The Autonomous Mobile Buoy Project

Submitted to
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Dr. Stephen Wood,

Please review the attached report for the Autonomous Mobile Buoy Project. All research and calculations completed over the semester are included. We have prepared this report independently and to the best of our ability. Thank you and please contact us at zpfeiffe@fit.edu if you have any further questions.

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Executive Summary

The purpose of this project is to design and construct a remotely operated buoy that has the capability to moor and unmoor itself. It can therefore travel from location to location using GPS technology. It will eventually be made autonomous. The buoy has the potential to be used in many applications to conduct meteorological and oceanographic measurements along the pre-programmed transects. This would be very helpful in monitoring Indian River Lagoon and near shore areas.

The team designed and constructed a ship-shaped hull for the buoy. Also, the team established methods of maintaining power, controlling propulsion, mooring and unmooring, and knowing location. The prototype is comprised of the hull with a remote control system, solar panels for recharging, motors, anchor/winch system, and a GPS.

The hull and remote control system were tested with success in the laboratory. Problems occurred with the motor controllers when the buoy was placed in water for testing, however, the repairs are simple and are in the process of being fixed. In its current condition, the buoy is ready to be made autonomous within the next year. The total value of the project in remote control is $4,050.
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1.0 Introduction

1.1 Motivations

The purpose of this project is to design and construct a remotely operated buoy which will have the capability to moor and unmoor itself, which will eventually be converted to autonomous and be able to conduct meteorological and oceanographic measurements along pre-programmed transects. The key motivations for designing and building this product from an operational point of view are in the title: autonomous and mobile. The advantages of an autonomous mobile buoy make it superior to permanently moored buoys. Just like permanently moored buoys, the initial deployment will be the only required interaction with the buoy (besides programming). However, if you needed data from different locations, this would require the construction and deployment of many more buoys. This is where the mobility comes in. It can relocate itself unlike a permanently moored buoy which would require a vessel to travel to its location, unmoor the buoy, and carry it to the next deployment area. This buoy will also allow researchers to collect data at desired locations instead of estimating from the nearest permanently moored buoy or sending a cruise out to collect the data. In conclusion, an autonomous buoy will be much more cost and time efficient, and require less man-power than conventional buoys or research vessels.

From the aid of these operational advantages, the buoy will be able to monitor more coastal and lagoon areas, and collect more data on environmental ecosystems, processes and changes in one launch than other data-collecting options. Possible uses of the system encompass a wide variety of underwater and surface monitoring.
1.2 Objectives

The autonomous mobile buoy is aimed to moor and unmoor itself at specified locations in river, lagoon, or near shore ocean areas to take data for a certain amount of time. The buoy should be able to remain on mission for up to 1 month without contact other than communication through GPS/cellular phone technology. The GPS/cellular phone technology should allow for transmittal from the buoy to land of location, and possibly sending new commands from land that could alter the course of the buoy. The buoy must also be able to travel 2 mile transects before resting at a mooring location.

Before making the buoy fully autonomous, the goal is to have remote control. This includes the design and construction, controlling propulsion, a method of lowering and raising an anchor, knowing its location (referred to in the above paragraph), and maintaining power. The buoy will be constructed from light weight aluminum and built into the shape of a boat hull. This design allows for a more efficient course through the water and permits the buoy to face into the oncoming waves while moored, which prevents waves from constantly crashing over the side of the buoy. For better maneuverability in the water, two fixed motors will be installed to allow for differential steering. The differential steering will let the buoy make tighter and quicker turns in the water. A winch system will be utilized to allow the buoy to anchor itself when it has reached one of its desired locations, and retrieve the anchor when it needs to relocate. A solar panel(s) will be mounted to the deck of the buoy to recharge the below deck batteries, which will power all the systems aboard.
1.3 Organization

Organizational procedures were used in order to achieve all these objectives by the given deadline. A Gantt chart (see Appendix B) was made with each procedure that must be completed, and the order in which they were to be done. This provided a basis for our operations. Also, a design notebook and a logbook were kept to track our progress.

1.4 Background

People have been using buoys for research and navigational purposes for hundreds of years. There are numerous tasks for buoys in marine and environmental sciences. The first thought of a buoy is that they are normally designed to be a permanently moored structure that is used to take meteorological and oceanographic measurements. There are many different styles of moored buoys because of the many uses for them. Autonomous buoy development in the commercial industry is in its infancy. The main uses for existing autonomous buoys are for the study of the Arctic Circle or for fisheries. With autonomous buoys scientists would be able to move the buoy to the specific location that they want monitored\(^2\). These measurements are much more accurate than the approximation of measurements from the closest moored buoy to the desired point.

The format of the NOMAD buoy was used to spawn the design of the AMB. The Navy Oceanographic Meteorological Automatic Device (NOMAD) hull was originally designed in the 1940s for the U.S. Navy’s offshore data collection program\(^3\).
The highly successful and low cost design was the first attraction. The NOMAD buoy is an aluminum hulled buoy with a shape of a ship hull. This kind of buoy is cost effective, is known for its outstanding stability due to the hull and mooring designs, and can survive in severe seas. The shape of the hull also allows for quick rotational response, and there have been no recorded capsizing incidents of this buoy type. With the aluminum, the hull is less likely to corrode allowing for longer missions and less maintenance. The ship hull shape is reasonably hydrodynamic and will therefore be easier to operate while moving along long distanced transect. GPS and satellite transmitters onboard allow for the tracking and recovery by the Coast Guard of buoys in the event of a failed mooring.

Oceanographic and meteorological organizations have shown interest in this particular buoy design. A more recent NOMAD design was adopted by Canada’s
Atmospheric Environment Service for deep ocean stations off the East and West coasts of Canada. Attempts at modifying the hull design were also a significant interest.

2.0 Procedures

2.1 AMB Hull Design and Manufacturing

2.1.1 Introduction

The AMB buoy being a mono-hull or ship shape, allows for more efficient transect traveling and better maneuverability compared all other common buoy hull shapes. Discus buoys have downfalls that make them unattractive for being in the ocean environment. Large discus buoys are expensive in production, transportation and maintenance, and small discus buoys have the possibility of capsizing in severe weather conditions. Nomad and other ship shaped buoys are far more economical in production, transportation and maintenance, and have the survivability equivalent to that of a large discus buoy.

The AMB is a prototype which is aimed to be small, economical, and still have the functions and seaworthiness of other larger buoys. The AMB hull shape is a similar form to that of a Nomad buoy except for some distinct characteristics. First, it is only slightly larger than 1/3 the size of the Nomad buoys (approximately seven feet). The AMB buoy is constructed from 11 flat panels (four of which are slightly convoluted.) The Nomad buoys are made like a normal curved mono-hull vessel which is very difficult to machine. The purpose of the AMB design is ease of manufacturing.
2.1.2 Procedures

The AMB was designed using Pro Engineer Software. Multiple models were initially made and different parts from each were combined resulting in our final hull shape.

![Pro Engineer Model of AMB](image_url)

Figures 2 & 3: Pro Engineer Model of AMB

An initial (~1/5 size) model was made of the basic external hull shape. It was constructed from high density foam by the CNC machine in the Florida Tech Machine shop. The model was converted from Pro Engineer to Mastercam 9.0 to generate a program. Due to the CNC machine only having a 3-axis range, some hand sanding on the bow was necessary. Also, a scaled keel was attached, the anchor well was carved, and a layer of two part epoxy and paint were applied. Next, the model was moored in a wave tank using an anchor line ratio of three to one compared to depth.
The buoy was also modeled in GHS and ProSurf naval architecture software. The main components determined from these were hydrostatic characteristics such as total resistance on the hull and calculated drafts in certain sea conditions.

The original plan for constructing the actual AMB was to have 10 of the 11 panels bent from 1/8 inch 5052-H32 aluminum sheeting, using CNC presses at Shapes Group Inc., making only three main parts of the hull. For example, the front four flat panels of the buoy would all be bent from one sheet of aluminum. Therefore, once the transom and keel (1/4 inch thick) are machined there will be significantly less welding needed to build the basic hull shape. (One weld to connect the middle sections and keel together, one weld to secure the nose on, and one weld to mount the transom.)

However, Shapes Group was unable to complete this part of the project due to certain time constraints. Therefore, the dimensions of each panel were found using the measuring tool in Pro Engineer and a series of technical drawings were made for each part of the buoy. (See Drawings Appendix E) Aluminum sheets were ordered and then each panel was laid out in the FIT Machine Shop using calipers, protractors, and scales with accuracy to the nearest thousandth of an inch. Following this, the sheets were taken
to Don Bell Inc. machine shop and a ten foot hydraulic sheer was used to cut most of the panels. Ten panels (five pairs) were bent using a brake at the same machine shop. Completing this stage of the project mostly independently reduced the precision of the machining (Shapes Group had digital hydraulic brakes and laser cutting available) but enabled the team to save a large portion of the budget and gain experience in the machine shop.

Figures 5,6,7,8,9,10,11 Laying Out and Machining Panels.

Next, the panels were tack welded in place and then adjusted to the exact shape desired before being completely Tig welded together.
Figures 12 & 13 Hull tacked together.

The hull was constructed from mostly 50-52 H32 and some T6 marine grade aluminums. These are compatible to be welded together. Dimensions of the AMB are approximately seven feet long, three feet wide, and two feet deep. (See Appendix E) The anchor well is approximately 13.5 inches wide, 12.5 inches long, and 1 foot from the bow. When the buoy is moored, the anchor well is designed so the forces from the anchor line will be drawing from the bottom (slightly sternward from the bow) similar to a Nomad buoy. This increases stability and reduces trimming of the buoy extensively in rough seas.7

The keel extends from the back of the anchor well to the stern of the buoy (approximately 50 inches) at its maximum height of 8 inches and 1/4” thick. It will help with directional control and stability, reducing the roll of the buoy.7

Once everything was tacked together, Bill Bailey Tig welded all the seams making a watertight hull. The hull was then placed in a nearby pond to ensure water tightness.
2.2 AMB Naval Architecture

2.2.1 Calculating Hull speed for Displacement Type vessels

The hull speed is usually calculated for displacement type vessels. This speed is usually an estimate on how fast the vessel will be capable of going before the resistance increases too rapidly and the traveling becomes very inefficient. To find the hull speed, it is assumed that the waves along side the vessel have a wavelength (?) equal to its length (L).\(^7\)

The hull speed \(^7\) is given by a Froude number of 0.4 or

\[ V_{Hull} = \left( \frac{g \cdot L}{2 \cdot ?} \right)^{1/2}. \]

For the AMB case:

\[ V_{Hull} = \left( \frac{32.2 \cdot 7}{2 \cdot ?} \right)^{1/2} = 5.98945 \text{ ft/sec} \]

The design speed of the AMB will be less than the hull speed by approximately 2 ft/sec, which is 4 ft/sec or just under 3 mph. This is due to the amount of power that needs to be supplied to move the vessel efficiently on its designed two-mile transects.
2.2.2 Water plane Area and Total Wetted Surface

The design waterline is at 13 inches above the lowest part of the hull. This creates a horizontal plane that can be used to find the water plane area ($A_w$) and also total wetted surface area ($S$).

From the model in Pro Engineer, an extrusion was made that eliminated the part of the model that was going to be above the waterline.

Figures 16 & 17 ProEngineer renderings of water plane area and wetted surface area.

The total surface area of the water plane ($A_w$) was calculated to be 9.76 ft$^2$. The total wetted surface area ($S$) was found to be 16.5 ft$^2$, not including the material missing from the anchor well.

Due to the complexity of the hull shape, it isn’t practical to calculate the displacement by hand. Therefore, the model was converted into ProSurf software and analyzed to receive hydrostatic data. (See Appendix C for Pro Surf Renderings and Appendix K for ProSurf values) When modeled in ProSurf for two-foot waves, the draft increased to 21.7 inches. This increased the wetted surface area and water plane area significantly. All the hydrostatic values calculated using ProSurf for calm water conditions, and seas with a wave height equal to 2 feet and wavelength of 4 feet can be found in the Appendix K section.

The type of resistance calculation method used in ProSurf is the DispMode, which uses a formula developed by Savitsky and Brown for transom stern planning hulls.\textsuperscript{11} This
formula was developed from data taken from the following test series: NPL, Nordstrom, DeGroot, SSPA, Series 62, Series 63, and Series 64.

2.3 AMB Theoretical Current Demand Calculations using Drag Resistance

The sample calculation below is for the amount of current that is needed to supply enough power to achieve the design speed of 4 ft/sec and travel a distance of two miles on calm water. From ProSurf the calculated Total Resistance in these conditions at a draft of 13 inches equals 44.496 lb.

Transect distance = 2 miles = 10,560 ft

Time to travel this distance at 4 ft/sec = 44 min = 2,640 sec

2.3.1 Work

\[ W = \text{Force} \times \text{Distance} = (44.496 \text{ lb}) \times (10560 \text{ ft}) = 469,877.76 \text{ lb-ft} \]

2.3.2 Power

\[ P = \frac{W}{\text{Time}} = \frac{469,877.76}{2640} = 177.984 \text{ lb-ft/sec} \]

\[ 177.984 \text{ lb-ft/sec} = 241.314 \text{ watts} \]

2.3.3 Current

Where a 12 Volt Deep Cycle/Gel battery will be used.

\[ I = \frac{P}{\text{Voltage}} = \frac{241.314 \text{ watts}}{12 \text{ volts}} = 20.109 \text{ Amps} \]

Using two motors that will be \( \frac{20.109}{2} = 10.055 \text{ Amps per motor} \)

These calculations were also done using the calculated Total Resistance given from ProSurf for cosine type wave conditions with heights of 2 feet and wavelengths of 4 feet (an ideal choppy river condition.) With these design conditions the draft increased to 21.7 in (only 4.27 in from top deck of buoy.)

Total Resistance = 61 lb for these design conditions.
2.3.4 Wind Load Estimates

The design wind speed for the buoy to operate in is 15 knots. The loading from this calculated by assuming the vessel is heading directly into the wind. The surface area facing the wind is estimated:

- Solar panel box frontal area = 3 in x 24 in = 72 in
- Winch box frontal area = 8 in x 12 in = 96 in
- Freeboard Frontal Area = 30 in x 13 in = 390 in
- Total area = 558 in$^2$ = 3.875 ft$^2$

Design wind speed = $V_w = 15$ knots = 17.26 mph = 25.32 ft/sec

$$F_{wx} = (0.0034) C_{Dx} V_w^2 A_x$$

Using $C_{Dx} = 0.8$ for wind direction, T, equals zero.\(^5\)

$$F_{wx} = (0.0034)*0.8*15^2*3.875 = 2.37 \text{ lb}$$

For a wind speed of 65 knots (~75 mph) the force due to wind loading on the front of the AMB would be 44.5 lbs per hour.

Adding the design wind speed (15 knots) load to the Total Resistance from ProSurf will allow the current demand for these design conditions to be found for ideal transect crossings.

- Resistance = 61 lb + 2.37 lb = 63.37 lb

Using the same methods as above, the current demand for these forces applied is:

- Current = 28.639 Amps

Therefore each motor will draw 14.320 Amps for sea conditions of two-foot wave heights, four-foot wavelengths, and fifteen-knot winds heading into the bow.
It will be incorporated into the automation of the buoy that under certain sea conditions the buoy will remain moored until ideal conditions are available to pick up the anchor. This is because the buoy is much more stable when moored and allows it to withstand much greater seas. Future tests will be completed on exactly which sea conditions are suitable when the buoy is in either state.

2.4 Current Draw Estimates for Trolling Motors and Winch Using Power Supply

The Minn Kota trolling motors and winch purchased for the AMB were attached to a power supply and ran at each operational level to see how many amps would be drawn for each operating mode.

The trolling motors were run at each level for forward and reverse and the winch was run in the releasing and retrieving modes. Tables 1 and 2 show the results from this experiment.

<table>
<thead>
<tr>
<th>Forward Levels</th>
<th>Reverse Levels</th>
<th>Table 1: Trolling Motor Current Demand</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>6.25</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>14.5</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>22</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Position</th>
<th>Table 2: Winch Current Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down</td>
<td>8</td>
</tr>
<tr>
<td>Up</td>
<td>22</td>
</tr>
</tbody>
</table>

Therefore, using the data from the current demand calculation section, in calm conditions the motors only need 10 Amps. However, the closest level to this demand is level 3, which draws 13 Amps, therefore easily reaching the desired speed of 4 ft/sec.
rougher days, such as the conditions put forth above, the motors should operate on level 4 to complete the transect at the design specifications drawing 14.5 Amps. By knowing these current demand values and estimating the amount drawn by all the other electronics on the buoy (about 2 Amps when operating), a battery with the correct Amp-hour rating may be chosen and how efficient the AMB will be on each mission.

Designing for the rougher seas condition from above, the transect will take 44 minutes to complete at 4 ft/sec. Assuming the winch will have to pull up the anchor first, this would draw 22 Amps for approximately 1 minute. Next, the motors will run at 14.5 Amps each for the entire transect distance. Then the winch will then drop the anchor, drawing 8 Amps for approximately 1 minute. Estimating the current draw from the electronics to be 2 Amps at all times during the transect route, the total amount drawn in the 46 minute (44+1+1) period can be averaged to the following:

\[(22A + 8A) \text{ for 1 min} + (14.5A * 2A) \text{ for 44 min} + (1A) \text{ for 46 min} \sim 22.5 \text{ Amp-hours drawn per transect.} \]

Three 50 Amp-hour Deep Cycle Gel Marine batteries were chosen. Therefore 127.5 Amp-hours will be in reserve for longer transects or perhaps dynamic positioning.

Future plans are to have two 30-watt solar panels on the buoy, recharging the battery an average of 3.6 Amps per hour. Assuming, when the buoy is moored, the electronics draw one Amp only at intervals of data collecting (most likely every half an hour). The battery can then charge at least 3 Amps per hour. Estimating the average amount charging time per day to be 4 hours, then approximately 12 Amps per day will be replaced to the batteries. Having these estimates, our design goal is to be able to travel one transect every two days. This assumes at least 4 hours a day of maximum charging.
by the solar panels. Weather conditions such as overcast days may alter the amount of
time that the buoy may be able to move to another location. Below is a table showing the
theoretical efficiency of the AMB traveling transects at different intervals.

**Table 3: Efficiency of AMB at Different Transect Intervals**

<table>
<thead>
<tr>
<th>AMB Power Efficiency</th>
<th>Transects</th>
<th>Battery Life Span</th>
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<tbody>
<tr>
<td>1 Every Day</td>
<td>14 days</td>
<td></td>
</tr>
<tr>
<td>1 Every 2 Days</td>
<td>Completely Efficient</td>
<td></td>
</tr>
</tbody>
</table>

2.5 Winch and Anchor System

There were decisive factors for the choice of the AMB winch system. The
original design was to have at least 100 feet of mooring line and have enough power to
unhook an anchor from the bottom mostly by itself, with slight help from the motors.
Windlasses used for regular anchor hoisting were looked into, however were very
expensive and did not have spools to coil the anchor line. Having the AMB autonomous
leaves no allowance for tangled rope. The final choice was the Minn Kota Deckhand 40
anchor winch. This model has 100 ft of 800-lb test nylon rope and is capable of lifting a
40-lb anchor.

In the testing phase, many different types of anchors for various sea floor
conditions will be tested and analyzed. The anchor incorporated into the design of the
AMB is the Minn Kota 18-lb Crab Claw Anchor. This anchor has unique plow like
flukes that cause the anchor to dig itself down, for easier setting and therefore more buoy
stability. It also has a movable ballast system so that it can constantly adjust to different
floor conditions. Finally, like the trolling motors, it has a very strong outer casing that is
very resistant to corrosion.
Since the winch is designed to lift a 40-lb anchor, there should be little problems in retrieving the chosen 18-lb anchor. The capabilities of the winch will allow for any additional forces from the anchor locked into the seafloor, and also testing of heavier and different shaped anchors. The ratio of depth to mooring line used for the AMB will be three to one. Therefore, with this particular setup, the maximum design depth for safe mooring will be 33 feet.

The installation for this system is rather unique, because the hull is designed around the anchor well. In the design, a well was included large enough to allow the anchor to be pulled above the bottom of the hull and therefore, above most of the water flow. This well is located 18 inches aft of the bow. The top of the well is 4 inches below the plexi-glass deck. In between the well and the deck, there is a through hull fitting to pass the anchor line. The winch was disassembled so that the electronics can be safely housed inside the hull, while the spool and motor will be placed on top of the deck. A plexi-glass box was built to house the motor and spool in order to avoid contact with seawater or spray. The housing is long enough to allow room for a wedge roller inside. The roller is directly above the anchor well hole. This way the line is fed off the winch,
onto the roller, and then down into the well. Lastly, a PVC hose was halved and secured with two part epoxy around the perimeter of the anchor well to prevent wear and tear.

2.6 Steering and Propulsion

In the design of the AMB, the propulsion units must have enough thrust to power the buoy with all of the instrumentation and permanent parts included. Depending on the mission, the instrumentation onboard could be anywhere from 5 lbs. to 50lbs. Permanent parts on the buoy include the batteries (50 lbs each), the winch and anchor (28 lbs), hull (~65 lbs) and the solar panel (15lbs). Therefore, the minimum total weight, excluding the hull, is 163 lbs.

Two Minn Kota 50-lb thrust Rip Tide trolling motors were chosen. These are built with premium grade alloys that make them very resistant to rust, putting a longer lifespan on the buoy. They also each have a weed-less wedge on both of their props. This is a sharpen lip that that extends of the prop, but at a slightly different angle. So, the motor can operate very efficiently in grassy areas like the inter-coastal. With these motors, the buoy will be time efficient and has the possibility of planning (in certain conditions). Besides power, having two motors also works well with solving the steering problem. The solution is simply using differential steering to navigate the buoy. This means that the motors can be used individually to create a larger or lesser thrust on one side of the buoy that causes a turning motion. Each motor is going to be directly connected to the RC system. This will allow for operations such as having one motor in a forward gear and the other in a reverse gear.

The motors were modified for installation. The head was removed, leaving just the wires, and the shafts were shortened to approximately 8 inches. The shafts were
inserted into the motor mounts and fastened onto the internal cross beam with hose clamps and a 2 part epoxy.

![Mounted motors](image19.jpg)

Figure 19 Mounted motors.

![Internal view of mounted motors](image20.jpg)

Figure 20 Internal view of mounted motors.

This is to account for the moment and drag forces that are going to be on the shaft when maneuvering. They are both just aft of the center of gravity (CG) with the propeller 4 inches from the keel. Placing the motors exactly at the CG would make for good turning, but less efficient for traveling long distances. Placing them further back makes for good long distance travel, but poor turning. So, these two situations were compromised.

2.7 RC System

The RC system has six things to control: both of the trolling motors in forward and reverse, and the winch up and down. Directly from the package, the trolling motors
come with 5 speeds in forward, and 3 reverse speeds. However, continuous acceleration was looking to be achieved.

First, speed controllers with a forward setting only were ordered with the hope of being able to configure them also for a reverse setting. They were set up and each motor was able to use the forward gears. With the help of a mechanical engineering professor, the conclusion was made that it would be difficult and risky to operate the speed controller in reverse in order to have forward and reverse options for each motor. So, two new speed controllers (Graupner Speed Profi 50 Electric Motor Control) that include reverse were ordered. The installation process given by Graupner JR Remote Control is as follows (see controller instruction manual in design notebook):

1) Connect the drive battery and receiver (not the motor) to the Speed Profi 50. Switch on the Speed Profi 50 and the transmitter and set the transmitter stick to the neutral position. Carefully rotate the neutral point adjustor (STOP) on the Speed Profi 50 to left or right until both check lamps go out.

2) Now move the transmitter stick to the “full throttle” position and carefully rotate the full throttle adjustor (Speed) on the Speed Profi 50 to the point where the red check lamp (REV) starts to glow. Continue rotating the pot until both check lamps (REV and FWD) glow simultaneously. The full throttle adjustor is now correctly set.

3) Move the transmitter stick back to the neutral position, and both check lamps should go out. Move the transmitter stick to the reverse position, and only the red check lamp (REV) should light up.
The remote controller that was purchased is the Hi-Tec Laser 4, which has four channels controlled by two joysticks. Toggling a joystick forward and backward corresponds to one channel; left to right corresponds to another. One Speed Profi 50 uses one channel. The starboard motor was installed to channel 1, therefore for it to be in forward, the operator must move the right joystick forward. The port motor was installed to channel 2; therefore it is in forward when the right joystick is to the right. By configuring both of the motors to be controlled by the same joystick, the operator can combine the directions to have the motors in four situations: full forward, full reverse, full right turn, and full left turn (see Figure 21). These are the extreme situations, meaning these actions can be performed at different velocities.

A circuit was built to have three commands for the winch: (1) Release rope when there was tension on the rope, (2) release rope continuously, and (3) retrieve the rope. (See Figure 21 for the corresponding movements of the joystick.)
The winch’s operations were included on the same Laser 4 remote control along with the motors. The left joystick is used for the winch. In the lab, the team set up the winch on the deck in preparation for testing. The winch and speed controllers were connected to the battery. The remote control was left to charge overnight, in order to reduce the chance of voltage fluctuations.

2.8 Permanent Instruments

2.8.1 GPS System

The GPS is an important instrument for the AMB. When completed, the GPS will be connected to a data logger to record the data collected. This data will then be transmitted from the buoy to a transceiver on land. The GPS will be programmed with coordinates of locations where measurements are desired. Coordinates can be added or changed while the buoy is out at sea relaying messages between the transceiver on land and aboard the buoy. The GPS system is an integral part in allowing the buoy to operate autonomously.

The first step in the design of the GPS system was to decide what kind of GPS would best suit our needs. We decided that the GPS Hunter Brown designed was the best choice.
Hunter gave us the Schematic and overview of how to assemble and operate the GPS. Once all components were ordered and received the assembly began. For preliminary testing we put the system together on a breadboard. We varied from Hunter’s design by using the free SiRF demo software as the program to test the GPS instead of HyperTerminal. The free software was used because it was compatible with the SiRFstarIII chip in the GPS. The GPS was tested and the path mapped out on Google Earth. After the successful test, the GPS was then transferred from breadboard to PC board.
The receiver used in this system is an EM-406 GPS Receiver. An RS-232 Linedriver was also used in the circuit. The GPS was complete after a serial connector, a 5-volt regulator, and a few capacitors were attached.

The data logger that will be used is the Logomatic Serial SD Data logger. This data logger will be able to plug directly into the GPS system and begin recording data. The data logger can store a few weeks worth of data on an SD card that can be inserted into a computer and downloaded, with no tweaking, to show clear and logical data.

2.8.2. Solar Panel

Another permanent instrument is the solar panel. Its purpose on the buoy is to recharge the deep cycle/gel batteries. One panel has been purchased, with a second purchase in consideration, depending on the efficiency of our current system. The panel
is a General Electric 30 watt photovoltaic module, which features 40 single crystal cells connected in series. The peak power is 30 watts at 16.8 volts, which supplies a maximum current of 1.8 amps. The output tolerance is +/- 5%. A charge controller was also purchased for the panel to regulate input and prevent back flow out of the battery. According to our design calculations and estimates, it will take the buoy 29 amps in moderate conditions (2 feet seas and 15 knot winds) to run a two mile transect and gather data. Assuming 4 hours a day of peak charging time, it will take around three days before each transect can be made to be completely efficient.

The solar panel is going to be housed on top of the deck in a lifted plexi-glass box. The box will be built around the solar panel giving an inch of space in all three dimensions. The panel itself is 28.0” x 20.8” x 1.4”. The plexi-glass was joined using marine grade 5200 sealant, then screwed the top and bottom pieces together. The solar panel is positioned on the stern of buoy. If another solar panel is purchased, it can be positioned above the winch box. Five aluminum brackets will be machined to support the solar panel box. The brackets will be made out of 1” square aluminum tubing and pieces of sheet aluminum for mounting. Finally, the cables running from the solar panel will pass through two watertight through-hull fittings in the bottom of the solar panel box and into the plexi-glass deck.

2.8.3 Weather Station

Figure 25 Weather Station.
In the designing of the buoy it was important to plan where meteorological and oceanographic instruments could be mounted. The Davis Weather Monitor II weather station was installed for basic meteorological measurements and is currently the only instrument onboard for meteorological data acquisition.

The weather station was donated to the project by Dr. Craig Tepley of Arecibo Observatory in Puerto Rico, with affiliation to Cornell University. The weather station consists of four parts, one of which will not be used. Because of the requirement of external mounting in an area where there will be a lot of splash and spray, the rain gage seemed unnecessary. The remaining three components are the anemometer, the external temperature/humidity sensor, and the internal sensor/weather monitor display.

Both the anemometer and the external sensor are installed above the deck. The data from them is transmitted through a basic phone cable that pass through a water tight connector and into a small junction box inside the hull. From the junction box, the data is passed onto the weather monitor/internal sensor. This monitor acts as a focal point for the data before it goes on to the data logger. The weather monitor also has a six-hour memory bank of its own.

Figure 26 Weather monitor.
The weather monitor is convenient for presentation purposes because it has a display where one can observe barometric and wind measurements without having to load the data onto a computer. The monitor was therefore installed up against the inside of the plexi-glass deck for easy viewing and next to one of the hatches for accessibility. Aside from the display and temporary data logging, the weather monitor takes data of its own, recording temperature and humidity. This will be an excellent way of monitoring whether or not the internal temperature is too high or contains moisture, since it is installed inside the buoy. The weather monitor contains an alarm function, so that if the inside temperature does in fact get too high, an alarm will trigger. This function may be programmed to abort the mission and send a distress call through the wireless transceiver and wait for rescue. Another scenario is a rapidly decreasing outside pressure, hence an incoming storm, might trigger another abort mission. The high and low alarms just have to be set.

An acrylic box was built for the external sensor and attached to the outside of the winch housing. This sensor records pressure, temperature, humidity, wind chill, and dew point.
The final component of instrumentation in the weather station is the anemometer. It is used to record wind speed and wind direction. The anemometer is designed to survive in hurricane force winds, but is even sensitive to a gentle breeze. It is mounted using U-bolts that are connected around a four foot PVC pipe and through the mounting plate that came with the station. The PVC pipe was inserted in the starboard aft section of the winch housing. Two more U-bolts secure the bottom of the pipe to the housing. A program can be written to determine the heading of the buoy from the GPS data and apply that to calculate the true wind direction.

3.0 Results

3.1 AMB Hull Design and Manufacturing

The first results obtained from the AMB hull shape was when the foam model was placed in the Florida Tech wave tank. It was analyzed for its response characteristics to relatively strong wind conditions and deep-water waves. When enough weight was placed in the model, making it sit at the design draft (about one half the depth of the buoy), it responded very well to the deep water wave conditions (the only type available in the wave tank at the time) and simulated wind blowing from a wet-vacuum. Righting moments were strong and allowed no water to come over edges. Also, due to the mooring
location on the buoy and piercing bow, whenever the “wind” turned the model sideways it quickly turned its nose back into the direction of wave propagation.

Figure 29 Foam model in wave tank.

After completing the design and manufacturing process of the actual hull, the AMB team was very pleased with the final hull shape. The overall dimensions are 7 feet long, 3 feet wide, and 2 feet deep. When tested in the Southgate pool, there was approximately 150-200 pounds of ballast weight necessary to make the buoy sit at its design draft. When this was achieved the buoy gained a great deal of stability. For the short time that the motors were functional, the hull seemed to perform exceptionally well when moving through the water.

Figure 30 AMB hull in pool.
Additional testing will be completed when the motors are functional again. Theoretical values of draft, hull speed, and current draw obtained from ProSurf and GHS Naval Architecture Software will be compared to actual field testing in river and near shore sea conditions. Hull responses of the AMB will also be compared to model responses in the wave tank.

3.2 Instrumentation

3.2.1 RC System

When the first type of speed controller was ordered, it was functional for its set purpose. It was installed and was able to have continuous acceleration. As stated above, the team did not take the risk of attempting to configure it for reverse. The speed controllers including reverse also worked perfectly. The motors have continuous acceleration. Having both motors on one joystick allows the operator to control the buoy with ease. There was no required troubleshooting or problems with the instruments.

It was necessary to stand clear of the propellers at all times when the remote control was being switched on and off. Often, a power surge would put the motors in gear, but very momentarily.

After the electronics were set up in the lab, the remote controller was then turned on and the motors and winch preformed all tasks properly. Next, the buoy was tested in the Southgate Pool. Once the remote control was turned on, the motors were in gear without any movement of the joystick. The left motor stayed in gear and the right motor came on and off. At times, the winch would release the rope, and then switch to retrieving the rope. All these actions were done without any movement of the joysticks. The actions continued to occur after the remote control was actually turned completely
off. The deck was filled with smoke and had the smell of burning plastic. The winch circuit and the speed controllers were disconnected from the battery. The buoy was brought back to the lab and the deck was taken off. The solar panel, which was intact during the testing, was extremely hot.

After the pool testing, the winch was still operable after a new voltage regulator was installed.

3.2.2 GPS

Using the schematic in Figure 23 from Hunter Brown, the GPS was built on a breadboard (Figure 24). We obtained and downloaded the SiRF demo software onto Adam Outlaw’s laptop for out of lab testing. The GPS antennae must be in clear view of the sky and the baud rate set to 4800. The first tests were not successful. Hunter came in one evening to help us find the problem. After comparing all variables of our GPS to the GPS Hunter built, we came to the conclusion that the serial-USB converter was faulty. The GPS finally gave data after a new cable was acquired. Once the program began collecting useable data we started to familiarize ourselves with the program (Figure 31).

Figure 31 SiRF demo software screen.
This was eventually done with help from the SiRF tech support. When we finally felt comfortable with the software we took the GPS for a test drive. Then we input the coordinates collected into Google Earth and plotted the course (Figure 32).

![Google Earth map](image)

Figure 32 Google Earth map.

The data collected is accurate in the latitude values but is three meters to the east in the longitudinal direction. For the most accurate coordinates and elevation values, the DOP should be under 2, the smaller the value the more accurate the data. The software shows the satellites being used, any errors that are occurring and real-time data (with a 5 second delay). The software can also run just NMEA data which can be used to find the coordinates with some modification. However, if used in the SiRF mode a log can be recorded with the coordinates ready for use after adding a decimal point. The GPS was then transferred onto a PC board and installed into the buoy (Figure 33).
Figure 33 GPS circuit on PC Board.

Setting up the circuit on the PC board was not difficult. Each component of the circuit was placed on the board as it had been on the breadboard. A final view of the schematic was made before soldering each piece to ensure that there was nothing out of place. To minimize the amount of wires exiting the pelican case a cable with six wires was used to connect the GPS antenna to the PC board. The cable consisted of red, red and white, orange, orange and white, black, and black and white wires. We used the orange and orange and white wires to connect to ground. The black and white wire was connected to power. The red wire was connected to prong 9 on the RS-232 chip and the red and white wire was connected to prong 10. To connect the PC board to the power supply a white wire was used to connect to ground and a white and blue wire was connected to power.

The data logger was not installed because the model that is compatible with the GPS will not be available until after the project deadline. The data logger will have to be moved into the list of things to do to make the buoy autonomous. Wireless transmitters and receivers were researched and we found that a transceiver with one mile coverage
would cost $1000 and with a two mile coverage would cost $2000. This item was out of our budget range since the software to run it would be another $1000.

4.0 Discussion

4.1 Hull Design and Manufacturing

The AMB design has proved to remarkably ease the manufacturing process of a Nomad type buoy. Because each panel was sheered along with a few being bent on a hydraulic brake, the complicated process of having curvature that normal boat or ship hulls embrace was eliminated. This would also allow for multiple buoys to be manufactured quite easily and rapidly. The time span from ordering the aluminum to painting the hull was less than a month. The aluminum hull stands for a relatively lightweight shape that is easy to work with.

Designing the hull shape in Pro Engineer software first allowed for multiple designs to be completed and compared without actually building them. It also made way for very precise dimensioning that would have been very tedious if completed by hand. The uses of other software such as Mastercam 9.0, ProSurf, and GHS allowed the AMB team to fully understand the characteristics of the innovative hull shape before manufacturing. Any future alterations that may be suggested to the design of the AMB hull can now be simply made because of modeling in Pro Engineer.

4.2 RC System

Testing done in the lab was successful. The speed controllers with the motors and the winch worked perfectly, aside from a few small surges in power. It was then tested in the Southgate Pool on the Florida Tech campus.
The team assumes that there was a short circuit which caused the motors and winch to be out of control. The short circuit then caused the speed controllers to overheat and melt due to the motors switching from forward to reverse gears too quickly. The actual speed controllers completely melted, and also burned and melted other wires. The other wires that were melted were connected to the winch. When those melted, the winch then began to operate uncontrollably. Even though cooling was not the cause of failure, improving the cooling mechanism for the electronics needs to be done.

Another possible cause for the errors during testing is that the motors actually draw more current that expected. Tests done with the motors in the wave tank reported
that each motor drew 22 Amps on max speed, so the speed controllers selected could take 35 Amps continuous, and 50 amps momentarily. However, a representative from Minn Kota stated that each motors draws 42 Amps continuously. This is much higher than the Speed Profi 50 controllers could handle. They could have just overheated, and then melted along with the touching wires. The team does not believe that their testing of the motors was incorrect, but the information does not match up. For a precautionary measure, the next speed controllers to be ordered can handle much more current (420 Amps). Also, a fuse box was installed to prevent any large power surges reaching the electronics.

Figure 36 Electronics inside pelican box.

The abilities of the winch are convenient in a few ways. Tension on the rope causes the winch to release more rope until tension ceases while in the down mode. So, the anchor will be released until it reaches bottom, meaning there is no more tension on the anchor rope. While anchored, as a large wave passes and puts tension on the rope and the bow of the buoy will not be pulled under. This prevents the buoy from the risk of taking on excess water. Also, the anchor will not be dragged along the bottom. However, this cause and effect, tension-releasing mechanism is only useful up to a
certain point. It would cause the buoy to be completely repositioned in high seas. Further testing will have to be done to find the maximum sea conditions the buoy can handle.

4.3 GPS

The design and build process flowed rather smoothly after the problem of the faulty USB connector was discovered, during the initial failed tests, and replaced. With some help from SiRF technology support, the testing and plotting of the GPS data was successful. Unfortunately, due to the fact that the data logger was not available we were unable to install it. The testing process was valuable and allowed us to find the error between the collected data coordinate and the actual coordinate. Testing also allowed us to familiarize ourselves with the process of inputting the data for plotting. The difference of actual and measured coordinates shows how accurate programmed locations can be.

5.0 Conclusions and Recommendations

There was successful design, construction, and testing of the hull. To achieve the design waterline, ballast weight needs to be added. The motors and winch were integrated into the remote control system. The GPS was tested and functional. Also, the solar panel, weather station, and batteries were successfully integrated. The anchor and winch, and steering and propulsion systems were not able to be fully tested past the fact that they work.

The buoy is ready for autonomous upgrade. A data logger and a wireless transceiver are needed for this transition, along with programs to operate in autonomous mode. The addition of another solar panel would allow for an extended mission. In the
future, the remote control will be eliminated for autonomous use. The circuit built for the
winch and the speed controllers will remain installed. The buoy will use the information
given by the GPS as its basis for maneuvering. Instruments from researchers mainly in
the Department of Marine and Environmental Science have the opportunity to be aboard
the buoy. Lastly, the buoy should be equipped with indications of its restrictions
underway to prevent collisions with other vessels.
6.0 References

1 Alternate Energy Store. http://store.altenergystore.com

2 Autonomous Ocean Flux Buoy for Polar Studies. www.oc.mps.navy.mil/~stanton/fluxbuoy/. Stantonn@mps.edu


6 GHS General HydroStatics Software. Creative Systems Inc. Copyright 1997-2003


9 Minn Kota Trolling Motors. www.minnkota.com

10 NOAA. http://www.ndbc.noaa.gov/mooredbuoy.shtml

11 Procedures for Hydrodynamic Evaluation of Planing Hulls in Smooth and Rough Water, Marine Technology - SNAME, Oct, 1976 that covers the pre-planing mode [1.0 <FroudeNo. < 2.0

12 Pro Engineer Wildfire 2.0 Student Edition. 3D Modeling Software.


7.0 Appendix

A. Economics

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C. ProSurf Renderings of Buoy

Key:

Orange lines - Waterlines
Blue lines - Station lines
Green lines – Actual Hull lines

Figure 1: ProSurf 3D Drawing of Buoy Hull
Figure 2: ProSurf Front View Drawing displaying location of Water and Station lines
Figure 3: ProSurf Bottom View Drawing

Figure 4: ProSurf Side View Drawing
D. Pro Engineer Renderings
Twisted Panels View
Bottom Panels View
Note: Only concerned about outside dimensions.
The front top panels are offset 21.325 degrees inward from the front bottom panels.

Note: Angle between the two front bottom panels is 90 degrees.
F. Acrylic Technical Drawings
#2, Winch Housing Long Side
5.23-06
Acrylic Winch Housing
AMB Team
Florida Tech