PEAK OF FLIGHT
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Catapulting A Rocket Skyward

By Eagle Sarmont

My lifelong dream is to help create a spacefaring civilization, from cities on the Moon and Mars, asteroid mining, and space colonies throughout the solar system. And to make that dream a reality, a necessary step will be to make spaceflight as affordable and convenient as air travel.

Believe it or not, model rocketry can help make that a reality. One of the ideas for reducing the cost of spaceflight is to use a ground accelerator/catapult to boost a launch vehicle up to somewhere between 500 and a 1000 MPH before igniting its rocket motor. This reduces the amount of propellant the launch vehicle needs to reach orbit and allows it to carry a larger payload. This will significantly reduce the cost of flying to orbit. Doing this on a mountaintop where the air is thinner and the drag of flying through the atmosphere is less will also help increase the performance and further reduce the cost of flying to orbit.

One person who shared my dream was a young girl named Frida Durazo. This is a story about Frida and myself and the adventures we had flying model rockets using a homemade ground accelerator.

I first met Frida early in 2014 when she was a junior in high school. Frida's dream was to become a rocket scientist. Since I was a retired aerospace engineer I figured what the heck, let's see what she's got. I introduced Frida to model rocketry and she quickly built and flew her first rocket from a homemade launch pad she created herself. She loved it and was even more determined to become a rocket scientist as a result of that experience. I asked her what she would like to do next. Her immediate answer was, "I want to go faster and higher!" I gave her a list of options: build a multi-engine rocket, a two-stage rocket, a rocket that uses a larger rocket motor, a rocket that uses some combination of those three, or even a catapult for launching model rockets.

The list led to a whole lot of questions about what it would take to build each one, as well as what their advantages and disadvantages were. After much discussion and a number of days to think about it, Frida chose the biggest and most involved project on the list: the catapult. I was very surprised. It was a choice that would take up her entire summer if we were to have a chance of finishing it before she started back to high school in the fall, and it was large enough that it would really test her resolve to become a rocket scientist. After all, it's easy to start a big project, but it's not always easy to finish one.

The first step in this new project was figuring out exactly what she wanted to build. There are many ways to build a catapult/ground accelerator, and they all have different advantages and disadvantages. There are a lot of different examples of ground accelerators: bows and arrows, blowguns, slingshots, even a potato cannon can all be considered ground accelerators. Even the catapults used by the US Navy to launch fighter planes off the deck of an aircraft carrier are ground accelerators! In addition, a ground accelerator can be horizontal like the ones used by the Navy or they can point vertically. They can be external to the object being accelerated, or they can house the object inside itself, like a potato in a potato cannon. There were many choices preparing for this project.

Frida chose to build a vertically oriented external catapult out of wood that is powered by a drop weight. She chose vertical because rockets take off vertically. She chose external because that would give her the greatest design freedom when it came time to design the rocket that would be launched by the catapult. She also chose to power her catapult using a drop weight and pulley system because that was the safest and simplest way to do it. And finally, she chose to build it out of wood because my workshop was well equipped to work with wood. As to the design details, the guide track for the launch tower was made from triple track curtain rails made by Kvartal that we found at IKEA. The pulleys were sailboat pulleys that we got from West Marine, the launch cable was Kevlar kite string, and the drop weight was made using multiple 25lb. plates from a weightlifting set. She also came up with a great name for her launch tower: the VALT, which stands Vertical Accelerator Launch Tower.

The next big design issue was how to ignite the rocket motor after the rocket was launched using VALT. For that, we chose to use the PerfectFlite MiniTimer4 Staging Timer (https://www.apogeerockets.com/Electronics-Payloads/Staging/PerfectFlite-MiniTimer4-Staging-Timer) powered by the smallest LiPo batteries we could find, two batteries for black powder motors (8v), three batteries for composite motors (12v).

Building the tower took most of the summer. Our first tests of the tower took place in my driveway using an unpowered

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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

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dummy rocket made out of a paper towel tube with a paper and tape nose cone and cardboard fins held on by masking tape. It flew quite well. It went really fast straight up, turned around and came straight down. It's final flight left it stuck in the top of a really tall palm tree in my neighbor's yard!



Figure 1: Pictures of the launch tower with Normandy.

The first flight using a real model rocket took place a few days later using a rocket that Frida named "Normandy". The tower was set up for 8 Gs of acceleration, giving us a calculated tower speed of 72 MPH, and the rocket with the onboard ignition system and a C6-5 motor had a launch weight of 170 grams. We made two flights that day and both went perfectly. You can see a video that Frida made of those flights here (https://www.youtube.com/watch?v=Cwejv1RqRZ8&t=126s)

After that, we started a very busy period of experimentation and development where we worked to upgrade the launch tower to increase its speed and tried out a number of new rocket designs, rocket motors, onboard video cameras, and altimeters. Not everything worked as expected and we had some failures, but we also had plenty of successes. The end result was that we learned from our failures and got better and better at what we were doing. We also had a lot of fun in the process. Frida also made a webpage and a second video that includes some of the videos from the onboard camera. You can see them at https://valtrockets.wordpress.com.

There were other results. Frida was invited to set up a display and give a presentation about her project at the 2014 California STEM Symposium. At the symposium, she met Jamie Hyneman from the TV show Mythbusters who was so impressed with her project that he made a very generous donation to Frida's college fund. In addition, as a result of Frida's high school grades and this project she was also awarded a Gates Scholarship. Thank you, Bill and Melinda Gates!

Frida went away to college in the fall of 2015 and the launch tower sat unused in my garage for a period of time. Finally, in the fall of 2017, I got it out and dusted it off. I wanted to explore some of the new design possibilities that the tower/ground accelerator concept makes possible. To give a real-world example, a 600 MPH ground accelerator, when used as part of a combination launch system that includes a 4,000 km long non-rotating skyhook, has the ability to reduce the apparent velocity

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for going to orbit from 9,100 meters per second to 6,000 meters per second. This reduction in apparent velocity makes possible the building of a small chemical powered single stage to skyhook launch vehicle that would look a lot like the spaceships that were originally envisioned back in the late 1940s and early 1950s.



Figure 2: Picture of the spaceship from the movie "When Worlds Collide."

I also wanted to see what kind of speeds and altitudes were possible using the maximum acceleration on the tower with larger reusable composite rocket motors. Prior to Frida going away to college, the highest acceleration and largest motor we had successfully flown from the tower was 14Gs in acceleration with a D12 motor. I wanted to explore increasing the tower acceleration to 16Gs, try using 24mm E and F composite motors in the rocket, and try launching from a higher altitude to see what the increase in performance would be. I also wanted to explore using 3D printing for making rocket parts and to design a really low-drag, lightweight rocket that incorporated everything we had learned to date.

Taking this project to the next level generated a number of new problems. Operating the tower at 14Gs of acceleration and flying with a D12 motor was starting to exceed the altitude limit of the local launch site we had been using. Therefore, going to significantly higher speeds and altitudes would require a new launch site. This would mean driving a couple of hours out to the desert to use the tower. A second issue was the new rocket with 3D printed parts. In order to save the time and trouble of driving to the desert for each test launch, I would need to build a new conventional launch pad to perform the initial flight-testing of the new rocket at our local launch site. Also, since I wanted to eliminate the launch lug from the rocket, it would be necessary for the new launch pad to allow for this. I also wanted a pad that would look more like a real launch pad used by NASA or the Air Force, and one that I can set on a table so that I wouldn't have to crawl around on the ground to prep the rocket for launch. This is what I came up with.



Figure 3: Launch Pad Bravo

When Frida came over to see how the new project was progressing we ended up getting a little carried away and started naming everything. The VALT launch tower is now Spaceport Alpha, my workshop is now the home of High Frontier Industries, the new conventional launch pad is Launch Pad Bravo, and the new rocket is for the United States Space Patrol. For those of you not familiar with the

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"Space Patrol" reference you should read "Space Cadet" by Robert Heinlein, the series of books about Tom Corbett by Carey Rockwell, and look up Commander Corry of the Space Patrol on the internet.



Figure 4: Terra One next to the Launch Pad Bravo

Figure 4 is a picture of the new rocket with 3D printed nose cone and tail cone. The first one is named Terra One, which will be the class name for this design. It has a built-in payload bay for carrying an altimeter and is also designed to carry an air start ignition system when it's flown from the Vertical Accelerator Launch Tower.

By the way, Terra One is not just another model rocket. It's a subscale model of a possible liquid oxygen/liquid hydrogen-powered single stage to skyhook spaceship that is designed to fly into space. It works by being boosted to 600 MPH on a ground accelerator like VALT and then flies a suborbital flight path to the lower end of a non-rotating skyhook that is in orbit around the Earth. Due to the way the ground accelerator and the skyhook reduce the amount of velocity the rocket needs to achieve to reach orbit, it allows the Terra One to be made much smaller than currently existing launch vehicles and to be made 100 percent reusable. This means that after returning from a flight to the skyhook, all that is necessary for Terra One to fly again is to refuel it and load a new cargo onboard. As to the size reduction this makes possible, a real-world Terra One would have a take-off weight of 200,000 pounds, and carry a useful payload of 12,000 pounds to the lower end of the skyhook. By comparison, the Falcon 9 rocket has a take-off weight of 1,200,000 pounds, delivers a useful payload of just 6,000 pounds to the International Space Station, and is only partly reusable.

This process of using a ground accelerator, a 100 percent reusable rocket like Terra One, and a non-rotating skyhook to reach orbit is how spaceflight can be made as affordable as flying on an airliner.

The ground accelerator has also been upgraded. The tower acceleration has been increased to 16 Gs and the drop weight was upgraded to take the additional weight this change in acceleration requires. The side tower that supports the drop weight was also shortened so as to reduce the overall length of the Kevlar string that is used to launch the rocket. This reduction in string length reduces the amount of stretch in the string, which adds to the useful track length of the tower thereby increasing the speed we should get from the tower. The new calculated speed for the tower is now over 100 MPH.

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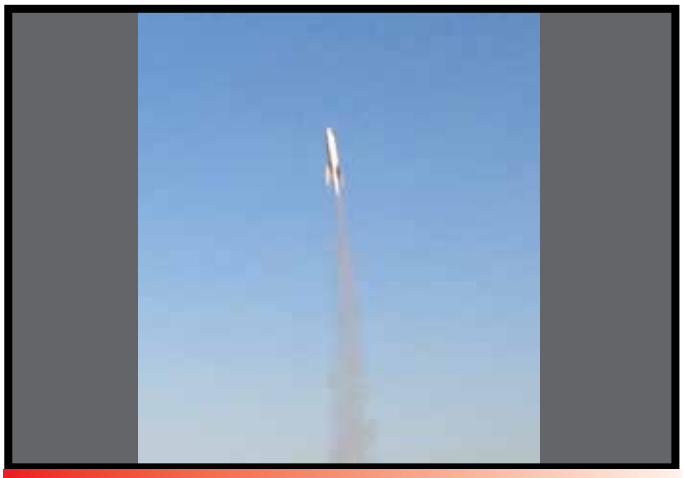


Figure 5: Picture of Terra One taking off from Launch Pad Bravo

Figure 5 is a picture of Terra One being test flown with a D12 at our local launch site using Launch Pad Bravo. It flew straight with no spin and was recovered undamaged. I also really like the 3D printed parts. They are tough, durable, weight competitive with conventional construction methods, and make assembly of the rocket real easy. Take-off weight with the D12 motor and onboard altimeter was 152 grams, the maximum speed achieved was 173 MPH, and the maximum altitude achieved was 905 ft. Now it is time to go to the desert to get some experience conventionally launching this rocket with the E18 and F24 reusable rocket motors. After that, it will be time to add the onboard ignition system to the rocket and finally start flying it on VALT.

For more information about combination launch systems, you can go to https://combinationlaunchsystem.wordpress.com and http://www.high-frontier.org or you can read the book "Opening the High Frontier" https://www.amazon.com/Opening-High-Frontier-Future-Space/dp/0692760024/ that is available on Amazon books.

Also, a special thanks to the Peak of Flight Newsletter for all the ideas and hard-won experience that you all share here so freely. It has been a big help with this project.

About the Author

Eagle Sarmont is a retired aerospace engineer who designed fighter planes, launch vehicles, and satellites for Northrop and Lockheed. He is also a licensed pilot who has designed, built, and test flew a number of homebuilt aircraft. After leaving the aerospace industry he returned to school, collected a number of new degrees and ended up becoming a civilian ship's officer who sailed all around the world with the United States Navy. In 2016, he published a book about how to make spaceflight affordable to everyone called "Opening the High Frontier."

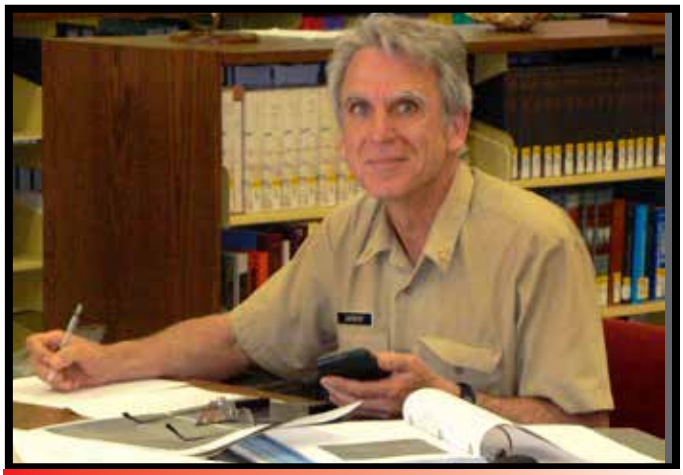


Figure 6: Eagle Sarmont

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