PEAK OF FLIGHT NEWSLETTER

ISSUE 515/FEBRURARY 18TH 2020

IN THIS ISSUE

A BEGINNER'S GUIDE TO THRUST VECTORING

https://www.apogeerockets.com/Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/Orion

www.ApogeeRockets.com
4960 Northpark Dr, Colorado Springs CO 80918
Ph# 719-535-9335

APOGEE COMPONENTS

PEAK OF FLIGHT

A Beginner's Guide to Thrust Vectoring

By Bobby Potter

It seems that the time where fins were the only way to keep a model rocket stable is quickly passing us by - everyday we are getting more and more inquiries into thrust vectoring systems.

You can't beat the ease and effectiveness of fins. They work and have guided model rockets for the entirety of the hobby's history. Why then, when you look at full sized rockets, do none of them have fins? How do these rockets remain stable?

The core of that question contains the flaw. Those rockets aren't stable by design, instead they use some form of reactive control system to keep the nose pointed toward the sky. There are several ways to accomplish this task, but this form is called thrust vectoring, and may be coming to model rockets sooner than you think.

What is Thrust Vectoring?

Thrust vectoring is the act of adjusting the directional thrust of a rocket. The most common method for applying a thrust vectoring system is through the use of a gimbaled engine or nozzle, but there are several alternatives.

By adjusting the direction of the exhaust you can effectively adjust the orientation of the rocket around its center of gravity. For instance, if you adjust the nozzle of a rocket to push the exhaust five degrees left of center you would also apply an opposite force on the nose of the rocket, adjusting its orientation by five degrees around the rocket's center of gravity.

By allowing for a continuous adjustment of these forces, you can hold the rocket upright by constantly re-orienting it. If the tip of the rocket moves three degrees in any direction, the motor will move three degrees in the opposite direction. These opposing forces cancel each other out and the rocket stays upright.

Traditionally, there are quite a few ways that thrust vectoring or reactive control systems can be accomplished, and some of these would work on the model scale.

Gimbaled Motors and Nozzles

First and foremost, we have the gimbal motor. This is essentially a motor that can move the entire combustion chamber and nozzle to direct the exhaust and steer the rocket. This seems to be the most viable choice for model rockets, especially in the case of solid propellant like most of us use. Model rocket engines are small, with a single compartment, and so it would make sense to just gimbal that whole apparatus.

This is the style of thrust vectoring selected by Joe Barnard from BPS.Space. He has successfully created a thrust vectoring system using the gimbaled motor for model rockets.

This style is not perfect though, as there are some pretty big limitations. Even Joe hit some barriers that just can't be overcome on the model rocket scale, which is what has led him to work on "Sprite", his attempt to develop a compressed gas reaction control system. Gimbaled motors on the model rocket scale just have some physics limitations that the larger scale rockets don't have to contend with.

For starters, model rockets use a motor that burns very quickly and produces a large amount of force, effectively exploding off the launch pad. These motors are burned up over just a few seconds. Large scale rockets do this much slower, burning their fuel over several minutes with a steady stream of force. Essentially, model rockets take off like a bullet whereas full-scale rockets are more like a car slowly building up speed.

This explosive liftoff creates a big limitation on thrust vectoring systems. For one, thrust vectoring systems can only direct the rocket while the motor is producing thrust, so as soon as the motor is burned up, you no longer have any control over the rocket. This leaves an un-stable rocket, moving extremely fast, with no aerodynamic control or stabilization throughout the entire coast phase of the flight.

About this Newsletter

You can subscribe to receive this e-zine FREE at the Apogee Components website www.ApogeeComponents.com, or by clicking the link here Newsletter Sign-Up

Newsletter Staff

Writer: Bobby Potter
Layout / Cover Artist: Matthew Martinez
Proofreader: Michelle Mason

Continued on page 3

A Beginner's Guide to Thrust Vectoring

Continued from page 2

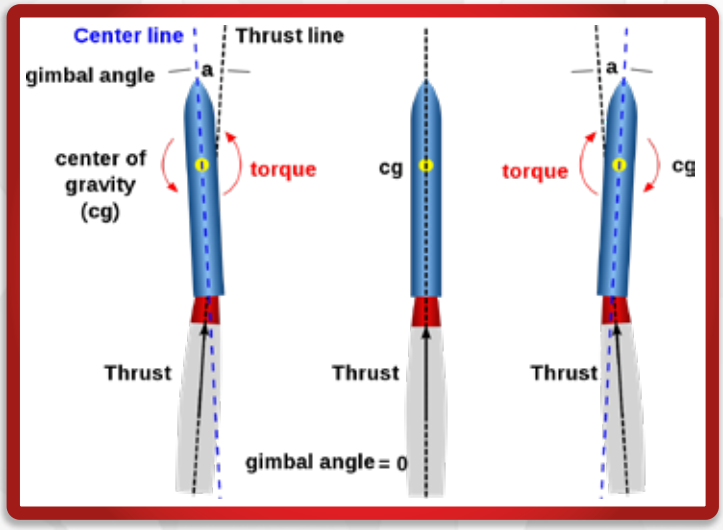

FIGURE 1: DIFFERENT ANGLES FOR A TVC SYSTEM AND HOW IT AFFECTS THE ROCKET AROUND THE CENTER OF GRAVITY.

The gimbaled motor TVC system also has limitations when correcting the rocket, even while the motor is burning. For instance, Joe's TVC system can gimbal five degrees, so it can correct any force applied to the rocket that would adjust its orientation in any direction up to 5 degrees from its center of gravity. What happens if the force applied would change the orientation six degrees?

That is a problem. The gimbal will max out and can't correct the angle of flight causing the rocket to go unstable.

Some of the available model rocket motors do burn slow enough to make for a sweet spot. Joe was able to control his Echo rocket with TVC systems so long as the motor produced less than 40 N/s of force and had a long burn duration.

This whole system would work the same under a gimbaled nozzle, the only difference would be that just the very base of the rocket would move to adjust the stream of exhaust.

Although a gimbaled nozzle seems like a great solution for model rockets, you would be adding complexity without removing any of the physical limitations.

Reactive Fluid Injection

Reactive fluid injection is quite different than a gimbaled motor or nozzle, even though it may look the same from the ground observing a rocket in flight. Reactive fluid injection works by essentially gimbaling the fuel injectors themselves, which allows them to adjust the flight path of the rocket by introducing the fuel at different angles in the combustion chamber. From the outside, the result would look similar to a gimbaled motor with the exhaust coming out slightly angled as it steers the vehicle.

Many of the same limitations of a gimbaled motor are going to be present here. You still have some of the same physical limitations, but you also have an impenetrable barrier here as it applies to solid model rocket motors. To do this in model rocketry, you would have to use a hybrid or liquid motor. For this reason, it is not the most applicable to model rocketry.

Vernier Thrusters

Vernier thrusters can actually take many forms, and depending on the design of the rocket, have different functions. To be considered a vernier thruster just requires two things: It has to have an additional thruster outside of the main propulsion system, and it has to be designed to make small adjustments to the trajectory of the rocket.

Common versions of the vernier thrusters take the form of two small gimbaled motors located on either side of the main engine. These allow you to produce pitch, yaw and roll and reduce some of the physical limitations you would have if it was the main engine that was gimbaled. Vernier thrusters can also take the form of several sets of jets located throughout the body of the rocket. These fire in short bursts and are

Continued on page 4

A Beginner's Guide to Thrust Vectoring

Continued from page 3

primarily used for maneuvering the rocket or reorienting it. Both of these systems have been used to control the stability of large scale rockets.

Finally the vernier thrusters take one other common form, one that seems particularly suited to the application in model rockets.

Near the front of the rocket a series of air jets can be placed to guide and control the rocket around its center of gravity. The further from the center of gravity, the more impact it can have. These jets often use CO2 or compressed air to fire small bursts to keep the rocket upright or larger bursts to reorient.

FIGURE 2: REACTIVE CONTROL SYSTEM ON THE NOSE OF DISCOVERY.

Active Projects and Application in Model Rocketry

People working on thrust vectoring. It seems to have generated a new found excitement for innovation in the model rocket industry, for which we are grateful. That being said, apart from the occasional obsession and advanced university project, w`e have a hard time seeing a legitimate pathway for this technology to hit the mainstream hobbyist community. It's complicated stuff, and if you compare a TVC system with a standard model rocket, you are at least looking at an order of magnitude in increased complexity.

These systems are becoming commercially available. TVC systems like Joe's are starting to see orders from the general public, and he offers as much of a turnkey solution as possible. Even still, there are some limitations. Joe specifically designed his rocket to work with the TVC system. The rocket has a good profile, the right mass for the motors he was using, and it was continuously optimized for the system over his many years of testing. If you acquired his TVC system and wanted to do a completely different rocket, you may be forced into massive recalculations - something the average hobbyist may not be capable of.

On top of that, TVC systems for solid motors are just not optimal. Solid motors burn very fast, and these systems are best served under long burn times with steady thrust curves. Once the motor is burned up, you can move that motor all day long with no impact on the rocket. As soon as that rocket motor is burned up mere seconds into the flight, you no longer have a stable rocket, and it is still moving quite fast.

Some university projects are looking into alternative ways to do this, like a team at the Embry-Riddle Aeronautical University. This team, The Experimental Rocket Propulsion Lab (ERPL), is working on a reaction control system which they

Continued on page 5

A Beginner's Guide to Thrust Vectoring

Continued from page 4

have coined "Project Aether". This system utilizes vernier jets with either carbon dioxide or compressed air to adjust the flight trajectory and provide stability to a rocket in flight. The best part? This project is being led by Apogee's very own Carlos Cielo!

FIGURE 3: CARLOS CIELO BESIDE HIS TEAM'S ROCKET AETHER.

Join The NAR.org
Mention Apogee Components

These can still function when the solid propellant is burned up, and they can fire at different rates allowing for larger adjustments. The only real limitation to this system is just how much compressed gas you can carry.

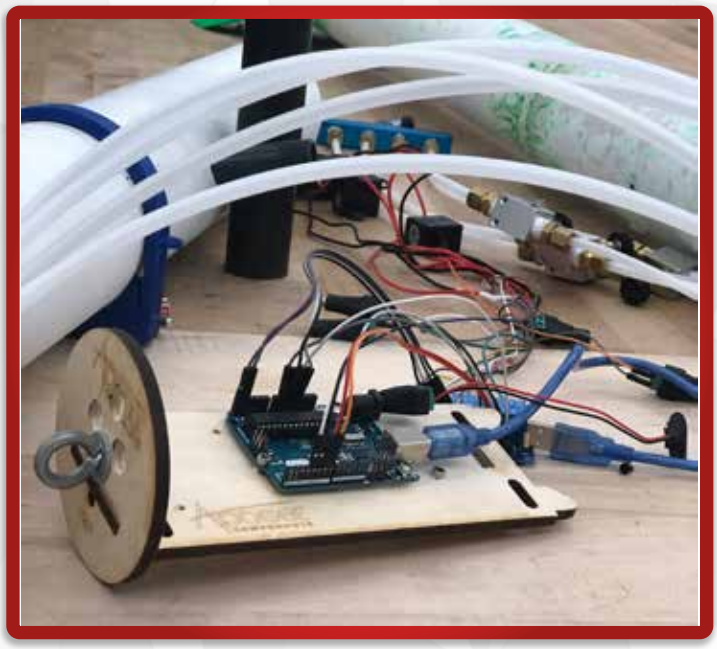

FIGURE 4: THE E-BAY DESIGNED TO CONTROL THE RCS

This system works through two manifolds with a series of air jets. The manifolds sit in between the nose cone and the body tube, keeping the weight at the front of the rocket and as far from the center of gravity as possible. The first manifold is designed to control the pitch and yaw of the vehicle while the other controls only the roll. These are completely independent systems that work together in unison. So far the system has passed their first test, a single axis test to verify

Continued on page 6

A Beginner's Guide to Thrust Vectoring

Continued from page 5

the capabilities of the manifold designed to control the pitch and yaw. You can see their rocket perform this test here: https://youtu.be/4vPOf3V9hFY

FIGURE 5: A DISASSEMBLED PROJECT AETHER

Right now, this system is still quite experimental in model rocketry. The primary objective of Project Aether is just to determine whether the benefits of the reactive control system are even worth the cost and additional mass. All to be determined, but we are excited to see where this project goes!

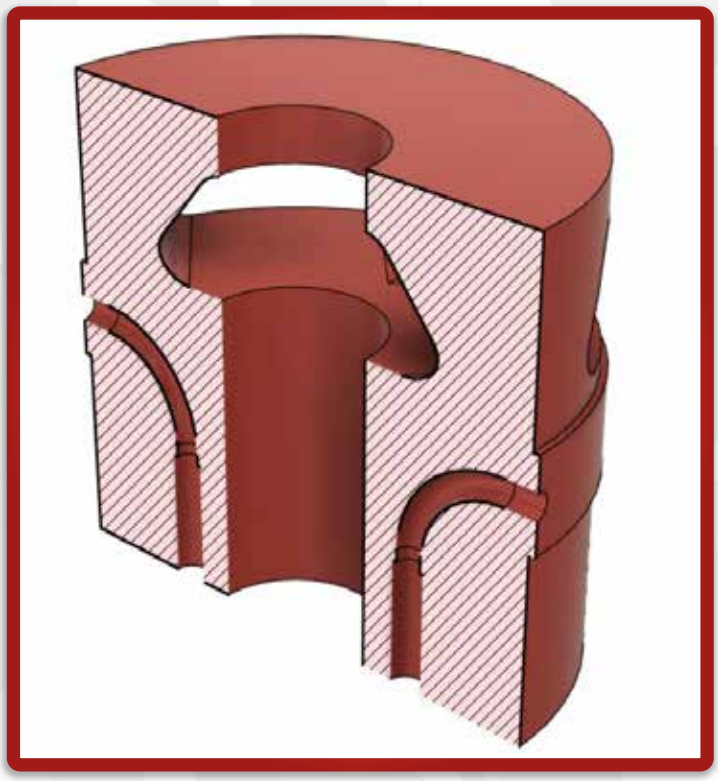

FIGURE 6: A CUTAWAY OF THEIR MANIFOLD SYSTEM

We know there are more people working on this. From hobbyists to a large variety of projects from other universities, attempts are happening more aggressively now than ever before. If you are part of a team working on this kind of technology, either TVC systems or other forms of reactive control, we want to hear about it! Let us know about your project here: https://www.apogeerockets.com/Contact