# Smart Trailer System

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by

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# Problem Statement

The problem we are focusing on are the issues people have when it comes to launching watercrafts. There are three distinct problems we will be addressing as a group when launching a watercraft. We will take into account the depth of the trailer in water, the speed of launching the watercraft, and the angle of the trailer when backing up.

# Research

## Back Up Angle

## Background of Problem

To discuss the issues with backing up trailers, we first have to discuss the trailer itself. Trailers are used for a wide range of applications. A trailer is something that we classify on a broad range. We see trailers everyday being used to haul equipment, boats, and even the ones with overload sized houses. From personal experience, trailers can be very difficult to back up, especially if the end goal is to maneuver that trailer into a tight spot. Trailers have been around for a long time and in turn are used very frequently.

Back in 1899 a man in Cleveland, Ohio by the name of Alexander Winton invented the semi-truck trailer (1). The first trailer used a modified short wheeled automobile with a cart attached to the rear of it (1). The platform used could only hold one car. Today, a flatbed trailer known as a RGN (removable gooseneck) operates in the same fashion and can be hitched onto a tractor (1). Eventually a man by the name of Charles Fruehauf built a carriage for a person that wanted to transport a boat, and that is when it officially got the semi-trailer name (1). Eventually more people continued to elaborate on this concept which led to an invention called the Trailmobile.

The Trailmobile was a chassis mounted on wheels and springs that could be trailed behind a Ford Model T (1).

The history of the trailer led to all the different types of trailers today. Currently there isn't much known about each trailer's specific history. Even after all these discoveries, backing up a trailer can prove to still be troublesome to trailer owners today. Many reasons prove to be difficult while backing up a trailer: the location, it is difficult to see, and low light or harsh weather. People have struggled to back up trailers and even have lost their property while launching boats. If you have ever backed up a trailer you know just how difficult it can be. Typically while driving you turn the wheel the way you want to go, with a trailer you have to turn the wheel in the opposite direction. Then there poses the issue with backing up the trailer too far. Personally, I have even backed up my trailer too far and it dented the side of my car. Obscured views and tight spaces can lead to frustration. There have been ideas on how to improve backing up a trailer, only a few are listed on the market currently which is discussed in the state of the art.

## State of the Art

There are only a few different inventions that are used today when allowing a user to back up their trailer more easily. They each have their advantages and disadvantages, whether it be price, accessibility, or even ease of use. They each operate differently, but have the same idea: to help the user backup a trailer. These inventions include SpotterCone, TowGo, and Ford's Pro Trailer Backup Assist.

SpotterCone is a system that uses two cones that can be set up to help guide you while you backup your trailer. Their three ideas when coming up with this system were based on being signaled precisely when to stop without the aid of a human spotter, a clearly marked stationary line that provides guidance and helps keep pedestrians/traffic out of the way, and colored cones with lasers that light up like a personal airport runway (2). The user sets up the cones where they ultimately want their trailer to be parked, and the cones light up when the trailer has backed up to that point. There are green lasers that shoot out on the ground along the side of the trailer, to show exactly where the trailer should be lined up (2). The main benefit with this product is that it can be used with any size trailer because the user decides the placement of the cones. This product helps the user guide the trailer, however there can be a lot of human error when setting up the cones.

TowGo is a system that is aimed to help the user back up straight (keeping the trailer within plus or minus 1 degree), follow a curve, perform a 90 degree turn, or to even be able to go in a 360 degree circle (3). The system has an app on your phone that links to a sensor mounted on your steering wheel and a sensor on your hitch. There is an arrow that is displayed which shows which way your trailer is turning and how gradual it will turn (3). Depending how you turn your steering wheel (which way and how far) the hitch and steering wheel sensors compute the angles necessary to keep the trailer in line and communicate those angles to each other and the app on the phone. This product costs $329 and can be used on various trailers. This product's advantages include everything we aim to accomplish. However, the disadvantage is that you can't actually see your trailer physically. The app may display an arrow, but that just shows you where the trailer is aimed to go.

Ford's Pro Trailer Backup Assist is a system used on Ford's trucks and SUVs. It is a knob that is located in the cab of the car which the user turns to go the way the trailer is desired to go. The system then starts to steer assist the truck automatically. After the user has entered some measurements into the system, the camera will track the trailer's position while the user is backing up and guiding the trailer (4). This system is very beneficial to Ford users. However, that is the disadvantage of this product. If you want this system, you have to own or purchase a Ford vehicle. Our plan for our system is aimed more toward the trailer itself, rather than the vehicle being used to tow that trailer.

The primary focus will be on the entirety of backing up the trailer itself. The angle at which the trailer is backing up, the accessibility to view where the trailer is going more easily, and the ability to control exactly where that trailer is going to end up. Incorporating a system that can deliberately do these things will put the user at ease so they won't have to focus too hard and struggle whilst backing up their trailer. Using cameras, sensors, and some more electronics will help accomplish the ultimate goal.

## End User

Our customer profile is geared toward users that own trailers and launch some type watercraft. Trailers and watercrafts date back for many years, so our product is aimed to accommodate for the many different types of trailers that are used today. We aim mainly towards new watercraft consumers and users who have limited experience backing up a trailer, especially whilst launching a boat that are around the average middle class. These are users that care about their trailer and watercraft, don't like to spend too much time while launching, and ultimately want a simpler way to back up their trailer. Our customers are willing to spend some money on our product, but also want it to be somewhat economical.

## Summary of Research

Trailers have been around for many years, yet there still isn't an efficient system to assist novice or experienced watercraft consumers to launch their watercrafts effectively. During a launch, users want to be able to back up their trailer quickly, without losing the trailer and possibly even the automobile in the water. SpotterCone, TowGo, and Ford's Pro Trailer Backup Assist are some examples of systems used to help drivers today. They can assist the driver, however they all have their disadvantages. Developing a system that can combine all these current systems into one will be beneficial to the user, the trailer, and the watercraft.

## Speed

### Background of Problem

Currently there are 12.2 million watercrafts registered in the United States which comes out to an average of every one in ten households in the U.S. This means that there is a large amount of watercrafts that will be launched into bodies of water each year. The average watercraft gets used 26 days per year. This means that out of those 12.2 million registered watercrafts, millions of them will be launched over 2 dozen times each year which would create a large consumer base for the product.

On a personal level the 3 of us have been around watercrafts each year. After seeing this exact scenario of time consuming difficult launches for first timers occurring at the boat ramp we have decided to create a system to alleviate some of the problems. The main overall issue to address is the time it takes to launch. By solving the other two problems the overall time will decrease and leave owners waiting at the ramp significantly less.

By solving these problems we would be able to tackle a multitude of issues. First and most paramount would be the safety of the users. Being able to know the perfect depth for launching specifically helps the speed and accuracy of your launch. Being able to increase the speed of launching would be beneficial to users who are launching by themselves and also reduces the wait time of other users waiting at the ramp. Trailer backup angle also helps with the speed of the launch as well as acts as a quality of life improvement for the user. Backing up trailers is difficult no matter how practiced you are therefore tackling this would help all ranges from experienced to beginner.

The general populace are mainly affected by the sheer amount of time a busy boat ramp can add to the outing. When self-launching your boat the steps include: Taking off your tie downs, waiting for your turn in line, reversing the trailer into the water, adjust the depth of the trailer, undo the trailer winch and launch, drive the boat to the dock and tie off, then back to the car to park your trailer, and finally back to the dock to enjoy the water. Many of these steps have the availability to be reduced in time but any speed increase would compound and allow for more boats to be launched per hour. All these steps added on the fact that a public boat ramp is going to be busy more often than not in the summer can make waiting the extra time for the first time or self-launchers stressful and very time consuming. It is also important to mention the safety aspects of launching. I have seen multiple groups of people forget to remove their tie downs from the trailer and countless videos of boats/cars/trailer lost to water. Launching can be especially dangerous for losing property and can also be dangerous for the user. Anytime there is mechanical and electrical parts around water there is a safety hazard. “Dry starting” which is starting your boat before the engine is in the water can cause the motor to burn up from not getting the proper amount of coolant from the water. This could lead to catastrophic failure of fire or explosion. Beside these major risks there are also a lot of minor risks including, not remembering to wear a lifejacket and losing appendages on the winch. By making the steps easier for the general public we can aim to reduce the amount of waiting time at the ramp. If these problems are addressed and solved in our project users could expect small quality of life changes for them at the ramp.

## State of the Art

One of the steps for self-launching is driving the watercraft off of the trailer and tying it off to the dock. One of the large watercraft manufacturers have addressed this issue in their newer models. SeaDoo's RXT iS 255 has a retractable cable built into the hull of the vessel. This removes the time of having to pull out a rope and tie down to cleats on the dock. By simply pulling the cord out and quickly attaching to the cleats, T-shaped metal brackets bolted to the dock, time can be saved by not having to take the time to tie off. This system provides benefits for speed of launching and launching from a dock. However if you remove tying to the dock altogether the overall time saved will be significantly more making this not an ideal method for our system (5).

A streamlined system such as the "Ford Pro Trailer Backup Assist" would be a massive help for first time launchers and self-launchers. A large majority of the time spent at the public ramp is waiting for other owners to back up their trailers. I've seen time and time again of people struggling to understand the basics behind backing up a trailer. The Ford backup assist system allows the user to not have to think about the way they turn the wheel while reversing. The user activates the system and turns a knob the specific way they want the trailer to go eliminating the extra thought process step. Unfortunately to con of this system is the shear cost. After years of development Ford released it as a package deal on many of their trucks. This means to have access to this system you have to own a Ford truck with the package. We can however utilize the same type of sensory system that Ford uses by imitating it ourselves.

Work in recent years has been done to maintain the upkeep and quality of the physical ramps around the globe. There have been many conferences on how the physical ramps and associated parking lots can be made more ideal for drivers and boat owners. Currently the main issues with ramps are the people. Mainly the owners not being aware of ramp etiquette. Just above the slips in the parking lot is the zone for turning your car and trailer around. This area should not be used to load and unload your gear; it should only be used for reversing. Another issue is the erosion of the ramps below the concrete. When owners go to startup their boat while still on the trailer the propeller can move enough water to wash and erode away the dirt below the end of the concrete. This can cause many the trailer wheel to fall off of the concrete ledge when the water level is low which will ruin the trailer and can sometimes lead to a complete loss (6) (7). Another factor that isn't necessarily part of state of the art is following an exact checklist by the watercraft/trailer manufacturer for launching. Their guidelines provide everything from reminding to check for lifejackets to guidance on releasing the winch. By following an exact checklist you can assure nothing will be forgotten or misplaced which causes a lot of safety concerns at the ramp. There have been many horror stories of boaters forgetting to put their drain plug in and having their boat begin to sink immediately after leaving the dock. I have seen specifically one boater who had not put their drain plug in and came back to the dock 25 minutes later with their boat halfway underwater in a panic. This boat was luckily able to be pulled out of the water but required an elaborate setup of multiple trucks pulling the trailer to deal with the added weight (8) (9).

## End User

Based on the three problems our team has decided our ideal customer would be more geared towards first time and/or self-launchers. This would include first time boat owners or customers in the market for PWC or Personal Watercraft. Most watercraft owners according to the National Marine Manufacturers Association are average middle class families that make less than $100,000 (10). This means our solution to these problems would be targeted towards these customers. We are targeting mostly first time launchers but veteran launchers would also see a decrease in their overall wait time and launch time if they used our product.

## Summary of Research

Based on our research we have decided to create a product that solves our 3 problems all in one. The final result would have to be cost effective, safe, and easy to use. These factors would be the driving force behind the marketing of our product towards first time launchers and self-launchers. There are products out there that address the problems that we've stated but none of them combine all into one solution. We are proposing a modified trailer system that can be targeted towards middle class families to reduce time at the ramp and increase the overall safety.

## Depth

## Background of Problem

For many people being out on the water on a boat or personal watercraft (PWC) on a hot summer day is a must. However, to get out on the water you first need to launch your boat or Jet Ski into the water off of your trailer. Many people struggle while trying to launch their watercraft, especially if they are attempting the launch alone. To launch a boat you need to back the trailer the correct depth into the water, unhook the boat from the trailer then take the boat off and tie it to a dock. Once you have the boat tied off you need to drive your vehicle and trailer off of the ramp so the next person can launch. Some problems people face while launching are difficulty backing up the trailer, knowing how deep the watercraft is in the water and how long it can take to launch the watercraft. These difficulties can lead to damaging your trailer, or losing time trying to launch and making other boaters that are waiting to launch very angry. The problem I am targeting in this project is how to know when you are in a good depth to launch your PWC.

There are currently over 1 million Jet Skis registered in the United States (11). PWC's are also becoming increasingly popular. Sales have gone up 5 percent in 2017 and 7 percent in 2018 (12). If this trend continues there will be many more Jet Skis out on the water in the coming years. Some people only have to launch their PWC at the beginning of the season and keep it at their dock the rest of the summer. However, the majority of people have to launch their watercraft every time they want to use it. The average Jet Ski is used over 8 days a year which makes ease of launching very important (13).

## State of the Art

The first product I discovered is the TowGo. This consists of two sensors, one on the steering wheel and one on the hitch of the trailer, to tell you what angle you are back up at. There is an app you download that connects to the sensors and can show you the path your trailer will take based on the angle of your hitch and your steering wheel. This product is helpful because you can see exactly the path your trailer will take. However, it is an app which means you would have to hold your phone in one hand and watch the screen while you are trying to back up and steer with the other hand.

The second product I found is for the speed of launching and it is called the Z-Launch watercraft launch cord. This is a flexible cord that helps someone launch a watercraft by themselves. You can attach the cord to your wench and to your boat so when you pull the trailer out of the water the cord is connected to the boat and it does not float away. Once you drive the trailer out of the water you have to tie the boat to the dock and go park your car then come back to the boat. The pros of this item is launching a boat by yourself is easier because you still have control on the boat. The speed is not increased much however.

For the depth of water for launch I have not been able to find any kind of trailer attachment. The closest product would be a handheld depth gauge however, the problem is you have to get out of the car to check the depth so this would not be a benefit. The depth gauge would tell you the exact depth for people who want to check. It would not help with the speed of launch however.

## End User

The reason for the growth in popularity over the last 6 years is the younger generation. Millennials are the group pushing the PWC business however, they are not the people buying the jet skis. The parents and grandparents are the ones making the purchase. The older generation are purchasing Jet Skis so the younger generation can take them out on the water (12). We will also be targeting the middle class because most of the Jet Skis are used by middle class citizens and not the top percent.

## Summary of Research

PWC trailers have been around for many years but there are still many problems with launching and retrieving of the watercraft that can be fixed to make it a faster process. There are no trailer attachments on the market that will tell you when you are in deep enough water to launch your Jet Ski. This results in people having to get out and look how deep the trailer is then get back in and try again. If I can create a way to know if you are in an ideal depth for launching from your driver seat that will vastly increase the speed of launching alone.

# Quality Function Deployment

## Customer Features

In the following list, you will find the features that the end user of the Smart Trailer System would expect to see, as defined by our team.  Based on our surveys, the customer selected the following features in descending importance.

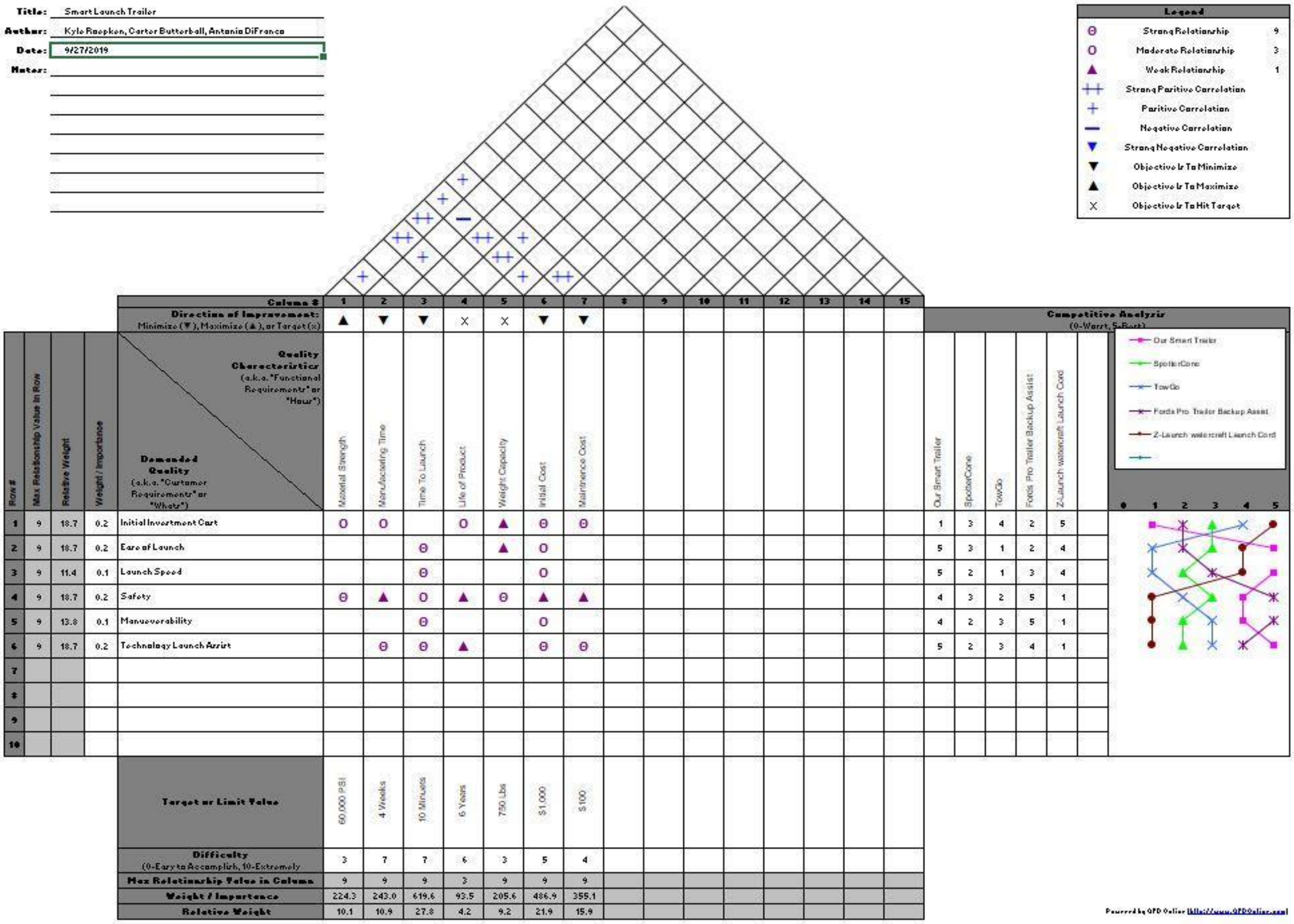
1. Ease of Launch
2. Initial Investment Cost
3. Maneuverability
4. Safety
5. Technology Launch Assist
6. Launch Speed

## Engineering Characteristics

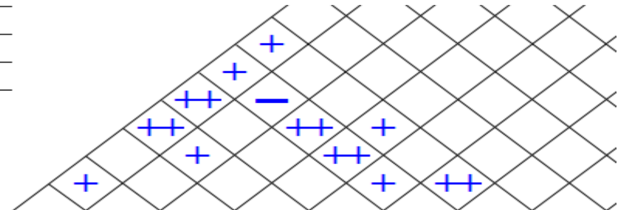
Many people each day struggle with the fact of not properly being able to back up a trailer. Providing a new system that will ensure launching can be done simpler will allow users to not worry while backing up their trailer to launch a watercraft. The main effect of this device will deeply impact boat users, and even people that launch a wide variety of watercrafts. In the following list, you will find the characteristics that satisfy the features outlined in the previous section, as defined by our team.  It is important to note that this list does not represent an order of any kind.

1. Material Strength (psi)
2. Manufacturing time (weeks)
3. Time to launch (minutes)
4. Life of Product (years)
5. Weight Capacity (lbs.)
6. Initial Cost ($)
7. Maintenance Cost ($/year)

# House of Quality




Entire HOQ

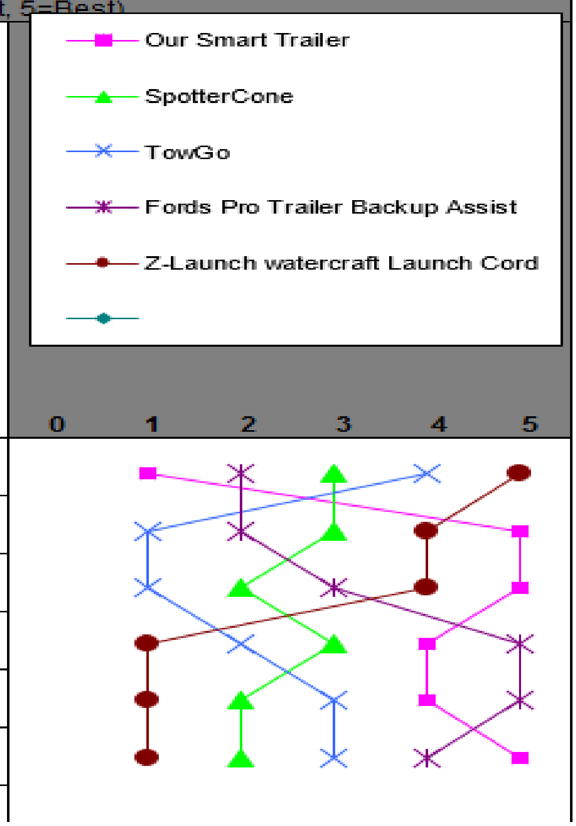



| Row # | Max Relationship Value in Row | Relative Weight | Weight / Importance | Column # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x) | ▲ | ▼ | ▼ | x | x | ▼ | ▼ | |
| | | | | Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats") | Material Strength | Manufactering Time | Time To Launch | Life of Product | Weight Capacity | Initial Cost | Maintinence Cost | |
| 1 | 9 | 18.7 | 0.2 | Initial Investment Cost | ○ | ○ | | ○ | ▲ | ⊝ | ⊝ | |
| 2 | 9 | 18.7 | 0.2 | Ease of Launch | | | ⊝ | | ▲ | ○ | | |
| 3 | 9 | 11.4 | 0.1 | Launch Speed | | | ⊝ | | | ○ | | |
| 4 | 9 | 18.7 | 0.2 | Safety | ⊝ | ▲ | ○ | ▲ | ⊝ | ▲ | ▲ | |
| 5 | 9 | 13.8 | 0.1 | Manueverability | | | ⊝ | | | ○ | | |
| 6 | 9 | 18.7 | 0.2 | Technology Launch Assist | | ⊝ | ⊝ | ▲ | | ⊝ | ⊝ | |
| 7 | | | | | | | | | | | | |

Above are quality characteristics cross referenced with demanded duality

**Competitive Analysis**
(0=Worst, 5=Best)

| Our Smart Trailer | SpotterCone | TowGo | Fords Pro Trailer Backup Assist | Z-Launch watercraft Launch Cord | |
|---|---|---|---|---|---|
| 1 | 3 | 4 | 2 | 5 | |
| 5 | 3 | 1 | 2 | 4 | |
| 5 | 2 | 1 | 3 | 4 | |
| 4 | 3 | 2 | 5 | 1 | |
| 4 | 2 | 3 | 5 | 1 | |
| 5 | 2 | 3 | 4 | 1 | |
| | | | | | |




Above are our customer comparisons

| Target or Limit Value | 60,000 PSI | 4 Weeks | 10 Minuets | 6 Years | 750 Lbs | $1,000 | $100 | | |
|---|---|---|---|---|---|---|---|---|---|
| Difficulty (0=Easy to Accomplish, 10=Extremely Difficult) | 3 | 7 | 7 | 6 | 3 | 5 | 4 | | |
| Max Relationship Value in Column | 9 | 9 | 9 | 3 | 9 | 9 | 9 | | |
| Weight / Importance | 224.3 | 243.0 | 619.6 | 93.5 | 205.6 | 486.9 | 355.1 | | |
| Relative Weight | 10.1 | 10.9 | 27.8 | 4.2 | 9.2 | 21.9 | 15.9 | | |

Product Objectives

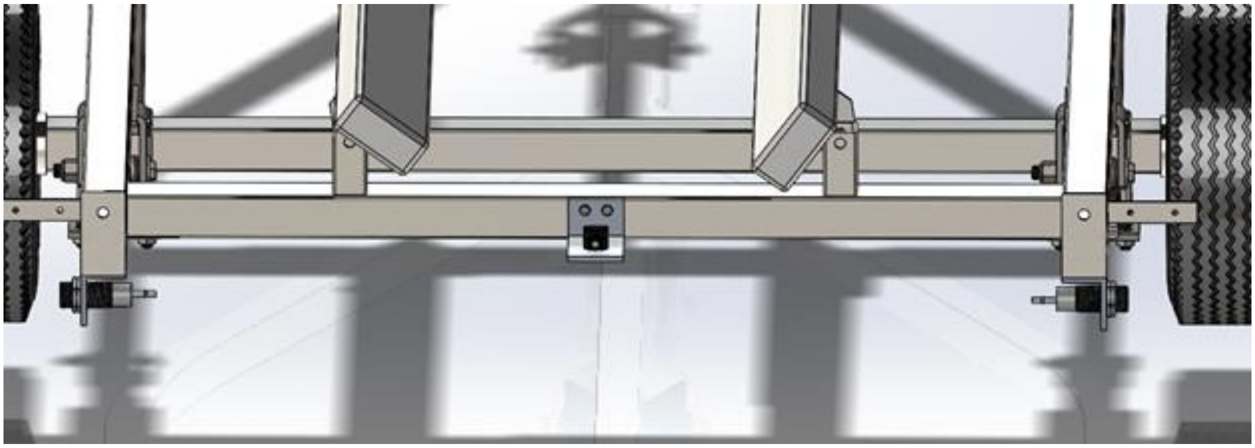
## Product Objectives

Based on the results of the House of Quality the engineering characteristics are listed below in order of weighted importance, starting with the most important specification to the least:

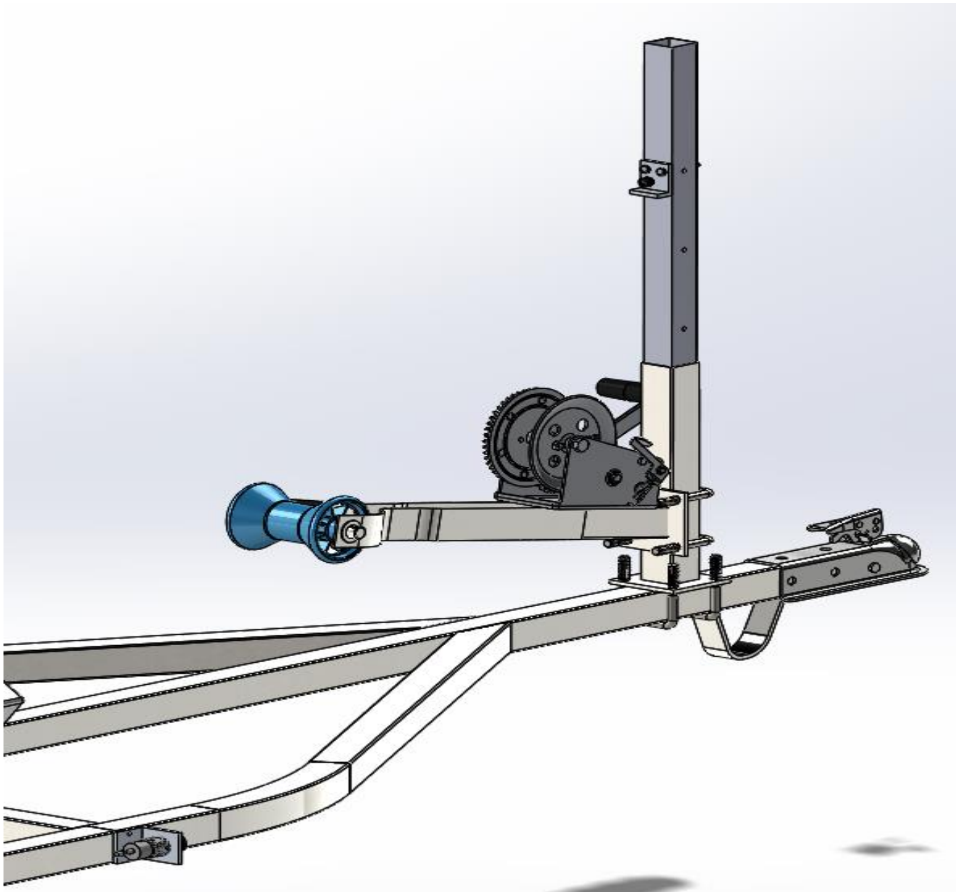
1. Time to launch (minutes)
2. Initial Cost ($)
3. Maintenance Cost ($/year)
4. Manufacturing time (weeks)
5. Material Strength (psi)
6. Weight Capacity (lbs.)
7. Life of Product (years)

Our whole premise for our project was to develop some kind of system that will provide a new way to launch watercrafts easier. It is no shock that our first objective is that this system will serve that purpose. However, we didn't want to just leave it at that. We plan to go above and beyond what is to be expected in such a system.

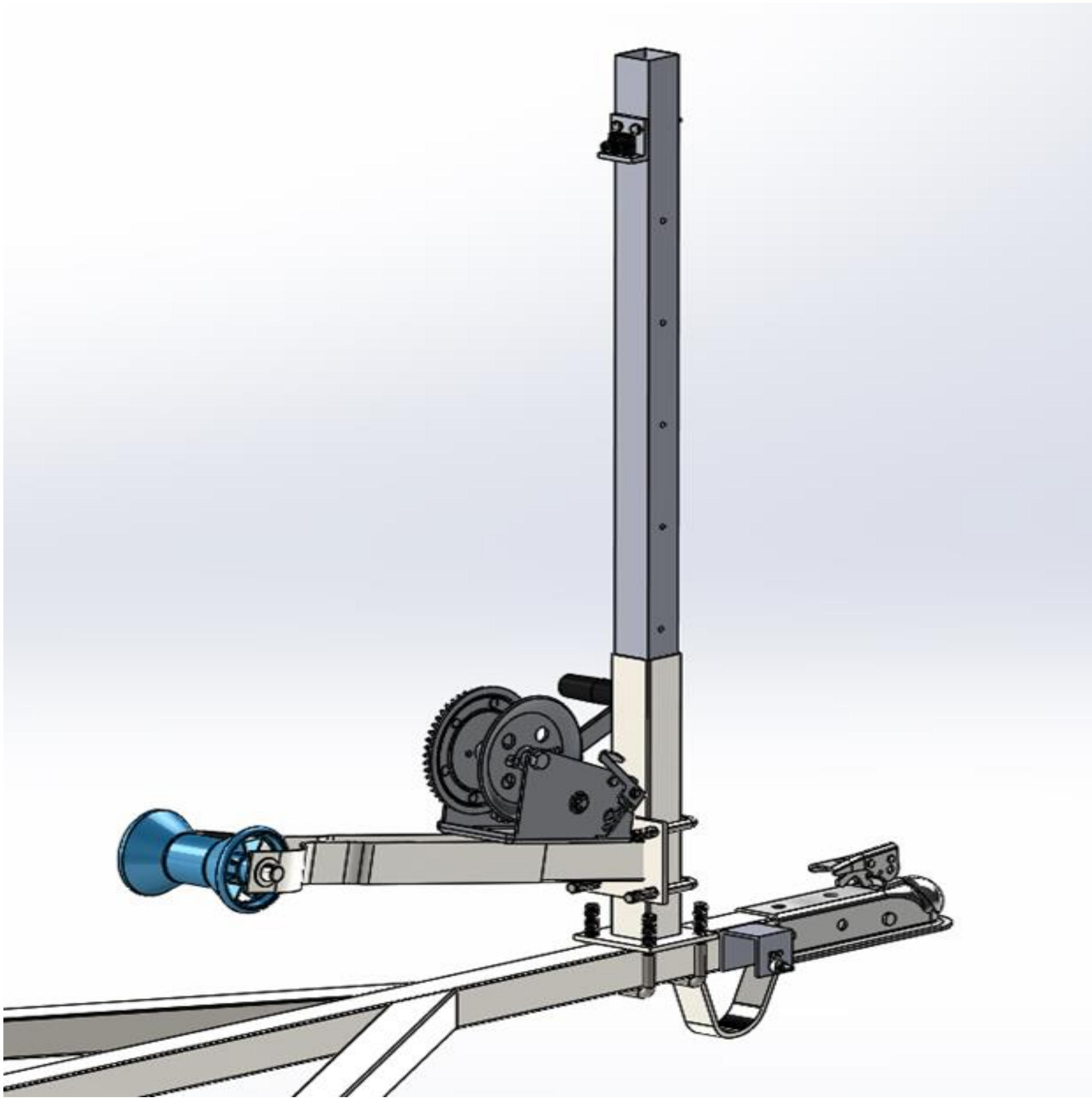
## Concept Drawings



The above picture is an image of the first concept drawing. In this drawing, the idea was to mount one camera on the rear end of the trailer and two sensors at the back facing outwards. The camera would allow the user to see directly behind them while backing up. The issue with the camera location is it is low and will not have much visibility. The sensors on the side would be proximity sensors that can indicate a distance between the sensor and an approaching object. They would indicate when the user is getting to close and needs to turn the wheel the opposite way.

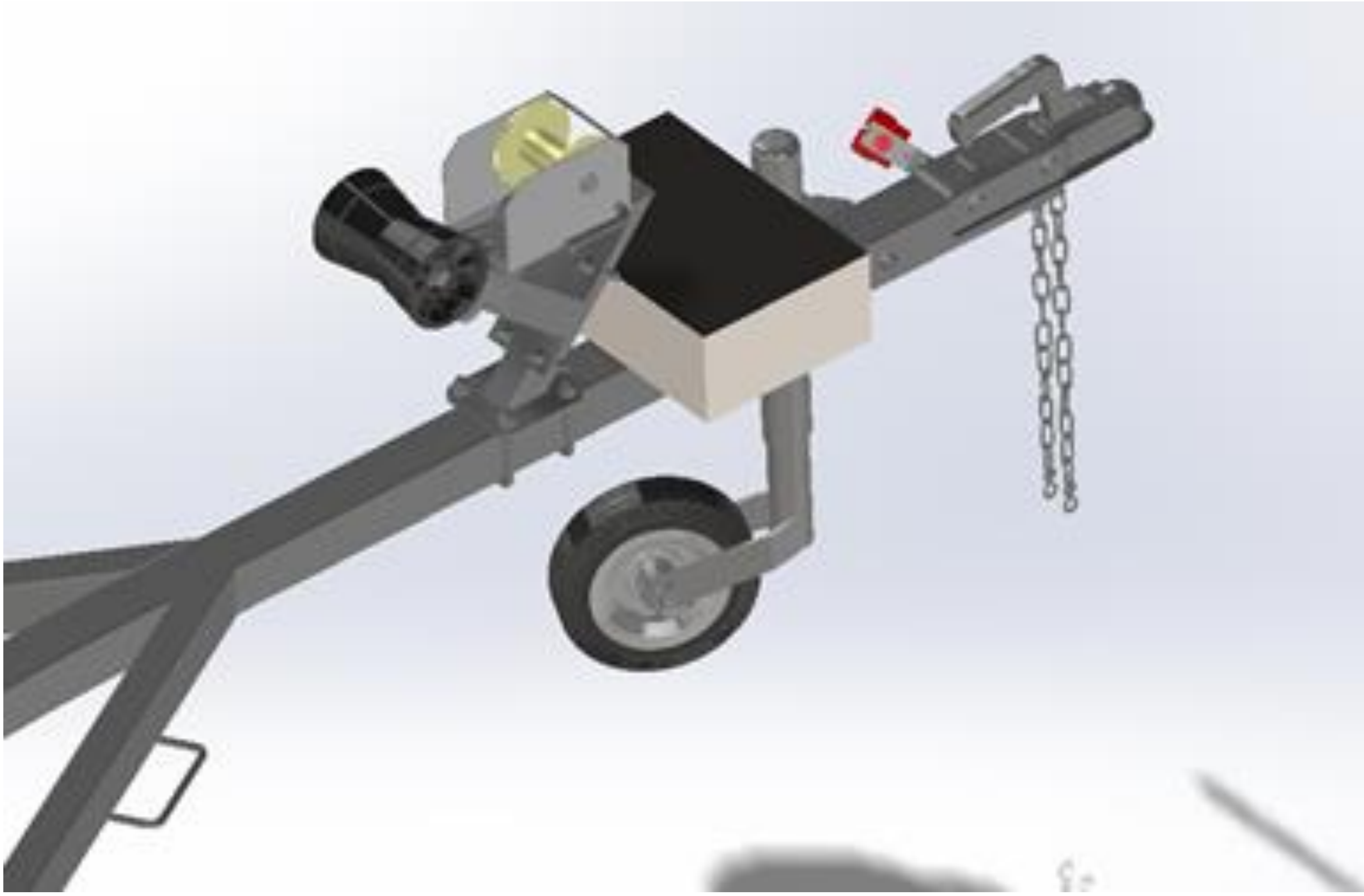
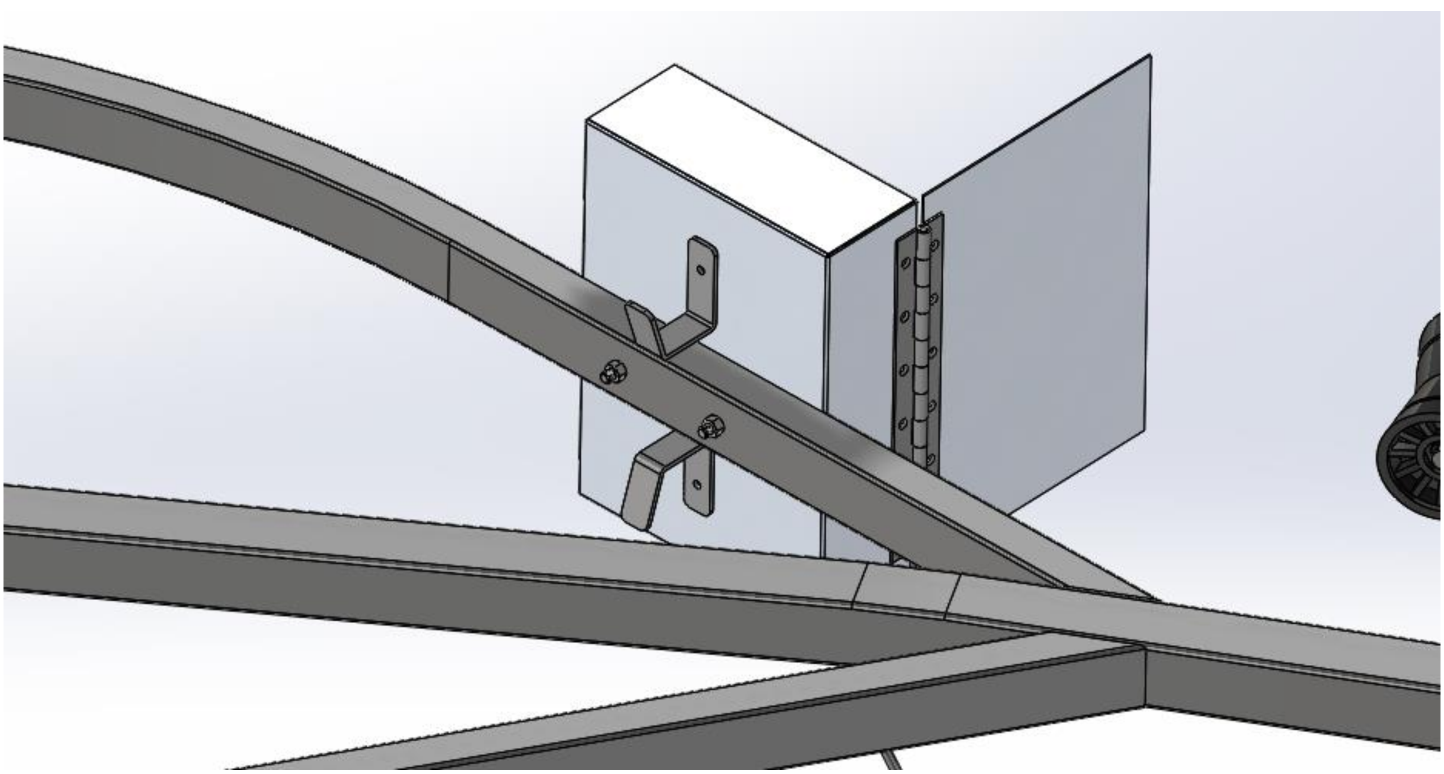


The above image is a picture of the second concept for the backup angle. In this drawing, the idea was to mount one camera on a post overseeing the top of the trailer with two sensors on the side facing the vehicle. This concept helps the user mainly with back up assistance. This camera location is more ideal because it has a better overall field of view. The sensors mounted on the side would be ultrasonic sensors that can detect the presence of the vehicle. So, depending on how much the vehicle is turned, the sensors will indicate a distance from the trailer to the vehicle and tell the driver to divert to the opposite direction.

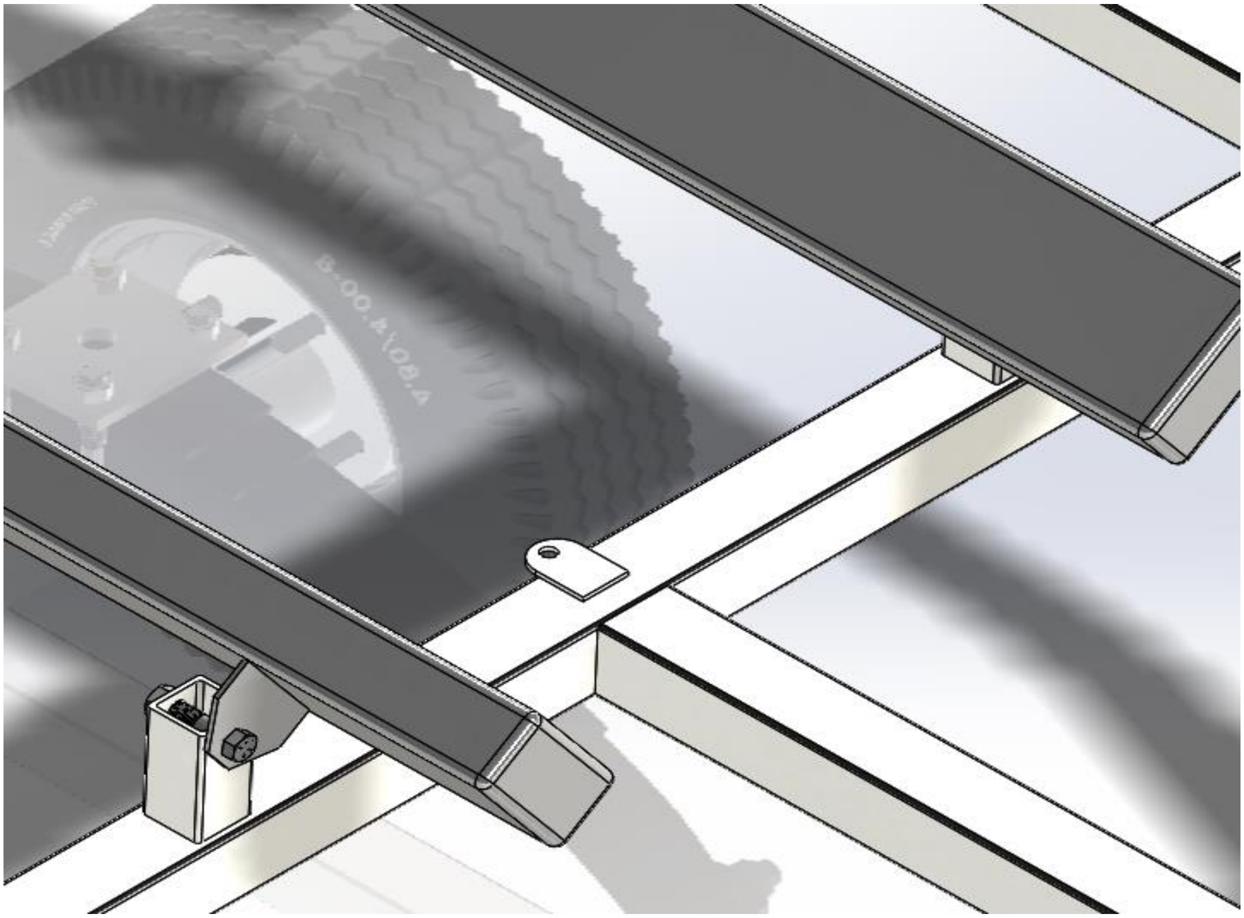


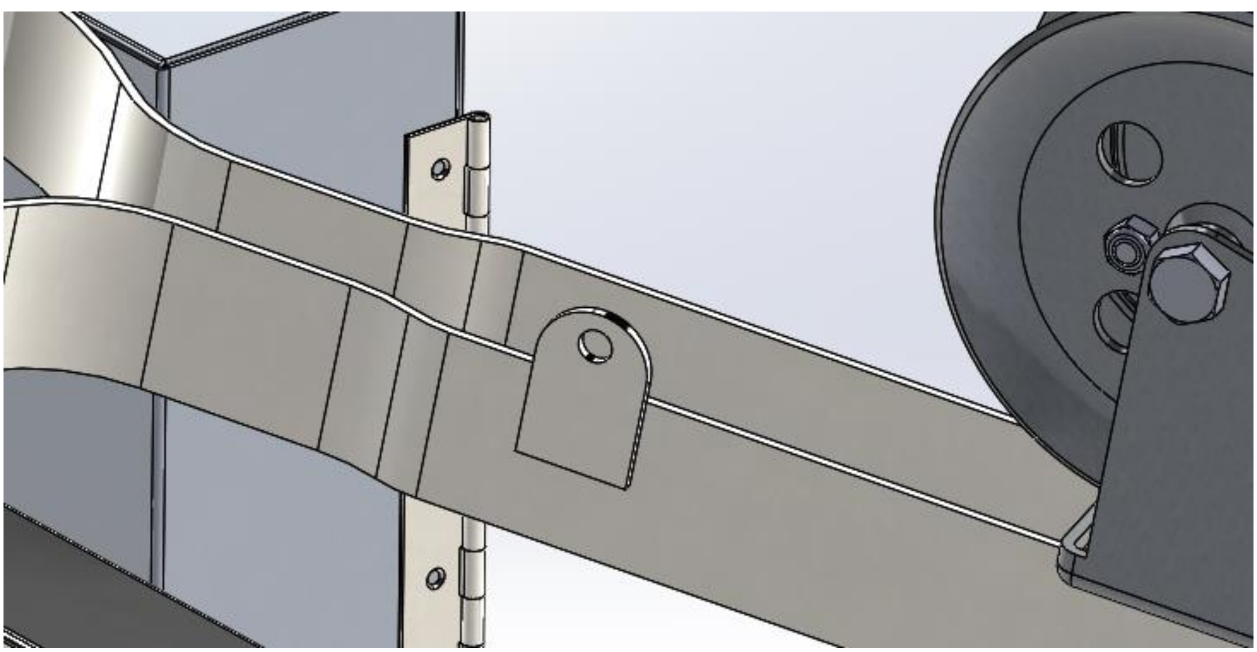
The above image is a picture of the third concept drawing. In this drawing, the idea was to mount a camera on an extendable post overseeing the top of the trailer with a string potentiometer mounted on the tongue of the trailer. The extendable post is under the impression that the driver won’t have something sticking out in their rear-view mirror while they are driving until they have to back up the trailer. This camera will allow the driver to see what is around them and let them know where they are at all times. It allows them to not only see over the watercraft, but also what is on the side of it. The string potentiometer would be programmed using the simple

Pythagorean theorem and would indicate which way the trailer was veering towards. It would then communicate with the driver to start turning in the other direction. This choice seems like the most probable and realistic.

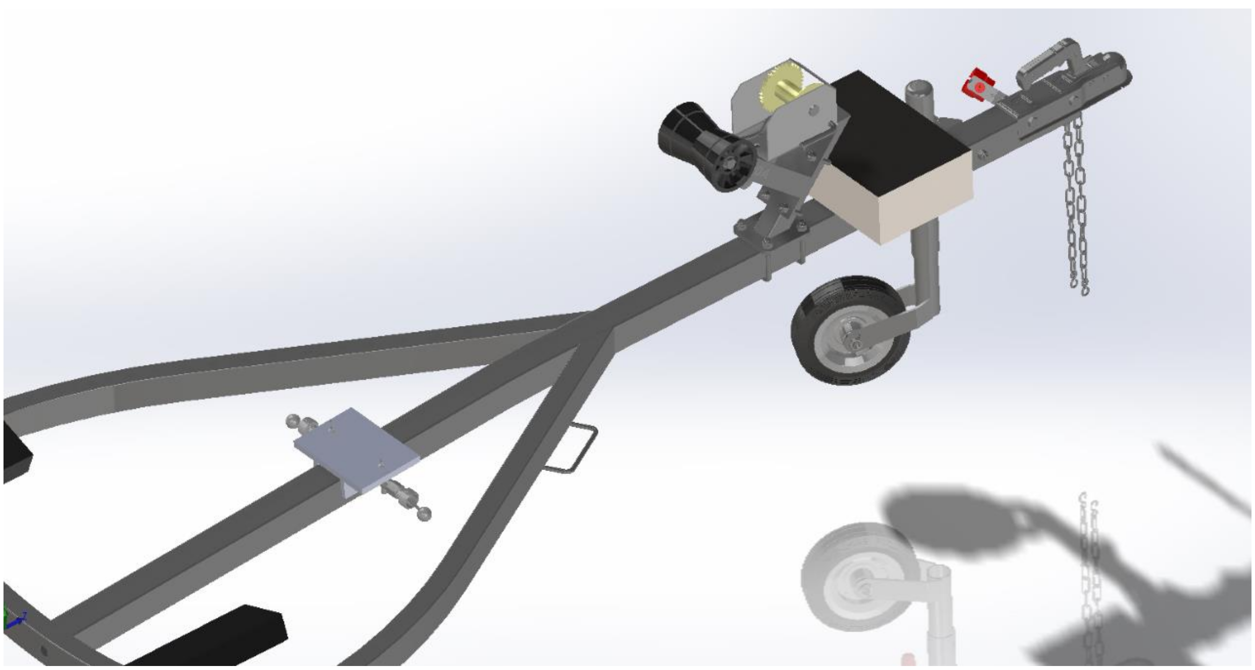



The above three concepts outline different locations for the electrical box that will be used to house our electronics.  Concept number 1 shows the location of the electrical box to be up on the tongue of the trailer.  This concept was brainstormed mainly due to its location.  Being close to the hitch of the car gives the easiest form of access for the user and keeps the box the furthest from the water's edge.  Concept number 2 shows the location of the box mounted horizontally on the tongue of the trailer.  This would be the most ideal option for us as manufacturers due to the ease of wiring but having the box mounted this way was not visually or structurally appealing to the eye.  Concept 3 is the box mounted on the leading edge of the trailer vertically.  This is the concept we went with due to the visually appealing solution while retaining the most structurally sound aspects.  In this concept there are two through bolts providing support as well as a hanger for the Z-Launch cable on the back.  The box will be waterproofed to keep all of our electronics safe as well as have an emergency power off switch on the top.  The camera, sensor, and light post from the other concepts will be wired directly into this box.

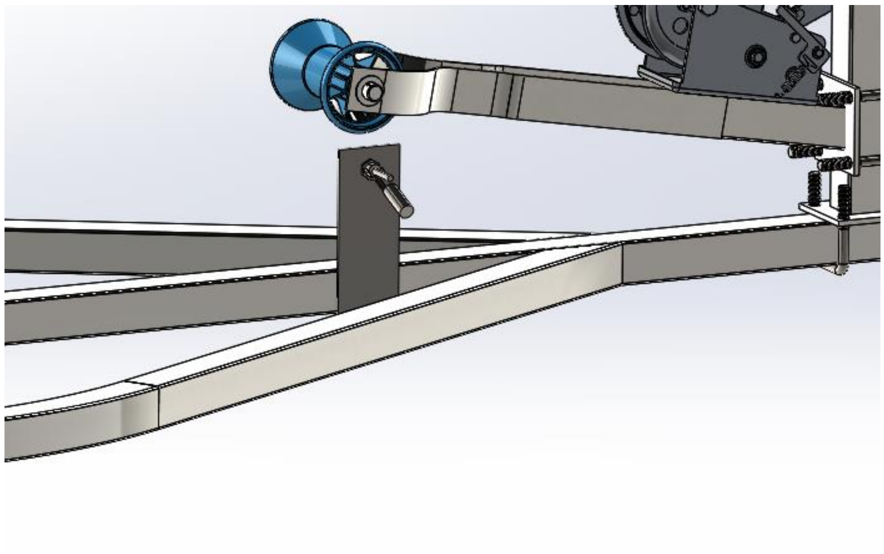


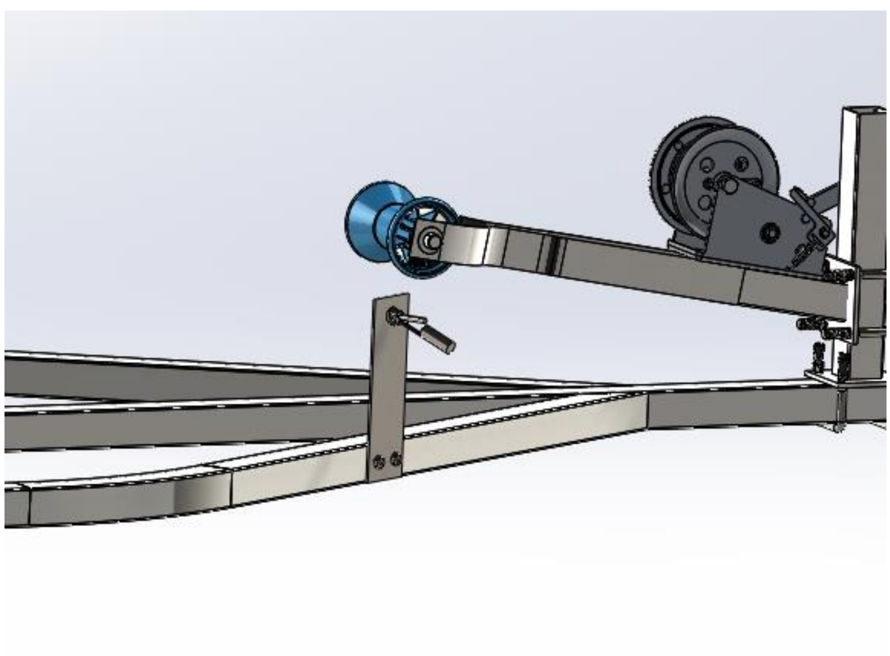


The above are images of the connection point for the Z-Launch cable.  The cable we will be purchasing utilizes a quick release hook on one end and a more rigid screw carabiner lock on the other.  We will utilize the quick release on the watercraft side and the more rigid carabiner on the trailer side.  These eyehole bracket locations are two that we came up with to solve where to attach the cable.  Concept 1 shows the bracket welded directly to the frame in the center middle. This felt like the most ideal solution due to the structural integrity of the arm that holds the bow roller in concept 2.



The above image is the first concept design for sensing the depth the jet ski is in the water. As you can see it utilizes two water level switches mounted to the middle bracket of the trailer. Once the water gets to the level to flip the switch a light will turn on informing the driver that they are far enough in the water and safe to launch their watercraft. The pros to this design is the sensors are out of the way and visually appealing. When the jet ski is on the trailer you would not even see it. The con to this design however is being mounted down under the jet ski does not allow for the sensor to detect the correct water depth.





The above two concepts for depth are very similar. They use the same water level sensor attached to a raised up bracket to detect the correct water depth but they are mounted on different parts of the trailer. The first picture shows the bracket mounted to the middle beam of the trailer right under the bow wheel. The pros of this concept is the sensor can detect the correct depth but it could get in the way of the jet ski depending on the shape of the hull and how far up the jet ski sits on the wheel. The last concept shows the bracket mounted to the outside of the trailer frame. The cons of this concept is it is not very visually appealing however, it can detect the correct launch depth and it will not get in the way of the jet ski. For these reasons I chose to use the third concept because of its functionality.

# Component and Material Selection

## Back Up Angle Components & Materials

Based upon calculations and ingenuity, the following components were selected:

- All 304 AISI Stainless Steel
- Potentiometer (draw wire encoder)
- Camera with wifi transmitter
- 1.75” square tube stock
- Hardware of different sizes (¼”, 5/16”, ⅜” with lengths of 2.75”, 2.5”, 2.25”, and 1”)
- 11 Gauge ⅛” steel plate 6” x 12” flat bar steel plate for brackets

## Speed of Launch Components & Materials

Based upon the calculations in appendix C & knowledge gained from school the components for the electrical box as well as the speed of launch are listed below. Some of these components would change over the course of manufacturing.

- Z-Launch cable rated over 100lbf tensile strength
- Stainless Steel 316 eye hole bracket for the cable

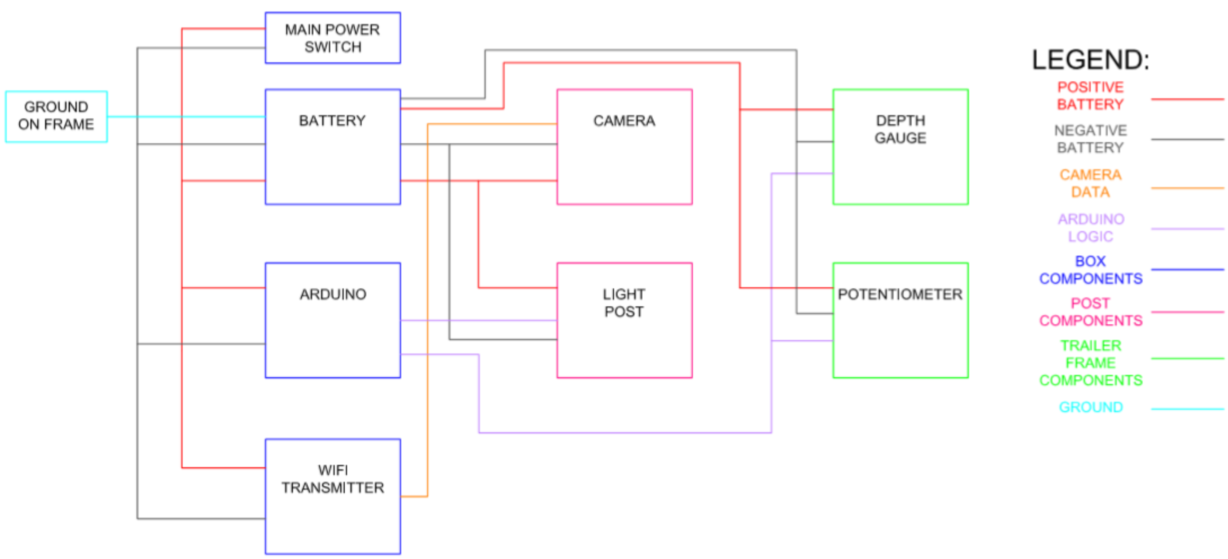
- Aluminum sheet metal box (eventually changed to a purchased outdoor rated electrical box)
- Rubber sealing gasket for the box door
- Piano hinge & appropriate hardware
- 90 degree sealing latch
- Stainless Steel hardware with rubber and metal washers for mounting
- Purchased hanging brackets for the Z-Launch cable during towing.

## Depth Components & Materials

Based on the calculations for the depth sensor in Appendix D, this is the list of components needed to find the correct depth.

- 10x3x1/8” 304 stainless steel plate
- 2 ⅜” x 2.5” 304 stainless steel bolts and nuts
- Water level sensor (316L stainless steel)

## Electrical Components & Schematic

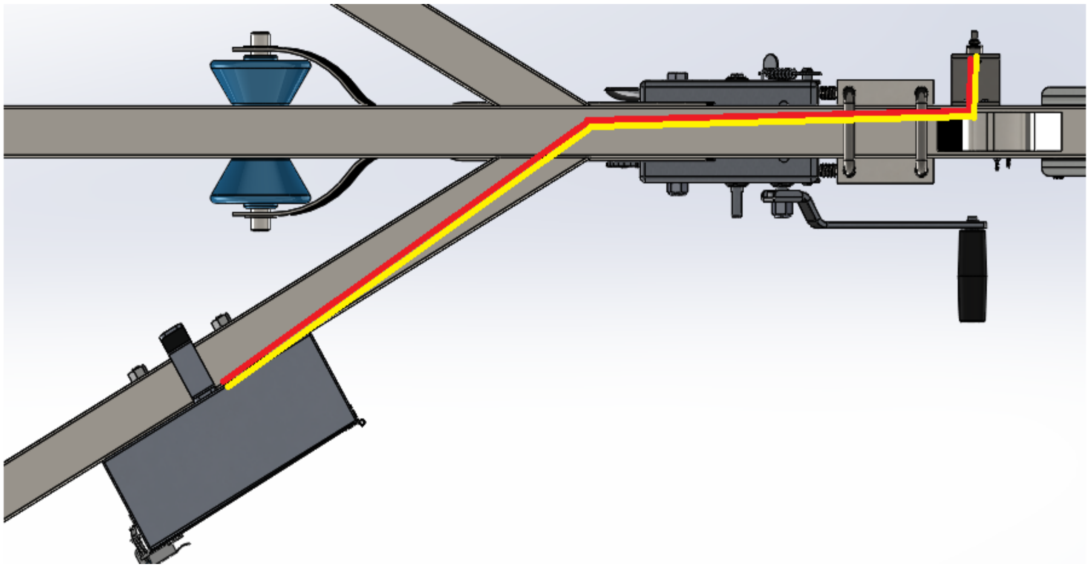


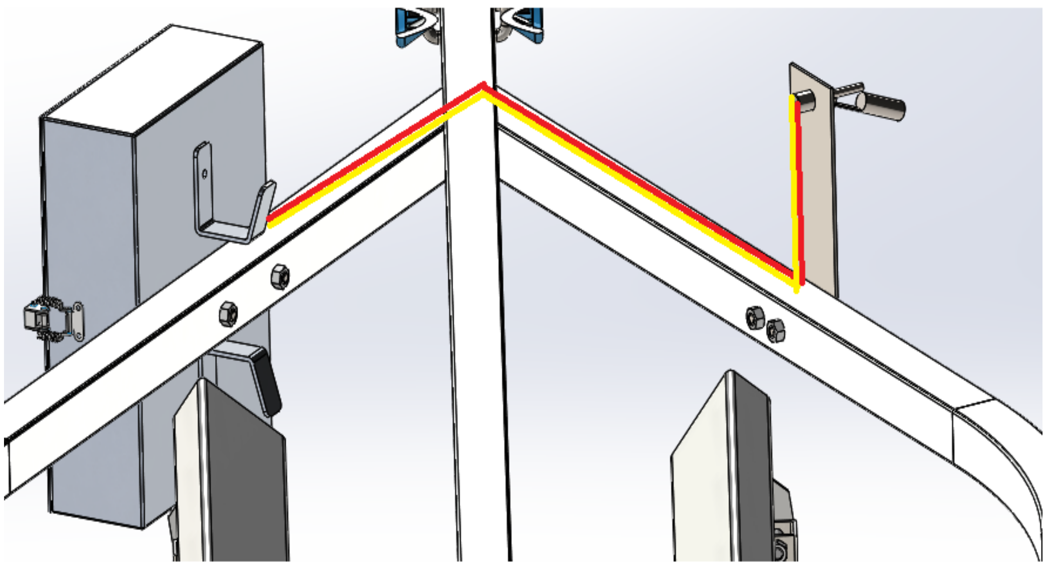
## Electrical Components

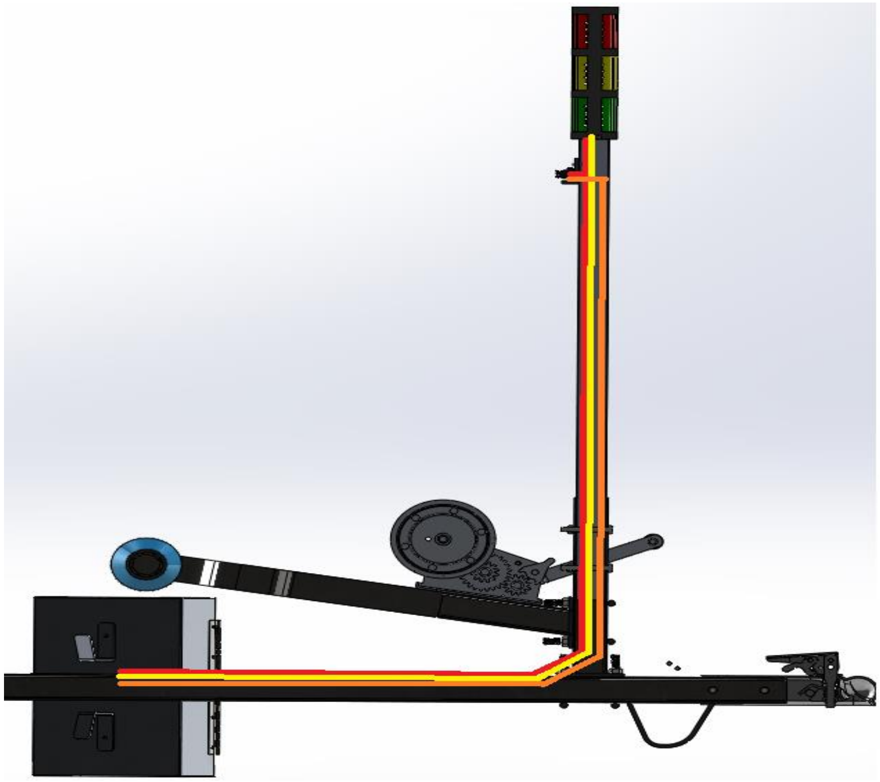
- 24V DC Battery
- Ardunio Mega 2560
- Potentiometer
- Wifi backup camera
- Wifi transmitter
- Water level switch
- Tri-color indicator light
- Master power switch
- Liquid tight conduit
- Liquid tight elbow connector
- 16 gauge wire (50ft)

## Electrical Diagram

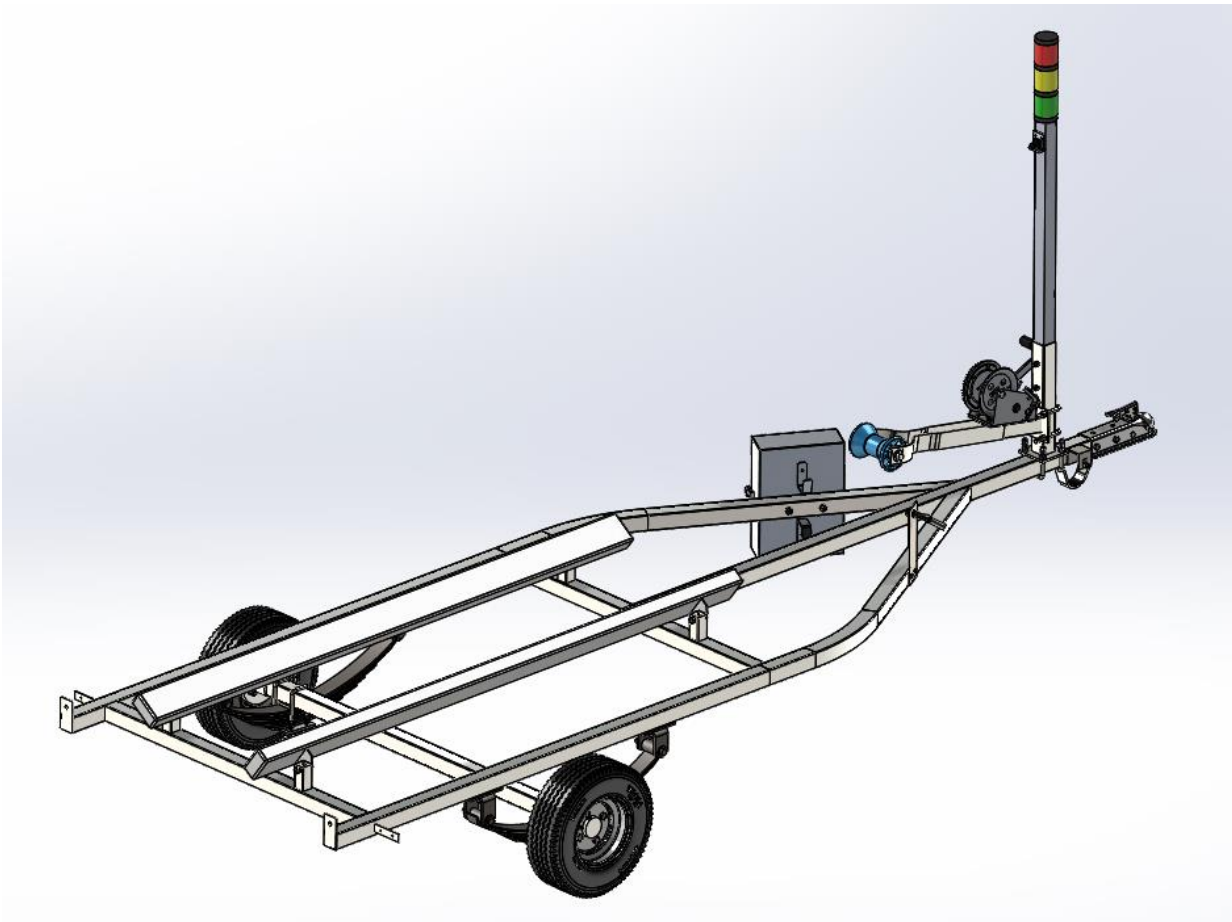
The below images are outlining the plan for wiring the components to the E-box. The combined lines show the locations of the liquid tight flexible conduit. The individual lines indicate power (in red), data for the Arduino (in yellow), and data for the wireless Bluetooth transmitter (in orange).







# Final Design Concept



# Manufacturing Plans and Completed

## Completed:

1. Purchased trailer & jet ski on January 11th from Louisville, KY and moved it to our manufacturing location in Sharonville, OH where Carter's Stepdad has a shop
2. Finished complete solid model assembly in mid-February
3. Ordered parts in the 3rd week of February which arrived the last week of February into the first week of March. While waiting for our parts to arrive we removed the oil, fuel, & battery from the jet ski. After removing and safely disposing of them we took the jet ski to the dump to get it out of our way for further manufacturing.
4. After removing the jet ski we spent time removing odds and ends from the previous owner and cleaned the trailer. This included purchasing a new set of wheels/tires.
5. After our main parts began to arrive the first week of March we made an initial trip to home depot for extra tools we needed as well as hardware.
6. We bent our sheet metal for Antonio and Kyle's brackets and drilled the holes for all of our components the first week of March.
7. Later during that same week we drilled the holes and mounted the post for the camera and light. We mounted the camera and light on the post.
8. We pivoted during this time with the electrical box to save some money. We purchased an outdoor fitted electrical box in order to match up with our liquid tight conduit we were going to run. Using a pre-manufactured electrical box and Flex Seal we were able to test and ensure the box was watertight. We purchased a hinge and manufactured a sealable latch system for the box to close and stay sealed.
9. In the week before spring break (March 16th - March 20th) we had mounted the aforementioned box to the frame as well as welded the eyehole bracket. The post with camera and light attached were mounted to the trailer. The float switch bracket and float switch were mounted to the frame as well based on our model. The float switch bracket model was outfitted with a slot rather than a singular hole so we could adjust the exact height when testing began.

### Incomplete (Due to Covid-19):

The three of us traveled to Mexico during the first weekend of spring break and arrived back in town to the University of Cincinnati closing as well as the discontinuation of senior design manufacturing. The below items are what was planned in the week of spring break as well as the following weeks. These items were not completed.

1. The week of spring break we planned to run our liquid tight conduit to all of our electrical components and wire everything to the box.
2. We were also going to drill and mount the final bracket & component, the linear potentiometer, to the tongue of the trailer.
3. In the week following we had planned to wire all of our electrical components together inside of the box according to our schematic pictured above. Our plan was also to add an electrical stop on and off switch on the top of the box to preserve the battery charge. This would leave us the task of creating and modifying the program for the Arduino as the last thing to complete.
4. Once the program was created we were going to spend a couple of days at East Fork lake in order to test and dial in our program for our specific components. We would then return the following weekend in order to bring test subjects and complete testing which is outlined below.

## Testing Plans

Our plan, after completed fabrication, was to test the trailer to time how long it takes to back up and launch the jet ski with our system off and then again with the system turned on. We were going to test both men and women who have never backed up a trailer or jet ski, have very limited experience backing up a trailer or launching a jet ski, and have extensive knowledge of backing up a trailer and launching a jet ski. Following all the testing, we were going to compare the launch time results with the system on and the system off to determine whether or not the speed increased. Unfortunately, these tests were unable to be performed, deeming results inconclusive due to COVID-19.

# Project Management

## Project Budget

Our team estimated a budget of $2,000 at the start of this project. We broke that down into four $500 categories of the trailer, parts for backup angle, parts for speed, and parts for launch depth. We first bought a trailer for $500 which came in right on budget then we proceeded to purchase sensors and hardware for manufacturing. We were not able to finish manufacturing due to covid-19 and did not yet purchase some items such as wiring so those will be estimates in the final cost below.

| | Money Spent |
|---|---|
| Trailer | $500 |
| Sensors | $297 |
| Hardware | $124 |
| Electrical | Estimated $88 |
| Total | $1009 |

## Schedule

1. Finalized concept and design by the end of Senior Design II
2. Purchased trailer on January 11th
3. Decided to store trailer at Carters Step-Dads workplace
4. Ordered parts at the end of the third week of February
5. Took old jet ski to the dump at the beginning of March to begin work on the trailer.
6. Began manufacturing process at the beginning of March
7. Bent the sheet metal and brackets then drilled holes for brackets.
8. Mounted sensors on trailer in the first week of March and continues manufacturing through the second week.
9. Covid-19 stopped manufacturing on the trailer and ruined plans for testing.

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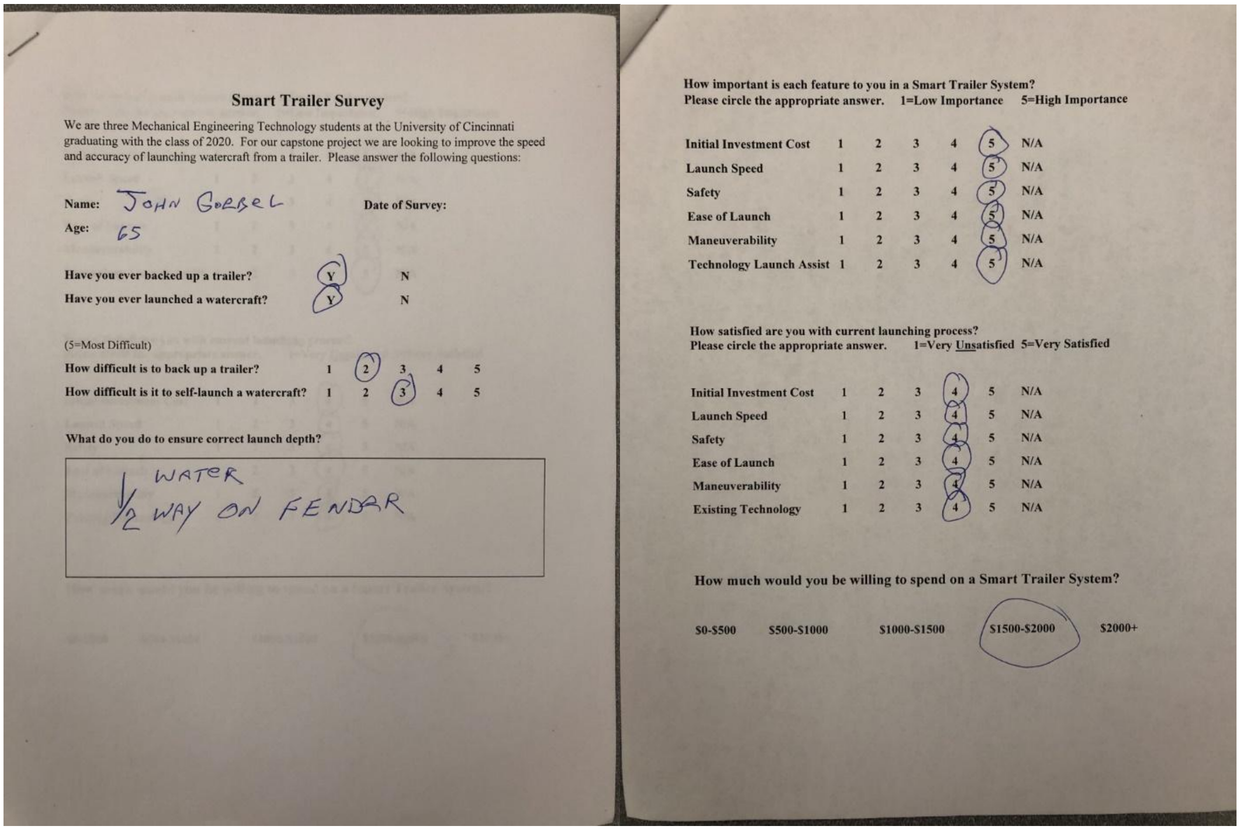
# Appendices

## A -Survey



Smart Trailer Survey

We are three Mechanical Engineering Technology students at the University of Cincinnati graduating with the class of 2020. For our capstone project we are looking to improve the speed and accuracy of launching watercraft from a trailer. Please answer the following questions:

Name: JOHN GOEBEL    Date of Survey:

Age: 65

Have you ever backed up a trailer? Y N

Have you ever launched a watercraft? Y N

(5=Most Difficult)

How difficult is to back up a trailer? 1 2 3 4 5

How difficult is it to self-launch a watercraft? 1 2 3 4 5

What do you do to ensure correct launch depth?

WATER
1/2 WAY ON FENDAR

How important is each feature to you in a Smart Trailer System?
Please circle the appropriate answer. 1=Low Importance 5=High Importance

Initial Investment Cost 1 2 3 4 5 N/A
Launch Speed 1 2 3 4 5 N/A
Safety 1 2 3 4 5 N/A
Ease of Launch 1 2 3 4 5 N/A
Maneuverability 1 2 3 4 5 N/A
Technology Launch Assist 1 2 3 4 5 N/A

How satisfied are you with current launching process?
Please circle the appropriate answer. 1=Very Unsatisfied 5=Very Satisfied

Initial Investment Cost 1 2 3 4 5 N/A
Launch Speed 1 2 3 4 5 N/A
Safety 1 2 3 4 5 N/A
Ease of Launch 1 2 3 4 5 N/A
Maneuverability 1 2 3 4 5 N/A
Existing Technology 1 2 3 4 5 N/A

How much would you be willing to spend on a Smart Trailer System?

$0-$500 $500-$1000 $1000-$1500 $1500-$2000 $2000+

Above is an example of one of our completed surveys

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Name | Age | Backed up trailer? | Launched a watercraft? | Difficult to back up trailer | Dificulty of self launching | Investment Cost | Launch Speed | Safety | Ease of launch | Manueverability | Launch Assist | | Investment Cost | Launch Speed | Safety | Ease of launch | Manueferability | Launch Assist | How much would you spend? |
| 2 | Bryce Hardin | 22 | N | N | 4 | 5 | 5 | 2 | 1 | 5 | 4 | 3 | | N/A | N/A | N/A | N/A | N/A | N/A | $1500-$2000 |
| 3 | Donald Roepken | 50 | Y | Y | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 3 | 3 | 2 | 3 | 2 | 1 | $1500-$2000 |
| 4 | Brandon Barrows | 27 | Y | Y | 4 | 5 | 4 | 3 | 4 | 3 | 3 | 3 | | N/A | N/A | 3 | 3 | 3 | 3 | $1000-$1500 |
| 5 | Jessie Gray | 25 | N | N | 4 | 2 | 5 | 3 | 5 | 5 | 5 | 4 | | N/A | N/A | N/A | N/A | N/A | N/A | $1000-$1500 |
| 6 | Kevin Murray | 23 | Y | Y | 2 | 5 | 3 | 4 | 5 | 5 | 5 | 3 | | 4 | 4 | 5 | 3 | 3 | 2 | $1500-$2000 |
| 7 | John Schlangen | 46 | Y | Y | 2 | 3 | 2 | 3 | 2 | 3 | 4 | 2 | | 1 | 2 | 3 | 3 | 2 | 2 | $0-$500 |
| 8 | John Goebel | 65 | Y | Y | 2 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | | 4 | 4 | 4 | 4 | 4 | 4 | $1500-$2000 |
| 9 | Boray Rin | 22 | Y | N | 4 | 5 | 5 | 3 | 4 | 5 | 5 | 5 | | N/A | N/A | N/A | N/A | N/A | N/A | $1500-$2000 |
| 10 | Ronnie Ehemann | 22 | Y | Y | 4 | 5 | 5 | 2 | 5 | 4 | 4 | 4 | | 4 | 2 | 2 | 1 | 1 | 3 | $1000-$1500 |
| 11 | Matt Blume | 22 | Y | N | 4 | 5 | 4 | 3 | 3 | 4 | 3 | 2 | | N/A | N/A | N/A | N/A | N/A | N/A | $1000-$1500 |
| 12 | Jeff King | 50 | Y | Y | 2 | 2 | 5 | 3 | 3 | 4 | 4 | 4 | | 3 | 3 | 3 | 3 | 2 | 2 | $0-$500 |
| 13 | Billy Lawson | 42 | Y | Y | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | $0-$500 |
| 14 | Kevin Omalley | 22 | N | Y | 2 | 4 | 5 | 4 | 4 | 5 | 4 | 5 | | N/A | N/A | N/A | N/A | N/A | N/A | $0-$500 |
| 15 | Michael Stutz | 57 | Y | Y | 2 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | | 5 | 3 | 3 | 3 | 3 | 2 | $2000+ |
| 16 | Kenneth Tritschler | 22 | N | N | 3 | 4 | 3 | 4 | 5 | 5 | 4 | 3 | | 1 | 1 | 1 | 1 | 1 | 1 | $1000-$1500 |
| 17 | Michelle Taylor | 34 | Y | Y | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | | 3 | 3 | 3 | 3 | 3 | 3 | $1500-$2000 |
| 18 | Michelle Borman | 51 | Y | Y | 4 | 5 | 3 | 4 | 5 | 5 | 4 | 4 | | N/A | 4 | 4 | 3 | 3 | N/A | $500-$1000 |
| 19 | Andrew Brueneman | 22 | Y | Y | 4 | 5 | 4 | 3 | 5 | 5 | 4 | 3 | | 3 | 2 | 2 | 2 | 4 | 2 | $2000+ |
| 20 | Nick Gusching | 23 | Y | Y | 1 | 1 | 5 | 4 | 4 | 5 | 4 | 4 | | 4 | 2 | 3 | 4 | 4 | 1 | $2000+ |
| 21 | Bryce Becker | 22 | Y | Y | 2 | 2 | 4 | 3 | 3 | 4 | 3 | 2 | | 5 | 3 | 2 | 3 | 5 | 1 | $1500-$2000 |
| 22 | Nick Stose | 22 | Y | Y | 2 | 2 | 5 | 3 | 1 | 2 | 3 | 3 | | 3 | 3 | 1 | 2 | 3 | 1 | $0-$500 |
| 23 | John Morris | 22 | Y | Y | 3 | 5 | 3 | 3 | 5 | 5 | 4 | 5 | | 3 | 3 | 3 | 2 | 3 | 2 | $1500-$2000 |
| 24 | James Byrne | 26 | Y | Y | 4 | 5 | 4 | 4 | 5 | 5 | 5 | 3 | | 2 | 2 | 2 | 1 | 1 | 2 | $1500-$2000 |
| 25 | Anthony Dietz | 22 | Y | N | 4 | N/A | 5 | 3 | 4 | 4 | 3 | 4 | | N/A | N/A | N/A | N/A | N/A | N/A | $1000-$1500 |
| 26 | Emily Butterbaugh | 26 | Y | Y | 3 | 4 | 5 | 2 | 3 | 4 | 4 | 4 | | 4 | 3 | 4 | 4 | 2 | 2 | $500-$1000 |
| 27 | Jeff Butterbaugh | 53 | Y | Y | 4 | 5 | 2 | 4 | 4 | 5 | 5 | 4 | | 5 | 2 | 1 | 2 | 2 | 1 | $1500-$2000 |
| 28 | Brad Borman | 51 | Y | Y | 2 | 4 | 4 | 3 | 5 | 5 | 4 | 4 | | 3 | 4 | 3 | 3 | 4 | 1 | $500-$1000 |
| 29 | | | | | 3 | 3.923076923 | 4.074074074 | 3.296296296 | 3.851851852 | 4.333333333 | 4 | 3.592592593 | | 3.210526316 | 2.7 | 2.619047619 | 2.571428571 | 2.666666667 | 1.85 | |
| 30 | | | | | | | | 27.07122507 | | | | | | | | | | | | |

Above is a screenshot of our survey results compacted into one excel spreadsheet

| Name | Age | Backed up trailer? | Launched a watercraft? | Difficult to back up trailer | Difficulty of self-launching | Investment Cost | Launch Speed | Safety |
|---|---|---|---|---|---|---|---|---|
| Bryce Hardin | 22 | N | N | 4 | 5 | 5 | 2 | 1 |
| Donald Roepken | 50 | Y | Y | 5 | 5 | 5 | 5 | 5 |
| Brandon Barrows | 27 | Y | Y | 4 | 5 | 4 | 3 | 4 |
| Jessie Gray | 25 | N | N | 4 | 2 | 5 | 3 | 5 |
| Kevin Murray | 23 | Y | Y | 2 | 5 | 3 | 4 | 5 |
| John Schlangen | 46 | Y | Y | 2 | 3 | 2 | 3 | 2 |
| John Goebel | 65 | Y | Y | 2 | 3 | 5 | 5 | 5 |
| Boray Rin | 22 | Y | N | 4 | 5 | 5 | 3 | 4 |
| Ronnie Ehemann | 22 | Y | Y | 4 | 5 | 5 | 2 | 5 |
| Matt Blume | 22 | Y | N | 4 | 5 | 4 | 3 | 3 |
| Jeff King | 50 | Y | Y | 2 | 2 | 5 | 3 | 3 |
| Billy Lawson | 42 | Y | Y | 1 | 2 | 1 | 1 | 1 |
| Kevin Omalley | 22 | N | Y | 2 | 4 | 5 | 4 | 4 |
| Michael Stutz | 57 | Y | Y | 2 | 4 | 4 | 4 | 3 |
| Kenneth Tritschler | 22 | N | N | 3 | 4 | 3 | 4 | 5 |
| Michelle Taylor | 34 | Y | Y | 3 | 5 | 5 | 4 | 5 |
| Michelle Borman | 51 | Y | Y | 4 | 5 | 3 | 4 | 5 |
| Andrew Brueneman | 22 | Y | Y | 4 | 5 | 4 | 3 | 5 |
| Nick Gusching | 23 | Y | Y | 1 | 1 | 5 | 4 | 4 |
| Bryce Becker | 22 | Y | Y | 2 | 2 | 4 | 3 | 3 |
| Nick Stose | 22 | Y | Y | 2 | 2 | 5 | 3 | 1 |
| John Morris | 22 | Y | Y | 3 | 5 | 3 | 3 | 5 |
| James Byrne | 26 | Y | Y | 4 | 5 | 4 | 4 | 5 |
| Anthony Dietz | 22 | Y | N | 4 | N/A | 5 | 3 | 4 |
| Emily Butterbaugh | 26 | Y | Y | 3 | 4 | 5 | 2 | 3 |
| Jeff Butterbaugh | 53 | Y | Y | 4 | 5 | 2 | 4 | 4 |
| Brad Borman | 51 | Y | Y | 2 | 4 | 4 | 3 | 5 |
| Average: | - | - | - | 3 | 3.923 | 4.074 | 3.296 | 3.851 |

| Name | Age | Ease of launch | Maneuv erability | Launch Assist | Investment Cost | Launch Speed | Safety | Ease of launch | Maneuve rability | Launch Assist |
|---|---|---|---|---|---|---|---|---|---|---|
| Bryce Hardin | 22 | 5 | 4 | 3 | N/A | N/A | N/A | N/A | N/A | N/A |
| Donald Roepken | 50 | 5 | 5 | 5 | 3 | 3 | 2 | 3 | 2 | 1 |
| Brandon Barrows | 27 | 3 | 3 | 3 | N/A | N/A | 3 | 3 | 3 | 3 |
| Jessie Gray | 25 | 5 | 5 | 4 | N/A | N/A | N/A | N/A | N/A | N/A |
| Kevin Murray | 23 | 5 | 5 | 3 | 4 | 4 | 5 | 3 | 3 | 2 |
| John Schlangen | 46 | 3 | 4 | 2 | 1 | 2 | 3 | 3 | 2 | 2 |
| John Goebel | 65 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 |
| Boray Rin | 22 | 5 | 5 | 5 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ronnie Ehemann | 22 | 4 | 4 | 4 | 4 | 2 | 2 | 1 | 1 | 3 |
| Matt Blume | 22 | 4 | 3 | 2 | N/A | N/A | N/A | N/A | N/A | N/A |
| Jeff King | 50 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 |
| Billy Lawson | 42 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kevin Omalley | 22 | 5 | 4 | 5 | N/A | N/A | N/A | N/A | N/A | N/A |
| Michael Stutz | 57 | 4 | 4 | 4 | 5 | 3 | 3 | 3 | 3 | 2 |
| Kenneth Tritschler | 22 | 5 | 4 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| Michelle Taylor | 34 | 5 | 5 | 4 | 3 | 3 | 3 | 3 | 3 | 3 |
| Michelle Borman | 51 | 5 | 4 | 4 | N/A | 4 | 4 | 3 | 3 | N/A |
| Andrew Brueneman | 22 | 5 | 4 | 3 | 3 | 2 | 2 | 2 | 4 | 2 |
| Nick Gusching | 23 | 5 | 4 | 4 | 4 | 2 | 3 | 4 | 4 | 1 |
| Bryce Becker | 22 | 4 | 3 | 2 | 5 | 3 | 2 | 3 | 5 | 1 |
| Nick Stose | 22 | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 1 |
| John Morris | 22 | 5 | 4 | 5 | 3 | 3 | 3 | 2 | 3 | 2 |
| James Byrne | 26 | 5 | 5 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| Anthony Dietz | 22 | 4 | 3 | 4 | N/A | N/A | N/A | N/A | N/A | N/A |
| Emily Butterbaugh | 26 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 2 | 2 |
| Jeff Butterbaugh | 53 | 5 | 5 | 4 | 5 | 2 | 1 | 2 | 2 | 1 |
| Brad Borman | 51 | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 1 |
| Average: | - | 4.333 | 4 | 3.592 | 3.210 | 2.7 | 2.619 | 2.571 | 2.667 | 1.85 |

## B - Backup Angle Calculations and Stress Analysis

The following assumptions were made:

- 100mph = 146.67ft/s
- Drag coefficient of shape = 1.05
- Air is @ 68 degrees with a density of .07518 lbm/ft^3
- Bolts can be treated as a beam with supports
- Bracket for camera and bracket for sensor both weighs 1 lb
- Material is AISI 304 stainless steel

<u>Camera on Bracket:</u>

$$\mathrm{w} = 0.26\ \mathrm{lbf}$$

$$F = ma = w = 0.26\ \mathrm{lbf}$$

$$\sum M_A = F(1\ in) - R_2(0.75\ in) = 0$$

$$\sum M_A = 0.26lbf\ (1\ in) - R_2(0.75\ in) \rightarrow R_2 = 0.346\ lbf$$

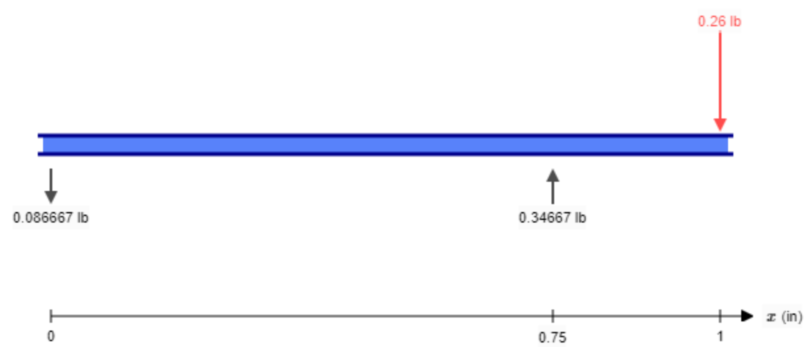
$$\sum F_y = 0$$

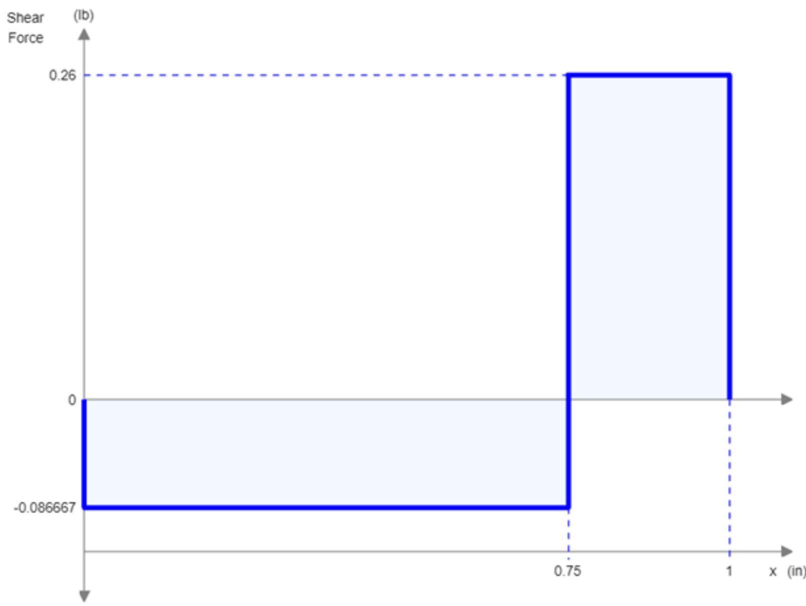
$$\sum F_y = R_1 + R_2 - F = 0$$

$$\sum F_y = R_1 + 0.346 - 0.26 = 0 \rightarrow R_1 = -0.086lbf$$

---

Shear Force:



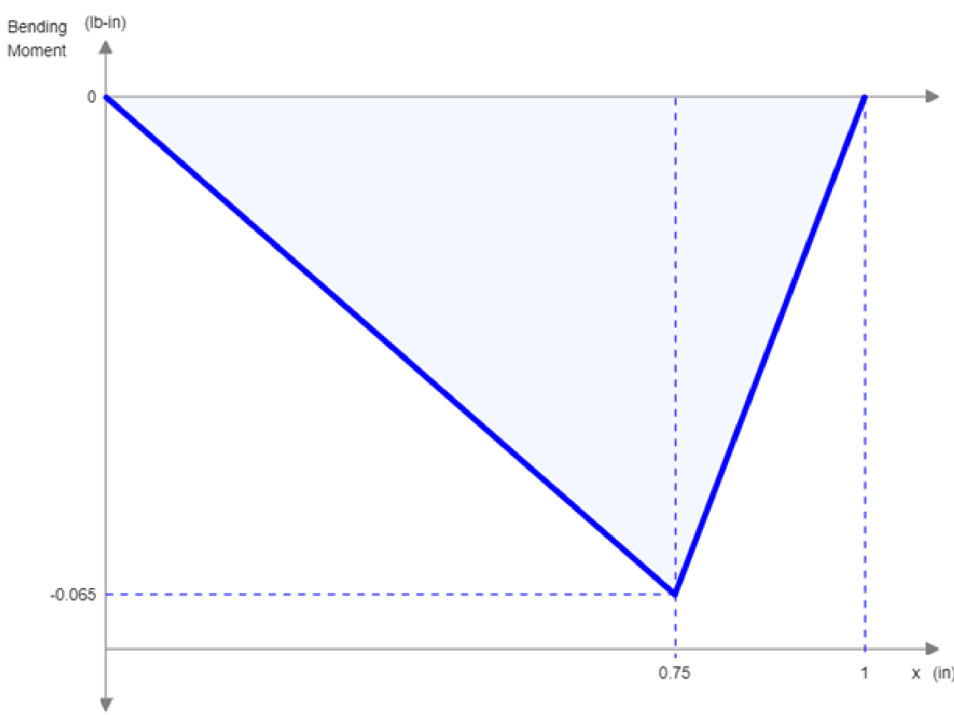



Moment:

$$\sum M_{R1} = 0$$

$$\sum M_{R2} = 0 + -0.086(0.75) = -0.065$$

$$\sum M_F = -0.065 + 0.26(0.25) = 0$$



Max Shear and Torsion:

**Max Shear**

$$\tau_{Max} = \frac{4V}{3A}$$

$$\tau_{Max} = \frac{4 * 0.26\ lbf}{3 * \frac{\pi(0.25)^2}{4}}$$

$$\tau_{Max} = 7.06\ \ psi$$

$$\mathrm{SF} = 2$$

$$\tau_{Max} = 7.06 * 2 = 14.12\ psi$$

**Torsion**

$$J = \frac{\pi * D^4}{32}$$

$$J = \frac{\pi * (0.25)^4}{32}$$

$$J = 0.000383\ in^4$$

$$Torsion = \frac{torque * r}{J}$$

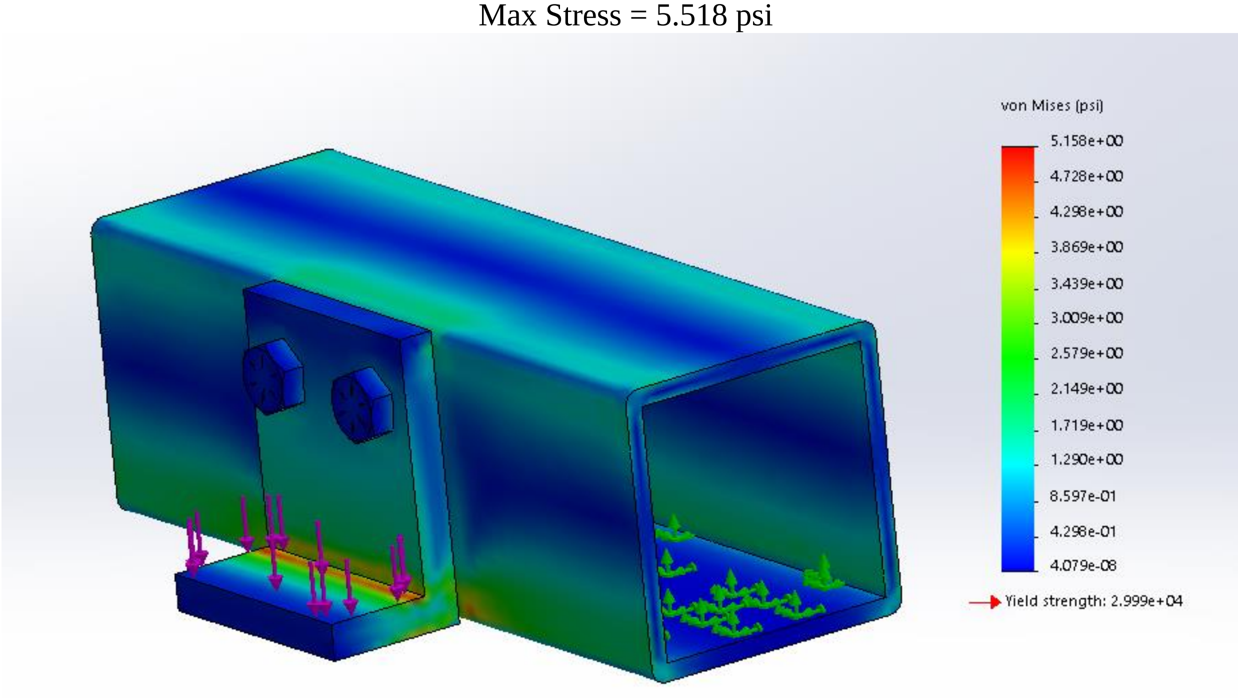
$$Torsion = \frac{0.26 * 0.125}{.000383}$$

$$Torsion = 81.49\ psi$$

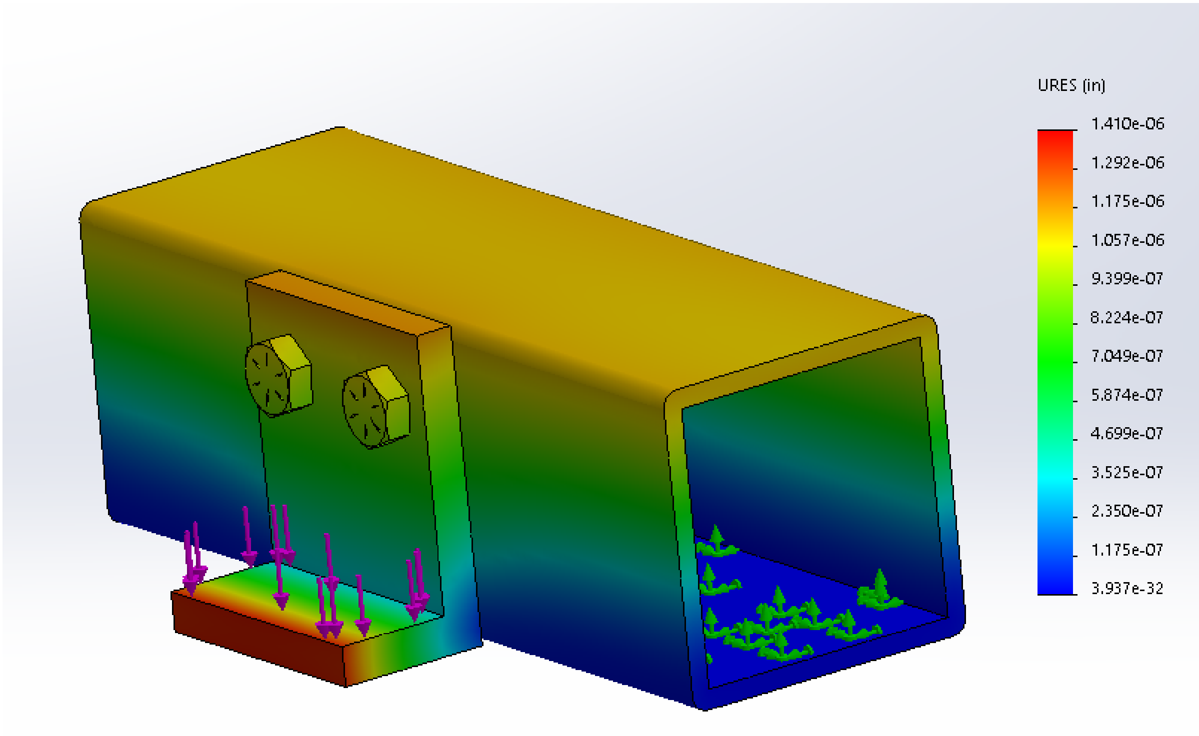
$$Stress_{Total} = \frac{81.49\ psi + 14.12\ psi}{2\ bolts}$$

$$Stress_{Total} = 47.8\ psi$$

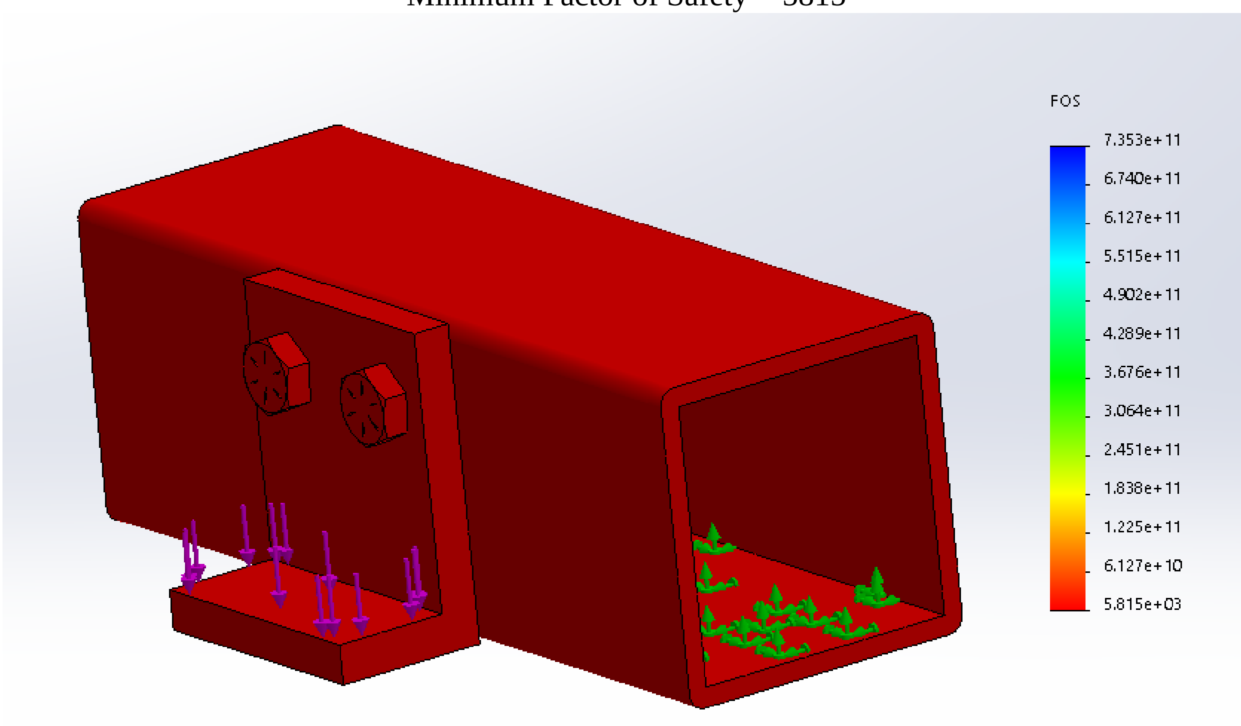
Max Stress = 5.518 psi



Max Deformation = 0.00000141 in




Minimum Factor of Safety = 5815



# Weight on Vertical Post:

**Weight on Vertical Post**

Steel weighs 7.98, light weighs 1.1, bracket weighs 1, camera weigh 0.26

$$F_1 = 1.26 + \left(\frac{1.1 + 7.92}{2}\right) = 5.77\ lbf$$

$$F_2 = \frac{1.1 + 7.92}{2} = 4.51\ lbf$$

$$\sum M_A = F_1(0.5\ in) - F_2(2.25\ in) - R_2(2.75\ in) = 0$$

$$\sum M_A = 5.77(0.5\ in) + 4.51(2.25\ in) - R_2(2.75\ in) = 0 \rightarrow R_2 = 4.73\ lbf$$

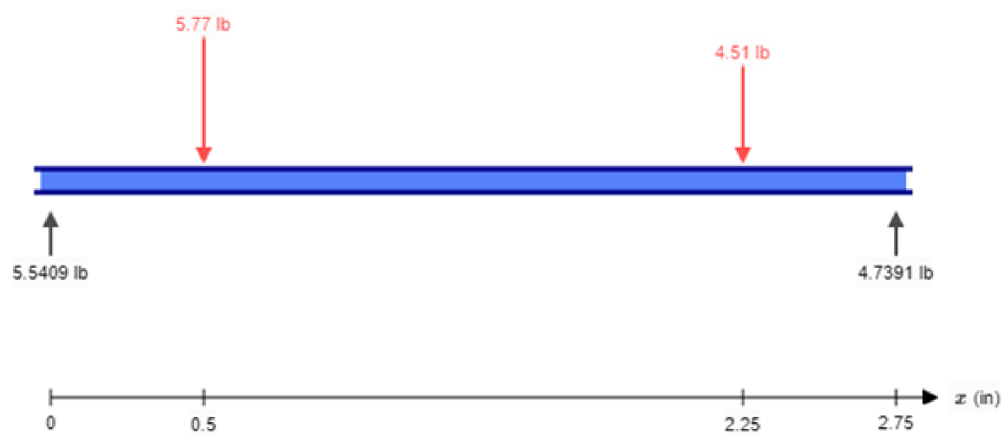
$$\sum F_y = 0$$

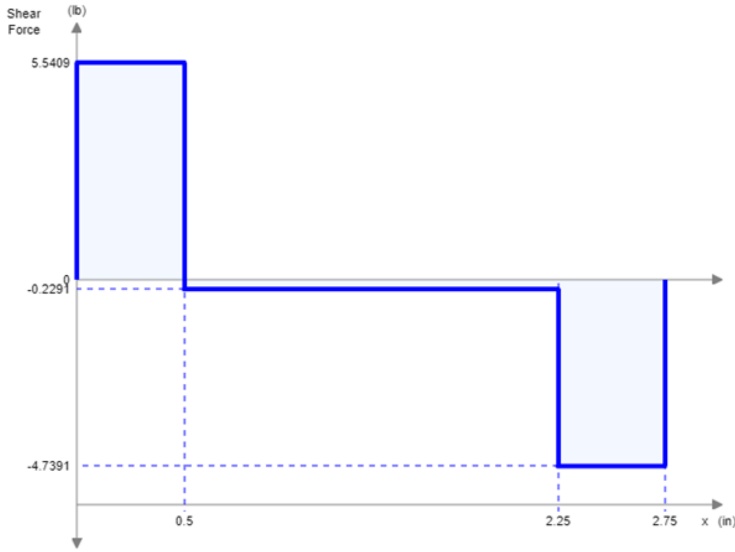
$$\sum F_y = R_1 + R_2 - F_1 - F_2 = 0$$

$$\sum F_y = R_1 + 4.73 - 5.77 - 4.51 = 0 \rightarrow R_1 = 5.54$$

---

Shear:





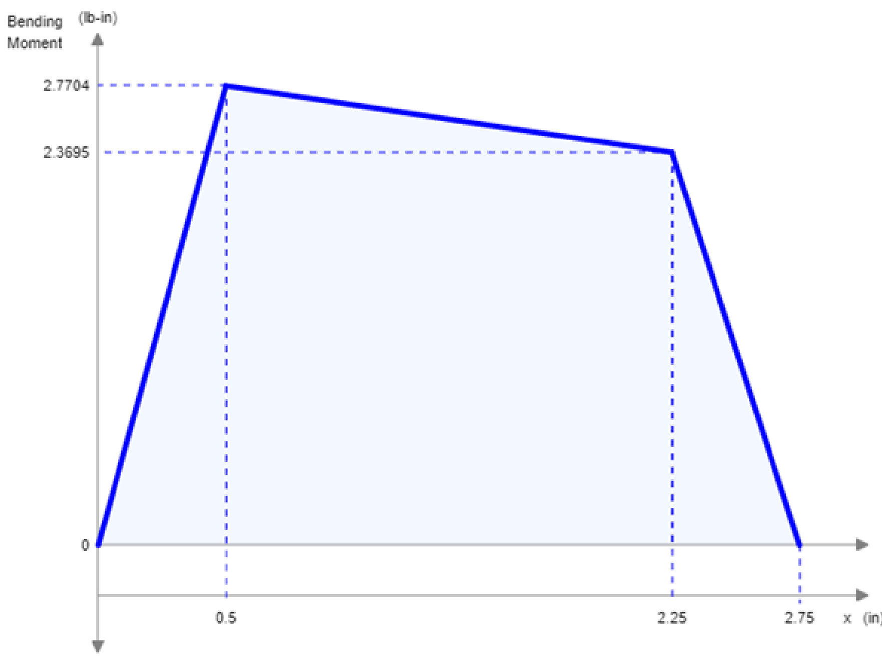

Moment:

$$\sum M_{R1} = 0$$

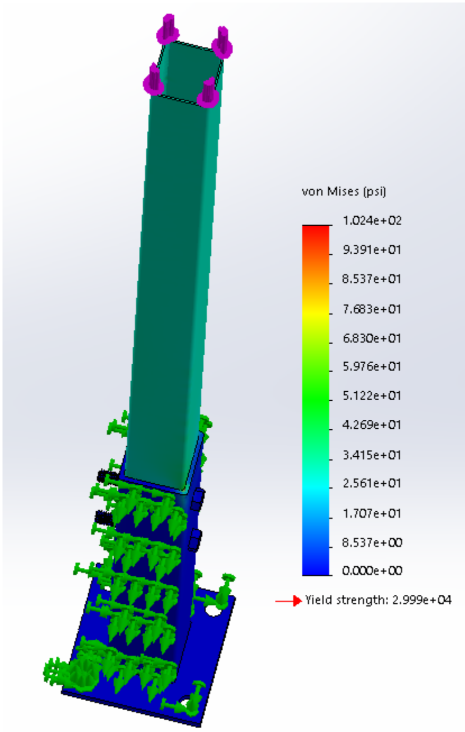
$$\sum M_{R2} = 0 + 5.54(.5) = 2.77$$

$$\sum M_{F1} = 2.77 + -0.2291(.75) = 2.36$$

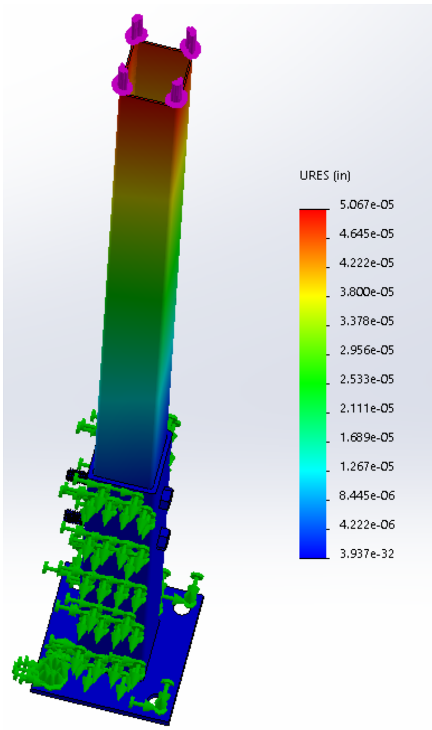
$$\sum M_{F2} = 2.36 + -4.7391(.5) = 0$$



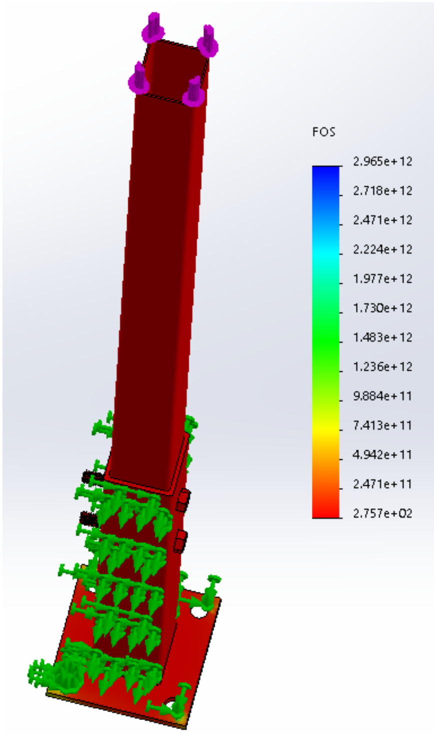

Max Stress = 102.4 psi




Max Deformation = 0.00005067 in




Minimum Factor of Safety = 275.7




Vertical Post with Wind:

**Vertical Post with Wind**

$C_D = 1.05$

$\rho = 0.07518\,\frac{\text{lbm}}{\text{ft}^2}$

$A = (1.75/12)*(7/12) = 0.085\text{ft}^2$

$V = 146.67\ \text{ft/s}^2$

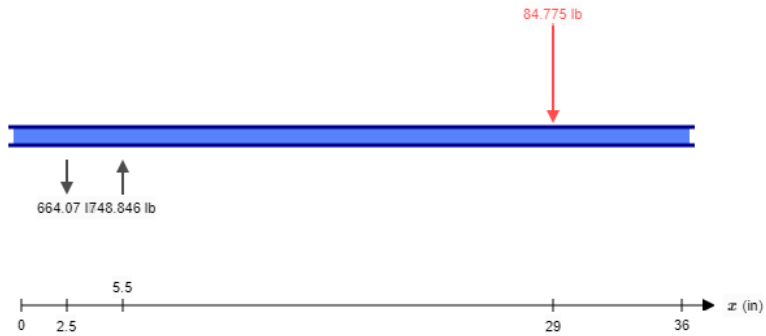
$$F_d = \frac{1}{2} * cd * \rho * A * V^2$$

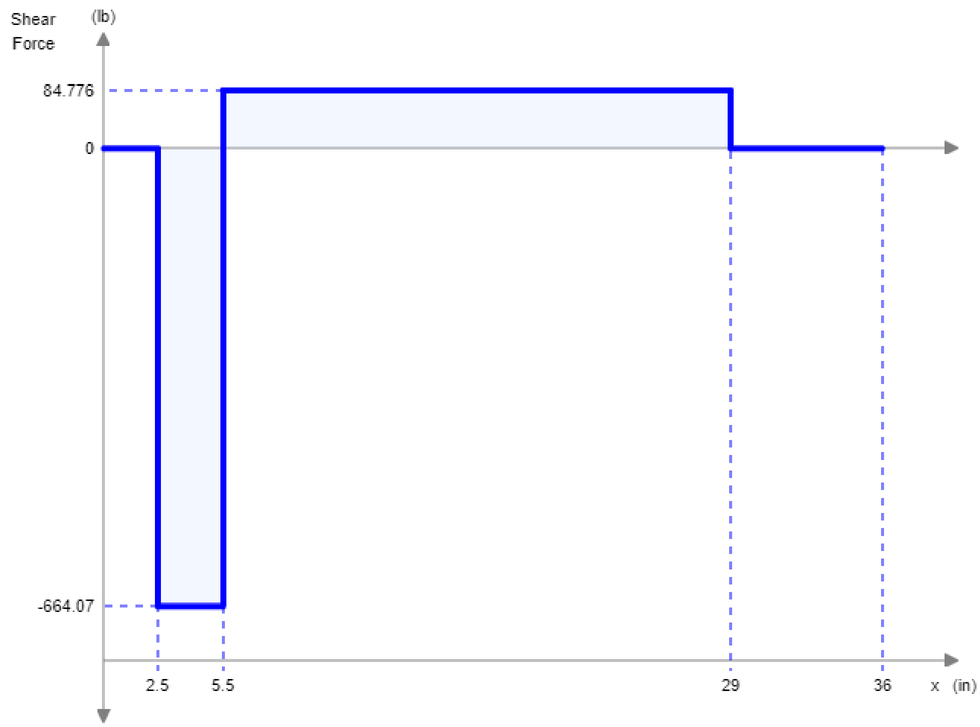
$$F_d = \frac{1}{2} * 1.05 * 0.07518 * .085 * 146.67^2$$

$$F_d = 72.42\ lbf$$

$$F_{tot} = 72.42\ lbf + 10.34lbf = 84.755\ lbf$$

Shear:



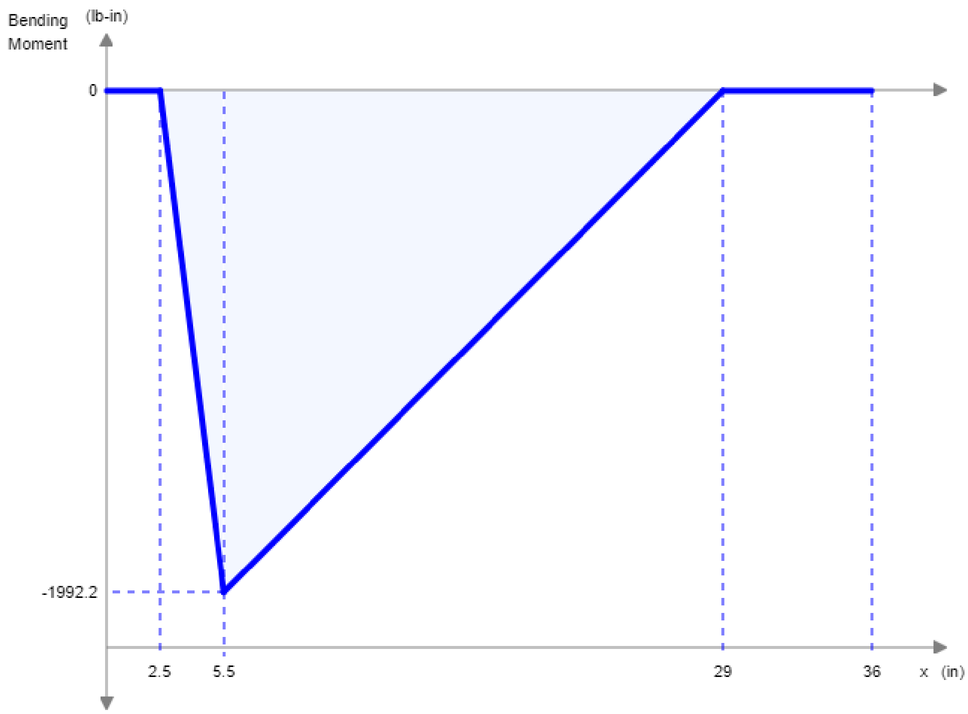




Moment:

$$\sum M_{R1} = 0$$

$$\sum M_{R2} = 0 + -663.91(3) = -1991.76$$

$$\sum M_F = -1991.76 + 84.755(23.5) = 0$$




Max Shear and Torsion:

**Max Shear**

$$\tau_{Max} = \frac{4V}{3A}$$

$$\tau_{Max} = \frac{4*84.755\ lbf}{3*\frac{\pi(.375)^2}{4}}$$

$$\tau_{Max} = 1023.17\ psi$$

$$\mathrm{SF} = 2.5$$

$$\tau_{Max} = 1023.17 * 2.5 = 2557.95\ psi$$

## Torsion

$$J = \frac{\pi * D^4}{32}$$

$$J = \frac{\pi * (0.375)^4}{32}$$

$$J = 0.0019\ in^4$$

$$Torsion = \frac{torque * r}{J}$$

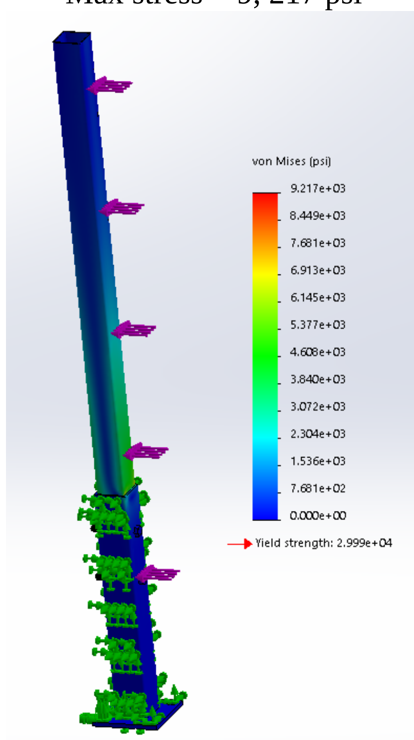
$$Torsion = \frac{84.75 * 0.1875}{.0019}$$

$$Torsion = 8363.49\ psi$$

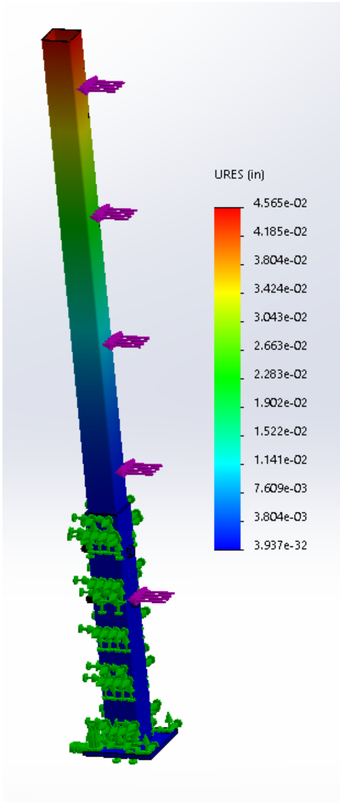
$$Stress_{Total} = \frac{2557.95\ psi + 8363.49\ psi}{2\ bolts}$$

$$Stress_{Total} = 5460.72\ psi$$

Max stress = 9, 217 psi




Max Deformation = 0.04565 in




Minimum Factor of Safety = 2.8 -- this is okay because the SF for an axial load = 2.5

# Potentiometer on Bracket:

## Potentiometer on Bracket

$$F = ma = w$$

$$F = 0.6625\ lbf$$

$$\sum M_A = F(0.5\ in) - R_2(0.25\ in) = 0$$

$$\sum M_A = 0.6625\ (0.5\ in) - R_2(0.25\ in) \rightarrow R_2 = 1.325\ lbf$$

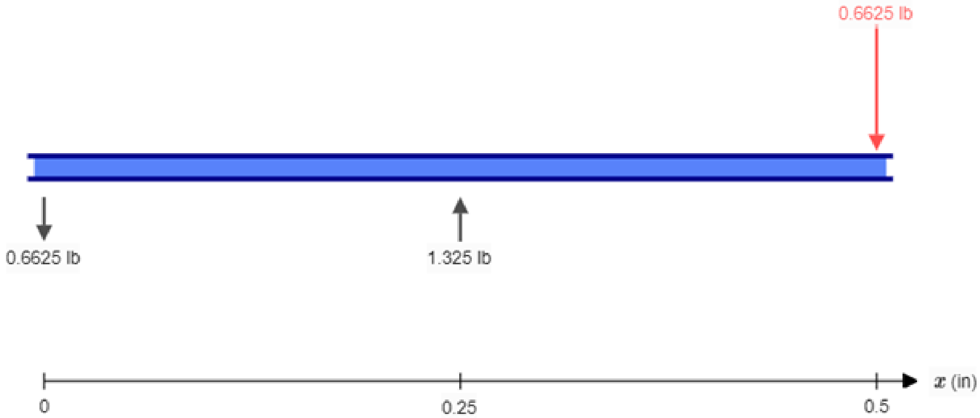
$$\sum F_y = 0$$

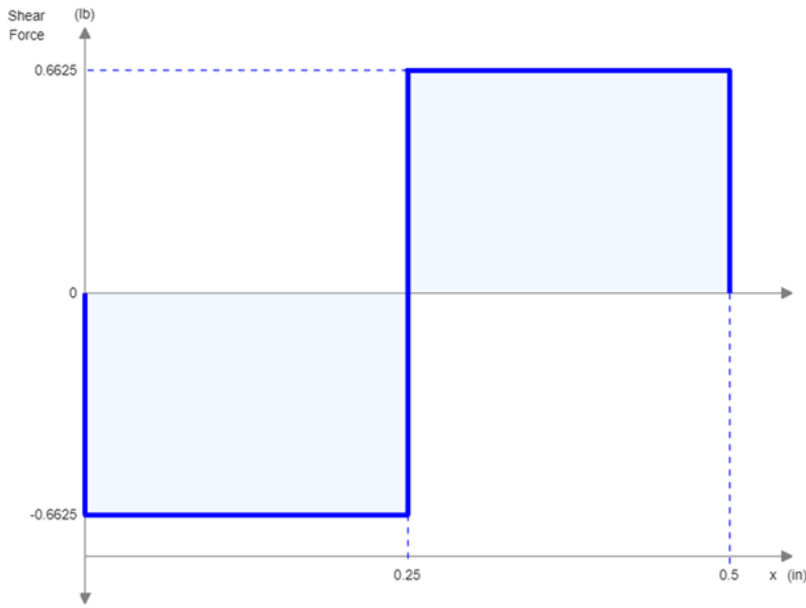
$$\sum F_y = R_1 + R_2 - F = 0$$

$$\sum F_y = R_1 + 1.325 - 0.6625 = 0 \rightarrow R_1 = -0.6625\ lbf$$

---

Shear:



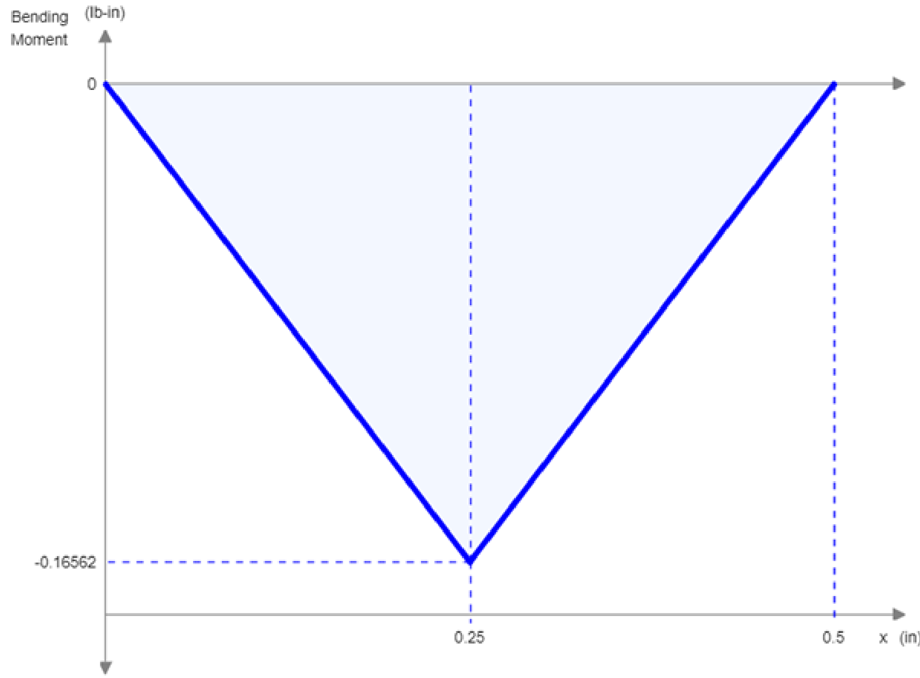




Moment:

$$\sum M_{R1} = 0$$

$$\sum M_{R2} = 0 + -0.6625(2) = -0.165$$

$$\sum M_F = -0.165 + 0.6625(0.25) = 0$$




Max shear and torsion:

## Max Shear

$$\tau_{Max} = \frac{4V}{3A}$$

$$\tau_{Max} = \frac{4*0.6625\ lbf}{3*\frac{\pi(0.375)^2}{4}}$$

$$\tau_{Max} = 71.98\ psi$$

$$\mathrm{SF} = 2$$

$$\tau_{Max} = 71.92 * 2 = 143.96\ psi$$

**Torsion**

$$J = \frac{\pi * D^4}{32}$$

$$J = \frac{\pi * (0.375)^4}{32}$$

$$J = 0.0019\ in^4$$

$$Torsion = \frac{torque * r}{J}$$

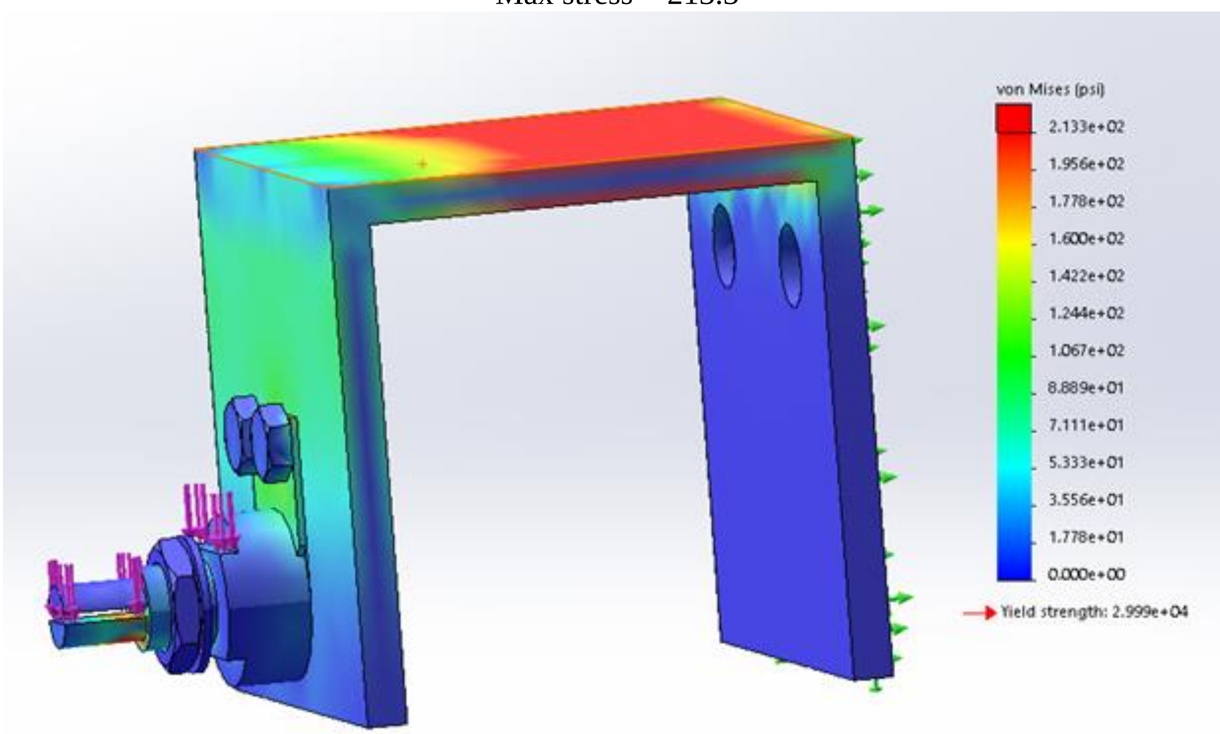
$$Torsion = \frac{.33125 * 0.1875}{.0019}$$

$$Torsion = 32.69\ psi$$

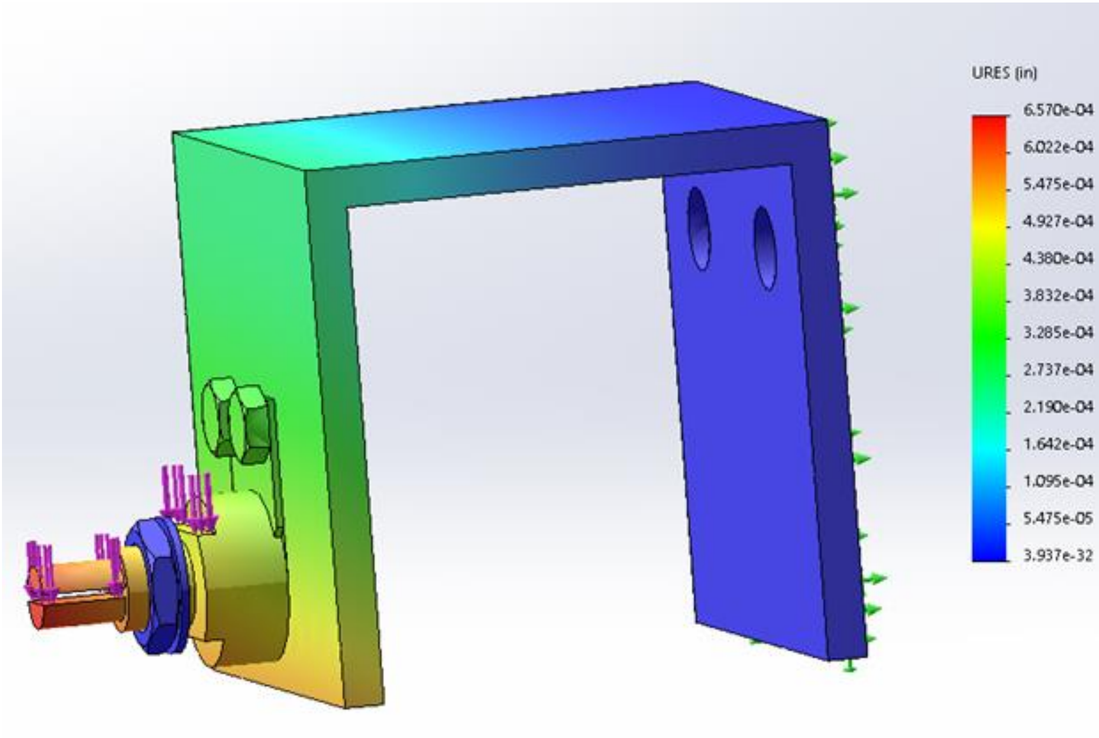
$$Stress_{Total} = \frac{32.69\ psi + 143.96\ psi}{2\ bolts}$$

$$Stress_{Total} = 88.32\ psi$$

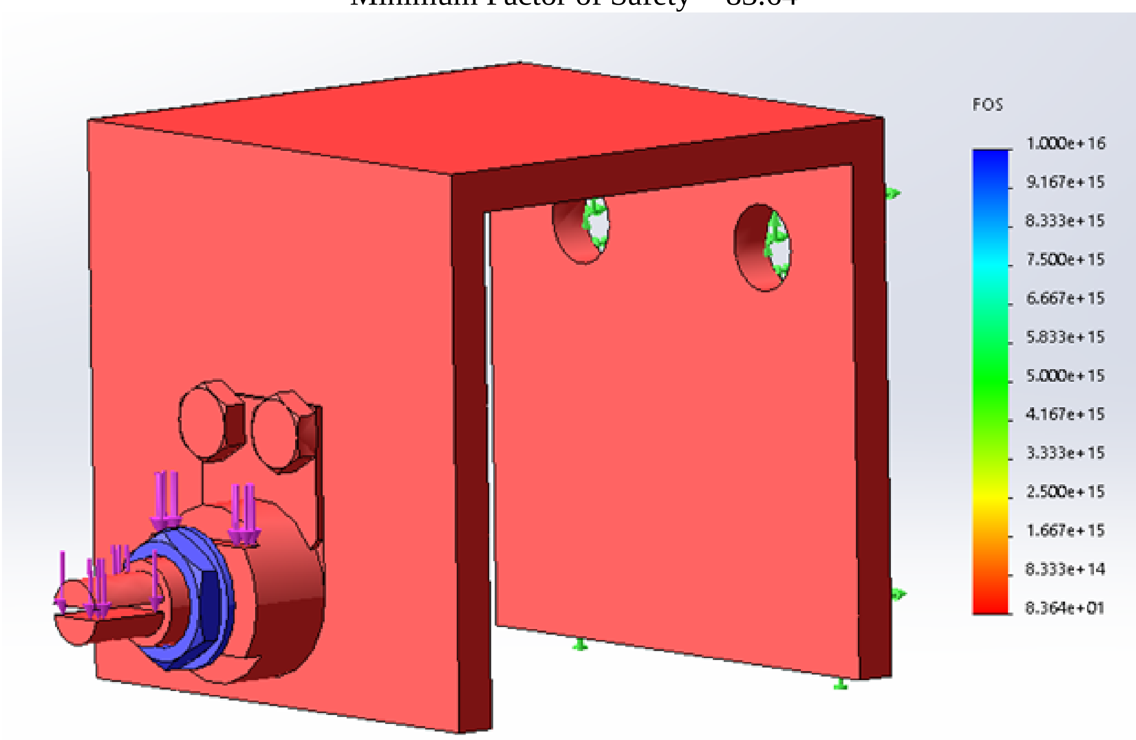
Max stress = 213.3



Max Deformation = 0.000657 in




Minimum Factor of Safety = 83.64



Potentiometer and Bracket on Frame:

$$F = ma = w$$

$$F = 1.6625\ lbf$$

$$\sum M_A = F(2.5\ in) - R_2(2.25\ in) = 0$$

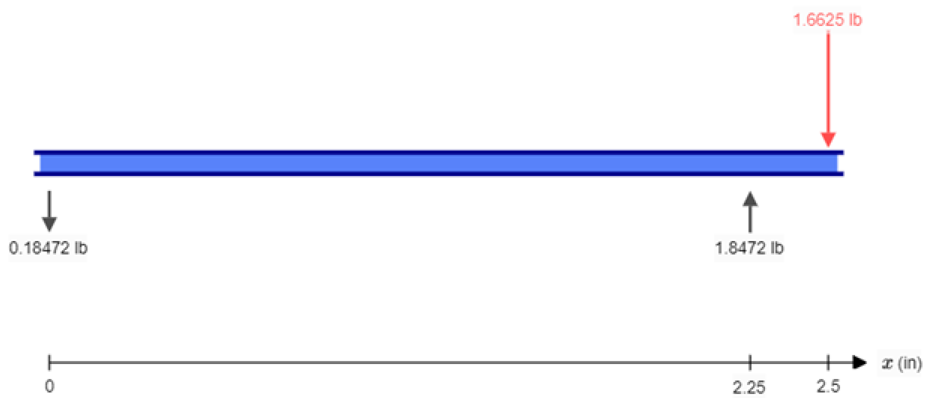
$$\sum M_A = 1.6625\ (2.5\ in) - R_2(2.25\ in) \rightarrow R_2 = 1.847\ lbf$$

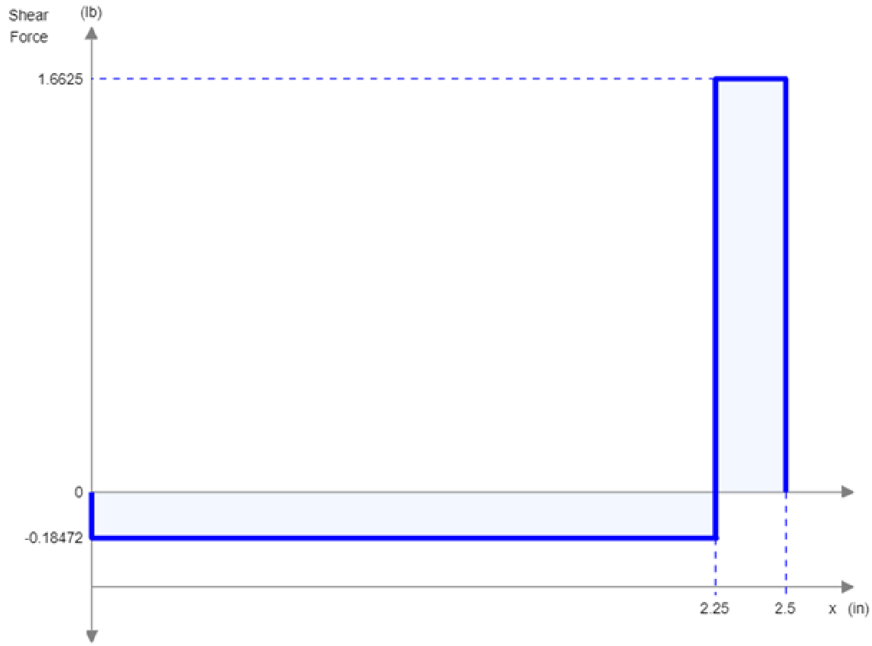
$$\sum F_y = 0$$

$$\sum F_y = R_1 + R_2 - F = 0$$

$$\sum F_y = R_1 + 1.847 - 1.6625 = 0 \rightarrow R_1 = -0.1845\ lbf$$

Shear:



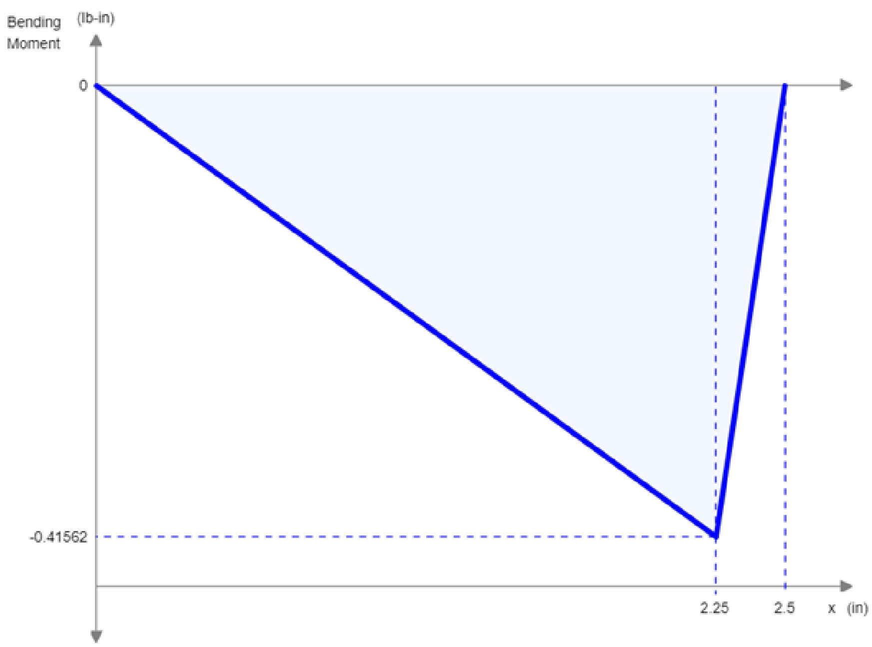



Moment:

$$\sum M_{R1} = 0$$

$$\sum M_{R2} = 0 + -0.1845(2.25) = -0.415$$

$$\sum M_F = -0.415 + 01.66(0.25) = 0$$




Max Shear and Torsion

## Max Shear

$$\tau_{Max} = \frac{4V}{3A}$$

$$\tau_{Max} = \frac{4*1.6625\ lbf}{3*\frac{\pi(.3125)^2}{4}}$$

$$\tau_{Max} = 28.9\ psi$$

$$\mathrm{SF} = 2$$

$$\tau_{Max} = 28.9 * 2 = 57.8\ psi$$

### Torsion

$$J = \frac{\pi * D^4}{32}$$

$$J = \frac{\pi * (0.3125)^4}{32}$$

$$J = 0.00094\ in^4$$

$$Torsion = \frac{torque * r}{J}$$

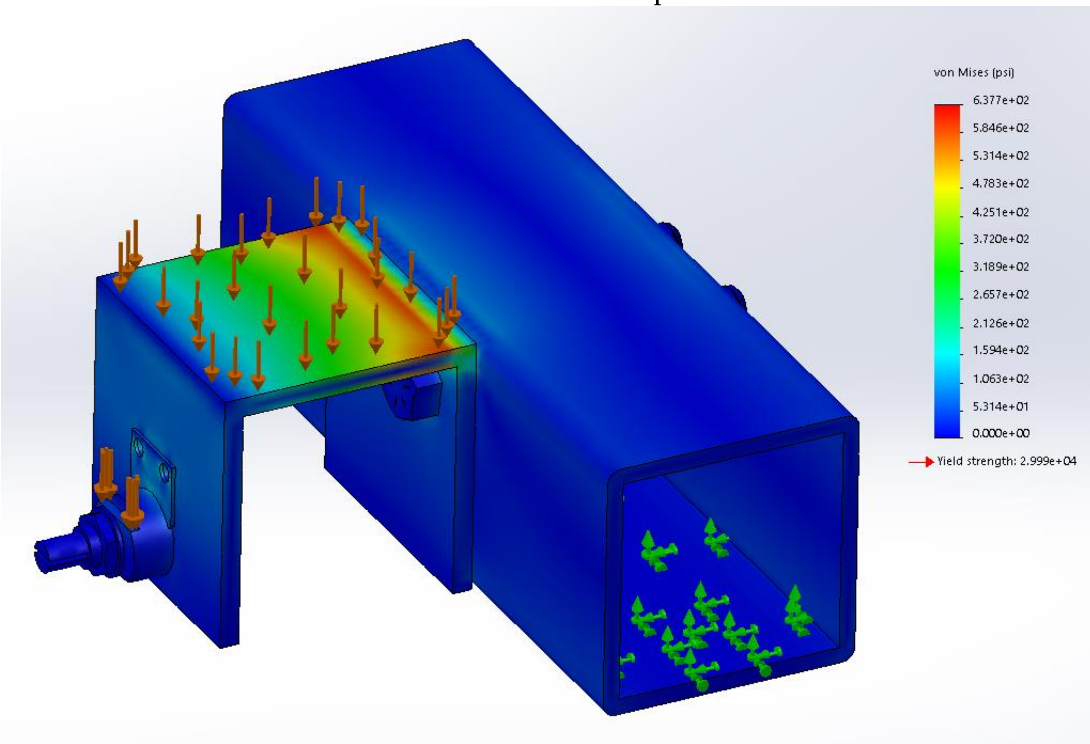
$$Torsion = \frac{4.16 * 0.15625}{.0094}$$

$$Torsion = 69.09\ psi$$

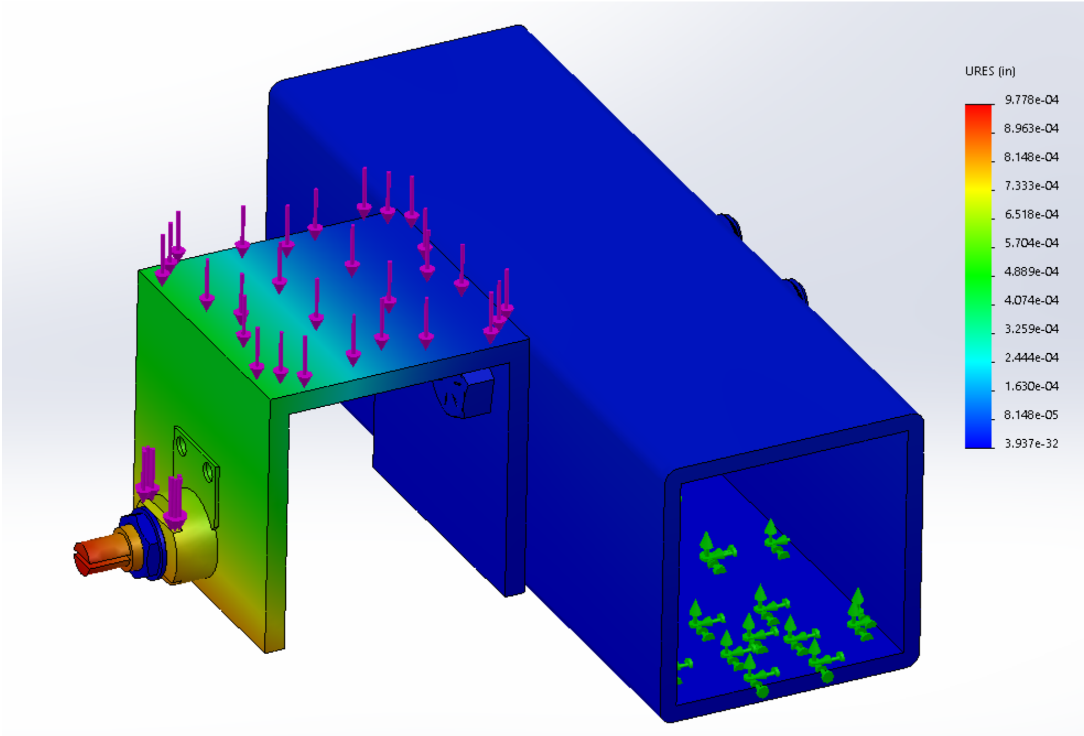
$$Stress_{Total} = \frac{69.09\ psi + 57.8\ psi}{2\ bolts}$$

$$Stress_{Total} = 63.44\ psi$$

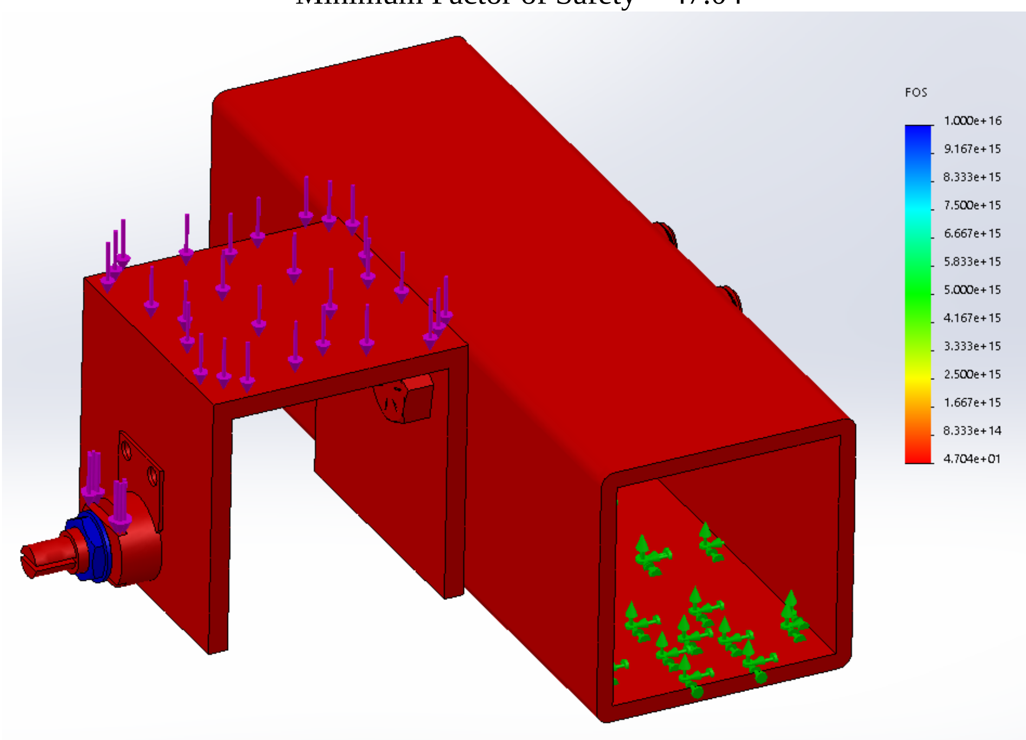
Max stress = 637.7 psi



Max Deformation = 0.0009778 in




Minimum Factor of Safety = 47.04

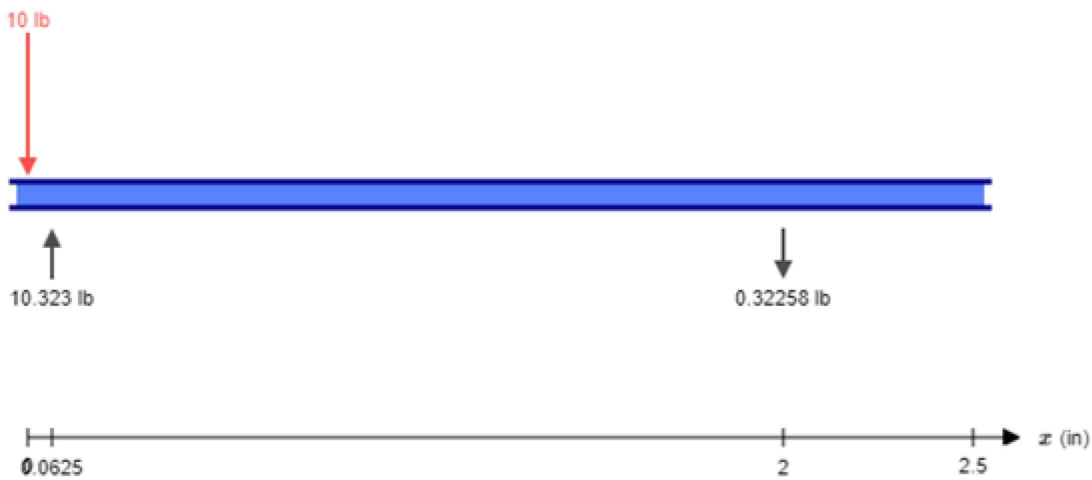


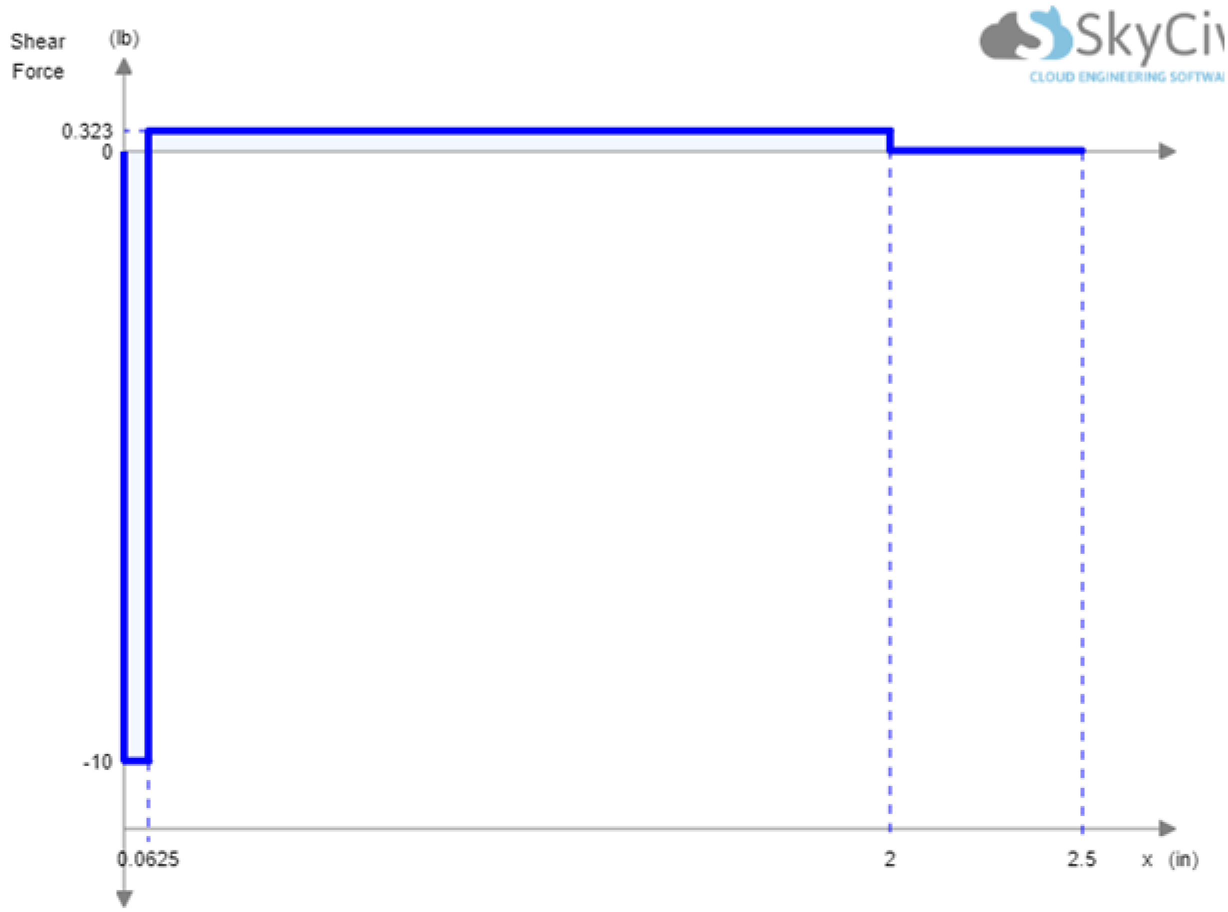
## C - Speed Calculations and Stress Analysis

The following assumptions were made:

- Worst case driving speed of 100mph which is 146.67ft/s
- Box is perpendicular to airflow
- Drag coefficient of 1.28 for the box
- Air is @68 degrees with a density of .07518 lbm/ft^3
- Bolts can be treated as a beam with supports
- Overall box weight of 10lbs
- Use ⅜" 2.5"long Stainless Steel 316 hex bolts with rubber and metal washers

Finding overall shear & axial stress on the box:






$$M_B = 10 * \frac{1}{16} - C * 2$$

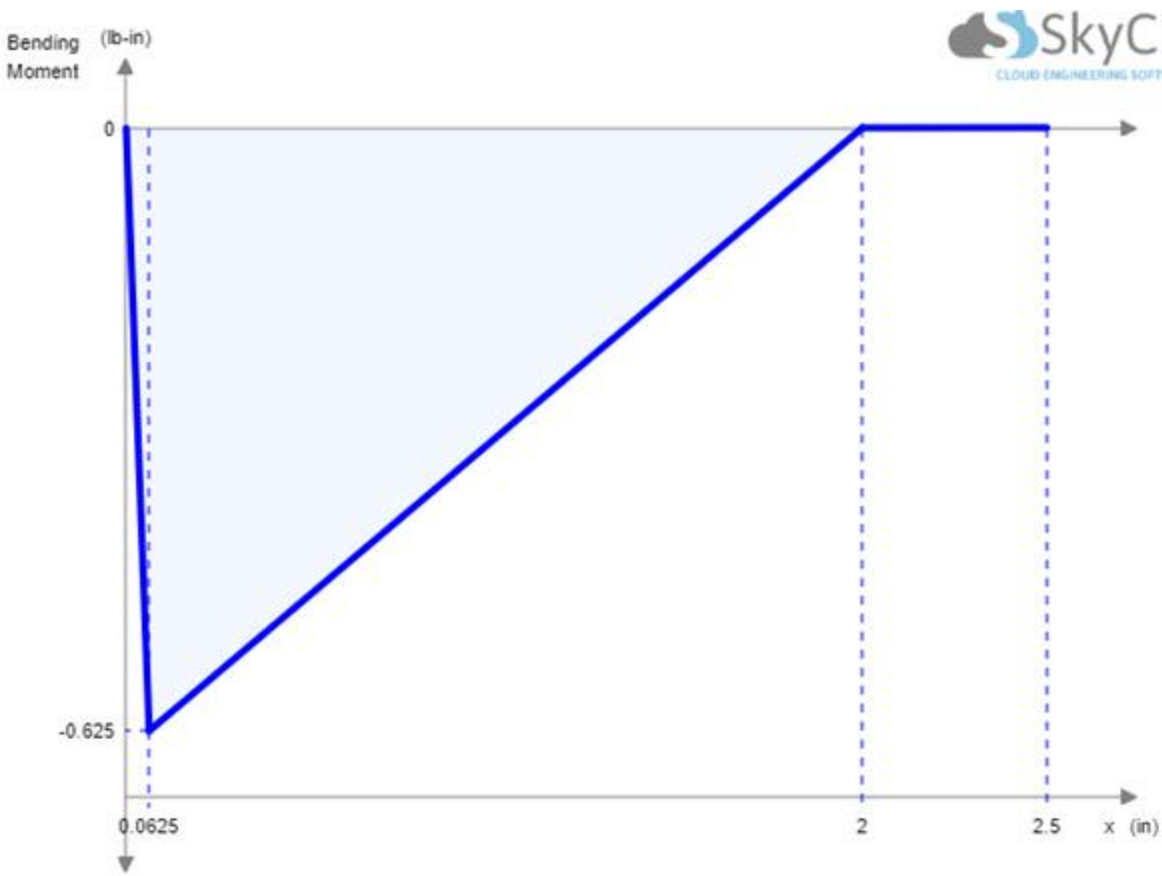
$$.625 = C * 2$$

$$C = .3125\ lbf$$

$$\sum F_y = -A + B - C = 0$$

$$0 = -10 + B - .3125$$

$$B = 10.3125\ lbf$$




$$M_A = 0$$

$$M_B = M_A + .3125 * 2$$

$$M_B = .625\ lb * in$$

$$M_C = M_B - .3125 * 2 = 0$$

**Shear Max:**

$$\tau max = \frac{4V}{3A}$$

$$A = \pi * r^2$$

$$A = \pi *.1875^2$$

$$A = .110 in^2$$

$$\tau max = \frac{4 * 10}{3 * .110}$$

$$\tau max = \frac{40}{.33}$$

$$\tau max = 121.2\ psi$$

**Design factor of 2.5 for repeated shear:**

$$\tau max = 121.2 * 2.5$$

$$\tau max = 303\ psi$$

**Drag force on the box:**

$$F_d = \frac{1}{2} * C_d * \rho * A * v^2$$

$$F_d = \frac{1}{2} * 1.28 * .07518 * (\frac{10}{12} * \frac{14}{12}) * 146.67^2$$

$$F_d = 1006.26\ lbf$$

**Axial Stress on the bolt:**

$$\sigma_{axial} = \frac{F_d}{A}$$

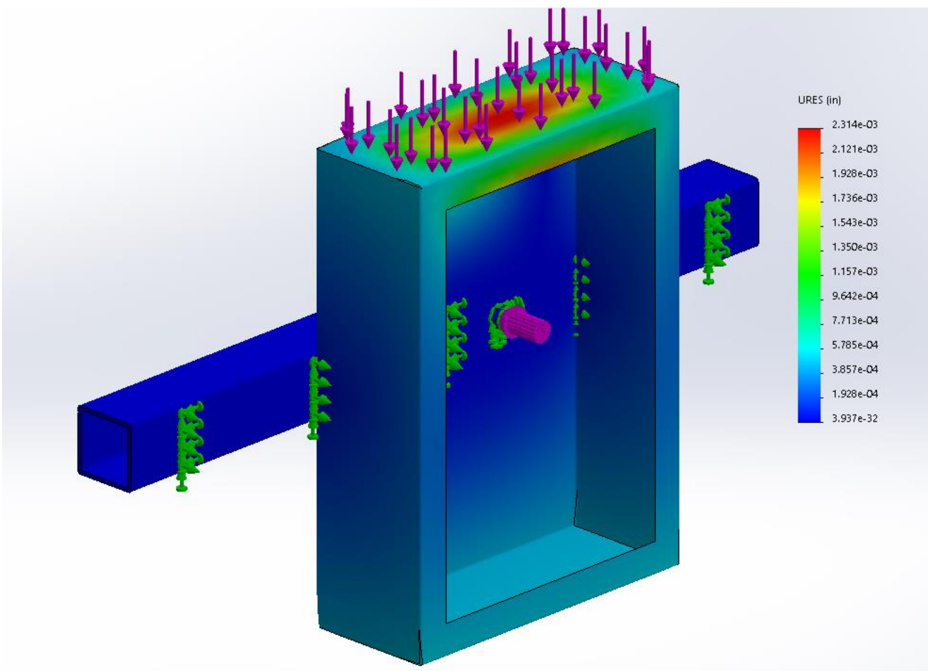
$$\sigma_{axial} = \frac{1006.28 lbf}{.110 in^2}$$

$$\sigma_{axial} = 9148\ psi$$

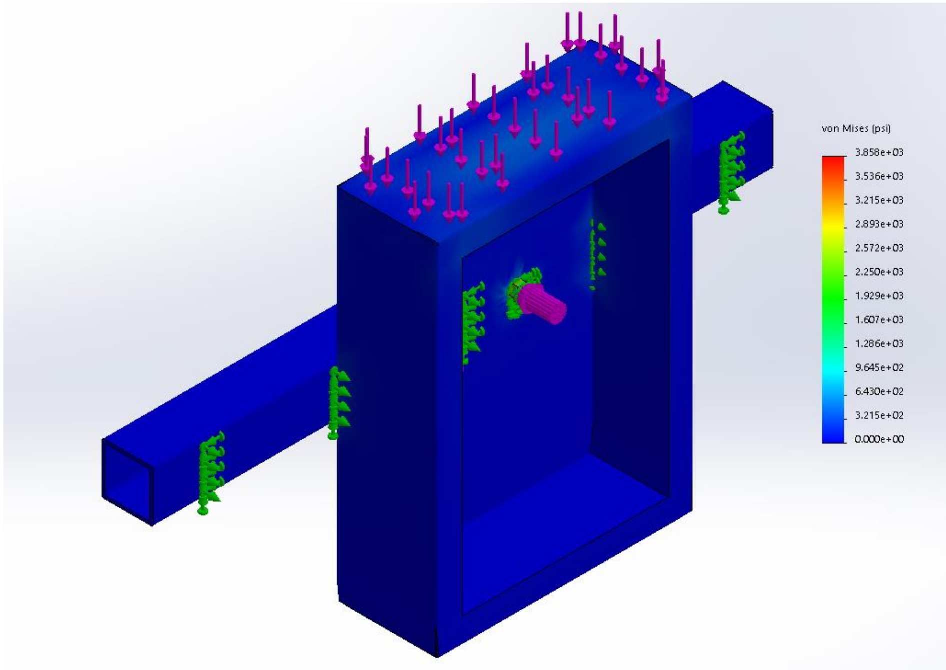
**Design factor for repeated axial loading of 2.5:**

$$\sigma_{axial} = 9148\ psi * 2.5$$

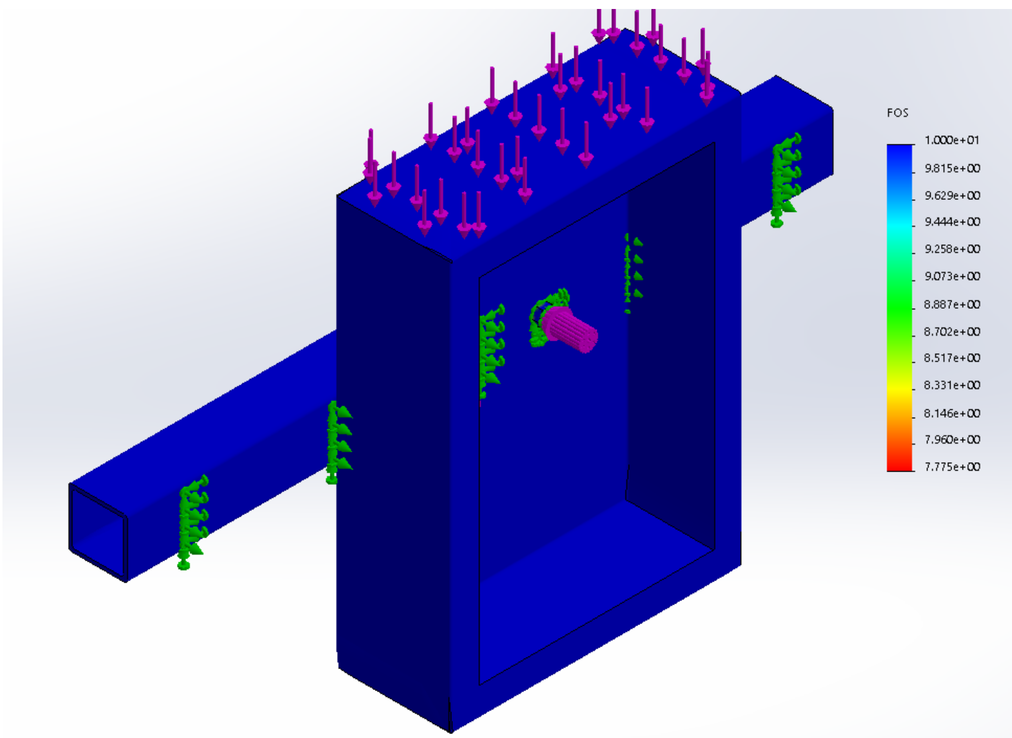
$$\sigma_{axial} = 22{,}870\ psi$$




Max Deformation:
0.002314 in




Max Stress:
3858 psi




Lowest Factor of Safety: 7.775
Highest Factor of Safety: >10

**Finding Bungee tension & weld stress on bracket:**

Jet-Ski approximate weight:

825 lbs dry weight

Safety factor of 1.5 increases this weight to 1237.5lbs

**Find mass to use tension equation:**

$$mass = \frac{1237.5\ lb}{32.2\ m/s^2}$$

$$mass = 38.43\ lbm$$

**Assume launch speed of 5 mph and 5 seconds to reach that speed:**

$$acceleration = \frac{7.33\ ft/s}{5s}$$

$$acceleration = 1.466\ ft/s^2$$

**Tension:**

$$T = m * a$$

$$T = 38.43 * 1.466$$

$$T = 100.73\ lbf$$

**Shear Stress on welds:**

$$\tau = \frac{F\ (Tensile\ Force)}{A\ (Effective\ Weld\ Area)}$$

$$A = Weld\ radius * theoretical\ throat * \#of\ welds * length\ of\ weld$$

$$A = \frac{1}{12} * \left(\frac{1}{12} * \cos(45)\right) * 3 * 1$$

$$A = .0147 in^2$$

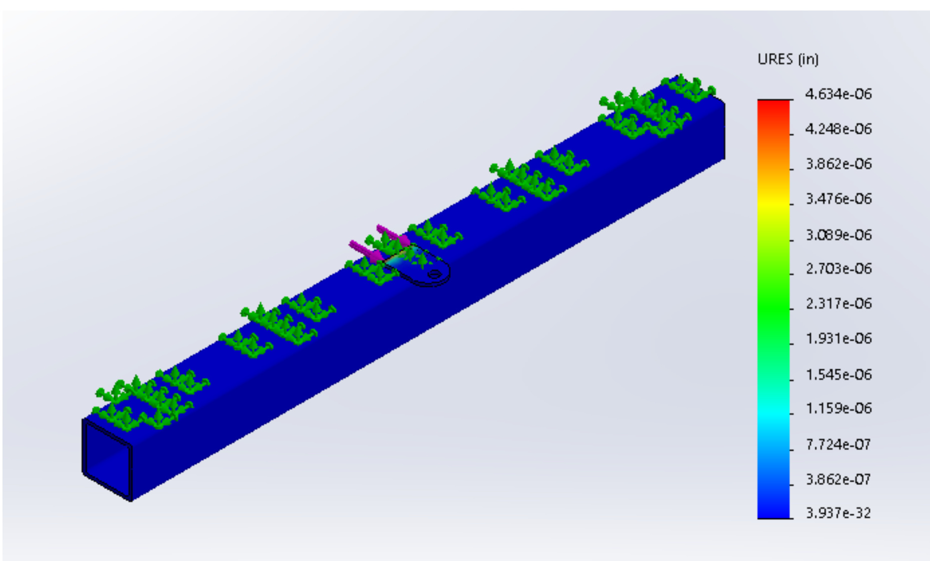
$$\tau = \frac{100.73 lbf}{.0147 in^2}$$

$$\tau = 6852.4\ psi$$

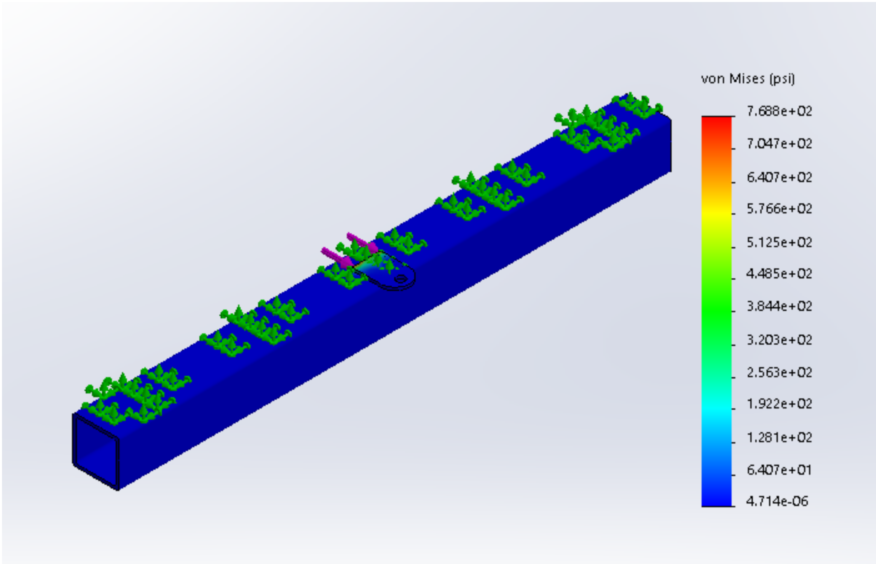
**Using Design factor of 2.5 for repeated shear:**

$$\tau = 6852.4\ psi * 2.5$$

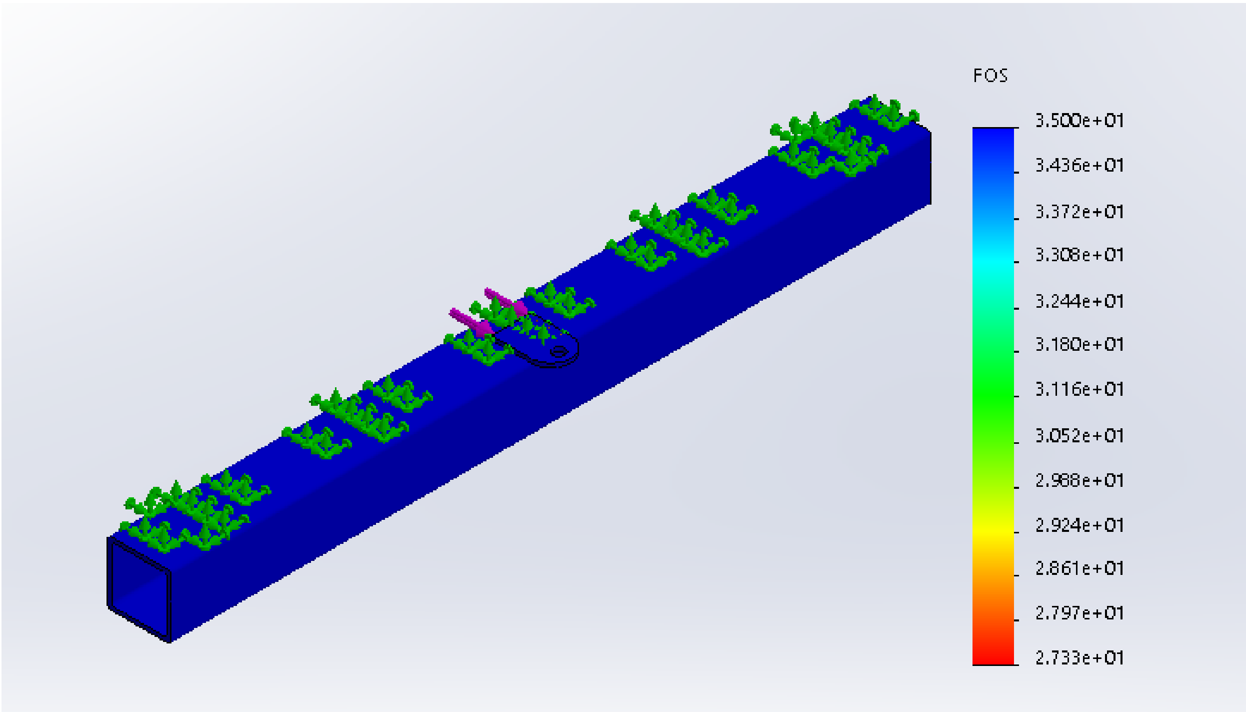
$$\tau = 17{,}131\ psi$$




Max Deformation:
0.000004634 in




Max Stress:
768.8 psi




Lowest Factor of Safety: 27.33
Highest Factor of Safety: >35

## D - Depth Calculations and Stress Analysis

### Jet Ski Specs

Length = 11 ft

Width = 4 ft

Weight = 825 lbs * 1.5 = 1237.5 lbs

### Depth Calculation

$$Depth = \frac{Weight}{WPA*Weight\ of\ water}$$

$$WPA = L * W * .6$$

$$WPA = 11\ ft * 4\ ft * .6$$

$$WPA = 26.4\ ft^2$$

$$Depth = \frac{1237.5\ lbs}{26.4\ ft^2*62.5\ \frac{lbs}{ft^3}}$$

$$Depth = \ .75\ ft\ =\ 9\ in$$

## Force on Bracket

### Specs

Height = .791 ft

Width = 0.25 ft

Thickness = 0.0104 ft

Weight = 2.5 lbs

**Assumptions**

Speed = 100 mph = 146.67 ft/s

cd = 1.28

$\rho = 0.07518 \frac{\text{lbf}}{\text{ft}^3}$

$$F_d = \frac{1}{2} * cd * \rho * A * V^2$$

$$F_d = \frac{1}{2} * 1.28 * 0.07518 \frac{lbf}{ft^3} * .0104\, ft^2 * \left(146.67 \frac{ft}{sec}\right)^2$$

$$F_d = 10.45\, lbf$$

$$F_{shear} = 10.45 + 2.5 + 0.17$$

$$F_{shear} = 13.12\, lbf$$

## Force on Sensor

**Specs**

Diameter = 0.058 ft
ft/s

Length = 0.328 ft

Weight = 0.17 lbs

**Assumptions**

Speed = 100 mph = 146.67 ft/s

cd = 1.20

$\rho = 0.07518 \frac{\text{lbf}}{\text{ft}^3}$

$$F_d = \frac{1}{2} * cd * \rho * A * V^2$$

$$F_d = \frac{1}{2} * 1.20 * 0.07518 \frac{lbf}{ft^3} * .0191\, ft^2 * \left(146.67 \frac{ft}{sec}\right)^2$$

$$F_d = 18.534\, lbf$$

$$F_{shear} = 18.534 + 0.17$$

$$F_{shear} = 18.704\, lbf$$

**Bolt Calculations**

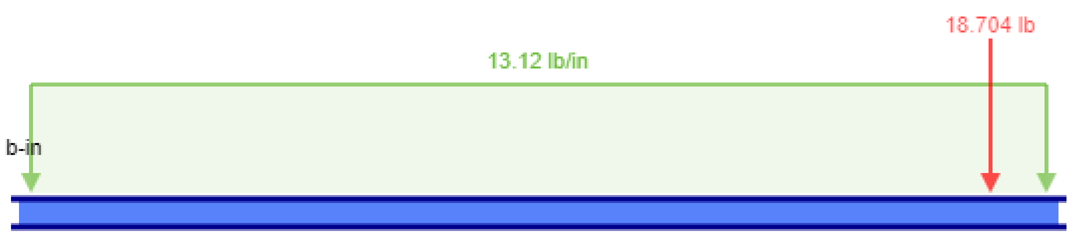
$$\sum F_x = 0$$

$$\sum F_x = R_1 - 13.12 \frac{lbf}{in} * 8.5\, in - 18.704\, lbf$$

$$R_1 = 130.224\, lbf$$

$$\sum M_{R1} = -13.12 \frac{lbf}{in} * 8.5\, in * 4.25\, in - 18.704\, lbf * 8\, in$$

$$\sum M_{R1} = 623.59\, lbf * in$$




**Bolt shear diagram**

$$\boldsymbol{Q_0 - Q_8}$$

$$Q_0 = R1$$

$$Q_0 = 130.224\ lbf$$

$$Q_8 = 130.224\ lbf - 13.12\ \frac{lbf}{in} * 8\ in$$

$$Q_8 = 25.26\ lbf$$

$$\boldsymbol{Q_8 - Q_{8.5}}$$

$$Q_8 = 25.26\ lbf - 18.704\ lbf$$

$$Q_8 = 6.56\ lbf$$

$$Q_{8.5} = 130.224\ lbf - 13.12\ \frac{lbf}{in} * 8.5\ in$$


**Bolt moment diagram**

$M_0 = M_{R1}$

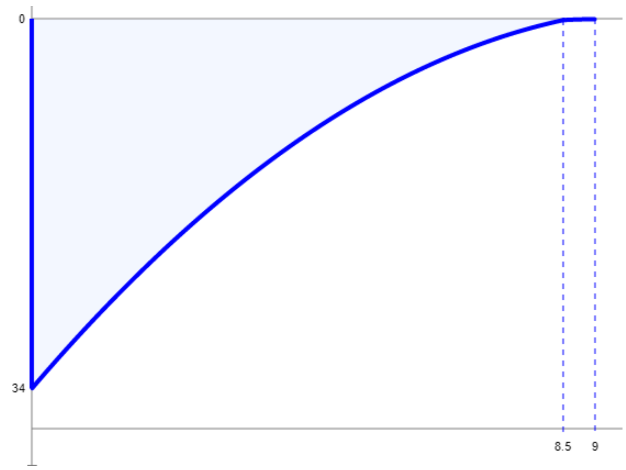
$M_0 = -623.59\ lbf * in$

$M_8 = 130.22\ lbf * 8\ in - 623.59\ lbf * in - 13.12\ \ lbf * \frac{8^2}{2}\ \text{in}$

$M_8 = -1.64\ lbf * in$

$M_{8.5} = 130.22\ lbf * 8\ in - 623.59\ lbf * in - 13.12\ \ lbf * \frac{8.5^2}{2}$

$M_{8.5} = 0\ lbf * in$




**Max shear and torsion on bolt**

## Max Shear

$$\tau_{Max} = \frac{4V}{3A}$$

$$\tau_{Max} = \frac{4*130.22\ lbf}{3*\frac{\pi\left(\frac{3}{8}\right)^2}{4}}$$

$$\tau_{Max} = 1572.04\ psi$$

## Torsion

$$J = \frac{\pi * D^4}{32}$$

$$J = \frac{\pi * (\frac{3}{8})^4}{32}$$

$$J = .0019\ in^4$$

$$Torsion = \frac{torque * r}{J}$$

$$Torsion = \frac{205.392 * \frac{3}{16}}{.0019}$$

$$Torsion = 20268.95\ psi$$

**Combined stress and safety factor**

$$Stress_{Total} = \frac{20268.95\ psi + 1572.04\ psi}{2\ bolts}$$

$$Stress_{Total} = 10920.49\ psi$$

$$Stress_{Total} = Total * SF(2)$$

$$Stress_{Total} = 21840.98\ psi$$

Static Load = safety factor of 2

Material selection - 304 stainless steel

Yield strength = 31200 psi

## Sensor Calculations

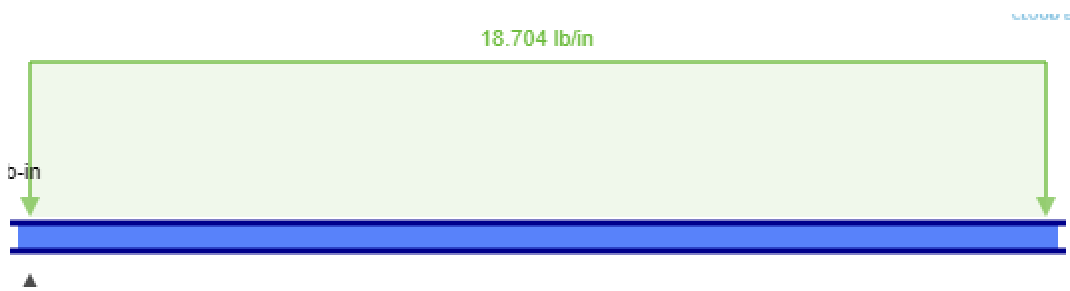
$$\sum F_x = 0$$

$$\sum F_y = 18.704\ \frac{lbf}{in} * 3.987\ in$$

$$\sum F_y = 73.637\ lbf$$

$$\sum M_{R1} = 18.704\ \frac{lbf}{in} * 3.937\ in * \frac{3.937}{2}\ in$$

$$\sum M_{R1} = 144.96\ lbf * in$$




## Sensor shear diagram

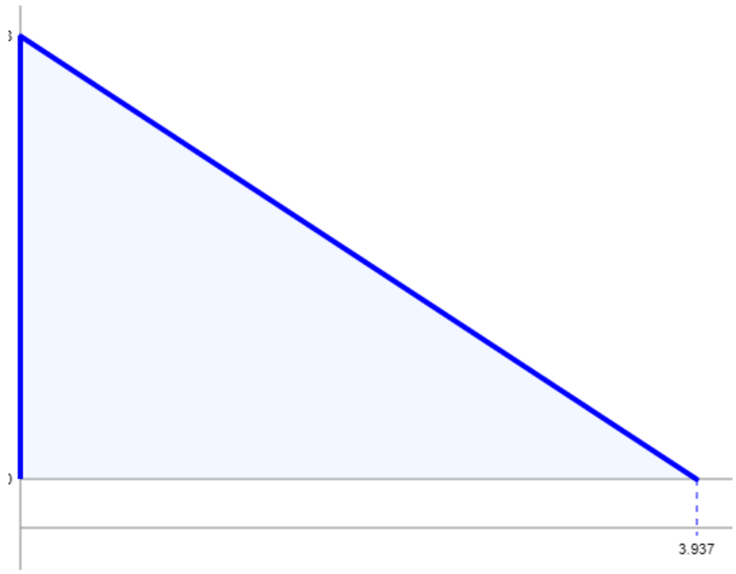
$$\boldsymbol{Q_0 - Q_{3.987}}$$

$$Q_0 = R1$$

$$Q_0 = 73.637\ lbf$$

$$Q_{3.937} = 73.637\ lbf - 18.704\ \frac{lbf}{in} * 3.937\ in$$

$$Q_{3.937} = 0\ lbf$$



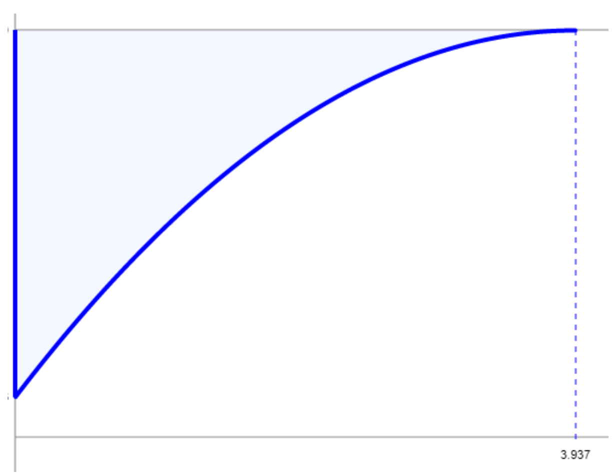

**Sensor bending moment diagram**

$$M_0 = M_{R1}$$

$$M_0 = -144.96\ lbf * in$$

$$M_{3.937} = 73.64\ lbf * 3.94\ in - 144.96\ lbf * in - 18.7\ \ lbf * 3.94\ in$$

$$M_{3.937} = 0\ lbf * in$$



**Max shear and torsion on sensor**

**Max Shear**

$$\tau_{Max} = \frac{4V}{3A}$$

$$\tau_{Max} = \frac{4*73.637\ lbf}{3*\frac{\pi\left(\frac{3}{4}\right)^2}{4}}$$

$$\tau_{Max} = 666.72\ psi$$

**Torsion**

$$J = \frac{\pi*D^4}{32}$$

$$J = \frac{\pi*(.7)^4}{32}$$

$$J = 0.0235\ in^4$$

$$Torsion = \frac{torque*r}{J}$$

$$Torsion = \frac{36.818*0.35}{0.0235}$$

$$Torsion = 548.365\ psi$$

**Combined stress and safety factor**

$$Stress_{Total} = 666.72\ psi + 548.365\ psi$$

$$Stress_{Total} = 1215.085\ psi$$

$$Stress_{Total} = Total * SF(2)$$

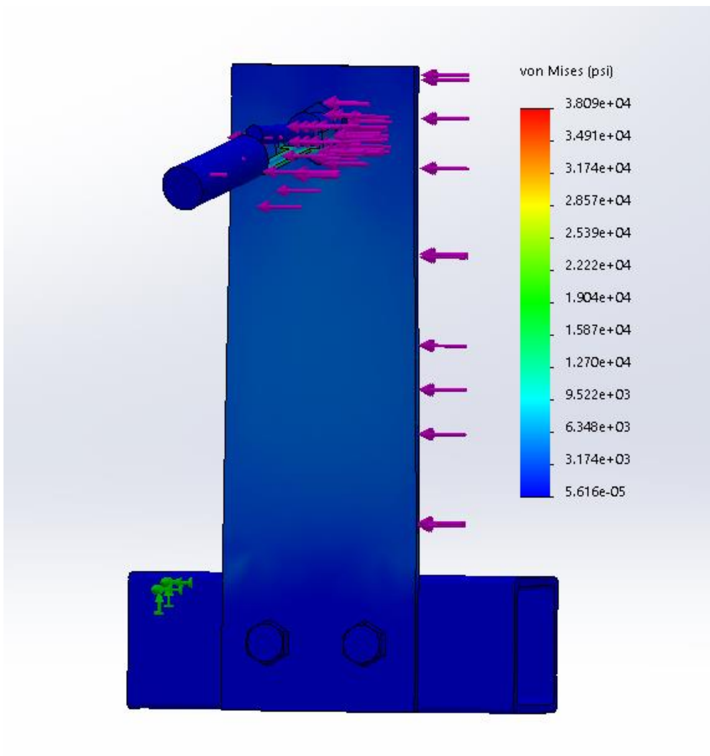
$$Stress_{Total} = 2430.17\ psi$$

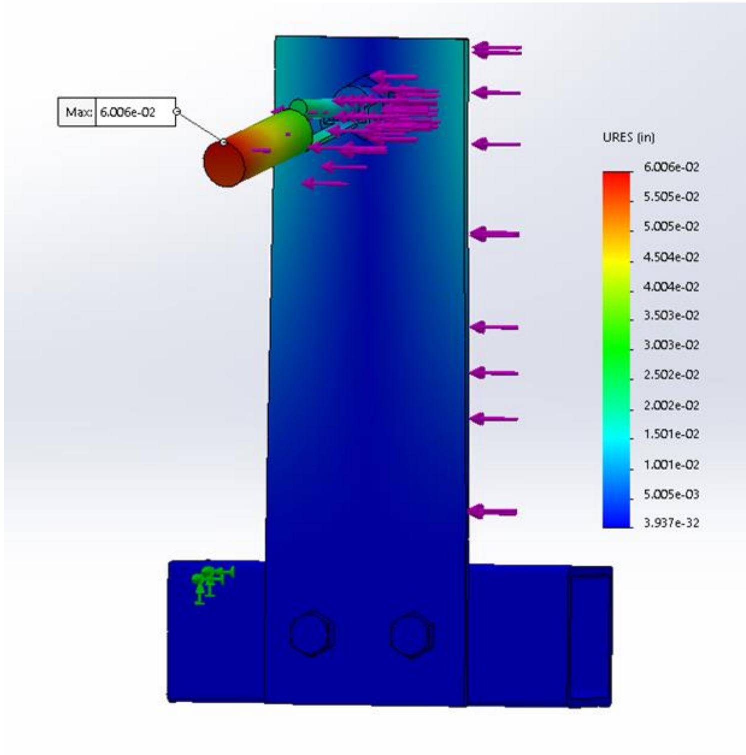
Static load = Safety Factor of 2

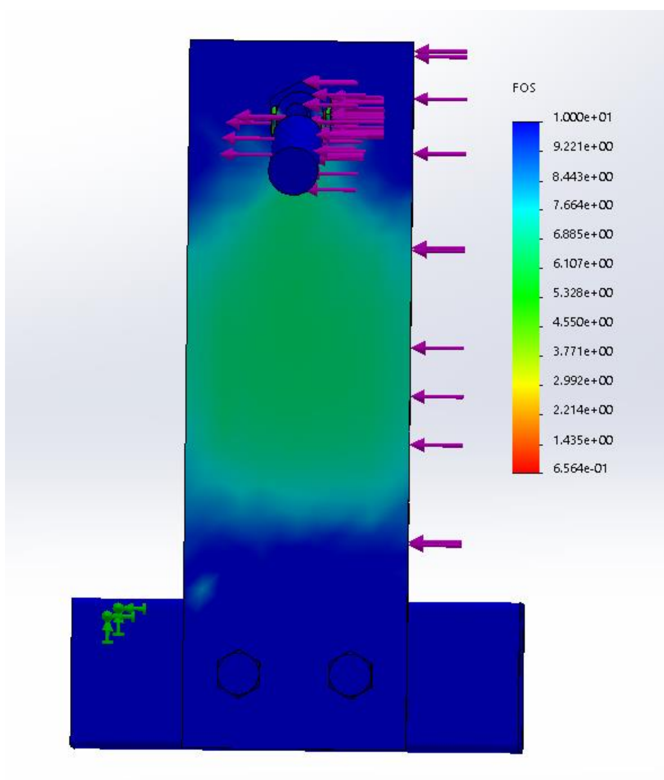
Material Selection - 316L stainless

Yield Strength = 29700 psi

## Stress Analysis




Max: 6.006e-02
URES (in)
6.006e-02
5.505e-02
5.005e-02
4.504e-02
4.004e-02
3.503e-02
3.003e-02
2.502e-02
2.002e-02
1.501e-02
1.001e-02
5.005e-03
3.937e-32


FOS
1.000e+01
9.221e+00
8.443e+00
7.664e+00
6.885e+00
6.107e+00
5.328e+00
4.550e+00
3.771e+00
2.992e+00
2.214e+00
1.435e+00
6.564e-01

## E - Industry Codes and Standards

- ABYC (The American Boat and Yacht Council)
- AISI (American Iron and Steel Institute)
- UL listings
- ANSI (American National Standard Institute)
- DOT (Department of Transportation)
- FMCSA (Federal Motor Carrier Safety Administration)

## F - Watercraft Terms and Definitions

**Watercraft -** Any kind of ship, boat, water vessel

**Boat ramp -** A ramp beside a body of water, constructed to allow boats to be launched or hauled out

**Tie-downs -** rope, cord, straps, or chains used to attach or secure an item onto a trailer

**Dry-starting -** Starting a boat engine while out of the water not allowing much needed cooling from the water

**Hull -** The structural body of the boat that rests in the water

**Dock Cleats -** Hardware piece on a boat or a dock to which lines are attached

**Ramp slips -** A boat berth between two piers or floats. Also, the slight loss of efficient power delivery as a propeller spins in the water

**Drain plug -** a wood or metal plug stopping up the drain hole near the keel of a boat and removable when the boat is dry-docked to drain out bilge water

**PWC (Personal Watercraft) -** A small, lightweight craft designed to be either sat-on or stood-on with motorcycle-like handlebars and squeeze throttle, usually jet-propelled

**Hitch -** Steel framework on a tow vehicle used to hook up a trailer