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Team 518: Yamaha Trash Interceptor

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Abstract

In 2019, Yamaha Motors created the Rightwaters Initiative to protect marine environments. Using an intercepting device, trash collection occurs in storm drains before it enters larger bodies of water. This stops pollution early in the cycle. Yamaha discovered that the first machine was too solid and heavy, making it difficult to move around. Similarly, the objective of this project is to create a trash interceptor to prevent waste from entering these large bodies of water. Collecting debris in storm drains will stop trash from reaching both oceans and rivers.

The team designed a new machine that is both cheaper and more readily available. Easy setup, sustainability, and being scalable are factors this new design addresses. The interceptor consists of a rotating basket wheel that will pick up trash and move it to a single collection site. A conveyor belt will move the trash from the collection site to a dumpster. For easy setup, the device will arrive on site in a few, simply assembled pieces. Once put together, the collector will rarely need human contact. The dumpster will be emptied according to a weekly pick-up schedule per city regulations. The collector will contain both a solar panel set and battery storage, so it will always have power. Solar panels will work during ideal weather, and the battery will provide power at all other times. By using renewable energy, the team further protects the environment. This helps to limit human input and reliance on outside power sources. The ability to scale the interceptor allows the device to operate in many environments. The expandable floating boom will allow the interceptor to scale to these different environments. To further improve performance, a water jet accelerator will pull the trash into the interceptor. The interceptor will collect trash before it spreads into larger water ways, allowing preservation of marine environments.

Disclaimer

The FAMU-FSU College of Engineering, as well as Yamaha Motors, is not responsible for any damages or injuries that result from any attempt to replicate the trash interceptor. After machining, many edges are sharp, and caution must be taken when handling the materials.

Acknowledgement

We would like to recognize the sponsor of our trash interceptor project: John O'Keefe of Yamaha Motors. The amount of guidance and encouragement received from you cannot be understated. We appreciate you greatly.

We would like to recognize our academic advisor, Dr. Shayne McConomy. Thank you for everything that you have done for us. The knowledge that you have given to us throughout the process has helped us immensely. We appreciate the amount of support and effort that you have showed us over the past two semesters does not go unseen. We are forever indebted to you.

We would also like to express our appreciation for the Mechanical Engineering department at the FAMU-FSU College of Engineering, specifically, Neil Coker and Chrissy Karantinos. Thank you for all of the help that you provided by ordering the materials that we needed.

Next, we would like to recognize the machinists of the FAMU-FSU College of Engineering Machine Shop. We appreciate all of your help when it came to actually building our device. Small suggestions to our project that allowed it to be more feasible was greatly appreciated.

We would also like to thank the machinists at the High-Performance Materials Institute for machining the things that were too large to be done at the college machine shop.

Table of Contents

List of Tables

List of Figures

Notation

CAD	= Computer Aided Design
AHP	= Analytical Hierarchy Process
HMI	= Human Machine Interface
IoT	= Internet of Things
DC	= Direct Current
CR	= Consistency Ratio
MIL-STD	= Military Standards
PWM	= Pulse Width Modulation
UHMW	= Ultra-high-molecular-weight
RPM	= Revolutions per minute

Chapter One: EML 4551C

1.1Project Scope

1.1.1 Project Brief

This project aims to study and implement an effective land-based trash interceptor, collecting debris – primarily plastic wastes – in storm drains before being released into bodies of water.

1.1.2 Key Goals

Our team in tandem with our Yamaha sponsor, Mr. John O'Keefe, has created multiple goals that we wish our project can accomplish. One of the most important goals is the project's cost. We would like to design a product that is economical for Yamaha to replicate on a mass scale in such a way that it is also affordable to the rural municipalities that are in desperate need of it but may not be able to afford it. Mr. O'Keefe and Yamaha ask that the product not exceed a cost of $100,000. The design also needs to be scalable; storm drains have different topography around them, some are very wide and some very narrow and it is our goal to create a design that can accommodate various settings. This product is one that might be put at various locations that might have rugged terrain to overcome so the design needs to be able to fit on the back of a regular sized 18-wheeler truck for ease of transport to the deployment site. This also calls for easy deployment with the use of a maximum of three skilled contractors that might have limited access to large equipment. The design must be easy to move to any location, so it is also our goal to incorporate sustainable energy into the product.

1.1.3 Markets

It is very important to define the market to maximize sales to a large group of customers. There are two main markets that this project could be utilized in; the primary market would small municipalities and rural counties and the secondary markets would be more populated cities. Our primary market is composed of small municipalities and rural counties that do not have the means to acquire such a device. Therefore, the price/cost has to be carefully considered when manufacturing the trash interceptor. The trash interceptor project could be expanded to fulfill the needs of big cities regarding combatting plastics, as our secondary market. The main focus is intercepting plastic debris before they enter the oceans, thus the metropolises and big cities would also qualify as potential customers.

1.1.4 Assumptions

There are assumptions that will be held as true throughout the entirety of this project; they will help control the scope of our project. There will be a stable embankment where the device is to be installed and operated, meaning that there would be a stable enough foundation for the device. Multiple people can install and uninstall the device without assistance from major machinery. Some source is present for varying sustainable energy sources, such as wind, sunlight, or geothermal energy that could be utilized to power the device. A person or persons are available to dispose of trash intermittently while the device is in operation. Minor disturbances to the land area around the device when being installed are permitted. These controls will guide our project by focusing our attention on what the team needs to address and consider throughout the design process.

1.1.5 Stakeholders

The stakeholders of this project are Yamaha Motors, more specifically Mr. O'keefe and Mr. Martin Peters, our faculty advisor/senior design professor Dr. Shayne McConomy, and rural municipalities. The project sponsor, Yamaha Motors, has a direct stake in this project as they are providing resources and time to guide the team to a final design that could be adopted as a Yamaha Motors product. Dr. McConomy has a stake in this project as he is helping pave the way in the process while guiding and assisting the team as needed. He has also invested significant time and effort in finding sponsors for all senior design projects. Rural municipalities have a stake in this project as they will allow the product to be implemented in these areas. Additionally, FAMU-FSU College of Engineering is a stakeholder as they are allowing our team to use resources within the college to carry out the project and produce a tangible product.

1.2 Customer Needs

Yamaha Motors Rightwaters Initiative wants to develop a device that collects trash at the source before it can enter the oceans and major waterways. The stakeholders of this project were contacted to establish the end users of the device. Mr. John O'Keefe of Yamaha Motors is our standing sponsor and provided the answers via Microsoft Teams shown below in Table 1. These questions were proposed to John O'Keefe to narrow down the scope of the project, and each customer statement provided was interpreted into a need for the project.

Table 1 Customer Responses and Interpreted Needs

Customer Needs Q&A			
Number	Questions	Customer Statement	Interpreted Need
1	How will the product be transported?	The device should be easily transported on a flatbed of a size up to an 18-wheeler.	The upper limit of our device's dimensions is **Length- 48 ft – 53 ft**. **Width- 8.5 ft**.
2	Will the device be assembled on or off site?	Some preparation should be done before deploying the device.	Parts are assembled into sub-assemblies before being assembled and deployed on site.
3	Who will assemble the device?	Hired contractors will be responsible for assembling the device.	Device would be assembled and deployed by a professional.
4	What is the expected size of collected trash?	Water bottle or small tree branches and twigs.	Objects in the range 5" T and 2.25" D to 13" T and 4.7" D.
5	What kind of sustainable energy would be preferred?	The previous ideas were mostly solar powered, but another source can be used. A water wheel is not a sufficient source of power.	Any sustainable power source other than water will work.
6	What is the desired lifespan of the device?	The device is not expected to survive a large hurricane. Do not nickel and dime the design at the expense of quality. In terms of corrosion once again durability is more important than cost.	Quality of the device is more of a priority than the budget.
7	Are there any preferred materials for our device? What materials were used in previous designs?	Stainless steel might be a good idea. Carbon fiber was feasible in previous designs, but the cost must be carefully considered.	Stainless steel and carbon fiber are the two main materials since we have to account for corrosion and rust. We might have to consider other materials as well.

8	Will the device have to account for wildlife?	The storm drain is pretty much isolated, so the device will not have to be designed around fish.	The device does not have to accommodate for any wildlife.
9	In what way will the device be operated?	The device could be operated remotely. The device should have as little interaction as possible. The device has to operate when there is some kind of fluid flow going through it.	The device needs to be able to operate for as long as there is water flowing. It could potentially operate remotely.
10	What is the preferred way to empty the design?	The design must have an attached dumpster that can be emptied by a standard garbage truck.	Incorporate a trash dumpster to the device.
11	Will the device have to intercept trash that has sunk or only floating trash?	The device should be oriented towards floating debris.	The device will intercept debris that will flow with water rather than pick up sunken trash.
12	What safety features does the device need to have?	There should be some form of fencing to dishearten anyone from climbing on the device or in the dumpster.	The device needs to have protection around it.
13	Is there an upper limit in size concerning the scalability of the device?	Approximately 20 feet.	About 20 feet is the largest the device has to expand to.
14	What are the likes of the similar Mr. Trashwheel?	It functions and has made a large change in its area. It is simple to operate. The only interaction with Mr. Trashwheel is emptying the dumpster.	Functionality is very important. Simple design with little interaction is desired.
15	What are the dislikes of the similar Mr. Trashwheel?	The cost per ton collected is too high. Mr. Trashwheel is not easily replicated. The device is also too expensive because it is built to survive a category 4 hurricane.	The device has a low cost per ton ratio without sacrificing quality/durability.

16	Is the target cost of $100,000 a cost of production or is it a desired cost to sell?	The device should be designed to be expendable. But quality should not be cut. The upper limit (cost of $100,000) is when clients start losing interest.	Make a high-quality product at a low cost.

The team was provided with a project background and had a meeting with the sponsor to inquire further details regarding their needs from the project. The table above was created by the team after analyzing the customer's statements and researching solutions. From our interactions with the customer, we have gained a better understanding on the needs that are to be incorporated in our design.

The main things we learned is that our trash interceptor has to be functional, simplistic, and cost effective. It is important that the device created removes small debris, such as, floating plastics and small tree branches/twigs so the amount of power supply needed is minimal; this means that the motor will not be required to lift larger debris, so a smaller motor will be sufficient. However, the customer wants the device to be interacted with minimally. Therefore, a large dumpster will be placed on or near the device, this way it can collect trash and be picked up by a typical garbage truck. The device is meant to be easily deployable, which means that two or three people will deploy it; the design will be broken up into pieces of less weight and then assembled at the location. The largest transport vehicle that the device would be transported on is that of an 18-wheeler flatbed trailer.

A simplistic design will meet the need for ease of removability in case there is need for it to be transported to another location, where the conditions are more optimal; the reason behind it is for better accessibility for the dumpster truck or more ideal for debris collection. This will allow easy disassembling of the device, which will lead to an easier and more efficient transport. The device being created is expected to be cost efficient meaning that the cost per ton of trash would as low as possible without sacrificing quality. The customer expects the device to be expendable; for instance, if a storm was to wash the device away or get severely damaged, the cost of the product would be low enough to have the entire device replaced. For this particular reason, the device does not have to be able to withstand high scale hurricanes. After collaborating with our sponsor and creating interpreted needs for the project, the items listed above will enable our device to fulfill the desired customer needs.

1.3 Functional Decomposition

1.3.1 Introduction

After analyzing our project scope, we were able to identify the main functions of our device. We developed key goals that must be accomplished in order to effectively build our trash interceptor. The functional decomposition facilitates the understanding of large and complex processes by breaking down the main functions and targets of the project. This breakdown sets each project function with subfunctions that can be tackled individually. The functions written in Figure 1 were created by analyzing key goals, customer needs, assumptions, and project description about what the device has to do. From synthesizing previous work, the functions developed included the required major and minor that were deemed necessary to create a scalable, self-sustainable, and easily deployable trash interceptor.

1.3.2 Flow Chart Reasoning

The functional decomposition hierarchy chart for our trash interceptor, seen in Figure 1 below, is broken down into five major systems. The six main systems of our device are *collecting*, *scaling*, *powering*, *transporting*, *operating*, and *deploying*.

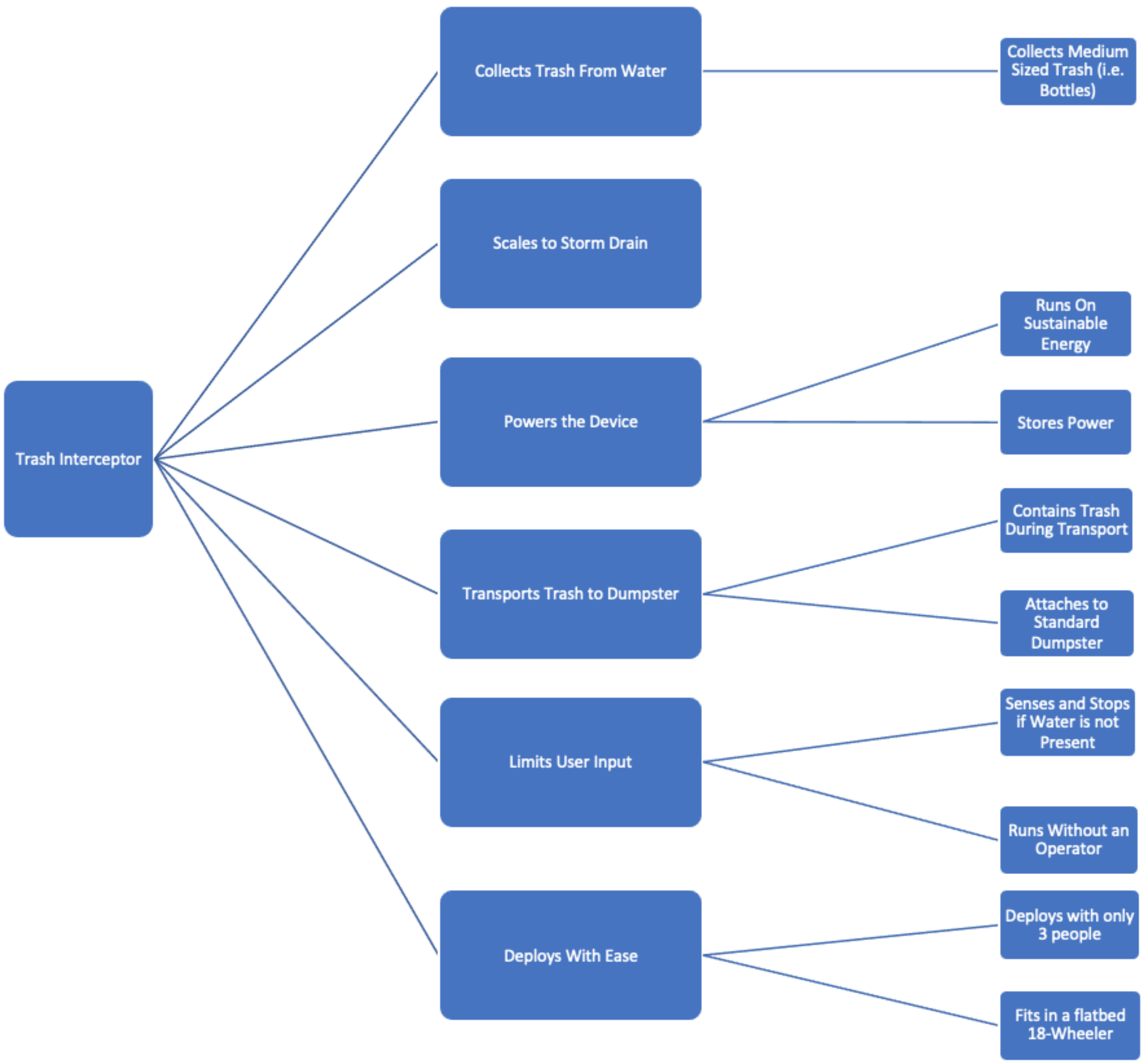

Figure 1 Functional Decomposition Flow Chart.

Collecting trash is one of the main functions of our project; this system is divided into one subfunction, which is collecting medium sized trash, such as plastic bottles and other debris.

Scaling the device to any storm drain is important for versality and ease of deployment. *Powering* the device is another important system in this project since we were required to design a self-sustainable device; a subfunction that has to be accomplished is being able to store energy considering that our sources might not supply power constantly. *Transporting* the trash to the dumpster is divided into two functions: effectively moving the trash to a container, without leaving anything behind, and also being able to attach it to a standard dumpster for pickup. The device is desired to be *operated* remotely; the trash interceptor has to sense and stop when there is no water flowing. Easily *Deploying* the device means that it must fit in an 18-wheeler flatbed truck. In addition, the device needs to be deployed by a maximum of three people, which in this case, is going to be hired contractors.

1.3.3 Connections to System

The functional decomposition cross reference chart in Table 2 is a visual representation of how systems relate to functions. The cross references aid in determining the priority of systems in the design process. The X shows which of the systems have overlapping effects on other systems. There potentially could be physical interactions between multiple systems that needs to be considered. For example, storing power addresses how the device will be powered and limiting user interactions. Since the device will need a power source to be functional and with sustainable energy, there will be less interaction with the device due to minimal maintenance or fuel replenishing. Though these physical interactions are all relevant and pertinent to the functionality of the device, the priorities are limiting user input, collecting trash, and deploying with ease in that order of importance.

Table 2 Functional Decomposition Cross Reference Chart

	Collects Trash From Water	Powers The Device	Transports Trash To Dumpster	Limits User Input	Deploys With Ease	Scales to Storm Drain	Total
Collects Medium Sized Trash	X			X		X	3
Runs On Sustainable Energy		X		X	X		3
Stores Power		X		X			2
Contains Trash During Transport	X		X	X			3
Attaches to Standard Dumpster	X			X	X		3
Senses & Stops If Water Is Not Present				X		X	2
Runs Without An Operator	X		X	X			3
Deploys With Only 3 People					X		1
Fits On A Flatbed 18-Wheeler					X		1
Total	5	2	2	8	4	2	

1.3.4 Action and Outcome

The trash interceptor will need to be scalable, interacted with minimally, and an easily deployable device that collects trash. It will need to take in a sustainable supply of power and convert it into an autonomous motion that collects trash from storm drains. These major functions will enable the team to develop targets and metrics that will help to achieve the key goals of our project prioritizing the functionality of it.

1.4 Target Summary

When beginning our concept generation and concept selection, it is imperative to set certain targets and parameters of what is expected from our device. In the sections below, we choose certain metrics for each of our subsystems and explain the purpose and reasoning behind each number.

1.4.1 Method of Validation

Using Creo Parametric 7.0 a design can be built and tested to ensure proper motor function. Once the design has been assembled, a collision detection will be used to ensure that no parts are colliding, creating failure to the device. Once a device is created without collision, forces will be applied in the assembly to simulate the trash that will be on the device to ensure that the motor being applied has enough torque to run the device. Using Matlab we can mathematically simulate the forces and moments of inertia to ensure the design does not fail even after long periods of time in constant use.

1.4.2 Scalability

To ensure that the trash interceptor device is scalable to many if not all sized storm drains, it is important to know the upper and lower limit dimensions that the device will have to size to. It was mentioned to us that our device needs to be capable of spanning across a 20-foot storm drain. So, with that, our device must be able to extend horizontally to a maximum of twenty feet. The device must also be able to be scaled down. The trash interceptor device should also be able to reduce to a 3-foot-wide horizontal extension. This will allow our device to be placed into storm drains that are dimensioned between three and twenty feet wide. The device also must be scalable in the vertical direction to ensure that, regardless of the depth of the storm drain, the device will be able to be scaled to size. This scalability will allow the device to be scaled to 7 feet above the flow of water, as well as being reduced to only 2 feet above the flow of water. These dimensions will allow the device to be beneficial to minimizing trash in both deep and shallow storm drains.

1.4.3 Collecting

It was determined that the device should focus on intercepting "medium sized trash". Yamaha has mentioned multiple times the example of water bottles being the trash we pick up. To quantify a size parameter for water bottles, we are specifically looking at something roughly about the size of a 44-ounce Styrofoam cup so that we have an upper limit for our design. Looking at the volume of the cup in respect to the dumpster size, the dumpster dimensions are in cubic feet, so converting the 44 ounces to cubic feet we see that the volume of the cup is 0.046 ft^3. This is a larger sized cup that could hold upwards to a pound and a half of fluid if filled. Assuming a trash flow that has ten 44-ounce Styrofoam cups that are filled, the weight would be roughly 15 pounds. To introduce a factor of safety, we will set the target weight for the device to be able to pick up a maximum of 20 pounds at one time. In our discussions with Yamaha, we also determined that we are looking at picking up floating trash exclusively so to ensure the ability to scoop up all partially submerged plastics thus we are aiming to scoop at least 2 feet deep into the water.

1.4.4 Power

Our device may be limited by the availability of sustainable energy sources. Therefore, it is important to power the device for the intended amount of time considering that availability or lack thereof (i.e., rain, clouds, lack of wind), to do this while using a sustainable energy source, time in operation will need to be intermittent so energy can be obtained and then stored in a battery. Based on the upper limit of our weight and average vertical distance, the calculated potential energy to move 50 lbs out of a storm drain was proven to be 700 lb-ft. The relative time to pick up the upper limit was decided to be 60 seconds. The required power for the device is therefore 11.67 lb-ft per second.

Figure 2: 8-Yard Slanted dumpster

1.4.5 Transporting

To maximize the amount of trash that is being collected and minimize the number of times the dumpster needs to be emptied; an 8-yard slant dumpster, as depicted in Figure 2, will be utilized. This dumpster will allow for a standard trash truck to be able to pick up and empty without having to go through many struggles. Having an 8-yard dumpster that the device will be emptying into, the overall width of the device must be less than 71.5 inches, the width of the dumpster, to ensure no trash is missing from the dumpster. The 8-yard slant dumpster has a volume of 216 ft^3, with a weight limit of 1,600 lbs. If we assume that after a good rainstorm (when the device will be running), and not letting the dumpster fill up past 75% of the way full, the device collects around 50 pounds of trash, the dumpster will need to be emptied every 24 rainstorms. Due to the trash that the device will be intercepting, our device must be able to withstand 40 pounds of trash at a time, to ensure that the device is stable enough to continue to function. Considering our trash size constraints, the dumpster would be able to hold roughly 4,700 44-ounce Styrofoam cups.

1.4.6 Limiting User Direct Interaction

Considering the device's functionality and deployment location and setting, we need to limit the direct contact of human interaction with the device as much as possible. The device requires direct human interaction only when emptying the dumpster, switching the state of the device (ON/OFF), or for monitoring the device's condition and behavior.

In the previous concept of the Trash Interceptor, the dumpster is incorporated within part of the device's design, where it is placed on a connecting bridge. Such design requires significant human effort and interaction with the device due to the tight space and direct connection to the device. To resolve the issue and guarantee less direct interaction with the device, the dumpster should be separated from the device and easily accessed by a garbage truck. Doing so requires a clearance of at least 14.76 feet in height, 8.2 feet in width, and 41 feet in length, to allow easy access of the garbage truck. It is also required that the dumpster is separated from the device.

We also need to control and monitor the device remotely. Installing a human machine interface (HMI) would allow us to achieve the desired need. To establish the communication method, we need an Internet of things (IoT) device simulator, a solution that enables customers to create and simulate hundreds of virtual connected devices from anywhere and anytime if the emitting (controlled – monitored) device is connected to the internet. This remote interface minimizes direct contact of the user with the device. In case of severe weather conditions, we can implement radio signal controls instead of the IoT device simulators within a smaller range. Considering the targeted storm drain in Brunswick, GA, a radio signal controller with a range of about 2 miles would be ideal.

1.4.7 Deploying

One of the main requirements for our device is that it must be easily deployable; this means that the device must be put together and deployed by a maximum of three people, who in this case, will be hired contractors. Since our device is going to have a few different subassemblies that will be assembled prior to arrival at the site, it is important to consider how much weight a person can carry, and this number may vary from forty-five to sixty pounds. In other words, each individual part will have a weight upper limit of a hundred pounds, which would be carried by two people. In addition, considering the size of a certain part is also important when deploying the device although there is not a specific limit.

On the other hand, all the parts to our device must fit in an 18-wheeler truck bed, allowing relatively easy transportation to the site. An 18-wheeler wedge trailer has an average dimension of 48-53ft long by 8.5ft wide; this defines our upper limit size of the complete device disassembled. We also considered transporting our device in a smaller vehicle such as the Ford F-350 flatbed, whose bed dimensions are 8.17ft long by 5.4-ft wide; using this specific vehicle to transport our trash interceptor might limit the size of it, that explains why there is an upper size limit.

1.4.8 Critical Targets

The table below shows the targets and metrics for the critical targets of the trash interceptor device. The *critical targets,* those that must be met to accomplish our project's main goals, are bolded on the table to facilitate. Some of our targets are subjected to changes as we make progress on the project. A table with all of the targets and metrics is included in appendix B.

Table 3 Critical Targets Summary

System	*Function*	*Target*	*Metric*
Scalability	**Horizontal Expansion**	**20 [ft]**	**Width**
Scalability	**Vertical Expansion**	**7 [ft]**	**Height**
Collecting	**Intercepting**	**0.046 [ft^3]**	**Volume**
Deploying	**Assembling**	**45-60 [lbs]**	**Weight**
Deploying	**Transporting**	**48-53 [ft] X 8.5 [ft] (LxW)**	**Area**

1.4.9 Other Targets

While discussing our critical targets along with functional targets a few other targets had to be determined. One of the functions that came up in discussion is some form of lighting on the device. When lighting the device, we would not be looking to do it for long periods of time. It would only be lit while someone was there working on or near it. It was decided that there would be some form of switch or button on the device and be able to be remotely turned on. The lights should have at least 7500 lumens with a protection grade of IP65 so that it is completely dust tight and protected against low-pressure jets of direct water.

Including a factor of safety an enclosure needs to be added surrounding the device to guarantee the safety of those who may try to interact with the device. There needs to a clearance surrounding the device of at two least feet. Considering general fencing regulations for the state of Georgia the enclosure should not exceed eight feet vertically. The enclosure will surround the land perimeter of the device.

To ensure that the device can be monitored to determine if it is blocked or jammed or things of that nature, a camera will be implemented. This camera will have a 1080p video feed that can be accessed from a nearby source. This would allow a person to constantly monitor the device to ensure that everything is running smoothly. This software would not necessarily be used to do maintenance on the device remotely but to determine when there is a problem. This would then allow them to send out the proper maintenance crew to determine and resolve the conflict. This camera would either pull power from the battery that is used to power the device itself or will have a sustainable energy source like that of the overall device itself.

1.5 Concept Generation

While partaking in any project, concept generation is a critical aspect to allow the engineers to have an array of possible solutions. Sitting down and trying to configure a variety of ideas can be very difficult to the designer. With that being said, a multitude of different concept generation tools were utilized so that, we as a team could come up with 100 different concept ideas. The list of 100 concepts could be found in Appendix D.

1.5.1 Concept Generation Tools

Throughout the process of creating our 100 design concepts, several concept generation tools were utilized to guide us along the process of designing concepts. These tools included a morphological chart, biomimicry, and crapshoot. Biomimicry allowed designs to be created based off what animals do in their everyday lives and putting them into designable objects. Crapshoot allowed creating ideas that could be difficult to implement, but they could potentially be solutions to the problem at hand. A morphological chart was used to list out everything that is desirable in the project and match different combinations of these items.

1.5.2 Medium Fidelity Concepts

Five medium fidelity concepts were selected out of the hundred concepts that were created. These concepts meet most of our desired project goals and requirements; however, they are not necessarily the path that our team would like to follow. These five concepts will be helpful to show what our main project goals are.

Table 4 Medium Fidelity Concepts

Concept #	Description
88	A conveyor belt angling trash towards a wheel that will remove the trash out of the storm drain being powered by solar energy, connected to the ground via corkscrews with a jet that will accelerate the water to ensure that the trash flows in the direction that is needed.
63	Three metals barriers on each side placed at an angle that intercepts any plastic going through a waterway. The accumulated trash stays at the end (back) of the land-based device until it is sucked in by a pipe. Before transferring the waste to the dumpster, the water is drained out.
22	A helical water wheel that catches trash from a funnel, the wheel has cubies that hold the trash until the top of wheel where it's released into a shoot that leads to the dumpster.
39	A design like a water wheel that scoops the trash out of the water and as the net rotates the trash slides to the center where there is a single inclined plane at the pivot point that slides the trash to side of the device and onto the conveyor belt that dumps the trash into the dumpster.
50	A floating dam "barrier" that guides debris into a waterwheel. The water wheel acts as a gate that only opens when water is present and flowing. Then the debris is carried on a conveyer belt and guided into the dumpster.

1.5.3 High Fidelity Concepts

Three high fidelity concepts, found in Table 5, were chosen from all the hundred ideas that were put together. These concepts appear to satisfy most of our needs and goals and the most feasible concept will be determined by the concept selection process.

Table 5 High Fidelity Concepts

Concept #	Description
37	A design like an Alaskan fishwheel that scoops the trash out of the water and as the net rotates the trash slides to the center where there is an inclined plane on each scoop that slides the trash to side of the net and into the dumpster. This can be paired with a floating wall that uses the water flow to bring the trash to one side of the drain and onto the conveyor belt that dumps the trash into the dumpster.
29	A single floating boom which is angling trash to one side of the storm drain which is then carried out of the storm drain via another conveyor belt which then deposits the trash into a separate reservoir with another conveyor belt out of the second reservoir to go into the dumpster to ensure that trash is not continually being dumped as the dumpster is gone. The trash will be flowing in the right direction due a jet connected to the conveyor belt taking the trash out of the storm drain
60	Debris Separating Baffle Box. We use a funnel shape directing lines that guide the water to a triangle shaped gate that separates debris from water into two chambers. Whenever we intend to empty the chamber. The gate folds to close the path of that chamber and guide debris into the second one. the chambers are portable for dumping. When the chamber is lifted from water, a gate would open at a certain angle allowing the debris to slide directly into the dumpster.

High Fidelity Concept #37

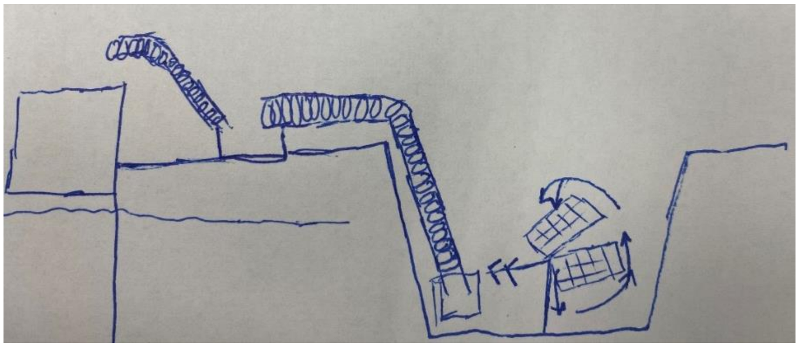

Figure 3 High Fidelity Concept #37

High Fidelity Concept # 29

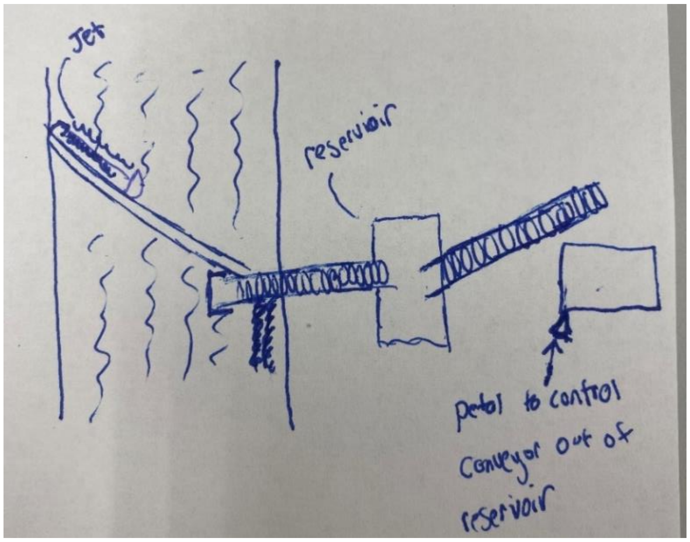

Figure 4 High Fidelity Concept #29

High Fidelity Concept # 60

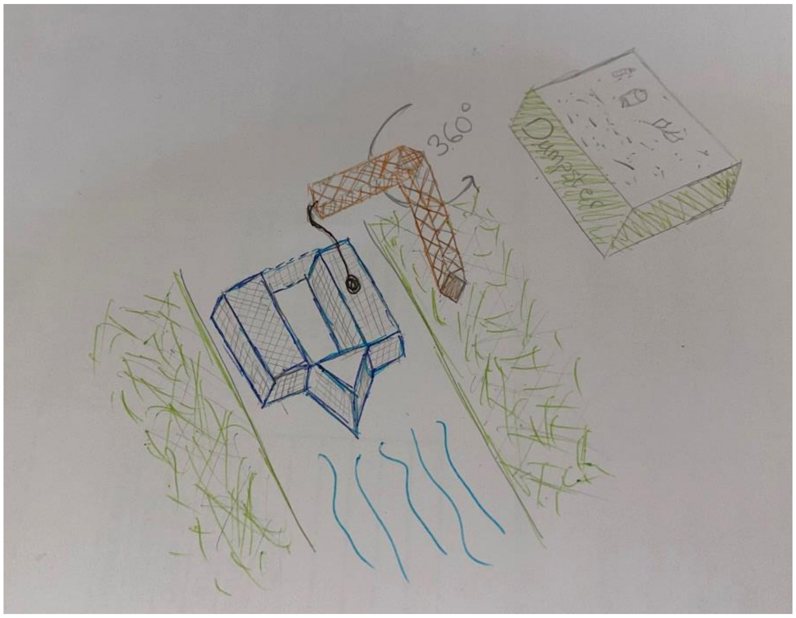

Figure 5 High Fidelity Concept #60

1.6 Concept Selection

1.6.1 House of Quality

Using the customer needs gathered from talking with Yamaha Motors, they were analyzed using a binary pairwise comparison chart which can be seen in appendix E. A list of the customer needs and engineering characteristics can be seen in table 6. When using the binary pairwise comparison, each customer need was weighted against the other customer needs and was determined to be more or less important and received a 1 or a 0. Resulting from the comparison chart is an importance weight factor for each need. After analyzing the chart, the most important customer needs are that the device must intercept trash and that the device must be able to intercept medium sized wastes.

Table 6: Customer Needs and Engineering Targets

Number	Customer Need	Engineering Target
1	Fit on 18-wheeler trailer	Horizontal Expansion
2	Has Sub-Assemblies	Vertical Expansion
3	Deployed by Professional	Device Width
4	Medium Sized Trash	Intercepting Volume
5	Sustainable Energy	Intercepting Weight
6	High Quality	Intercepting Depth
7	Incorporates a Standard Dumpster	IoT Remoting Monitoring
8	Intercepts Trash	IoT Remote Controlling
9	Is Protected from Children	Easy Access
10	Expands to fit a 20 ft drain	Power
11	Limits User Input	Duration of Transport
12	Low Cost per collected ton ratio	Assembly Weight
13	Inexpensive/Expandable	Fits on 18-Wheeler

The importance weight factor gained from the binary pairwise comparison is then used in the house of quality to determine the ranking of the functions from the functional decomposition. The house of quality compares the engineering characteristics from the decomposed functions against the customer requirements/needs. The importance weight factor of the customer needs is used to rank how well the engineering characteristic meets the customer requirements. By doing this, a ranking of the most important engineering characteristics is created using a scale 0, 1, 3, 9. These are the engineering characteristics that the device must display. From the house of quality shown in table 7, the most important functions of the trash interceptor are: the power the device must have, the intercepting volume, ease of access of the device, and the device width. The least important functions of the device are: IoT monitoring and remoting, intercepting depth, and the duration of transport.

Table 7: House of Quality

		Engineering Characteristics												
Improvement Directions		↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↓	↓
Units		ft	ft	ft	ft^3	lbs	ft	miles	miles & Hz	N/A	$(lb*ft)/s^2$	sec	lbs	ft^2
Customer Requirements	**Importance Weight Factor**	1	2	3	4	5	6	7	8	9	10	11	12	13
1	2	3	3	9	1	0	1	0	0	9	9	0	9	9
2	3	1	1	3	0	0	1	0	0	9	3	0	9	9
3	2	0	0	3	0	0	1	3	3	9	9	0	3	9
4	11	1	1	9	9	3	3	0	0	0	1	3	1	0
5	3	0	0	0	1	1	0	3	3	1	9	9	1	0
6	8	9	9	1	3	9	9	9	9	3	9	1	3	0
7	9	0	0	3	9	1	0	0	0	9	1	1	1	0
8	12	9	9	9	9	9	9	1	1	9	9	3	1	0
9	0	1	1	1	0	0	0	0	0	0	0	9	0	0
10	9	9	9	1	0	0	0	0	0	1	0	0	3	0
11	8	1	1	3	3	3	1	9	9	9	9	3	9	0
12	6	3	3	3	3	3	0	3	3	1	9	9	9	0
13	5	3	3	3	3	3	0	3	3	1	9	9	9	0
Raw Score	3698	322	322	341	374	282	228	204	204	371	443	236	308	63
Relative Weight %		8.7	8.7	9.2	10	7.6	6.2	5.5	5.5	10	11.979	6.4	8.3	1.7
Rank Order		5.5	5.5	4	2	8	10	12	12	3	1	9	7	13

1.6.2 Pugh Chart

Pugh charts are a way of design selection that takes the medium and high-fidelity concepts of the trash interceptor and compares them to a datum. Compared to the datum, the concept will either receive a plus (+), a minus (-), or a satisfactory (S), relative to the engineering characteristic compared to that of the datum. In the first iteration of the Pugh chart, Mr. Trashwheel out of Baltimore Maryland was selected as the datum. The concepts that were selected to continue to the next iteration of the Pugh chart were concepts #88, #63, #22, #39, #50, #37, and #29. Shown in table 8 is the first iteration of the Pugh chart.

Table 8 Pugh Chart Iteration 1

Selection Criteria		Concepts							
		Concept 88	Concept 63	Concpet 22	Concept 39	Concept 50	Concept 37	Concept 29	Concept 60
10	DATUM: Mr. Trashwheel	+	-	+	+	+	+	s	-
4		+	-	s	+	+	+	+	s
9		+	+	+	+	+	+	+	-
3		s	-	s	s	s	s	+	+
1		s	s	-	s	s	+	+	-
2		s	s	s	s	-	+	+	+
12		+	+	+	+	+	+	+	-
5		+	-	s	s	s	+	+	-
11		+	+	+	-	-	+	+	-
6		+	s	+	+	+	+	+	-
# of Pluses		7	3	5	5	5	9	9	2
# of Satisfactory		3	3	4	4	3	1	1	1
# of Minuses		0	4	1	1	2	0	0	7

Moving onto to Pugh chart 2 the new datum selected to compare the remaining concepts was #39, because it was determined to be the most median concept of the group. Concept #39 was selected to be the datum instead of #22, because while their results are the same, the criterion that #39 over performed in was deemed more valuable. The concept eliminated from Pugh chart 1 was #60 because it had the worst performance, or largest number of minuses with little plus or satisfactory, compared to the datum. Continuing this process of eliminating concepts that did not meet the standard datum and implementing the concept that was a moderate performer in the previous chart as the new datum Pugh charts 2, 3, and 4 were created. These charts are located in Appendix F for further documentation. The final Pugh chart iteration 5 determined our top three remaining concepts, concept #39, #37, and #29. Concept #88 was removed from contention or being the final concept selection. The 5th iteration of the Pugh chart can be seen in table 9.

Table 9 Pugh Chart Iteration 5

		Concepts			
Selection Criteria		Concept 88	Concept 39	Concept 37	Concept 29
10	DATUM: Concept 39	-	s	s	-
4		s	s	+	+
9		s	s	s	s
3		+	s	s	+
1		s	s	+	s
2		s	s	s	s
12		s	s	+	s
5		s	s	+	+
Duration of Transport		s	s	s	s
Intercepting Depth		s	s	+	s
# of Pluses		1	0	5	3
# of Satisfactory		8	10	5	6
# of Minuses		1	0	0	1

1.6.3 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) charts were used to determine, in a quantitative way, the weight of each criterion we used to judge our concepts. This process removes bias from these decisions, by comparing an individual criterion to a different criterion one at a time. They were judged on a scale of 1, 3, 9 by the group to determine how much better each criterion were when compared to one another.

From the target comparison AHP matrix shown in table 10, the results were then normalized against the summed weight of each criterion, producing the weight of each criterion.

Table 10: Normalized Target Comparison

Normalized Criteria Comparison Matirx [NormC]								
	1	2	4	5	6	9	10	Criteria Weights {W}
1	0.067	0.067	0.059	0.059	0.043	0.111	0.077	0.069
2	0.067	0.067	0.059	0.059	0.043	0.111	0.077	0.069
4	0.200	0.200	0.176	0.176	0.130	0.111	0.231	0.175
5	0.200	0.200	0.176	0.176	0.130	0.111	0.231	0.175
6	0.200	0.200	0.176	0.176	0.130	0.111	0.077	0.153
9	0.067	0.067	0.176	0.176	0.130	0.111	0.077	0.115
10	0.200	0.200	0.176	0.176	0.391	0.333	0.231	0.244
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

The criteria weights were then used to create the weighted sum vector and consistency vector. These were used to calculate the consistency ratio (CR), an ideal CR is less than 0.1, meaning that our CR is well below the ideal limit at 0.04. The AHP charts were then used to compare the last three concepts to each other on a scale of 1, 3, and 9 on how they address each target. This allows the team to compare concepts through the lens of each individual target. The AHP tables called Concept Comparison for Target 1, 2, 4, 5, 6, 9, and 10 can all be found in Appendix G. For example, Concept Comparison for Target 1 we began by comparing the three concepts and determined that all three concepts can address that target equally, and therefore, the matrix was filled with 1. From there the concept comparison for each target was normalized against the summed weight of that concept with three concepts the normalized matrix consisted of 0.33 across the entirety. For each target the calculated CR returned with a value of 0.0 with that being lower than the ideal upper limit of 0.1, shows that results appear to be unbiased and consistent.

The Final Rating Matrix is a compiled list of the criteria weight produced during the AHP for each concept with respect to all the engineering targets, were evaluated during this process. These weights show how much better or worse each concept is when compared to each other at addressing each target. The final rating matrix can be seen below in table 11.

Table 11: Final Rating Matrix

Final Rating Matrix	Concept 29	Concept 37	Concept 39
1	0.333	0.333	0.333
2	0.333	0.333	0.333
4	0.143	0.429	0.429
5	0.143	0.429	0.429
6	0.206	0.429	0.429
9	0.655	0.187	0.158
10	0.206	0.429	0.429

The final step at arriving to our final alternative values for each concept was done by weighting the final rating matrix with the criteria weights. Therefore, the weight of each concept is evaluated considering the importance of the targets previously evaluated in the initial AHP. The higher alternative value means that concept best addresses the engineering targets. The alternative values can be seen in table 12. Ultimately, the concept that has the highest alternative value was concept #37, and this concept can be seen below in figure 6.

Table 12: Alternative Values

Concept	Alternative Value
Concept 29	0.253262079
Concept 37	0.38764171
Concept 39	0.384309438

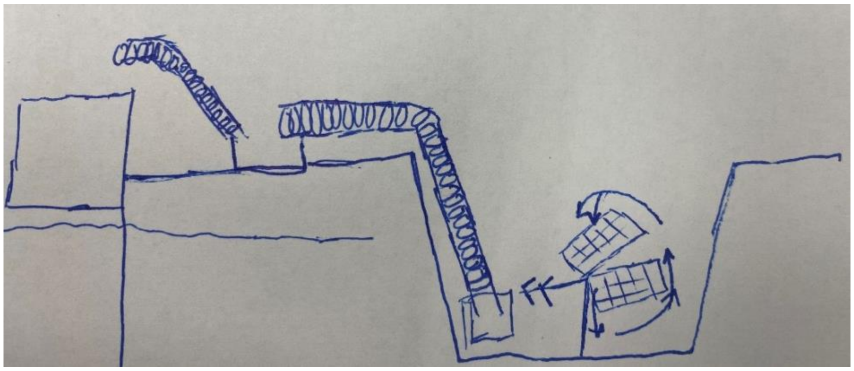

Figure 6: Final Concept Selected

1.6.4 Final Concept Selected

The final concept selected can be seen in figure 6. It will have a floating trash barrier with a jet accelerator connected to the end will accelerate the water and the floating trash in the water towards a basket wheel, without letting any trash float by without being caught. The basket wheel will have an angled slide in the middle, so that when the wheel makes its revolutions the trash will dump onto the slide and slide into a reservoir. The reservoir will then have a conveyor belt to carry the trash out of the storm drain and up into the dumpster. A sensor pedal will be installed next to where the dumpster will be placed to make sure that the conveyor belt is only running when the dumpster is there. While the dumpster is being picked up and dumped, the conveyor belt will not be running, and the trash will be coming off the slide into the reservoir and held there until the dumpster is returned and the conveyor belt begins to run again. Solar panels will be placed on the device with a solar inverter to create energy which will be stored in batteries to power the device.

1.8 Spring Project Plan

Shown below in Figure 7 is the Spring semester project plan, indicating which team member is responsible for which task and what date each assignment will be accomplished.

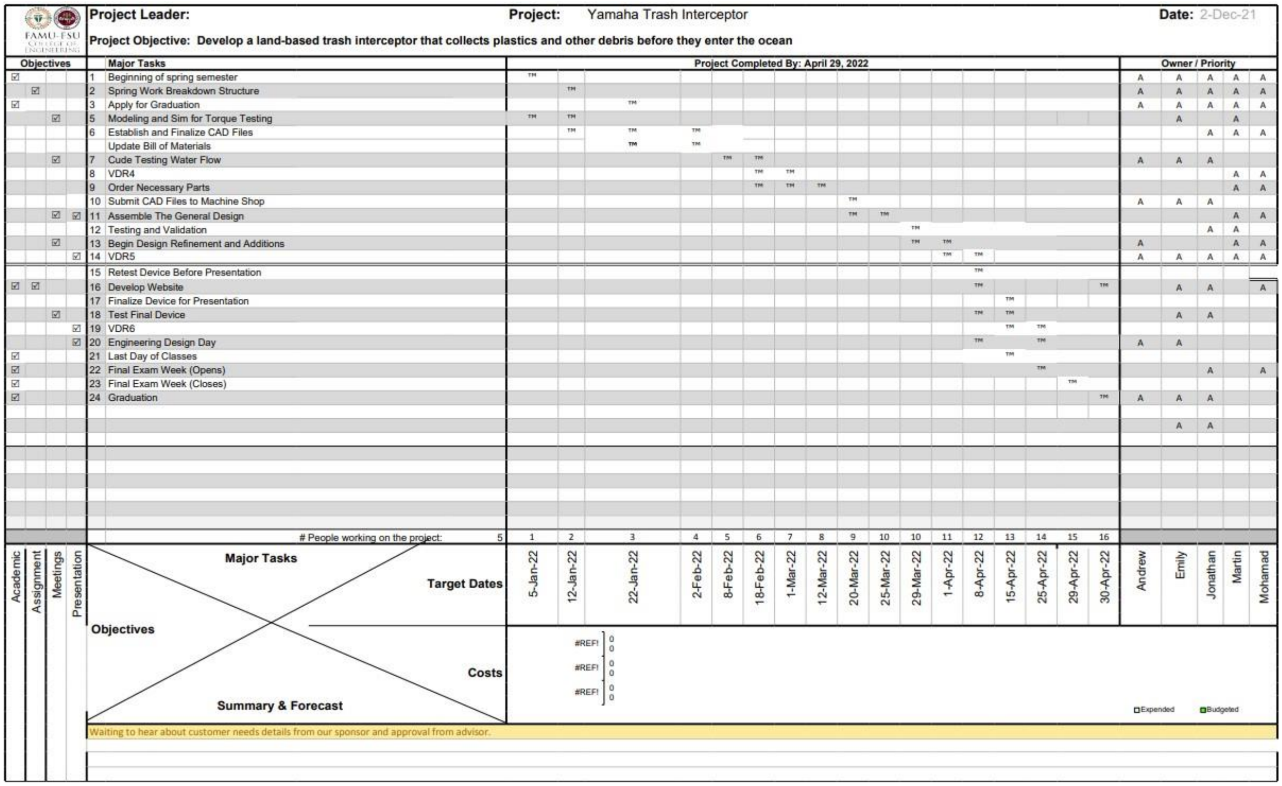

Figure 7 Spring Project Plan

Chapter Two: EML 4552C

2.1 Spring Plan

2.1.1 Project Plan

Shown below in figure 8 is the Spring project plan that the team intends to follow. It contains deadlines as well as the different tasks that need to be accomplished to finish a successful trash interceptor.

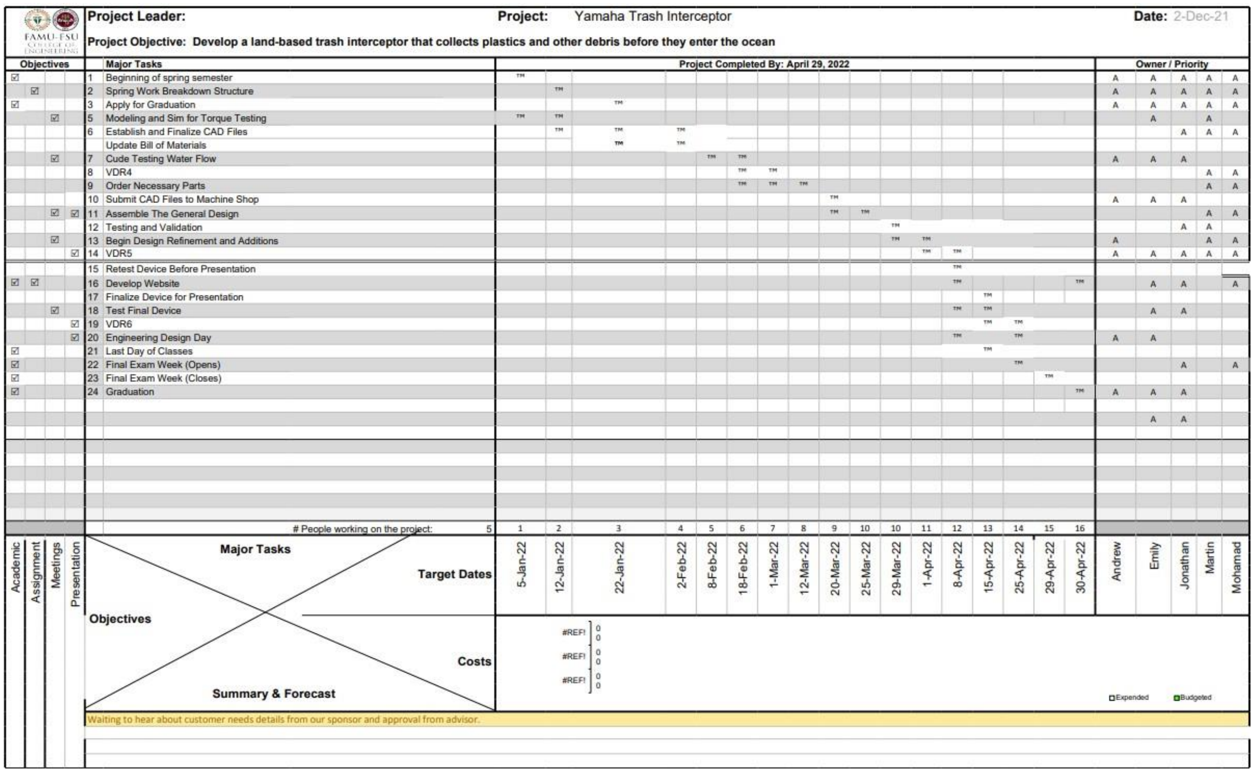

Figure 8 Spring Project Plan

2.1.2 Build Plan.

The build plan for this project will begin by finishing the CAD model for the trash interceptor design. The design must ensure that the machining and assembly of the device can be done with ease, while also making sure that the device meets all of the targets and metrics in place. Once the full CAD assembly is done, engineering drawings were created to have the necessary materials machined. These engineering drawings can be seen in appendix H. The drawings and materials were brought to the FAMU-FSU College of Engineering machine shop.

After the machine shop returned the machined parts, assembly began. Since one of the materials that was purchased was unable to be machined at the machine shop, they had to be machined elsewhere. The base was constructed, and the rectangular tube legs were installed. The basket was then placed onto the inner leg. The motor and pulleys were then installed to transmit power from the motor to the rotating baskets. Once everything was assembled, testing began to ensure that the targets that are in place were met. A few modifications had to be done before meeting the initial targets. Once modified, the targets and metrics were confirmed.

2.2 Results

The following sections outline the results of the trash interceptor and the way that the targets in place were able to be validated.

2.2.1 Weight Limit Results

According to MIL-STD-1472G, Section 5.8.6.2.5, “Individual portions of equipment shall not exceed 35 pounds, per person with load balanced equally.” With that being said, the subassemblies of the trash interceptor could not surpass 105 pounds with only three contractors deploying the device. The target that team 518 put in place was that each subassembly would not surpass 100 pounds, to have a little bit of room to play with. With that being said the heaviest subassembly that was created only weighed 61.4 lbs. This maximum weight allowed the device to be well under the target for the weight of each part. This was able to be validated by weighing each of the different subassemblies to ensure that they were under the weight limit.

2.2.2 Vertical Expansion Results

One of the main targets that team 518 has was to make sure the device was able to scale to many different depths of water. This was executed by implementing a flotation system. Two, 3-gallon jugs were attached to both legs to make sure that the device expanded at the same time to provide a level rotating shaft. Testing took place in the Wakulla River. The device was deployed into the river and was moved around to many different depths. At some depths the device was able to expand too high. This is when the buoys were able to be ballasted with water to provide the correct height. Through physical testing, it was confirmed that the device was able to expand the necessary 2 feet to 5 feet. This met the metric that was in place for the vertical expansion.

2.2.3 Solar Panel Testing Results

Due to our device trying to preserve the environment, it was important for the trash interceptor to be powered via a renewable energy source. The team researched all different types of sources, but due to the device being placed primarily in the Southeast United States, solar energy was the most readily available. The team purchased one solar panel to test to determine the adequate amount of solar panel area that would be needed to power the interceptor. Through testing the one solar panel over multiple days, simulations were able to be done to determine how many solar panels, as well as how much area of solar panel would be needed to completely charge the battery and run the device. Through these simulations, it was determined that the device would need four, 36 cell solar panels. This will be enough to run the device for the amount of time that was set forth while creating targets and metrics.

2.2.4 Collecting Results

Another main target that the team put in place was that the trash interceptor had enough power to not only collect 20 pounds of trash at one time, but also to have enough power to rotate through the water. It was also very important to achieve at least a 70% collection efficiency in the first rotation of the basket. After testing the device with the motor, the motor did have enough torque to completely rotate the baskets while having 20 pounds of trash in it, while also rotating through the water. The calculations for the amount of torque necessary for the device can be seen in appendix J. When testing with dixie cups and golf balls, it was determined that 73.3% of trash was being collected on the first rotation. The rest of the trash was being picked up with the subsequent rotations of the basket. The reason that the trash was missing the reservoir was hitting the end of the shaft, so to increase the efficiency, the shaft would need to be cut just a little bit shorter. All of the testing for trash collection was physically tested using the trash interceptor model.

2.3 Discussion

The trash interceptor created by the team was able to meet almost all of the critical targets and metrics that were set forth during the project. It was able to collect the necessary amount of trash at one time, was able to vertically expand the correct distance, and each subassembly weighed in at a weight that was less than the targeted weight.

One thing that could have created a more efficient device was the slot that was cut out of the rectangular tubes. This could have been just a little bit smaller to ensure that the buoys do not get crooked at all. This will provide a more efficient and quicker vertical expansion of the rotating baskets with the water level.

While testing the efficiency of the collection, it was noticed that as the trash was sliding out of the device, it was hitting the rotating shaft before entering the reservoir. This made the trash bounce off of the shaft and back into the water instead of going into the reservoir. To ensure that this doesn't happen the aluminum shaft can be cut down just a little bit more on this side to ensure that the trash goes into the basket rather than hitting the shaft.

One last thing that was causing the team issues was passing the wires from the battery to the speed controller and motor. Since, the motor is on the opposite side of where the solar panels and battery are located, a better way of insulating and passing the wires through the device is needed. One solution to this that the team has come up with is having a more hollow base to allow for the wires to pass through the base and up into the motor housing to attach to the motor.

2.4 Conclusions

Clearing trash and plastics from storm drains before allowing it to disperse into larger bodies of water will allow for cleaner oceans and lakes. Without the implementation of trash interceptors in storm drains, oceans will continue to fill up with trash and plastics. Team 518's trash interceptor provides an economical, expendable, and efficient way to rid these storm drains of plastics. The modular style of the device, as well as being powered by a renewable energy source, allows the trash interceptor to be placed into these storm drains rather easily. With all of the features that the trash interceptor possesses, there is a near-seamless transition into these small municipalities to begin removing trash, beginning to preserve the environment.

2.5 Future Work

To continue building off of the current trash interceptor, a full-sized model would need to be created in order for the interceptor to be implemented into small municipalities. Floating booms will need to be quoted in order to adhere to the dimensions of the storm drain. This will allow the trash to be funneled into the device to remove trash from the storm drain, before being able to reach the ocean.

Another stage of this project that can be continued would be to allow for the device to be controlled remotely from wherever the operator would be located. This would allow the operator to be prepared to turn the device on when a large storm is anticipated without having to go to the device and manually turn it on. The device would be able to be connected via and IoT (internet of things) device between the device and the operator.

A larger collection area in the basket can also be implemented, so that more trash can be collected in the first rotation of the basket. This could be executed by having larger baskets so that the slide can be lower down on the basket, hence increasing the collection area.

Lastly, the correct number of solar panels to provide the device with necessary power can be set up and wired to charge the battery. This will allow for the device to be powered via a renewable energy source. These will be set up with the battery underneath it, with wiring over to the motor.

2.6 References

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Appendix A: Code of Conduct

Mission Statement

Our mission is to create a trash interceptor delivered with consideration, ease, and innovation.

Outside Obligations

Andrew Walker:

Works on Sunday morning between 7 am and 2 pm.

Emily Haggard:

Works 15 hours per week

Jonathan Draigh:

Works 10 hours a week during school time as a teacher assistant. Mentors Lab sessions every Tuesday and Thursday. Grades Assignments and Exam.

Martin Senf:

Works 15-20 hours a week. Work shifts end at 5:00 PM.

Mohamad Kassem:

Is out of town working on Mondays, Wednesdays, and Fridays until 6 pm.

Team Roles

Andrew Walker: Has a strong ability in communication in many aspects. Strong design background. Exemplary work in multiple CAD systems including Autodesk Inventor and Creo Parametric.

Emily Haggard: Thorough research and prototyping experience. Expanding knowledge in the field of sustainable energy. Responsible for submitting documents when all other team members are unavailable.

Jonathan Draigh: Strong public speaking abilities. Exemplifies strong ability in drawing and sketching designs and then translating that into 3D modeling software such as Creo Parametric.

Martin Senf: Research, work with different CAD systems and designing tools, has programming experience in different languages (C++, Matlab).

Mohamed Kassem: Demonstrates strong problem solving and communication skills. Basic knowledge in designing and analyzing control systems. Knowledgeable of multiple coding languages. Automotive technical skills and hands-on experience.

Other duties

In case of having extra assignments and/or tasks to be completed, a team member (one or more) will be assigned based on availability and expertise to complete that certain task.

Communication

When the group electronically communicates amongst each other the predominant form of communication is iMessage group chat. This group chat shall never be muted in such a way that it could be of detriment to communication with the group. This form of communication is not to be abused by any form of Spamming or school-related discussion to ensure the purity of the communication forum.

If a member is unable to attend any meetings either with the Group or with anyone outside the group that member is to inform the group and attempt to call in either via phone call, Zoom, or Microsoft Teams.

To ensure the ease of scheduling, outside obligations interfering with group obligations need to be scheduled on the group outlook calendar at the earliest connivance.

When the group electronically communicates with anyone outside the group the agreed-upon forum is email, Zoom, or Microsoft Teams. All communication shall be professional please refer to the appropriate code of conduct section for more information on professional communication.

The team is expecting all group members to respond to either texts or emails within 24 hours of them being sent. This will ensure that all members are aware of what is happening and if extra work must be done to complete an assignment. Communication is vital when having to miss a meeting or when something comes up, so to ensure that all group members are kept in the loop, at most, a 24 hour response time is needed.

Dress Code

Our team has agreed to comply with different dress codes throughout the project. We chose to divide it into four main categories:

Class Meetings:

The use of business casual attire was decided, which combines traditional business wear with a more relaxed style still professional and appropriate enough for an office environment.

Advisor/Sponsor Meetings:

When meeting with our advisor, the dress code would be similar to class meetings. However, team members are encouraged to dress nicer for such encounters.

Presentations:

Presenting to other people requires the use of business formal attire, characterized by a suit jacket with matching pants or a skirt, and includes the use of a shirt and a tie.

Group Meetings:

Team meetings tend to be more relaxed, thus we agreed that the casual dress code is appropriated; casual attire refers to clothing that is informal and comfortable, yet clean and professional.

Attendance Policy

Members shall attempt to make all meetings that have been scheduled with at least a forty-eight-hour notice unless scheduling conflicts have been clearly added to the group calendar.

In case of emergency or unforeseen circumstances, all members shall be respectful in discussing tardiness or absence. Respect is to be the pinnacle of the attendance policy. Both sides shall be heard and understood as each member has varying time constraints, and difficulties.

If a member is late to a group meeting that does not involve the sponsor or advisor, the present members will decide to either start the meeting on time or to wait at most fifteen minutes before proceeding without the tardy party.

If a member is late to a group meeting that involves the sponsor or advisor, the present members will respectfully begin the meeting no later than five minutes after the planned meeting time. This is to ensure that the sponsor or advisor's time is well respected and not wasted.

If a member is repeatedly tardy or absent from meetings, please refer to the necessary code of conduct section to resolve the situation

How to respond to people in a professional meeting

It is important to know how to respond to people in professional meetings. One of the main steps to be followed is to always talk respectfully under any circumstances. Body language is another essential aspect that must be looked at in professional gatherings since it tells a lot about one's commitment and professionality. In addition, being well prepared for what is going to be discussed in a meeting will make a significant impact. The use of proper and formal language is recommended to make a good impression, however, making yourself understood should be a priority.

What do we do before Dr. McConomy or TA's

Before contacting Dr. McConomy our group attempt to have open and honest communication with the team member who is not in compliance with this document. We will respectfully and earnestly attempt to resolve the issue on our own without judgment or basis. If a team member does not deliver on an agreed-upon task with no communication to the group and without proof of a valid excuse, they will be expected to contribute double their work in the following deliverable. If there continues to be an issue, then Dr. McConomy will be contacted.

At what point do we contact Dr. McConomy

After talking as a team, and nothing seems to be changing, Dr. McConomy will be called upon to try to resolve the conflict. This will only be after the entire team has communicated and tried to fix the problem ourselves before getting Dr. McConomy involved. If the issue can be resolved amongst ourselves, Dr. McConomy will not be contacted.

What we want Dr. McConomy to do when going to him

When going to Dr. McConomy with an issue, we want him to hear both sides of what is going on and if he sees a flaw in one of the stories, talk to that person individually. We want Dr. McConomy to try to help the situation and try to learn what is going on if that individual is not communicating with other team members. We don’t want that individual to receive punishment or anything of that sort but rather have Dr. McConomy aware of the situation in case it becomes worse, and action must be taken. If the issue does not get fixed, we will go back to Dr. McConomy to see if he has any ideas on what could be a potential fix to the problem or take action on the issue.

Amending the Code of Conduct

To amend/change the code of conduct, it must be a unanimous decision among team members. Every team member must be present and communicating when changes are being made. When changes have been unanimously decided, a new copy of the code of conduct must be printed and resigned by every team member. The change of the code of conduct does not go into effect until every team member signs the new document.

Statement of Understanding

I understand all content discussed above including the dress code, attendance policy, professional expectations, and communications methods. This is a living document and is subject to change upon proper approval from the group.

Team Members

Signed September, 7 2021

X ______________________________

Andrew W. Walker

X ______________________________

Emily C. Haggard

X ______________________________

Jonathan Z. Draigh

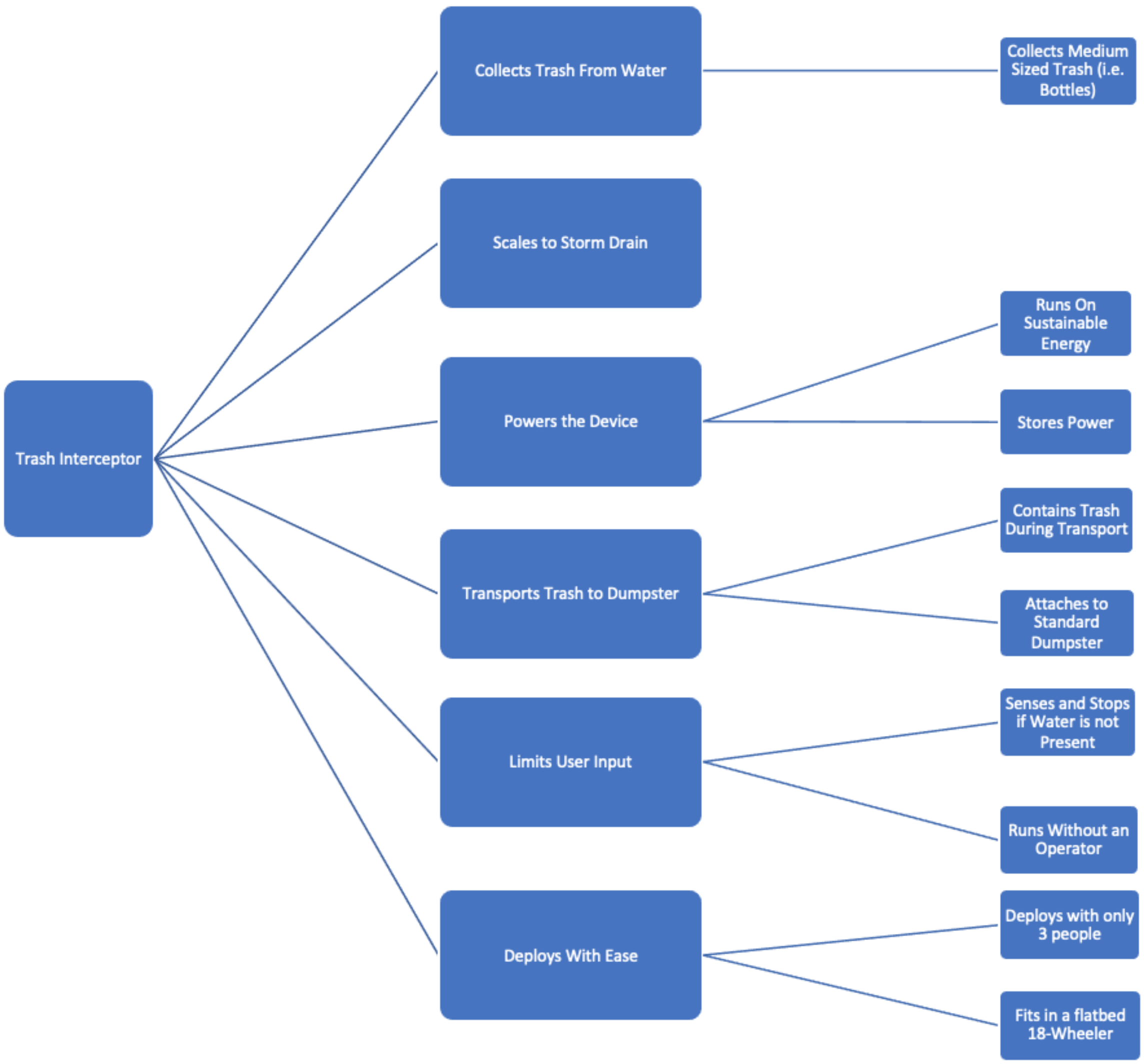
X ______________________________

Martin M. Senf

X ______________________________

Mohamad A. Kassem

Appendix B: Functional Decomposition



	Collects Trash From Water	Powers The Device	Transports Trash To Dumpster	Limits User Input	Deploys With Ease	Scales to Storm Drain	Total
Collects Medium Sized Trash	X			X		X	3
Runs On Sustainable Energy		X		X	X		3
Stores Power		X		X			2
Contains Trash During Transport	X		X	X			3
Attaches to Standard Dumpster	X			X	X		3
Senses & Stops If Water Is Not Present				X		X	2
Runs Without An Operator	X		X	X			3
Deploys With Only 3 People					X		1
Fits On A Flatbed 18-Wheeler					X		1
Total	5	2	2	8	4	2	

Appendix C: Target Catalog

Table 13 Target Catalog and Summary

System	*Function*	*Target*	*Metric*
Scalability	**Horizontal Expansion**	**20 [ft]**	**Width**
Scalability	**Vertical Expansion**	**7 [ft]**	**Height**
Scalability	Device Width	5.96 [ft]	Width
Collecting	**Intercepting**	**0.046 [ft^3]**	**Volume**
Collecting	Intercepting	20 [lbs]	Weight
Collecting	Intercepting	2 [ft]	Depth
Limiting User Direct Contact	IoT Remote Monitoring	Anywhere	Range
Limiting User Direct Contact	IoT Remote Controlling	Anywhere	Range
Limiting User Direct Contact	IoT Remote Controlling	2 [miles]	Range
Limiting User Direct Contact	Easy Access	41 ft x 14.67 ft x 8.2 ft (LxWxH)	Volume
Power	Power	11.67 $[\frac{lb*ft}{s^2}]$	Force

Power	Duration of Transport	60 [sec]	Time
Deploying	**Assembling**	**45-60 [lbs]**	**Weight**
Deploying	**Transporting**	**48-53 [ft] X 8.5 [ft] (LxW)**	**Area**
Deploying	Transporting	8.17[ft] X 5.4[ft]	Area

Appendix D: Concept Generation

Concept Generation List

Biomimicry

1. Floating barrier and a conveyer on top of it with a scooping mechanism similar to that of a pelican.
2. Arms that go into the water and pluck the trash out of the water and swivel and place trash in dumpster mimicking a bird catching fish.
3. Arms that have suction that suction the trash to the device and then placed into the dumpster like that of an octopus.
4. A system that has a sensor that can sense when trash his flowing through it and scoops it out mimicking a dog drinking water.
5. A device that has some sort of filtering teeth that mimics a whale.
6. A device that has many different arms going into the water when trash is sensed mimicking a crab claw.
7. A device that bonks trash out of the water mimicking a seal that smacks the trash into the dumpster.
8. A device that mimics a grouper that sits on the water's edge and sucks the floating trash up.
9. Two wing like structures that have nets attached that when full will rotate and flip trash into dumpster and return to their initial positions.
10. A device that mimics a living vine that sees the trash wraps it up and lifts is up and puts in the dumpster.

General Ideas

11. System of conveyor belts with one acting like a funnel to another belt before going into trash powered by solar panels.
12. System of conveyor belts with one acting like a funnel to another belt before going into trash powered by wind energy.
13. Floating wall nozzle to a conveyor belt system to the dumpster with solar panels to power.
14. Floating wall nozzle to a conveyor belt system to the dumpster with wind energy to power.
15. Floating wall nozzle to a conveyor belt system to a slide that places the trash into the dumpster with solar panels to power.
16. Floating wall nozzle to a conveyor belt system to a slide that places the trash into the dumpster with wind energy to power.
17. Multiple arms with scoopers with holes that are just big enough for water to go out of it but not the trash and then swiveling to bring trash to the dumpster.
18. A net that catches the trash and once full gets lifted out of the storm drain and dumped into the dumpster.
19. A double type of nozzle that is assembled with conveyor belts that resembles a funnel and a conveyor belt that is in the middle of the drain and brings trash into the dumpster.
20. A filter type mechanism that allows water to continue to flow through it but catches the trash and then gets transported to the dumpster through a crane type.

21. Multiple arms with scoopers which are constantly picking trash out of the flowing water.
22. A capsule that has an open front and closed sides, but the back has small holes to allow water to flow through it, but not large enough for trash to escape and once full, dumped into dumpster and then returned to the water.
23. A water wheel that has a conveyor belt through the middle and the water wheel spins and then the trash slides to the middle of the wheel and then taken to the dumpster with a conveyor belt powered by solar energy.
24. A water wheel that has a conveyor belt through the middle and the water wheel spins and then the trash slides to the middle of the wheel and then taken to the dumpster with a conveyor belt powered by wind energy.
25. A helical water wheel that catches trash from the floating wall, the wheel has cubies that hold the trash until the top of wheel where it's released into a shoot that leads to the dumpster. Powered by solar energy.
26. Clothesline like device that cascades a net or fabric like material down into the water when the net fills the connecting strings on two bottom corners contract pulling the net into a sack to be shifted over and dumped into the dumpster.
27. Angled vertical rotating shelves that catch water at the bottom and then stop at the top to release trash into the dumpster.
28. Horizontal vertical rotating shelves that catch water at the bottom and then stop at the top to release trash into the dumpster that uses a vacuum to pull trash out of the shelf and into the dumpster.

29. Expandable triangle shaped funnel that is made of metal mesh and collects trash and places trash on the conveyor belt and dumps the trash into the dumpster.
30. Rotating scoops that collect trash as they rotate trash is falls into the channel that is angle towards the dumpster.
31. A single conveyor belt which is angling trash to one side of the storm drain which is then carried out of the storm drain via another conveyor belt which then deposits the trash into a separate reservoir with another conveyor belt out of the second reservoir to go into the dumpster to ensure that trash is not continually being dumped as the dumpster is gone. The trash will be flowing in the right direction due a jet connected to the conveyor belt taking the trash out of the storm drain.
32. Scoop catapult like device that clamps onto the dumpster itself and lies in the middle of an expandable metal mesh that angles all the trash towards the middle and then when full dumps trash into the dumpster.
33. A helical water wheel that catches trash from a funnel, the wheel has cubies that hold the trash until the top of wheel where it’s released into a shoot that leads to the dumpster. Powered by wind energy.
34. Water skimming floating arms that collect trash with metal spikes and push it into a trough like bin that when full gets pulled up and dumped into a reservoir that has a conveyor belt attached that the carries the trash into the dumpster.
35. Rotating trough shaped scoop that collects trash as it rotates about an expandable metal rod so that as trash falls into the channel that is angle towards the dumpster

36. Water skimming floating arms that collect trash with metal spikes and push it into a trough like bin that when it gets full pulls up to the side of the storm drain and dumped into a reservoir that is attached to a conveyor belt that dumps trash into the dumpster.
37. Collapsible metal mesh that expands across the storm drain that a nozzle directs all the trash on to it, it would then push all the trash into a trough on the side of the storm drain by collapsing upward slightly. From there through a conveyor belt would deliver the trash to the dumpster.
38. Scoop catapult like device that clamps onto the dumpster itself and lies in the middle of an expandable metal mesh that angles all the trash towards the middle and then when full dumps trash into the dumpster. Solar powered and helical screw based.
39. A design like an Alaskan fishwheel that scoops the trash out of the water and as the net rotates the trash slides to the center where there is an inclined plane on each scoop that slides the trash to side of the net and into the dumpster. This can be paired with a floating wall that uses the water flow to bring the trash to one side of the drain and onto the conveyor belt that dumps the trash into the dumpster.
40. A design like an Alaskan fishwheel that scoops the trash out of the water and as the net rotates the trash slides to the center where there is an inclined plane on each scoop that slides the trash to side of the net and into the dumpster. This can be paired with a jet that increases the water flow creating a whirlpool to bring the trash to one side of the drain.

41. A design like a water wheel that scoops the trash out of the water and as the net rotates the trash slides to the center where there is a single inclined plane at the pivot point that slides the trash to side of the device and onto the conveyor belt that dumps the trash into the dumpster.
42. A device that shaped like a trash can that is semi submerged into the water that sucks up the top inch of water into a tube that dispenses into the dumpster. In the dumpster it filters the trash and the water and puts the water back into the stream. This system is most beneficial when thinking of microplastics as well.
43. A device that hooks onto the dumpster and is shaped like an L and pivots at the dumpster and dumps the trash into the dumpster.
44. A Laser that hangs over the storm drain and vaporizes the trash away.
45. Set the device up as a claw game. It is free to play and for every 10 pounds picked up it gives a small prize. This has it set up, so people do the work and learn about taking care of the environment for a small prize.
46. A design like a butterfly net that fills with trash and then every 12 hours raises up and dumps itself into the dumpster.
47. Create a whirlpool at the base of a vacuum that pulls the trash out of the water
48. A device like the fly trap that keeps the flies alive. It would sit in the center of the drain and spin in a circle with arms that pull all the trash into a screw like system that pulls the trash up and out of the water and dispenses it into the dumpster.
49. Net like that they use to catch animals in the jungle. Like the one they use in Tarzan

50. A floating dam “barrier” that guides debris into a waterwheel. The water wheel acts as a gate that only opens when water is present and flowing. Then the debris is carried on a conveyer belt and guided into the dumpster.
51. Something like a crab claw with a net in between.
52. A rotating wheel that flips the trash into a net, once the net is full it raises to drop them into the trash bin.
53. Water pump that pumps the water upward into the trash bin. Design a trash bin with the same outer design as that of a typical trash bin. However, on the inside the bin has a filtration system. “Diaper idea”
54. Guide the water through a water pump into punctured conveyer belt that guides trash into dumpster. The water dropping from conveyer can generate energy by dropping into a water wheel.
55. A structure in the pipes similar to that of a catalytic converter could help eliminate microplastics.
56. Wooden punctured wide boy bucket connected to an elevating arm immersed behind the debris barrier. When enough debris is collected we elevate the bucket shaped collector and dump it into the dumpster
57. Wooden dam that allows fish to pass through it “if fish were present in storm drain” connected to a conveyer belt. The belt is linked to a slide that is punctured allowing debris to slide directly into the dumpster using gravity and get rid of as much water as possible, of what the debris is carrying.

58. A spider web like net that would capture trash of the size we desire, yet allows fish to pass through it, since fish can swim and move however trash doesn't
59. Hydrodynamic Separators. Water is guided into a pipe the pipe has a pump that supplies enough force to push the water into a hydrodynamic separator. The separator hence separates water from debris and collects the trash and allows water to exit. The trash is collected in some way
60. Debris Separating Baffle Box. We a funnel shape directing lines that guide the water to a triangle shaped gate that separates debris from water into two chambers. Whenever we intend to empty the chamber. The gate folds to close the path of that chamber and guide debris into the second one. the chambers are portable for dumping.
61. A floating pipe that would funnel all the plastic to the center of the waterway, where it would encounter a significant larger tube placed vertically. The debris/plastic would by sucked in by a pump, which would drain the water and transfer it to the dumpster.
62. A land-based device that goes from to side to side (size is adjustable) with a plastic mesh/ or a wire cloth inside, filtering all the debris going through; the waste accumulated is moved to the dumpster by a conveyor belt placed at an angle.
63. Three metals barriers on each side placed at an angle that intercepts any plastic going through a waterway. The accumulated trash stays at the end (back) of the land-based device until it is sucked in by a pipe. Before transferring the waster to the dumpster, the water is drained out.

Crapshoot

64. An air pump tube placed at the bottom of the desired waterway that would push the waste to the surface as well as directing it to one side, where it could be picked up by a tube/conveyor belt.
65. Water Roomba this is a boat Roomba that collects trash near the device and then goes to a centralized location where it attaches to a "docking station" where it is automatically emptied into the dumpster and works as a charging station for the water Roomba.
66. Water skimming floating arms that collect trash with metal spikes and push it into a trough like bin that when full gets pulled up and dumped into the dumpster.
67. Two floating tubes point to the center of the waterway with a propeller in the center that would make the plastic debris go into a container; once the container/basket (drain) is full, it would be transferred to the standard dumpster by a moving ramp.
68. A net placed two feet underwater, side to side, with a connecting tube that allows it to be emptied instantly/ or when it is full. This tube is directly connected to a second container, which acts as a drain, then it is transferred to the standard dumpster.
69. A giant floating tube, placed closely to the exit of a storm drain, that is also connected to the sides. This giant tube has a filter inside which allows water to go through it; the plastic waste filtered is then moved up by a ramp coming from the side of the waterway, where the dumpster is fixed.

70. An anchored device placed at the center of the waterway, with two moving floating booms. The angle of the booms would force plastic in the direction of the device.

71. A scalable conveyor belt placed at an angle, two feet underwater, which senses when there is water flowing. It would elevate the plastic waste to a drain basket/container, then it gets moved to the standard dumpster.

72. A floating boom placed at an angle that directs the waste to one side of the storm drain where there is a propeller. The propeller leads the plastic debris to a drain, which is then moved to the dumpster on the side of the waterway.

73. A rotating shelf, with holes to filter out the water, fixed on one side of the waterway that elevates the trash collected and dumps it to an intermediate container. A water jet activates when there is water flowing directing the trash to the side, which is then moved to the dumpster by a conveyor belt system.

74. A metal cage, made of wire mesh, that covers the waterway from side to side. It contains a tube attached to the back of it whose function is to empty out the cage as the waste comes in.

75. A snorkel placed on one side of the waterway, activated by a pump that sends all the plastic up to a middle container before being transferred to the dumpster.

76. Two floating booms point towards the center of the waterway with an air pump tube placed at the bottom to push the plastic waste up, where it encounters a tube that is connected to the dumpster.

77. A large Seabin, anchored at the center of the waterway directed by a floating barrier at an angle, with an U-tube sucking up the waste (without any water), moving it straight to the dumpster by a pump.
78. A stationary rotating device with wings around it that filters out the plastic waste, moving it to one side of the waterway, where it encounters an elevating conveyor belt that is connected to the dumpster.
79. A walking perforated belt, from side to side, that is elevated above the water level attached to an intermediate container, then the waste gets moved to the dumpster place on the side of the waterway.
80. A stationary floating device with a wire mesh, scoop shaped, at the front that rotates backwards moving the plastic to the back of the device. The trash is transferred to a dumpster by a tube.
81. A giant rotating wheel with holes that allow the water to be separated from the plastic waste. The plastic is moved to one of the sides of the water by a treadmill, where the dumpster is located.
82. A floating boom connecting from one side to the other, on a curved shaped, with a conveyor belt going up on top of the waterway wall moving the plastic waste to the dumpster.

Morphological Chart

83. **11211** A conveyor belt will angle the trash to another conveyor belt that will remove the trash from the storm drain which is connected to the ground via cement, powered by solar energy with a jet accelerating the water
84. **11212** A conveyor belt will angle the trash to another conveyor belt that will remove the trash from the storm drain which is connected to the ground via cement, powered by solar energy with a whirlpool accelerating the water
85. **11213** A conveyor belt will angle the trash to another conveyor belt that will remove the trash from the storm drain which is connected to the ground via cement, powered by solar energy with a super cavitation accelerating the water
86. **11313** A conveyor belt will angle the trash to another conveyor belt that will remove the trash from the storm drain which is connected to the ground via cement, powered by wind energy with a super cavitation accelerating the water
87. **11113** A conveyor belt will angle the trash to another conveyor belt that will remove the trash from the storm drain which is connected to the ground via cement, powered by water energy with a super cavitation accelerating the water
88. **12221** A conveyor belt angling trash towards a wheel that will remove the trash out of the storm drain being powered by solar energy, connected to the ground via corkscrews with a jet that will accelerate the water to ensure that the trash flows in the direction that is needed
89. **13323** A floating wall will angle the trash towards a tube system that is connected to the ground via a corkscrew that is powered by wind energy that has a super cavitation to ensure trash is flowing in the correct direction

90. **21211** A floating wall will angle the trash towards a conveyor belt connected to the ground via cement, powered with solar energy with a jet accelerating the water
91. **31211** An angled bubble barrier will angle the trash towards a conveyor belt connected to the ground via cement, powered by solar energy with a jet accelerator
92. **12311** A conveyor belt will angle the trash towards a wheel which will be connected to the ground via cement powered by solar energy with a jet water accelerator
93. **13211** A conveyor belt will angle the trash towards a series of tubing, connected to the ground via cement, powered by solar energy, with a jet water accelerator
94. **14311** A conveyor belt will angle the trash towards a series of arms, connected to the ground via cement, powered by wind energy, with a jet water accelerator
95. **21212** A floating wall will angle the trash towards a conveyor belt connected to the ground via cement, powered with solar energy with a whirlpool accelerating the water
96. **23213** A floating wall will angle the trash towards a tube connected to the ground with cement powered by solar energy with super cavitation to accelerate trash and water towards the tubes
97. **32211** An angled bubble barrier will angle the trash towards a wheel connected to the ground via cement, powered by solar energy with a jet accelerator
98. **33211** An angled bubble barrier will angle the trash towards a tube connected to the ground via cement, powered by solar energy with a jet accelerator

99. **34211** An angled bubble barrier will angle the trash towards a set of arms connected to the ground via cement, powered by solar energy with a jet accelerator

100. **21131**A floating wall will angle the trash from the storm drain onto a conveyor belt which will take the trash out of the storm drain powered by water energy with an anchor type attachment to the sides of the storm drain to make sure it has good stability with a jet accelerator to ensure trash is making it to the conveyor belt which will then go into the dumpster

Table 14 Morphological Chart

Function		Solution			
		1	2	3	4
1	Nozzle	Conveyor	Floating Wall	Angled Bubble Barrier	
2	Collecting Trash	Conveyor	Wheel	Tubes	Arms
3	Power	Water	Solar	Wind	
4	Connection to Ground	Cement Pad	Corkscrew	Anchor	
5	Water Accelerator	Jet	Whirlpool	Super Cavitation	

Appendix E – Binary Pairwise Comparison

Table 15: Binary Pairwise Comparison

Customer Need	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	Sum
#1	-	0	1	0	0	0	0	0	1	0	0	0	0	2
#2	1	-	0	0	1	0	0	0	1	0	0	0	0	3
#3	0	1	-	0	0	0	0	0	1	0	0	0	0	2
#4	1	1	1	-	1	1	1	0	1	1	1	1	1	11
#5	1	0	1	0	-	0	0	0	1	0	0	0	0	3
#6	1	1	1	0	1	-	1	0	1	0	0	1	1	8
#7	1	1	1	0	1	0	-	0	1	1	1	1	1	9
#8	1	1	1	1	1	1	1	-	1	1	1	1	1	12
#9	0	0	0	0	0	0	0	0	-	0	0	0	0	0
#10	1	1	1	0	1	1	0	0	1	-	1	1	1	9
#11	1	1	1	0	1	1	0	0	1	0	-	1	1	8
#12	1	1	1	0	1	0	0	0	1	0	0	-	1	6
#13	1	1	1	0	1	0	0	0	1	0	0	0	-	5

Appendix F – Pugh Chart

Table 16: Pugh Chart Iteration 2

Selection Criteria		Concept 88	Concept 63	Concpet 22	Concept 39	Concept 50	Concept 37	Concept 29
		Concepts						
10	DATUM: Concept 39	-	-	s	s	-	s	-
4		s	-	s	s	s	s	s
9		s	-	-	s	s	s	s
3		s	s	s	s	s	s	+
1		s	s	s	s	s	s	+
2		s	s	+	s	s	+	s
12		-	-	-	s	s	+	s
5		-	-	-	s	s	s	s
11		s	+	s	s	s	s	s
6		s	-	-	s	s	s	s
# of Pluses		0	1	1	0	0	2	2
# of Satisfactory		7	3	5	10	9	8	7
# of Minuses		3	6	4	0	1	0	1

Table 17: Pugh Chart Iteration 3

Selection Criteria		Concept 88	Concept 22	Concept 39	Concept 50	Concept 37	Concept 29
		Concepts					
10	DATUM: Concept 50	-	s	s	s	s	s
4		s	s	s	s	+	s
9		s	s	s	s	s	+
3		+	s	s	s	s	+
1		+	-	s	s	+	+
2		s	s	s	s	s	s
12		s	-	+	s	+	s
5		s	s	s	s	+	s
11		s	s	s	s	s	+
6		-	s	s	s	+	s
# of Pluses		2	0	1	0	5	4
# of Satisfactory		6	8	9	10	5	6
# of Minuses		2	2	0	0	0	0

Table 18: Pugh Chart Iteration 4

Selection Criteria		Concepts				
		Concept 88	Concept 39	Concept 50	Concept 37	Concept 29
10	DATUM: Concept 88	s	+	+	+	s
4		s	-	-	+	s
9		s	s	s	s	s
3		s	-	-	s	+
1		s	s	-	s	s
2		s	s	s	s	s
12		s	-	-	s	s
5		s	s	s	+	s
Duration of Transport		s	-	-	-	s
Intercepting Depth		s	s	s	+	s
# of Pluses		0	1	1	4	1
# of Satisfactory		10	5	4	5	9
# of Minuses		0	4	5	1	0

Appendix G – Analytical Hierarchy Process

Table 19: Concept Comparison for Target 1

Development of Candidate Set of Criteria Weights {W}

Criteria Comarison [C]

	Concept 29	Concept 37	Concept 39
Concept 29	1.00	1.00	1.00
Concept 37	1.00	1.00	1.00
Concept 39	1.00	1.00	1.00
Sum	3.00	3.00	3.00

Table 20: Normalized Concept Comparison for Target 1

Normalized Criteria Comparison Matirx [NormC]

	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.333	0.333	0.333	0.333
Concept 37	0.333	0.333	0.333	0.333
Concept 39	0.333	0.333	0.333	0.333
Sum	1.000	1.000	1.000	1.000

Table 21: Consistency Check for Concept Comparison with Target 1

Consistency Check

{Ws}= [C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./ {W} Consistency Vector
1	0.333	3
1	0.333	3
1	0.333	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Table 22: Concept Comparison for Target 2

Development of Candidate Set of Criteria Weights {W}			
Criteria Comarison [C]			
	Concept 29	Concept 37	Concept 39
Concept 29	1.00	1.00	1.00
Concept 37	1.00	1.00	1.00
Concept 39	1.00	1.00	1.00
Sum	3.00	3.00	3.00

Table 23: Normalized Concept Comparison for Target 2

Normalized Criteria Comparison Matirx [NormC]				
	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.333	0.333	0.333	0.333
Concept 37	0.333	0.333	0.333	0.333
Concept 39	0.333	0.333	0.333	0.333
Sum	1.000	1.000	1.000	1.000

Table 24: Consistency Check for Concept Comparison with Target 2

Consistency Check		
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
1	0.333	3
1	0.333	3
1	0.333	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Table 25: Concept Comparison for Target 4

Development of Candidate Set of Criteria Weights {W}			
Criteria Comarison [C]			
	Concept 29	Concept 37	Concept 39
Concept 29	1.00	0.33	0.33
Concept 37	3.00	1.00	1.00
Concept 39	3.00	1.00	1.00
Sum	7.00	2.33	2.33

Table 26: Normalized Concept Comparison for Target 4

Normalized Criteria Comparison Matirx [NormC]				
	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.143	0.143	0.143	0.143
Concept 37	0.429	0.429	0.429	0.429
Concept 39	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.000	1.000

Table 27: Consistency Check for Concept Comparison with Target 4

Consistency Check		
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
0.428571429	0.143	3
1.285714286	0.429	3
1.285714286	0.429	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Table 28: Concept Comparison for Target 5

Development of Candidate Set of Criteria Weights {W}			
Criteria Comarison [C]			
	Concept 29	Concept 37	Concept 39
Concept 29	1.00	0.33	0.33
Concept 37	3.00	1.00	1.00
Concept 39	3.00	1.00	1.00
Sum	7.00	2.33	2.33

Table 29: Normalized Concept Comparison for Target 5

Normalized Criteria Comparison Matirx [NormC]				
	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.143	0.143	0.143	0.143
Concept 37	0.429	0.429	0.429	0.429
Concept 39	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.000	1.000

Table 30: Consistency Check for Concept Comparison with Target 5

Consistency Check		
{Ws}= [C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
0.428571429	0.143	3
1.285714286	0.429	3
1.285714286	0.429	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Table 31: Concept Comparison for Target 6

Development of Candidate Set of Criteria Weights {W}			
Criteria Comarison [C]			
	Concept 29	Concept 37	Concept 39
Concept 29	1.00	0.33	0.33
Concept 37	3.00	1.00	1.00
Concept 39	3.00	1.00	1.00
Sum	7.00	2.33	2.33

Table 32: Normalized Concept Comparison for Target 6

Normalized Criteria Comparison Matirx [NormC]				
	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.143	0.143	0.333	0.206
Concept 37	0.429	0.429	0.429	0.429
Concept 39	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.190	1.063

Table 33: Consistency Check for Concept Comparison with Target 6

Consistency Check		
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
0.492063492	0.206	2.384615385
1.476190476	0.429	3.444444444
1.476190476	0.429	3.444444444

Average Consistency (λ)	3.091168091
Number of Criteria	3
Consistency Index	0.045584046
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.09

Table 34: Concept Comparison for Target 9

Development of Candidate Set of Criteria Weights {W}			
Criteria Comarison [C]			
	Concept 29	Concept 37	Concept 39
Concept 29	1.00	3.00	5.00
Concept 37	0.33	1.00	1.00
Concept 39	0.20	1.00	1.00
Sum	1.53	5.00	7.00

Table 35: Normalized Concept Comparison for Target 9

Normalized Criteria Comparison Matirx [NormC]				
	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.652	0.600	0.714	0.655
Concept 37	0.217	0.200	0.143	0.187
Concept 39	0.130	0.200	0.143	0.158
Sum	1.000	1.000	1.000	1.000

Table 36: Consistency Check for Concept Comparison with Target 9

Consistency Check		
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
2.004554865	0.655	3.058117498
0.563008972	0.187	3.014781966
0.475610766	0.158	3.014698163

Average Consistency (λ)	3.029199209
Number of Criteria	3
Consistency Index	0.014599605
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.03

Table 37: Concept Comparison for Target 10

Development of Candidate Set of Criteria Weights {W}

Criteria Comarison [C]

	Concept 29	Concept 37	Concept 39
Concept 29	1.00	0.33	0.33
Concept 37	3.00	1.00	1.00
Concept 39	3.00	1.00	1.00
Sum	7.00	2.33	2.33

Table 38: Normalized Concept Comparison for Target 10

Normalized Criteria Comparison Matirx [NormC]

	Concept 29	Concept 37	Concept 39	Criteria Weights {W}
Concept 29	0.143	0.333	0.143	0.206
Concept 37	0.429	0.429	0.429	0.429
Concept 39	0.429	0.429	0.429	0.429
Sum	1.000	1.190	1.000	1.063

Table 39: Consistency Check for Concept Comparison with Target 10

Consistency Check

{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
0.492063492	0.206	2.384615385
1.476190476	0.429	3.444444444
1.476190476	0.429	3.444444444

Average Consistency (λ)	3.091168091
Number of Criteria	3
Consistency Index	0.045584046
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.09

Appendix H – Operation Manual

Project Overview

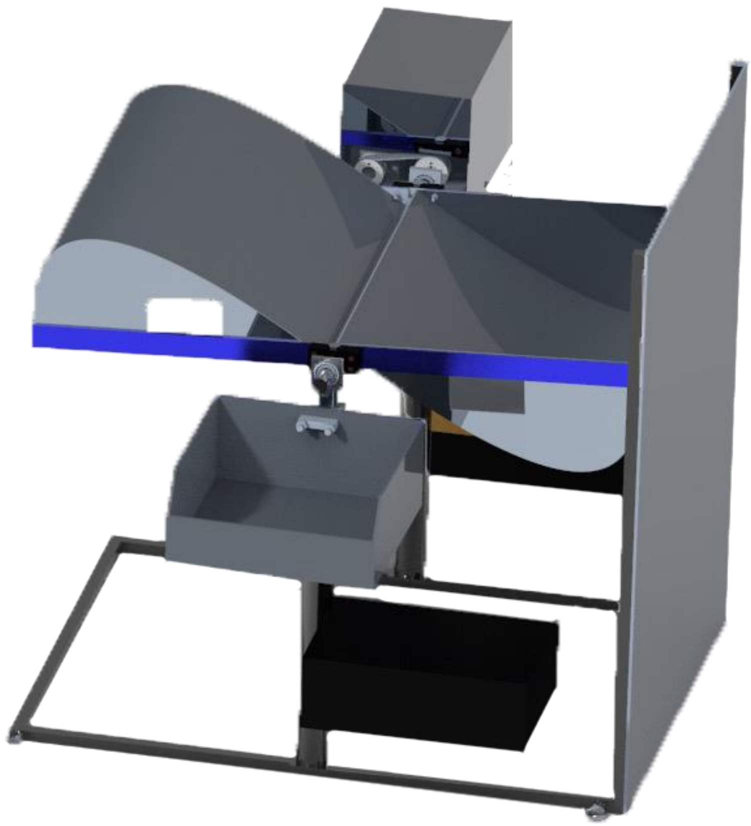


Figure 9: Trash Interceptor

Project Description

In 2019, Yamaha Motors created the Rightwaters Initiative to protect marine environments. Right now, it is estimated that for every three pounds of fish in the ocean, there is one pound of trash. By 2050, it is estimated to be a one-to-one ratio. It was determined that collecting trash in storm drains allows for trash collection early in the pollution cycle before the trash can reach larger bodies of water. This will allow trash to be collected before reaching rivers and oceans, therefore preserving marine environments. Yamaha wants to create a means of trash collection that is simple, yet effective and cost efficient.

Project Objective

The objective of this project is to implement an effective land-based trash interceptor that collects debris in storm drains to prevent trash from entering larger bodies of water.

Key Goals

A key goal for the trash interceptor is that it can scale to many different storm drains. Being scalable will result in the device being able to be used regardless of the water level in the storm drain, as well as different overall sizes of storm drains.

Another key goal is to design the trash interceptor so that it doesn't have to withstand major storms/hurricanes. However, the device will be able to withstand minor, everyday storms. This will allow the device to be expendable and easily replaced if damaged. Having the device be expendable will result in lower material costs, creating a more easily replaceable device as well as a more readily available product.

The final key goal of the trash interceptor is that the machine will be broken into modules of small subassemblies, which will result in easier deployment at the storm drain. Breaking the trash interceptor into modular subassemblies will result in lightweight modules, as well as being able to replace the specific module if damaged/broken.

Assumptions

Assumptions were made to control and narrow the scope of the project at hand. It is assumed that there will be a stable embankment where the device will be operating, meaning that there will be a stable foundation for the device. Additionally, it is assumed that the device will be installed by three skilled contractors that will be able to assemble the subassemblies without assistance from major machinery. Also, it is assumed that there will be a sustainable energy source present at the site of deployment. It is also assumed the dumpster that the trash is collected in will be emptied regularly with the city trash schedule. One last assumption is that minor disturbances to the land area around where the device is deployed is permitted.

Component/Module Description

Since one of the key goals of the trash interceptor is having a modular style, there are multiple different modular pieces of the device. These modules are the basket, the base, the motor housing, the wiring/powering, and the basket bracket. The basket module is the double-sided basket that is rotating around a center shaft collecting trash. The base module is the support system as well as providing the device with buoyancy to rise to the water level. The motor housing module is in place to provide cover to the motor. The wiring/powering module contains the wiring to the motor and battery. Finally, the basket bracket allows the basket to be removed from the device in case of issues that could arise.

Basket Module

To assemble the basket, expanded metal(aluminum), 1/8" aluminum sheets, 1/4"x2"x48" aluminum plating, and aluminum rivets are used. The tear drop shaped basket sides are water jetted from the 1/8" aluminum sheet, and the drawing can be seen in appendix A, figure 22. The basket is comprised of 4 sides of aluminum plating. Two of the aluminum plates will be cut to 48.25", the other two will be cut to 30.75 inches. A U-shape will be cut out in the direct center of the longer two plates with a 1.5" diameter. This will be cut 1.5" into plate. Four holes will be drilled through the plate, so the bracket will be able to be bolted together to the outline. These holes will have a 0.26" diameter. Seven rivet holes on each side of the U-shape cut will be drilled through the longer two aluminum plates. The corners of each of the aluminum plating will be welded together. Once this is welded, the teardrop shapes will be riveted to the inside of the aluminum outline. The expanded metal is then shaped and welded to the shape of the teardrop to make two baskets. This assembly and exploded view can be seen in figure 2 and 3, respectively.

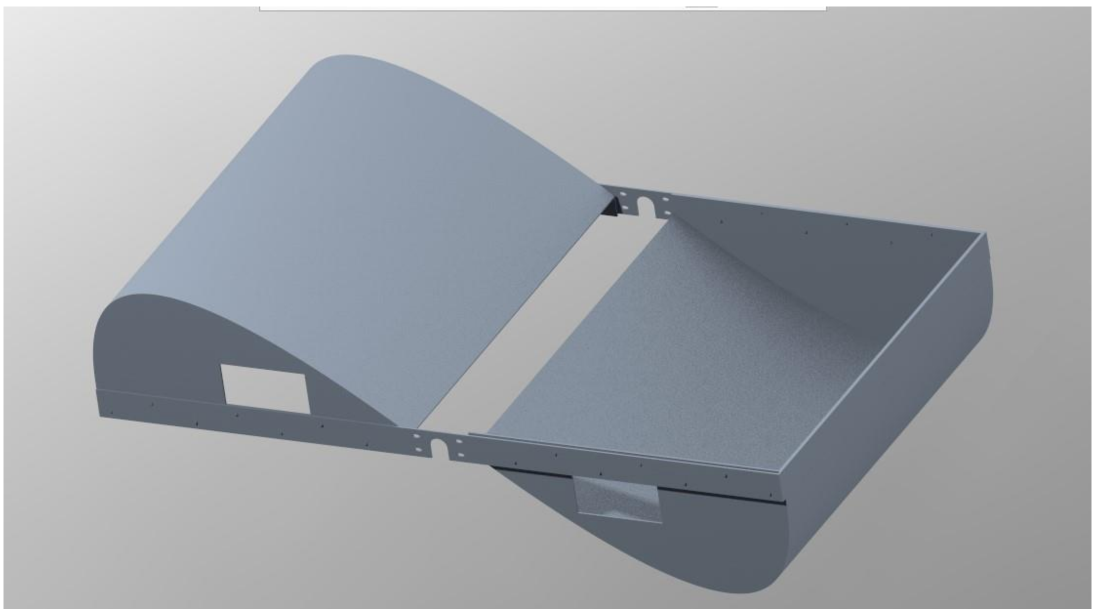


Figure 10: Full Basket Module

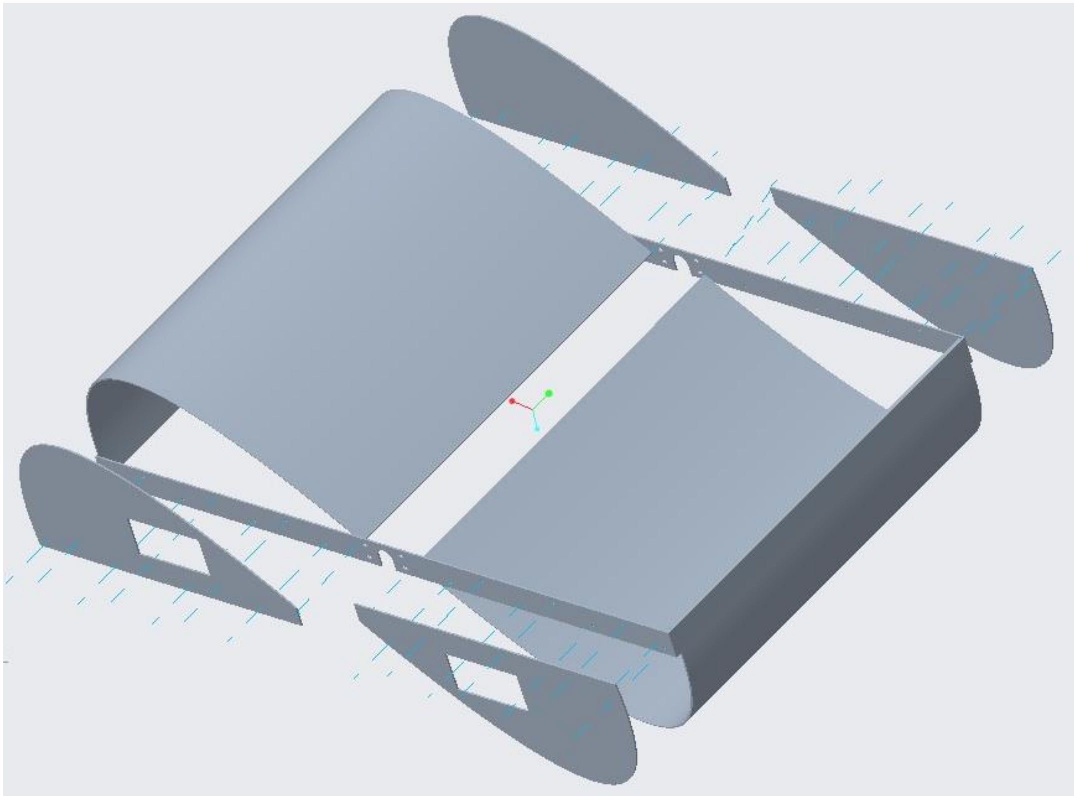


Figure 11: Exploded View of Full Basket

Base Module

The base consists of four, one inch by one inch steel bars. The length of the base is 48 inches, while the width of the base is 36 inches. One 48-inch bar will be welded together with a 36-inch bar to create an L-shape with a 90-degree corner. Two L-shapes will be made to create a rectangular base. The two corners that are not welded together will be connected via an L-bracket on the inside of the corner. The dimensions of the L-brackets are 5”x5”. Six, 2-inch, 1/4-20 bolts will be used for each bracket. The vertical rectangular tubes that are seen in figure 4 are 30 inches in length and are 1.25”x1.25”. On one side of each rectangular tube, there is a 0.5” slot cut 25.25 inches down from the top. These tubes are supported by gussets that are 4”x4”.

The gussets are fastened to the rectangular base via 2 inch, 1/4-20 bolts. The vertical part of the gusset is attached to the rectangular tube via 3 inch, 1/4-20 bolts and fastened with a nut and washer. All the holes drilled through the base bars and the vertical rectangular tubes are 5/16 of an inch. A fully assembled base and an exploded view of the base can be seen in figure 4 and 5, respectively.

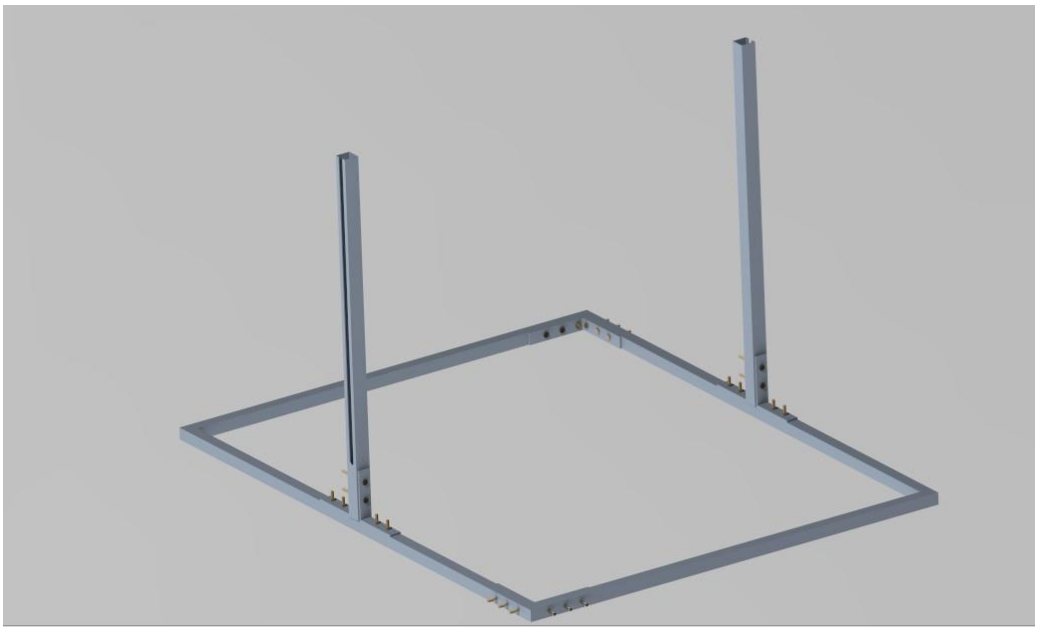


Figure 12: Full Base Module

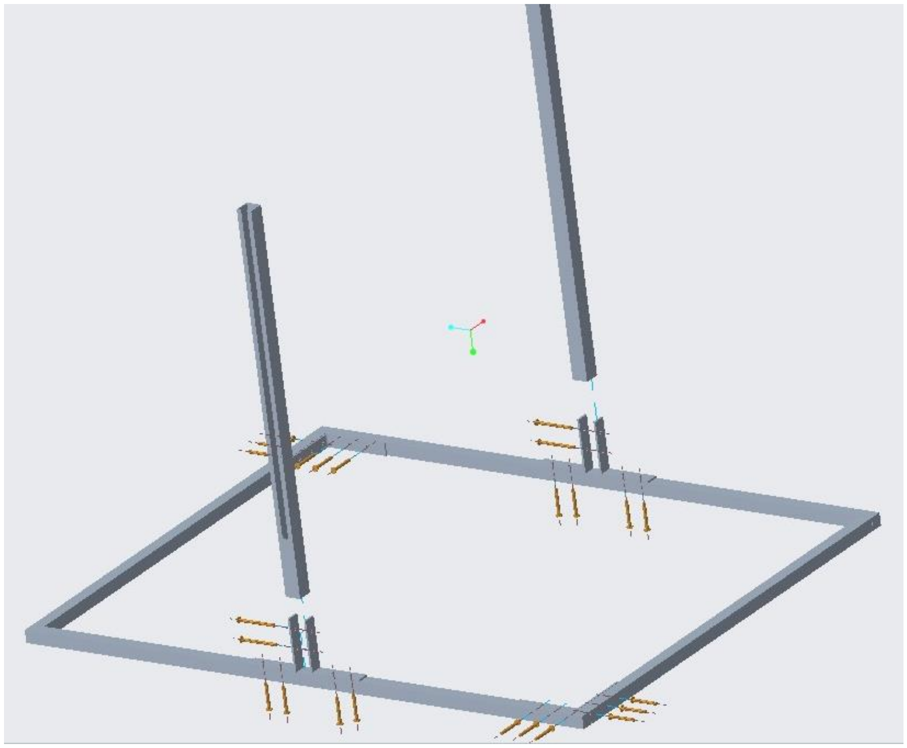


Figure 13: Full Base Module, Exploded View

Motor Housing Module

To assemble the motor housing, a 0.05” thick aluminum sheet, 1/4-20 bolts, a 0.19”x12”x24” aluminum sheet, and four, 3/8”x2”x2”, 90-degree aluminum will be used. The 0.05” thick aluminum sheet will be water jetted to the dimensions shown in appendix A, figure 24. Once the piece is water jetted, all of the flaps are bent in, so the corner is as close to 90 degrees as possible. Four different pieces of the 90-degree aluminum will be used to create the motor housing bottom. Two pieces will be cut to 13”, while the other two are cut to 12”. At the ends of all of the pieces of 90-degree aluminum, it will be cut at a 45-degree angle, so the pieces can mesh together to create a rectangle. These edges will be welded together to ensure a strong connection. The 0.19” thick aluminum sheet will act as the base. It will be cut to 11.25”x12.25”. With three evenly spaced holes along the edge. These holes will match with the holes on the 90-

degree aluminum. These pieces will be fastened together via 1/4-20 bolts. Slots will also be cut out, so the motor has a little bit of play to determine the tension of the belt. The distance between the rotating shaft and the motor shaft is 6.25 inches. One the bottom of the motor housing as been assembled, the top of the motor housing that is water jetted will be bolted on to the bottom, so the motor will be encapsulated. A gusset will be used to add additional support to the motor housing that is attached to the concentric pipe. U-bolts will be used to attach the housing to the concentric pipe. The gusset will just add additional support to the motor.

Figure 14: Motor Housing Assembled

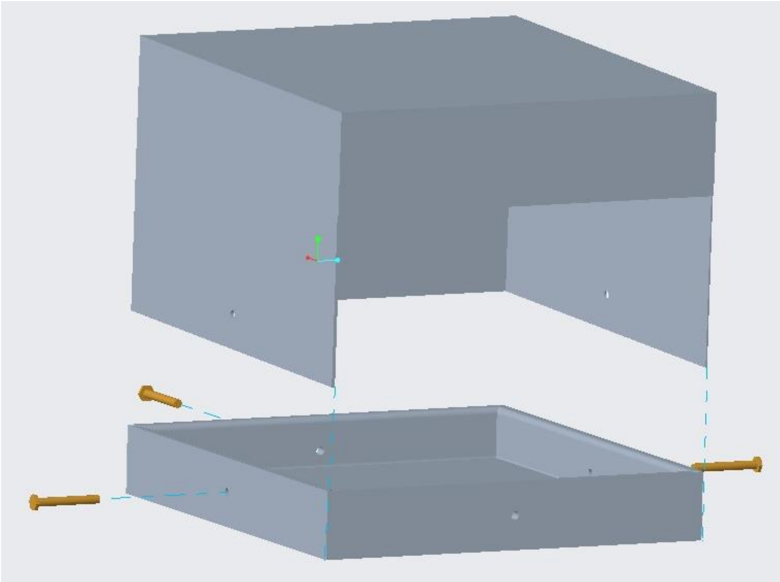


Figure 15: Motor Housing Exploded

Wiring/Powering Module

The wiring module consists of a 12-volt, 20 Ah DC battery, a 12-volt DC gearmotor, a Dart Controls 65 series DC PWM speed controller, a 10 Amp fuse with a fuse holder, and a simple on-off switch. After all of the wiring is connected and secure, the user is able to flip the switch and the motor will begin to rotate. The speed the motor is rotating can then be controlled using the speed controller dial. Shown below is a wiring diagram that the device will follow in order to provide the motor with the correct voltage, as well as being able to control the speed of the motor.

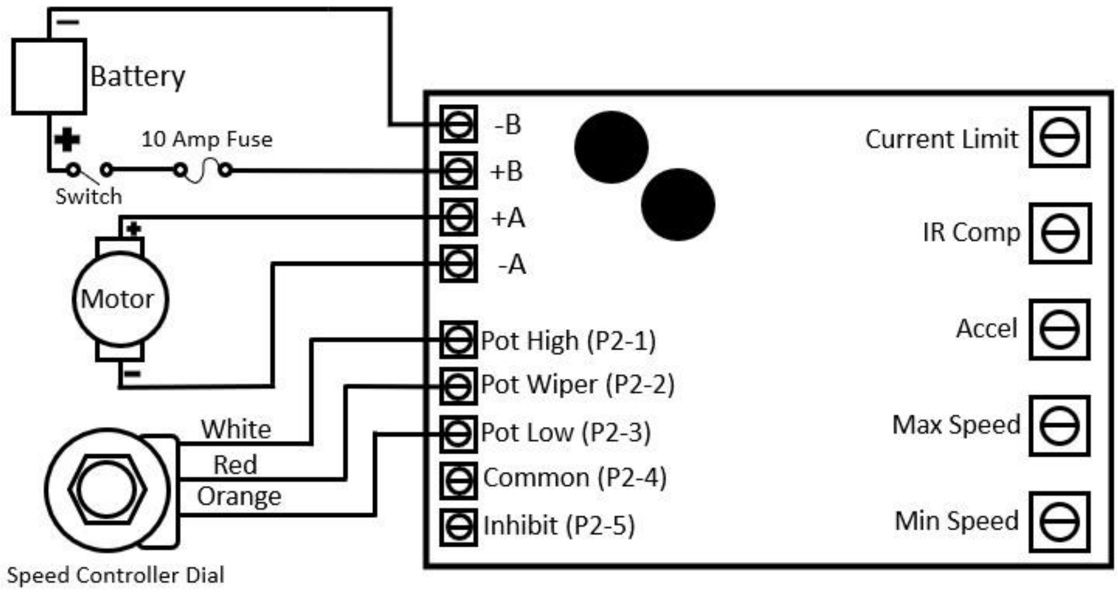


Figure 16: Wiring Diagram

The black wire coming out of the top left pin is connected to the negative end of the battery. The yellow wire is the fuse which is attached to the switch which is attached to the positive end of the batter. The white and black wires are coming out of the motor. The white, red, and orange wires are connected to the speed potentiometer. The connected assembly can be seen below in figure 9.

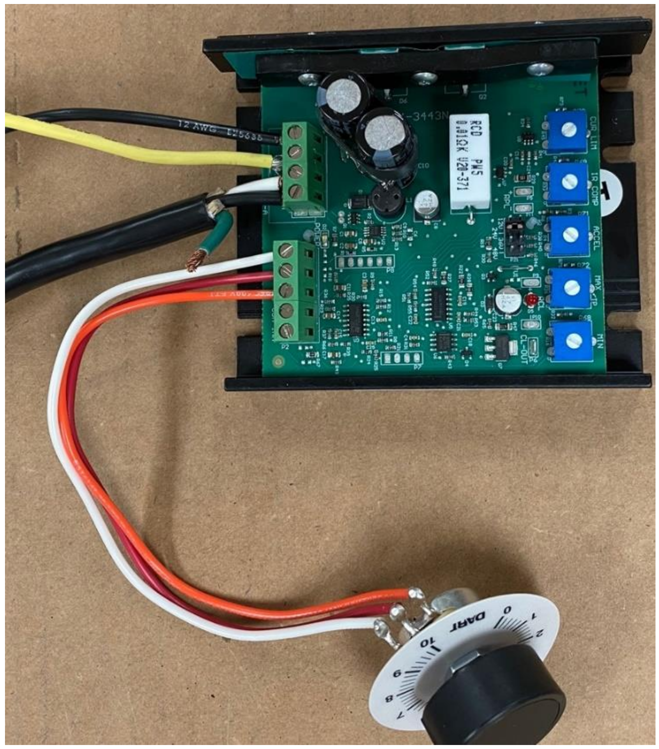


Figure 17: Assembled Wiring Diagram

The motor shaft has a 5/8” bushing with a 3/16” keyway, which is then mated to a 1” thick timing pulley. This will allow the transmission of power from the motor to the rotating shaft. The belt used is a 1” thick, 21 inches long, with 56 teeth. This will match with the bushing and pulley that is placed onto the rotating shaft to produce the transmission of power that is needed.

Basket Bracket/Bearing Housing Module

To allow the basket to have a modular style, the assembly had to take a different approach. A bracket needed to be created using an aluminum sheet with dimensions 1”x8”x8”. Two brackets that are 4 inches long by 2 inches wide are made of this aluminum sheet. The same U-shape is machined out with a diameter of 1.25”, 1.5” into the bracket, so it can cup the shaft. There are also four 1/4-20 tapped holes that will line up with the basket outline. A hole is drilled through the top of the bracket that goes directly through the U-shape to go through a hole in the shaft as well, to lock in the baskets to the shaft. The bracket is fastened to the basket outline via 1/4-20 bolts. This same aluminum sheet will be used to create the bearing housings.

The bearing housings are circular with a square piece coming out of the bottom. The outer diameter of the bearing housing is 2.75” with a wall thickness of 0.75”. Through the square piece there is a hole that a 1/4-20 bolt will go through. Through the bottom of the square piece, a hole is machined out, so a 3/4 concentric tube can fit into the hole. A hole is also drilled through the concentric pipe, so the hole on the bearing housing matches with the hole on the concentric pipe. A 1/4-20 bolt is then used to fasten the two together. Two corrosive resistant ball bearings that fit a 1.25” shaft are used. The rotating center shaft that the baskets are revolving around has one end lathed to fit into a 1-inch bushing. This bushing is then mated with a gear pulley that will have a belt around it. This will allow power transmission from the motor to the baskets.

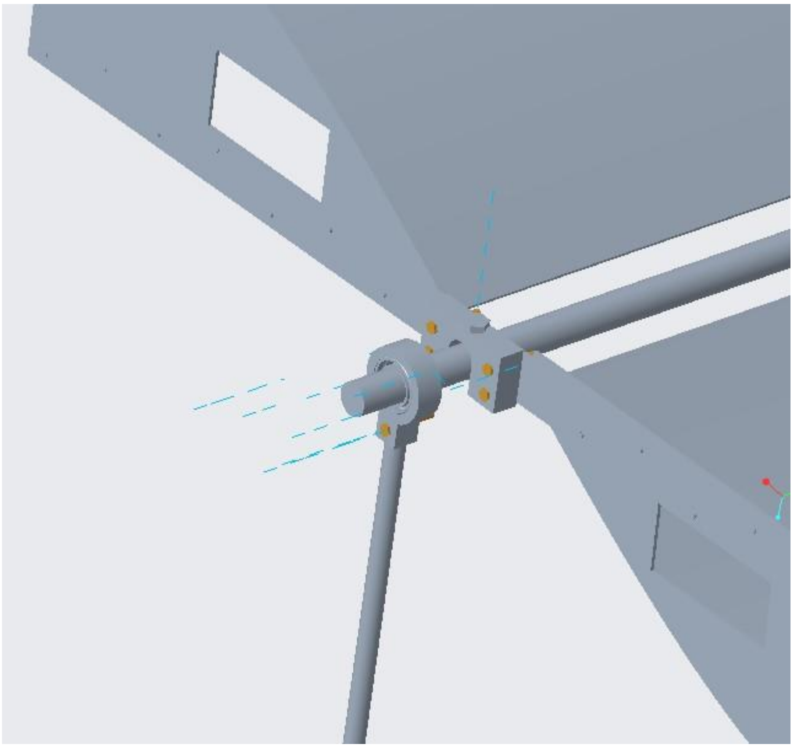


Figure 18: Bracket and Bearing Housing Assembled

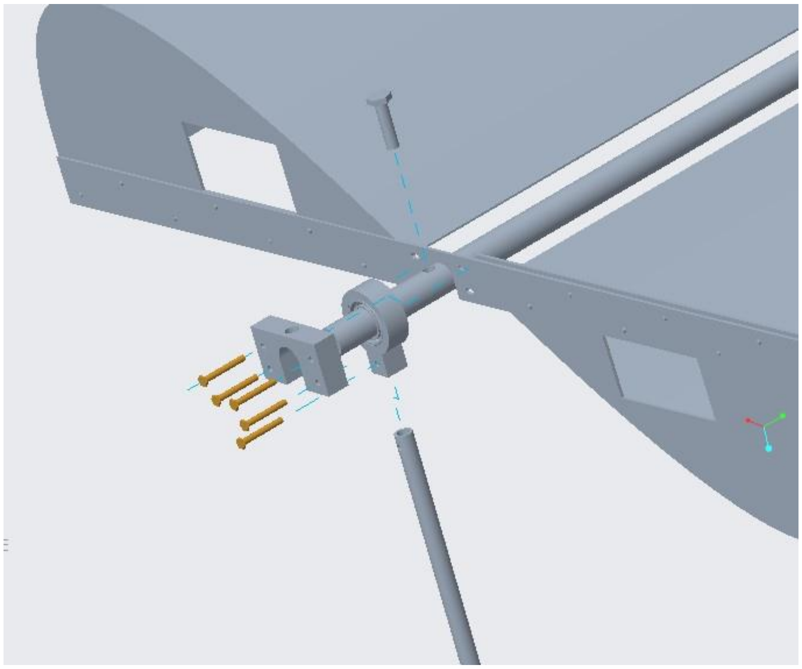


Figure 19: Bracket and Bearing Housing Exploded

A temporary reservoir is added to the concentric pipe shown above. The reservoir is a mesh type basket with a length of 16 inches, a width of 15 inches, and a depth of 7 inches. This reservoir is attached to the concentric tubes via two U-bolts that are meant for a 3/4-inch pipe. On the inside of the reservoir the bolts go through a 6"x6" sheet of UHMW Polyethylene. This will serve as a type of washer to not put stress onto the mesh of the basket. A photo of the basket can be seen below in figure 12.

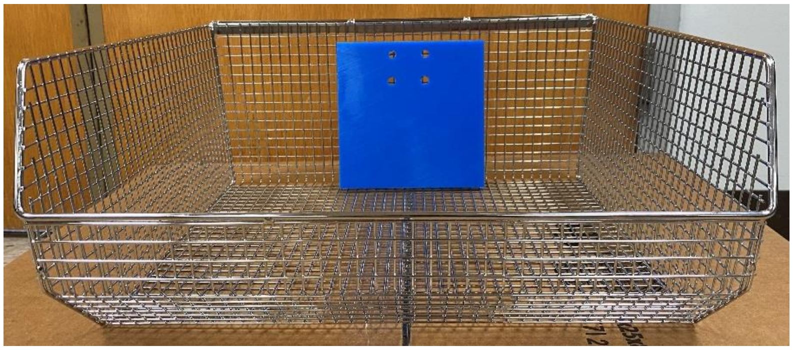


Figure 20: Reservoir Basket with UHMW

Flotation with Concentric Pipe Module

To make the device rise and lower with the level and depth of the water, a flotation module must be created. To achieve raising and lowering, buoys will be attached to the inner concentric pipe leg that is attached to the rotating baskets. This will allow for the module with the baskets and motor housing to raise with the baskets to continue to transmit power. A thin aluminum plate that is 5"x2"x0.25" is welded onto the pipe four inches up from the bottom. Off of this plate, another aluminum plate with dimensions 12"x2"x0.25" will be attached perpendicular to the plate that is attached to the concentric pipe. This plate will be what the buoy is attached to. The buoys that are used are three-gallon jugs that will contain air. If needed, they will be able to be ballasted, so that the device does not raise too much. To ensure that the inner concentric pipes do not raise too high and exit the outer rectangular tube, a safety wire will be attached around the plate coming off of the inner concentric pipe and the gusset attaching the rectangular tube. The jugs will be attached to the aluminum plate via rivets with rubber grommets. This will ensure that no unwanted water will be entering the jugs. An assembled view with the concentric pipe and an exploded view of the assembly of the flotation module can be seen below in figure 13 and 14, respectively.

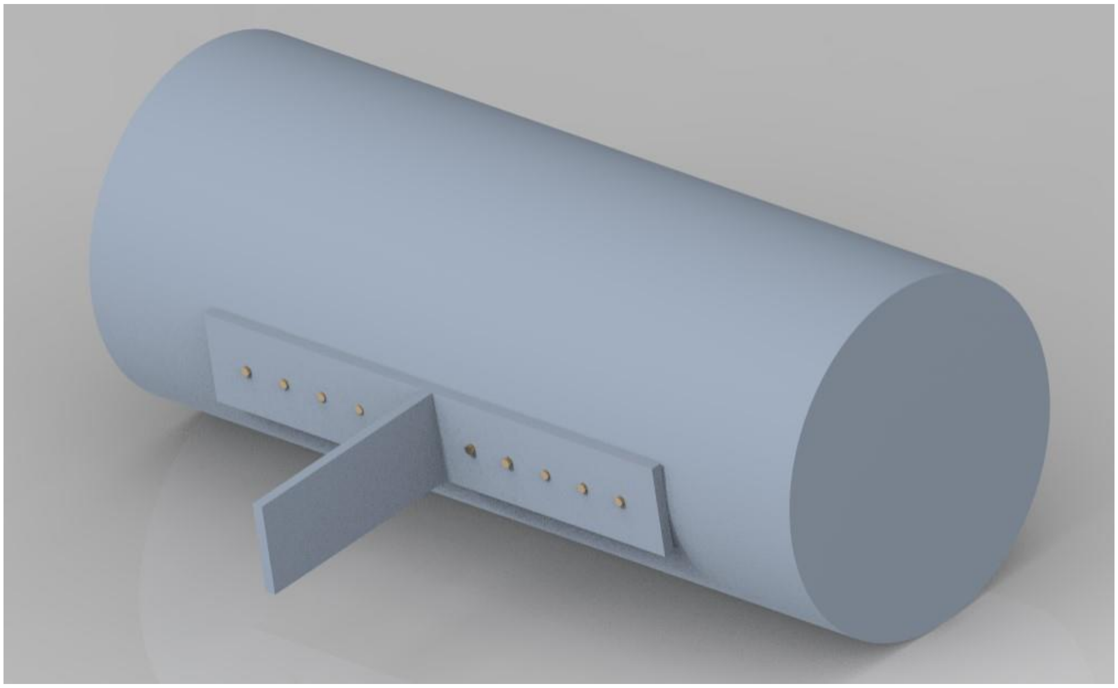


Figure 21: Assembled Buoy Connection

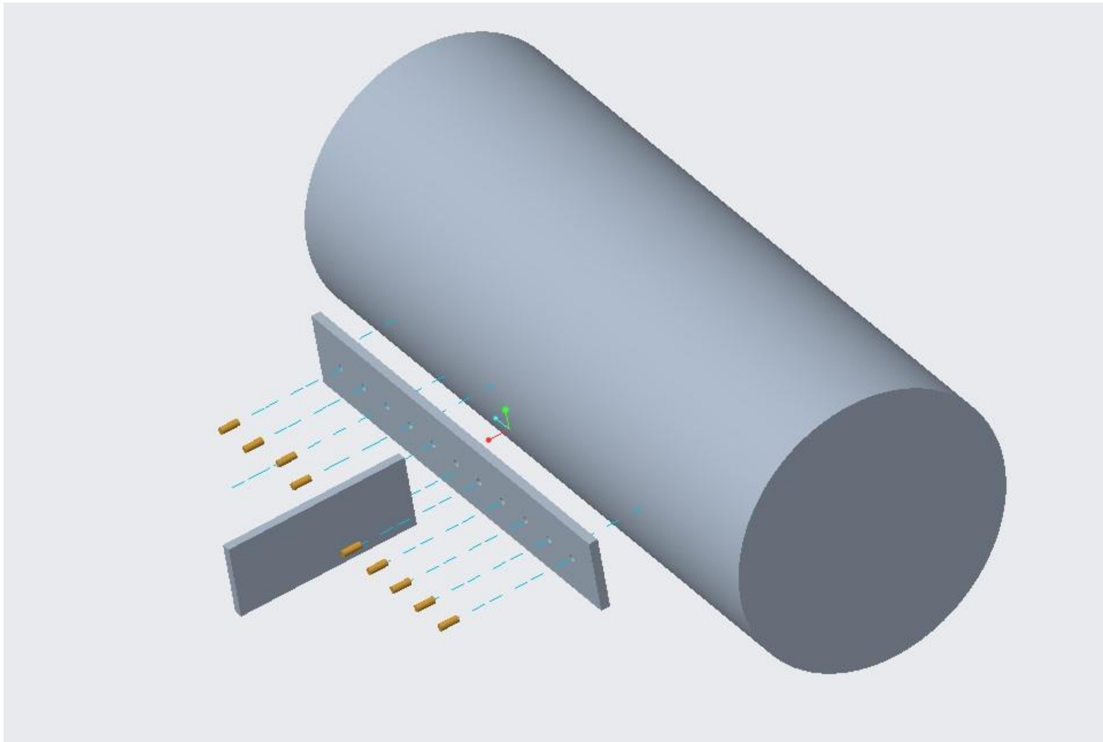


Figure 22: Exploded Buoy Connection

Integration

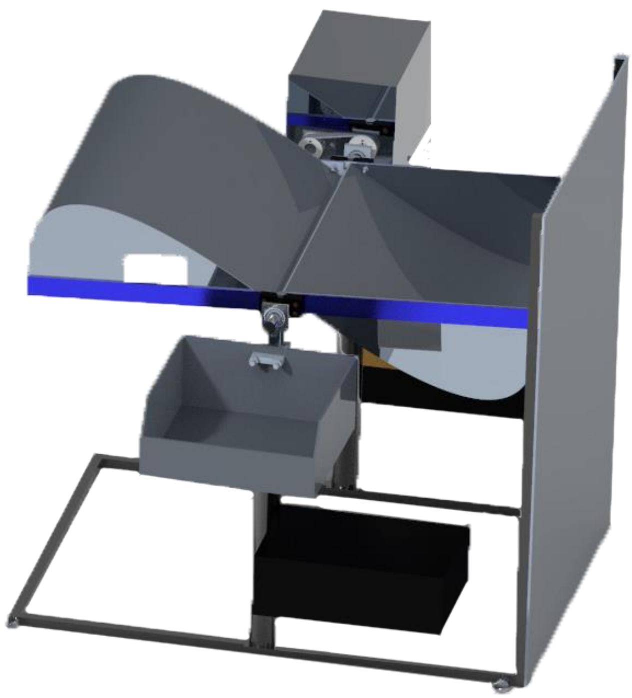


Figure 23: Full Trash Interceptor with all modules

Once all of the individual modules have been assembled, the final product can be assembled. The base will be placed onto the ground first and everything else will be added to the base. The basket will then be taken, and the concentric tubes connected to the basket will be placed inside the rectangular tubes that are connected to the base. To ensure that it is properly attached, the piece of the shaft that the floating buoys are attached to should follow the slot cut out of the rectangular tube. Once this is attached, the motor housing can then be attached to the concentric pipe to give the rotating baskets power. The motor is in the motor housing when attached to the concentric pipes. The belt is then placed onto both pulleys to ensure that the belt has enough tension to transmit power. The brackets are attached to ensure that the basket rotates as the shaft rotates. The user is then able to make sure that the device is moving at the correct RPM. This can be done by playing with the speed controller dial. After the subassemblies have been created, the only thing that is left to do is putting all of the modules together. Once this is done, the device is ready to go and is ready to collect trash.

Operation

Once the device has been fully assembled in the storm drain, a collection of solar panels will be set up in order to gain the necessary amount of charge to power the device. The edge of the device containing the temporary reservoir basket will be placed onto the edge of the storm drain that is closest to the dumpster. This will allow for a conveyor belt to be able to take the trash from the temporary reservoir and place it into the dumpster. An expandable floating boom will be placed on the front corner that is not along the bank. It will be placed on an angle connecting the front edge on the motor side to the opposite side of the storm drain. The trash will then be guided into the device, allowing the rotating baskets to remove the trash from the storm drain. All of the wiring will then be inspected to ensure that it is required correctly. The user will want to set the speed dial to 2.5 to ensure that the device is rotating at 6 revolutions per minute. When water is flowing through the storm drain, the device will begin to rotate and remove trash from the storm drain. The battery will be able to be charged autonomously due to the solar panels. The trash that is transported to the dumpster will be emptied with the regular trash schedule that the city has in place.

If the trash interceptor is being monitored and it is determined that there is a better place to deploy the device, contractors will be able to disassemble the device and move it to another location. The device will only be running while there is water flowing through the storm drain, meaning that it will most likely be running only after a significant rainstorm.

Troubleshooting

If there are issues while operating the trash interceptor, there are a few aspects to check for that may be causing the problem. First, it would be a good idea to check the wiring between the battery, the motor, and the motor speed controller to ensure that everything is wired properly by referring to the wiring diagram shown in the Component/Module Section. One thing to check in particular about the wiring is that the fuse has not been blown. If this is the case, one can simply open the fuse holder and insert a new 10 Amp fuse. Along these similar lines, it is essential that the solar panels are properly connected to the battery to ensure that the battery will remain charged to power the device. Another item that may be causing errors is the timing belt and the timing belt pulleys. It is very important to ensure that the motor shaft and the rotating middle shaft are level with one another, so that the timing belt is rotating properly. If this is not the case, one can tighten the bolts between the gusset and the inner concentric pipes to ensure it is properly placed. As well as tightening these bolts, one can ensure that the bolts connecting the motor and the motor housing are securely tightened, ensuring correct spacing between the two pulleys. Another possible issue that could cause the device to stop operating is a build up of dirt or algae in both the rectangular outer concentric tubes, as well as the bearings. To do this, the contractor will be able to take apart these small subassemblies to clean and rid these parts of dirt and algae.

Appendix I – Machine Drawings

The following images are drawings brought to the FAMU-FSU College of Engineering Machine shop to be machined.

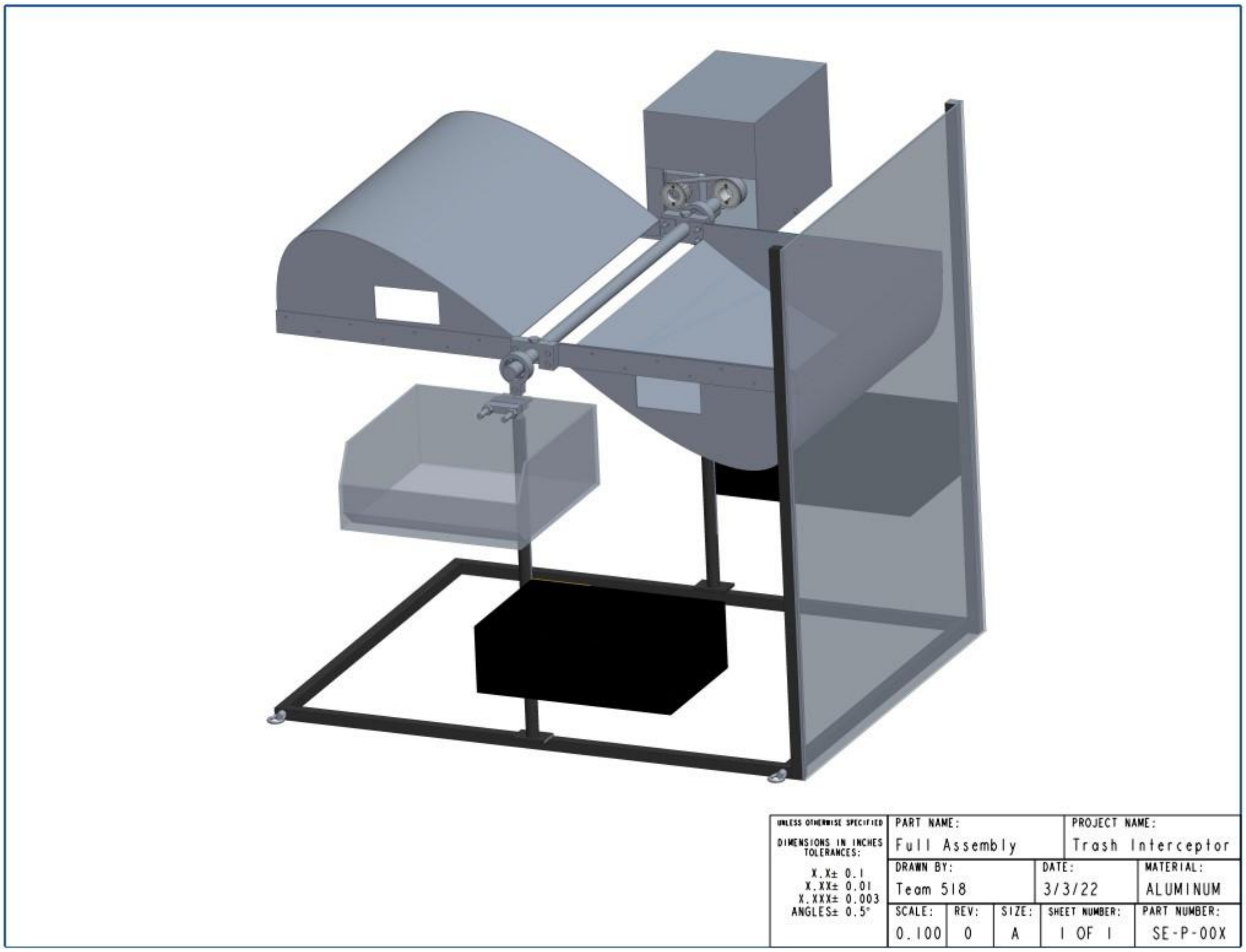


Figure 24: Full Assembly Drawing

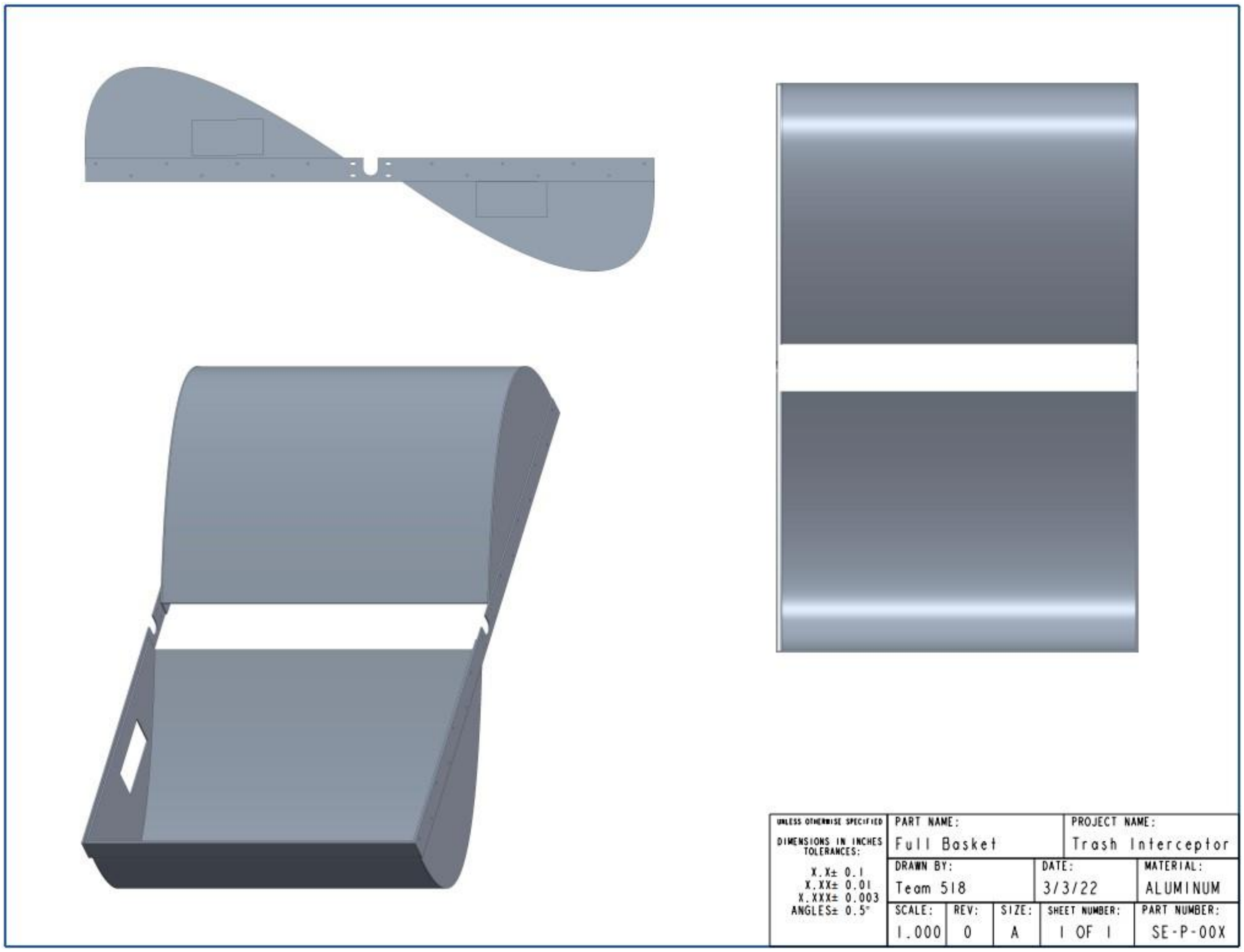


Figure 25: Full Basket Assembly

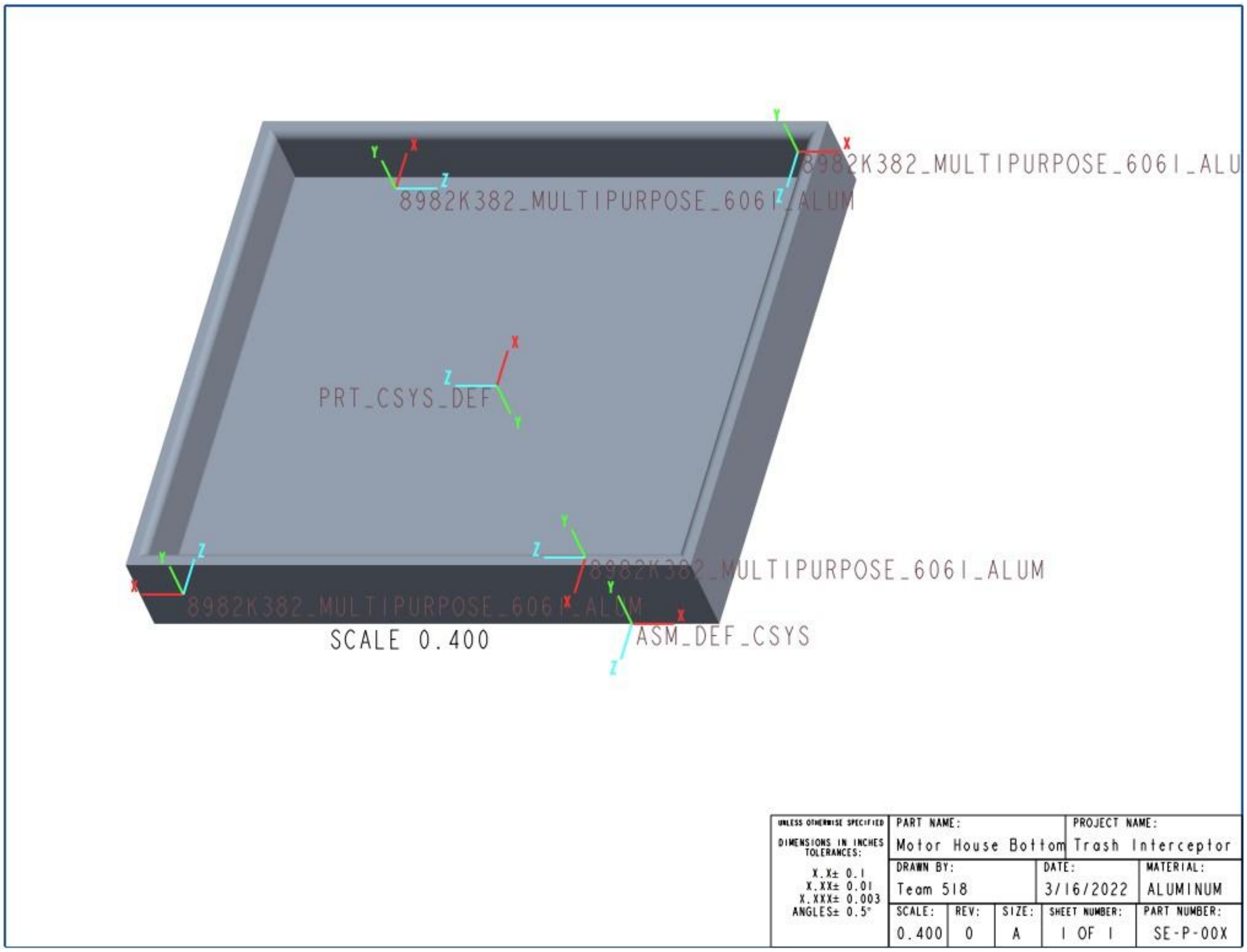


Figure 26: Assembled Motor Housing Bottom

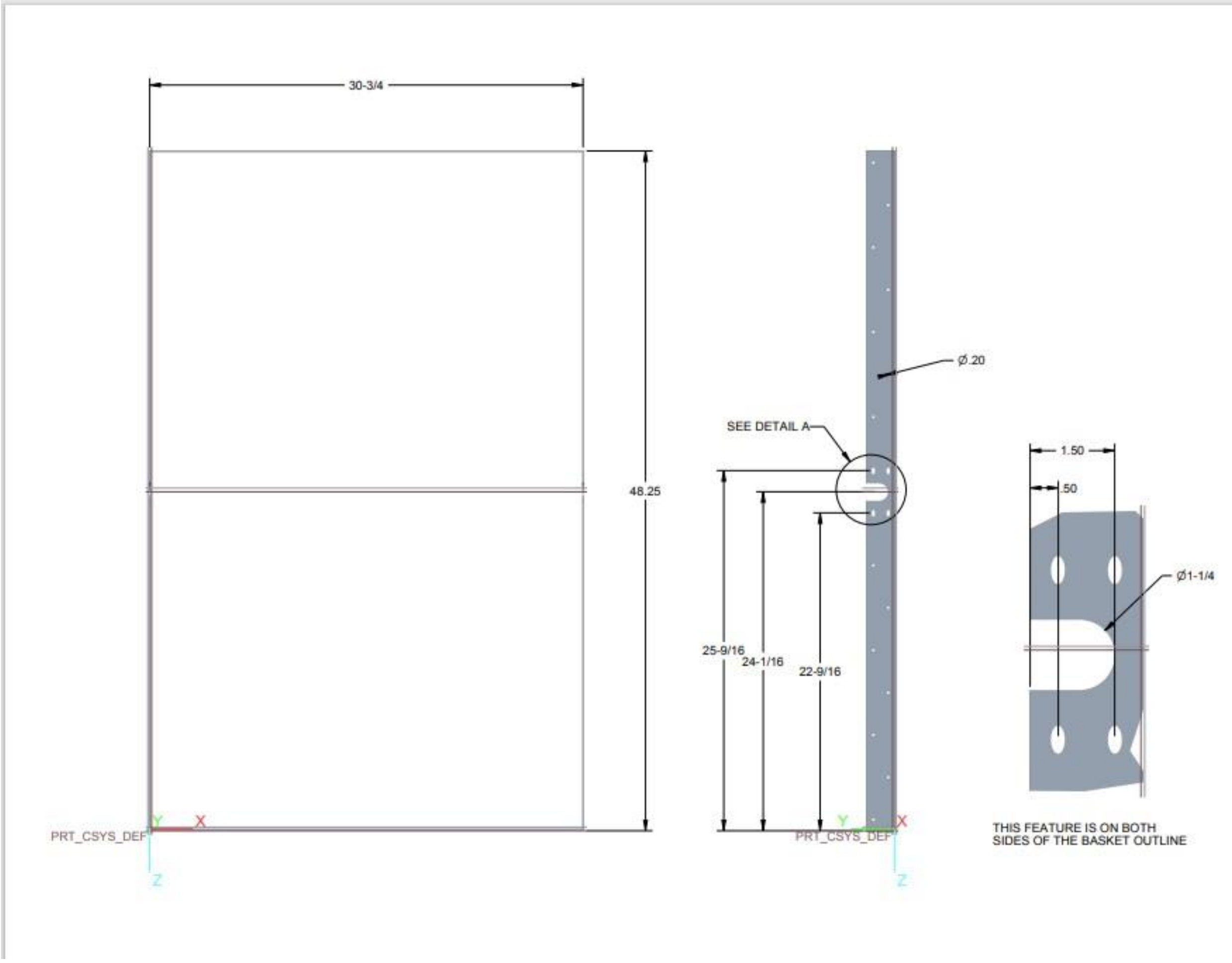


Figure 27: Basket Support/Outline

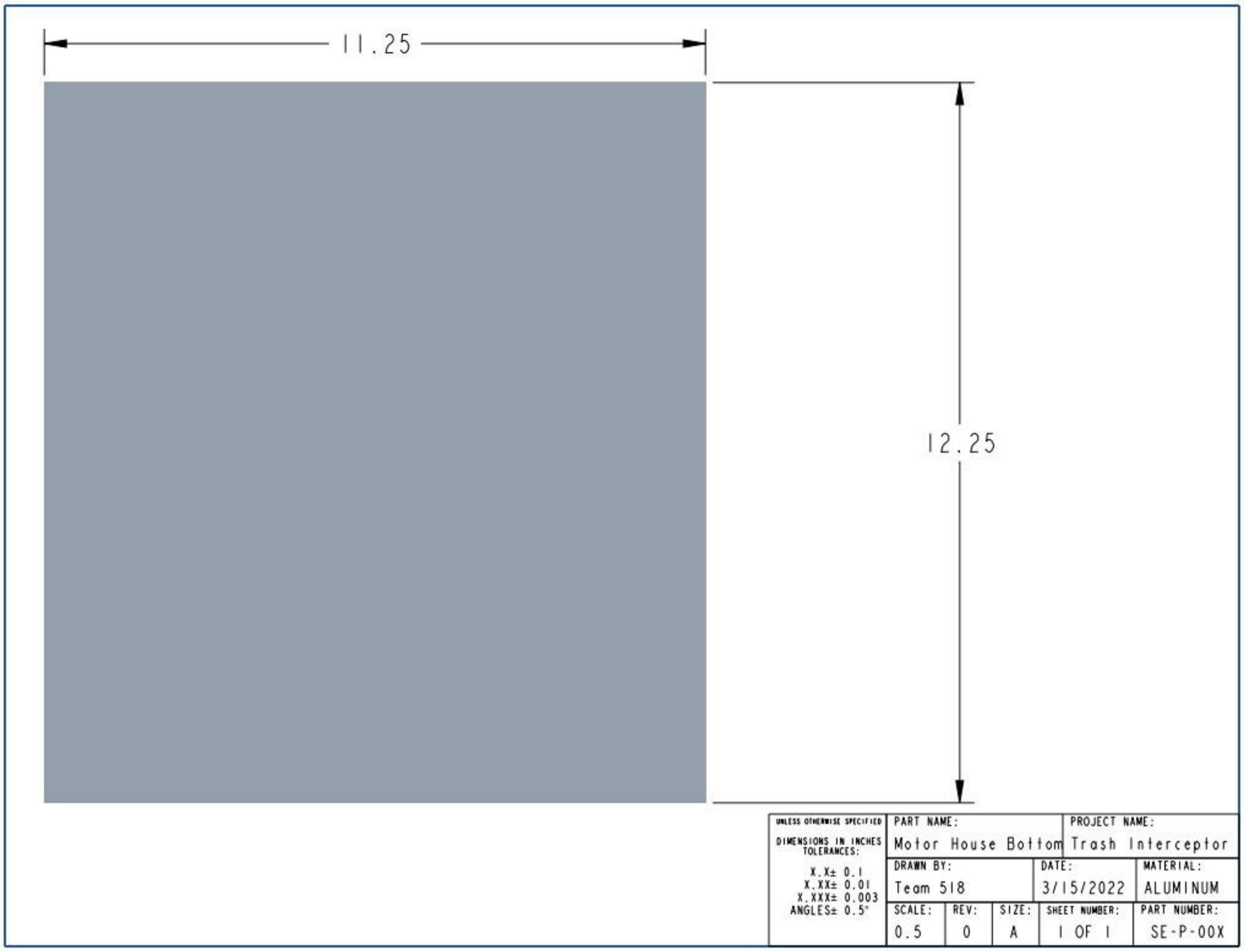


Figure 28: Motor Housing Bottom

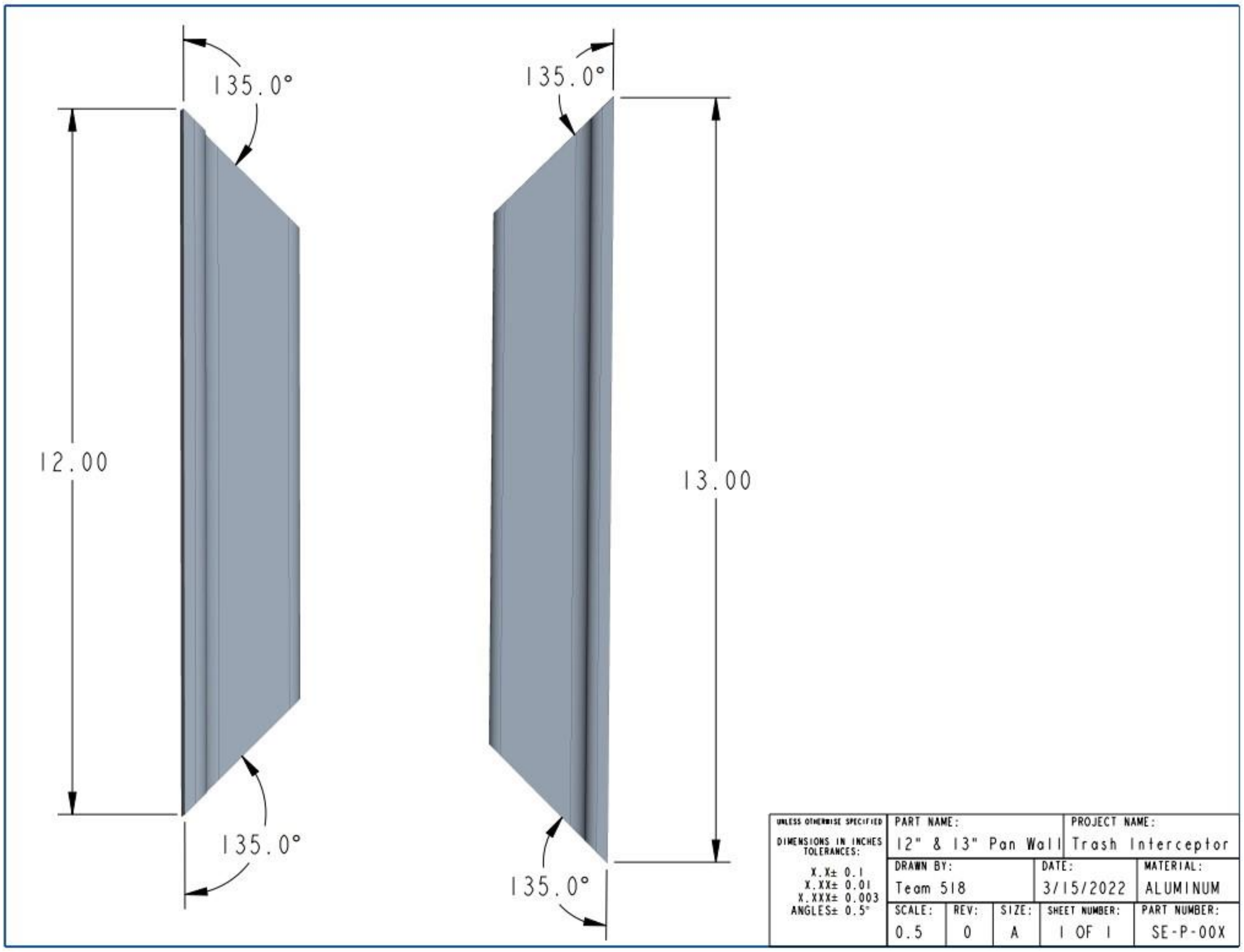


Figure 29: Motor Housing Bottom Walls

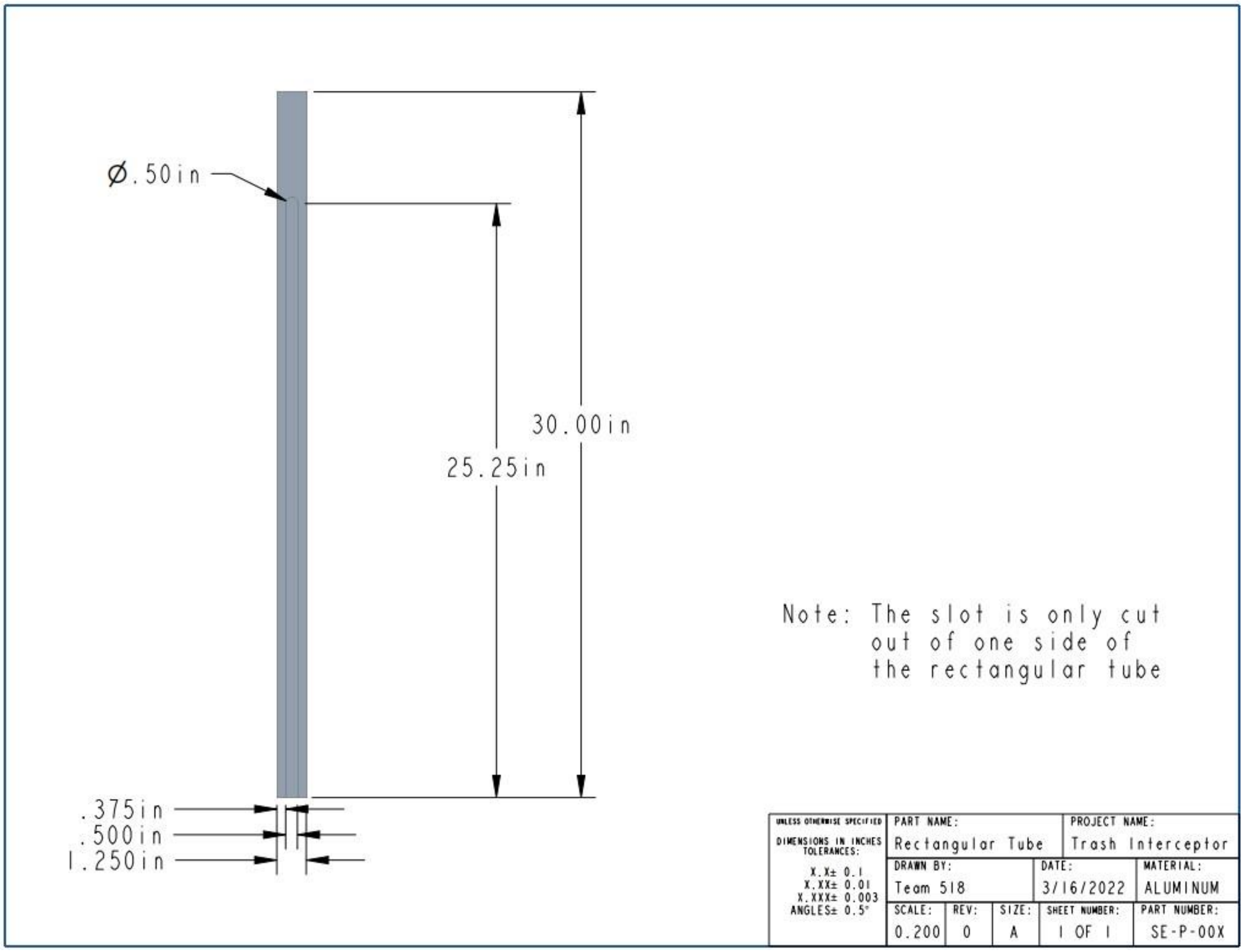


Figure 30: Rectangular Tubes

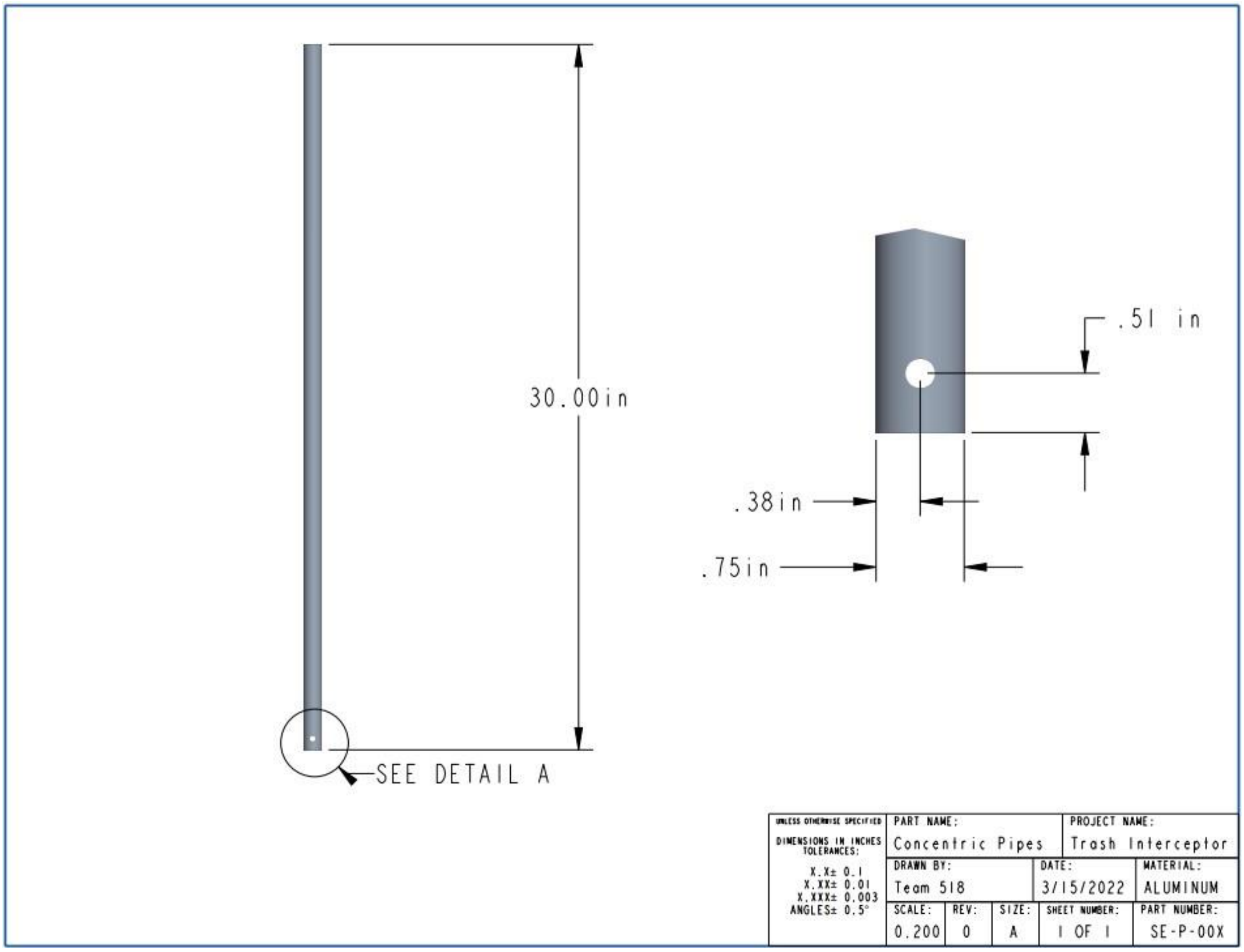


Figure 31: Inner Concentric Pipes

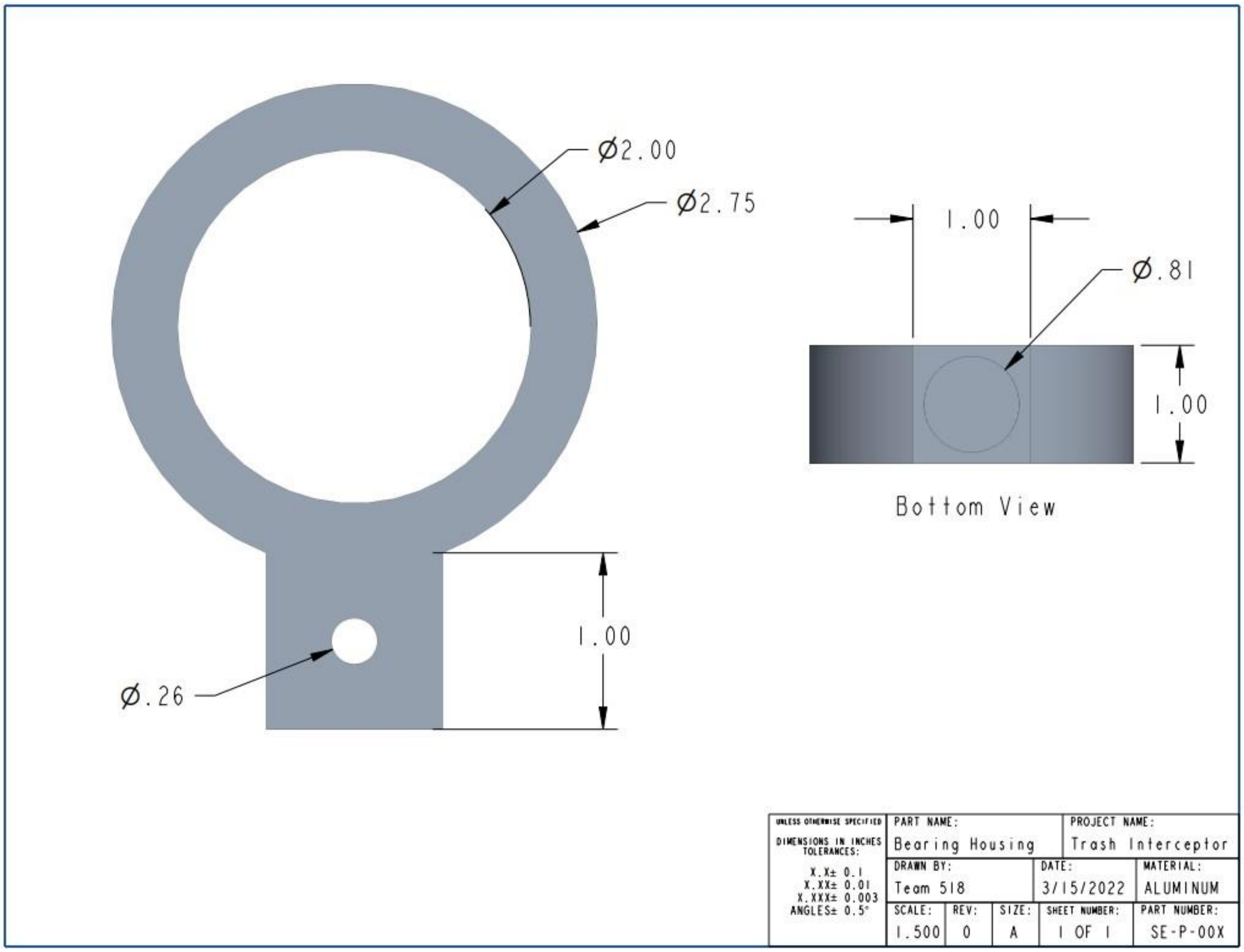


Figure 32: Bearing Housing

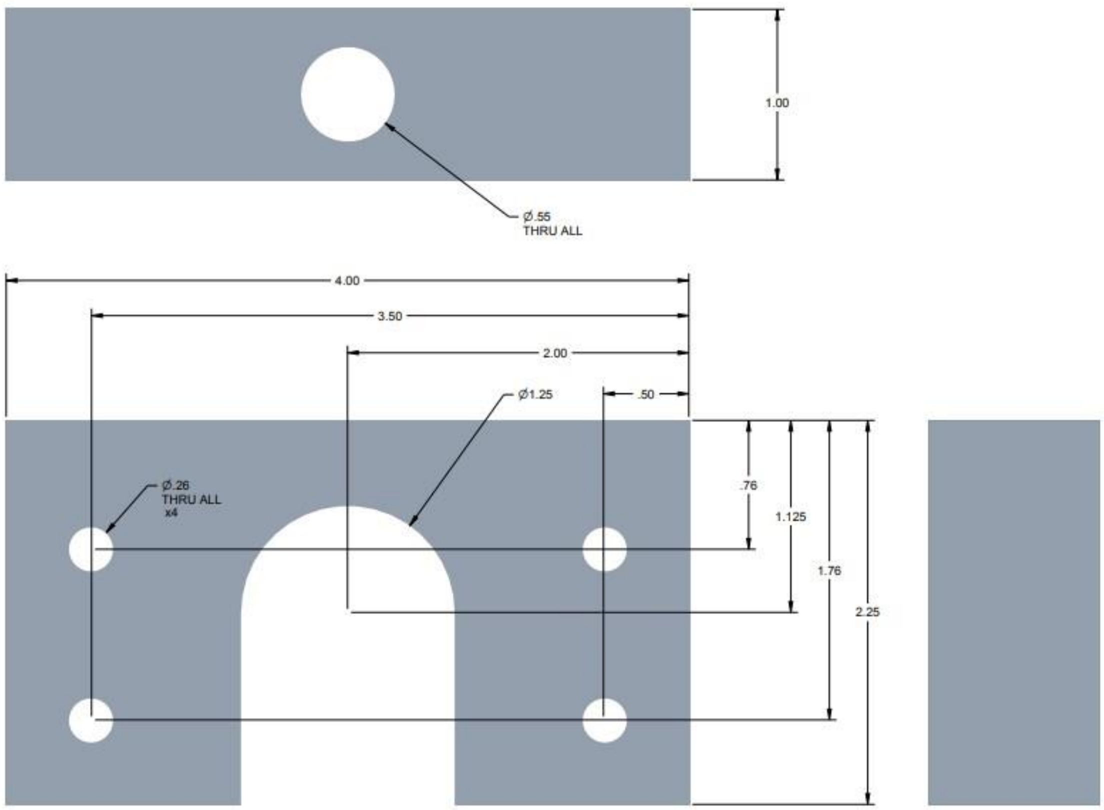


Figure 33: Basket Bracket

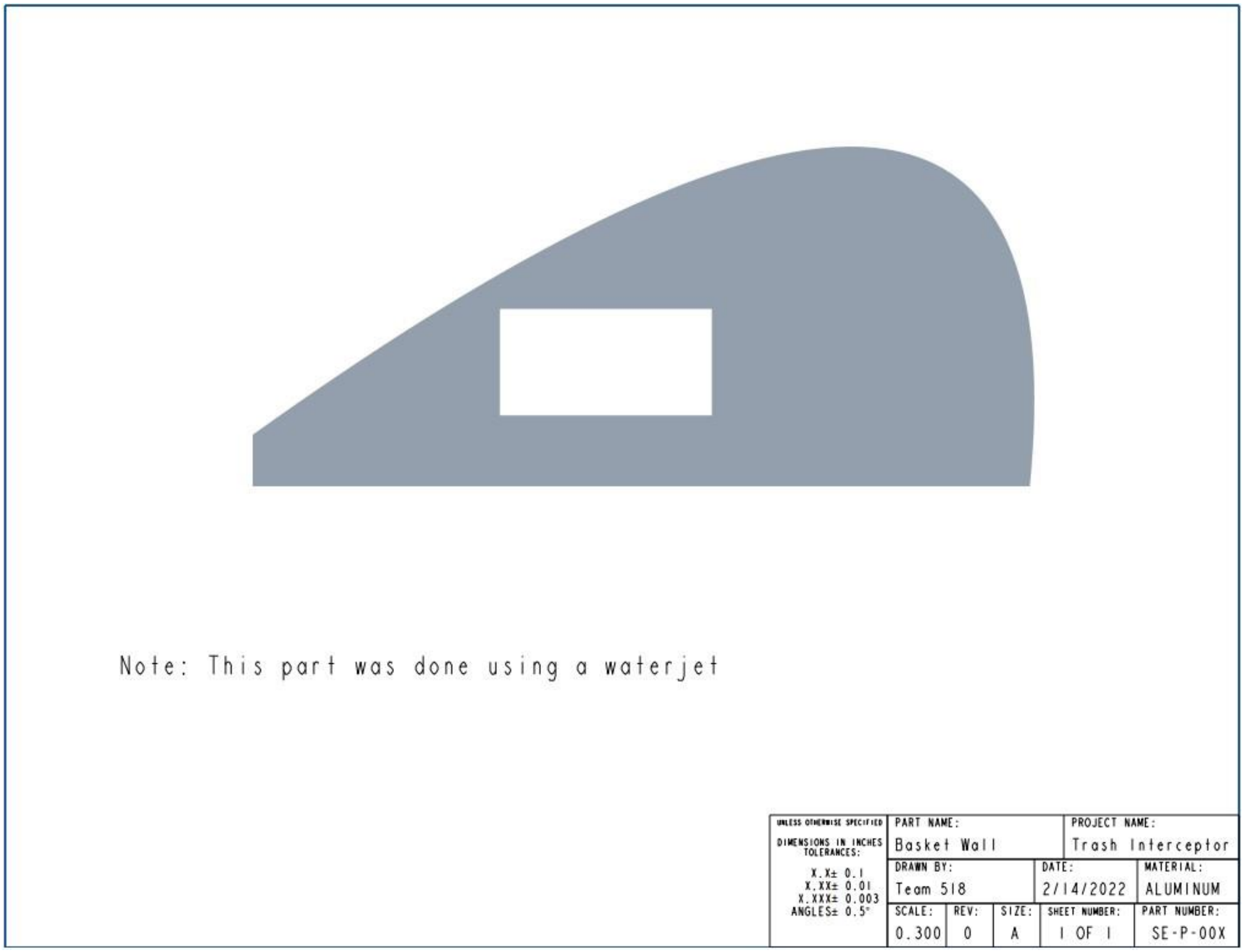


Figure 34: Basket Wall

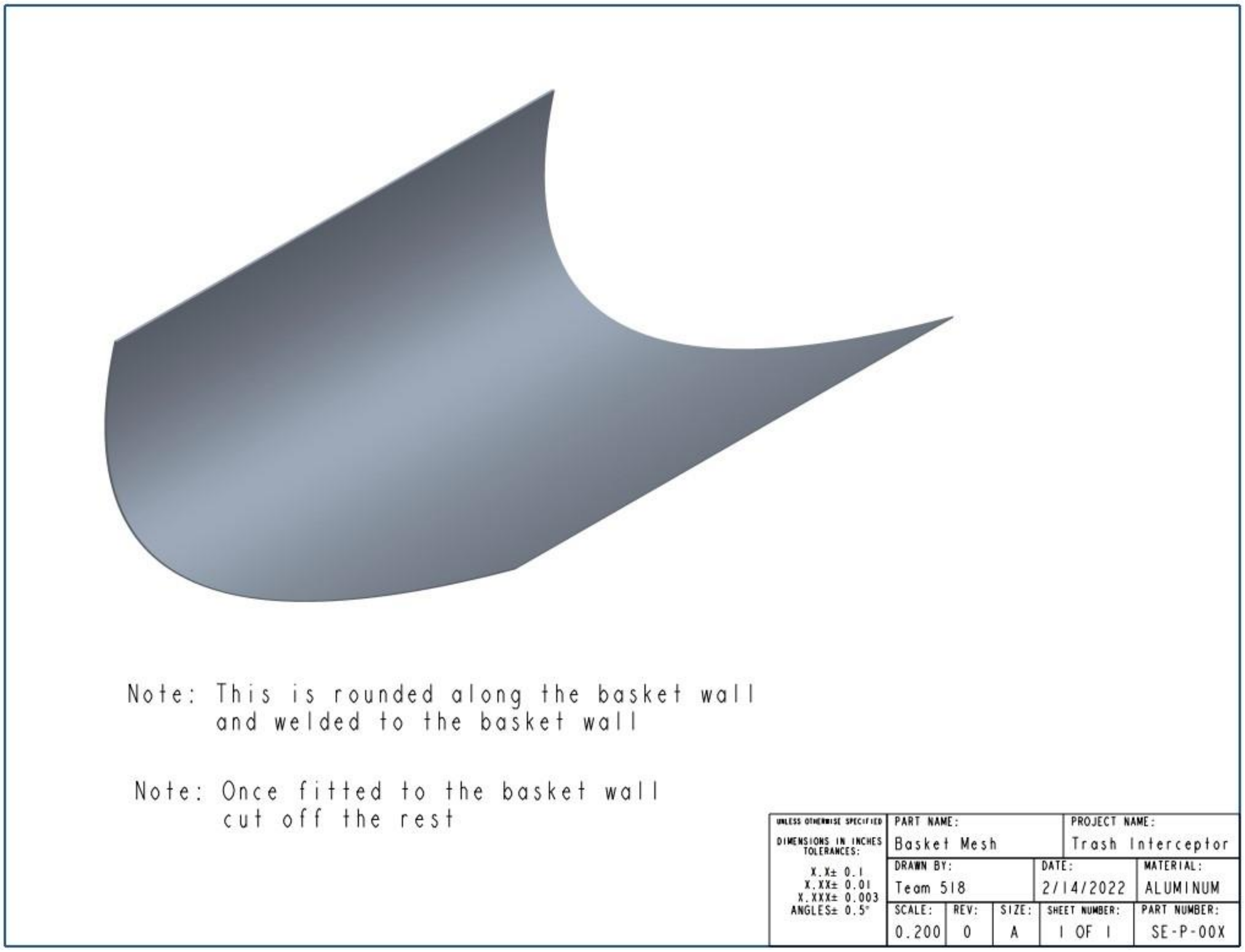


Figure 35: Basket Mesh

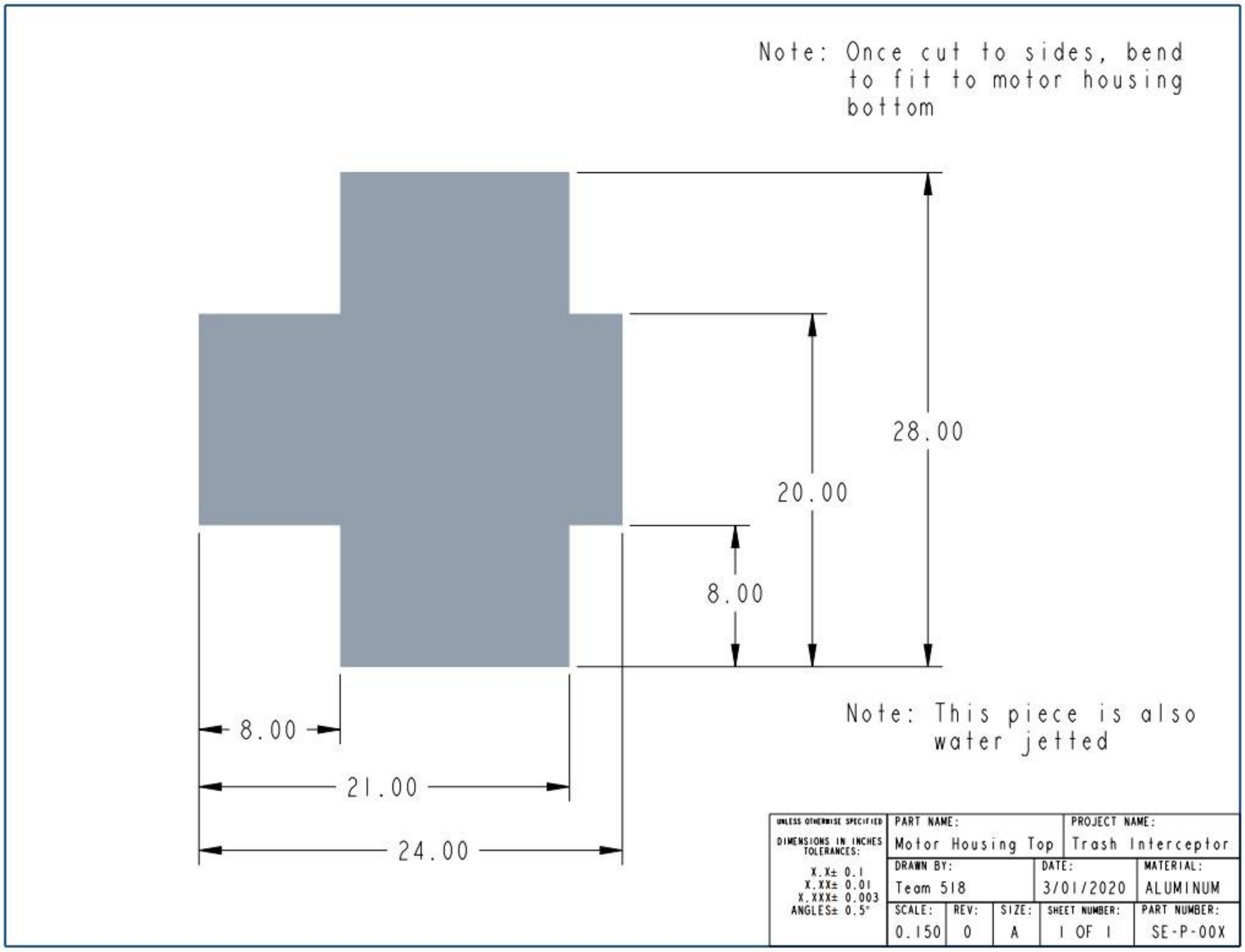


Figure 36: Motor Housing Top

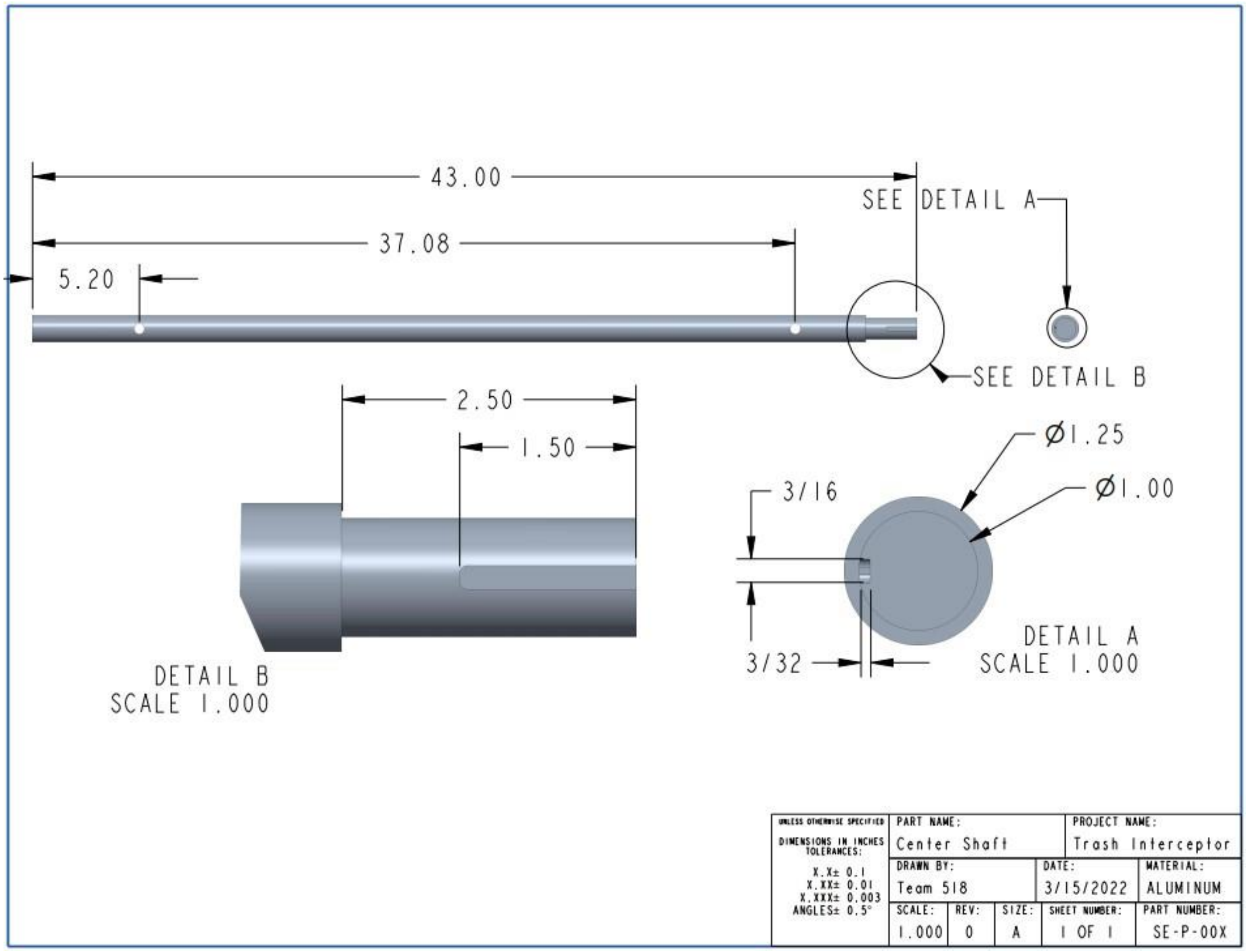


Figure 37: Center Shaft

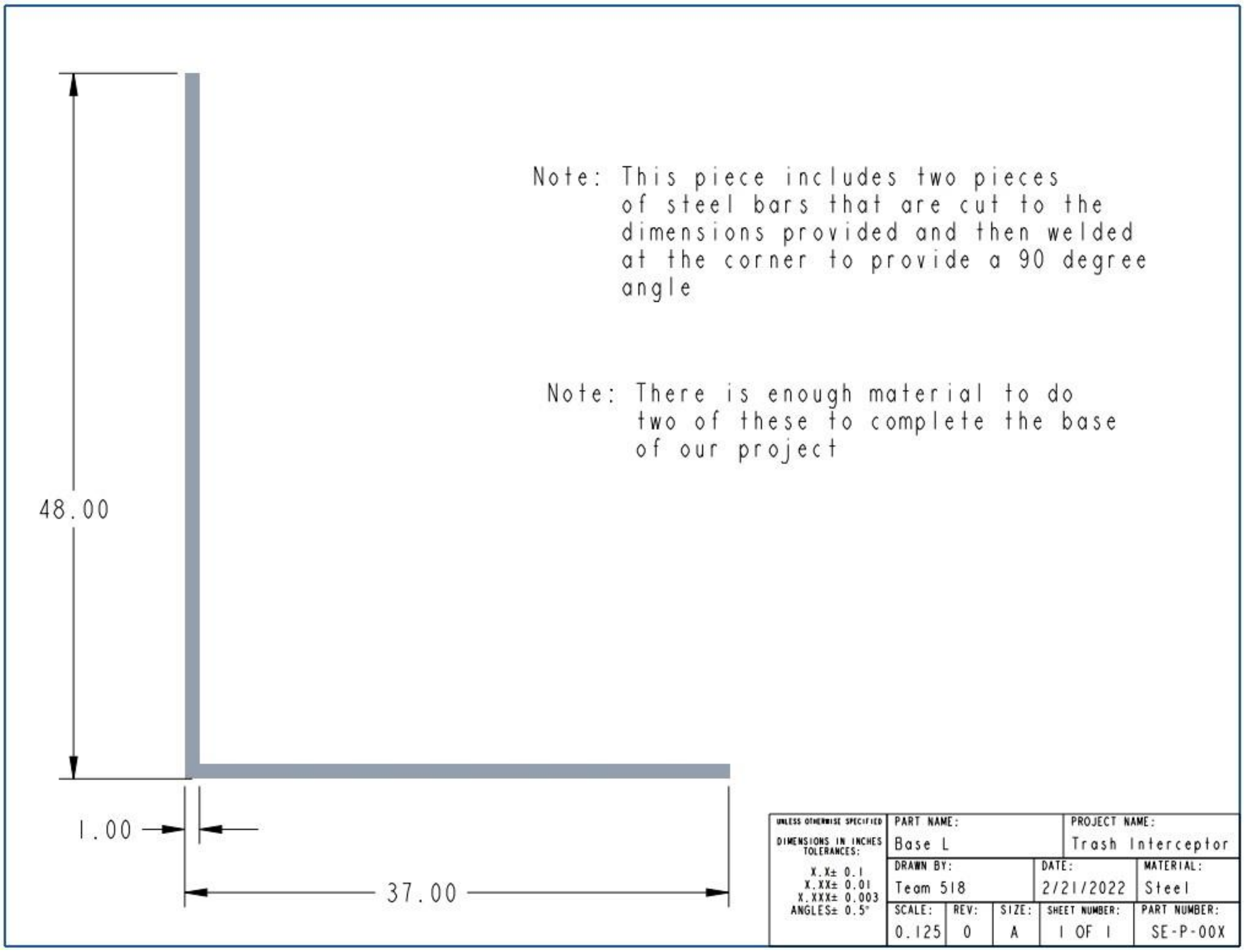


Figure 38: Base L, two of these make up the base

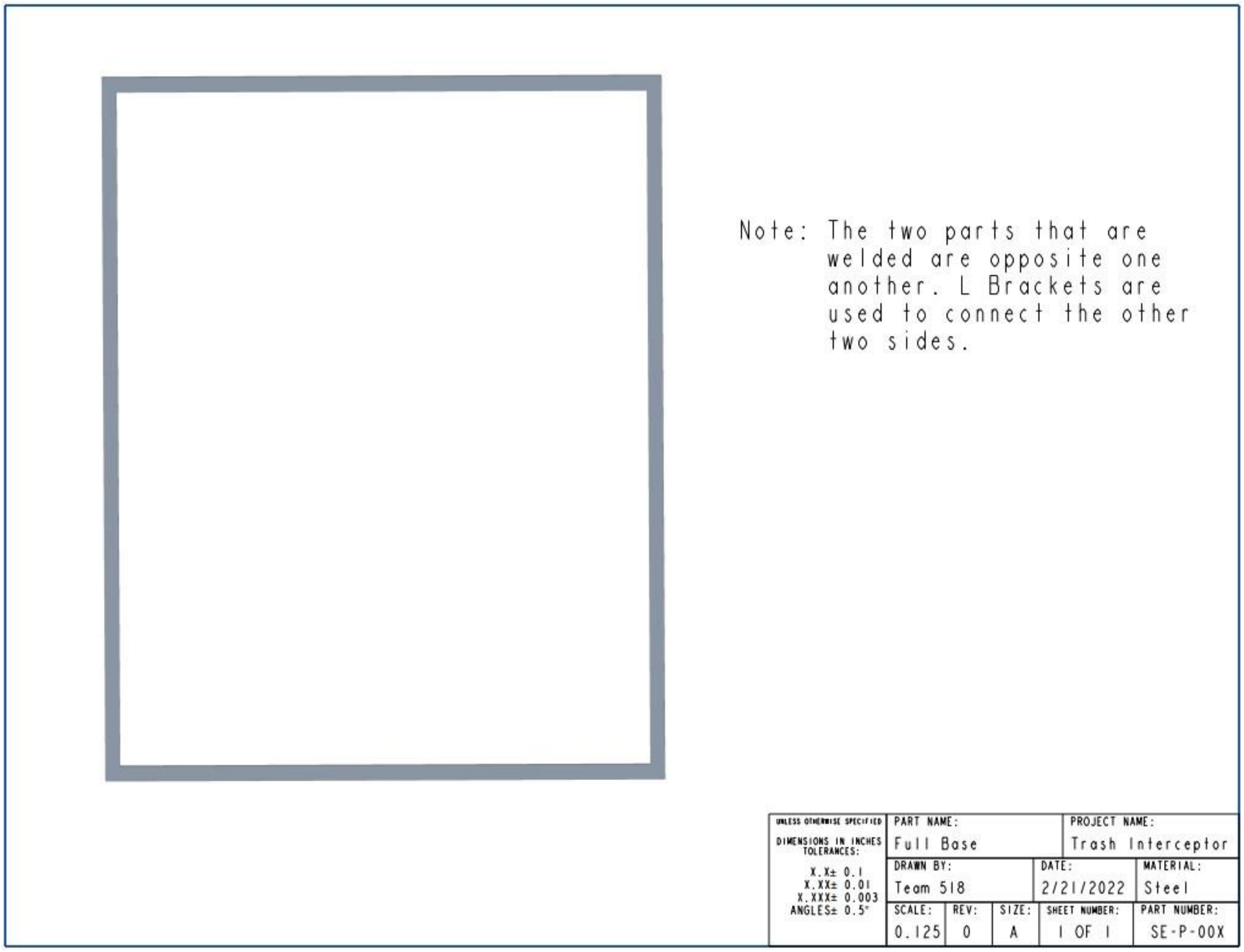


Figure 39: Full Base Assembly

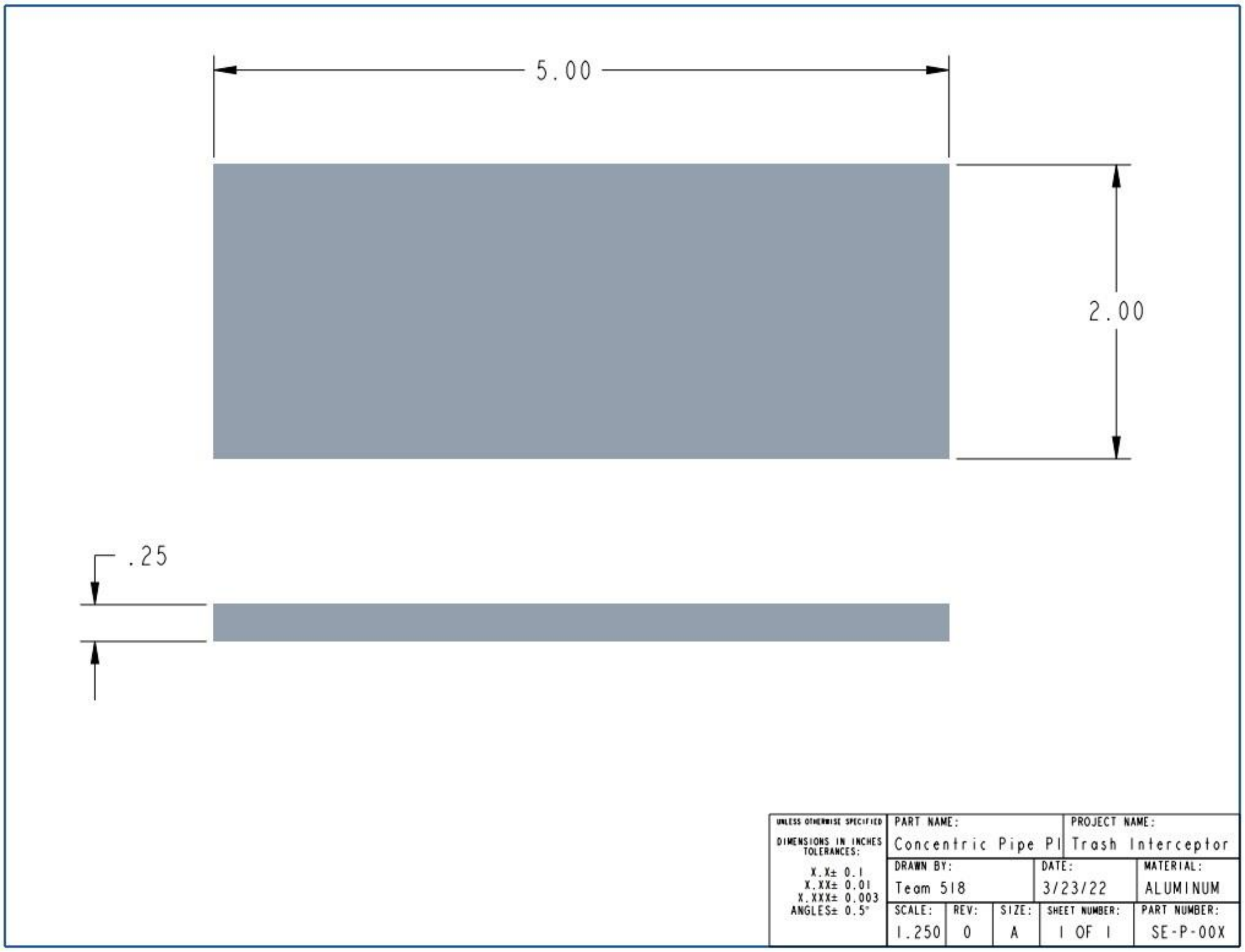


Figure 40: Concentric Pipe Plate

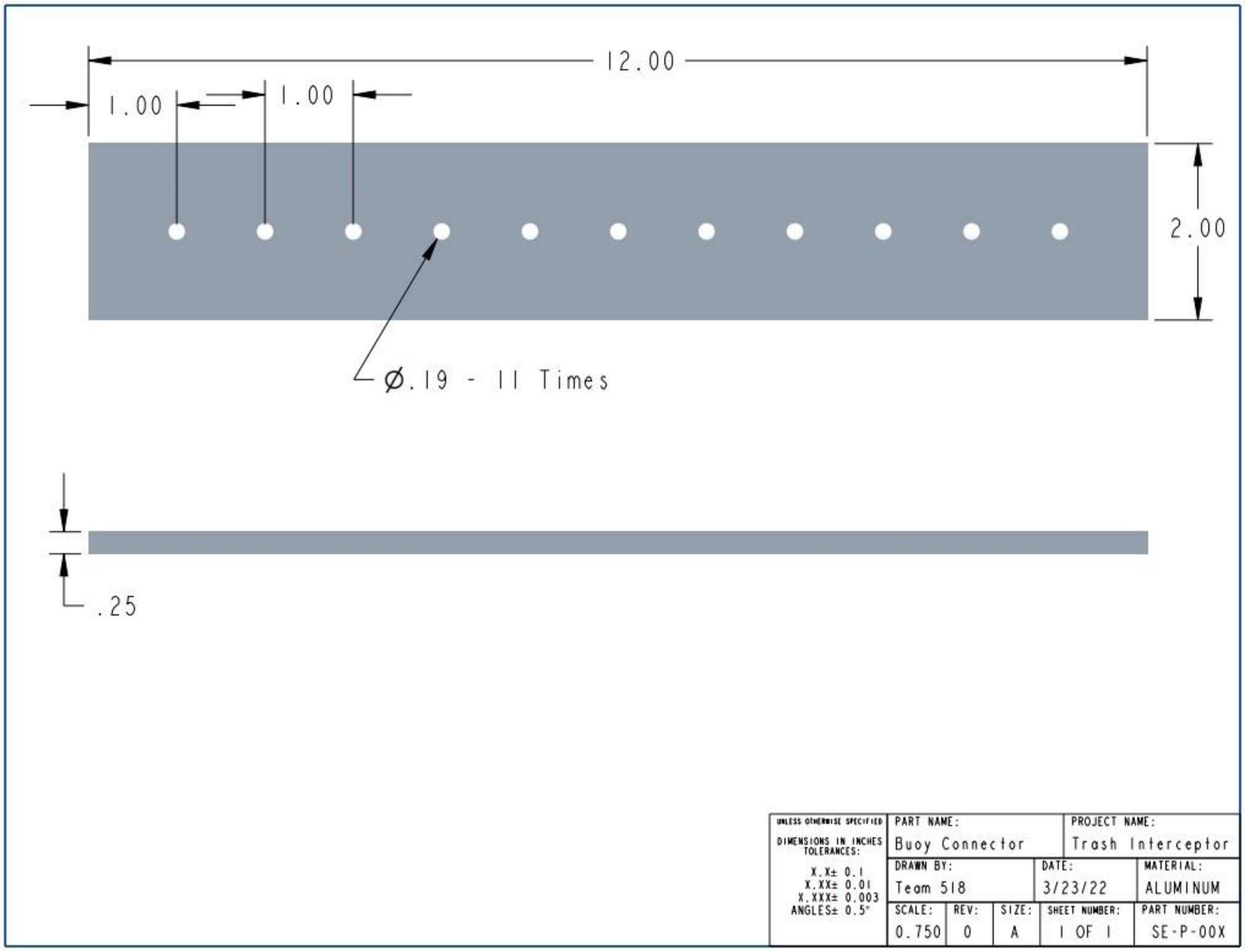


Figure 41: Buoy Connector Plate

Appendix J – Calculations

Table of Contents


```
clear all
clc
```

Constants and Assumptions

```
%the stress due to bending will be greater than torsional stress on
 the
%shaft since there won't be any twisting
shaft_length = 30; %inches
```

determining the weight of the basket

```
%parts included basket, basket walls, trash slide, basket frame
rho_al3003 = 0.098; %(lb/in^3) density of al 3003
%approach triangle approximation
tri_l = 24; %inches
tri_depth = 14; %inches

basket_width = 30; %inches
basket_height = sqrt((14^2) + (24^2)) ;

slide_width = 8;
slide_length = 35;

frame_width = 2; %inches
frame_height_long = 48;
frame_height_short = 30;

Area_walls = tri_l*tri_depth ;
Area_basket = basket_width*basket_height*0.34 ; %34% of area taken
 based on mesh
Area_frame = (frame_width*frame_height_long) +
 (frame_width*frame_height_short) ;
Area_slide = (slide_length*slide_width);
```

thickness and volumes

```
wall_thickness = 0.25;
```

```
basket_thickness = 0.032;
frame_thickness = 0.25;
slide_thickness = 0.125;


frame_volume = Area_frame*frame_thickness ;
wall_volume = Area_walls*wall_thickness ; %0.125 thickness perferred
basket_volume = Area_basket*basket_thickness;
slide_volume = Area_slide*slide_thickness;
```

Mass = density/volume

```
mass_wall = rho_al3003*wall_volume;
mass_basketbase = rho_al3003*basket_volume;
mass_frame = rho_al3003*frame_volume;
mass_slide = rho_al3003*slide_volume ;
mass_basket = mass_basketbase + mass_wall + mass_frame +
 mass_slide; %lb

p = ['Mass of Basket = ',num2str(mass_basket), ' in lbs']
disp(p)


p =

    'Mass of Basket = 16.3728 in lbs'

Mass of Basket = 16.3728 in lbs
```

Determining Shaft Radius

```
gravity = 32.2;  %ft/s^2
force_weight = gravity*mass_basket ; %lbft/s^2

moment_weight = (force_weight/2)*(shaft_length/24) ; %lbft/s^2
yield_Al6061 = 35,000; %psi or lbf/in^2
%formula for bending stress Sigma = 4M/I
    %M = moment
    %I = 0.258pi*R^4


yield_Al6061 =

    35
```

Radius Requiredf

```
R = [(4*moment_weight*144)/(pi*35000)]^(1/3); %inches
shaft = ['Radius of Shaft = ',num2str(R),' in inches']
disp(shaft)
```

2

```
shaft =

    'Radius of Shaft = 1.1996 in inches'

Radius of Shaft = 1.1996 in inches
```

Torque Measurement

```
radius_basket = 24; % inches

theta = 0:1:359 ;

force_trash = 7; %lbs

Torque = (radius_basket*force_trash).*cos(theta);
MaxTorque = (max(Torque))/12;%lb ft
TorqueSI = 1.3558179483314*MaxTorque; %Nm

tor = ['Max torque required = ',num2str(MaxTorque),' in lbft']
disp(tor)
```

```
tor =

    'Max torque required = 14 in lbft'

Max torque required = 14 in lbft
```

Power

```
angular_Vel = 2*pi*(1/12) ;
Power_required = TorqueSI*(angular_Vel)% Watts
```

```
Power_required =

    9.9387
```

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```
clear all
clc
```

Testing Results

```
eff = 0.15; % 15 percent is normal solar eff
[num,txt,raw]=xlsread('pv_open_2020.xlsx');
Current = num(:,1);
Voltage = num(:,2);
[array_meanC, array_stdev, error] = Measurement(Current)
[array_meanV, array_stdev2, error2] = Measurement(Voltage)

Mean_PowerOut = array_meanC*array_meanV

Power_In= 5.75.*(1/24).*eff.*(1/10.7639).*(13.75*8.8125*(1/12)).*1000
RealEff = Power_In/Mean_PowerOut

Efficiency_Error = ((RealEff - 6)/6)*100
```

```
array_meanC =

   2.7772e+04


array_stdev =

   1.6029e+04


error =

  204.1145


array_meanV =

    0.1930


array_stdev2 =

    0.0250


error2 =

    3.2500


Mean_PowerOut =
```

```
   5.3607e+03


Power_In =

   33.7131


RealEff =

    0.0063


Efficiency_Error =

  -99.8952
```

Solar Panel Area Required for Greater South-east United States

```
[num,txt,raw]=xlsread('pv_test.xlsx');
Georgia_irr= num(:,3); %average readings for each month
Minimum_irr = min(Georgia_irr) ; %Design for the minimum irr (Dec,
 Jan, Feb)
Power_Required = 240; %Watts

eff = 0.05+(Efficiency_Error/100);
num_of_Cells = 0:1:73; %ft^2
i = [];
k = 73;
power_provided_G = zeros(numel(k)) ;
for i = 1:73
    power_provided_G(i) =
 num_of_Cells(i).*Minimum_irr.*(1/24).*eff.*(1/10.7639).*1.*1000;
end

x = max(power_provided_G)

power_provided_G2 = Minimum_irr.*(1/24).*eff.*(1/10.7639).*50.*1000 ;

peak_sunHours = 4.09 ; %calc for fixed solar panels, average in
 Georgia for Winter


x =

     0
```

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2

Appendix K – Risk Assessment

FAMU-FSU College of Engineering
Project Hazard Assessment Policy and Procedures

INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

PROJECT HAZARD ASSESSMENT POLICY

Principal investigator (PI)/instructor are responsible and accountable for safety in the research and teaching laboratory. Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures. PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.
3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.
6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :

a. Performing periodic laboratory visits to prevent the development of unsafe practice.
b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
c. Assigning a safety representative to assist in implementing the expectations.
d. Etc.

8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor's office (if experiment steps are confidential).

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Shayne McConomy	Phone #: 850-410-6624	Dept.: Mechanical	Start Date: 03/05/22	Revision number: 2
Project: T518 Yamaha Trash Interceptor			Location(s): FAMU FSU College of Engineering (COE)	
Team member(s): Jonathan Draigh, Emily Haggard, Momahad Kassem, Martin Senf, and Andrew Walker			Phone #: (850)-728-4516	Email: yamahatrashinceptor@admin.my.fsu.edu

Experiment Steps	**Location**	**Person assigned**	**Identify hazards or potential failure points**	**Control method**	**PPE**	**List proper method of hazardous waste disposal, if any.**	**Residual Risk**	**Specific rules based on the residual risk**
Wiring/Soldering (motor/solar panels)	College of Engineering	Emily H. Mohamad K. Martin S.	Exposure to hazardous fumes, Burns, and	Ensure the room is well ventilated	Safety glasses, protective	Soldering waste will be properly disposed of at	HAZARD: 2 CONSEQ: Minor	All PPE must be applied before the soldering device is

			electrocutio n		gloves, and fume fan	the college of engineering.	Residual: Low	turned on.
Coding and CAD	Remote	All team members	Eye strain, Carpal Tunnel	Every 20 minutes of computer use, look at something 20 feet away for at least 20 seconds to prevent eye strain. Take a 5 minutes walk for every hour of continuous computer use.		N/A	HAZARD: 1 CONSEQ: Negligible Residual: Low	Proper breaks shall be taken, and timers set to ensure the proper breaks are taken.
Machining materials	College of Engineerin g Remote	Andrew W. Jonathan D.	Exposure to being injured (cuts, bruises, etc…)	High difficulty metalwork will be done by a machine shop. Metal work done by members will be done with at least one other member present. It will be done in a well ventilated room that has ample lighting.	Safety glasses or face shield Thick leather gloves Long Sleeve protective shirt Long protective pants	Ensure all hands are washed and all work surfaces swept clean of any metal shards.	HAZARD: 2 CONSEQ: Moderate Residual: Medium	SEE BELOW Safety controls are planned by both the worker and supervisor. All PPE must be worn while doing any machining. A second worker must be in place before work can proceed (buddy system). An approval form and a

					Close Toe Shoes According to OSHA, safety goggles are expected when the user is subjected to flying particles			project hazard control form must be approved by both the PI and the safety committee. A second worker must always be present. The work space must have limited workers to ensure a safe environment All PPE must be applied before any equipment is used
Testing	College of Engineering Remote	All team members	Potential Fall Hazard Potential Lifting Hazard	Wear appropriate clothing Always test with at least	Safety glasses Long Sleeve protective shirt		HAZARD: 2 CONSEQ: Minor Residual: Low med	A second worker must always be present

			Potential injury due to device motion Potential slipping hazard	one other team member present.	Long protective pants Close Toe Shoes Hard Hat (especially if the device or any testing equipment is above head height)			Supervisor or PI must be notified before testing begins All PPE must be applied before ar equipment is usec testing commence Buddy system wi implemented when testing. Safety shoes must comply with the ASTM F2413-18 M/I/C EH standard
Installation	Storm drain	All team members	Potential slipping hazard	Proper PPE Proper administrative	Wear safety (Steel toe – non-slip – electric		HAZARD: 2 CONSEQ: Minor	Eliminate sources of potential hazards to the

			Potential lifting hazard Potential injury by the device Electric hazard	controls of the installation process Avoid carrying more than 35 lbs. individually	hazard protection) boots Protective goggles High visibility vests/jackets Hard hats Protective gloves		Residual: Low med	surrounding environment. Install administrative controls to hold inexperienced personnel from interacting with the device on-site. Ensure every team member is wearing their PPE. Supervisor or PI must be notified before installation process begins The buddy system will be utilized during installation, to ensure there is always

								supervision of one another Safety shoes must comply with the ASTM F2413-18 M/I/C EH standard
Assembling	College of Engineerin g Remote	All team members	Potential Lifting Hazard	Objects over 35 pounds will be carried by two people.	Safety glasses Metal toe shoes Hard Hat (especially if the device or any equipment is above head height). According to OSHA, protective helmets should be worn when there is potential for		HAZARD: 1 CONSEQ: Minor Residual: Low	All PPE must be applied before any equipment is used Supervisor or PI must be notified before testing begins All PPE must be applied before an testing commence Buddy system wi be implemented when assembling. Safety shoes must comply with the

					injury to the head from falling objects			ASTM F2413-18 M/I/C EH standard

Principal investigator(s)/ instructor PHA: I have reviewed and approved the PHA worksheet.

Name	**Signature**	**Date**	**Name**	**Signature**	**Date**
______________________	_______________	_________	_______________________	_______________	______

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	**Date**	**Name**	**Date**
Jonathan Draigh	03/05/22	Mohamad Kassem	03/05/22
Emily Haggard	03/05/22	Martin Senf	03/05/22
Andrew Walker	03/05/22		

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DEFINITIONS:

Hazard: Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as "*any source of potential damage, harm or adverse health effects on something or someone".* A list of hazard types and examples are provided in appendix A.

Hazard control: Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into following three groups (priority as listed):

1. **Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.
2. **Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.
3. **Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

Team member(s): Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

Safety representative: Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

Residual risk: Residual Risk Assessment Matrix are used to determine project's risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table2) are used to identify the residual risk category.

The instructions to use hazard assessment matrix (table 1) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.
2. Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

Table 1. Hazard assessment matrix.

		Complexity		
		Simple	Moderate	Difficult
Familiarity Level	Very Familiar	1	2	3
	Somewhat Familiar	2	3	4
	Unfamiliar	3	4	5

The instructions to use residual risk assessment matrix (table 2) are listed below:

1. Identify the row associated with the familiarity/complexity value (1 – 5).
2. Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
    a. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
    b. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
    c. Moderate: injuries that require treatment above first aid but do not require hospitalization.
    d. Significant: severe injuries requiring hospitalization.
    e. Severe: death or permanent disability.
3. Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.
4. Enter value next to: RESIDUAL on the PHA worksheet.

Table 2. Residual risk assessment matrix.

Assessed Hazard Lev	**Consequences**				
	Negligible	Minor	Moderate	Significant	Severe
5	Low Med	Medium	Med High	High	High
4	Low	Low Med	Medium	Med High	High

3	Low	Low Med	Medium	Med High	Med High
2	Low	Low Med	Low Med	Medium	Medium
1	Low	Low	Low Med	Low Med	Medium

Specific rules for each category of the residual risk:

Low:

- Safety controls are planned by both the worker and supervisor.
- Proceed with supervisor authorization.

Low Med:

- Safety controls are planned by both the worker and supervisor.
- A second worker must be in place before work can proceed (buddy system).
- Proceed with supervisor authorization.

Med:

- After approval by the PI, a copy must be sent to the Safety Committee.
- A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee.
- A second worker must be in place before work can proceed (buddy system).
- Limit the number of authorized workers in the hazard area.

Med High:

- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written Project Hazard Control is required and must be approved by the PI and the Safety Committee before proceeding.
- Two qualified workers must be in place before work can proceed.
- Limit the number of authorized workers in the hazard area.

High:

- The activity will not be performed. The activity must be redesigned to fall in a lower hazard category.

Project Hazard Control- For Projects with Medium and Higher Risks

Name of Project:		Date of submission:
Team member	**Phone number**	**e-mail**
Jonathan Draigh	**(616)558-6628**	**Jzd18@my.fsu.edu**
Emily Haggard	**(405)388-8532**	**Ech18@my.fsu.edu**
Mohamad Kassem	**(850)999-9819**	**Mak20ds@my.fsu.edu**
Martin Senf	**(954)684-9510**	**Mms18cy@my.fsu.edu**
Andrew Walker	**(850)728-4516**	**andrew2.walker@famu.ed**
Faculty Mentor	**Phone number**	
Shayne McConomy	**850-410-6624**	**smcconomy@eng.famu.fsu.edu**
Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").		

Wiring and soldering the electrical components of the trash interceptor has a Minor risk. The potential injuries include, but are not limited to electrocution, burns, and fume inhalation. To combat these risks, eyeglasses, masks, and non-loose clothing will be worn. A fan will be used to reduce the fumes, and all electrical equipment will be properly grounded prior to use.

Any cad and coding for the trash interceptor has a Negligible risk. The potential injuries include but are not limited to eye strain and carpal tunnel. To combat these risks proper breaks and stretches will be followed. A timer will be used to ensure that breaks are taken at proper times.

Any metal machining for the trash interceptor has a Moderate risk. The potential injuries include but are not limited to exposure to being pinched, punched, cut, or blinded. To combat these risks proper PPE will be worn before beginning any machining, a second worker must be present for all machine use, and a room that is well ventilated with ample lighting will be used.

Testing for the trash interceptor has a Minor risk. The potential injuries include, but are not limited to fall hazard, lifting hazard, and injury due to device motion. To combat these risks, eyeglasses and non-loose clothing will be worn and a second worker must present for all testing.

Assembling for the trash interceptor has a Minor risk. The potential injuries include, but are not limited to fall hazard, lifting hazard, and injury due to device motion. To combat these risks proper PPE must be worn when applicable during the assembling process. OSHA standards will be followed to determine when certain PPE is needed to worn.

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

If there are any injuries, fires, or an emergency, the first step to be taken is to call 911.

If there are any problems that may concern the facility, we have to contact our department representative.

- Remove the injured person from location of accident if safe to do so
- Call the appropriate authority (supervisor, FSUPD, 911, Poison Control dependent on severity and injury)
- Call emergency contact of injured person and inform them of incident

• Shut down/close off source of injury, if possible, in a safe and controlled manner • Isolate scene until the responding authority arrives • Ensure responding authority has all necessary information on the situation and assist them however they may need
List emergency response contact information:
• Call 911 for injuries, fires or other emergency situations • Call your department representative to report a facility concern

Name	Phone Number	Team Member	Faculty or other COE emergency contact	Phone number
Macray Simmers	(850) 598-4667	Emily Haggard	Shayne Mcconomy	850-410-6624
Pete Draigh	(616) 450-6355	Jonathan Draigh	Donald Hollett	(850) 410-6600
Eduardo Senf	(305)332-6325	Martin Senf	Jeremy Phillips	(850) 410-6113
Atif Kassem	(850) 300-9785	Mohamad Kassem		
Steve Walker	(850)-544-4815	Andrew Walker		

Safety review signatures

Team member	Date	Faculty mentor	Date
Martin Senf	03/05/2022		
Jonathan Draigh	03/05/2022		
Emily Haggard	03/05/2022		
Mohamad Kassem	03/05/2022		
Andrew Walker	03/05/2022		

Report all accidents and near misses to the faculty mentor.

Appendix A: Hazard types and examples

Types of Hazard	Example
Physical hazards	Wet floors, loose electrical cables objects protruding in walkways or doorways
Ergonomic hazards	Lifting heavy objects Stretching the body Twisting the body Poor desk seating
Psychological hazards	Heights, loud sounds, tunnels, bright lights
Environmental hazards	Room temperature, ventilation contaminated air, photocopiers, some office plants acids
Hazardous substances	Alkalis solvents

Biological hazards	Hepatitis B, new strain influenza
Radiation hazards	Electric welding flashes Sunburn
Chemical hazards	Effects on central nervous system, lungs, digestive system, circulatory system, skin, reproductive system. Short term (acute) effects such as burns, rashes, irritation, feeling unwell, coma and death. Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage.
Noise	High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term.
Temperature	Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C. Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures.
Being struck by	This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death.

Crushed by	A typical example of this hazard is tractor rollover. Death is usually the result
Entangled by	Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death.
High energy sources	Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death.
Vibration	Vibration can affect the human body in the hand arm with `white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems.
Slips, trips and falls	A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills.
Radiation	Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples.
Physical	Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures
Psychological	Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects
Biological	More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response.