Let's see about that.

In Figure 3, the first launch had 85% relative humidity conditions and the second had 15% (same temperature for both: 68 degrees F). While the difference is only 51 ft, it does make the point clear that rockets launched in humid climates are not necessarily disadvantaged by it and that the humidity is potentially a factor in their favor.

Wind Effects

Wind is a variable all rocketeers must face at some stage or another. In fact, when the wind becomes greater than 20 mph, then it is not advisable to launch at all. Moreover, the wind velocity at ground level is not necessarily the same as the wind at 5,000, 10,000, or 20,000 ft. Even the direction can change at various altitudes.

To simplify matters, let us consider the wind as a horizontal vector that is perpendicular to the vertical flight of our rocket and that the wind is constant from a particular direction. This time we'll run a series of simulated launches, in each case increasing the velocity component of the wind. Of course, we would expect the rocket to go highest when there is no wind at all, and attain progressively lower maximum altitudes with increasing wind velocity. In these simulations, we will use a smaller Aerotech I117 rocket motor as over 20,000 ft the jet stream comes into play and we wish to ignore this factor.

The real world conditions are generally more complicated due to wind variability and thermals, but it is clear that anything other than a strong updraft will be detrimental to the maximum altitude, and the stronger the wind the worse things get.

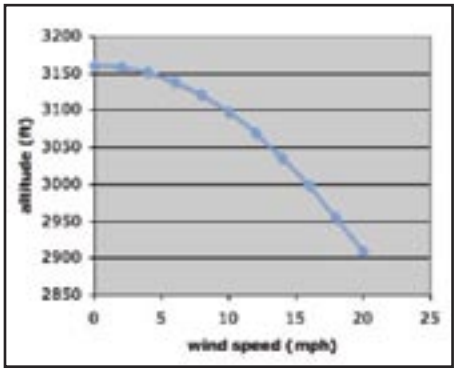

Figure 4: The effect of wind on the Kestral flight.

Launch Site Elevation

The one factor that remains unchanged at the launch site is its elevation above sea level (mean sea level – MSL).

This is a geologic factor that can

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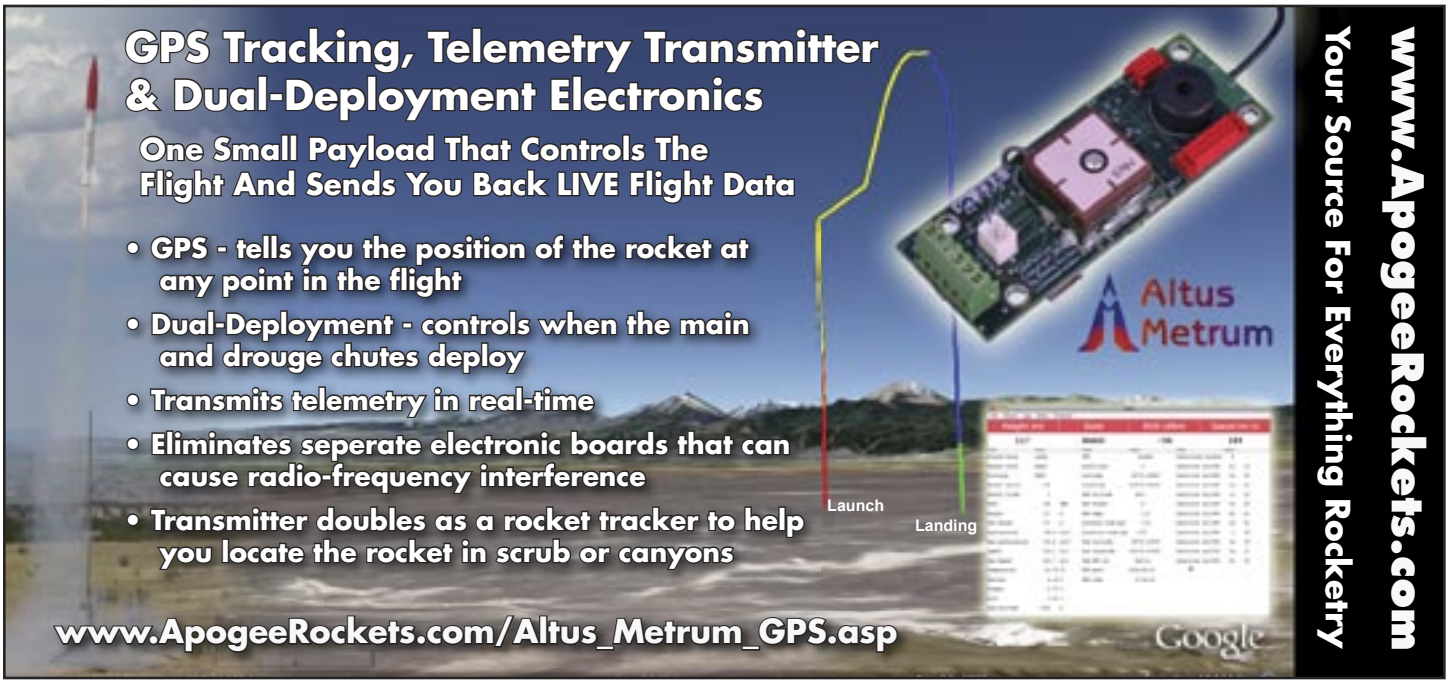

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Best Conditions For High Altitude Flights

only be altered by launching at a different location. As the elevation rises, the air density decreases, so much so that when hiking in the Rocky Mountains over 8,000 ft people often get altitude sickness due to lack of oxygen. But once again lower air density is good news for rocketeers and means higher altitudes can be attained.

As it turns out, the MSL elevation plays the most significant role in determining the maximum height of a rocket, all other factors being equal. This is why several Tripoli Rocket Association altitude records have been set at Black Rock, Nevada, which just so happens to lie at an elevation of 3,907 ft. At this altitude, the air density is only 89% than that at sea level! And it is a desert, so if you launch in the hot afternoon, you also have the benefit of the high temperature. No amount of additional humidity at lower elevations can possibly compensate for the high elevation of Black Rock.

Figure 5 shows a set of results from launches at: sea level, 500 ft, 1000 ft, and Black Rock. The results speak for themselves.

Notice that we obtain a 7.6% increase in altitude when launching at 3,907 ft compared to launching at sea level. It is very clear from these results that if you have any intention of setting a TRA altitude record, then you should launch your rocket from Black Rock, Nevada, or some site even higher, like Denver, Colorado, the mile high city.

Figure 6: The Tripoli Colorado launch field, near Hartsel Colorado (Lat 39.015685° Lon -105.710825°) has a base elevation of 8,777 feet above sea level. It is a near perfect site for setting altitude records.

It could be considered unfair to any of those who cannot launch from such a high altitude … Such are the vagaries of launch site conditions.

	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee
1	0		[K250W-24]	21676.41	1561.94	344.27	33.33
2	1		[K250W-24]	21873.72	1568.57	344.64	33.51
3	2		[K250W-24]	22066.21	1574.59	345.05	33.69
4	3		[K250W-24]	23319.16	1614.55	347.72	34.76

Figure 5: The higher the launch site, the higher the rocket will fly.

Reader Comments and Questions

By Tim Van Milligan

Using A Video Camera To Measure the Velocity Of A Mdel Rocket

Bart Hennin comments on Newsletter #292 (www.ApogeeRockets.com/Education/Downloads/Newsletter292.pdf): *"I was thrilled and impressed with your latest newsletter 292 - on using a video camera to measure altitude vs time (and thus speed and accel. too!) of a model rocket - simply brilliant! I LOVE the simple straightforward approach! This is something anyone can do and you're right, it's a great teaching tool!"*

William Blair asks: *"Couldn't about the same thing be accomplished via pixel counting within each still frame with the video camera placed at a distance and the zoom used to reduce angular errors? The cursor's pixel position within a frame is shown and continuously updated in the photo editor I use (Corel Paintshop Pro Photo X2)."*

Tim's Response: That should work, but you still need something in the video image to give you a distance scale to refer to. The vertical divider pole is my favorite because it doesn't move around. But you could use the length of the rocket itself to get a good ratio of pixel height to rocket altitude. The only problem is that the rocket must be perfectly vertical in at least one frame of the video to make your measurement. But once you get a ratio, the use of pixel count should greatly speed things along.

Building a High Power Rail Launcher

William Buchanan writes: *"I found Daniel Kirk's plans for a large rail rocket launcher in Peak-of-Flight Newsletter 235 (www.ApogeeRockets.com/education/downloads/Newsletter235.pdf) and I have made a small modification to it so it can also be used on smaller rockets.*

After putting this Launcher together per the article, I then had a brainstorm. I cut an 18 inch extra piece of PVC

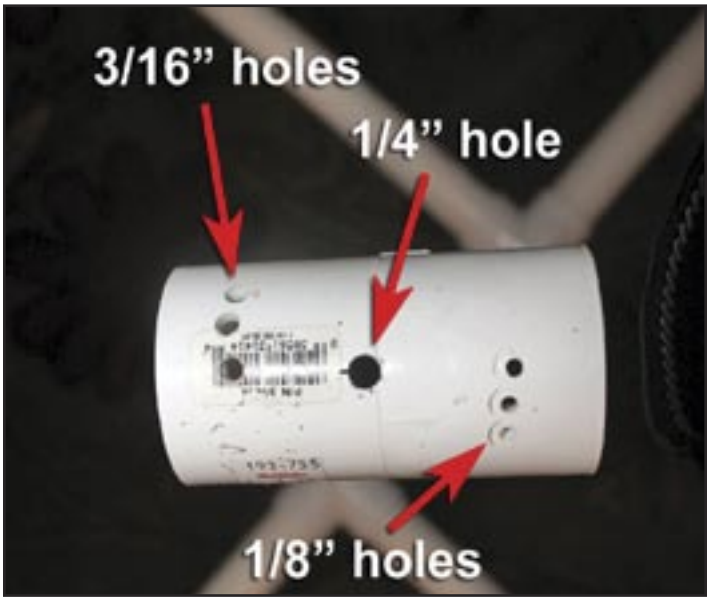

Photo 1: The launcher head modified to accept launch rods instead of a rail.

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Reader Comments and Questions

Photo 2: The modified pad with different size launch rods in place.

and glued a T-fitting onto the top of it. I then drilled a 1/4" hole through it and the bottom T-fitting on the stand. I put a 6 foot 1/4" rod through it for smaller mid-power rockets to launch using an Estes blast deflector drilled out to the quarter inch dia.

Then, I drilled 1/8th inch and 3/16th inch holes in the end of the T-fitting. I drilled multiple holes at angles so you can launch the smaller rockets into the wind, or straight up. I bought a 3 foot 1/8th inch rod , and a 4 foot long, 3/16th inch diameter rod at a local hardware store. You can also find small clamps or vise grips to keep the smaller rods from slipping through the t-fitting or being pulled out by the rockets when launching.

The center pole is not glued in so you can rotate it any direction into the wind, and so you can replace it with the larger rail support for the bigger mid-power and smaller high power rockets.

Thought you both might be interested in this stuff so am passing it on!"

Thanks Bill. I'm pleased to pass it along to the readers of the Peak-of-Flight Newsletter.

Fin Flutter Revisited

Joel Schiff (the same guy that wrote the launch site article on page 2) writes: *"I liked the recent article by Zachary Howard in Peak-of-Flight Newsletter #291 (www.ApogeeRockets.com/Education/Downloads/Newsletter291.pdf) so much I decided to implement the whole procedure in Excel (it can be downloaded at: www.ApogeeRockets.com/Education/Downloads/Fin_Flutter_Velocity.xls. I only altered the Shear Modulus to 425,000 psi, which is the standard value for fiberglass. If you put in the value of 380,000 psi as in the article, you get exactly the same fin flutter velocity: 788.6 ft/sec as Mr. Howard did (try it). Of course the Shear Modulus can be altered in the program as well to the value of any material.*

One thing that Mr Howard did not mention is that you can determine the altitude at which the maximum velocity is attained simply by graphing the altitude vs. velocity in RockSim (below)! I mention this in the program."

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Reader Comments and Questions

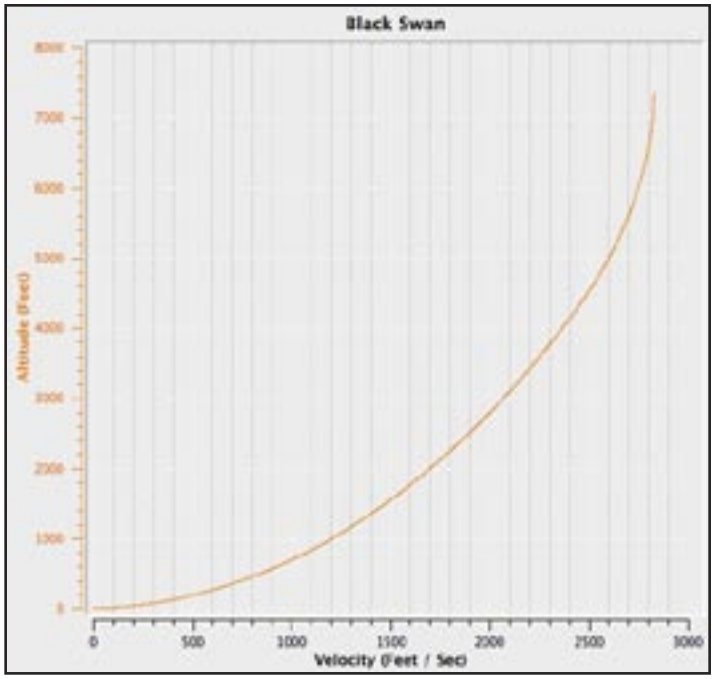

Illustration 1: RockSim can give you a chart showing velocity with increasing altitude to determine where during the flight the fin flutter may occur.

Fiberglass Technical Data

Properties			
Mechanical			
Tensile Stress, LW	D638	PSI	30,000
Tensile Stress, CW	D638	PSI	7,000
Tensile Modulus, LW	D638	PSI	2,500,000
Tensile Modulus, CW	D638	PSI	800000
Compressive Stress, LW	D695	PSI	30,000
Compressive Stress, CW	D695	PSI	15,000
Compressive Modulus, LW	D695	PSI	2,500,000
Compressive Modulus, CW	D695	PSI	1,000,000
Flexural Stress, LW	D790	PSI	30,000
Flexural Stress, CW	D790	PSI	10,000
Flexural Modulus, LW	D790	PSI	1,600,000
Flexural Modulus, CW	D790	PSI	800,000
Modulus of Elasticity	Full Section	PSI	2,600,000
Parallel Compressive Shear Stress LW	D3846	PSI	3000
Shear Modulus, LW	----------	PSI	425000
Short Beam Shear, LW	D2344	PSI	4,500
Bearing Stress, LW	D953	PSI	30,000
Poisson's Ratio, LW	D3039	in/in	0.33
Notched Izod Impact, LW	D256	ft-lbs/in	25
Notched Izod Impact, CW	D256	ft-lbs/in	4
Notched Izod Impact, CW	D256	J/mm	0.214

Illustration 2: Techincal data for fiberglass.