Issue 635 / September 24th, 2024

PEAK OF FLIGHT NEWSLETTER

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

3 Seconds into the Future

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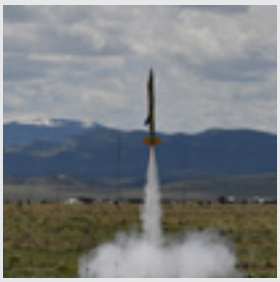
COVER PHOTO



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FEATURED ARTICLE

3 Seconds in the Future

by Tim Van Milligan

In our feature article on 2-stage rocket ignition, we compare Apogee's Simple Timer, to the advanced Blue Raven from Featherweight Altimeters. Learn the features, benefits, and key differences between these devices to make the right choice for your next launch.

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An Upscaled Version of the Apogee Wayfarer at the Score Club Launch in Pueblo, Colorado

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www.ApogeeRockets.com

3 Seconds into the Future

by Tim Van Milligan

Figure 1: The Invicta Rocket set up on the launch pad.

Because we have been working on new two-stage kits that require electronic ignition of the rocket's upper stage, like the Nike-Hercules and the Invicta, I've been contemplating the different staging electronic devices we carry. Since we sell multiple devices, the question we always get is which one should a modeler use. Because of this, I've been exploring the features of one of the newest devices that we carry, the Blue Raven from Featherweight Altimeters. That is what I want to talk about in this article.

Figure 2: TTV rocket staging with the use of the Simple Timer.

For someone that is just getting into staging composite motors, I highly recommend the **Simple Timer** (**https://www.apogeerockets.com/Electronics-Payloads/Staging/Simple-Timer-for-Staging**) that we at Apogee produce as the device to control the flight. As the name says, it is the simplest to use. It is bare-bones, so the only variable you have set before the launch is the "ignition time" when you want the upper stage motor to fire.

The specific "ignition time" for the upper stage motor is measured from the lift-off of the rocket. So for example, when you push the button on the launch control system to fire the booster stage on the ground, the lift-off of the rocket is the "trigger" to start the clock. So for example, if you set the ignition time on the Simple Timer to

Figure 3: TTV rocket on lift-off.

three seconds, then the upper stage is going to ignite 3-seconds after the rocket leaves the pad.

A question we often get about the Simple Timer, is what time should be set as the ignition time. The answer depends on what motor you have in the booster stage of the rocket. As an example, let's say you were flying the **T.T.V. rocket kit** (**https://www.apogeerockets.com/Model-Rocket-Kits/Skill-Level-4-Model-Rocket-Kits/TTV**), which is what we suggest for a first rocket if you want to learn how to do electronic staging. The reason we recommend it is that it is small and inexpensive compared to larger and higher powered kits. You can use smaller and less expensive motors in it that allow you to get the hang of things.

Now the T.T.V. rocket uses a 24mm diameter motor in the booster stage, and an 18mm motor in the upper stage. If you look at the recommended motor chart on the Apogee website, you'll see that one possible combination is the D12-3 motor for the booster stage and a C6-5 motor for the upper stage. This is one combination that we'd suggest you start with, because those motors are readily available and easy to ignite.

When it comes time to setting the ignition time of the upper stage in the Simple Timer, what we do is to look at the burn time of the **D12-3 rocket engine** (**https://www.apogeerockets.com/Rocket_Motors/Estes_Motors/24mm_Motors/Estes_Motors_D12-3**). From our website, you'll quickly find that the burn time of the D12-3 motor is 1.7 seconds. This is the lowest (minimum) time you should set as the ignition time of the upper stage. If you set the value lower, what is going to happen is that the upper stage is going to ignite while the booster motor is still burning.

There is a term for this, called "hot staging." If you've been following the flights of the Space X Starship test flights, you've probably seen that they intentionally hot-stage the rocket in order to separate the two stages of their rocket. But they have a different situation than we have with model rockets. Their rocket is so massive that they can't easily separate the upper stages without losing a lot of altitude and speed. They are trying to get as much speed as possible in order to reach orbit.

For model rockets, hot-staging would not be a good thing, as you'll be wasting the thrust of the booster motor. We need to let it consume all of its propellant before firing off the upper stage motors. As soon as the upper stage motor ignites, I guarantee you that the upper stage will separate from the booster stage. That is why the minimum time you should set the Simple Timer at is just a split second longer than the burn time of the booster stage motor.

What is the maximum time you should set the Simple Timer to fire? That is harder to determine, and I recommend that you use a simulation program like Rocksim. Before we run the simulations, let's set up some "criteria" for a successful flight.

First of all, we want the rocket to go "upwards" when the motor in the upper stage fires. Going "up", rather than sideways, is the safest direction for a rocket to travel.

In RockSim, we have a simple visual device for determining if the rocket's flight is safe. That is the "weathercocking" cone as

FREQUENT FLYER PROGRAM

seen in the 2D flight profile. It is an imaginary 30° cone where the point of the cone is at the launch pad of the rocket, and the wide part is up in the sky. We want the rocket to stay within this cone until it reaches apogee. What this tells us, is that the rocket is going up, rather than sideways.

Now the rocket will always tend to try to point into the wind (which we all know as weathercocking). The imaginary cone shown in RockSim defines how much weathercocking we can tolerate and the flight still be deemed "safe." As long as it stays inside the cone, until it reaches apogee, we have a safe flight.

With a 2-stage rocket, the weathercocking of the rocket (turning into the wind) is going to be exaggerated. In fact, the longer the delay between the first stage burnout, and the upper stage ignition, the worse the weathercocking.

What this tells us, is that we can't let the ignition delay be too long on the Simple Timer. The way we determine the maximum ignition delay to set the time is to adjust the "delay time" that is built into the booster stage rocket motor.

In RockSim, the trigger to ignite the upper stage motor is determined by the delay time of the booster motor. We chose that "trigger" because it is what most rocketeers are familiar with using multi-stage rockets that have Estes motors. In the traditional two-stage Estes rocket kits, you'd put a special motor in the bottom stage called a booster motor, which always has a -0 (dash zero) following the motor name. For example, a D12-0. The booster stage motor is what ignites the upper stage motor. This means that the upper stage ignites immediately after the propellant in the booster motor burns out. Remember that the D12 has a burn time

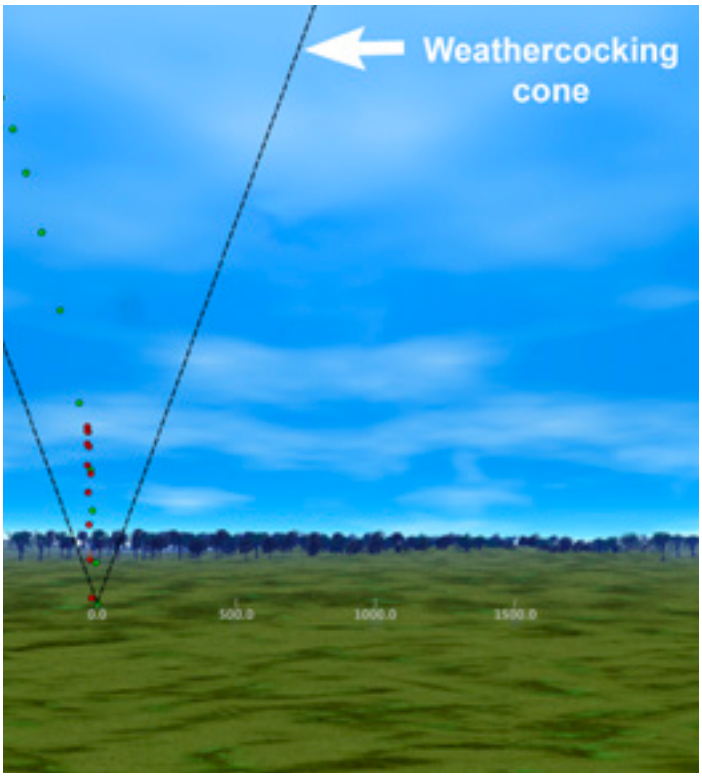

Figure 4: The weathercocking cone in RockSim's 2D Flight Profile screen gives us an indication if the rocket is going straight enough upwards on its trajectory.

of 1.7 seconds, so when measured from lift-off, the upper stage ignites 1.7 seconds into the trajectory.

In RockSim, if we want to inhibit, or delay the ignition of the upper stage motor, we just select a different delay time for the booster stage engine. So if you choose a D12-3 motor in RockSim, the upper stage lights 3 seconds after the propellant burns out in the booster stage. What this translates to in real life, is that the upper stage actually ignites 4.7 seconds from lift-off. That comes from the 1.7 seconds of thrust time, plus three seconds of delay.

The cool thing is that in RockSim, we aren't limited to the available delays of the motors. In other words, we can override the D12-3, and tell Rocksim to make the delay a different number. We can choose anything we want for the delay. For example, we can make it a 1.3 second delay; which would mean the motor is a D12-1.3. This sounds like an odd number, but it makes programming the value of the ignition time in the Simple Timer easier. The actual time for the Simple Timer would be 3 seconds. This comes from 1.7 seconds of burn time of the D12, plus 1.3 seconds of coast time, for a total of 3 seconds.

This means that the upper stage would ignite exactly 3-seconds from lift-off of the rocket from the ground. That's a nice round number that is easy to program into the Simple Timer.

All this discussion was to get to the point that setting the delay in RockSim is what causes the upper stage to ignite. The "delay time" of the booster motor is the trigger to start the second stage burning.

To figure out the maximum delay you can use for the simple timer, you'll have to do some simulations in RockSim by adjusting the delay time of the booster stage motor and then looking at the

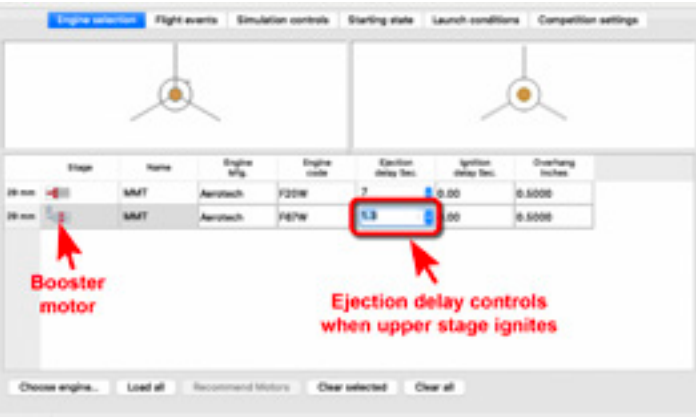

Figure 5: In RockSim, it is the Ejection Delay time of the "booster stage motor" that controls when the upper stage ignites.

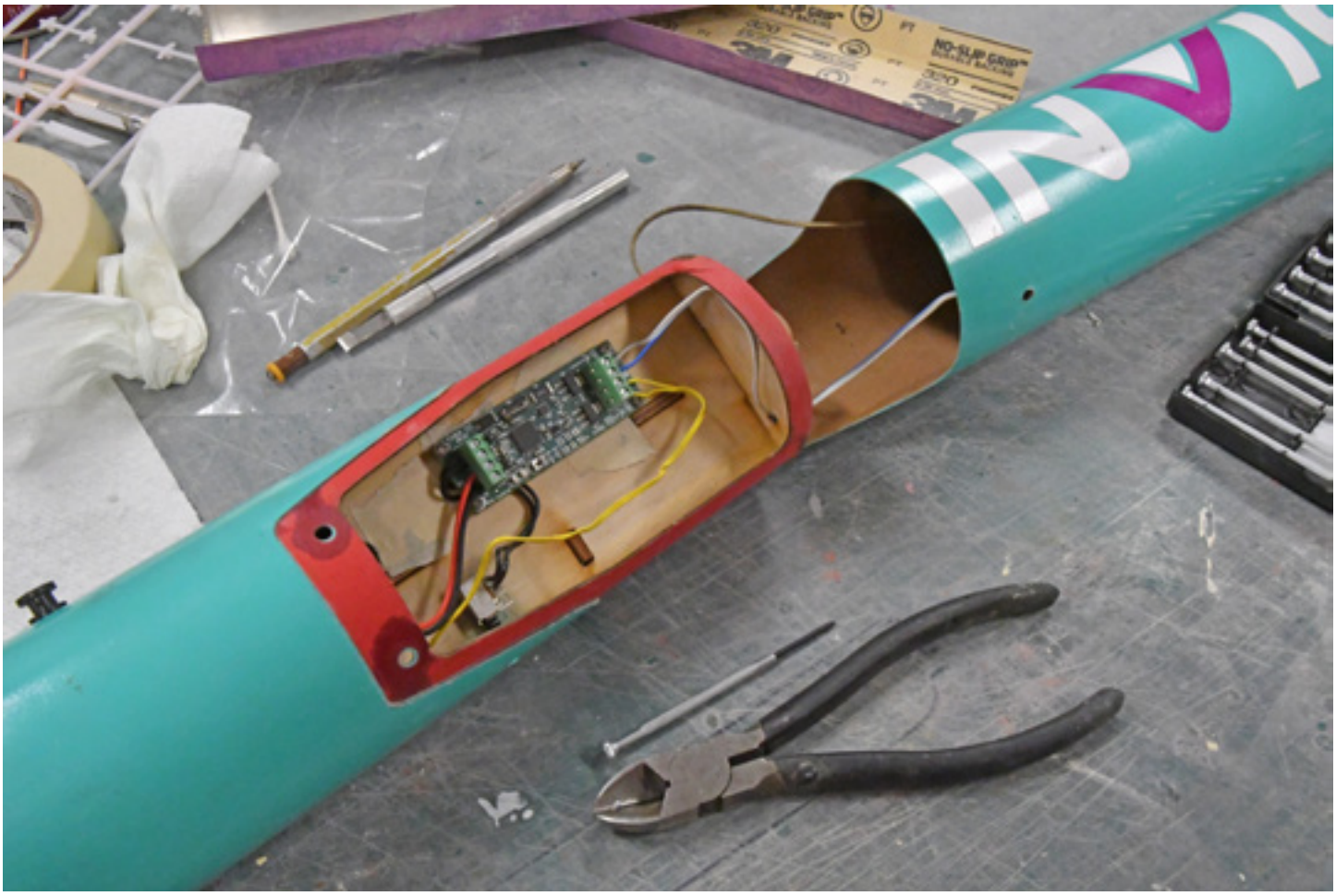

Figure 6: A "Simple Timer" device mounted in the Invicta rocket.

trajectory in the 2D flight profile. As long as the apogee point stays within the weathercocking cone with your wind conditions, you're OK.

You can keep extending the delay time of the booster stage motor in RockSim until the rocket's apogee point is outside the weathercocking cone. That will tell you the maximum time you can set your Simple Timer for your particular rocket.

Remember, the time you set as the ignition time is going to be different for each rocket, each motor selection, or the wind conditions you're flying in. Each of these variables will affect the trajectory of the rocket.

As a general rule-of-thumb, I like to set my delay time on the simple timer to about one second longer than the burn duration of the rocket motor in the booster stage. The rocket doesn't slow down much during just one second of coasting, so its trajectory stays pretty straight and it doesn't weathercock much before the upper stage ignites.

So if I was using a D12 in the booster stage, an acceptable ignition time for the Simple Timer would be 2.7 seconds (1.7 seconds for the booster thrust time, plus 1 second of coasting time). Then I'd round it up to the next nearest full second because whole numbers are easier to program into the Simple Timer.

I don't know if you've noticed it or not, but in general, most commonly used rocket motors have burn times less than 2 seconds. So if you just set your simple timer for 3 seconds, you probably could leave it at that setting for a wide range of two stage rockets. I personally don't recall having to change my setting since the first flight I've made with the Simple Timer.

But… before you fly the model, at least verify it the setting will

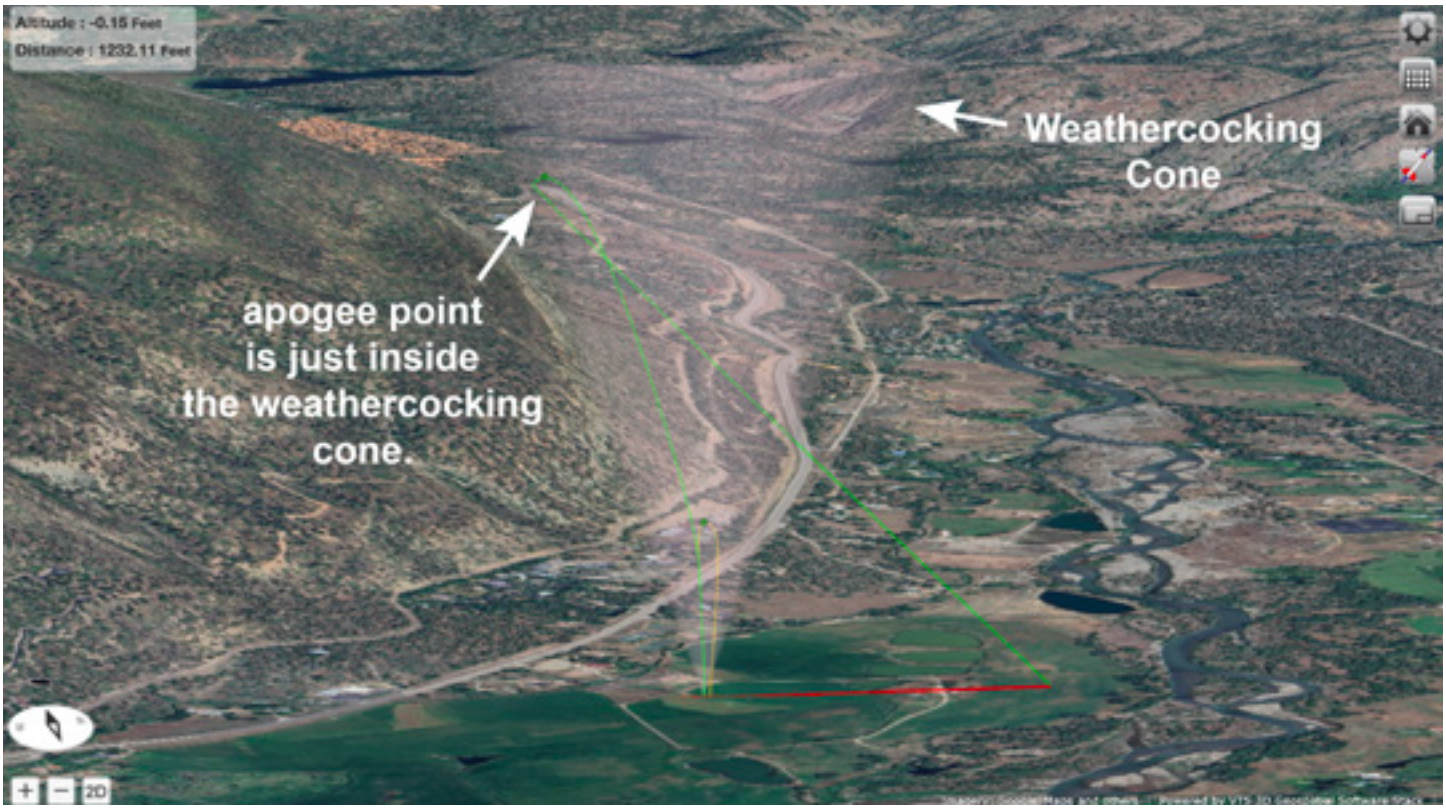

Figure 7: RockSim Pro displays the weathercocking cone too. The apogee point of the trajectory needs to stay inside the cone for the flight to be called "good."

be OK by running your RockSim simulation and verifying that the apogee point of the flight will remain in the weathercocking cone of the 2D flight profile.

There is one thing you have to be aware of with the Simple Timer. That is, the device will allow the rocket to weathercock up to a point where the nose is pointed 45° from vertical, and still fire off the upper stage motor. If the rocket points greater than 45° from vertical, the brains on the device will detect that and prevent the upper stage from igniting because it is going too far in the horizontal direction.

If it doesn't fire the upper stage motor, there is a second pyro channel that will still fire off a deployment charge and eject a parachute as soon as the rocket reaches apogee in the trajectory. This is for safety reasons. The only way to get the parachute out of the upper stage if the motor fails to ignite is to have a separate ejection charge that is fired off by the electronics.

The 45° tilt limit of the Simple Timer is somewhat controversial.

The generally accepted range rules for high power rockets is that the tilt limit should be less than 30°. In other words, if the rocket tilts more than 30°, the upper stage won't be fired off. This is really important in really high-altitude flights where the rocket would fly out of the launch range if it goes beyond 30° from vertical.

The 45° tilt limit the Simple Timer uses, comes from how it senses the orientation of the rocket by using earth's magnetic fields. Using this type of sensor is very cheap, which keeps the cost of the device really low. But it will allow rockets to successfully stage at higher tilt angles than what many people are comfortable with. If your rocket is going really high because it uses high power motors, you really need to verify the construction and stability of the rocket before the flight. Definitely run those RockSim simulations and make sure to set the time at just after motor burnout of the booster stage to limit weathercocking and the subsequent tilt.

For higher altitude flights, you might want to consider a device like the Blue Raven that is more programmable and that limits the tilt angle of the rocket to prevent staging to a smaller value.

Simple Timer vs the Blue Raven

The Blue Raven altimeter is much more advanced with lots of additional sensors than the Simple Timer. The additional sensors mean it has more features that make setting up when the upper stage ignites more precise.

First of all, the Blue Raven is like a swiss army knife. It can do a lot of different things besides just as a ignition device for a multi-stage rocket. With the additional sensors on board, and four pyro channels, it can control and do a lot of different things.

It can be used for dual-deployment. It is a data-logging device where you can download flight information. It can be used for air-starting motors. It can also be used for combinations of different events like both staging and dual-deployment at the same time.

As expected, with more sensors and more pyro channels, the Blue Raven is more expensive by a significant amount. But for what it can do, its price is very reasonable.

With the Blue Raven, you could set up the ignition of the upper stage similar to the Simple Timer by setting a time from lift-off. But then you have to know the burn time of the booster motor. Instead,

Figure 8: The Blue Raven device mounted in the Invicta's ebay compartment.

since the Blue Raven can detect the burnout of the booster motor by measuring the negative acceleration that occurs when the rocket starts slowing down, you can just program it to fire the upper stage motor at a time after motor burnout. That eliminates all the calculations you have to do ahead of time. But note that you still have to do that in Rocksim, because of how it triggers the upper stage ignition.

However, using a "time" variable isn't typically how staging is triggered when using the Blue Raven. With so many sensors on the device, the typical trigger for deciding when to fire the upper stage motor is determined by other means.

The primary purpose of a multi-stage rocket is to get to the highest altitude possible. To do that, you actually want to stage as late in the flight as you can. Why? Because of air drag. When you are flying through the atmosphere, the drag forces on the rocket vary as a function of the square of the rocket's speed. What that means is that if your rocket goes twice as fast, the drag forces acting on the rocket go up by a factor of four.

In other words, you're not only fighting the force of gravity, your

rocket is fighting drag. The faster it goes, the more drag it has to fight against. The rocket would go higher in the sky if we can keep the drag low. And the way to do that, is actually to fly slower. Therefore, we want the rocket to slow down after the booster motor burns out so that the drag force drops down. This is how we get to the highest altitudes.

This is different from flying in outer space… where there is no drag. In outer space, we want to fly as fast as possible because we're only fighting against gravity. But our rockets are in an atmosphere, so drag is something we have to minimize.

The most common way for staging with the Blue Raven is with a "velocity-driven" trigger. It isn't a minimum velocity that a rocket has to achieve, but a maximum velocity that it can have. The speed of the rocket must drop below that maximum velocity. We don't want to go so fast that we're using up all of the energy of the rocket engine by fighting against drag. We want to wait until the rocket drops below a maximum velocity before we allow it to fire off the upper stage motor. By default, the velocity of the rocket has to drop below 250 feet/sec (170.45 mph). See Figure 9.

That's still pretty fast. I speculate that it was chosen because it limits the amount of weathercocking the rocket will experience.

But with the Blue Raven, it isn't just one condition that has to be met in order for ignition of the upper stage to be triggered. There will be several variables that must be true in order to prevent an unsafe condition (see Figure 9). For example, in the above case where the rocket has to slow down to a speed less than 250 ft/sec, that condition will happen on EVERY single flight, including those that go unstable. You don't want to stage a rocket that is going unstable, so you'll have to add other conditions to eliminate the possibility of staging when things are going bad.

The conditions of a default set-up (out of the package) for the Blue Raven based on a Velocity-Driven trigger are:

The minimum altitude the rocket has to reach is at least 500 feet (this tells us that the rocket is probably moving upwards, and not sideways).

The current angle of the rocket is less than 30° (this is the tilt limit to prevent it from flying out of the landing zone area)

The rocket cannot have ever gone more than 60° from vertical (this tells us that it never flipped or went unstable during the booster's burn)

The rocket has to slow down where its velocity has to be less than 250 ft/sec (this helps us to maximize the altitude the rocket

Figure 9: The control panel of the Blue Raven, and how it triggers ignition of the upper stage motor based on a maximum velocity.

Figure 10: The default angle-driven flight criteria shown in the Blue Raven's control application.

will reach by minimizing the drag forces during flight)
The booster stage motor must be done burning

To really maximize the altitude of the flight, there is another set of conditions you can use in the Blue Raven. This is an "Angle-Driven" set of conditions for staging. This one is special, and what got me thinking about writing this article.

In the above conditions, if the rocket is pointing 30° from vertical and it fires, it is not going to reach as high an altitude compared to if it was going straight up (0° from vertical). It will still ignite, but if you're going for an altitude goal, you probably won't get there. In other words, you're going to burn an expensive upper stage motor without reaching your altitude goal.

If it is the "goal" and not just the spectacle of staging that is important, then wouldn't it be cheaper for you to not fire the upper stage motor, and use it on a different flight? Think about that… Buying one booster stage motor is far cheaper than having to buy two motors in order to try to repeat the altitude attempt in order to reach the goal.

In the angle-driven set of conditions, you still have a number of conditions that are similar to the velocity-driven triggers as shown in Figure 10.

For instance, you still have:

- The minimum altitude the rocket has to reach is at least 500 feet (this tells us that the rocket is probably moving upwards, and not sideways).
- The current angle of the rocket is less than 30° (this is the tilt limit to prevent it from flying out of the landing zone area)
- The rocket has to slow down where its velocity has to be less than 250 ft/sec (this helps us to maximize the altitude the rocket will reach by minimizing the drag forces during flight)
- The booster stage motor must be done burning
- The Future angle must be greater than 12°

That final criteria is the special one… This is the "don't stage too late" criteria, and it is predicted by the computer's brain - three seconds into the future. This allows a strategy of "wait as long as you can but ignite before the angle gets too large." The estimation into the future is used to account for the fact that airstarted motors take some time to come up to pressure, with 3 seconds being a conservative approach.

So what the Blue Raven is doing is thinking ahead. It is using the current sensor data to predict what angle the rocket will be pointed at - three seconds later in the trajectory.

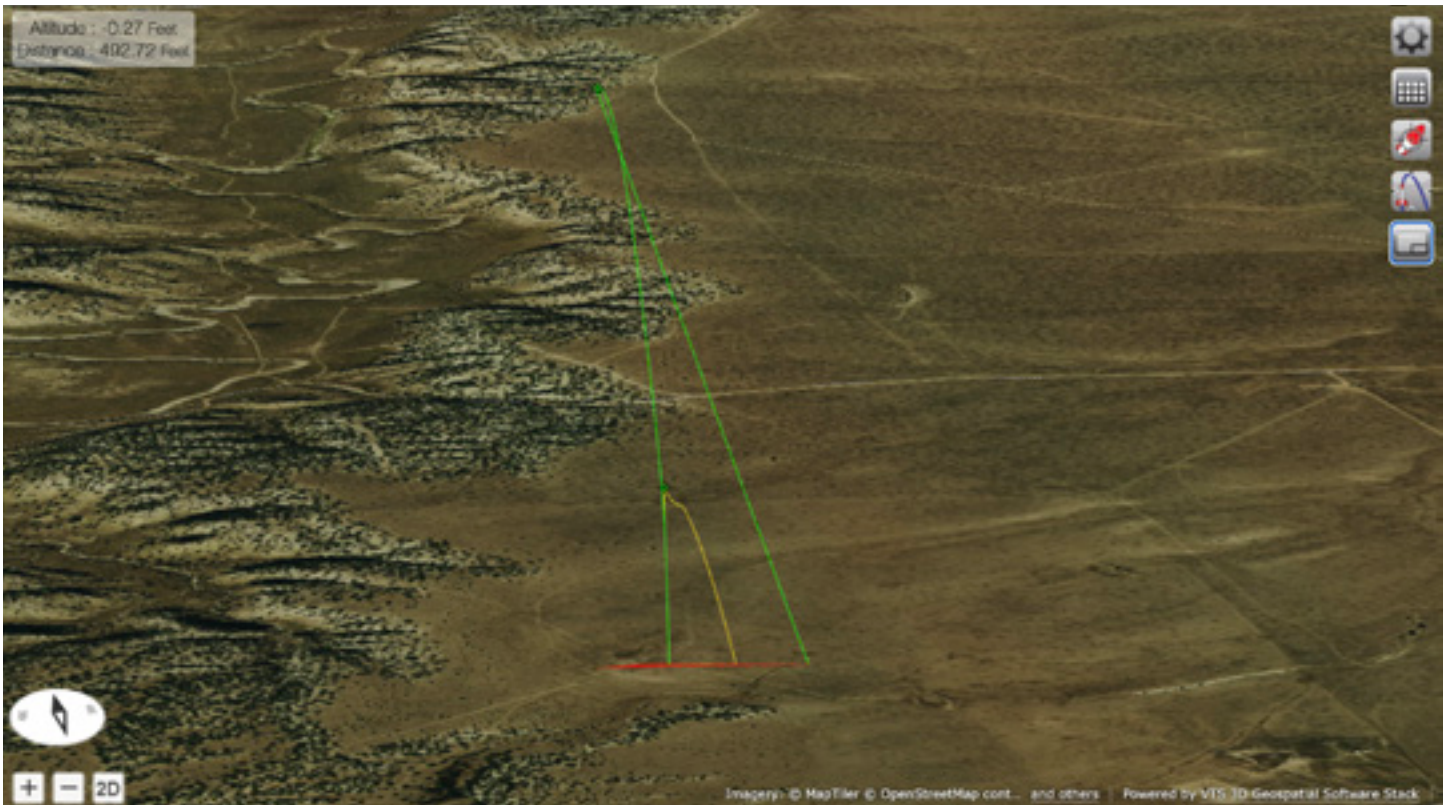

Figure 11: Trajectory path of a two stage rocket. Notice that at apogee, the rocket will point to the horizontal.

We know that the highest flight will be achieved if the rocket is pointed as straight up as possible. So the computer is predicting at what angle the rocket will be pointed at three seconds later in the flight. As long as that angle is less than 12 degrees, it thinks to itself… "OK… I'm going straight up, and everything is good. I'll coast for a while longer so the rocket's speed slows down to less than 250 feet/second."

But at some point in the flight, the rocket WILL have its nose pointed away from the vertical path. That's guaranteed. It has to. Recall what happens at apogee, right? At apogee, the rocket's nose will be pointed to the horizontal at 90°.

So the computer knows that eventually it will start to turn from vertical. And if the highest altitudes are achieved when the rocket ignites the upper stage when it is pointing to as close to vertical as possible, it needs to get ready ahead of time. It is saying to itself: "I'm going to fire that upper stage motor as soon as I determine that three seconds from now, my nose is going to be pointed 12° from vertical. Because if I wait too long and it is past 12°, this rocket that I'm on won't even get close to reaching the goal of maximum altitude."

It should be noted that under this condition, there is a greater chance that the rocket won't fire the upper stage. Why? It is to save you money because you won't reach your altitude goal. Because if the rocket hasn't slowed down to be below 250 feet/second, then the other criteria won't trigger. That also has to be true from the rocket to reach the maximum altitude goal. If it is going too fast, then you're fighting higher drag as well. Therefore, we'll save the upper stage motor by not firing it off, so it can be used for another altitude attempt at a later date.

But this situation got me thinking about the process of planning for a flight. I just find it really fascinating that the computer can think ahead to help you achieve your goal. The goal isn't just to stage the rocket, it is to reach a specific altitude in the sky.

So if you want to just stage the rocket for the spectacle of staging (which is always my personal goal), then just use the velocity-driven set of conditions, and not the angle-driven conditions.

However… It doesn't have to be an either/or situation. The Blue Raven has four pyro channels, where you can use two pyro channels to control staging. You might have one igniter in the motor that is set up for an angle-driven condition, and the other one set up for velocity-driven conditions.

The conditions would probably be slightly altered, so that for the angle-driven, the maximum speed the rocket would be at would be slower so that it wouldn't trigger unless everything was going absolutely perfect.

Conclusion

Selecting the right electronic device for staging in model rocketry is crucial for achieving successful flights and reaching desired altitudes. For beginners, the Simple Timer is an excellent choice due to its straightforward setup. It allows modelers to easily set ignition times based on motor burn durations, helping to ensure safe and effective staging.

For those seeking more advanced features and flexibility, the Blue Raven altimeter offers some advantages. Its ability to use various sensor data for precise staging makes it ideal for maximizing altitude and safety. By considering factors such as weathercocking, ignition timing, and rocket trajectory, rocketeers can make informed decisions to enhance their launch experiences. Whether using the Simple Timer for its simplicity or the Blue Raven for its advanced capabilities, both devices provide valuable tools for exploring the world of multi-stage rocketry.

Figure 12: In my opinion, the act of staging is a spectacle in its own right, and is a worthy launch goal.

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 (http://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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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 more 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 (MS Word, Libre Office, etc.) or as plain-text. Graphics, meanwhile, should be provided 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 a width of 1200 pixels for two-column images. If possible, it is generally preferable for images to be simple enough to be readable in a two-column layout, but special layouts can use the whole page width if required.

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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