Dr. Wood,

Please review the attached Final Report for the Wet Mobile Watts Ocean Energy System.

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Ocean Energy System

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Executive Summary

To minimize the time and expense to effectively harness the energy from coastal current sources, the following system has been devised. A turbine will be mounted on a floating platform, which will be moored in the current of a coastal inlet. Water flow will transform mechanical energy from the spinning turbine to electrical energy via a generator. This energy will be stored in batteries housed aboard the platform, from which the energy may then be exported to the source that demands it. The entire apparatus is free to rotate about its mooring such that current flow around the platform and through the turbine will automatically orient the system in a manner that electricity is produced regardless of flow in or out of the inlet. The direct application of this system will be to provide emergency power to coastal regions affected by natural disasters. In the event of a hurricane, flood, earthquake, etc., which causes normal power sources to be disabled, these units can be quickly deployed in coastal inlets to temporarily supply power, while the damaged infrastructure is repaired or rebuilt. As the technology is further developed, similar systems may become available for permanent production of electricity for a small region. This system requires the design and construction of four major elements (platform, turbine, turbine support structure, and electrical system) which must ultimately be integrated together to accomplish the goals of this project.
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1. INTRODUCTION

1.1. Motivations

As we look to the future, it is apparent that utilizing renewable resources will be necessary to meet the global energy demands. It is widely accepted that our reliance on fossil fuels for the majority of our energy needs is a major concern, not only because of the dwindling supplies, but also its harmful effects on the environment. It is imperative that new methods for tapping other resources are discovered, or existing methods are refined, such that renewable energy can become a reliable and competitive means of providing society with power.

Producing energy to meet the demands of society can be met in essentially two ways. The first, and more common, uses relatively few locations to generate energy on a very large scale, which is then distributed throughout a region. An example of this would be nuclear power. The second method works by generating energy on a small scale, using many locations, and retaining that energy locally. In terms of renewable resources this method seems to be practical, but thus far, not widely implemented. After all, it may be a long time before every home comes standard with its own nuclear reactor, however putting a wind generator or solar panels on every home doesn’t seem too far fetched. Conversely, it is equally impractical to harness the wind using a single turbine the size of the empire state building which would supply the power for a large region. In order for renewable energy to catch on, practicality and effectiveness are very important considerations that must be addressed.

In the state of Florida (and throughout the world), coastlines commonly have inlets which connect the ocean with inland waterways. These inlets provide a strong potential for a good source of renewable energy. Driven by currents from the tides, water flows either in or out of these inlets nearly 24 hours a day. So far, it is uncommon for these inlets to be utilized as a
source of power. It is the goal of this design team to develop a practical and effective system to harness the energy of flowing water from these inlets.

To tackle the issue of practicality, the traditional methods for harnessing hydropower are to be disregarded. Conventionally, hydroelectric power plants are made by damming up a river to create a large reservoir. Potential energy from the elevated water is converted to kinetic energy and electrical energy as it flows down through turbines driving electrical generators. While one cannot argue this is an effective method of renewable energy production, it is simply not practical for harnessing the energy of coastal inlets. Such a project requires a major civil engineering undertaking, feasibility studies, planning, maintenance, etc. All of which takes time and massive expenses to accomplish.

To minimize the time and expense to effectively harness the energy from coastal current sources, the following system has been devised (fig. 1). A turbine will be mounted on a floating platform, which will be moored in the current of a coastal inlet. Water flow will transform mechanical energy from the spinning turbine to electrical energy via a generator. This energy will be stored in batteries housed aboard the platform, from which the energy may then be exported to the source that demands it. The entire apparatus is free to rotate about its mooring such that current flow around the platform and through the turbine will automatically orient the system in a manner that electricity is produced regardless of flow in or out of the inlet. The direct application of this system will be to provide emergency power to coastal regions affected by natural disasters. In the event of a hurricane, flood, earthquake, etc., which causes normal power sources to be disabled, these units can be quickly deployed in coastal inlets to temporarily supply power, while the damaged infrastructure is repaired or rebuilt. As the technology is further developed, similar systems may become available for permanent production of electricity for a
small region. This system requires the design and construction of four major elements (platform, turbine, turbine support structure, and electrical system) (fig. 2) which must ultimately be integrated together to accomplish the goals of this project.

1.2. Background/History

Humans of been harnessing the power of flowing water for thousands of years. Early Greeks and Romans used a waterwheel in the current of flowing streams to grind corn around 100 BC. Since then designs have been changed and improved upon. Eventually, flowing water was used to generate electricity. The first hydroelectric plant in the world was constructed in Wisconsin in 1882 providing 12.5 kW of power.¹ Currently, all types of hydroelectric power make up roughly 19% of the world’s energy production.² The first recorded instance of tidal power dates back to around 900 AD in Europe. Most common tidal power plants involve damming off a coastal basin and driving turbines by water flow through the structure. The first tidal plant was built in St. Malo, France in the 1960’s.³ As mentioned earlier, it is the goal of this team to develop a non-permanent, environmentally friendly tidal generator used to supply emergency power to coastal regions immediately following a natural disaster. Our system will fall under a relatively new and developing category of hydropower called Micro-Hydro. There are a wide variety of prototypes
and patented systems available now, which also focus on smaller scale power generation. What separates this system from the rest is that it is designed to be completely modular, allowing an operator with minimal training, to easily assemble and deploy this system in order to facilitate the recovery process following a natural disaster.

1.3. *Project Design Goals*

1) Demonstrate that a cost effective system can be used to transform energy from currents in coastal inlets into electricity.

2) Produce enough electricity to maintain charge in onboard batteries subject to an electrical demand.

3) Evaluate the practicality of this system as applied to providing a means for supplying emergency power to a coastal region affected by a natural disaster.

4) Demonstrate the design process from start to finish of naval architecture, turbine design, electrical engineering, and materials engineering.

5) Minimize environmental and aesthetic impacts.

6) Design a system that is user friendly to those operating it. It must be easy to deploy and set up by someone of minimal experience. If service or repairs are required, the design will allow for any maintenance to be done on site with only basic tools.

7) Demonstrate that a system which integrates ocean energy and naval architecture can be reproduced on a larger scale and/or used in an array of multiple platforms to produce enough energy to supply a local region with electricity by using renewable resources already present in that region.
2. RESEARCH AND INITIAL DESIGN

2.1 Developing World applications

In different parts of the world that are less developed our project could be a permanent source of free energy. The benefit of our design is in its complexity. One of our major objectives for this project was being able to make a system that was simple enough to construct with as little experience as possible. We have successfully been able to make a system that is completely modular and is easily manufactured. Our design was primarily made to be a temporary source of energy for disaster areas that need their infrastructures repaired. It turns out that our system could be a great source of energy in developing countries. The reason for this is its ability to be moored in any location. Such areas of the world where our system could be deployed is the Amazon river, the Nile river, Euphrates river, Tigris river, etc. We were able to make our system out of many available resources because we have the luxury as a well developed country.

Our platform is made from fiberglass (fig.3-5). A detailed list of the fiber glassing process is seen in Appendix C page 34 in our report. In other areas of the world fiberglass may not be readily available so other material such as bamboo, PVC, and wood can be used to construct a platform. The platform is simply just a means of holding the turbine so it doesn’t need to be anything special. Our turbine was a simple paddle wheel design which we made from two aluminum plates and 3 fifty five gallon heavy duty plastic drums cut into thirds to make the blades (fig. 6). The aluminum plates were used as end caps to hold the blades in place. We wanted to use the 55 gallon drums as our blades because we wanted to prove that using everyday materials can make an efficient turbine. The more ideal blade design is the flat blade for slower
water speeds as determined on the day of testing. In most cases the current flow in a river will not exceed 5 miles per hour which would make flat blades the configuration of choice. In less developed parts of the world flat blades would be much easier to manufacture or produce using any type of available resource.

The electrical generator we used for our project was a brushed DC electric motor we obtained from Astro Too (fig. 7). The cost of this motor was five U.S dollars from a recycled aircraft wing. Any electric motor can be converted to a generator by simply adding a diode that restricts current flow in one direction and allows it to pass in the opposite direction. In a developing area of the world electric generators can still be found in old vehicles. Vehicle alternators make great generators because their sole purpose is to charge the vehicle’s battery. Our project proved that a simple electric motor could produce enough energy to charge 12 volt batteries. In a more developed part of the world our motor would not be efficient enough to
maintain the demand of electric power although a simple change of the generator to a more sophisticated modern generator would be good enough to keep up with the modern energy demands.

![Figure 7 Belt & motor mount system.](image)

We met our goal in this project by building an electrical turbine generator under our budget and with recycled materials. The only part of this project that was expensive was the fiberglass for the platform construction. The reason we spent time and money on our platform construction was for durability reasons. Like we mentioned earlier our preliminary design was a temporary source of energy in a disaster area. With dangerous water flow and debris drifting past our project during storm surge we wanted to make a platform that was durable. If our design would be used in developing areas of the world the materials used to construct the entire project would be determined by the material present at the location of the demand of the system.
2.2 Summary of System Components

Platform

The platform is essentially the foundation of the system to which all of the other components will be attached (fig.8). This platform must be designed in a manner to make the generation of power as efficient as possible, while maintaining structural integrity during normal operating circumstances in addition to handling the punishment of extreme ocean conditions. The turbine will operate best if it is kept stable and oriented directly facing the current. To address these issues, the overall platform design will model that of a twin hulled catamaran vessel. This design is extremely stable due to the fact that large restoring moments are created by moving the buoyant forces outward from the center of gravity on either side. The mooring point will be attached to the forward portion of the platform allowing for the water flowing around it to maintain the proper orientation (much like a weather vane but in the water), despite prevailing wind conditions. The shape of the vessel is to be designed in a manner which is hydro-dynamically efficient to facilitate the transport and deployment of the apparatus, and minimize the stresses imparted by unnecessary drag imparted by the currents. The platform is to be constructed with fiberglass surfaces, and an internal skeleton which will provide the structural support which the hardware is mounted. (fig. 9)
Turbine

A wide variety of turbine options are available to capture the energy from the currents. For this system a cylindrical drum style turbine will be used to harness the energy. A horizontal axle oriented perpendicular to the direction of the current flow, will provide a base for 5 to 6 blades that will radiate from the central axis of rotation. In order to maintain efficiency of this design, the number of moving parts underwater will be kept to a minimum. The axle, and support bearings are positioned just above the waterline, and the force of the flowing water will act on the blades below this as seen in (fig.8&11 pg.42&44). In addition keeping the axis of rotation above the waterline, will greatly reduce entanglements by floating debris. Also, bio-fouling and corrosion are important considerations affecting the efficiency of the system, so the blades are constructed from materials that resist deterioration in the marine environment. Also the turbine blades will be designed in a way such that they are easily interchangeable. In the case that a blade needs to be repaired or cleaned, it can be replaced quickly with a new one on site, without removing the entire apparatus from the water.

Figure 10  Draft in relation to wheel
Turbine Support Structure

The turbine will be located between the pontoons of the platform near the aft end of the structure. The idea is that the pitching of the platform in rough conditions will occur about the same axis which the turbine is spinning, and thus have minimal effect on the efficiency of the turbine. The axle that holds the blades of the turbine is to be held in place by stainless steel ball bearings. An aluminum support structure will carry the weight of the turbine. This structure is to be designed in a manner which can be easily disassembled if the entire turbine needs to be removed for maintenance (Figure 11). In addition this structure must also support the generator, and include a tensioning system to keep the driving belt at the proper tension. (fig.12)

![Figure 11 Support beams](image1)

![Figure 12 Silicone drive belt and motor.](image2)

Electrical System

Electricity will be produced by spinning a generator wheel driven by a belt running around the turbine. An electrical system must be devised to maintain charge on batteries housed inside the platform. The voltage and current coming from the generator is to be regulated using onboard computer and circuitry, to provide safe and efficient power generation. In addition, the batteries will power emergency bilge pumps used to remove excess water that may accumulate in the
platform, and lights which will make the platform visible at night. Lastly, in order for the power to be exported from the platform to the shore, the appropriate transformers and cables are to be integrated into the electrical system to accomplish the task with a minimal loss of power. All of these components must be designed with corrosion resistance in mind, due to the residing environment the platform is subject to.

2.3 Design Requirements and Considerations

The normal, day to day conditions of coastal inlets are relatively simple to design for. However since this system is intended for use immediately after a natural disaster, extra precautions must be taken to ensure the unit is rugged enough to perform well in less than optimum conditions. In the case of a hurricane, the platform may be deployed and set up as soon as hurricane force winds subside. However, deployment in tropical storm force winds (39-73 mph) and rain may be necessary especially if the storm is slow moving. The platform must be designed to hold up in the wind and waves present during these types of conditions. Another consideration is that the water flowing through the inlets in the aftermath of a natural disaster may be filled with floating debris. For this reason it is absolutely imperative that the turbine is designed to avoid fouling and entanglements by this debris. To do this an optimum turbine style must be selected (discussed in detail in section 2.3), and the blades must be sturdy enough to hold their shape, yet forgiving enough so that small to moderate impacts will not affect their performance. Lastly, another major design consideration is that this system must be simple to operate, deploy, and maintain. Someone with minimal training needs to be able to quickly set up this system in potentially adverse weather conditions. In addition, if the unit requires a repair, the operator must be able to do so on site, in a short amount of time, with only basic tools. To accomplish this, the system is designed to be as modular as possible. This starts with the turbine
blades, as these parts are most susceptible to damage by floating debris. The blades can be easily interchanged with new ones via four simple bolts. Another advantage of this is that some locations may have different current conditions than others. A set of blades may be designed and optimized for a particular location that may not work as well in another location. By making the process to change blades quick and simple, maximum efficiency can be obtained from any coastal location. The second part of the system that must be modular is the circuitry. The marine environment is a hostile place for sensitive electronics. Although every precaution will be taken to keep the electronics dry and secure, a single organized circuit board can easily be swapped out with a new one if it is damages. A simple connection of fittings (like inserting a plug into a light socket) is all it will take to get the system up and running again. By creating a user friendly system designed for adverse conditions, the unit will perform its best when nature is at its worst.

2.4 Investigation of Turbine Options

There are many options available for turbine designs applicable for ocean energy. The details of the pros and cons of each of the options are discussed below. It is important to select a design that complies with requirements and considerations discussed in section 2.2.

A turbine is defined as “a rotary engine actuated by the reaction or impulse or both of a current of fluid (as water, steam, or air) subject to pressure and usually made with a series of curved vanes on a central rotating spindle”. Perhaps the most common type of turbine is the standard “fan” or “propeller” style turbine (fig.13). A popular design used for wind energy, this concept is being taken underwater. However it is the conviction of this team that this design poses a major problem for use in near shore locations. That is bio-fouling and entanglement with debris. As seen in the picture of the boat propeller below (fig.14), this would bring energy
production to a halt, especially in debris filled waters of areas recently affected by natural disasters. It is a major goal of this project, to create a system that is impervious to this situation, therefore an alternate design will be used.

A possible alternative candidate is the ring turbine (fig.15-16), also known as the open center turbine. This design is essentially an inverted propeller. Instead of using a central shaft with the blades radiating outward, this design incorporates a ring with the blades pointing inward, and an open center. The advantage of this design is that debris can pass right through without entanglement. Also the design greatly inhibits cavitation. The main drawback with this idea is that it becomes a challenge to support the turbine in a manner that allows for effortless rotation. This essentially involves creating a giant “bearing”, and such a large part (at least 4 ft in diameter required for the scale of this project) will require extremely tight tolerances during construction. Even if these tolerances were met, the design requires many moving parts completely submerged underwater in a corrosive environment. What this means is that even if the turbine itself keeps free of entanglement, the support structure may not be as resistant, therefore defeating the purpose of opting for the ring turbine design. Lastly for testing and maintenance purposes, it is a desirable feature of the final turbine to have interchangeable blades. This would allow for optimization of blade design, and the quick repair/replacement of a blade if it is damaged or it
needs to be cleaned. This is a major challenge for a ring turbine design considering the tight tolerances required for an efficient system.

A third design for this system is a modified Pelton wheel turbine (fig 17-18). These turbines extract energy from the impulse of a strong jet of water aimed at the blades radiating outward from a central axle. For the locations this system is to be deployed, the current velocity is lower than many instances where this design is used. However, through proper optimization, a turbine can be designed to be efficient in the specific conditions present in the coastal inlets. Like the ring turbine, this design is also resistant to becoming entangled by debris, since the central axle can be placed just above the waterline. This also removes the moving parts required to support the structure from beneath the water, since the only a small portion of the turbine need be submerged. The structure supported by bearings placed above the water’s surface, carrying the weight of the axle and the turbine. This is a much simpler and more reliable system compared against that of the support structure required for the ring turbine. Lastly, the general design facilitates the idea of incorporating the interchangeable turbine blades, since only the central axle
requires tight construction tolerances, and not the entire wheel. For these reasons, this design is a good candidate suited for the system being designed and built by this team.

Figure 17 Pelton Wheel\textsuperscript{6} Figure 18 Pelton wheel in a system\textsuperscript{6}

A fourth option, would be to take the water wheel design (fig.19), and modify it into a belt system. Instead of having the blades rotate about a single axis, they would operate similar to a tread mill, tank tread, or simple conveyor belt. (fig. 20) This design would have the same weedless capabilities as the water wheel, but would provide more torque on the drive system since more blades are in the water at any given time. Also, a simple hinge on the blades would allow them to fold down flush to the belt along the topside of the path when the blades are out of the water. This could drastically cut down on wind resistance of the platform. When the cycle brought the blade back into the water, the current would open the hinge and return the blade to the optimum position for harnessing energy. A negative aspect of this option is that there are considerably more moving parts than the water wheel (hinges, bearings, axles), many of which would hinder the efficiency of the system if they became corroded, fouled, or jammed. This would negate the benefit of the added torque, and a more complicated design may require more maintenance, and increase the possibility of failure.
2.5 Existing Similar Designs

After this team decided on the concept for this project, research was done to investigate similar designs already in existence. While there are countless examples of small scale hydroelectric generators (“micro hydro”) available, there were two companies in particular that closely model this project.

The first model comes from a company called Hydro-Turbines. Like our project, it is a paddlewheel device that is situated between two pontoons to be anchored in a stream for power generation in remote locations. (Fig 21 - 22) At a current speed of 4 mph (similar to the conditions that our project is designed for) this device will produce 100 W of electricity. \footnote{1}
A Second Company called Hydro-Gen based out of France has developed a system on a similar scale to the size of our project. It too is moored in flowing coastal waters and generates electricity via a paddle wheel is transported to shore (Fig 23) A further application of this system is to use the electricity created to produce hydrogen gas. Although this device is currently in the prototype stage, it is designed to produce 10 kW of electricity.  

Figure 21 Concept Hydro-turbine design¹

Figure 22 Actual hydro-turbine design¹

Figure 23 Hydro-Gen system²
3. FINALIZED DESIGN

3.1 Platform Design Details

The platform is made up of two fiberglass hulls each 7’ 8” long by 21” wide by 16” deep (fig. 24). The hulls are connected together by two 6.5’ sections of 3” square aluminum beams located at the front and back of the platform (fig. 25). The inner structure of the platform consists of marine grade plywood bulkheads that are fiberglassed over. These bulkheads support the platform and serve as an anchor point for the support beams and additional hardware to be mounted on. A top deck constructed out of fiberglassed plywood will keep the water out of the interior of the platform, and serve as additional structure. Watertight hatches are mounted on the top deck to allow access to the battery array and the electrical system. The turbine support structure mounts the turbine bearings at the aft end of the platform, thus allowing for the maximum wheel diameter. This design serves as a very stable and rugged platform.

Figure 24 Final Design ready for deployment  
Figure 25 Final assembly sans platform to show beams
In order to design the platform based on a necessary weight capacity, a displacement curve was constructed for each hull. This curve is based on the Archimedes Principle which states that the buoyant force of an object is equal to the weight of the volume of fluid displaced by the object. Or more simply put, if an object weighs more than the weight of the water it displaces then it will sink, and if the object weighs less than the water it displaces then it will float. Since 1 cubic inch of lead weighs more than 1 cubic inch of water, the lead sinks. Since 1 cubic inch of cork weighs less than 1 cubic inch of water, the cork floats. That is why container ships over 1000 feet long weighing thousands of tons still float. They displace so much water that the buoyant force pushing up is greater than the force of gravity pulling down. In naval architecture, the displacement curve shows how deep the ship will sit in the water in relation to the amount of weight loaded on to it. This same process was used for this project to develop the displacement curve. Using the CAD drawing of the Hull in AutoDesk Inventor, the hull was divided into 1” slices starting at the bottom and working up to the top deck. The software provides the exact volume of each slice and by multiplying that volume by the density of seawater (64.1 lbs / ft$^3$), the weight of the water displaced by each slice is the result. These 1 inch slices are equal to the draft of the hull when that amount of weight is added to the platform. This data provided in the figure below becomes the displacement curve when plotted on a graph of Displacement vs. Draft. Since the platform consists of two identical hulls, the data for the single hull is multiplied by two to get the information for the entire platform. From the displacement curve, the various waterlines for the hull can be determined as well as safe working loads for the platform. From the graph it is determined that a maximum safe working load for this platform is right around 1000 lbs total weight giving the platform a draft of roughly 8”. This proves that this design is suited to handle the weight of the platform, inner structure, the turbine assembly, and up to eight
12 V marine batteries. In addition the information provided by the displacement curve, is very beneficial to an engineer desiring to reconstruct the exact dimensions and shape of the platform.

### 3.2 Final Turbine Design Details

Of all the turbine options discussed in section 2.3, the standard water wheel design was selected to be most suitable for this project. The main reason for this decision is simplicity. By minimizing the moving parts, this design should be the most reliable in the marine environment. It satisfies the requirement to be weedless and it allows for easily interchangeable blades. The center shaft will sit in bearings aboard the platform, and the blades will bolt into brackets on the shaft. There are curved blades constructed of plastic formed to an optimized shaped designed to capture the most energy. This construction is rigid enough to hold a shape, yet forgiving enough to withstand some punishment. The blades are attached to 46 inch diameter aluminum sheet end caps (4 bolts per blade). The design allows for a configuration of 6 or 9 blades to be used. A belt in the form of silicone tubing runs around the wheel and to the electric generator. The large gear ratio (1:8) provides ample rpm’s at the generator for energy production (fig.26).

![Figure 26 Gear ratio shown](image)
3.3 Electrical System Design Details

The electrical system consists of five major parts. The first is the generator. The generator is mounted on an adjustable track to control belt tension and converts mechanical energy from the spinning turbine into electrical energy. In addition a solar panel may be used to serve as a backup generator during slack tide periods. The next part of the electrical system are the batteries. An array of 12 V marine batteries is housed in each pontoon of the platform. All electrical loads will be drawn from the batteries and not the generator itself. The generators will maintain a charge on these batteries. This is done in order to provide a steadier flow of electricity, rather than a potentially erratic flow that comes out of a generator. The third part of the system is the relay apparatus. An electrical circuit consisting of two LM 317 chips delivers a safe level of current and voltage to the batteries to be charged. If there is a full charge on the batteries, the electricity generated will be burned off at a heat sink using a zener diode. This system prevents overcharging. The final part of the system connects the platform with the shoreline. A 1500 Watt DC to AC converter transfers the direct current produced by the batteries to alternating current which can be used on shore. A 100 yard wire (housed on a spool aboard the platform) connects the platform to the shore, where the electrical demands may be met. The last part of this system is the electronics involved to power bilge pumps, and safety lights. This will be tied into the battery array just as on any standard boat.

3.4 Design Evolution

Through the course of the design process, the details of the design have changed from initial concepts to a final product. The original platform was intended to be constructed for use with a large ring turbine. As discussed earlier, this option soon proved not to be feasible for this project.
considering budget and design flaws. The ring turbine is a very large part that must be machined to very tight tolerances. Commercial ring turbines do not use a simple belt system to drive a generator, but ring itself is the actual generator. By incorporation coiled wire and magnets into the support structure electricity is produced when it turns. The design of such a system alone would be a major engineering undertaking without consideration for the rest of the product. Lastly, the support structure for the turbine would not necessarily be weed less, which would defeat the purpose of going through the extra effort to develop the ring turbine in the first place. The obvious alternative to the ring turbine was the water wheel idea. It is a tried and true technology, and its simplicity will reduce the possibility of failure. A belt system was considered, on the basis that it could provide more torque than the wheel, but the complexity and amount of moving parts required for that design, made it impractical. An initial design positioned the water wheel in the center of the platform. In the end, it was decided that the wheel would be moved from the middle to the aft end of the platform. This would allow for a significantly larger diameter turbine. The only sacrifice is that more weight is added to the aft end and therefore the battery array must be shifted forward to properly balance the platform. Another major design change was the dimensions of each of the pontoons. Given the block of foam, the original design called for each pontoon to be 7’ 8” long by 14” wide by 20” tall. The tool path of the CNC machine used to cut out the plug was re worked such that the new dimensions of each pontoon would be 7’ 8” long by 21” wide by 16” tall. This change significantly added to the displacement of the platform. By sacrificing 4” in height, 7” in width were gained. This new design with greater displacement and thus more interior room, allows space for several more batteries which would increase the overall electrical output of the system. The last major change involved the support structure of the turbine. Originally the bearings would be permanently mounted on the
platform. The problem with this is that when the platform was sitting on land waiting to be deployed, the turbine would be below the draft of the platform. For this reason the turbine was mounted on movable forks that lifted the turbine out of the way when the platform was bottomed out. Once the platform was pushed in to the water the turbine would naturally lower down to the proper operating position. Through these changes and adjustments, the final product is engineered for optimum performance (fig.27-29)
4. MANUFACTURING

4.1, Safety, Displacement Hull Process, Where and What Company Help

A good portion of this project is going to be made in variety of locations outside of the campus grounds. Two major places where most of the build will take place is at Structural Composites and at Mr. Shaws business location. It is crucial that while we perform the build at these locations that we take safety very seriously considering liability concerns. These businesses were nice enough to let us use their facilities and their resources in order to complete our project on time so there is no need for carelessness while we are in their working environment. The machining of the hulls was done at Structural Composites where we were informed by Eric on the progress of the hulls over a week period. We weren’t on site while it was being machined for liability reasons but Eric kept a digital camera log of every step taken. When we picked the finished product up we made sure all excess foam particles were removed as best as possible to reduce the amount of foam particles inhaled. We had red warning signs ready if the vessel didn’t fit in the transport vehicle. The next step in safety for this project will be under the supervision of Mr. Shaw. Mr. Shaw specializes in fiberglass work which we will need to complete the next crucial part of the project. While we are working with Mr. Shaw we will be fallowing his safety plan when it comes to handling epoxy, fiberglass resin, fiberglass, and gel-coat. Since this is our first fiberglass mold we ever made we will be extra careful when working with these materials measuring twice cutting once sort of speak. Such safety steps required in this project are; wearing protective breathing apparatus, long shirts, long pants, closed toe shoes, eye protection, and face shield if necessary. Power tools are going to be used as well so being responsible is key when avoiding accidents. Our project is going to have an electrical system that will be located on the water so shock hazards are going to be presented on
the project along with breakers to prevent any short circuits or surges. Other safety plans will be put into effect after deployment. Once the project has been deployed we will have deck lighting and navigation lights for night use so mariners can maneuver accordingly. All moving parts of the vessel will be clearly labeled as pinch hazards along with full concealment of viable components. Choice of colors is another way of providing safety to others. We will be using bright colors on the vessel such as yellow which easily announces to others of its presence and warnings. Safety is an important part of any project not only for the people working on it but everyone that could come in contact with it once it is in the presence of the public.
5. MATERIALS AND SAFETY

5.1-Types of materials and Safety

Our project requires a variety of materials that have the potential to cause harm. There are three areas in the build process that we will come across which could cause injury or harm. These areas are chemical, raw material, and build safety. Chemical hazard is one of the most concerning factors of the build process. While we are constructing the hull of our project we will be using the majority of the chemicals. When the hulls are first machined from a solid piece of foam we will then be doing a lot of cosmetic work with bondo to achieve the appropriate hull shape. Bondo has the potential to cause harm in both the paste form and after sanding (airborne particles). Once the hull shape is achieved we will then coat the plug with epoxy. Epoxy can cause many health issues such as irritation to skin, nose, and eyes. Once the epoxy has hardened we will then apply a mold release which will allow the mold to be removed.

Mold release causes most harm by inhalation in both short term and long term. Fiberglass resin is going to be one of the most hazardous chemicals we come across in the build process. Fiberglass resin can cause injury in more than one area of the body such as eyes, skin, lungs, brain, nervous system, and liver. Once we have our hull completed structurally we will then paint the hull. The paint will take four steps; base paint color, clear coat, gel coat, and antifouling. The base paint and clear coat has the potential to cause skin irritation and eye irritation. Gel coat is flammable as a liquid and a vapor which can also cause skin, eye, and throat irritation. Gel coat is also carcinogenic over long periods of exposure. Antifouling paint will be applied to the structure exposed to water. Antifouling paint has the potential to cause many health hazards because it is extremely toxic. It is a pesticide which usually contains heavy
metals. Antifouling paint can causes skin and eye irritation, as well as serious health issues after long term exposure. We will also be using marine batteries which usually contain lead and acid. Batteries contain corrosive material that can also cause skin, eye, and respiratory problems.

Raw materials is the second area where hazards will be found. The first material we will be in contact is fiberglass. Fiberglass can cause respiratory problems, skin irritation, and eye irritation. Aluminum and wood is going to be used for the frame structure of the project. Aluminum and wood can be dangerous in a variety of forms. In the solid state it can cause injury by impact and sharp edging. In a particle state after cutting can be an eye, skin, and respiratory irritant. The electrical system can be hazardous because we are going to be generating electricity in salt water which can pose a shock hazard.

The third area where hazards can be found is in the build safety. Machining of the hull is going to be dangerous primarily because of the tools needed. We will be machining the hull off campus at Structural Composites where the heavy machinery will be located which all can cause serious injury. There will also pose a hazard in the shipment and deployment of the project. The device could fall or malfunction during testing which could cause serious injury.

5.2-Price/Suppliers/Ordering

The pricing of the materials will vary as the project unfolds. The beginning of the build has been relatively cheap primarily due to the surplus of materials from prior projects as well as donations. Surplus parts has been working really well considering the generator was only 5 dollars and the foam was left from a bulk order from Stephanie Hopper. Astro Too is where the generator was purchased along with a majority of the electrical components. Astro Too is willing to give great student discounts to any student from Florida Institute of Technology. The
most expensive part of the project is going to be the fiberglass mold and hulls that are going to be made. We are in possession of plenty of fiberglass fiber and matte however we are not in possession of fiberglass resin, epoxy, or hardener. We will also need fiberglass gel-coat as a protective layer for the fiberglass to prevent the fiberglass from becoming soft from the salt water. The fiberglass resin is one of the most expensive parts of the project. One gallon of resin can easily run upwards to 90 dollars while the gel-coat will also run in the 70 dollar range for a quart. Epoxy costs up to 75 dollars for a half gallon plus an extra 75 dollars for the hardener. We are hoping that Mr. Shaw will be able to help or contribute some raw material for the fiberglass work. We keep tabs on everything we buy using an excel spreadsheet dating every purchase made as well as the quantity and the price.
6. GENERATOR/ENERGY CONVERTING SYSTEM

6.1, Turbine Size Gear Ratios/Desired RPM Generator Type

This project will be taking mechanical energy and converting it to storable, useable electric energy. In order to achieve this we must use a generator system that transforms the mechanical energy into electric energy. The generator that is being used in this experiment is an old industrial brushed DC motor that will be converted to make electricity rather than converting the energy to mechanical. In order to capture this mechanical energy and turn it into electrical energy we will be constructing a turbine wheel that is approximately 5 feet in diameter. The reason behind picking this size of a turbine is to have a proper ratio from the turbine wheel to the generator wheel to achieve ultimate revolutions per minute. We have calculated that anything over 100 rpm’s will achieve our goal of charging our onboard batteries. The gear ratio we are shooting for is between 10:1 to 16:1 between the turbine and the generator motor. The electrical system will be simple and complicated at the same time. We want to be able to transfer the energy made on the vessel to shore where it can be used by emergency vehicles and residential neighborhoods, so we will have to incorporate converters to meet these needs. The electrical energy produced on the vessel will be in the form of D/C or direct current which in terms needs to be converted to A/C or alternating current for use. A simple D/C to A/C converter allows this to happen easily.

An inverter will be used to translate the 12 volts produced into 120 volts A/C that will be used for other applications. In order to get the generated electricity to shore we will have a tether cable that will run from the turbine to the shore. For testing purposes we will be using simple electrical extension cords but in industry we will most likely be using specialized underwater cables for efficiency and safety.
7. FIELD TESTING

7.1 Test site and type

Testing occurred on July 15 and 16, 2009 in the Indialantic River.

Theory:
As the water flows through hulls the wheel will turn. As it turns a belt will turn the DC generator which will charge batteries. $P = \eta \cdot \rho \cdot g \cdot h \cdot v^3$ is the governing equation that gives our maximum mechanical power within the system. $\eta$ is the efficiency of the turbine, $\rho$ is density, $g$ is the acceleration due to gravity, $h$ is the pressure head defined as $v^2/2g$, and $v$ is the flowrate. This means that the power within the system is dependent on the velocity in two places, both the pressure head and the flow rate. Extracting the mechanical power present, shown is the chart below, is wholly dependent on the electrical generator used.

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<th>mph</th>
<th>m/s</th>
<th>blade area (m^2)</th>
<th>$\dot{v}$ (m^3/s)</th>
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Table 1. Theoretical Mechanical Power for various current speeds

Procedure
The pontoon boat testing will take place over the course of 4 hours.

1. Attach the unit securely to the right side of the pontoon boat a rope at the front and back of the boat.
2. Set the wheel, containing all nine blades in the highest height position, height 2.
3. Confirm that the flowmeter is working properly.
4. Make 3 consecutive runs at 2, 3, and 4 mph.
   Note: do not use the onboard GPS or pontoon boat projected speed. Only use what the flowmeter states for the speed as the standard.
5. The max sustained output will be read and recorded.
6. Repeat the process at height 1 with 9 curved blades.
7. Repeat the entire process with 9 flat blades.
8. Repeat entire process with 6 flat blades.
7.2 Results

**Curved Blade Data**

Figure 30 Comparison of curved blades power outputs to the speed of the water

**Flat Blade Outputs**

Figure 31 Comparison of flat blades power outputs to the speed of the water
8. Discussion

8.1 Data Analysis

Blade outputs, while not in the projected ranges of hundreds of watts, provide a solid comparison for the blade configurations. The system handled a maximum speed of 5 mph, much less than the originally planned for 10 mph. Above this speed the system started rising out of the water and the blades started to shake violently. Even at the lower speeds ever-present turning and slamming into the water caused some failure of the blades over time. This shows the need for a smoother transition for the blades to enter the water. Comparing the six curved blades to the nine showed a greater overall output across the various speeds. This could be due to resistance created by more blades entering the water. The flat blades were very consistent with their maximum output all around but at low speeds flat blades excelled above the curved blades. The one time when the blades were pushed to 5mph on the flat blade configuration; a decision made due to the blades lack of violent vibration at the lower speeds seen in the curved blades; a decrease in power output was seen. This is shown in the 9 blade flat height 2 line on the graph. The flat blades seemed to have a maximum power output of around 4 mph. As the blades exited water, some water was left on the surface and since the blades were trying to move at such a great speed, it did not have time to flow off the blade, weighing the blade down and slowing the system. The curved blade did not have this phenomenon, both because of the material used and the curvature of the blade. Six flat blades worked better at lower speeds than nine which again can be contributed seemingly to the water buildup on the back of the blades. This again suggests that different blade types work better for different current speeds and applications. Again the higher setting of the flat blades produced more power than lower settings which suggests that
less is more, meaning the less blade produces greater output because there is less resistance outgoing side. Furthermore, a less curved blade, something between what was used for this project and a perfectly flat blade would be optimal. Further testing should be completed to see at what point if any this becomes untrue.

8.2 Future Concerns

We have not fully delved into the topic of blade design and construction. The curve on the blade will need to be optimized for maximum torque. Every other part of the system is fairly straightforward, but deployment will become an issue as items become bulky and difficult to move with only 3 people. The more parts we create the harder the system will be to assemble. The team needs to be careful to limit the number of removable parts so that assembly will be quick and easy.
9. Conclusions

This system worked and proved that the concept of an easily deployable current power unit is feasible. Blade optimization, an in depth and complicated problem needs to be addressed before application in the real world. Having smaller blades, or less blade in the water would increase power to a certain degree and also decrease material costs. That being said, flat blades do work moderately well and are easily manufactured. Use of flat blades in developing world would be a cheap and easy alternative to construction of curved blades. Having smaller blades, or less blade in the water would increase power to a certain degree and also decrease material costs. While the cost of this project came out to be $27,120.57, this number would go down significantly once mass production started. Materials costs would go down and the consulting fees would decrease dramatically.
10. Constructive Criticism

The platform has proven to be more complicated in its construction than originally planned. Using a pre-existing platform or some other system would have sped the process along. Building a smaller platform might also prove helpful to reduce the number of people required to deploy the system. If money is of no concern, building this project out of molded plastics or another strong lightweight material might prove to create a more easily used and manufactured system.

The area that can be most improved is the blade systems. As the results showed there is an optimal blade design for the conditions we were in. Finding that blade configuration and types for other scenarios would provide a difficult project that could be easily tested since the support structure and electronics have been designed and constructed. The electrical system has been designed but not tested. A cooling system will need to be implemented if consistent use is planned. Additionally, finding a cheaper electrical system that a developing nation could construct is also necessary. Scaling the project down so that everything fits within the two hulls would improve transport without reducing power output. The wheel could still be geared so that the desired rpm’s are achieved with a much smaller profile. Moving the wheel to the center of the boat as originally designed would reduce balance issues and could still be raised and lowered using the armature mechanism developed.
11. References

Section 2.1


Section 2.3

1"History of Hydropower." Penn State. 20 April 2009 <http://www.personal.psu.edu/ces957/History%20of%20Hydropower.htm>.


Section 2.4

1 "Floating Turbine." Hydro-Turbines. 15 Jul 2009

2 "Main Features." Hydro-Gen. Hydro-Gen. 15 Jul 2009

Section 7.1

1 “Mechanical Power in a stream of water equation” 15 May 2009
<http://www.wikipedia.org/hydropower>
Appendix
## Appendix A: Data

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<th>rpm</th>
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**Total**: $2,276.57

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### Donations

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**Total Donations**: $550.00

**Consultants $5,000.00**

**Total $5,050.00** for all consultant time.

**Hours Worked**: 505.00 hours

**Project Value (w/20 h) $10,200/($20 per hour)**

**Total**: $27,208.57
Appendix C: Fiberglassing process.

1. Create foam plug. This can be done with hotwire cutting or on a CNC machine.
3. Create slurry of silica balloons and resin, approximately 20 ounces resin, 4 ounces hardener. The silica micro-balloons act as a 3-D filler in the Styrofoam so that the fiberglass adheres completely to the surface. The slurry should be the consistency of cake icing.
4. Lay out the mat cloth on a table covered in plastic and cover it in a 5-1 ratio of resin to hardener. We use the mat to create a hard surface onto which we can lay our fiberglass. The process of covering the mat in resin is called wetting out. Wetting out could occur directly on the surface of the mold, but by laying it down, covering it in resin and then laying it on the plug, we can move much more quickly. Once the wet mat is placed on the plug, remove air bubbles and wrinkles by smoothing out the mat. This also helps stick the mat cloth to the foam plug. Any unused resin/hardener mixture should be placed in the freezer until needed so that the hardening process is slowed or even halted. This reduces waste.
5. 2 layers of cloth should be laid to ensure the hull is strong. Areas such as corners should be targeted for overlap sections of mat cloth.
6. A hot coat which is a sealant is placed over the plug once the resin has cured for 3-4 hours.
7. Once the hot coat has dried and cures, 3 layers of wax and 4 layers polyvinyl alcohol (PVA is sprayed over the entire mold where fiberglass will be laid. PVA is the mold release. It does not allow the fiberglass and resin to stick to the mold. Let the PVA dry. (PVA is green)
8. Apply a layer of resin to the mold so that the fiberglass will stick.
   There are two types of glass that will be laid; mat and cloth. The mat has fibers in all directions and is only moderately strong. The cloth has fibers only in two directions, in a perpendicular weave pattern. This provides the strength.
9. The mat is laid in three strips, one for each side being glassed. Resin is then applied using a brush and roller. It is important to get everything wet and then go back and work out the wrinkles. The resin will break down the starch that makes the glass stiff. The bow and stern have small squares of fiberglass laid on and wetted with resin. It is easier to do these in small sections of glass because of the wrinkles that are formed over the curves. The resin is mixed with hardener and a small amount of catalyst so that the resin will not start to set and will be workable for a fair amount of time. The more catalyst added the faster the reaction. The resin is a brown color as it is applied.
10. A layer of cloth is laid. This is done with only two sections, and are overlapped on the bottom so that there is added structure.

11. 2 more layers are added. One of mat, one of cloth. The overlap gives some areas such as curves and the bottom 6 layers of cloth. This must cure for 8-12 hours.

12. The fiberglass is then sanded and a layer of resin is applied to fill some of the pores left in the hardened fiberglass. This reduces the amount of gel coat needed. A layer of white gel coat is applied using a pneumatic sprayer. Curing time is 4 hours.

13. The hull is now sanded where bumps have occurred. The entire piece should be sanded to remove the glossy finish left by the gel coat. A final coating will be applied once the internal structure is completed. Bondo, a fast drying filler agent is applied to areas where there are large amounts of pores and to imperfections in the fiberglass where air bubbles formed. The bondo dries quickly and can be sanded to keep everything smooth.

14. The hull can now be removed from the male mold. Starting on the sides and working forward to the nose the hull is slowly pulled away from the mold. The green film of the PVA did its job and the hull released from the mold with ease. The green film peeled off and could be washed out since it is water soluble.
Appendix E. Detail Drawings of major Parts
Displacement vs. Draft (Both Pontoons)

Draft (inches)

Displacement (lbs)

Depiction of Water Lines

- Maximum Draft (1000 lbs total weight)
- Intermediate Draft (500 lbs total weight)
- Minimum Draft (250 lbs total weight)
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**Displacement vs. Draft (Single Pontoon)**

![Displacement vs. Draft (Single Pontoon)](image-url)
Displacement vs. Draft (Both Pontoons)
*Single Hull Only

Representation of Waterlines Based on Displacement Curve

1 inch increments