Rocket Report 2015

By: Name Nomiddlename Lastname

Rocket: Jefferson Starship

Date Submitted: January 22, 2016

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<u>Purpose</u>: The goal of this lab was to figure out a way to overcome the challenges presented with building a rocket made out of multiple bottles spliced together. These challenges include the actual splice between the bottles, designing fins, and designing a nose cone. All of these things come together to make a rocket that will go as far as possible.

<u>Background</u>: When researching other successful bottle rockets it turned out that a longer slimmer rocket went further than the traditional 2-liter bottle. Doing this could be achieved by splicing 2 or more smaller bottles together with a type of glue or epoxy. Others have used construction adhesive or epoxy. It also made sense that pvc cement would work well because it bonds pvc pipes by melting them together. Based on other's attempts at this in the past, the most difficult part would be to get the splice to work. The splice would be carried out by cutting the bottoms or tops off of bottles. Then at each splice one end needs to be put in hot water to shrink it so that it will make a snug fit inside the other bottle. Both ends need to be sanded then glued together. Amy who was previously the only successful person at building a multi-chamber rocket had used construction adhesive. US Water Rockets showed tutorials of how to make this splice, which is where the steps to splice the bottles came from, used epoxy. This also made sense that pvc cement would also work very well because it basically melts together pvc pipe to make a bond.

<u>Experiment and Analysis</u>:

Launch 1 (9/22/15):

The goal of this launch was to see if pvc cement would be good for splicing the bottles together. Another goal of this launch was to see if there was a benefit to splicing the bottles both facing the same direction (see figure 1). In figure one only the bottom of one bottle was cut off then the inside of it sanded. The other bottle was only sanded on the outside of it where it would be in contact with the other bottle. They were both then spliced together using pvc cement. This was allowed to cure for about twenty-four hours then it was wrapped with duct tape to add more support. The other rocket was two bottles with their ends cut off (see figure 2). Then one bottle was carefully placed in nearly boiling water in order to shrink it slightly so it would fit inside the other one. The outside of this bottle was sanded where it was make contact inside the other one which was sanded on the inside. These were then spliced using pvc cement and allowed to cure for about twenty-four hours then duct tape was wrapped around the splice to add extra support. One end was left with a cap on whereas the other rocket did not have any caps.

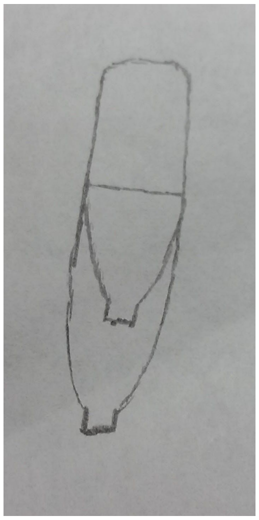

Figure 1

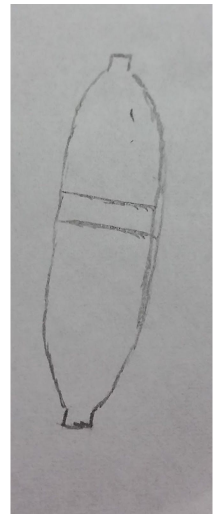

Figure 2

Rocket	**PSI**	**Distance (yards)**
Rocket 1 (figure 1)	**60**	**Blew up**
Rocket 2 (figure 2)	**60**	**Blew up**

Figure 3

Based on the results of the first launch day it was found that the pvc cement was not strong enough to hold up the pressure necessary to launch the rockets. The reason behind this was that the plastic used for bottles is very different from the plastic the pvc pipe is made out of. This launch day also showed that the bottles could not be spliced the way they were spliced in figure 1 because it didn't even rise up on the launcher like all of the other rockets did. In all this launch day showed that something better would be needed to splice the bottles together and that they would need to be spliced like in figure 2.

Launch 2 (9/28/15):

The goal of this launch was to test which epoxy would hold up better under pressure for a launch. The two epoxies being tested were Gorilla Epoxy and Loctite Epoxy. The idea for using an epoxy came from US Water Rockets. The reason both epoxies were being tested was because both epoxies had very different application methods and cured differently. Both rockets were built the same as the rocket in figure 2. The rocket in figure 4 was spliced with Gorilla Epoxy and the rocket it figure 5 was spliced with Loctite Epoxy.

Figure 4

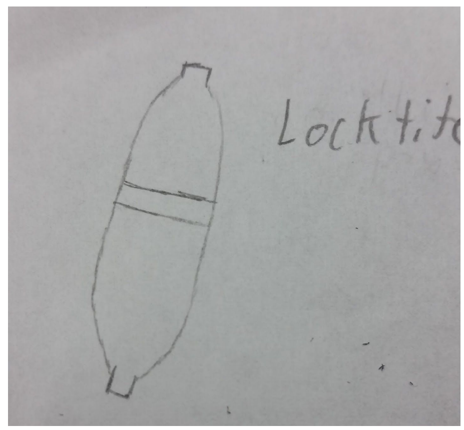

Figure 5

Rocket	**PSI**	**Distance (yards)**
Rocket 1 (Figure 4)	**80**	**26**
Rocket 2 (Figure 5)	**80**	**23**
Rocket 1 (Figure 4)	**100**	**29**
Rocket 2 (Figure 5)	**100**	**28**
Rocket 1 (Figure 4)	**120**	**30**
Rocket 2 (Figure 5)	**120**	**Blew up**
Rocket 1 (Figure 4)	**130**	**30**
Rocket 2 (Figure 5)	**130**	**N/A**

Figure 6

The findings of this launch were that the Gorilla Epoxy used in figure 4 made for a stronger splice. The Loctite Epoxy used in figure 5 made more of a brittle splice whereas the Gorilla Epoxy made a flexible splice. This flexibility made the Gorilla Epoxy more durable for more launches and stronger under a lot of stress. The Gorilla Epoxy is much easier to work with as well. The two compounds are mixed and painted on both surfaces that need to be bonded. The set time is five minutes allowing time to get it right and the cure time is about a half hour but it was left for a full twenty-four hours before the launch day. The Loctite Epoxy was more difficult because it required an activator to be rubbed on first with a highlighter-like pen and a very runny liquid was then put on both surfaces and it would set within thirty seconds. This made working with it very difficult. Based on these results the decision to use the Gorilla Epoxy was made. This was because it was stronger and easier to work with. Now that a good epoxy was chosen for the splice, a rocket could be designed with fins and a nosecone.

Launch 3 (10/2/15):

Now that an epoxy was found that was strong enough to hold the rocket together, fins and a nosecone could be designed. One of the major things that a successful rocket needs in order to go far is stability which is the job of the fins. Most successful rockets seemed to have three fins as opposed to four and they tended to be larger fins. This will cause the rocket to have as much stability as possible during flight. As well as having fins the rocket would need a nose cone to add mass and make the rocket more aerodynamic. Using the top of one of the polar seltzer bottles being used for the rocket would be aerodynamic due to its pointed shape. Using wet cat litter would also add a good amount of mass to the rocket and increase stability. US Water Rockets also found that more bottles making a larger fuselage makes the rocket go farther because it has more fuel. The rocket being tested was to test the nose cone, fins, and is adding more bottles really does make the rocket go farther (Figure 7). The goal was to see how stable the rocket was when leaving the launcher, how far the rocket went, and how durable the rocket was.

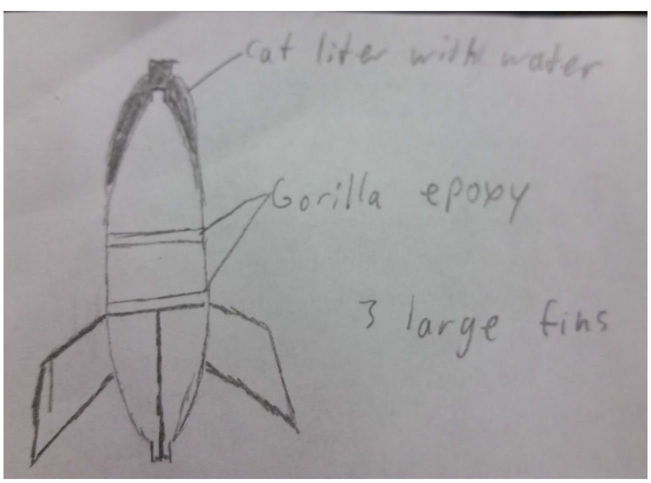

Figure 7

Rocket	**PSI**	**Distance (yards)**
Jefferson Starship	**100**	**145**
Jefferson Starship	**140**	**174**

Figure 8

The results of this launch were very positive reaching 174 yards. The flight was relatively stable but the fins loosened up and the flight wasn't completely stable. This was due the to fins being made out of cardboard and only being taped down. The nose cone was also a little bit too light. Having more bottles did add more power and a longer thrust time due to having more water but the biggest issue was the landing. When the rocket landed the nose cone crushed into the fuselage. The rocket still launched after a few minor repairs but eventually those bends and folds would create weak points that could cause a blowout. The next step was to make it more stable, add a little more mass, and increase the durability.

Launch 4 (10/7/15):

The goal of this launch was to test a new design for a nose cone. One of the problems encountered during the last launch day was the rocket getting crushed on impact. This was also an issue that Amy had talked about with her rocket as well. This could be solved by using a different material in the nose cone. With the mass being too little during the last launch this would solve two problems at once. Using caulk which is denser and would better absorb an impact. One of the other issues from the previous launch was the stability of the fins. Hot gluing them on along with tape would add rigidity to them and keep them from moving during flight.

The rocket for launch 4 in figure 9 was built very similar to the previous rocket but had a new nose cone and fins. The nose cone was still just the top of a bottle but filled with caulk this time and offset from the fuselage slightly more so it could better absorb the impact. The fins were the same size and shape but were attached with hot glue and tape for more stability.

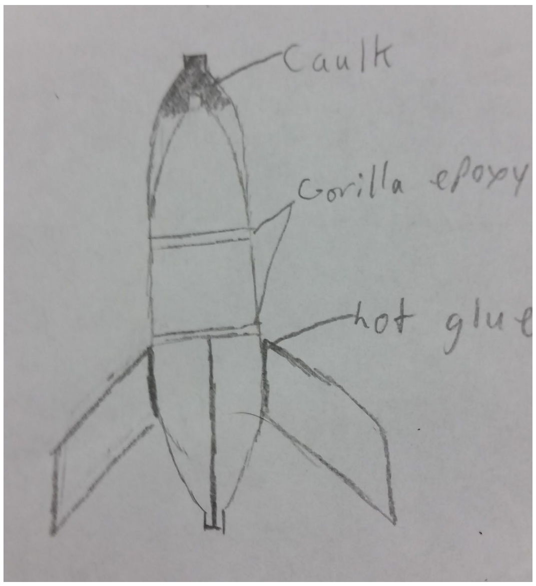

Figure 9

Rocket	**PSI**	**Distance (yards)**
Jefferson Starship 2	**130**	**195**
Jefferson Starship 2	**130**	**197**
Jefferson Starship 2	**138**	**203** *this was the class record up to this point
Jefferson Starship 2	**138**	**197**

Figure 10

Based off of the results from launch 4, the rocket was coming along very well taking the lead in the class. The flights were very stable. The only real issue was the durability. Even with a better nose cone the rocket was crushed on impact. The next step would be to design a nose cone to absorb the impact better and keep adding more bottles to lengthen the fuselage.

Launch 5 (10/14/15):

The goal of this launch was the test a newly redesigned nose cone (see figure 11). This new nose cone was actually two nose cones on top of each other. The idea was to copy the concept similar to a car where it collapses absorbing the energy from the impact and keeping the driver from absorbing it. This nose cone can collapse back on itself and reduce the energy transferred into the fuselage. It was still filled with caulk just like the previous nose cone. The other change from the previous rocket was adding another bottle for more fuel and thrust.

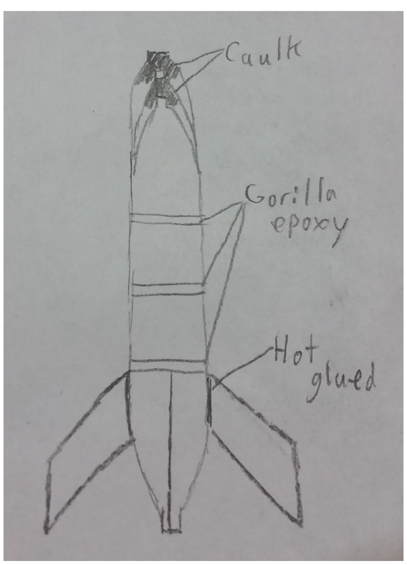

Figure 11

Rocket	PSI	Distance (yards)
Jefferson Starship 3	138	Blew up

Figure 12

These results were very unexpected but the most likely suspect to this was that the quality of the gluing wasn't good enough. Either too much epoxy was applied and didn't cure properly or not enough was used creating a weak point. The next rocket would be the same with a more careful build.

Launch 6 (10/20/15):

The goal of this launch was the same as the previous with a rocket exactly the same and the previous put built more carefully (see figure 13). The nose cone was the same double nose cone design filled with caulk. The fuselage was also five bottles long again. The goal was to see if the quality of the splices was the issue. Significantly more care was given while splicing these bottles so that that would not be the issue again.

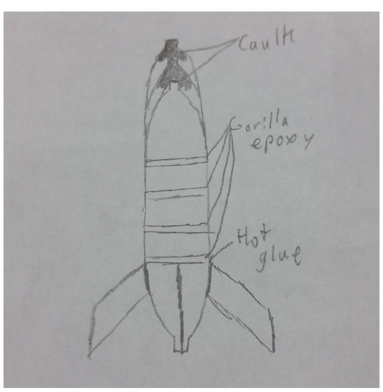

Figure 13

Rocket	**PSI**	**Distance (yards)**
Jefferson Starship 4	**138**	**Blew up**

Figure 14

These results were also very unexpected but after close examination of the wreckage, it appeared that the splice wa not the culprit. The top bottle actually exploded leaving ripples in the plastic and a very large tear. The only thing that could be done to avoid this would be to try new bottles.

Launch 7 (10/30/15):

The goal of this launch was to test new bottles and a possible new adhesive instead of the epoxies that were previously tested. The first rocket pictured in figure 15 was Gorilla Epoxy with Adirondack seltzer bottles instead of the Polar seltzer bottles that had been used for every other rocket. The rocket still had a double nose cone filled with caulk and fixed fins. The next rocket pictured in figure 16 was the same as the last one except instead of Gorilla Epoxy, Gorilla construction adhesive was used. Construction adhesive was what Amy had used the previous year. The final rocket was exactly like the first pictured in figure 16 except instead of Adirondack seltzer bottles, Polar seltzer bottles were used. This was an attempt to see if using a different adhesive would work better.

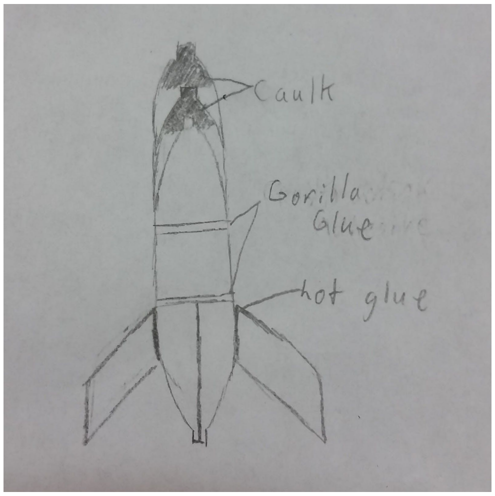

Figure 15

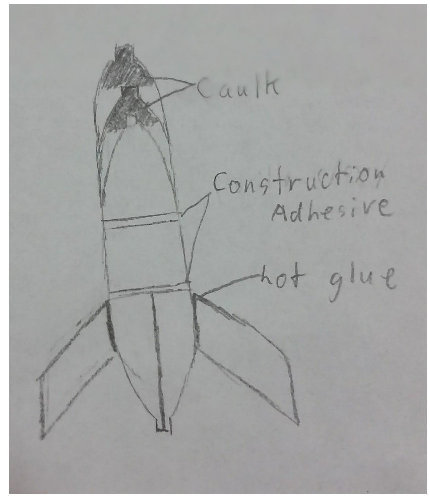

Figure 16

Rocket	**PSI**	Distance (yards)
Rocket 1 (Gorilla epoxy with adk bottles)	**138**	**Blew up**
Rocket 2 (Construction adhesive with adk bottles)	**138**	**Blew up**
Rocket 3 (Gorilla epoxy with polar bottles)	**138**	**Blew up**

Figure 17

The results didn't really say much except for the possibility that the quality of the splices was low again because of how quickly they blew up at. None of them reached pressure. There was also no broken pieces like every other explosion that had happened. This meant that more care needed to be taken when splicing the bottles. The next launch would be rocket day so trying another type of bottle might help.

Conclusion:

The most valuable lessons during this project were that you can never have enough duct tape and that all results need to be studied thoroughly. Repairs are nearly impossible on a launch day unless duct tape is readily available. It is also impossible to improve a design if the results aren't studied thoroughly so that some minor things that seem insignificant can be addressed. Studying other people's results and designs is also very useful. Good ideas and inspiration for a new design can be found in previous years lab reports and on launch days watching for good launches and seeing the designs. Trudi and Laura also building a multi-chamber rocket used Smart water bottles which seemed to hold together better. Tony and Jose also had a good idea by using a rubber ball in the nose cone for aerodynamics and durability.

The final design used on Rocket Day was inspired by how well Laura and Trudi's rocket held together. It was made out of four Smart water bottles spliced together using Gorilla Epoxy. The nose cone was inspired by Tony and Jose's rocket. In order to attach the rubber ball to the nose and make it smooth a top to a bottle needed to be cut off then the cap cut off of that. The ball went inside the bottle top which was then placed over the end of the rocket. To increase strength Gorilla tape was applied to the entire outside of the rocket. Gorilla tape is significantly stronger than normal duct tape. All of these changes can be seen in figure 18.

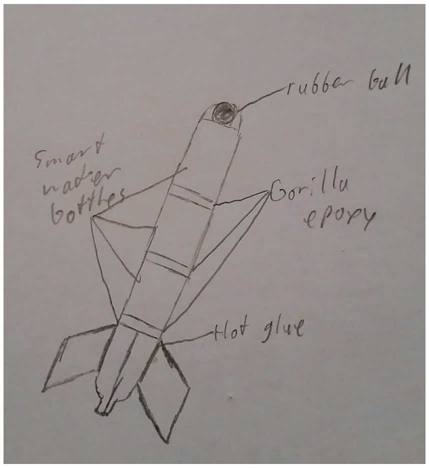

Figure 18

Rocket	**PSI**	**Distance (yards)**
Jefferson Starship	**138**	**159**
Jefferson Starship	**138**	**210** *This was the record for this rocket

Figure 19

If someone is planning on building a multi-chamber rocket such as this one they should be very prepared for a very frustrating build. The rocket will fail many times. It is a lot more work but in the end it is much more entertaining. On of the biggest things is to stay organized with all of the data and results. It is easier to learn from mistakes when they are documented. Another piece of advice is to be careful building it. It can be messy and some things need to be done very carefully so that they work fit and work properly. If the bottles don't fit snugly then they won't make good seal but if they are too snug then the epoxy will get pushed out of the splice and a seal will not be made. Launch days are the time to see if things work well and building multiple rockets allows for more than just one thing to be tested at once so that the most can be made out of each launch day.

Launch Team: Water team was in charge of making sure that all of the rockets are filled properly before going up the the launcher to be launched. This required talking with the people in charge of the order to make sure that the correct rockets were ready to go. Most rockets were just one liter of water but some of the multichamber and other different rockets needed more or less so that they had a half air and half water ratio when going to launch.

Sources:

Amy Engle's Lab Report

Linsey Carlson's Lab Report

U.S. Water Rockets." *U.S. Water Rockets*. N.p., 5 July 2003. Web. Oct.-Nov. 2015.

http://uswaterrockets.com/