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MECHANICAL ENGINEERING

Group 3 - FIU Eco-Friendly Shallow Draft Boat

100% Report

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Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of José Arrautt, David Neer, Domingo Malavé, and Sebastian Lopez and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text, and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development, and testing reported in this document are also original and prepared by the same team of students.

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Abstract

The continued use of fossil fuels as a primary source of energy has a harmful impact on both the environment and ecosystems. It is therefore becoming increasingly necessary to find and apply more environmentally and eco-friendly technologies which utilize alternative, renewable sources of energy.

The goal of this project is to design and create an eco-friendly, solar powered, shallow draft boat that will be used to transport people to and from a small island in Biscayne Bay. The concept of using a renewable energy source as the primary means of energy addresses the environmental impact, while the shallow draft design aids in conserving the local ecosystem. The major issues in building the boat are the regulations and requirements that are implemented by the government. One such regulation protecting the seabed is based on the water level at low tide, and allows boats a maximum of one foot draft.

One of the keys in achieving a successful outcome of this project is finding the optimal combination of materials, choice of hull, the propulsion and solar-based power system that will adhere to all rules and regulations while still blending aestheticism with functionality. We have chosen three conceptual designs for the hull, of which one is the most promising to use to begin designing the eco-friendly boat.

1 Introduction

1.1. Problem Statement

The main purpose of this project is to properly design an eco-friendly boat capable of transporting residents from a condo association to an island in Biscayne Bay area.

One of the main challenges this team will face is ensuring that any vessel built will comply with all rules and regulations established by all local and governmental agencies. This regulatory information is needed in order to successfully develop a usable design. Such a design will also require mathematical calculations, analysis of power systems, and performing software simulations.

It is important to take into account that speed is not an issue in this design, a maximum cruising speed is expected to be around 5 mph. The boat should also be able to transport up to 15 people. Our goal is to power the boat with solar energy. This entails installing a photovoltaic system with battery storage able to create enough energy to power two electric motors. With this goal, the team would be trying to achieve a design free carbon dioxide emission.

1.2. Motivation

The Senior Design Team is very excited to work with the client on such an innovative project, as it will give the chance for all team members not only to demonstrate the knowledge obtained through coursework taken at Florida International University. It will also show society that students become engineers when they are able to demonstrate their abilities to recognize a need, analyze problems and to find unique solutions through research, analysis, modeling, through the use of our minds and the appropriate engineering tools. This ability will be shown throughout the development of this project.

1.3. Literature Survey

1.3.1 History of Boats

The ocean has always caused fascination in humans since the beginning of time. Likewise, it has always provided food for their livelihood. Since the beginning of civilization, humans have had the necessity to move from one place to other. That is why more than 10 000 years ago, man first used a properly carved trunk as a means of transportation in the waters (Mai, 2012).

The Egyptians were one of the ancient civilizations that pioneered in the development of river crafts. They built many types of boats each for different uses. Some of these were used to transport agricultural products, troops, cattle, stones, funeral processions, hunting, and some solely to travel around rivers. These first boats were made of bundles of bound papyrus reeds (Papyrus is different from paper in that papyrus is a laminated material made from thinly cut strips from the stalk of Cyprus Papyrus plant) and used on the Nile River and its tributaries. These boats, powered by water current and wind, were steered with oars. These kinds of boats were built around 4000 B.C. (Mai, 2012).

After that, around 2500 B.C., the Egyptians replaced the papyrus for wood or conifers from Lebanon. They consisted of short blocks of timber and wood other to increase stability, allowing them to sail across the ocean.

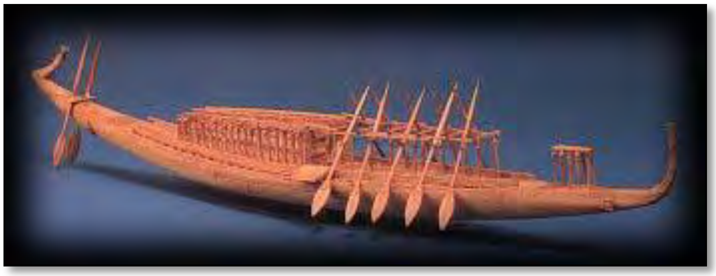


Figure 1 - Egyptian First Wood Boats replica **(Mai, 2012)**

In 1200 B.C., another civilization that started the development and construction of boats was the Phoenicians. These sea-faring ships were one hundred feet long and capable of supporting between one to two hundred tons. Similar to the Egyptians, the source of power for these ships were wind, water current, and brute human force (Salim, 1996).

By 500 B.C., the Phoenicians started building ships with masts and sails. The mast in the middle had a square sail, while the other one was triangular, and supported the main sail (Salim, 1996).

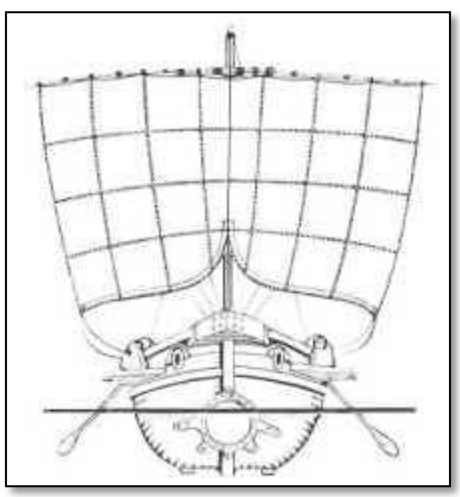


Figure 2 Phoenician Boats designs **(Salim, 1996)**

In 1000 A.C., The Vikings starts to play an important role in the history of ship construction, and became known for their elaborate and long ships. The designs of these ships were long and narrow, usually around eighty feet long by seventeen feet wide. The purpose of this design was to better enable navigation through the seas and rivers, while at the same time being used for trading, colonization, and war. Around sixty Vikings were needed to power the ships by use of oars (Lunde, 1999).

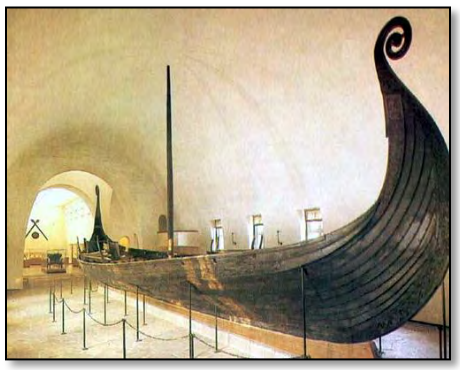


Figure 3 The Gokstand Viking Ship ISO view **(Lunde, 1999)**

Figure 4 The Gokstand Viking Ship front view **(Lunde, 1999)**

Starting in the 1200's ship designs began to improve, showing components we still see today. These ships now had rudders for steering, and batten on the sails to increase strength and water tightness. Also, the sails change from square to triangular in shape. The hulls became long and slim, and tall masts with triangular sails increased speed. They also had fore and stern castles for people, shelter and cargo. These ships where used for battles and by explorers for exporting and importing merchandise.

Around the 1750's a new era in design began. With the invention of the steam engine, would temporarily replace wind and man power to energy extracted from steam. The inventor of the Steamboat, John Fitch, born in Connecticut on January 21 1743, and was a watchmaker by trade. He became aware that steam could move gears and wheels, and took it to a larger scale, building the prototype of the Steamboat in 1787. This boat was 40 feet in length and had a series of paddles linked, together, which were powered solely by his steam engine. The invention performed with great success, navigating through the Delaware River.

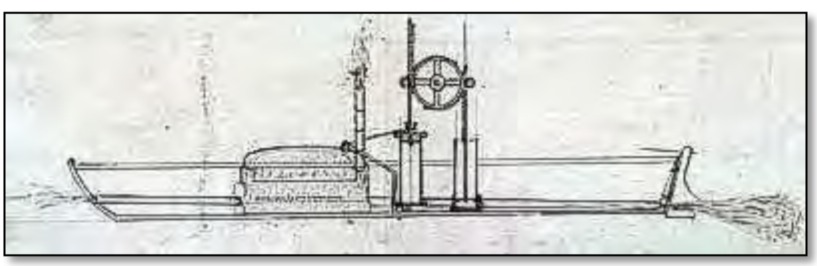


Figure 5 John Fitch Design Sketch 1787 **(Bellis, 1966)**

In 1807, engineer Robert Fulton was able to expand the use of steam ships by building the Clermont. This was the first steam boat that had commercial success in US waters. This new version placed a wheel of blades in the center of the boat, which replaced paddles, and was capable of carrying passengers and merchandise.

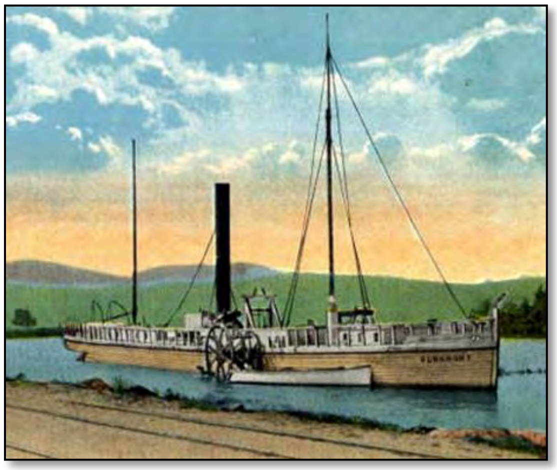


Figure 6: The Clermont -First Commercial Steam Boat in the US **(Bellis, 1966)**

In 1845, the materials used for the steam boat changed from wood to iron. These ships were driven by a propeller or by huge paddles wheels located on the back or in the middle of either side of the ship.

In the 1900's steamboats engines where replaced with diesel powered engines. This change started a new period in the development and design of new technology in the maritime industry.

1.3.2 Why do "things" float?

Archimedes' principle is a physical law which established a relationship between an object totally or partially immersed in a liquid, and the force the object experienced on the liquid by the water. The principle says the immersed object feels an upward thrust equal to the weight of the liquid displaced. Generally, this principle is applied to the behavior of objects in water, and explains why objects float or sink. The key concept of this principle is the 'thrust', or buoyant force, acting upward on the object, in effect reducing its weight in the water.

An object floats if its average density is less than the density of water. If it is completely submerged in water, the weight of water that is displaced is greater than its own weight, and the object is driven up and out of the water until the weight of the water displaced by the submerged part is exactly equal to the weight of the floating object.

Archimedes' principle can be illustrated by using the following formulas

$$Weight\ of\ immersed\ object\ = Weight\ of\ the\ object - weight\ of\ displaced\ fluid$$

$$\frac{\rho_{object}}{\rho_{fluid}} = \frac{W_{object}}{W_{displaced\ fluid}}$$

For example, a block of wood, with a density 1/6th that of the water, will float with 1/6th of its volume immersed below water, since at this point the weight of the displaced fluid is equal to the weight of the block.

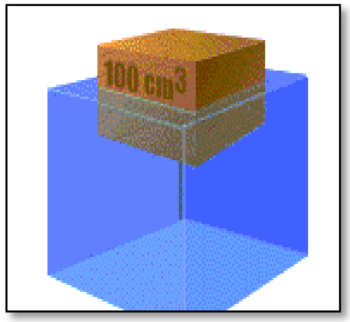


Figure 7 Archimedes' principle

By this principle, it is explained why boats and big ships do not sink in the water. Any boat will float lower in the water when they are heavily loaded because more water needs to be moved to generate the necessary force to keep it floating.

In addition, it is important to keep in mind that that if the ship is navigating in fresh water, it cannot be loaded as if it were going to be sailing in salt water. This is due to the fact that fresh water is less dense than sea water.

2 Project Formulation

2.1 Overview

Onyx on the Bay Condominium Association, Inc. is a non-profit organization located on the Miami side of Biscayne Bay at NE 25th Street. There is an island with a sandy beach approximately one mile from the Condo location in Biscayne Bay along the Intercostal waterway. Currently, there are very few means to reach the island, such as kayaks, jet skis, or private boats, of which one would first need to, travel a distance to the marina and embark from there. The Onyx is only one of tens of thousands of condos, hotels, and apartments built east of

I-95, north of the MacArthur Causeway, and south of I-195 (Julia Tuttle Causeway) over the last 10 years. A more practical means of reaching the island is to be found, while still being both friendly to the environment and the local ecosystem.

2.2 Project Objective

The President of the Onyx on the Bay Condominium Association, Inc. approached us with an idea for a means of transporting both residents and tourists directly from the Onyx location to the island. To stay eco-friendly, his idea is for a solar powered boat that would both accommodate his desires of reaching the island, and ensure the local/global environment is impacted as little as possible.

2.3 Design Specifications

The area in which the boat would function is a relatively narrow waterway with a wide variety of plant and animal life. Additionally, the shore lines of both the city side and around the island have very shallow water, with its lowest water level being reached at low tide. In order to keep true to the client's objective, the boat must therefore be shallow draft, such that the plants and sea floor remain undisturbed during docking, loading, and departure.

In order to meet and exceed the client's desire for having an eco-friendly vessel, we are attempting to have the boat be run solely off of solar power. This shall be achieved by use of solar panels for energy absorption, and batteries for energy storage. Although this will be the primary source, conventional sources of power will still be available and used as needed. It will also accommodate needs of the handicapped and disabled, which needs to follow its own specific set of regulations.

2.4 Constraints and Other Considerations

As mentioned in section 2.3, the bay area has many forms of wildlife, including manatees, fish, and sea grass, all that give character and add to natural value of the area. This is one of the greatest considerations that must be taken into account when developing a design for the boat. In order to not disturb the wildlife or the seabed, we must take into consideration the worst case scenario, which is being located near the shoreline during low tide. This gives a maximum allowable underwater depth of no more than one foot.

While that is on its own taking an environmentally positive approach, there are also many legal matters that govern everything from use of the waterway itself, the island, any docking that may be implemented, noise levels, and also specifics regarding aspects of the vessel itself. To ensure that all the proper permits are received and laws are adhered to, we must contact a number of different local and governmental agencies to learn of all constraints and limitations that must be strictly adhered to. The following is a list of each of the agencies that need to be contacted, along with which legal aspect of the project they are in charge:

- Biscayne Bay Aquatic Preserve Statute – *governs the use of the area in which we want to operate.*
- Fl. Department of Environmental Protection (DEP) – *owns the Island and bay bottom. Also, it has regulations for boat usage and dockage.*
- U.S. Coast Guard (USCG) – *Boat rules (Commercial vs. private) and standards.*
- Miami Dade County Department of Environmental Regulation & Management (DERM). *Regulates access rights, permitting, and usage of the area we want to operate in.*
- City of Miami – Building & Zoning (& Parks Dept.). *Dockage and access rules, regulations, and permits.*

2.5 Rules and Regulations

For the construction of a vessel, there are a number of rules and regulations that must be adhered to in order to ensure no unnecessary setbacks and/or fines might be issued after the vessel's launch. As the boat will be used in the Biscayne Bay area, one of the main agencies that needed to be contacted was the Biscayne Bay Aquatic Preserve. This agency, established in 1974, is managed by the Florida Department of Environmental Protection to protect "the exceptional biological, aesthetic, and scientific values of the bay for future generations." The Biscayne National Park, which covers 173,000 acres and are governed by special regulations enforced within its boundaries. These regulations cover terrestrial as well as marine wildlife, along with the water itself and the seabed. Figures 8 and 9 show maps of the protected area, while Figure 10 gives a legend describing the regulation zones (DEP, 2013).

Figure 8- Maps and legend for affected areas in Biscayne Bay

Figure 9 -Maps and legend for affected areas in Biscayne Bay 2

Figure 10 - FWC Manatee Regulation Zone

One of the most important regulations that needed to be considered in the design of the vessel was the allowable draft. In determining the draft, the lowest known water level, which occurs around the shoreline at low tide, had to be the baseline from which we worked. This level at its lowest is 3 feet deep. However, the sea grass, which can reach lengths of up to 2 feet, must also be protected, as it is an invaluable plant life that in and of itself helps to protect the water quality, along with providing food, home, and shelter to many types of animal life, such as manatees, sea turtles, shrimp, crabs, worms, snails, and small fish. Therefore, the allowance of a 1 foot became the maximum draft that must be attained.

The shallow draft is just one part of the Aquatic Preserve regulations that need to be cared for. One must also have knowledge of the boating signs and markers, and also be able to ‘read the waters’. Figures 11 and 12 are images which display how one can read the waters, and the signs which one must be familiar with while operating the vessel (DEP, 2013).

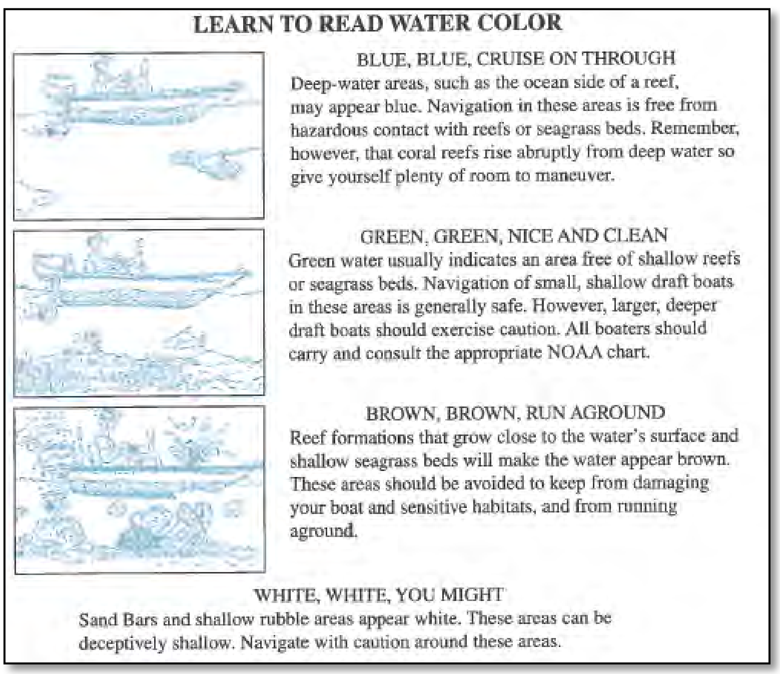


Figure 11 - Guide to reading the water color

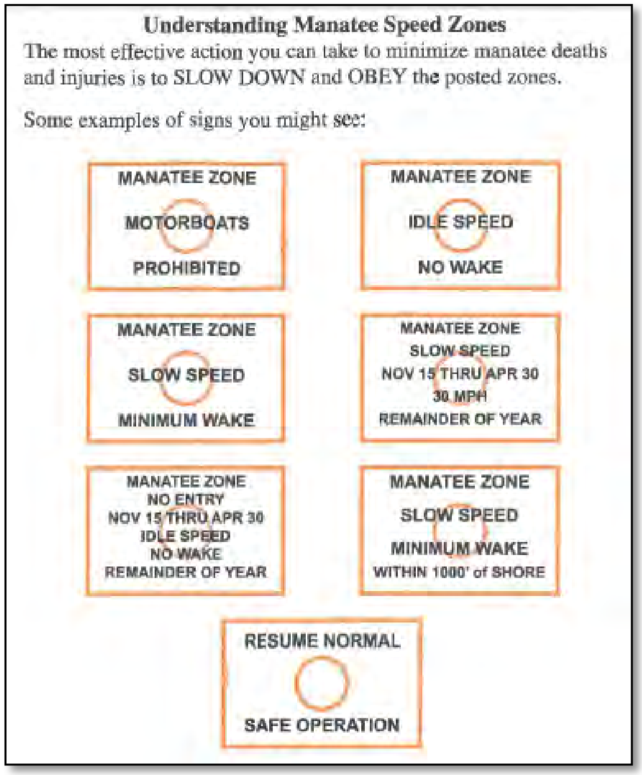


Figure 12 - Manatee speed zone signs

To further explain the signs, definitions are provided for clarification.

Motorboats Prohibited – An area where the entry of vessels powered or propelled by machinery is prohibited. This does not apply to vessels using sails, oars, poles, etc., provided that propelling machinery is not being used and, to the maximum extent possible, raised out of the water.

Idle Speed – The minimum speed that will maintain the steerageway of the boat.

Slow Speed - The speed at which a vessel proceeds when it is fully off plane and completely settled in the water.

30 MPH or 35 MPH - These speeds are defined as a vessel's speed over the bottom, measured in statue miles per hour.

The other rules and regulations that will need to be adhered to are mainly the responsibility of the boat manufacturer. One such rule applies to the ADA (Americans with Disabilities Act). Being a passenger vessel, the client wants to ensure that anyone would be able to board. According to ADA Guideline 4.13.5 describing clear width, Therefore, a ramp must be provided, with a doorway of minimum width 32 inches. The threshold itself, according to guideline 4.13.8 shall not exceed ¾ inches, and in the case of floor level changes, this change shall be beveled with a slope no greater than 1:2. Once on board the vessel, according to guideline 4.8.3., clear passage and walkway room of 36 inches must be maintained.

Once the vessel is built, and before it is sea bound, it needs to go through an inspection by the Coast Guard, and must also be registered with the Florida Wildlife and Protection Committee.

3 Design Alternatives

3.1 Overview of Conceptual Designs Developed

The Design Project Team was approached with an idea that, in and of itself, had very few constraints based strictly on the wishes of the client. The main constraint was that the hull of the boat must remain at a depth of no more than one foot below water. The client also wished to have ease of access in both loading and departing from the boat, including making the vessel handicap accessible. Other serious constraints, ranging from noise level, to boat dimensions, to speed, are regulated by numerous local and governmental agencies. As of yet we have not been able to reach all necessary parties. Therefore, we are focusing on the client's primary constraint. One of the main factors in determining how deep a boat will go below water is the hull, in addition to the material used in its manufacturing. The Design Project Team chose as a first attempt to analyze flat bottom hulls, round bottom hulls, and pontoons. More detailed descriptions of each of these will be found in the following sections.

3.2 Design Alternate 1

Flat bottom boats can be an ideal candidate when the area of use is shallower bodies of water. The shape of the hull allows the boat to ride, or plane, on top of the water rather than through. This attribute gives the boat a very stable design. Additionally, flat bottom hulls have greater buoyancy. Therefore, boats of these types tend to have very high decks, making the rides dry. This type of design also allows for a very smooth ride in calm waters.

On the contrary, in choppier waters, the ride can become significantly rougher. Another disadvantage is that generally, flat bottom boats are less maneuverable than some other hull types. As the intent is to be used mainly in calmer waters, very low horsepower motors are needed. If the power to the boat's motors is too great, that would also increase the roughness of the ride.

3.3 Design Alternate 2

The catamaran design is a hull design that consists of two hulls joint by a structure, most commonly being a frame, formed of akas. This type of boat can be powered by engine or by sail. Although catamarans have been known to exist for many centuries, it was not until recently the design was introduced on a grander scale by boat manufacturers. Catamarans are becoming one of the most popular designs for cruising boats for their stability, their speed, and large capacity.

Other advantages to this type of boat are the low cost and ease of manufacturing – they require no ballast, and have good performance. They also provide large and broad decks for passenger comfort.

3.4 Design Alternate 3

The final design alternative we are investigating is the pontoon. Like the round bottom hull, the pontoon is also a displacement hull. This type of hull shape allows for a larger flat deck area, which can be desirable if one wishes to carry a greater number of people. One disadvantage is that this design shape has lower efficiency, and should only be used at very low speeds. We were taking into consideration this design because it is very simple design. As explained above, a pontoon boat is just a flat raised deck that is being held by outer typically circular hulls.

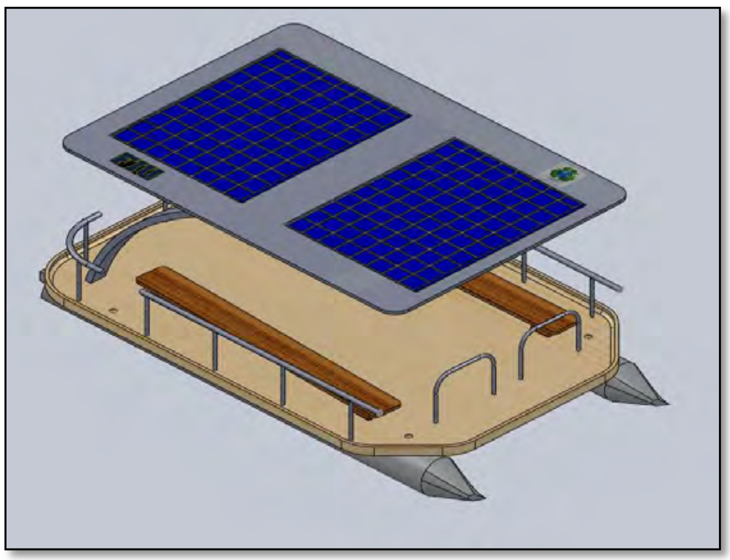


Figure 13 – Design Alternative 3

Pontoons are generally constructed in cylindrical shapes, and built using light metals to best compensate other loads they need to hold. Due to being lightweight, strong, and flexible; aluminum, is considered by many to be an ideal material for boat hull building.

To build the pontoons, a sheet of aluminum is continuously put through a rolling process to standard sizes, and then turned into tubes and welded. They are also not entirely cylindrical, as the pontoon's nose is built in a cone shape, which is purposely designed to serve as a waive breaker. All these sections are welded together to form a complete pontoon.

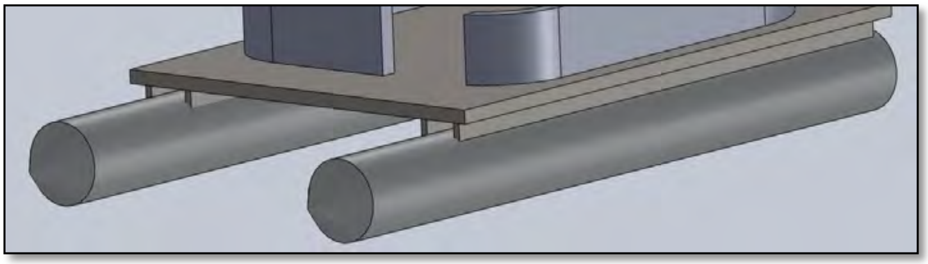


Figure 14 - Pontoon Design

Each pontoon is constructed with several brackets welded to it, which are used to hold aluminum cross members between both pontoons to support all the weight that will be added to the top. To construct the boat floor, pressure treated plywood is placed on top of the frame previously constructed between the pontoons forming the flat platform.

3.5 Other Considerations

The material to be used for hull construction is another large factor to be considered. The Design Project Team needs to complete a series of studies considering all materials characteristics; choosing a material for the wrong application design could be costly. There are many options out there on the market such as aluminum, fiberglass, carbon fiber/Kevlar, and even wood. Aluminum, being less costly, can be an ideal candidate for pontoon boats. Fiberglass, being lightweight and durable, provide long lifespan, is often a first choice for boat builders. Carbon fiber/Kevlar is used by many companies in the production of flat boats in order to accomplish designs that require light weight and shallow draft. Wood, already haven proven its worth by successfully being used to construct boat hulls for centuries, is now being incorporated into the newest boat designs by getting mixed with other materials. These new composites have more desirable properties, making the construction lighter and cost efficient.

3.6 Proposed Design

The main objective of this project is to build a solar powered shallow draft water vessel for the purpose of transporting people. After analyzing several boats designs, taking into account the study building analysis of all parts, and following guidance and advice from Dreamboats Manufacturing a Catamaran hull was the best choice. First and foremost, it is the most effective in shallow water. Also, as explained previously, a catamaran has great stability because they have wide beams for extra structural support.

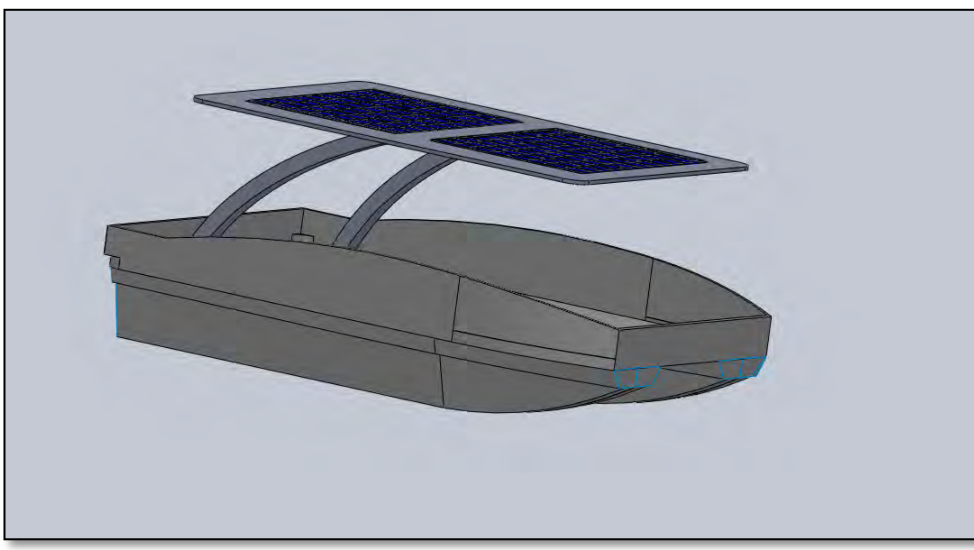


Figure 15 - Catamaran Proposed Design

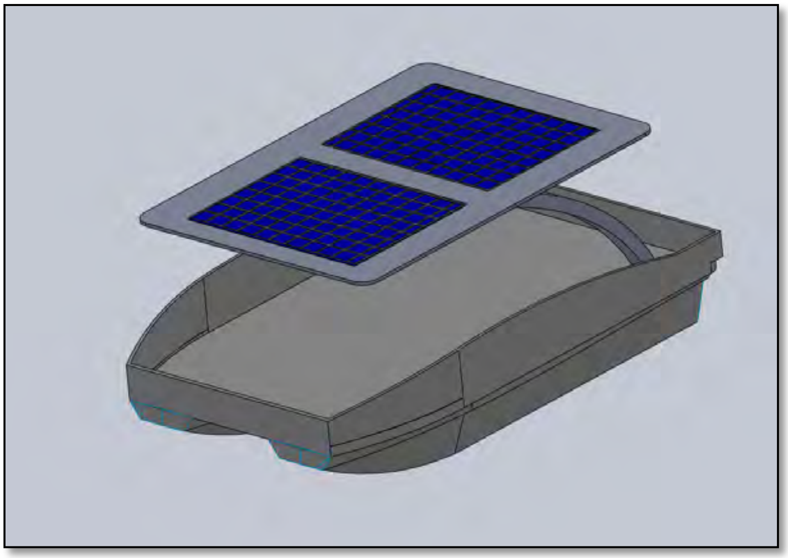


Figure 16 - Catamaran Isometric View

The dimensions for this design will be between twenty four and twenty 6 feet in length and eight and half feet wide. This design will have a set of stairs that flip over the bow for people to walk out on dry land. Also, another door will be place on the side of the boat with a ramp in order to provide an easy access to people with disabilities. The main deck will be just above water level and the forward deck will be elevated for storms and larger waves. Also, the deck will be self-bailing, so if any water gets in to the boat it drains out immediately.

Solar panels on the overhead canopy area will also work as shelter from the sun while providing the necessary output to power the electric motors. This hard top would have a clearance of 78 inches above the deck.

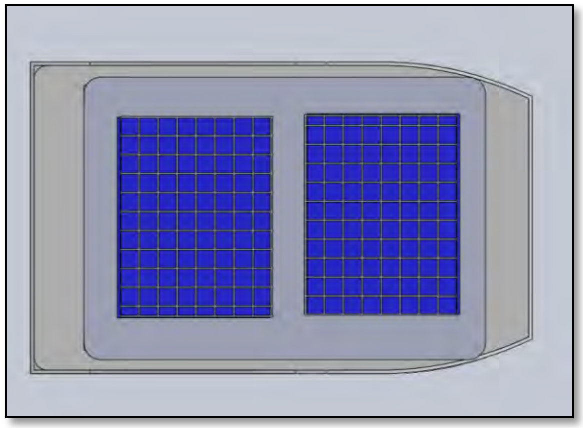


Figure 17 - Catamaran Proposed Design Top View

The most important aspect when moving a boat through the water is to displace as little water as possible, so the biggest factor concerning the boat efficiency is the drag. Using the catamaran's square type sponsor will allow the reduction of drag at lower speeds and increase efficiency.

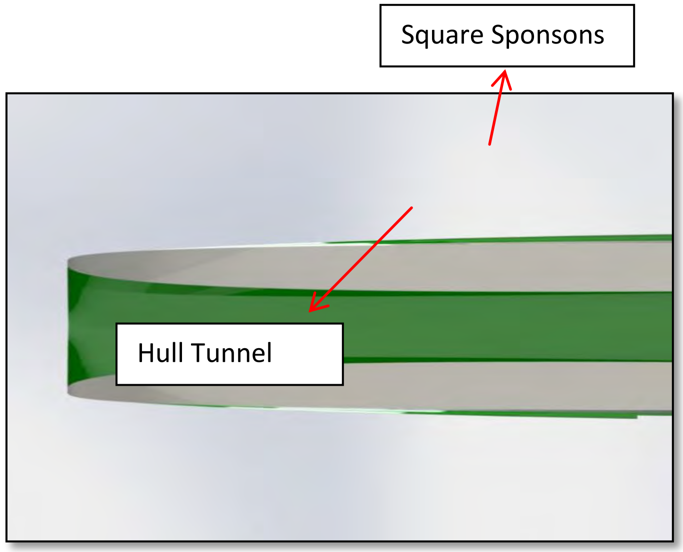


Figure 18 - Catamaran Square Sponson

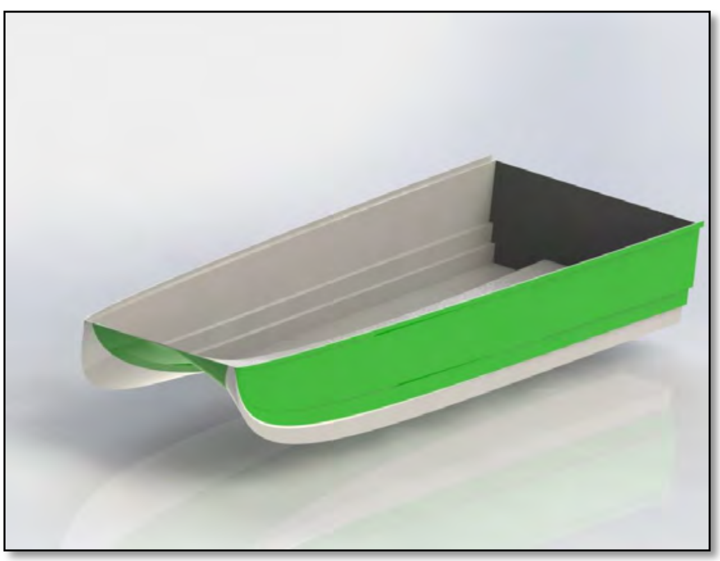


Figure 19 – Final Catamaran hull design

4 Project Management

4.1 Assigned Tasks for Senior Design Project

Our team decided to distribute each responsibility depending on everyone's individual strengths in order to work efficiently at achieving every single task. In the table below, each task and their assignments are listed.

Task Name	Assigned to
Site Visit Meeting with Client	All members
Contact local and government agencies	David Neer, Sebastian Lopez
Literature Survey	Jose Arrautt & Sebastian Lopez
Design Alternatives	Domingo Malave & David Neer
10% Report	All members
Conceptual Design	Domingo Malave & David Neer
Poster Design	David Neer & Domingo Malave
SolidWorks Modeling	Jose Arrautt
SolidWorks Analysis	Jose Arrautt & Sebastian Lopez
25% Report	All members
Research & Solar Panels Selection	Sebastian Lopez, Domingo Malave & David Neer
Research & Battery Selection	David Neer & Domingo Malave
Research & Engine Selection	Jose Arrautt & Domingo Malave
50% Report	All members
Analytical & Structural Analysis	David Neer, Sebastian Lopez, Jose Arrautt

Research & Materials Selection	Jose Arrautt
75% Report	All members
Cost Analysis	All members
Final Design	All members
100 % Final Report	All members

Table 1 - Assigned Tasks for Senior Design Project

4.2 Projected Timeline for Senior Design Project

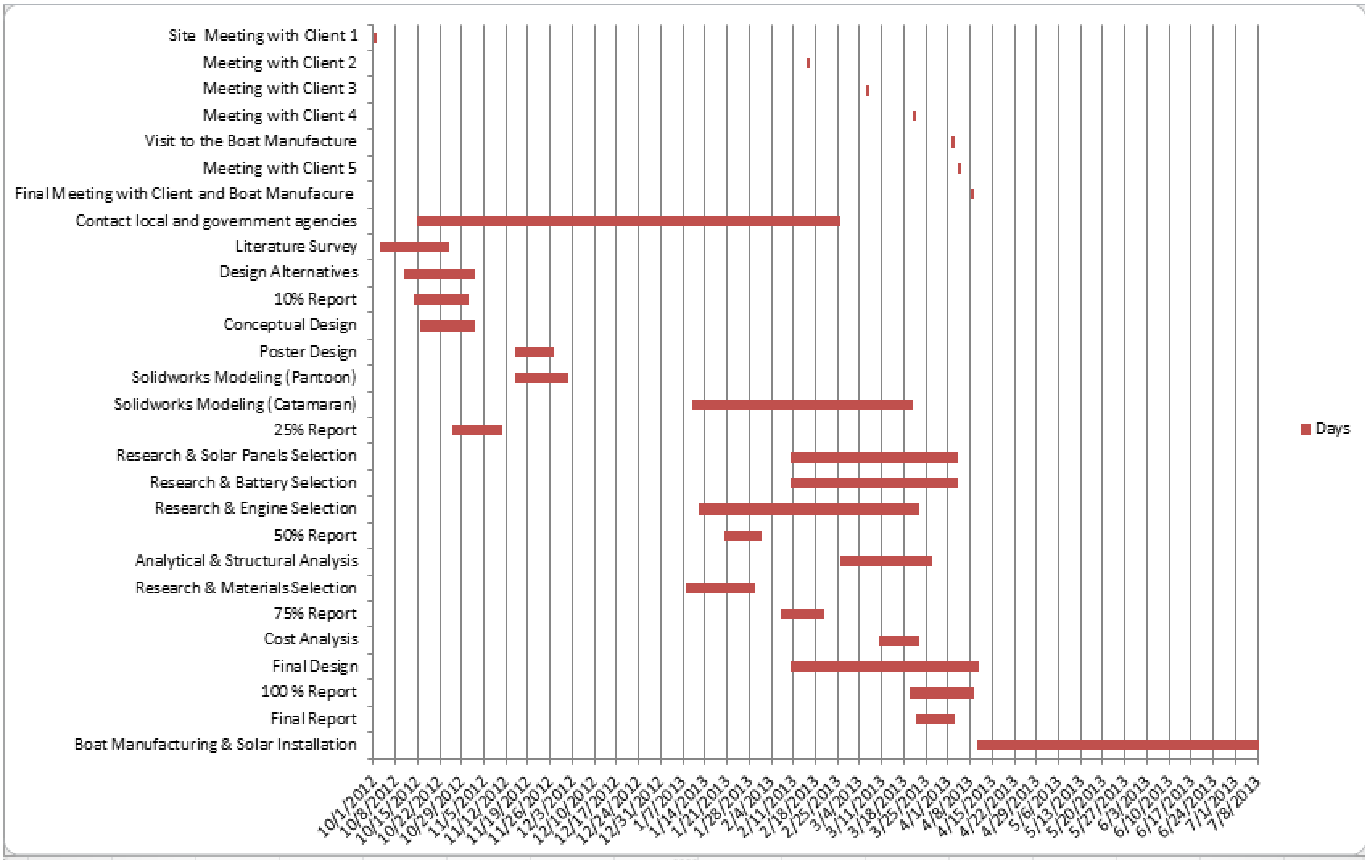


Table 2 - Timeline

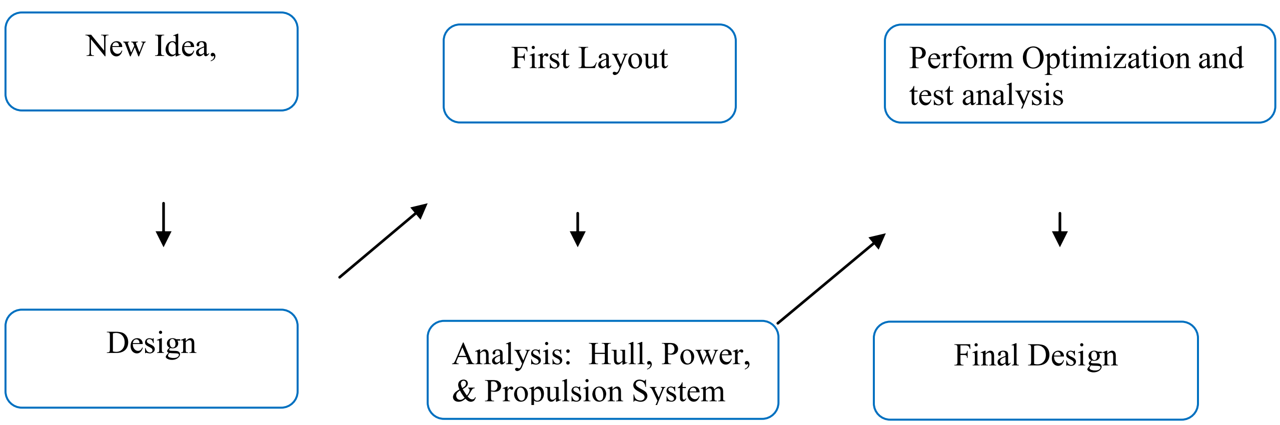
Task Name	Start Date	Days	End Date
Site Meeting with Client 1	10/1/2012	1	10/1/2012
Meeting with Client 2	2/15/2013	1	2/15/2013
Meeting with Client 3	3/6/2013	1	3/6/2013
Meeting with Client 4	3/21/2013	1	3/21/2013
Visit to the Boat Manufacture	4/2/2013	1	4/2/2013
Meeting with Client 5	4/4/2013	1	4/4/2013
Final meeting with client and boat manufacturing	4/8/2013	1	4/8/2013
Contact local and government agencies	10/15/2012	134	2/25/2013
Literature Survey	10/3/2012	22	10/24/2012
Design Alternatives	10/11/2012	22	11/1/2012
10% Report	10/14/2012	17	10/30/2012
Conceptual Design	10/16/2012	17	11/1/2012
Poster Design	11/15/2012	12	11/26/2012
Solid works Modeling (Pontoon)	11/15/2012	17	12/1/2012
Solid works Modeling (Catamaran)	1/10/2013	70	3/20/2013
25% Report	10/26/2012	16	11/10/2012
Research & Solar Panels Selection	2/10/2013	53	4/3/2013
Research & Battery Selection	2/10/2013	53	4/3/2013
Research & Engine Selection	1/12/2013	70	3/22/2013
50% Report	1/20/2013	12	1/31/2013
Analytical & Structural Analysis	2/26/2013	29	3/26/2013
Research & Materials Selection	1/8/2013	22	1/29/2013
75% Report	2/7/2013	14	2/20/2013
Cost Analysis	3/10/2013	13	3/22/2013
Final Design	2/10/2013	60	4/10/2013
100 % Report	3/20/2013	20	4/8/2013
Final Report	3/22/2013	12	4/2/2013
Boat Manufacturing & Solar Installation	4/10/2013	90	7/8/2013

Table 3 –Detailed Task Schedule

5. Engineering Analysis

Vessels and ships designs are a very huge and complex process. The first step in the construction and fabrication of any kind of vessel or ship is to have a conceptual design. In addition to that, it has to define what will be the purpose of the vessel. This could be for cargo, sporting, fishing, purposes or as a ferry.

The following diagram shows an idea of the flow and the steps that it takes to design a boat.



For purpose of this project the team has decided to use a Catamaran Boats design as initial and most convenient design. In addition to that, the requirements and standards established by the state need to be follow in order to have a safe design and be able to be approved by the state and federals Laws.

The next step is to calculate the capacity or amount of water that the vessel will displace. This is known as the buoyancy force. This is very simple process which is retrieved by finding the volume of the boat or ship hull, and multiplying that total volume by the weight of the water which is 62.4 pounds per cubic foot.

The easiest way to find the total volume of the vessel is by dividing the hull in individual boxes. Mostly, these boxes turn into really simple geometric shapes such as triangles, squares or rectangles. The following picture represents an example of this method.

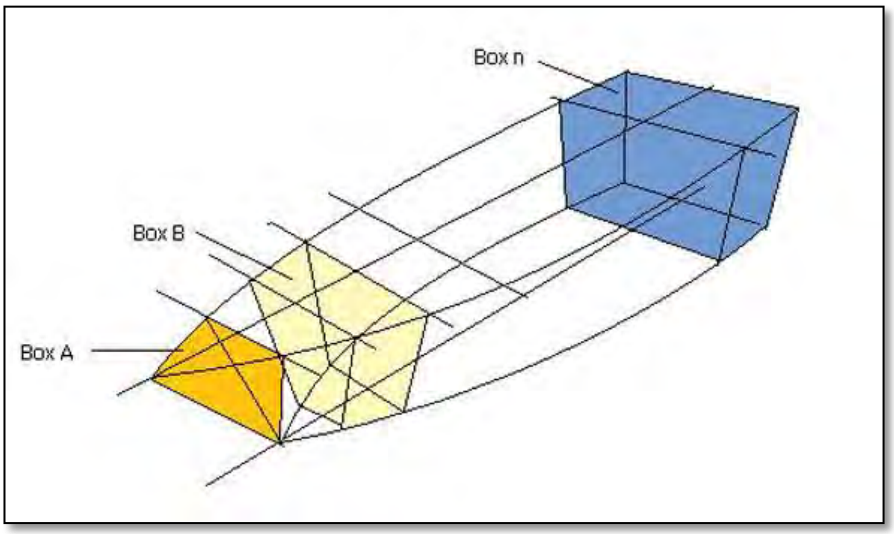


Figure 20 -Volume of Boat hull **(Betran, 1998)**

As mentioned before, for purposes of this report, the selected design was a catamaran s type. This allows us finding the volume of the catamaran that is submerged into water easily and faster.

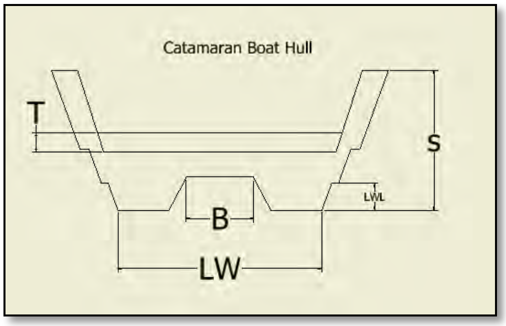


Figure 21: Side view of catamaran hull

Figure 22: Back view of catamaran hull

B	Distance between each sponson
S	Deck surface
H	Height of hull
T	Thickness of the deck
L_H	Sponson length
L_W	Length between outer edges of sponsons

Table 4 -Catamaran Boat Parts

Here are some calculations that were done in order to obtain the water displacement for the design of the vessel. These calculations shows how long and wide the catamaran must be in order to fulfill the design constraints of the project.

Buoyancy Force

Buoyancy occurs when an object is placed in a fluid, and the fluid will exert an upward force that is call the buoyant force. This buoyancy force is proportional to the area of the submerged object and the total volume of fluid displaced. Therefore, the force will continue to increase as the object is placed deeper in the fluid; force on the bottom of the object will be always larger than the force on the top of the object.

Figure 23 – Top View of Sponsons (Dimensions in feet)

Figure 23 shows the top view of the two sponsons. To find the area and volume at one foot below water the team decided to cut the sponsons into three different sections. To find the area of section 1, multiply base (2.5) times length (6) then divide by 2. The height of each sponson is 8 inches, or 0.667 ft. Therefore multiply by 0.667 to get the volume.

$A = \frac{b*l}{2} = \frac{2.5*6}{2} = 7.5ft^2$

$V = 7.5ft^2 * 0.667ft = 5ft^3$

Section two is a rectangle. The team multiply base (2.5) times length (14). Then multiply it by 0.667 to get the volume.

$A = b*l = 2.5 * 14 = 35ft^2$

$V = 35ft^2 * 0.667ft = 23.345ft^3$

To find the area of a half parabola, which is the shape of section three, it was multiply 2/3 times base (2.5) times length (6). Then multiply it by 0.667 to get the volume.

$A = \frac{2}{3}*b*l = \frac{2}{3} * 2.5 * 6 = 10ft^2$

$V = 10ft^2 * 0.667ft = 6.67ft^3$

The volume of the three sections were added and multiplied by two to compensate for the boat's second sponson. After that our team multiply the total area times the density of water.

$F_{b1} = [(5+23.345+6.67)*2]\ ft^3 * 62.4\frac{lb}{ft^3} = 4369.87\ lbs$

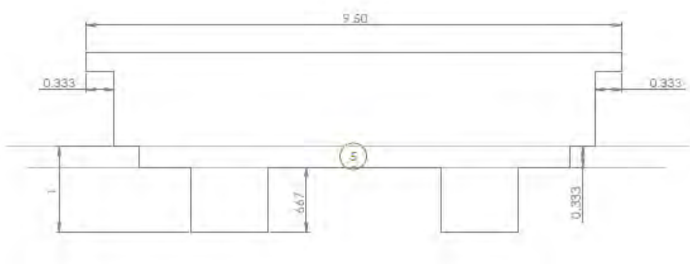


Figure 24- Cross-section of boat

Figure 24 shows section 5, which will be the remainder of the submerged boat that makes up the 1 ft draft. The submerged length is 20 ft, the width of the base is 8.33 ft, and the depth is 0.33 ft.

$A = b*L = 20ft * 8.33ft = 176.67ft^2$

$V = 176.67ft^2 * 0.33ft = 58.889ft^3$

$F_b = 58.889ft^3 * 62.4\frac{lb}{ft^3} = 3674.67lbs$

Total F_b = 4369.87 lbs + 3674.67 lbs = 8044.54 lbs

Total weight for the boat is 6700lbs. With a total for the buoyancy force equaling 8044.54 lbs., we arrive at a factor of safety for 1ft of draft as 1.23.

<u>Frictional Resistance</u>

A resistance to the relative movement of two objects is usually proportional to the force which presses the surface together. The internal resistance to flow is known as viscosity. The less viscous a fluid is the easier it will be for an object to move through it.

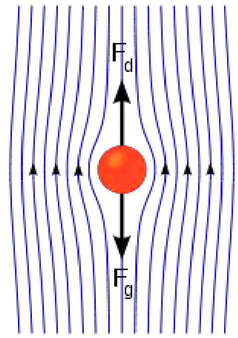


Figure 25 - Drag Force

During a period of 100 years, it was found that friction varied with the surface that was wetted and the square of speed. William Froude came out with the equation below to find the frictional resistance.

$$R = fSV^{1.83}$$

R = Resistance in lbs.

S = Surface in ft^2 = $281.67ft^2$

L = Length in ft. = 26ft

V = Speed in knots = 5 knots

L		***f***
15'		0.01093
20'		0.01052
30'		0.01007
40'		0.00979
50'		0.00961

$$\frac{26-20}{30-20} = \frac{f-0.01025}{0.01007-0.01025} \rightarrow f = 0.01025$$

In order to find f our team needed to interpolate from 20 to 30 to get the exact f. After interpolating the value is 0.01025. After doing the calculation of the friction resistance, the result was 109.8lbs and you can see it in the equation below.

$$R = fSV^{1.83} = 0.01025\ (281.67ft^2)\ (5knots)^{1.83} = 109.8lbs$$

Effective Horsepower

P_e (Kw) = 0.0697*C_t*S*V_k^3

C_t = total resistance coefficient

S = wetted surface in m^3

V_k = speed in knots

$$C_t = \frac{2358.68}{\frac{1}{2}*1027*2.265*2.058\text{^}2} = 0.48$$

P_e (Kw) = 0.0697*0.48*2.265*4^3 = 4.85 Kw = 6.50hp

Fb > or = Wt	Float
Fb< or = Wt	Not Float

Table 5 - Weight, Volume, Buoyancy Force

Once the amount of displaced water is calculated, the maximum weight capacity needs to be found. The maximum weight capacity of a catamaran is found by subtracting the total weight of the boat from the volume of displaced water when both sponsons are submerged. The factors that should be included in the total weight of the boat are the weight of the hull, motor, batteries, solar panels, and associated miscellaneous electrical equipment. This weight is referred to as dead weight, as they comprise the permanent fixtures in the boat. In addition to the dead weight, it is of course important to add the weight of the passengers. According to Coast Guard specifications, the average weight to be used per person is 141 lbs. At maximum capacity, the boat will carry 15 passengers plus the helmsman.

6. Major Components

6.1 Propulsion System

In order to power the boat, several systems have been studied. The first option that the team took into account was a jet propulsion system. Some of the disadvantages of the jet propulsion are their low efficiency. This system wastes lots of energy because of the high internal friction in the pump assembly. In addition to that, at slow speed they get clogged a lot and have even lower efficiency. On the other hand, this system has great performance, acceleration, and it is very safety to people around it.

A different option the team took into consideration was the propeller propulsion system. The stainless steel ducted propellers will perform better at lower speeds. They do not flex, but in order to get one with a shield or duct around it, the propeller will have to be custom made and it will increase the cost in the design. Despite this increase in cost, the duct will provide extra protection for the propeller from wear, allowing it to last longer. On the other hand, if plastic propellers are used they can flex and loss energy for the system. Propellers come in different sizes and shapes. They have to match the engine power and also the displacement of the boat. The propeller is determined by the numbers of the diameter, the pitch, and the blades. They come with two, three, and four blades. A three blade propeller is the most widely used by boats manufactures.

The propeller diameter is based on the distance measured from the tip of the blade to the center of the propeller hub this distance needs to be double. In addition, the propellers are more effective as the diameter increases.

If a large boat runs with a small propeller the engine will not work as well as having the right one, as a consequence the engine will go in high RPMs beyond the maximum set by the manufacturing resulting in a permanent damage for the engine. Opposed to that, by putting a bigger propeller will not give the right horsepower for the boat. It can be concluded that the shape of the propeller will affect the performance the engine will produce.

The propeller is also one of the main components of the boat. It transmits power by transforming rotational motion into thrust. When its rotating, the forced created by the rotation is converted into pressure and is used to accelerate the boat forward or backwards. Most propellers have their axis of rotation parallel to the fluid flow. In the past there have been some research about powering vehicles the same way they do with boat but they have been unsuccessful. There are different types of propellers: controllable pitch, skewback, and modular. (Devlin, 1978)

6.1.1 Controllable Pitch Propeller

This type of propeller has some advantages with ships. One of them is the ability it has to move the vessel backwards, adjusting the blade pitch with this the optimum efficiency can be achieved and fuel can be save, and finally the propeller has a “vane stance” this will give the least resistance of water when not using the propeller (Devlin, 1978).

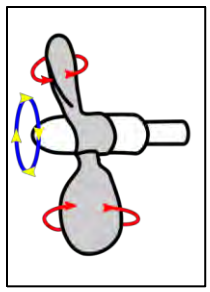


Figure 26 - Controllable Pitch Propeller **(Devlin, 1978)**

6.1.2 Skewback Propeller

It is a type of propeller that was used on Germans Type 212 submarines. These skewback propellers are swept back against the direction of the rotation. The blades are inclined backward along the longitudinal axis.

Figure 27 - Skewback Propeller **(Devlin, 1978)**

6.1.3 Modular Propeller

It’s a type of propeller that uses much different type of materials that has replaceable parts. The purpose of modular propeller is that it will provide more control of the boat at high speed. Each modular propeller it's made of the three different parts: front end cap, replaceable blades, and a rear shaft.

Figure 28 - Modular Propeller **(Devlin, 1978)**

In order to act extra protection for the ecosystem in the Biscayne Bay Aquatic Preserve, a duct will be made to fit around the propeller. This will keep the manatees safe and away from being cut by the actual propeller.

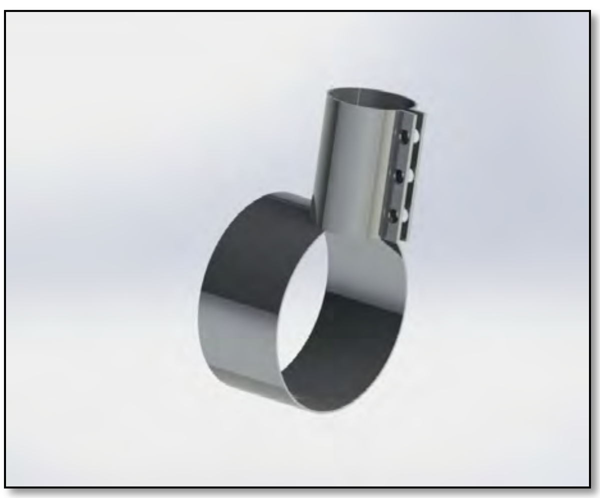


Figure 29 – Propeller Duct Concept Design

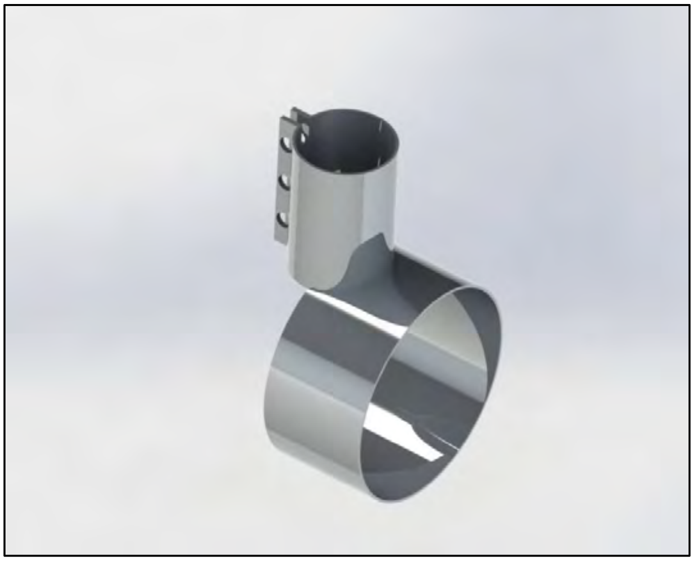


Figure 30 - Propeller Duct Isometric View

6.2 Power System Overview

The main power supply for the system is to come by means of solar energy through a photovoltaic (PV) system. Generally speaking, a photovoltaic system directly converts solar energy into electricity. The setup for such a system can be broken up into two main categories: one which is grid connected, and the other which is a stand-alone system. Regardless, the main element in any system is the photovoltaic array. Other common components are batteries for storage of energy, a charge controller for regulating output, and an inverter if the power needs to be supplied to an AC load. As the power system would be used for a sea bearing vessel, it would of course be a stand-alone PV system. Within the category of stand-alone, there are a number of subcategories. The most practical system for our application would be a stand-alone hybrid PV system. A hybrid system system's key component is a non-grid source of electricity. This source is used as a backup in the event that the solar output or battery storage becomes insufficient to meet the required load capacity. It then becomes necessary to add a rectifier to the system, which converts the AC current from the non-grid source to DC for charging the battery.

A rough schematic of a stand-alone hybrid PV system is shown in Figure 28. The other main system components will be described in greater detail in the following sections.

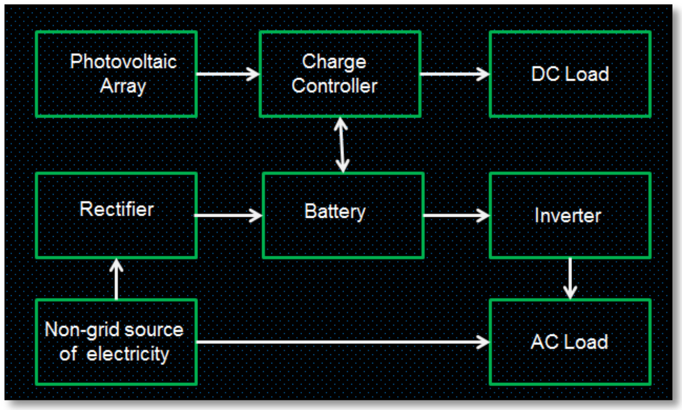


Figure 31 - Hybrid PV system with battery storage (Hodge, 2010)

6.2.1 Solar Panel

The central building block and smallest element of a solar panel is the photovoltaic cell. It is within this cell that the photovoltaic effect takes places, initiating the power for the rest of the system. The PV effect results from the electrical potential that develops between two dissimilar materials within the cell, separated by a common junction which is illuminated with radiation of photons. The individual cell, however, is quite small, being only a few square inches in size, and producing on its own about 1 watt of power. Therefore, in order to reach the demands of the load, the cells are combined to form modules. Just as with DC circuits, these cells can be arranged in both parallel and in series. When in series, the current is constant while the voltages add up. Conversely, when in parallel, the voltage is constant and the current is added. The most appropriate configuration is determined by the amount of power needed and the space one has to work with. These modules can be further developed by forming arrays consisting of several modules. This progression of the combining of parts is illustrated in Figure 29.

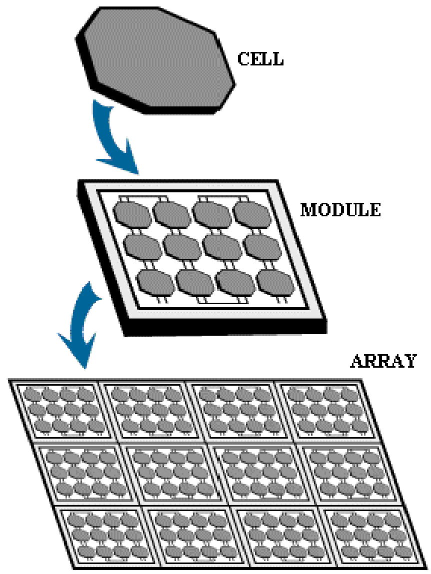


Figure 32 - Combining cells makes up a module, while combining modules make up an array (Hodge, 2010)

In general the electrical characteristics of the PV cell are illustrated by the current versus voltage (i-v) curve. Maximum power is found at the voltage corresponding to the knee of the curve. An example of an i-v curve is shown in Figure 30, where I_{SC} is the short circuit current, and V_{oc} is the open circuit voltage. These are the two main parameters when determining the electrical performance of the cell. The photoconversion efficiency of the cell is simply given by:

$$\eta = \frac{electrical\ power\ output}{solar\ power\ impinging\ the\ cell}$$

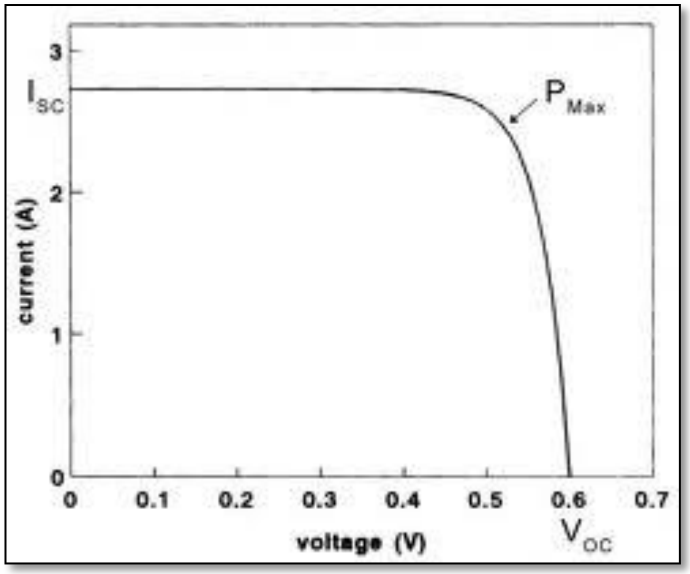
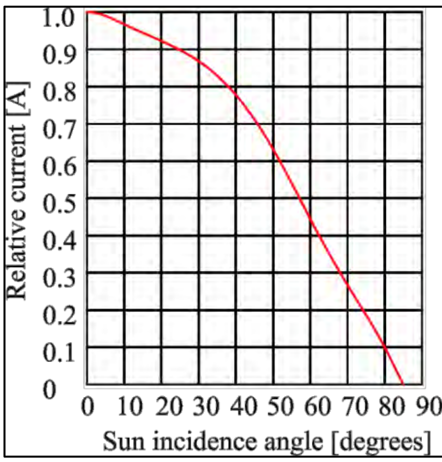


Figure 33 - I-V characteristic of PV module with maximum power at the knee of the curve (Hodge, 2010)

There are yet additional factors to the array design that must be considered, as they may have a large impact on achieved electrical power output, and therefore the overall efficiency of the system. Other important factors are sun intensity and sun angle.

Electrical photocurrent is, as one would expect, at its maximum when the sun is at its full brightness, denoted by 1.0 sun. Solar radiation is not effected by cloudier days when the sun shows less brightly in the sky, and therefore the amount of solar power hitting the panel does not change. However, the open circuit current, I_o, has a significant decrease. As the electrical output is heavily dependent on I_o, the photoconversion efficiency of the panel drops as the sun intensity drops.

The location of the sun in the sky, defined here as the sun angle, plays another role the electrical output of a solar panel. For flat panel arrays, the greatest output current will occur when the sun is normal with reference to the panel. This normal current is given by I_o. As the sun angle changes throughout the day, the corresponding current is given by the expression $I = I_o cos\theta$. For angles of 0 up to 50^0, the output current can be determined with relative accuracy. A graphical representation of such a curve, called the Kelley cosine curve, plots the angle of the sun in degrees versus the relative current of the PV cell. Figure 31 shows the Kelley cosine curve for angles from 0 to 90^0 degrees. Alongside of the figure shows how the curve deviates from acceptable accuracy beyond 50 degrees.



Kelly Cosine Values of the Photocurrent in Silicon Cells

Sun angle degrees	Mathematical cosine value	Kelly cosine value
30	0.866	0.866
50	0.643	0.635
60	0.500	0.450
80	0.174	0.100
85	0.087	0.000

Figure 34 - Kelly cosine curve for PV cell at sun angles from 0 to 90 degrees (Hodge, 2010)

Another plus for the use of solar energy to power today's systems is that, although still currently more expensive than more common means, the dollar price per peak watt has dropped significantly over the last decade. In 2002, solar module costs hovered around $3.75/peak Watt. In 2011 that number dropped down to only $1.50/peak Watt. That is a 60% reduction in cost. With this type of trend, in another 10 years it is quite viable that solar costs will be competitive with modern fuel costs. In Figure 32 (U.S. Energy Information Administration, 2011) a trend graph from the Environmental Information Association (EIA) shows the drop in costs for both modules and fuel cells.

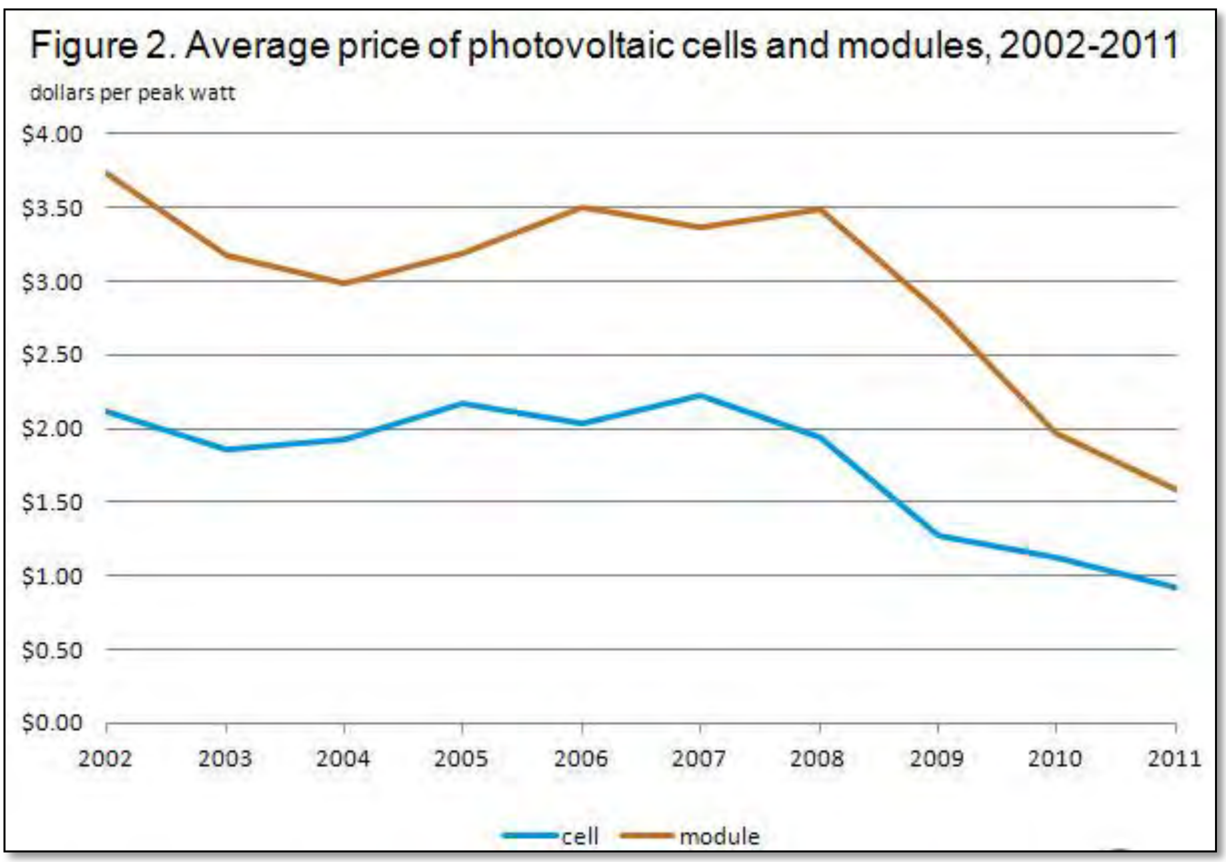


Figure 35 - Average price of PV cells and modules, 2002-2011 (U.S. Energy Information Administration, 2011)

The Shallow Draft Boat will use Eight (8) Suniva 265W PV Modules that will produce 2120 W of power at peak.

6.2.2 Photovoltaic System Calculations

How to estimate a Solar Electric (PV) System Size:

Photovoltaic (PV) solar panels will produce on average from 8 - 10 watts per square foot of solar panel area. For example, if a roof area is 200 square-feet (20 ft. x 10 ft.). This would produce, roughly, 9 W/ft^2, or 200 ft^2 x 9 W/ft^2= 1,800 W (1.8 kW) of electric power. (Mayfield, 2010)

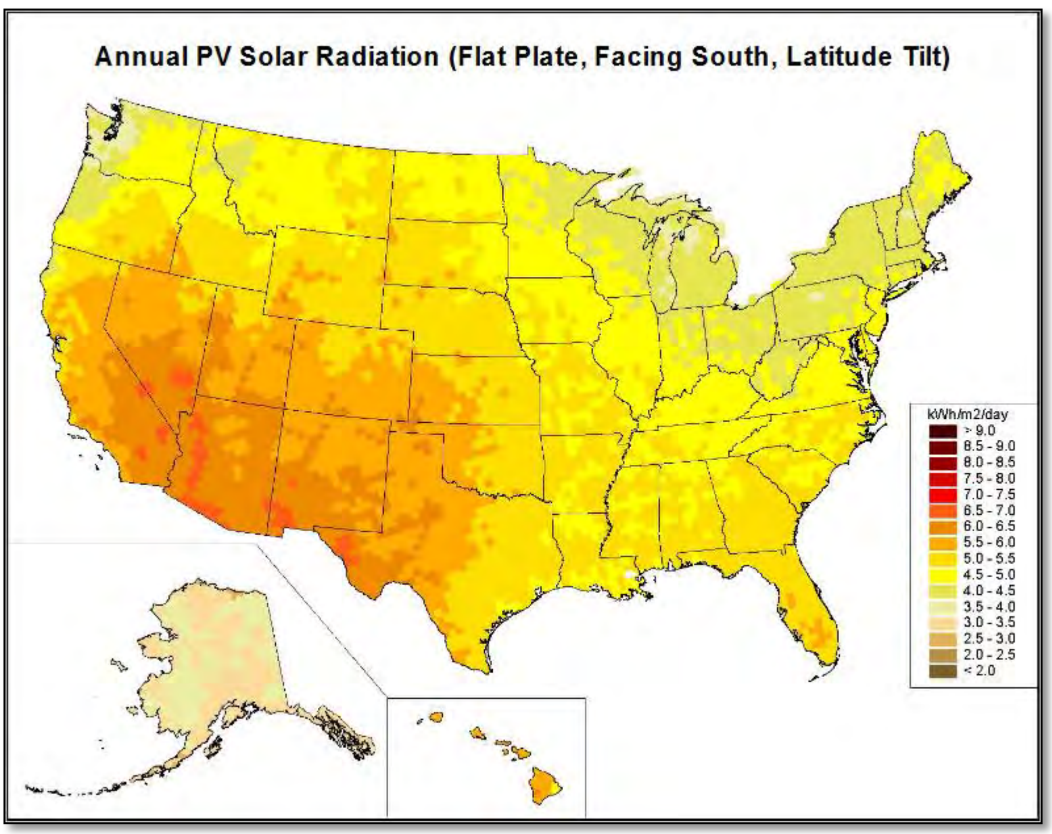


Figure 36 - Annual PV solar Radiation (Energy, 2010)

Converting Power (watts or kW) to Energy (kWh)

In order to understand how to select the right solar panel is needed to explain a little bit the basic principle. One kilowatt-hour (1 kWh) implies that an energy source supplies 1,000 watts (1 kW) of energy for one hour. In Florida, the useful solar energy will provide output for about 5 hours per day. So, if you have a 1.5 kW system and it produces for 5 hours a day, 365 days a year: This solar energy system will produce 2,737.5 kWh in a year (1.5 kW x 5 hours x 365 days).

Load Calculation

$$10.6\ \text{HP} = 7.7962868\ \text{KW} * 5\ \frac{hr}{day} = 38.981434\ \frac{KW * hr}{day}$$

Required Solar Panel Input Calculation

$$= \frac{\text{Total Load}}{Peak\ Sun\ Hours\ per\ day} * 1.4 \quad = \left(\frac{38.981434\ \frac{KW*hr}{day}}{5\ hr} \right) * 1.4 = 10.9148\ KW$$

6.3 Battery

The battery is a key component to the PV system, as it is the means of storing energy to be discharged to the load thus making the system operate. Therefore, choosing the correct battery for the job is a crucial task, and many factors need to be taking into consideration. Some key metrics worthy of discussion when designing a battery operated system are:

- Voltage/charge capacity.
- Cycle capability.
- Round trip energy efficiency.
- Charge efficiency.
- Depth of charge

Once these metrics are known, one is better able to look at specifications of different battery types in order to make a proper selection for the application at hand.

The voltage (V) and charge capacity (denoted in amp hours, Ah) are metrics that defines the energy storage of the battery, along with its retrieval potential. The total energy stored in the battery, given in Watts (W) or kilowatts (kWh), is found by multiplying the two metrics together: $\textit{Total Energy Stored} = V \cdot Ah$.

The cycle capability is simply the total number of full charges and discharges a battery is expected to go through in its useful lifetime. The battery's efficiency is a function of the energy output and input during full discharge and restoration of full charge, and is shown by:

$$\eta_{battery} = \frac{energy\ output\ over\ full\ discharge}{energy\ input\ to\ restore\ full\ charge}$$

For use in photovoltaic applications, these batteries require high cycle capacity along with high depth of charge. The depth of charge, given as a percentage, is the amount of stored energy that may be extracted, or discharged, from a battery that is at full capacity without causing any damage to the battery.

6.3.1 Battery Size Hours of Operation

The number of electric motoring hours depends on your battery configuration combined with any generated capacity (in this case from solar power). Depending on the type of motor, for operation of up to 6 to 8 hours, it is suggested to use 4.6 times the motor's power output in kWh. For example: 4.6 x 3.5kW = 16.1kWh. This would be the required battery capacity for six to eight hours of electric power operation (Burden, 1995).

The team selected Rolls, S12-230AGM Front Terminal Batteries for this project. Each battery is 12V / 210Ah (at 20 hour rate) for a total of 2520Wh of storage at the 20 hour discharge rate. Two battery banks will be set up for this project, one battery bank for each motor

Total power generated from the battery banks = 2520 Wh. x 8 Batteries = 20160 Wh.

Charging Time on the battery banks from Solar Modules = 20160 Wh. / 2120 W = 9.5 Hr.

Draw on Batteries from Torqeedo motors = (2 x 1800W) – (80% x 2120W) = 1904W at 5.2 MPH. 20160Wh. / 1904W = 10.58 Hr.

Charging Time on Batteries from IOTA DLS – 75 Power Converter/Battery Charger =

48VDC x 75A = 3600W, 20160Wh. / 3600W = 5.6 Hr.

6.4 Charge Controller

A charge controller, or charge regulator, is a device that is installed between the solar arrays and the battery bank. Aptly name, as the voltage input from the solar array increases, the charge controller regulates the amount of voltage that reaches battery, and helps to maintain a proper voltage level. Without such a device, excessive voltage could reach the battery, causing permanent damage. The majority of charge controllers have a 3-stage charge cycle: bulk, absorption, and float.

In the bulk stage the batteries draw maximum current while the voltage is increased to near full capacity. Once this bulk level is reach the absorption stage begins. Here, the drawn current begins to dwindle down while the voltage in the battery continues to rise slowly to capacity. In the float stage of the 3-stage cycle, the voltage drops slightly, and the battery continues to draw a small amount of current to keep the power level steady until the cycle begins again. A graphical representation of the voltage and current drawn, in relation to time, during the 3 stages is shown in Figure 36

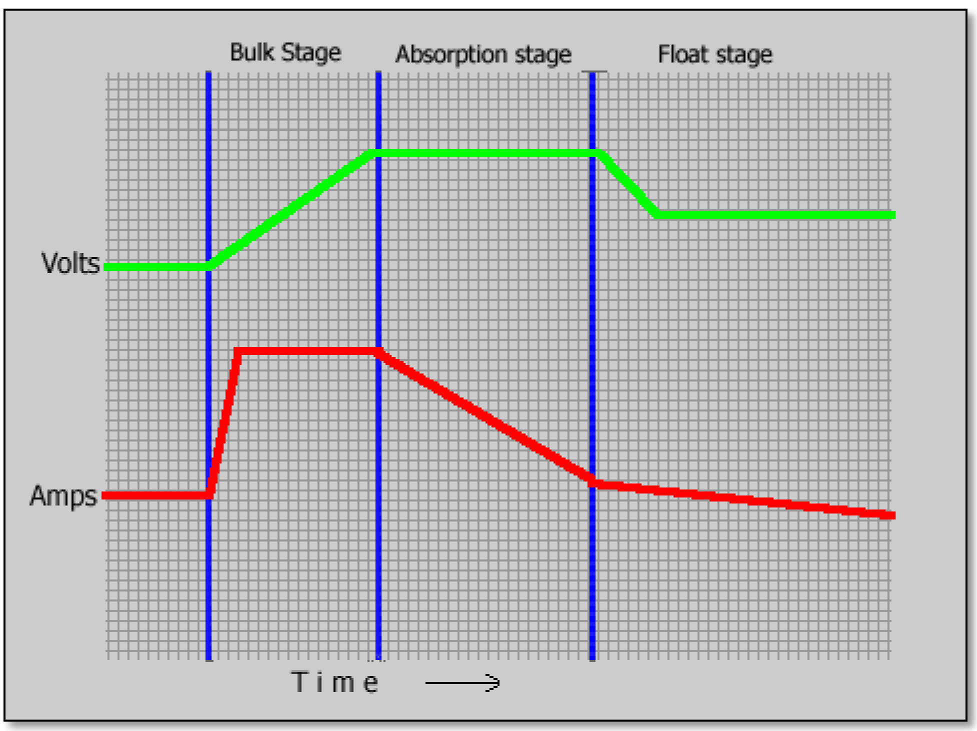


Figure 37 - Graphical representation of the 3-stage cycle of a charge controller (Free Sun Power, 2012).

The Shallow Draft Boat requires an Outback Power Systems FLEXmax 60 MPPT charge controller, which will regulates the output voltage from the solar panels to a even level, enhancing the solar panels power yield and preventing the batteries from being overcharged.

6.5. Motor

6.5.1 Gas vs. Electric Engines

One of the main differences between an internal combustion engine and an electric engine is the torque ratio. Electric motors have a flat curve of torque. In gas engines, the torque increases only when the engine starts to reach high RPMs. On the other hand, the electric motor can have high torque at low RPMs. This principle makes it possible to replace a big gas / diesel engine with a small electric motor. (Burden, 1995)

The following diagrams show the main components for gasoline and electrical outboard motors.

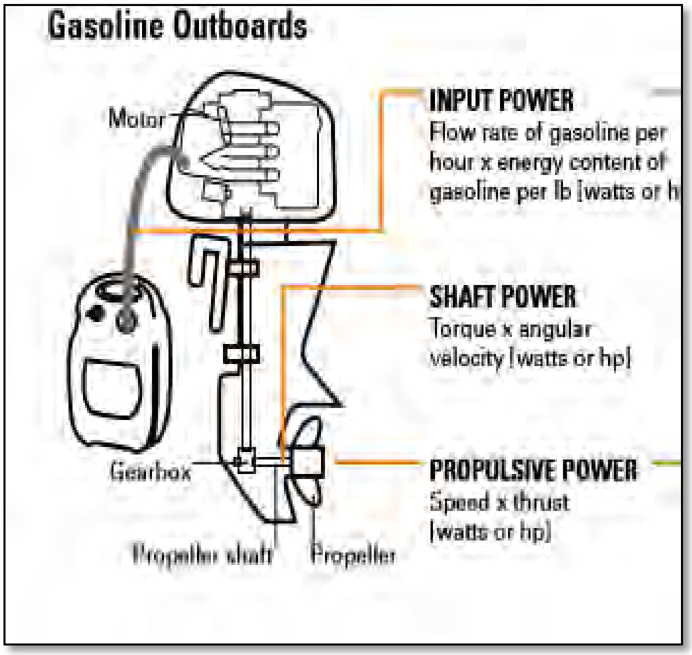


Figure 38 - Gasoline Engine (Torqeedo, 2005)

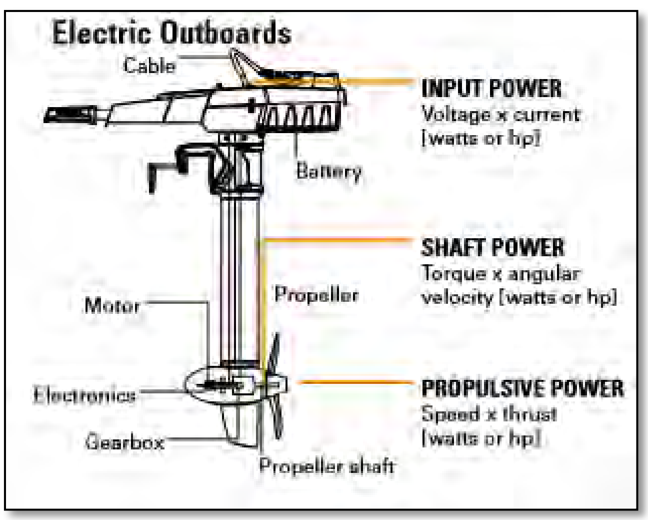


Figure 39 - Electrical Motor (Torqeedo, 2005)

6.5.2 Motor Used

In order to choose the proper electric motor, inboard and outboard motor styles were taken into consideration to power the vessel. Some disadvantages when using an inboard motor are: the hull design would have to include hull penetration in order to place the propulsion shaft beneath the water line. This would imply an increase in the installation and maintenance due to the amount of extra components needed to attach this shaft with the motor. On the other hand, some of the advantages of an outboard motor style are: a very easy installation to the hull vessel; because it is just a single component, it requires in some designs as few as a two bolts to attach to the vessel. This implies fewer components due to the fact that hull penetration is not needed. Its efficiency is greater by having the motor's placement in the same line with the propeller in the hub of the motor.

An outboard electric motor was the type of propulsion that the team decided to use in order to obtain the maximum displacement of the vessel. Based on weight and drag calculations, the amount of total peak output voltage needed to run these motors will be a total of 96 Volts. The team has been looking to install two electric motors of 48 V each in order to satisfy this necessity

The team began investigating different options of motors by comparing the weight, efficiency, and performance from three different manufactures. In order to make the selection process easier, all three options were put together in a decision matrix, shown in Table 6. Selected motor data specifications can be found in Appendix A.

Motor Brand (option)	Static Thrust (lbs)	Volts	Max Amps	Imput Hp	Shaft Hp	Thrust per HP	Weight
ETEK	200	44	50	5	3.3	45	80
Ray Electric	250	60	84	6.8	5.00	50	100
Torqeedo	214	48	83	5.3	4	54	40

Table 6 - Different Electric Motor Outboards.

All of these different brands have a forward /backward control speed, which make it easy to steer, move, and dock in narrow spaces.

Based on electric outboard manufacturers, this amount of voltage will be equivalent to 10.6 horsepower. In order to keep setting up the other component and have a successful installation of the batteries and solar panels, it is needed to convert the horsepower in to watts

$$Power\ in\ Watts = Volts\ x\ Amps$$

$$1\ Horse\ power\ =\ 746\ Watt$$

$$746 * 9HP = 7.907\ kW$$

The following figure shows the propulsive power and overall efficincy between different kinds of electric outboards motors.

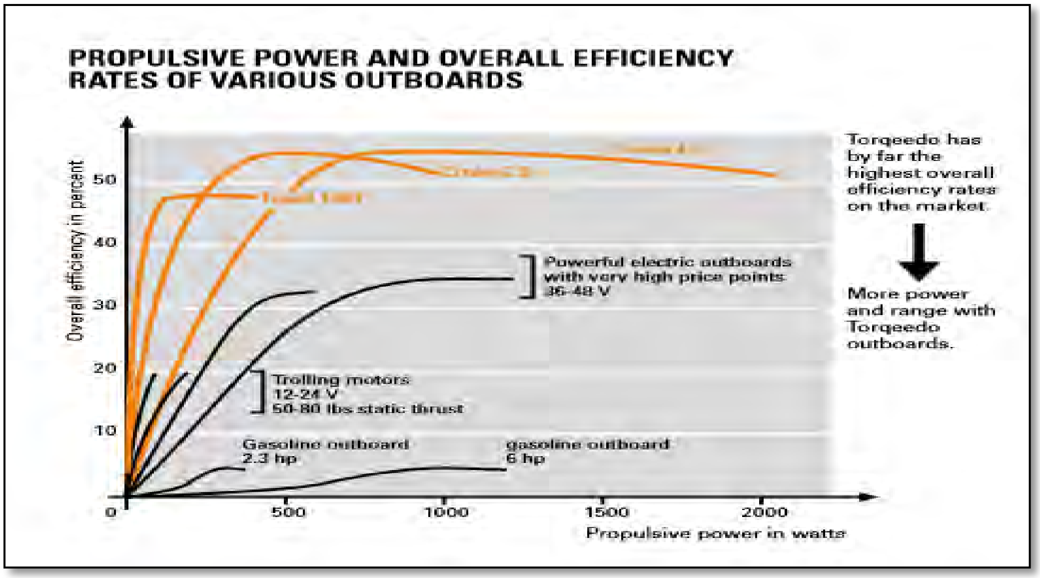


Figure 40 - Torqeedo Propulsive Power vs. Efficiency Graph (Torqeedo, 2005)

Analysis of the system

By using eight (8) Batteries, each battery is 12V / 210Ah (at 20 hour rate) for a total of 2520Wh. of storage at the 20 hour discharge rate. Eight (8) Suniva 265W PV Modules, will produce 2120W of power at peak.

From the motor user manual it is estimated that the motors are each:·

4000 Wh. ~ 6.9 – 12.7 MPH ~ 1.10 Hr.

1800 Wh. ~ 5.2 MPH ~ 3 Hr.

650 Wh. ~ 3.5 MPH ~ 8 Hr.

It can be assumed that the boat will be able to run indefinitely at 3.5mph. The draw on the batteries will be approximately (2 x 1800W) – (80% x 2120 W) = 1904W at 5.2 MPH

20160Wh / 1904 W = 10.58 Hr.

With four (4) battery bank, the runtime is equal to six (5) hours.

With eight (8) battery bank, the runtime is equal to fifteen (10) hours.

This data is obtained by assuming 80% of maximum voltage output for the PV modules. The draw on the batteries will be approximately (2 x 4000W) – (80% x 2120W) = 6304W at 12 MPH., which gives by using four (4) battery bank a runtime of approximately one (1.6) hour.

7 Structural Design and Analysis

After analyzing all parameters in this project, Dream Boat Manufacture explains that the most accurate design needs to be based on a catamaran hull. An important characteristic that makes catamarans very light boats is the fact that they use multihull combine with a light weight construction material, making the catamaran hull the best choice for this project. This kind of hull varies on shape widely depending on the desire application. This project is focused on using a displacement hull. For boats of this type, fiberglass is mainly used for its ability to be molded and reused in the manufacturing of other boats. Fiberglass is glass in the form of very fine flexible fibers. They may look fragile, but those fibers are stronger than steel, and they won't burn, stretch or rot; so they make the perfect boat building material. Fiberglass body requires low maintenance and they are durable, so these water boats do not deteriorate in the way wooden boat would.

Depending on the placement of the solar panels, which can add a considerable weight factor, a similar type of consideration needs to be addressed. Additionally, the deck itself needs considerable analysis not only as a structural member, but also for its qualities of sound and thermal insulation. These are mainly a question of type of material used.

7.1 Boat Distribution

7.1.1 Seating Arrangement

Different layouts for passenger seating organization were discussed with the client. Some of the possibilities presented were the following:

The first layout has two horizontal benches 36 inches apart along the gunwale, where passengers will be facing each other. Additionally, a long vertical bench is built at the end of the boat.

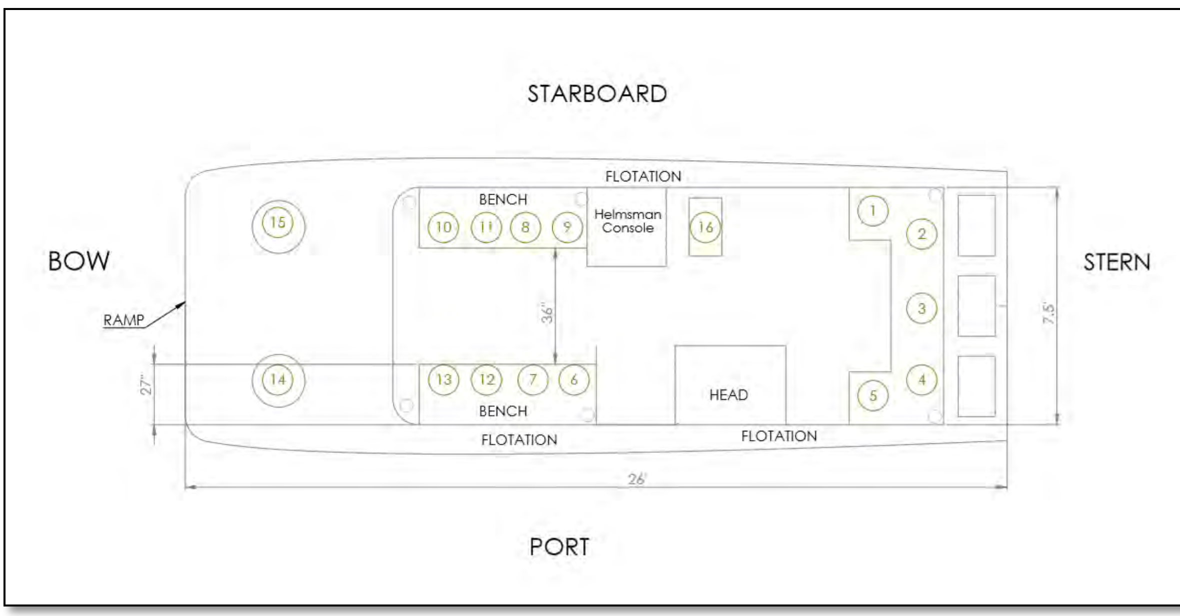


Figure 41 - Boat Layout Option number 1

The other option has two small vertical benches on each side of the boat. They are divided by a walkway.

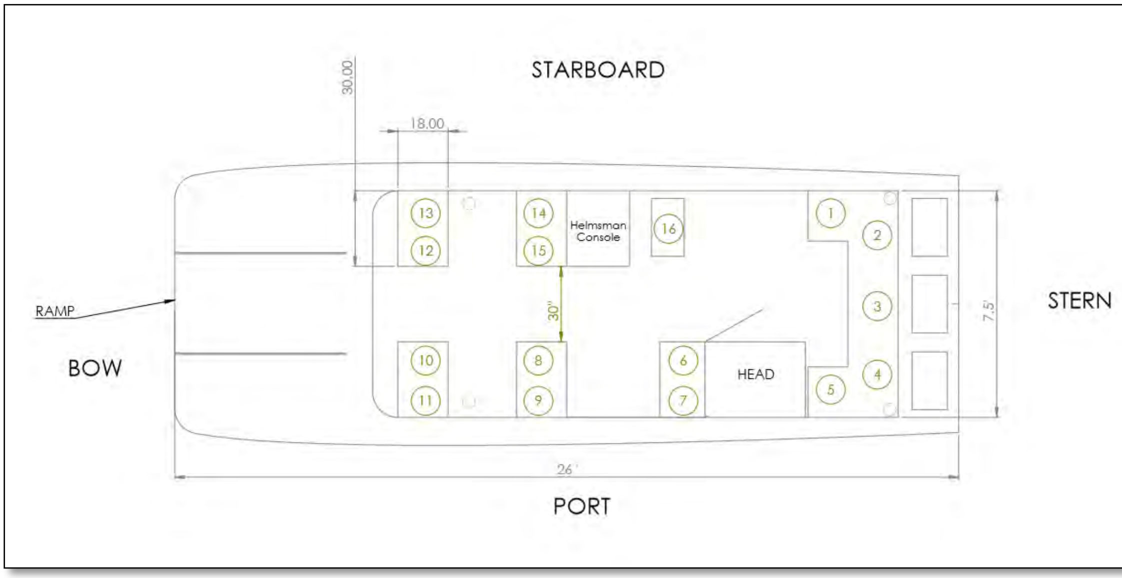


Figure 42 - Boat Layout Option 2

The second option was the one that the client decided on, as he felt it was the most appropriate for the passengers. With this configuration, passengers are allowed a better view of the landscape environment while traveling to the island.

The seats in the boat can also provide easy storage underneath them. This space will also be used to place the batteries that help power the boat. Each seat will be 18 inches deep and will range in width from 18 to 30 inches.

The major concern in regards to the seating arrangement was the available space inside the boat. In order to comfortably accommodate the movement of all fifteen passengers, a central aisle has to be included. In the first drafts of the layout, the aisle was established to be 30 inches wide. However, after meeting with the client, it was decided to make the vessel handicap accessible. To accomplish this, the width of the aisle had to be expanded to 36 inches. According to ADA (American Disability Association) the minimum clear width for a wheelchair is 36 inches for a hall. More information on these and other rules and regulations can be found in Section 2.5.

In order to meet that goal and still keep the original seating arrangement, the beam of the boat had to be increased by one ft. With this in mind, the power needed to move the boat will also increase, as well as the boat manufacturing price. In addition to the greater width allowing the vessel to be handicap accessible, the extra foot will also serve to make the boat more stable in rough seas and even more comfortable for passengers.

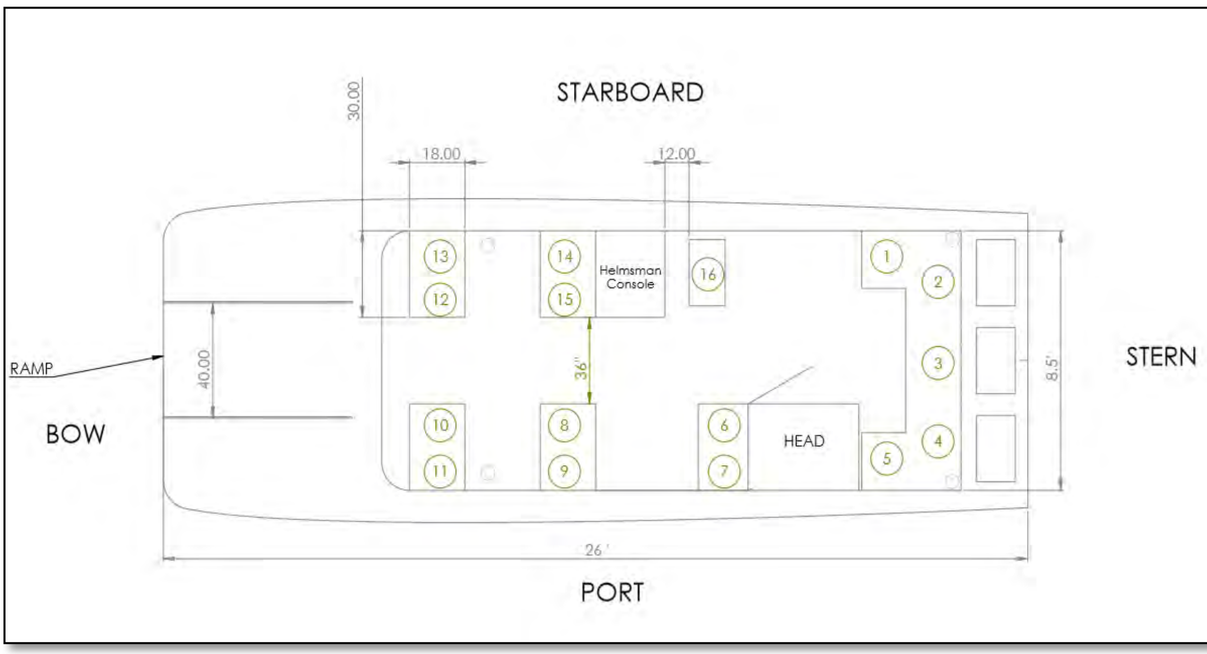


Figure 43 - Boat Final Layout

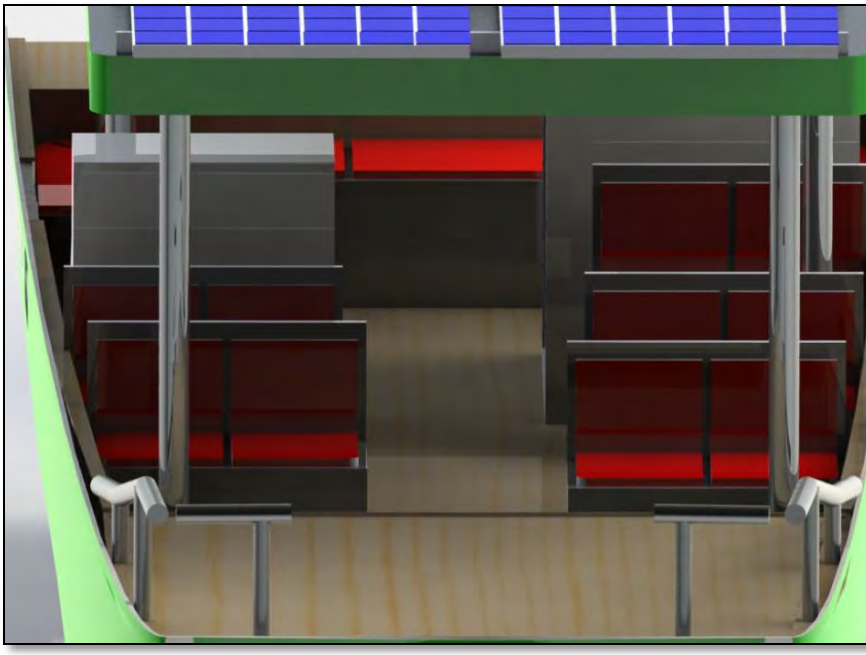


Figure 44 - Seating Arrangement

The Helmsman is located on the left hand side front of the boat. This was the best space available to have a clear vision from the captain. According to rules and regulations from the US Coast Guard, the captain of the boat, needs to have a clear front and ninety degrees vision at each side.

The front part of the deck was designed to be used as extra storage for passengers who want to bring additional items such as chairs, coolers, food, etc.

7.2 Boarding Access

For onboarding and off boarding purposes, the boat is designed to have a manual telescopic ramp located in the front part of the boat. This ramp provides easy access from the two dock areas which are the side walk and the sandy beach.

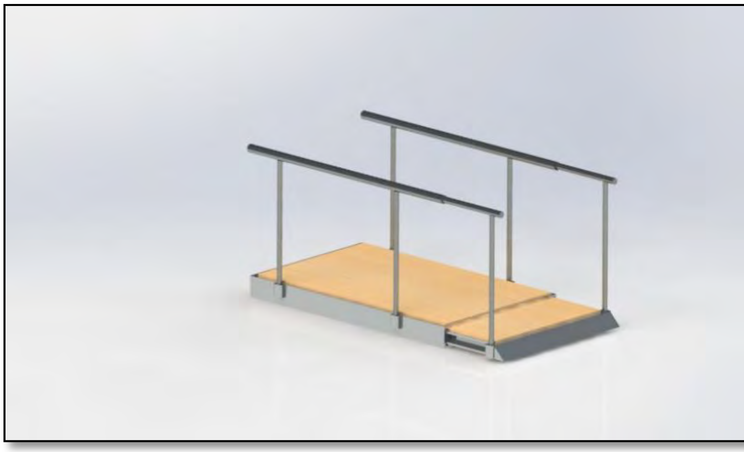


Figure 45 – Manual Ramp short extension

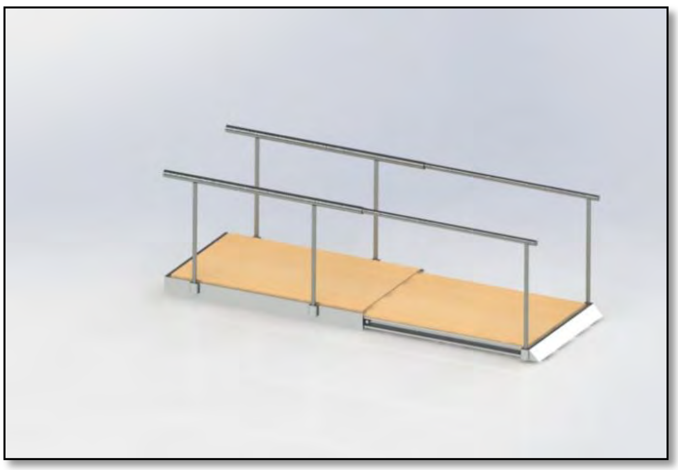


Figure 46 – Manual Ramp full extension.

The ramp will be 40 inches wide, with hand rails and 10 feet long. The material use for the construction is aluminum 6061. It will support up to 200 lbs.

7.3 Weight Distribution

The weight distribution was a very important factor. The catamaran's hull shape with square sponsons and foam filled sidewalls makes the boat very stable. Still, the weight of each passenger along with the power system components needs to be as evenly distributed about the boat as possible. If all passengers congregate on one side or the other, the boat is liable to tip. It is the job of the captain to maintain a proper distribution among the passengers. In the case of large waves, the stability of the boat is further increased if the passengers move more towards the center of the boat. A list of parts and total weight is provided in the following table.

Components	Weight (lb.)	Quantity	Total Weight (lb)
Hull	2400	1	2400
People	141	15	2115
Helmsman	141	1	141
Motors	40	2	80
Solar Panels	40	8	320
Batteries	146	8	1168
Ramp	80	1	80
Canopy	100	1	100
Miscellaneous	500	1	500
Total Boat Weight			6904

Table 7 - Total boat death weight

It is necessary to take into account the boat's center of gravity (CG) and center of buoyancy (CB). The CG is the point where the downward (gravitational) forces focus, while the CB is where the upward (floating) forces focus. The two forces should always line up vertically under the CG when at rest. Any offset can cause the boat to tip to one side or the other.

7.4 Structural Analysis of Canopy

Based on this design consideration, it was determined to place a canopy on top of the boat. The main purpose for this is to have a place to fit the solar panels needed it to provide power to the boat motors. At the same time, this will also act as a shelter providing protection against water and sunlight to the passengers.

The canopy will be located at a height of 78 inches from the boat deck, and will cover much of the boat, being 20 feet long by 7.5 feet wide, and having an area of 150ft^2. This area will be leaving enough room to place eight solar panels of 65.5 inches in length by 38 inches in width.

In order to mount the solar panels to the canopy, eight rails are placed 40 inches apart, to which the solar panels are then clipped. In order to allow air to circulate around the panels, ensuring they don't over heat, a space of 1 inch will be placed between them along the short edge, and a 10 inch gap will run along the long edge. The following figures further shows how the system is assemble

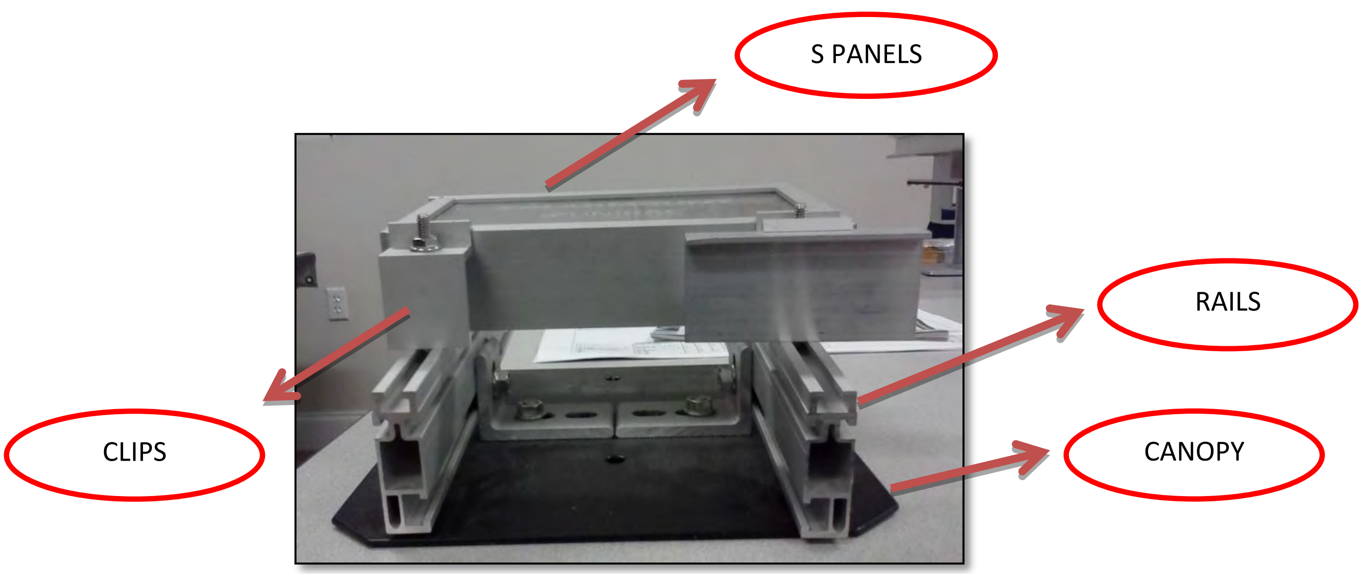


Figure 47 - Solar Panels and Canopy Assembly

Figure 48 - Solar Panels and Canopy Assembly top View

Figure 49 - Solar Panels and canopy assembly side view

The following model represents the final assembly of the canopy with the rails and Solar Panels attached to it.

Figure 50 - Canopy & Solar Panels

7.4.1 Force, Stress Analysis and Material Selection

Material selection was a very important part for this section. The most important factor that the team took into consideration was to select the material that gave a good factor of safety. The second aspect that was taking into account was the cost and the weight of the material.

The material that was chosen for use in this application was tube of Aluminum 6061. This type of tube is commonly used for structural components, frames, machine parts, marine components, marine fittings, electrical fittings and connectors, bike frames, railings, truck racks, etc. In addition to that, Aluminum 6061 is also used for heavy duty structures requiring a good strength-to-weight ratio with good corrosion resistance.

Some of the characteristics of aluminum are shown in the following table

Property	Value	Units
Elastic modulus	10007604	psi
Poisson's ratio	0.33	N/A
Shear modulus	3770981.2	psi
Mass density	0.0975437	lb/in^3
Tensile strength	44961.7	psi
Compressive Strength in X		psi
Yield strength	39885.38	psi
Thermal expansion coefficient	1.333333333e-005	/°F
Thermal conductivity	0.00223225	Btu/(in·sec·°F)

Table 8 - Properties of Aluminum

7.4.2 Supporting Members

In order to select the right area to place the supporting columns, an excel document was created with different iterations in order to select the right area that will support the total amount of weight form the panels and the canopy.

It was decided to use six members to support the canopy. All members will have to support a total of 420 lbs. pounds. This includes the weight of the eight panels at 40 lbs each, cables, and the canopy itself. To allow for dynamic forces from wind and vibration effects, the factor of safety from static forces was increased.

Each member that was used to support the canopy is a hollow cylindrical tube 78 inches in length, with an outside diameter of 2 inches, inside diameter of 1.75 inches, and a wall thickness of 1/8 inch. Using this information, stresses were calculated and initially a static loading was considered.

In order to find the critical loading that each member could support, a series of trials were performed using an excel sheet. For each trial, the area and shape of supporting columns were changed until the maximum desired factor of safety was reached.

In order to find the critical Load, Euler's formula is used, and is given by:

$$Pcr = \frac{\pi^2 EI}{{L_e}^2}$$, where E = modulus of elasticity, I= moment of inertia, and L = effective length

In this case, the supporting member will be fix in both ends, so the length will be divide by two

$$L_e = L/2$$

In order to find the critical load the moment of inertia of the column needs it to be found by:

$$I = \frac{\pi}{4}(R^4 - r^4)$$

Substituting values into the equation

$$I = \frac{\pi}{4}(1^4 - 0.875^4) = 0.3248 \text{ in}^4$$

According to those results, the critical load that the will support can now be calculated.

$$Pcr = \frac{\pi^2 * 10007602.08 * 0.3248}{39^2} = 21.074\ kipz$$

After that, the total load that the columns will support was calculated by $P = mg$. As mentioned before, the weight of the canopy plus the solar panels is 420 lbm and the acceleration of gravity is 32.2 ft. /s^2.

P_{all} = 2.254 kips.

With these two values now the Factor of Safety can be now calculated.

$$P_{all} = \frac{P_{cri}}{FS}$$

Solving for Factor of Safety

$$FS = \frac{P_{cr}}{P_{all}} = \frac{21.074\ kips}{2.254\ kips} = 9.34$$

In order to check those results, the stress that the beam will receive was also calculated

$$\sigma_{all} = \frac{P_{all}}{A} = \frac{2.254\ kips}{0.7359} = 3.062\ Ksi$$

Comparing allowable and ultimate stress (Aluminum 6061)

$$\sigma_{all} < \sigma_{ult}$$

$$3.062\ ksi < 45.00\ ksi$$

This means that the system will be safe.

The Following table shows some of the different trials performed with different areas. Also the price was taking into account in order to do the final decision.

Iterations	D	D	Fs	Price ($)
1	1.00	0.75	0.9652	27
2	1.00	0.50	1.32	98.28
3	1.50	1.00	5.73	55.57
4	1.75	1.50	6.095	84.4
5	2.00	1.75	9.34	44.19
6	2.00	1.50	15.44	87

Table 9 - Results obtained with different areas

Furthermore, simulation software was used to calculate same Factor of Safety, stress and the Buckling of the bar. Pretty close results were obtained in the expected areas. That information could be seen in figure number 50. Also figure number 52 describes the stress at each column. Finally buckling and displacement results are shown in figure number 53.

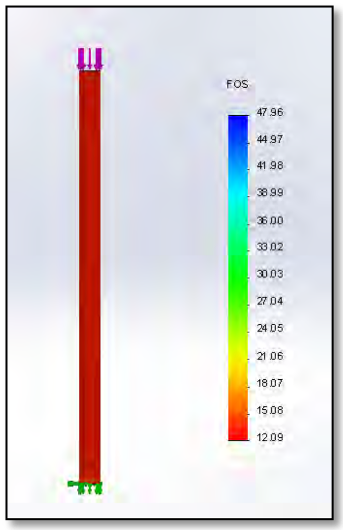


Figure 51- Supporting Columns Factor of Safety results

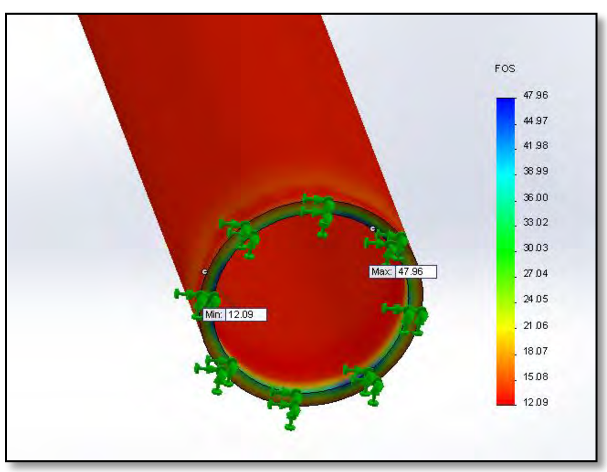


Figure 52- Min and Max Factor of Safety

The following picture shows the value for the maximum stress of 3.062 ksi that the column will received.

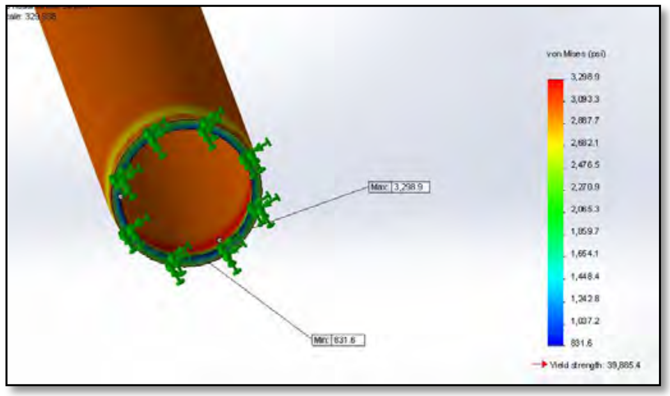


Figure 53 – Von Mises Stress from software simulation

The following pictures represent the maximum displacement value of the bar before it get to buckling.

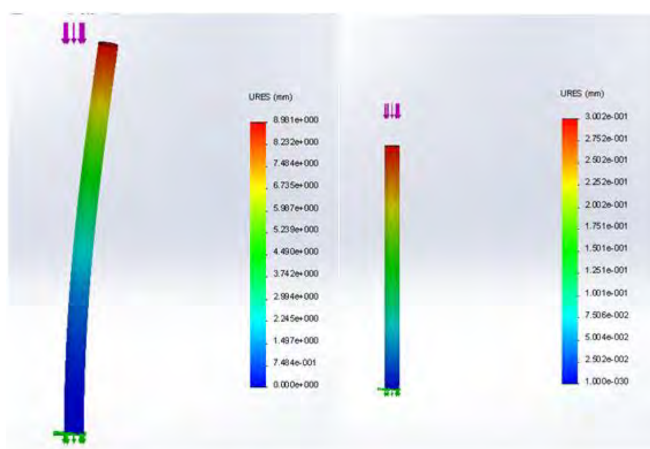


Figure 54 - Displacement and Buckling using Simulation Software

7.1 Deck Materials

The deck of a catamaran plays several rolls. However, as a structural member, the choice of deck and its properties of rigidity are the most important factors to consider, as this affects the amount of stress transferred to other components of the boat. It is therefore desirable to use a deck with greater rigidity. The less rigid the deck, the greater the torsional stress will be. Common deck materials used are aluminum, composites, and wood.

8. Testing and Simulation

One of the main considerations the client wanted for us to take into consideration was the desire that as many of the components as possible for the vessel be 'off the shelf'. Therefore, our testing was none down via prototype, but rather via hand calculations and computer software design and simulations.

One of the key aspects of the design is the shape of catamaran in the aft of the boat. The sponsons, rather than having a flat edge, come together at a point. The main purpose of such a design is based on the strong cohesive properties of water. To break water apart takes energy, which is what would occur with a flat edge sponson. In order to minimize energy lost, the curved edge of the sponson that leads into a point provides a path for the water to meet up at the tip of the sponson. This way, there is a minimum of water breakage, and therefore a minimum of energy lost.

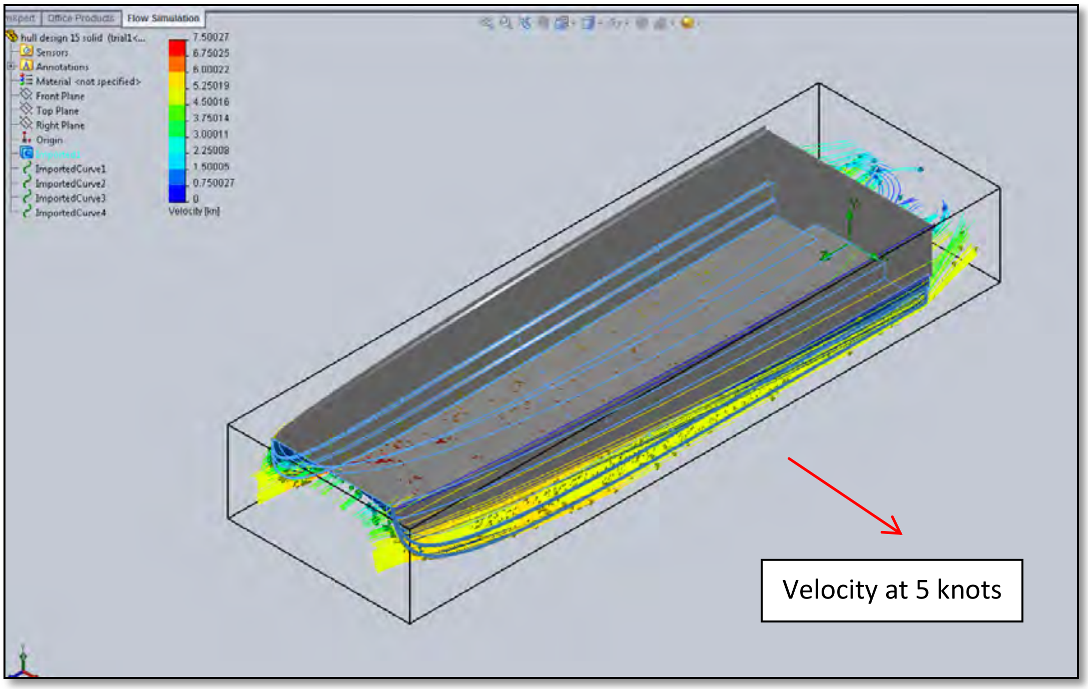


Figure 55 - Hull Flow Simulation (Velocity)

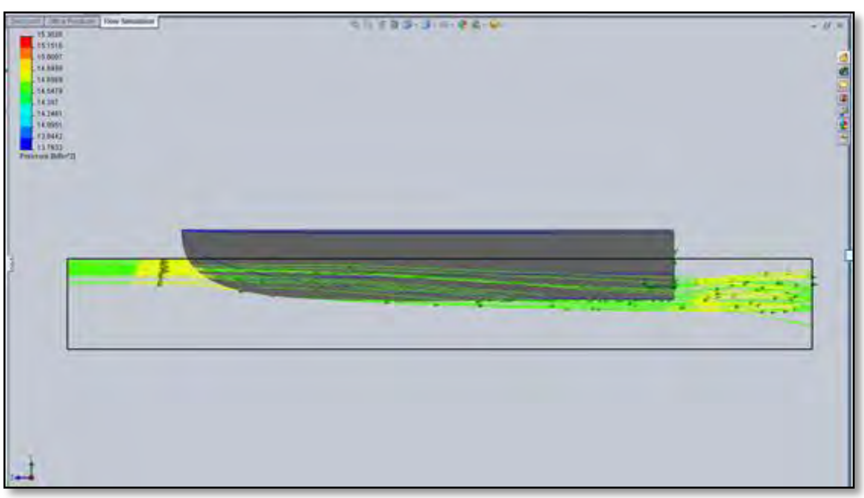


Figure 56 - Hull Flow Simulation 2

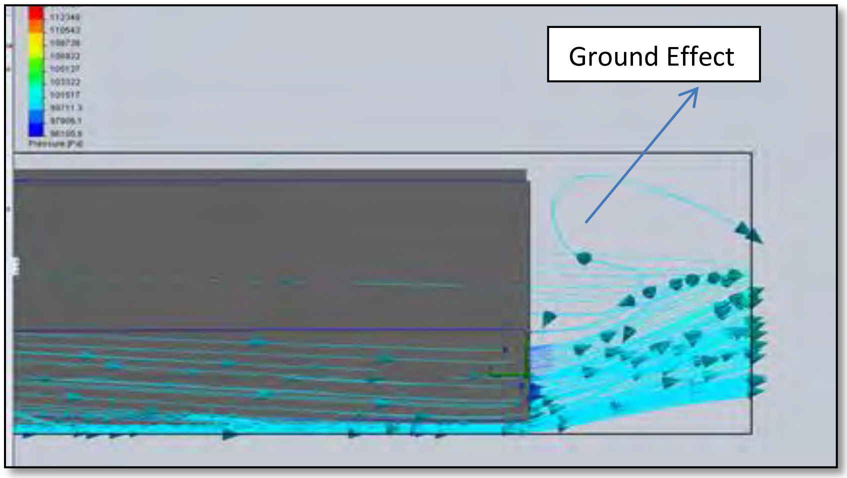


Figure 57 - Hull Flow Simulation (Pressure)

Figure 56 shows the flow of water as it exits the tunnel between the two sponsons. Within the tunnel a vacuum is formed, from which the resulting pressure as the exit pushes the water out and up depending on the incline of the boat. This water is pushed directly into the propeller which adds thrust.

8.1 Final Boat Design

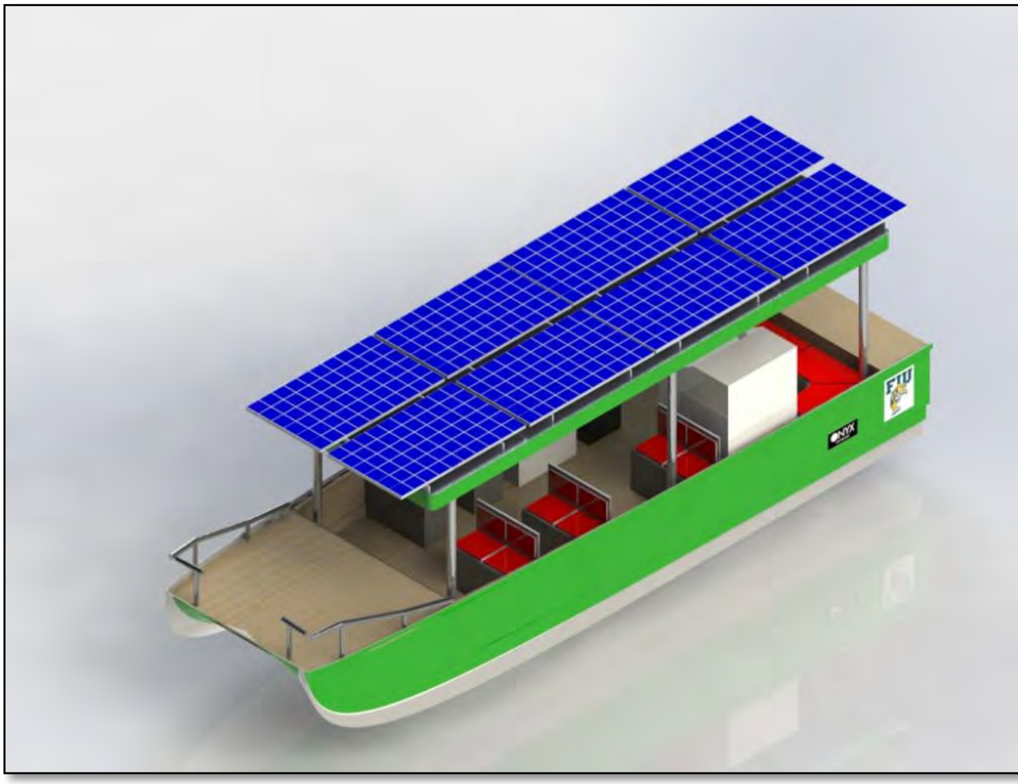


Figure 58 - Final Boat Design Isometric View

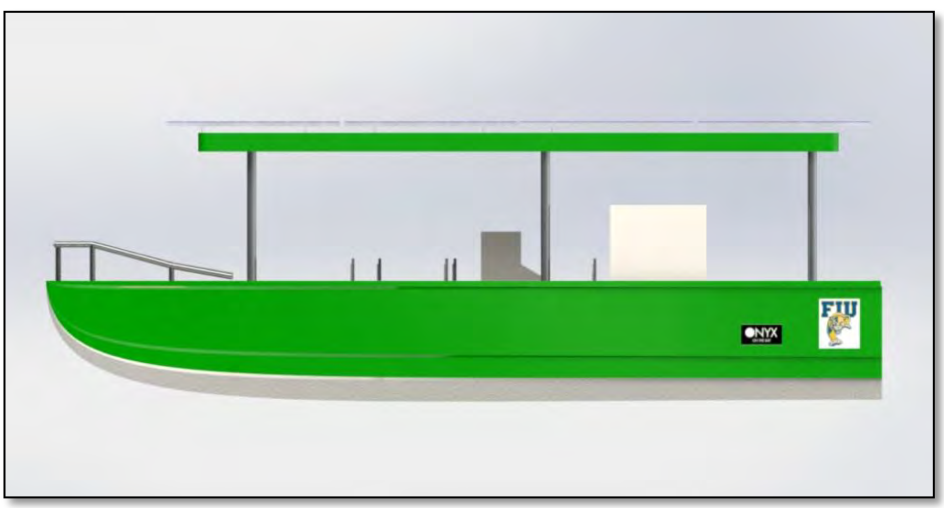


Figure 59 - Final Boat Design Side View

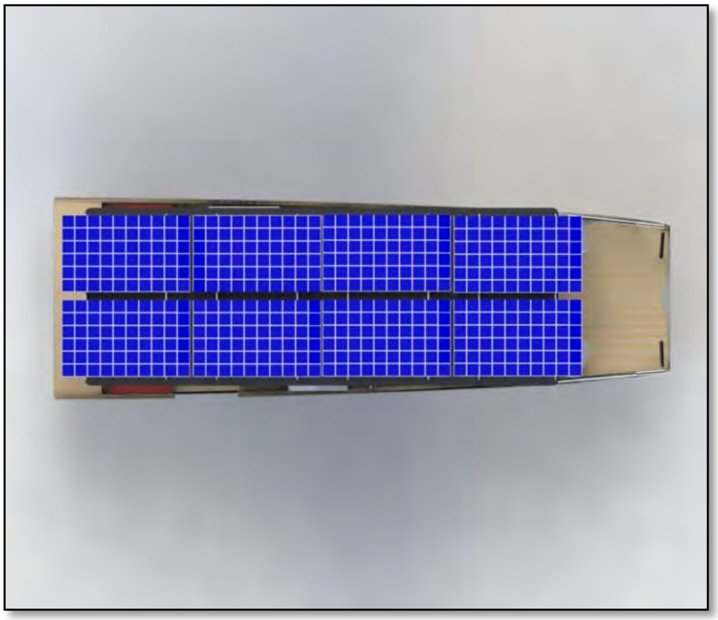


Figure 60 - Final Boat Design Top View

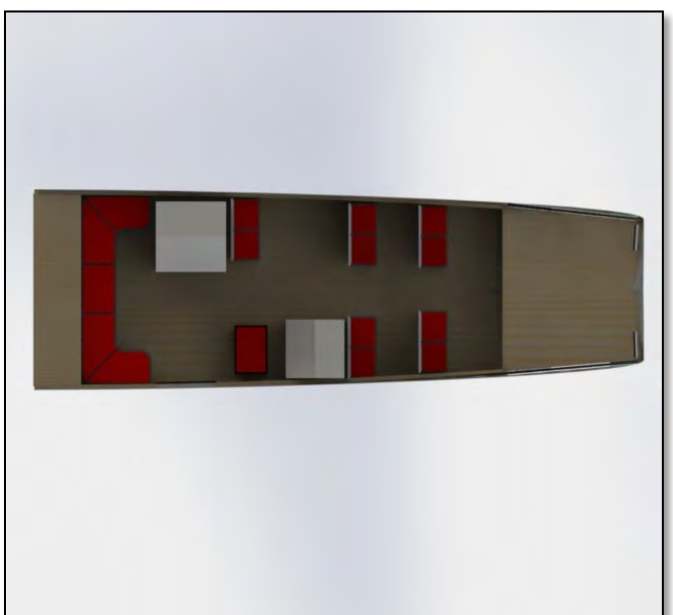


Figure 61 - Final Boat Design Top View

9. Manufacturing

The actual manufacturing of the boat is being down by Mr. Ralph Brown of Dreamboats, Inc., out of Hudson, Florida, just outside of Tampa. Mr. Brown is more than qualified for the job. Some of his accomplishments include:

- Over ten years and more than a million dollars researching how to get a boat to operate at extremely shallow draft levels without sacrificing off shore characteristics.
- Issued two patents for shallow draft boats.
- Set five world records taking his shallow draft boat out to heavy ocean seas.

Regular communication between the group and Mr. Brown has been kept throughout the duration of the project, ensuring all the necessary information from the client reached the manufacturing side. We were fortunate enough to visit Mr. Brown's sight during our research, of which pictures are shown in the appendix.

10. Research and Development Cost

An estimated summary of the tasks realized by each member is listed in the table below, indicating the hours invested and the percentage of each task among the entire project. The man-hours salary value for this project was $35.

				Domingo Malave		David Neer		Jose Arrautt		Sebastian Lopez	
Task	Days	Man-Hours	Cost ($35/hr)	Percentage	Hours	Percentage	Hours	Percentage	Hours	Percentage	Hours
Theoretical Research	60	90.2	$3,157	25%	22.55	25%	22.55	25%	22.55	25%	22.55
Theoretical Analysis	35	60.6	$2,121	25%	15.15	25%	15.15	25%	15.15	25%	15.15
Prototyping	50	100.6	$3,521	25%	25.15	25%	25.15	25%	25.15	25%	25.15
Total	145	251.4	$8,799		62.85		62.85		62.85		62.85

Table 10 – Development Cost

11. Cost Analysis

Ralph Brown from DreamBoats, Inc. has agreed to build the boat for a cost of $30,000. The length of the boat is to be 26 ft. width and 9.5 ft. beam. Included in the cost of the boat are the following features, which can be added to or taken away at your discretion.

- Seating for 15 passengers plus one helmsman.
- Seven 32” wide 2 person seats with back rests and under seat storage.

OR

- (Four 30” wide 2 person seats and a couch extending across the transom - *The flat surface forming the stern of a vessel.*)
- Two front pedestal seats.
- A *head* (restroom) area.
- A side console for the helmsman.
- Fold over ladder for front loading.
- Thirty six inch wide walkways.
- Side door that folds down to become a ramp – can be used as handicapped entrance.
- Rear wells, with large scupper drains. (*Scuppers let water out but not in.)*
- Closed cell flotation in gunnels *(side areas)* and sponsons (*pontoons).*
- Hard top covering 19ft of the hull.

Mr. Brown also offers additional options. These items are listed at cost plus 20% for labor. As an alternative, items may be ordered through Mr. Brown, who receives discounts greater than 20% off retail. These additional items include:

Additional Items	Cost
• An all-aluminum tandem axle trailer	$4,500
• Jack plate	$975
• Delivery to Miami	$1.25 per mile
• Two Torqueedo 48 V motors	Cost plus 20%
• No feedback steering	$300
• Wind mill generators	Cost plus 20%
• Nine foot wide hull (providing 33" wide seats with backs)	$3,000
• Solar panels	Cost plus 20%
• Batteries	Cost plus 20%
• Porte Pot (Toilet – Hand dumped)	Cost plus 20% (Approximately $500)
• Pump Out (Made to pump out by outside source)	Cost plus 20% (Approximately $700)
• Pump Out (Built in macerator)	Cost plus 20% (Approximately $1,500)
• Raw water wash down pump	$375

Table 11 – Break down Cost

Assuming the original dimensions of the hull are held firm, an estimated cost for all additional items would give a figure around $20,000 on top of the $30,000 price tag for the hull itself.

US Solar Institute will be in charge of providing all Photovoltaic System components.

Photovoltaic System	Cost
Solar Panels Suniva OPT-265	$ 2120.00 Cost per Eight (8) Panels
Energy Cell 200 RE Battery	$ 4032.00 Cost per Eight (8) Batteries
FLEXMax60 Charge Controller	$539.28
FLEXnet DC	$272.88
Outback Mate2 Remote Control Flush Mount	$212.40
Outback Hub4 - 4 Port Communications hub for VFX and GFX Inverters	$140.40
Nine foot wide hull (providing 33" wide seats with backs)	$3,000
Materials and other components	$1,000.00
System Installation	$600.00
Total Estimated Cost	$11,916.96

Table 12 - US Solar Brake Down cost

The boat will be powered by Two Torqueedo 48 VDC motors $ 8497.00

12. Global Learning Initiative

The purpose for the global learning initiative is to help new and seasoned engineers alike realize that engineering is not just about math, science, and technology – it is a multi-disciplinary field that encompasses politics, economics, social and intercultural understanding, and maybe most importantly, the very quality of life that humans experience day in and day out on both a local and global scale. To truly succeed as an engineer, one must demonstrate an awareness of the issues related to their technical focus, an understanding of the impact it has on human life along with the world at large, and an active engagement in analyzing problems and seeking solutions from the local to global scale, while still realizing that there will inevitably be limitations and obstacles to overcome.

The content of this report focuses on two main issues. One issue is developing water transportation that is environmentally conscious and friendly to the local ecosystem where it is to be used. The other issue is the source of the power for the boat, which is provided by a photovoltaic system with battery storage. The focus of this global learning will lean more towards the use of solar energy over traditional fuel sources, since its use in transportation falls into several subcategories, such as politics, economics, and quality of life. The following sections will serve to specify and expand on some of these issues, problems, limitations, and possible solutions within the framework of solar energy being the technology of focus.

12.1 Global Awareness

Solar cells are said to be the "Ultimate green energy" (Petroski, 2010). Such a statement is not surprising when one realizes that more energy from the sun falls on the earth in one hour than is used by everyone in the world in one year. (Learning About Solar Basics, 2013). With so much potential, engineers have found many innovative opportunities for harnessing the suns power. The main technologies out there today involve active solar thermal applications utilizing different shaped and angled collectors to capture the suns heat via flow tubes of water, passive solar energy, which the flow of energy occurs through a natural process, such as convection, and photovoltaic systems, which utilize fuel cells to convert the sun's energy input directly into electrical output. While some of these technologies only emerged in the past century, the concept of harnessing the sun's power has been around for thousands of years. It is said that Archimedes, the Greek engineer from the third century B.C., defended his home of Syracuse from a Roman fleet by reflecting the sun's rays off of highly polished shields, and then focused the concentrated resultant heat on the Roman ships, setting them afire (Crawford, 2013). This helped give rise to the concentrated solar power systems in use today; these use parabolic troughs to reflect the sunlight onto a concentrated point.

There are, in fact, numerous setups of these various systems throughout the world. The Southwestern United States has vast amounts of sun-soaked land. California has two enormous solar power plants capable of producing 800 MW when the sun is bright. Nevada has two non-energy firms which constructed elevated solar panels which powers half of all the firm's energy needs. Surprisingly, New Jersey is second in the nation in installed solar capacity, used mainly by homeowners, and some large commercial installations (Petroski, 2010).

On the global scale, Haiti, Nigeria, Cameroon, and South Sudan have come up with solar power stations in trailers, called SunBlazers, of which is said will be able to provide electricity for as many as 40 million people by 2020 (Engineeringforchange.org, 2013). By 2008 Germany was generating 14.2% of its electricity from renewable sources, including active solar panels. Dozens of concentrated solar power plants are scattered through Spain, France, Italy, India, Algeria, Egypt, and Morocco, with a cumulative output of a staggering 2,227.5 MW of power as of 2012 (Concentrating Solar Power Technologies, 2012).

Despite all the technologies both present and emerging throughout the world, one should not think this comes easily. Numerous issues ranging from ethical, political, economical, and cultural appear as often as the solar power systems themselves. In California, the National Park Conservation Association, along with other environmental groups, have actively lobbied against such projects on public lands for fear of the significant harm it may pose to the habitats and wildlife. Tribal groups also sued state and federal agencies for violated the federal law of engaging in "government –to – government" consultation with the tribes. Germany, which initially subsidized solar power installation, began to rule it mandatory, creating an outrage among the citizens and refusals to comply with such a mandate.

The price of solar power is far from just monetary. Inevitably, environmental, ethical, and legal issues will arise, creating setbacks for this emerging energy source. Among the biggest of setbacks, however, comes from politics and economy; the cost of implementing such technologies has been notoriously expensive. To reach a point of real widespread use, such issues must be addressed.

12.2 Global Perspective

Due to the high costs of manufacturing photovoltaic cells that convert the energy of the sun into electrical energy, the subsequent cost of solar panels has been notoriously high. One of the main reasons for this is the use of pure silicon in a majority of panels being produced. Although there are other alternatives, silicon gives the greatest efficiency, and when competing in a fossil fuel market, the greatest efficiency possible is nearly mandatory.

To help boost the sales of solar panels, President Obama added a provision for homeowners in the 2008 bailout that extended for 8 years a 30 percent tax credit for the installation of solar panels (Petroski, 2010). Still, the initial cost can still be quite steep. To navigate around this, 41 states offer loan programs, incentives, rebates, and grants for renewables. Figure number 61 is a map of the United States showing which 41 states provide loans along with the type of program offered.

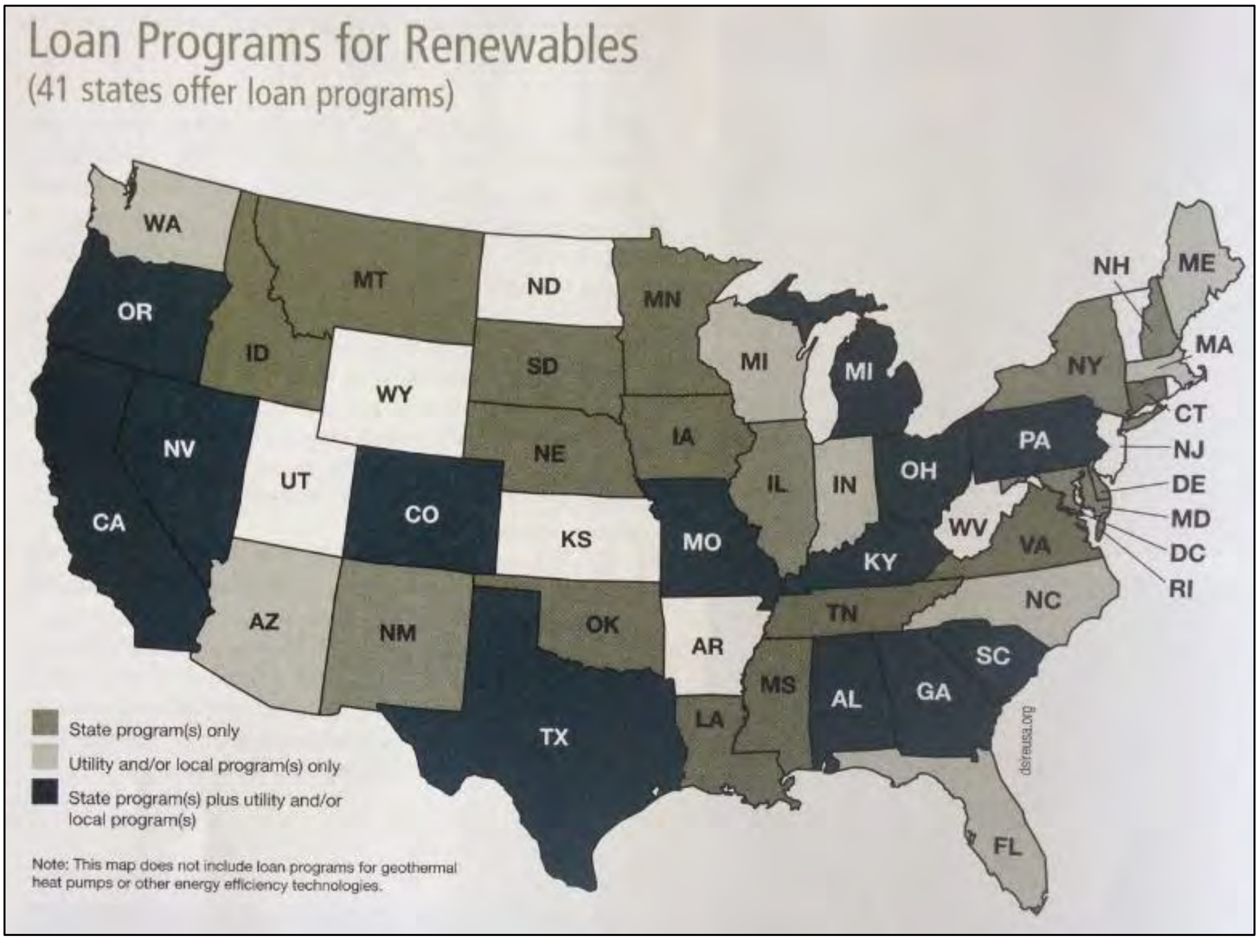


Figure 62: U.S. Loan programs for renewables

As mentioned earlier, when Germany wanted to generate over 14% of its electricity from renewables, they offered significant government subsidies that were financed by surcharges added to every monthly electric bill.

People may know that we need to change to renewables, but for the vast majority, if the same efficiencies, power, and cost effectiveness are not comparable, the willingness is low. Having different incentives in place is just one answer to solving the problem. Another area that would need to be addressed or spoken to is an appeal to the positive influence it can have on the quality of human life.

12.3 Global Engagement

Using renewables for transportation has been on the rise, though still has a long way to go before coming close to competing with the usual gas engines. As engineers, when looking strictly at output, the debate between gasoline and renewables that use batteries for storage of energy is a no brainer. Batteries are heavy, expensive, and of limited capacity and life. Gasoline packs 80 times more energy per kilogram than a lithium-ion battery, and holds 250 times more energy than a common lead-acid battery. To be truly competitive in the transportation market, the deliverable power and efficiency must be at least equal to that of the common gas powered vehicle. This, along with the similar issues faced by solar energy, is not a limitation that can be fixed by government subsidies or ethical persuasions. As engineers, we need to find innovation solutions to make such products more appealing by reaching the level that the consumer wants.

We are starting to see it in the automobile industry, with cars like the Chevy Volt that can fully charge it's batteries overnight, and boasts 150 mpg, along with it being able to run strictly on batteries for up to 40 miles. Tesla Motors did this same with its luxury Model S and the Roadster. Still, the price tags are high, and may need to come down significantly before their sales reach the desired goal. Photovoltaic cells are also constantly being tweaked to increase their efficiencies. In Figure number 62 we see the rise of efficiencies over the last 40 years. (Learning About Solar Basics, 2013)

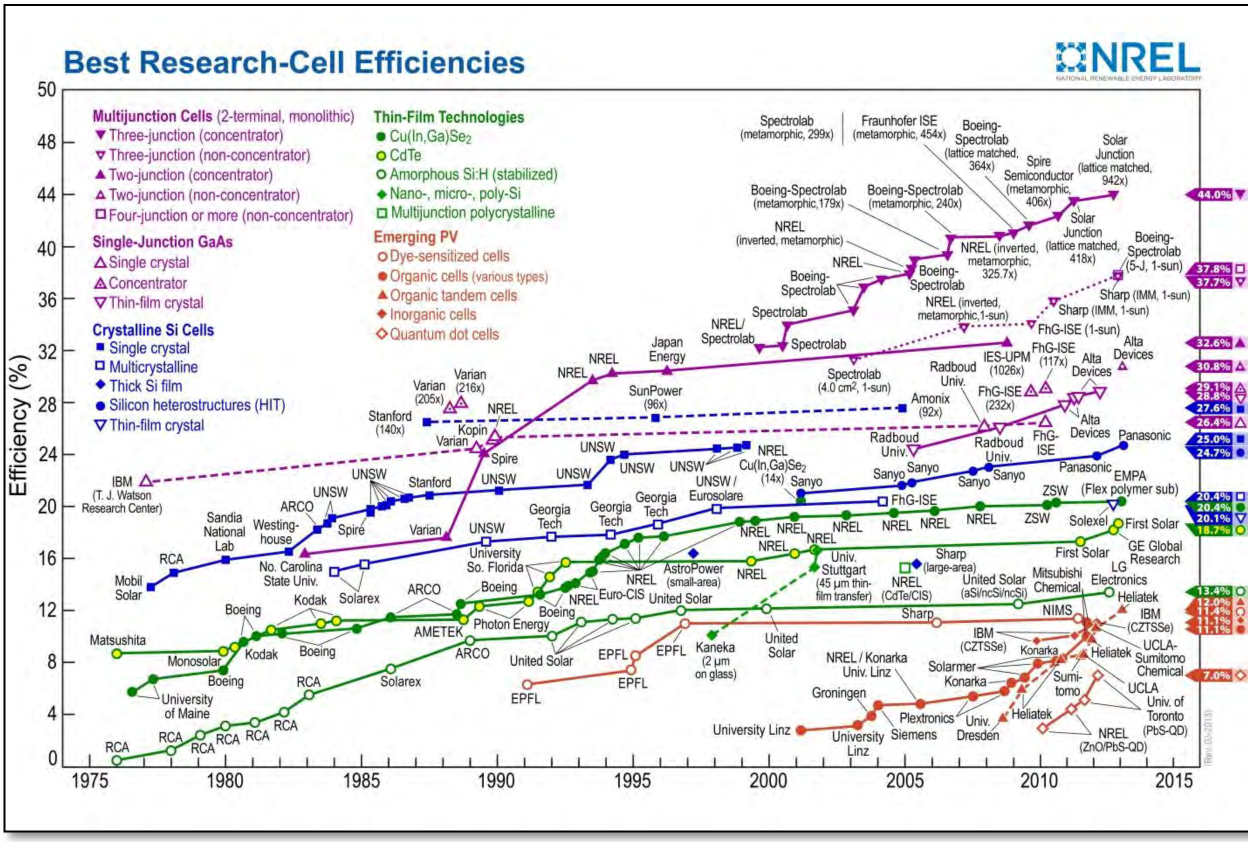


Figure 63: Photovoltaic cell efficiencies

13. Conclusions

With the design of the eco-friendly shallow draft boat, we are were able to protect both the environment from exhaust fumes by using a solar powered electric motor with zero emissions, along with keeping the local ecosystem safe from harm. Originally we had thought that having a boat custom built that is powered by a photovoltaic system with battery storage would certainly be more expensive than market comparable. To our surprise, the cost was less than other similar boats, both electric and gas powered, as shown in Table 12. Compared to the gas powered, that lower initial cost becomes an even better deal when refilling involves at the most plugging in the battery banks at not, rather than spending hundreds of dollars on gasoline. The implications of such a realization are astounding, since one of the major setbacks in the flourishing of solar energy is the (generally) higher costs associated with them. If similar price instances happen within other markets, and knowledge is spread, this could be a true turning point in the rise of renewables.

Option	Name	Description	Description	Manufacture	Base Price ($)	Average Custom Price ($)
1	Ocean Cat Series Catamaran	26' x 8.5' (12" draft)	Gasoline	Twin Vee Catamaran	30995	57604
2	Electric Boat	22' x 9' (29")	Electric	Duffy Boats	51990	51990
3	Solar Panter Boat (Water Taxi)	26' x 9.5' (12" draft)	Solar / Electric	FIU/ Dreams Boats	33000	51330.36

Table 13 - Market Comparables

However, to get to that point, we first needed to start in the beginning. After a brief history of the evolution of boats and boat technologies, we examined several different hull shapes that could be used for our project that might satisfy the customer's needs. Our final design choice was a catamaran style tunnel hull with two square sponsons. We chose this design for its stability and buoyant properties that allowed us to stay within the one foot maximum draft.

Once we had the design of the boat, we then needed to choose components for the power system that would optimize cost, efficiency, and power requirements necessary to not only move the boat but to keep it running long enough to go to and from its destination without problem. We also had to take into consideration the weight of the power system components to ensure that they did not affect the draft of the boat.

Throughout the duration of the project, regular meetings were set up with the client to go over our progress, accomplishments, success, difficulties, and future plans. This was a time when we could talk face to face with the client, show what we have, and get his feedback. As we were working for him, our main objective throughout the project was to ensure that he would end up with a product with which he was more than happy. We contacted a boat manufacturer out of Tampa who was perfect for the job, and we became the liaisons, getting ideas from the customer, working out the calculations, design, and feasibility of the requests, and taking that to the manufacturer for his input. In essence we all became one big team working for the same cause. In the end, if the client is happy, then everyone is happy.

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Appendix A: Cost Analysis

Electric Components

MOTORS

Brand	Description	Quantity	Price / unit ($)	Total ($)
Torqeedo	Cruise 4.0 (long shaft)	2	3849	7698

GOAL	Low efficiency	48 V / 4000 watts = 1 Motor Toquedo Motor 4.0
	Max efficiency	48 V / 9600 watts = 1 Motor Toquedo Motor 4.0

SOLAR PANELS

Brand (supplier)	Voltage (v)	Power (Watts)	Current (AH)	Quantity	Price / Unit ($)	Total Price ($)
et sun (sun-electric)	36.08	285	7.899113082	6	282.15	1692.9
Suniva (US solar)	30	265	8.833333333	8	265	2120
SunTech (Online)	35.4	285	8.050847458	6	222	1332
Jet Sun (online)	36.6	249.2	6.808743169	6	249	1494

BATTERIES

						Discharge Time (hrs.)						
Brand	Voltage (v)	Current (AH)	Power (Watts)	Quantity	:harge time (hrs.	(full) (hrs.)	(Med)	(low)	Weight (lb.)unit	Cycle Life	Price /unit ($)	Total Price ($)
DC105-12	12	100	1200	8	4.528301887	1.1	3	7	66.58	400	233	1864
UB121100	12	100	1200	8	4.528301887	1.1	3	7	65	300	209	1672
DC260	12	260	3120	4	5.886792453	1.1	3	7	172.4	400	664.96	2659.84
Torqeedo	25.9	104	2693	2	2.540566038	1.1	3	7	53.57 lbs.	800	2599	5198
Energy Cell 200E	12	178	2136	4	4.030188679	1.1	3	7	115	620	504	2016
S12-230AGM	12	210	2520	8	4.754716981	1.1	3	7	146.3	650	578	4624

BATTERY CHARGER

Brand	Voltage (v)	Current (A)	Quantity	charge time (hr.)	Weight (lb.)unit	Price /unit ($)	Total Price ($)
Torqeedo	26	9	1	6 ~ 7	8	699	699
The Pro Nautic P 2430	24	30	1	9 ~ 10	7	559	559
Pro Nautic 1260P	12	60	1	7 ~ 8	7	541	541
DLS-75	12	75	1	7 ~ 8	7	363.12	363.12
DLS90	12	90	1	6 ~ 7	7	430	430

CHARGE CONTROLLER

Brand	Voltage (v)	Current (A)	Quantity	(lb.)	Price /unit ($)	Total Price ($)
Outback Flex Max 60	12, 24, 36, 48	60	1	15	539	539
:leX mac 60 Charge C.	12, 24, 36, 49	60	1	15	539	539

HARDWARE

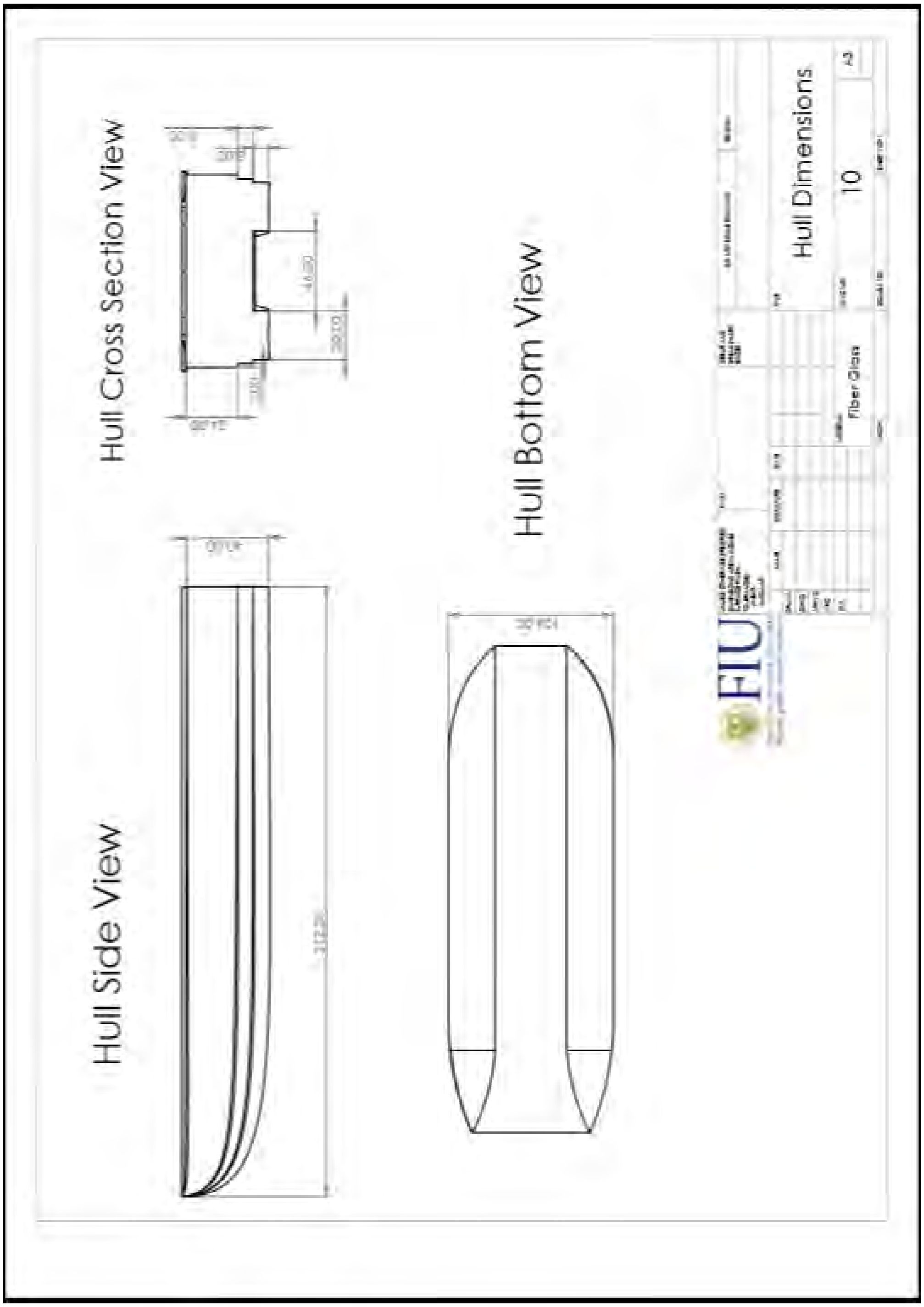
Description	Price ($)
Description Attached	1446.64

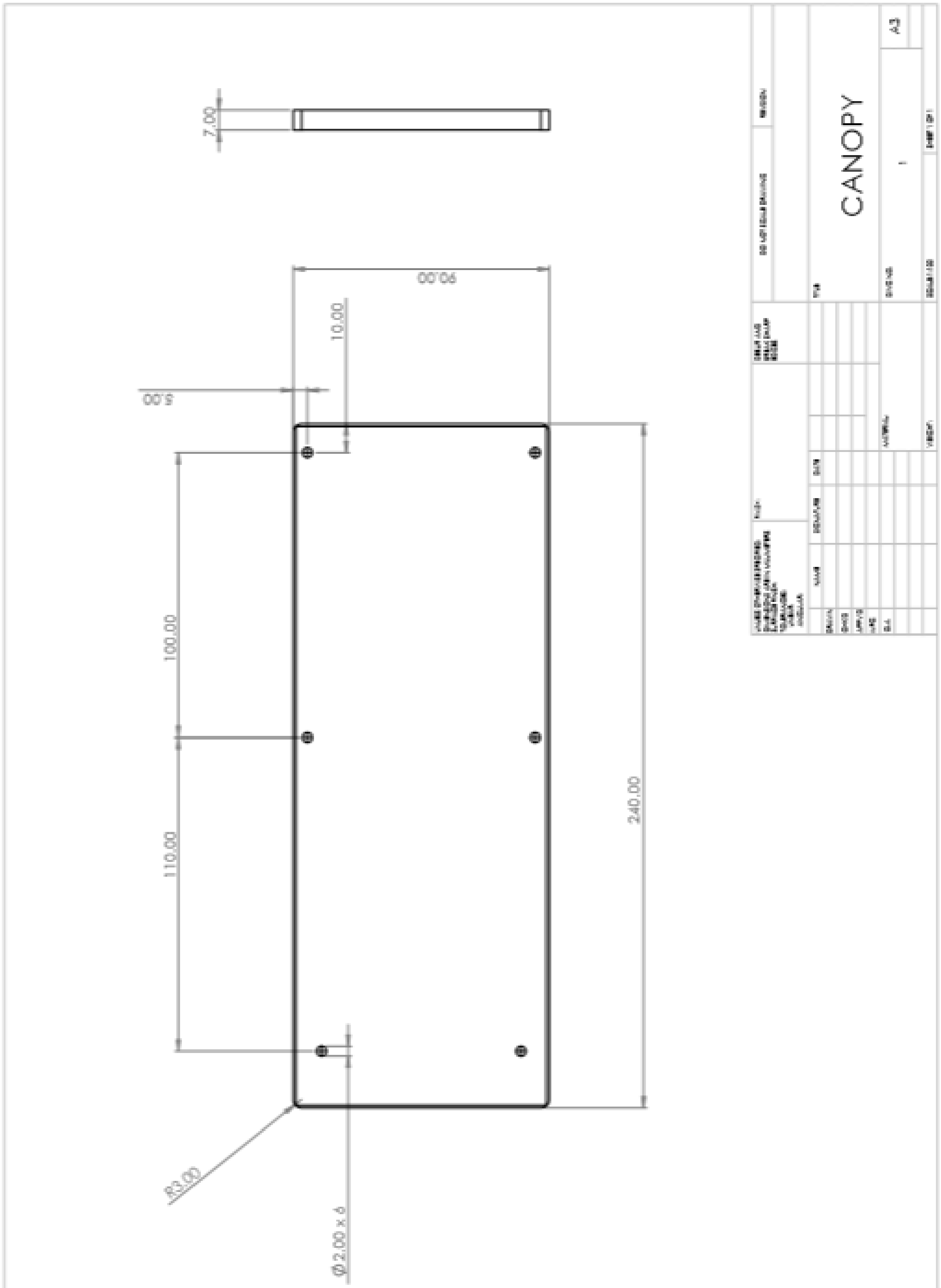
TOTAL	16790.76

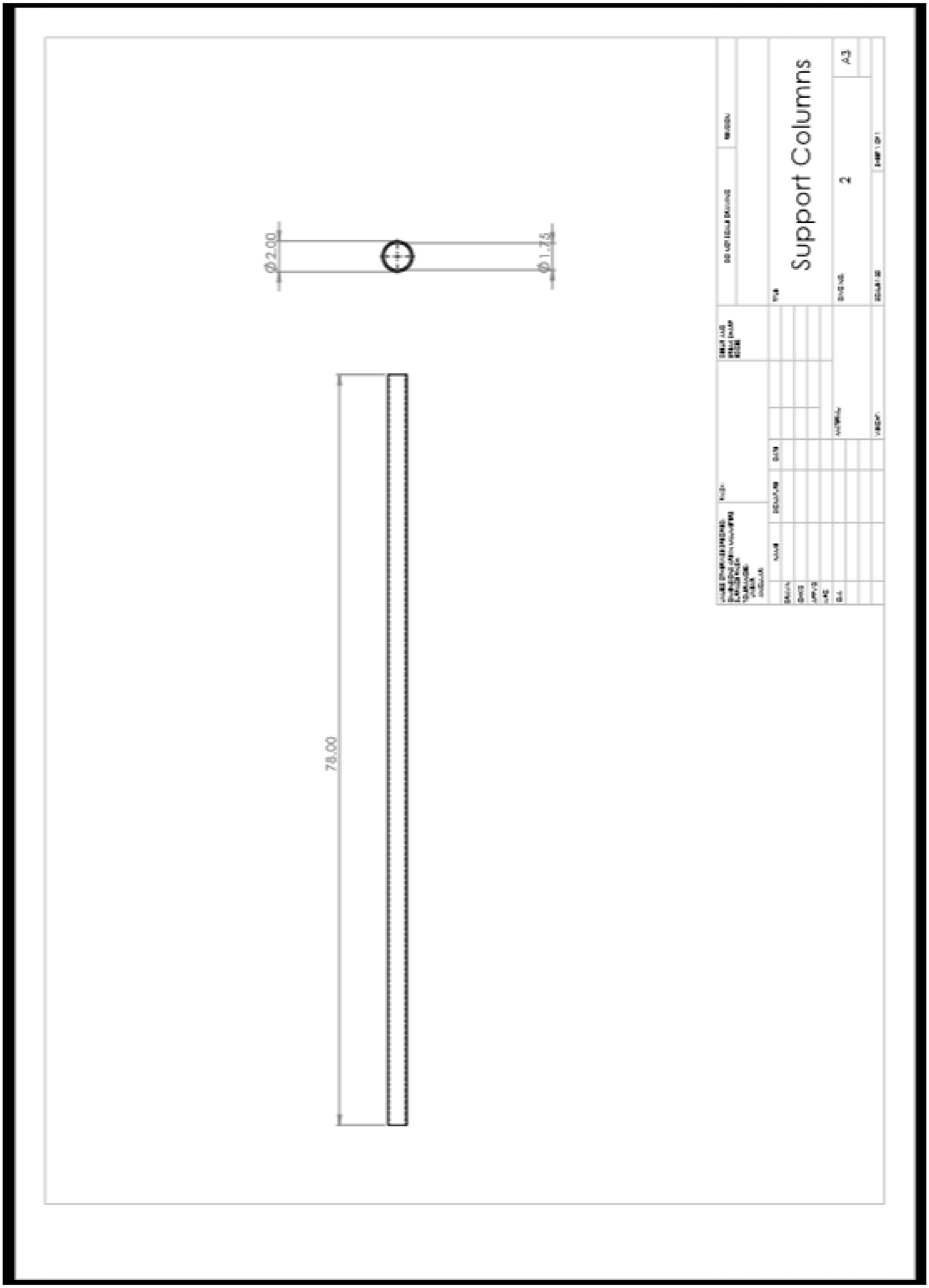
Ramp	
	Price ($)
The hydraulic ramp (42 inches wide with handrails and a 36 inch ramp)	6000
Mechanical (cables) (42 inches wide with handrails and a 36 inch ramp)	2500
Restroom (Additional)	
Average	500
Hull Manufacturing	
	Price ($)
Hull Manufacruring (8.5' x 26')	30000
Hull Manufacruring (9.5' x 26')	33000
Electric (Canopy Componets)	16790.76
20% Installation (Manufacturing)	1539.60
Total Cost	51330.36
TotaL Cost (including Restroom)	51830.36

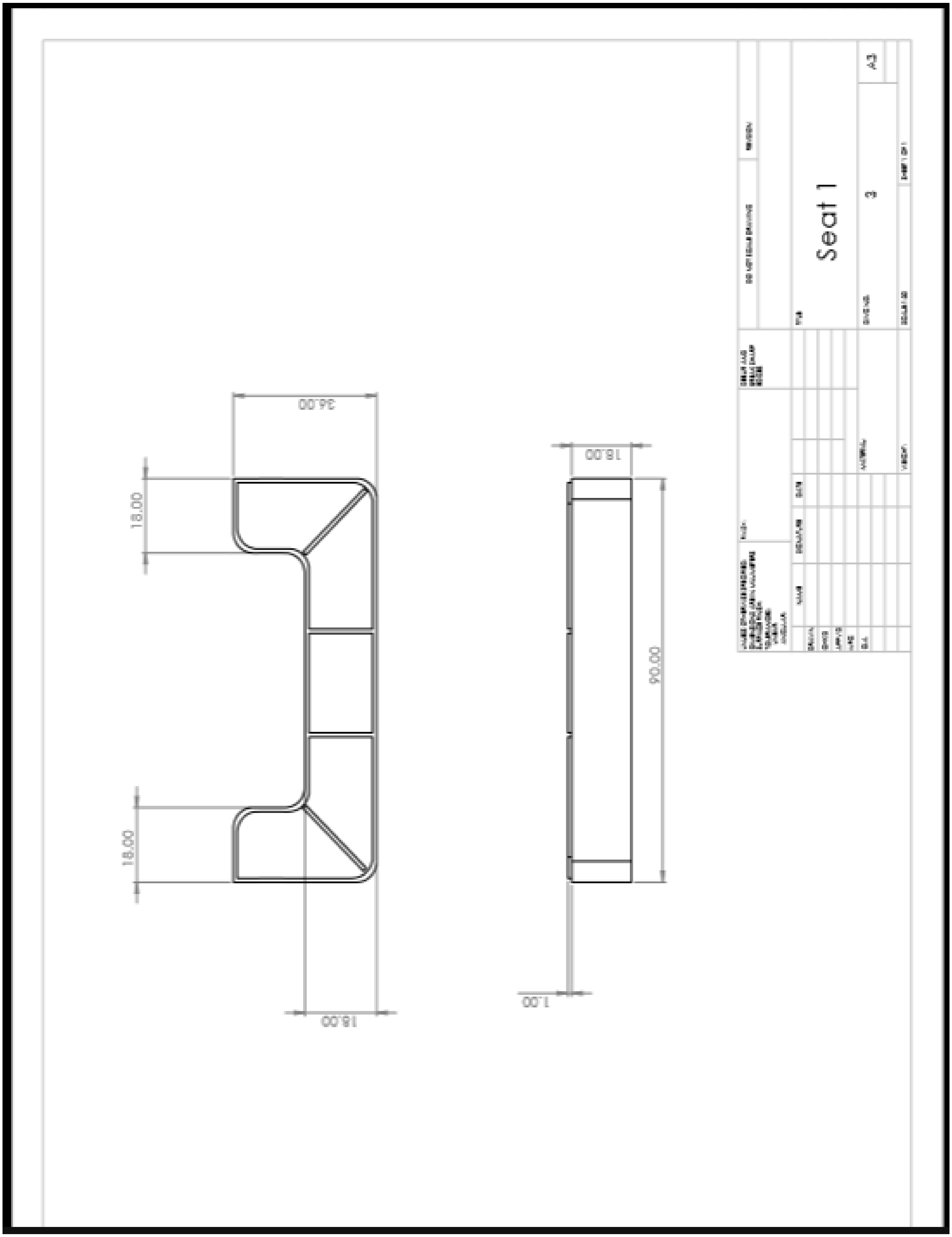
Appendix B: Dreamboats shop

Appendix C: Boat Drawings




7.00
90.00
10.00
5.00
100.00
110.00
240.00
R3.00
Ø2.00 x 6
CANOPY
A3


Ø2.00
Ø1.75
78.00
Support Columns
A3


Seat 1
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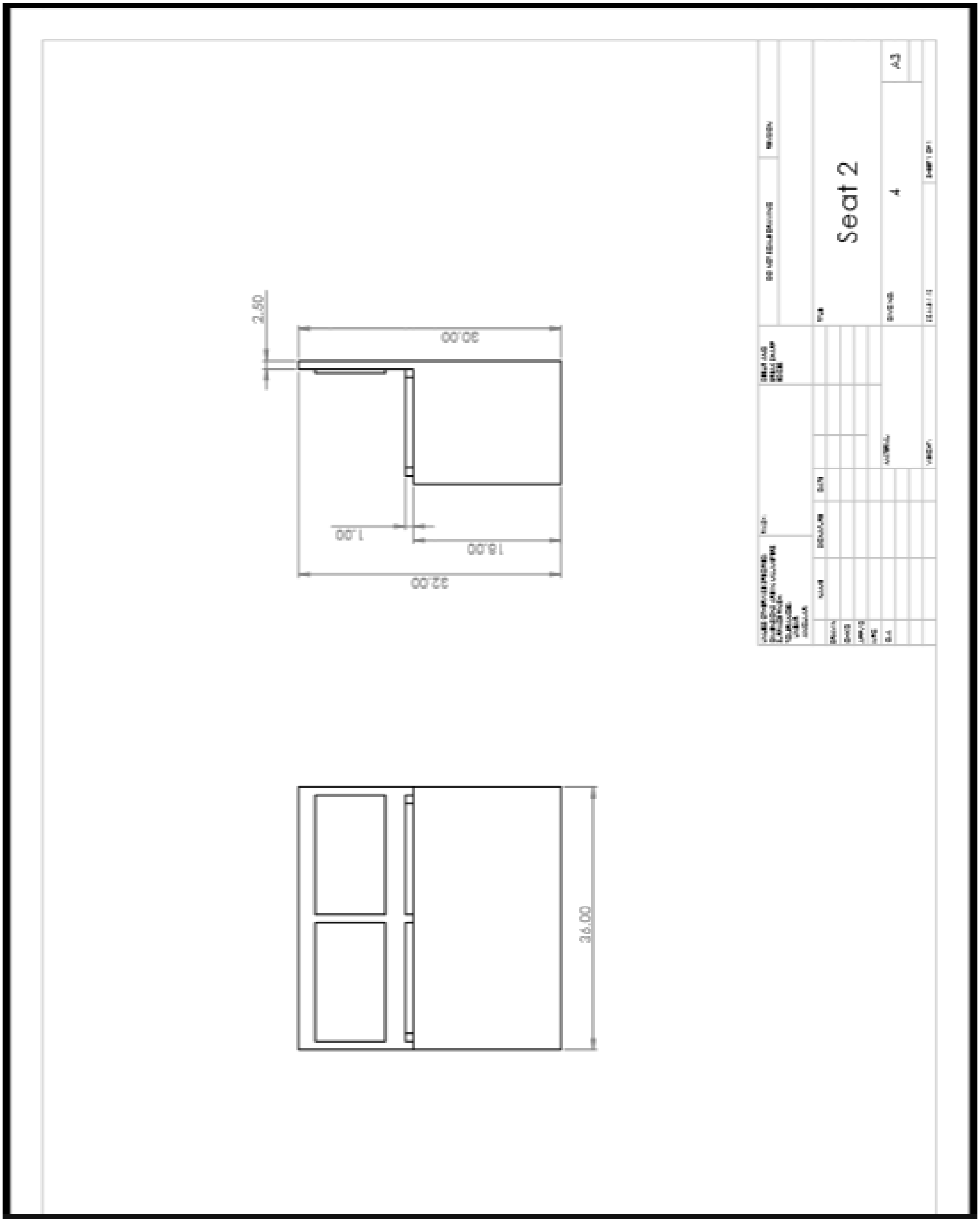
18.00
18.00
18.00
18.00
90.00
1.00
A3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4
A3
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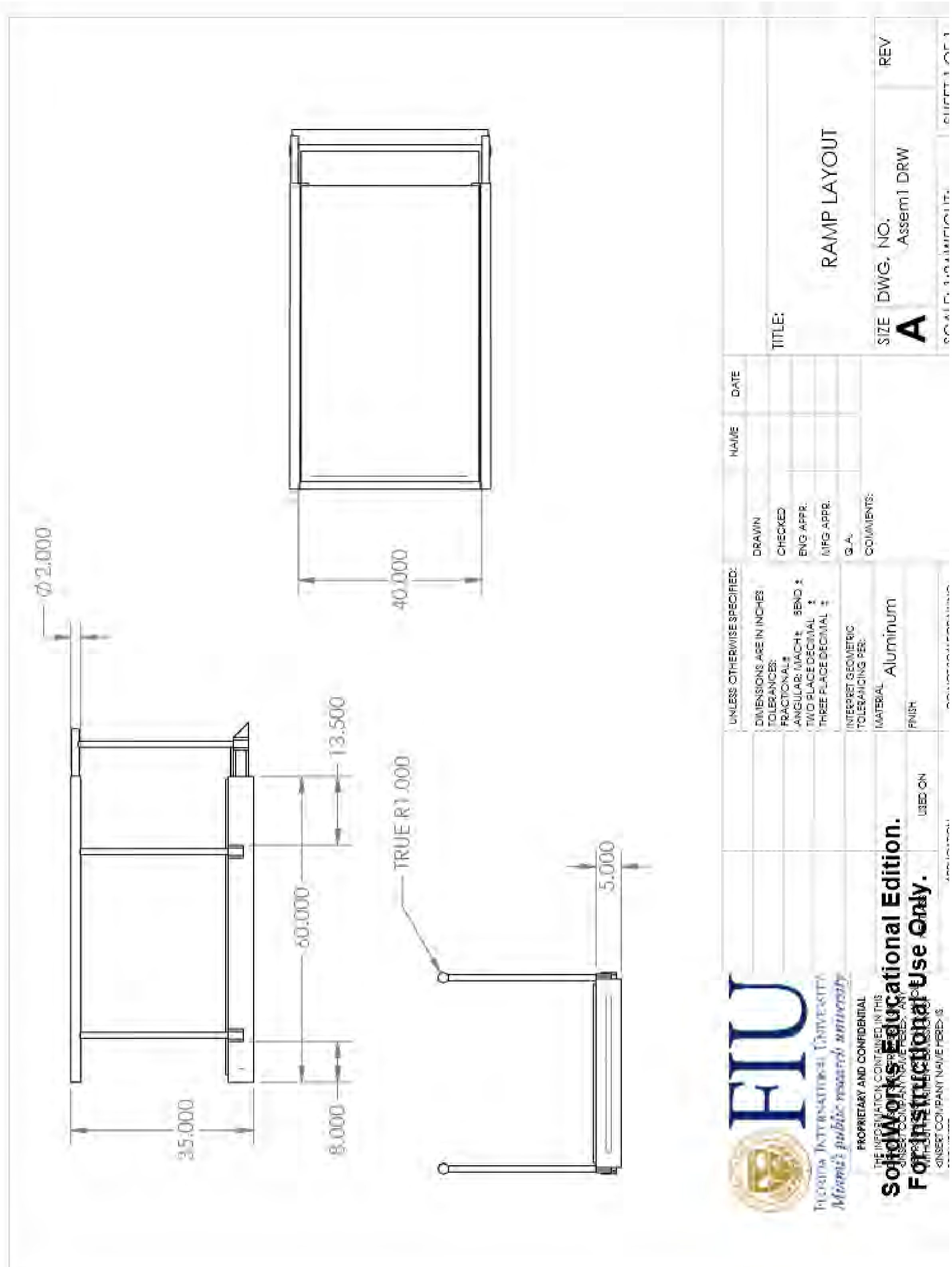
2.50
1.00
18.00
32.00
36.00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40.000
13.500
60.000
8.000
35.000
TRUE R1.000
5.000
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
FINISH
USED ON
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
RAMP LAYOUT
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DWG. NO.
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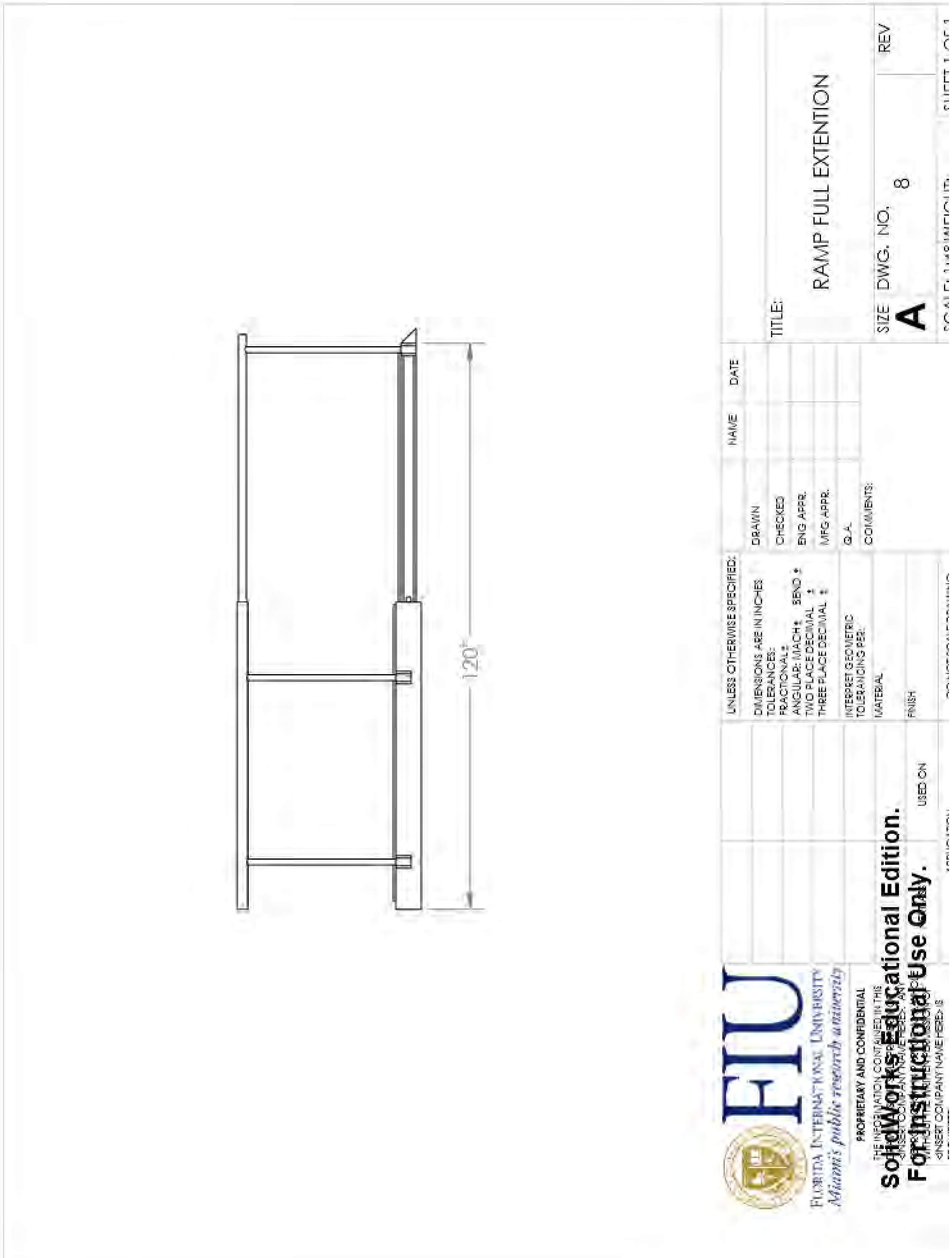
REV
PROPRIETARY AND CONFIDENTIAL
SolidWorks Educational Edition.
For Instructional Use Only.


120"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
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INTERPRET GEOMETRIC TOLERANCING PER:
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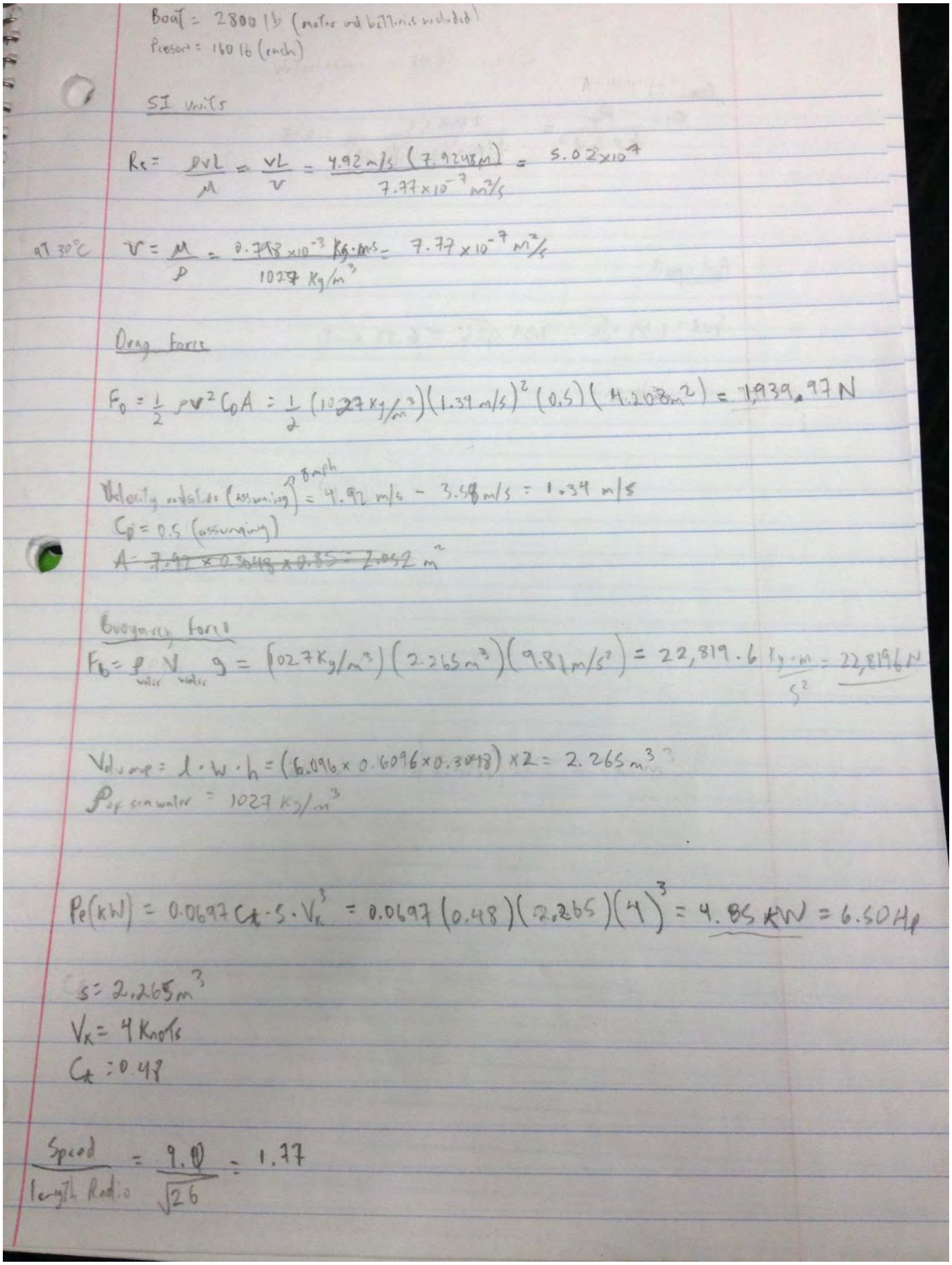
Appendix D: Raw Hand Calculations



Boat = 2800 lb (motor and batteries included)
Person = 160 lb (each)

SI units

$$Re = \frac{\rho v L}{\mu} = \frac{vL}{\nu} = \frac{4.92\ m/s\ (7.9248\ m)}{7.77\times10^{-7}\ m^2/s} = 5.02\times10^{7}$$

at 30°C $$\nu = \frac{\mu}{\rho} = \frac{0.798\times10^{-3}\ Kg\cdot m/s}{1027\ Kg/m^3} = 7.77\times10^{-7}\ m^2/s$$

Drag Force

$$F_D = \frac{1}{2}\rho v^2 C_D A = \frac{1}{2}(1027\ Kg/m^3)(1.34\ m/s)^2(0.5)(4.208\ m^2) = 1{,}939.97\ N$$

Velocity relative (assuming $\overset{8\ mph}{\uparrow}$) = 4.92 m/s − 3.58 m/s = 1.34 m/s
$C_D = 0.5$ (assuming)
~~A = 7.92 × 0.3048 × 0.85 = 2.052~~ m^2

Buoyancy Force

$$F_b = \rho_{water} V_{water}\ g = (1027\ Kg/m^3)(2.265\ m^3)(9.81\ m/s^2) = 22{,}819.6\ \frac{Kg\cdot m}{s^2} = 22{,}819.6\ N$$

Volume = $l \cdot w \cdot h$ = (6.096 × 0.6096 × 0.3048) × 2 = 2.265 m^3
$\rho_{of\ sea\ water}$ = 1027 Kg/m^3

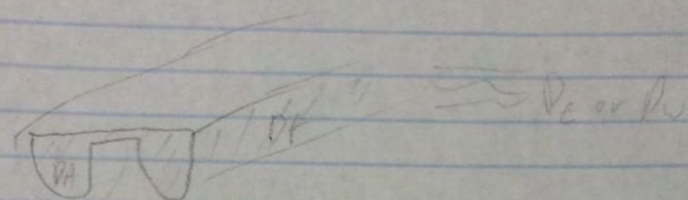
$$P_e(kW) = 0.0697\,C_t \cdot S \cdot V_k^3 = 0.0697(0.48)(2.265)(4)^3 = 4.85\ kW = 6.50\ Hp$$

$S = 2.265\ m^3$
V_k = 4 Knots
C_t = 0.48

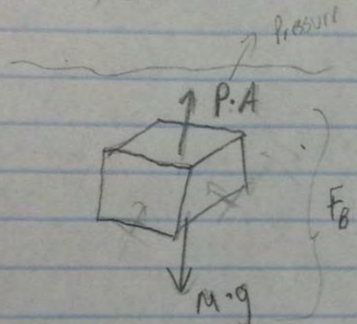
$$\frac{Speed}{Length\ Ratio} = \frac{9.0}{\sqrt{26}} = 1.77$$

$$Drag = (D_A + D_{friction} + D_W^{wake}) \times 1.15$$

10-25%



Buoyancy force

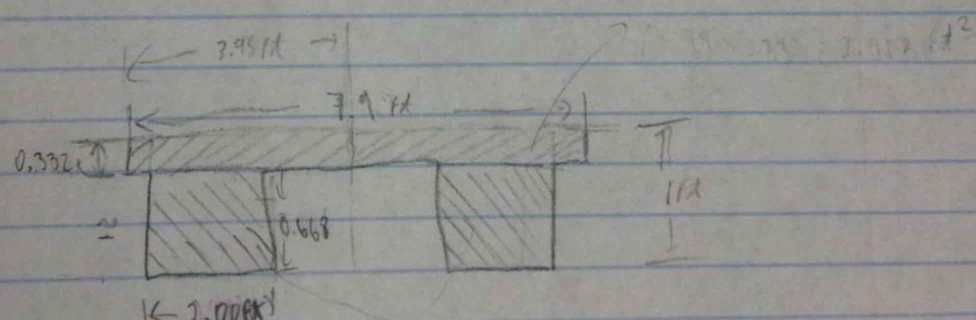


$$P = \rho g h = (1027\ kg/m^3)(9.81\ m/s^2)(0.3048\ m) = 3070.82\ kg/m \cdot s^2$$

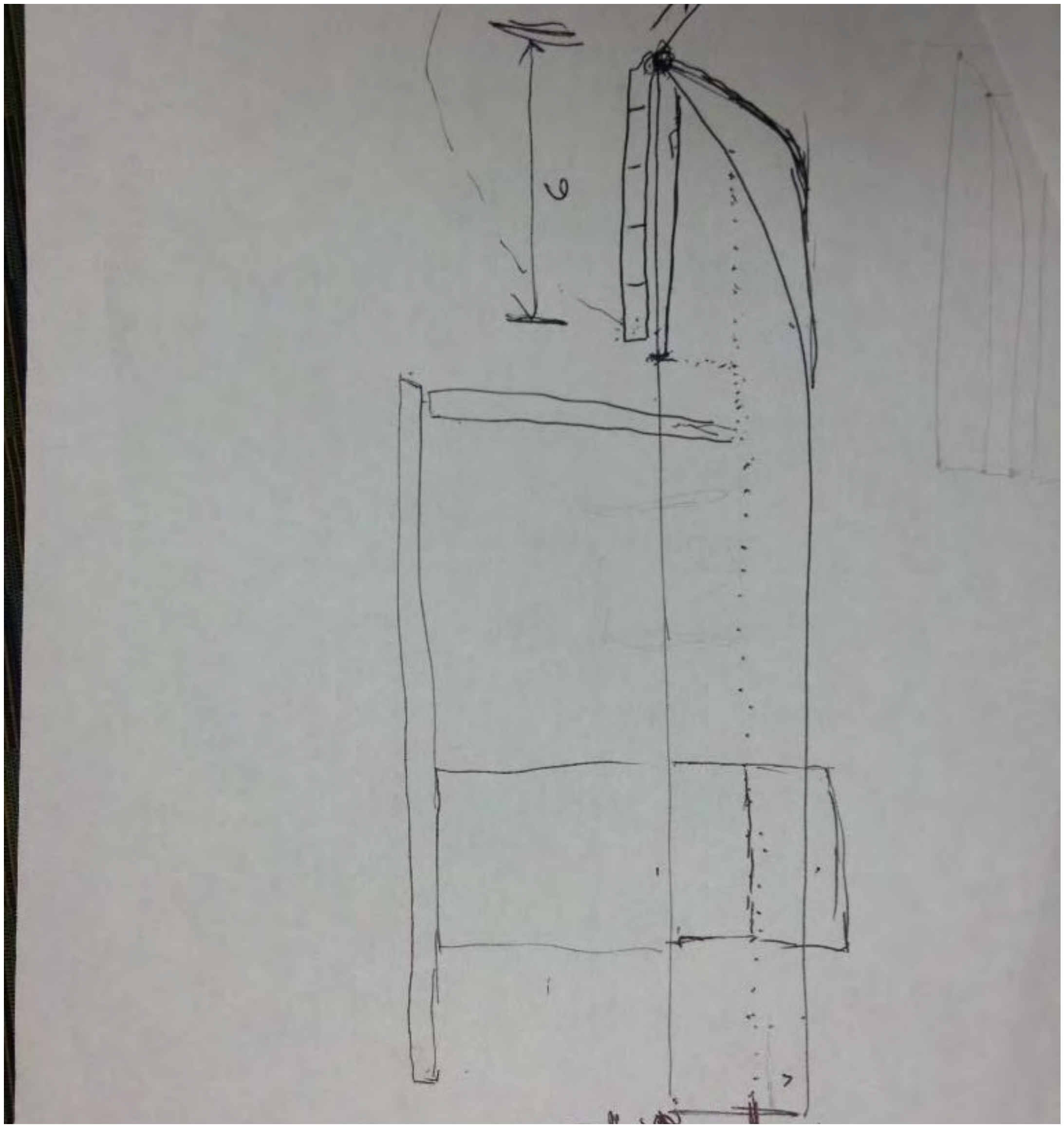
$$F_{\uparrow} = P \cdot A = (3070.82\ kg/m \cdot s^2)(4.219\ m^2) = 12{,}955.8\ kg \cdot m/s^2 = 12{,}955.8\ N$$

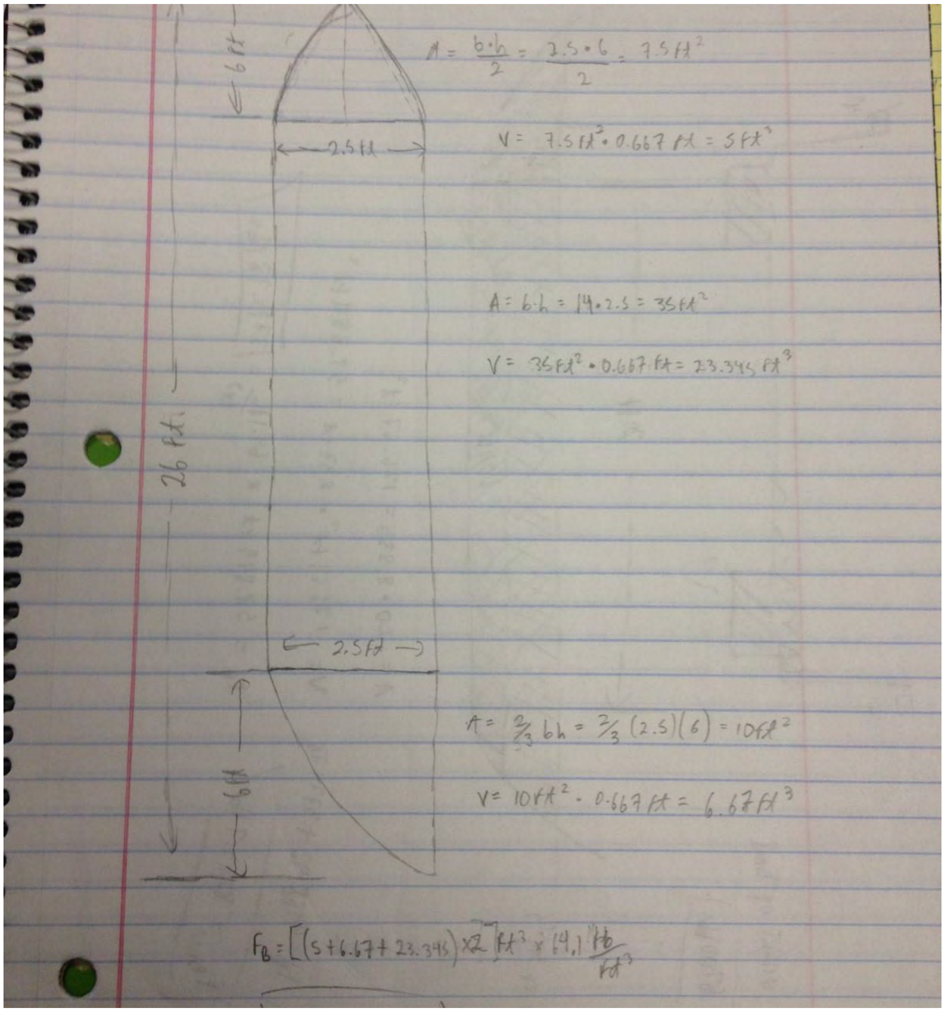
$$F_{\downarrow} = m \cdot g = (2358.68\ kg)(9.81\ m/s^2) = 23{,}138.7\ kg \cdot m/s^2 = \underline{23{,}138.7\ N}$$

$$F = F_{\downarrow} + F_{\uparrow} = \boxed{10{,}182.9\ N}$$



$$A = [(2.000 \times 0.668) + (3.95 \times 0.332) + (1 \times 20)] \times 2 = \underline{45.295\ ft^2} = 4.208\ m^2$$




6 ft
A = b·h / 2 = 2.5 • 6 / 2 = 7.5 ft²
2.5 ft
V = 7.5 ft² • 0.667 ft = 5 ft³
A = b·h = 14 • 2.5 = 35 ft²
V = 35 ft² • 0.667 ft = 23.345 ft³
26 ft
2.5 ft
A = 2/3 bh = 2/3 (2.5)(6) = 10 ft²
6 ft
V = 10 ft² • 0.667 ft = 6.67 ft³
F_B = [(5 + 6.67 + 23.345) x 2] ft³ x 64.1 lb/ft³

285 wAIS

weight => 59.5 lbs

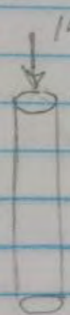
in L x W x D => 72" x 39.1" x 2"

Panels: $\boxed{6}$

Total weig => 357 lbs

≈ 380 lbs

14 => F = 95 lbs



$\sigma = \frac{F}{A}$ =>   D = (3.5) => 169

D = 2πRL

D = 2πRL =>

D = (1.25)(L) = 78.4)

Using Al 6061

$A = 857.22 \text{ in}^2$

allowable stress

48 r_1 2   37.69

$r_2 = 4$

h = 8

$\sigma = \frac{F}{A} = \frac{95 \text{ lbs}}{857.22 \text{ in}^2} = \boxed{0.11 \text{ Psi}}$

$(2\pi r h + 2\pi R h) + 2(\pi r^2 - \pi R^2)$

$F_s = \frac{\sigma_{ultimate}}{}$ =>

$A_1 = \pi r_1^2$

Appendix E: Torqeedo Motor Specifications

torqeedo

Torqeedo Cruise 4.0 R Electric Outboard Motor

CLICK HERE Flat Rate

5.0 (1 review) Read 1 Review Write a Review SHARE

JD Price Match Promise

The Torqeedo Cruise 4.0 R Electric Outboard Motor is a new, powerful model designed specifically for remote steering and throttle. The Cruise 4.0 R is a 48-volt motor that has the propulsive power of a 8 hp gas outboard and the thrust of a 9.9 hp gas outboard.

The 4.0 R motors feature an integrated GPS receiver with an information system, so you always know how much battery power and remaining range you have.

Now available in short shaft and long shaft versions.

Spare Propeller sold separately: **TOR-1915**

Factory Warranty: 2 years limited

TOR-1211 – Cruise 4.0 R Short Shaft $3,799.00 / ea qty. 1 Add To Cart Wish List

IN STOCK - Available for pickup

Additional shipping charges apply

- Warranty certificate
- Packaging

Torqeedo Model Technical Data	Cruise 4.0 R (short shaft -S) (long shaft - L)
Input power in watts	4,000
Propulsive power in watts	2,040
Comparable gas outboards (propulsive power)	8hp
Comparable gas outboards (thrust)	9.9hp
Maximum overall efficiency in%	51
Static thrust in lbs	214
Integrated battery	No
Rated voltage in volts	48
Total weight in lbs	37.7 (S) / 38.5 (L)
Shaft length in inches	24.6 (S) / 29.7 (L)
Propeller dimensions in inches	12 x 10
Propeller speed at full power in rpm	max. 1,250
Control	Remote throttle control
Steering	Provision for connection to standard remote steering lockable
Tilting device	Manual with grounding protection
Trim device	Manual, 4-step
Stepless forward/ reverse drive	Yes
Additional pre-set speeds	No

BRAND: Torqeedo
Inboard / Outboard: Outboard

Appendix F: Technical sheet Data for Apparatus

OPTIMUS SERIES: OPT 60 CELL MODULES

Suniva
The Brilliance of Solar Made Sensible®

High-quality and high-efficiency
PV yields sensible solar

SUNIVA OPTIMUS® SERIES MONOCRYSTALLINE SOLAR MODULES

OPTXXX-60-4-100 (60 CELL MODULE)

The Optimus® modules consist of Suniva's latest technology: ARTisun® Select. These superior monocrystalline cells are designed and manufactured in the U.S.A. using our proprietary low-cost processing techniques. Engineered with our pioneering ion implantation technology, high power-density Optimus modules provide excellent value, performance and reliability.

Certifications:

ISEC   AS5033 Compliant

Engineering Excellence

- Built exclusively with Suniva's highest-efficiency ARTisun Select cells, providing one of the highest power outputs per square meter at an affordable manufacturing cost
- Suniva's state-of-the art manufacturing facility features the most advanced equipment and technology
- Suniva is a U.S. –based company spun out from the Georgia Tech University Center of Excellence in Photovoltaics (one of only two such research centers in the U.S.)

Features

- Contains the latest ARTisun Select cell technology - over 19%
- Positive only tolerance ensures predictable output
- Marine grade aluminum frame with hard anodized coating
- Industry leading linear warranty (10 year warranty on workmanship and materials; 25 year linear performance warranty delivering 80% power at STC)
- Buy America compliant upon request
- Qualifies for U.S. EXIM financing
- System and design services available

Quality & Reliability

Suniva Optimus modules are manufactured and warranted to our specifications assuring consistent high performance and quality worldwide.

- Rigorous quality management
- Performance longevity with advanced polymer backsheet
- Produced in an ISO 9001: 2008 certified facility
- Passed the most stringent salt spray tests based on IEC 61701
- Passed enhanced stress tests[1] based on IEC 61215 conducted at Fraunhofer ISE[2]
- Certified PID free
- Ask about our validated PAN files

OUR PRODUCTS:

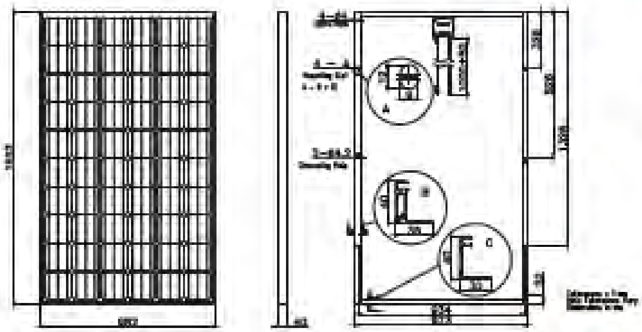
Monocrystalline Modules
OPTIMUS SERIES 60 cell
OPTIMUS SERIES 72 cell

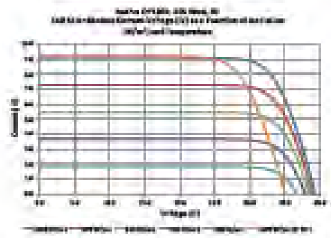
Monocrystalline Cells
19%+ efficiency

Multicrystalline Modules
MV SERIES 60 cell
MV SERIES 72 cell

Balance of Systems Solutions (BOSS)
Racking, Inverters, Batteries, Energy Storage Appliances and EV Chargers

OPTIMUS SERIES: OPT 60 CELL MODULES





ELECTRICAL DATA (NOMINAL)

The rated power may only vary by -0/+4.99W and all other electrical parameters by ± 5%

Power Classification	Pmax (W)	255	260	265	270
Module efficiency	%	15.71	16.02	16.33	16.60
Model Number	OPT	255-60-4-100	260-60-4-100	265-60-4-100	270-60-4-100
Voltage at Max. Power Point	Vmp (V)	30.00	30.20	30.70	31.20
Current at Max. Power Point	Imp (A)	8.50	8.60	8.64	8.68
Open Circuit Voltage	Voc (V)	37.90	38.10	38.30	38.50
Short Circuit Current	Isc (A)	9.05	9.08	9.12	9.16

The electrical data apply to standard test conditions (STC): Irradiance of 1000 W/m² with AM 1.5 spectra at 25°C.

DIMENSIONS AND WEIGHT

Cells / Module	60 (6x10)
Module Dimensions	1652 x 982 mm (65.04 x 38.66 in.)
Module Thickness (Depth)	40 mm (1.57 in.)
Approximate Weight	17.9 +/- 0.25kg. (39.5 +/- 0.5 lb.)

CHARACTERISTIC DATA

Type of Solar Cell	High-efficiency ARTisun® Select monocrystalline cells of 156 x 156 mm (6 in.)
Frame	Silver anodized aluminum alloy; black frame available by custom order
Glass	Tempered (low-iron), anti-reflective coating
Junction Box	NEMA IP65 rated; 3 internal bypass diodes
Cable & Connectors	12 AWG (4.0 mm²) cable with Tyco or MC4 compatible (H4) connectors³; cable length approx. 1000 mm
Hardware (Available Upon Request)	Grounding screws: (2) #10-32 12.7 mm (#10-32 x 0.5 in.) Stainless steel flat washers: (4) 5 x 10 x 1 mm (0.2 in. ID x 0.394 in. OD x 0.030 in.)

TEMPERATURE COEFFICIENTS

Voltage	β, Voc (%/°C)	-0.335
Current	α, Isc (%/°C)	+0.047
Power	γ, Pmax (%/°C)	-0.420
NOCT Avg	(+/- 2 °C)	46.0

LIMITS

Max. System Voltage	1000 VDC for IEC (600 VDC for UL)
Operating Module Temperature	-40°C to +85°C
Storm Resistance/Static Load	Tested to IEC 61215 for loads up to 5400 Pa; hail and wind resistant

Suniva® reserves the right to change the data at any time. View manual at suniva.com
¹UV 20 kWh, TC 400, DH 2000. ²Tests were conducted on module type OPT 60. ³See data rep. [SAMO_0010]

5765 Peachtree Industrial Blvd.
Norcross, Georgia 30092 USA
Tel: +1 404 477 2700

Please recycle

FLEXmax™

Continuous Maximum Power Point Tracking Charge Controllers

- **Increases PV Array Output by up to 30%**
- **Advanced Continuous Maximum Power Point Tracking**
- **Full Power Output in Ambient Temperatures up to 104°F (40°C)**
- **Battery Voltages from 12 VDC to 60 VDC**
- **Fully OutBack Network Integrated and Programmable**
- **Programmable Auxiliary Control Output**
- **Built-in 128 days of Data Logging**
- **Standard 5 Year Warranty**

The FLEXmax family of charge controllers is the industry leading innovation in Maximum Power Point Tracking (MPPT) charge controllers from OutBack Power. The innovative FLEXmax MPPT software algorithm is both continuous and active, increasing your photovoltaic array power yield up to 30% compared to non-MPPT controllers. Thanks to active cooling and intelligent thermal management cooling, both FLEXmax charge controllers can operate at their full maximum current rating, 60 Amps or 80 Amps respectively, in ambient temperatures as high as 104°F (40°C).

Included in all of the FLEXmax Charge Controllers are the revolutionary features first developed by OutBack Power, including support for a wide range of nominal battery voltages and the ability to step down a higher-voltage solar array to recharge a lower-voltage battery bank. A built-in, backlit 80 character display shows the current status and logged system performance data for the last 128 days at the touch of a button. The integrated OutBack Power network communications allow FLEXmax series charge controllers to be remotely programmed and monitored using the MATE family of system displays and provide unrivaled complete system integration.

FLEXmax MPPT charge controllers are the only choice when you demand a high performance, efficient and versatile charge controller for your advanced power system.

OutBack POWER®

www.outbackpower.com

FLEXmax™ Specifications

		FLEXmax-80 - FM80-150VDC	FLEXmax-60 - FM60-150VDC
Nominal Battery Voltages		12, 24, 36, 48, or 60 VDC (selectable using field programming at start-up)	
Maximum Output Current		80 Amps @ 104°F (40°C) with adjustable current limit	60 Amps @ 104°F (40°C) with adjustable current limit
Maximum Solar Array STC Nameplate		12 VDC systems 1250 Watts / 24 VDC systems 2500 Watts / 48 VDC systems 5000 Watts / 60 VDC Systems 6250 Watts	12 VDC systems 900 Watts / 24 VDC systems 1800 Watts / 48 VDC systems 3600 Watts / 60 VDC Systems 4500 Watts
NEC Recommended Solar Array STC Nameplate		12 VDC systems 1000 Watts / 24 VDC systems 2000 Watts / 48 VDC systems 4000 Watts / 60 VDC Systems 5000 Watts	12 VDC systems 750 Watts / 24 VDC systems 1500 Watts / 48 VDC systems 3000 Watts / 60 VDC Systems 3750 Watts
PV Open Circuit Voltage (VOC)		150 VDC absolute maximum coldest conditions / 145 VDC start-up and operating maximum	
Standby Power Consumption		Less than 1 Watt typical	Less than 1 Watt typical
Power Conversion Efficiency		97.5% @ 80 Amps in a 48 VDC System - Typical	98.1% @ 60 Amps in a 48 VDC System - Typical
Charging Regulation		Five Stages: Bulk, Absorption, Float, Silent and Equalization	
Voltage Regulation Set points		13 to 80 VDC user adjustable with password protection	
Equalization Charging		Programmable voltage setpoint and duration - automatic termination when completed	
Battery Temperature Compensation		Automatic with optional RTS installed / 5.0 mV per °C per 2V battery cell	
Voltage Step-Down Capability		Down convert from any acceptable array voltage (150 VDC max.) to any battery voltage	
Programmable Auxilary Control Output		12 VDC output signal which can be programmed for different control applications (maximum of 0.2 Amps DC)	
Status Display		3.1" (8 cm) backlit LCD screen - 4 lines with 80 alphanumeric characters total	
Remote Display and Controller		Optional MATE3, MATE or MATE2 with RS232 Serial Communications Port	
Network Cabling		Proprietary network system using RJ-45 Modular Connectors with CAT 5 Cable (8 wires)	
Data Logging		Last 128 days of operation: Maximum Battery Voltage, Minimum Battery Voltage, Time in Float, Time in Absorb, Peak Amps, Peak Watts, Daily High Solar Array Voltage, Peak Solar Array Voltage, Total Accumulated Amp Hours, Total Accumulated DC Watt Hours, Total Accumulated AC Watt Hours	
Positive Ground Applications		Requires double-pole breakers for switching both positive and negative conductors on both solar array and battery connections	
Operating Temperature Range		-40 to 60°C (power automatically derated above 40°C)	
Environmental Rating		Indoor Type 1	Indoor Type 1
Conduit Knockouts		One 1" (35 mm) on the back; one 1" (35 mm) on the left side; two 1" (35 mm) on the bottom	
Warranty		Standard 5 year / Available 10 Year	Standard 5 year / Available 10 Year
Weight	**Unit**	12.20 lbs (5.56 kg)	11.65 lbs (5.3 kg)
	Shipping	15.50 lbs (7.03 kg)	14.90 lbs (6.7 kg)
Dimensions (H x W x D)	**Unit**	16.25 x 5.75 x 4.5" (41.3 x 14 x 10 cm)	13.75 x 5.75 x 4.5" (40 x 14 x 10 cm)
	Shipping	21 x 10.5 x 10.5" (53 x 27 x 27 cm)	18 x 11 x 8" (46 x 30 x 20 cm)
Options		Remote Temperature Sensor (RTS), HUB4, HUB10, MATE, MATE2, MATE3	Remote Temperature Sensor (RTS), HUB4, HUB10, MATE, MATE2, MATE3
Menu Languages		English & Spanish	English & Spanish
Certifications		ETL Listed to UL1741, CSA C22.2 No. 107.1	ETL Listed to UL1741, CSA C22.2 No. 107.1

Available From:

OutBack POWER
member of The Alpha Group™

Corporate Office:
5917 195th St. NE
Arlington, WA 98223 USA
Phone: +1 360 435 6030
Fax: +1 360 435 6019

European Office:
Hansastrasse 8
D-91126
Schwabach, Germany
Phone: +49 9122 79889 0
Fax: +49 9122 79889 21

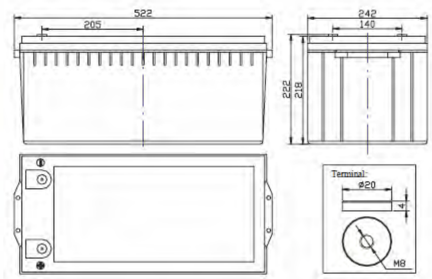
Asia Office:
Suite 1903, Tower 1, China Hong Kong City
33 Canton Road, Kowloon
Hong Kong
Phone: +852 2736 8663
Fax: +852 2199 7988

Latin American Office:
15105 Cedar Bluff PL
Wellington, FL 33414 USA
Phone: +1 561 792 9651
Fax: +1 561 792 7157

Rolls

CAUTION
ONE MEAN BATTERY

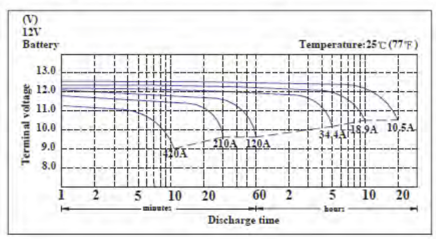
S12-230AG



Specifications

Nominal Voltage		12V
Rated Capacity (20 hour rate)		210AH
Dimension	Total Height (with terminals)	222mm(8.74inches)
	Height	218mm(8.58inches)
	Length	522mm(20.55inches)
	Width	242mm(9.53 inches)
Weight		Approx.66.5kg (146.3Ibs)

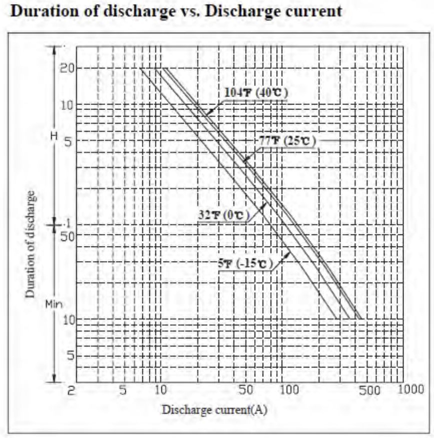
Discharge characteristics 77℉(25℃)



Characteristics

Capacity 77℉(25℃)	20 hour rate (10.5A to 10.5Volts)	210AH
	10 hour rate (18.9A to 10.5Volts)	189AH
	5 hour rate (34.4A to 10.2Volts)	172AH
Internal Resistance	Full charged 77℉(25℃)	2mΩ
Capacity affected by Temperature (20 hour rate)	104℉(40℃)	102%
	77℉(25℃)	100%
	32℉(0℃)	85%
	5℉(-15℃)	65%
Self-Discharge 77℉(25℃)	Capacity after 3 month storage	91%
	Capacity after 6 month storage	82%
	Capacity after 12 month storage	64%
Standard Terminal	M8	
Max. Discharge Current 77℉(25℃)	2100A (5s)	
Reserve Capacity (Minutes to 10.5V at 80℉(27℃)	@ 25Amps	415Min
	@ 75Amps	110Min
Charging (Constant Voltage) Cycle	Initial Charging Current 42A Or Small 14.5V~14.9V/77℉(25℃)	
Charging (Constant Voltage) Float	13.6V~13.8V/77℉(25℃)	

Duration of discharge vs. Discharge current

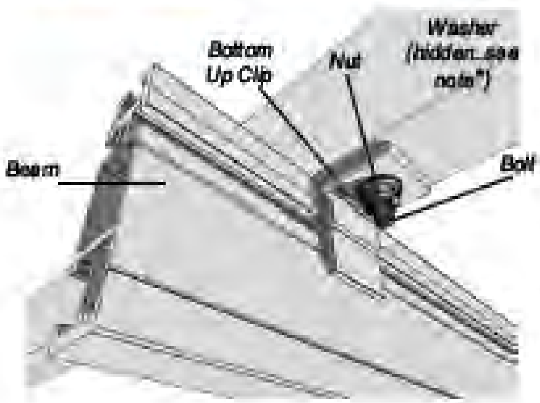


Constant Current Discharge Rating Amperes @77 ℉(25℃)

Cut off voltage V/cell	30M	45M	1H	2H	3H	5H	8H	10H	12H	20H	24H
1.75V	196	144	119.4	63.2	47.5	33.3	22.8	18.90	16.10	10.50	8.79

SolarMount Module Connection Hardware

SolarMount Bottom Up Module Clip
Part No. 302000C



- **Bottom Up Clip material:** One of the following extruded aluminum alloys: 6005-T5, 6105-T5, 6061-T6
- **Ultimate tensile:** 38ksi, **Yield:** 35 ksi
- **Finish:** Clear Anodized
- **Bottom Up Clip weight:** ~0.031 lbs (14g)
- Allowable and design loads are valid when components are assembled with SolarMount series beams according to authorized UNIRAC documents
- Assemble with one ¼"-20 ASTM F593 bolt, one ¼"-20 ASTM F594 serrated flange nut, and one ¼" flat washer
- Use anti-seize and tighten to 10 ft-lbs of torque
- Resistance factors and safety factors are determined according to part 1 section 9 of the 2005 Aluminum Design Manual and third-party test results from an IAS accredited laboratory
- Module edge must be fully supported by the beam

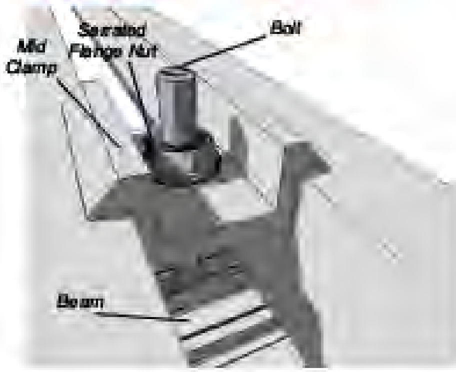
* **NOTE ON WASHER:** Install washer on bolt head side of assembly. DO NOT install washer under serrated flange nut

Applied Load Direction	Average Ultimate lbs (N)	Allowable Load lbs (N)	Safety Factor, FS	Design Load lbs (N)	Resistance Factor, Φ
Tension, Y+	1566 (6967)	686 (3052)	2.28	1038 (4615)	0.662
Transverse, X±	1128 (5018)	329 (1463)	3.43	497 (2213)	0.441
Sliding, Z±	66 (292)	27 (119)	2.44	41 (181)	0.619

SOLARMOUNT Technical Datasheets

SolarMount Mid Clamp

Part No. 302101C, 302101D, 302103C, 302104D, 302105D, 302106D



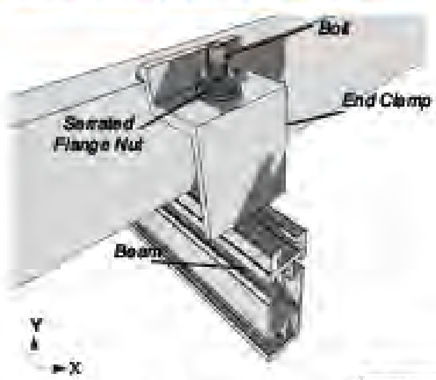
- Mid clamp material: One of the following extruded aluminum alloys: 6005-T5, 6105-T5, 6061-T6
- Ultimate tensile: 38ksi, Yield: 35 ksi
- Finish: Clear or Dark Anodized
- Mid clamp weight: 0.050 lbs (23g)
- Allowable and design loads are valid when components are assembled according to authorized UNIRAC documents
- Values represent the allowable and design load capacity of a single mid clamp assembly when used with a SolarMount series beam to retain a module in the direction indicated
- Assemble mid clamp with one Unirac ¼"-20 T-bolt and one ¼"-20 ASTM F594 serrated flange nut
- Use anti-seize and tighten to 10 ft-lbs of torque
- Resistance factors and safety factors are determined according to part 1 section 9 of the 2005 Aluminum Design Manual and third-party test results from an IAS accredited laboratory

Dimensions specified in inches unless noted

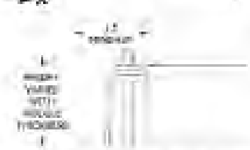
Applied Load Direction	Average Ultimate lbs (N)	Allowable Load lbs (N)	Safety Factor, FS	Design Load lbs (N)	Resistance Factor, Φ
Tension, Y+	2020 (8987)	891 (3963)	2.27	1348 (5994)	0.667
Transverse, Z±	520 (2313)	229 (1017)	2.27	346 (1539)	0.665
Sliding, X±	1194 (5312)	490 (2179)	2.44	741 (3295)	0.620

SolarMount End Clamp

Part No. 302001C, [illegible], 302007D, [illegible], 302010C-302011C, 302012C



- End clamp material: One of the following extruded aluminum alloys: 6005-T5, 6105-T5, 6061-T6
- Ultimate tensile: 38ksi, Yield: 35 ksi
- Finish: Clear or Dark Anodized
- End clamp weight: varies based on height: ~0.058 lbs (26g)
- Allowable and design loads are valid when components are assembled according to authorized UNIRAC documents
- Values represent the allowable and design load capacity of a single end clamp assembly when used with a SolarMount series beam to retain a module in the direction indicated
- Assemble with one Unirac ¼"-20 T-bolt and one ¼"-20 ASTM F594 serrated flange nut
- Use anti-seize and tighten to 10 ft-lbs of torque
- Resistance factors and safety factors are determined according to part 1 section 9 of the 2005 Aluminum Design Manual and third-party test results from an IAS accredited laboratory
- Modules must be installed at least 1.5 in from either end of a beam



Dimensions specified in inches unless noted

Applied Load Direction	Average Ultimate lbs (N)	Allowable Load lbs (N)	Safety Factor, FS	Design Loads lbs (N)	Resistance Factor, Φ
Tension, Y+	1321 (5876)	529 (2352)	2.50	800 (3557)	0.605
Transverse, Z±	63 (279)	14 (61)	4.58	21 (92)	0.330
Sliding, X±	142 (630)	52 (231)	2.72	79 (349)	0.555