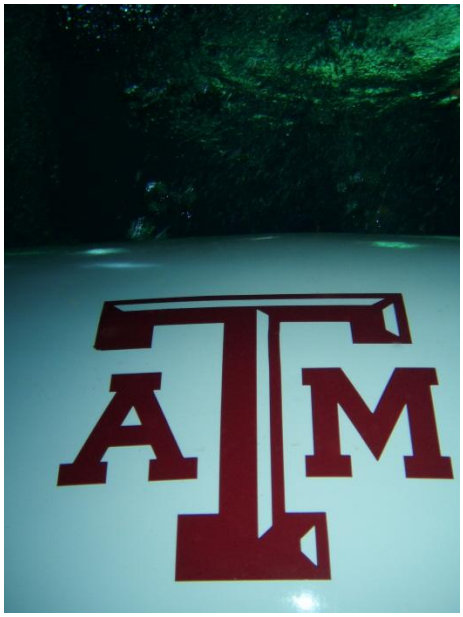
Texas A&M University
Human Powered Submarine Team
"Maroon Harpoon" Design Report
ISR 2011



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Introduction

Students in the Ocean Engineering Program at Texas A&M University in College Station, Texas designed and constructed a new submarine hull during the 2006-2007 school year and named it “Maroon Harpoon”. The submarine was raced in both the 9th International Submarine Races (ISR) in 2007 and the 10th ISR in 2009 at the David Taylor Model Basin in Bethesda, Maryland. While the hull has remained basically unchanged since 2007, there have been many modifications made to the rest of the operating systems.

The hull design is based on the dimensions from the earlier one-person propeller submarine, “Ol’ Sarge III”, but was scaled up to allow for a pilot up to 5 ft 10 in. The control system is comprised of a tensioned cable system that allows for roll adjustment in addition to pitch and yaw corrections. New propellers have been added, and the drive shaft and dead man buoy have been redesigned. Electronic sensors for shaft RPM and torque have also been added to provide feedback of pilot productivity. All designs for submarine controls and propulsion were kept in accordance with specifications of the 11th International Submarine Race rules and regulations.

Hull Design

The hull is designed for the one-person propeller driven category. In the initial design of the hull, a pilot height limit was determined. With these limits known, a study on hull shape design was completed to determine the proper length to diameter ratio to produce a hull with the lowest possible drag coefficient. The Reynolds number was calculated for a 7.0-knot velocity to give an idea for the drag coefficient. Figure 1 shows the drag coefficient curves for various hull shapes.

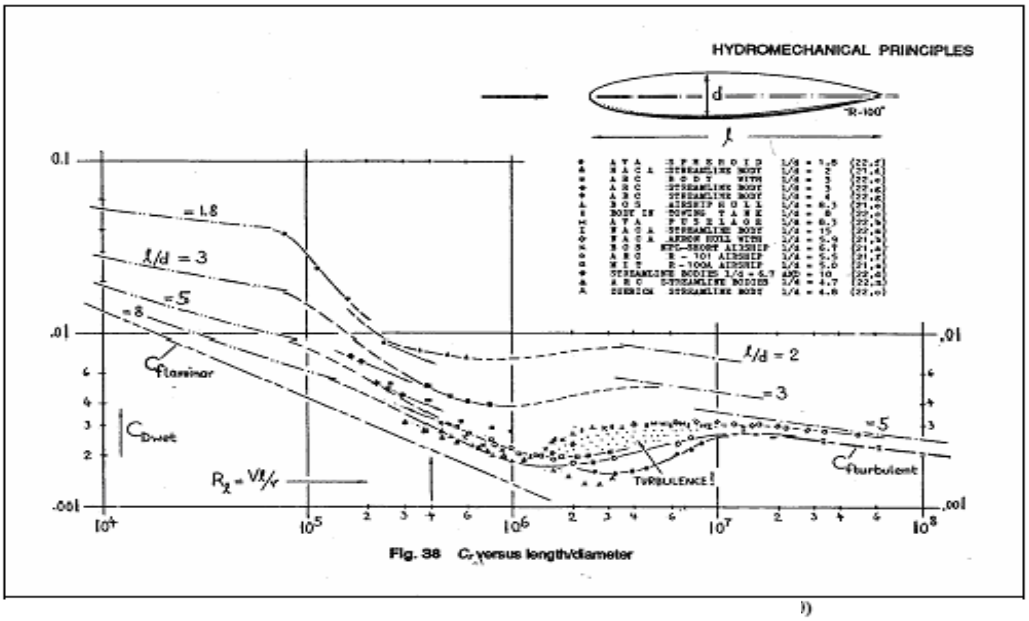

Figure 1: Drag Coefficients for Various Hull Shapes (Allmendinger, 1990)

The resulting length-to-diameter ratio of 5 correlates to a drag coefficient of 0.003. This ratio resulted in the shape shown in Figure 2 below. The shape in Figure 2 does not include the nose cone.

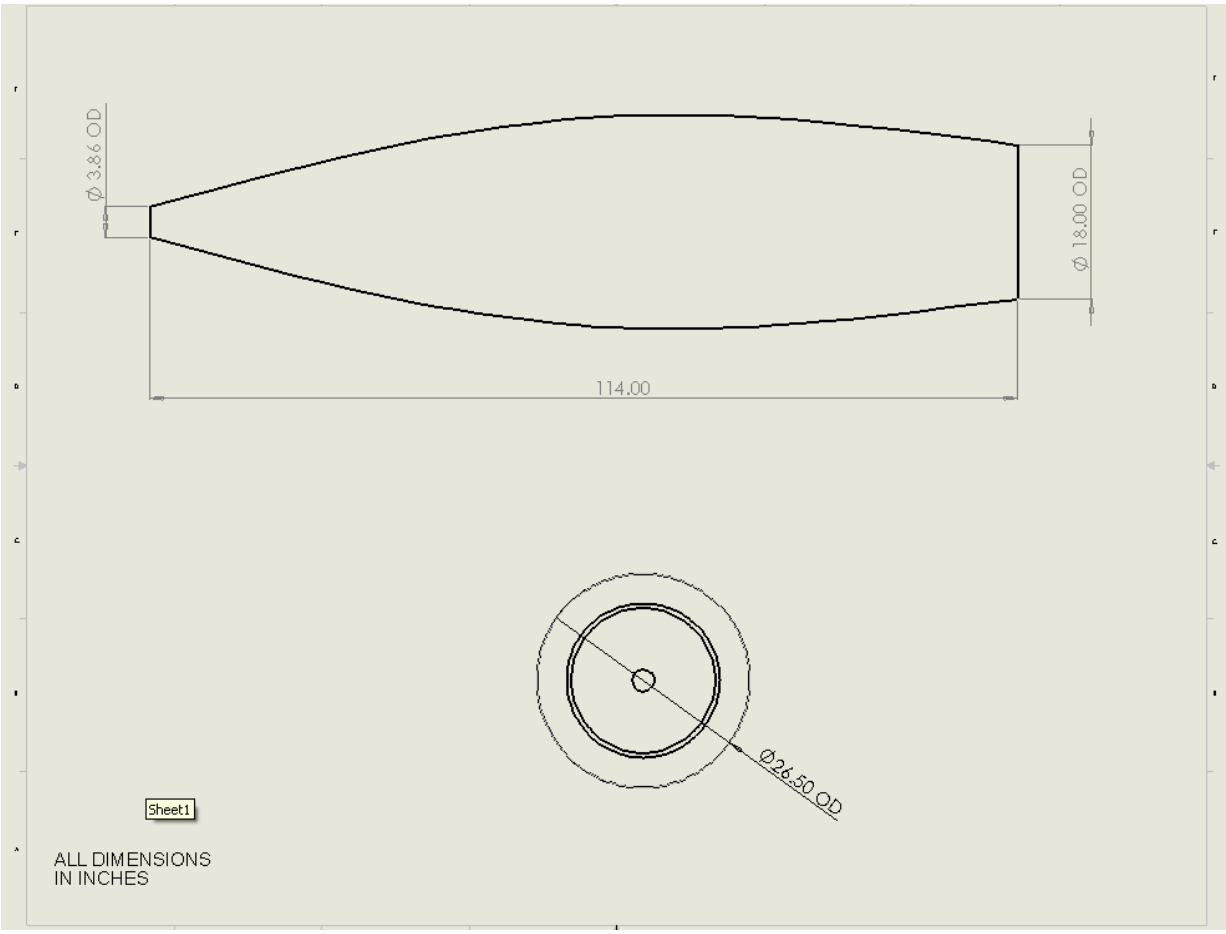

Figure 2: General Hull Design Dimensions

The pilot's position is shown below in Figure 3. The pilot is lying in the prone position with stomach downward and with the head toward the nose of the submarine. The air tank is mounted to a solid harness underneath the pilot's torso. In order to insure an optimum position for leverage on the drive system, a new top-mounted shoulder harness was designed for the pilot to lie against. The harness includes a waist belt to secure the driver's torso. Bicycle toe clips are used to ensure that the pilot's feet do not slip while pedaling.

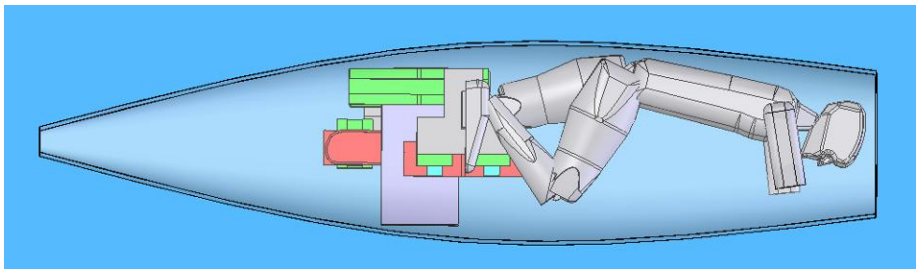

Figure 3: Pilot/Driver Position

Materials

The hull was fabricated using fiberglass sandwich technique with Kevlar material and flexible syntactic foam. Various other materials, such as carbon fiber, E-glass, and S-glass were considered while brainstorming the design of the hull. Carbon fiber would have been a great material due to its strength and flexibility, but it is also a very expensive material in comparison to the team's budget. E-glass and its stronger counterpart, S-glass, were also both discarded. E-glass is not as strong as Kevlar and S-glass was still too expensive. Kevlar also had the added advantage of superior impact energy absorption. After some consideration, Kevlar was decided as the best choice for the material. Kevlar is polymer material made of aramid fibers. Hexcell Schwebel donated a sixty-yard roll of the Kevlar material for the team to use. After two layers of Kevlar were applied with resin onto the foam mold of the hull, flexible syntactic foam was placed on top followed by three more layers of Kevlar. The details of the hull construction are discussed in depth in the next section. The flexible syntactic foam was donated by the DIAB Group in 3ft x 4ft sheets at a quarter inch thickness. Figure 4 shows the composite layer cross-section.

Figure 4: Hull Layers and Thicknesses

Construction

Before submarine construction began, it was necessary to build a ventilated room using 2-in x 4-in lumber and 6-mm plastic. The room was needed in order to contain fumes during the composite lay-up and to aerate when the submarine was primed before painting. The room was ventilated using a large fan that ducted the fumes and dust to the outside of the building. The wooden-framed lathe shown in Figure 5 was custom designed by the team to fit the 120 in foam block, which was used to shape the hull by means of a plywood template guide.

The 4-lb/ft^3 density foam from DUNA USA, Inc was donated as a 30 in x 50 in x 114 in solid block. After cutting the block in half, a 120 in long by 1.5 in diameter steel pipe was inserted through the center. The pipe, with a sidewall thickness of 0.5 in, was supported by two bearings on either side of the lathe. This setup easily supported the nearly 100 lb block that would become the hull mold. A sharpened heavy-duty tile scraper was used as a chisel to shape the submarine mold until only 0.125 in of material remained and was removed by sanding. Figure 6 shows the mold after chiseling and sanding. The mold was then wrapped with a cellophane wrap which was used as a release film.

Figure 5: Foam Block Lathing

Figure 6: Hull Foam Lathing

The five layers of Kevlar were cut using cardboard templates. The alternating layers of Kevlar were cut at 0-degree and 45-degree angles, respectively, in order to maintain rigidity and reduce stress. The order of hull material application was two layers of Kevlar first, followed by the syntactic foam, and then finally the last three outside layers of Kevlar. After the syntactic foam layer was applied, the hull was covered with release fabric. Subsequently, the hull was sealed with a vacuum bag, which was hooked to a vacuum pump, in order to remove the air within the layers, ensure hull evenness, and to allow the resin to cure. Again a vacuum bag was used after the fifth and final layer of Kevlar was applied. After ensuring that the resin cured sufficiently, the vacuum bag was removed and rough spots were smoothed using lightweight Bondo and paint primer.

The original foam male mold, now encased in Kevlar, was then carved out. Hatches and holes were cut for control surfaces, propellers, and the acrylic nose cone. The main hatch measure 3.5 ft long and is the primary entrance and exit for the submarine. The hatch, which is designed to be released from the inside and outside, was fastened with a spring mechanism and is capable of completely detaching and reattaching. The secondary hatch, also located in the rear on the starboard side, is permanently attached to the hull and will not be used for entry or exit. The purpose of the secondary hatch is for maintenance access to the sub while it is out of the water. Finally, the hull was primed and sent to a body shop to be painted. The first testing of “Maroon

Harpoon" took place on May 9 and 10, 2007, in the Offshore Technology Research Center at Texas A&M. For easy reference, Table 1 summarizes features of the "Maroon Harpoon" human powered submarine.

Table 1: Maroon Harpoon Basic Specifications

Lightship Weight in Air	Dry, Equipped Weight in Air	Hull Thickness	Overall Length	Max. Diameter	Volume	Category
72.5 lb	204.1 lb	0.375 in	10.3 ft	2.2 ft	25 ft^3	One-person, Propeller driven

Nosecone

The nosecone designed for "Maroon Harpoon" (Figure 7) is a molded, clear acrylic nosecone made by Texstars and cut to the proper length by the sub team members. The use of clear acrylic enables the pilot to have window visibility from the front of the hull. The cross-section that is attached to the hull is circular with a flared edge, 18 inch diameter. A 1 inch lip was added to the inside of the hull to fit the nosecone. To attach the nosecone to the hull with a tight seal, weather-stripping was laid around the 1-inch lip (Figure 8) and three rubber-tension latches (Figure 9) were spaced along the nosecone that connect to three small plastic notches on the inside of the hull (Figure 10). This system is considerably safer for the driver than previous designs as there are no sharp metal or plastic corners near the driver's head.

Figure 7: Nosecone

Figure 8: Weather-Stripping on Rim

Figure 9: Rubber-Tension Latches

Figure 10: Rubber-Tension Latch Connected to Plastic Notch

Controls and Braking

Control System

Control and stability is achieved through the use of four control planes mounted at 90-degree increments near the stern of the submarine. The two horizontally mounted planes account for pitch, and the two vertically mounted control planes account for yaw and roll. Movement of the control planes are governed by a system of tensioned cables routed between the steering mechanism mounted forward of the driver, shown in Figure 11, and a pair of slide plates mounted in the stern shown in Figure 12 and Figure 13. Each stern mounted slide plate is connected to two opposing control planes. These connections provide for both concurrent and opposing motion of the control planes. This system allows for the correction of yaw, pitch, and roll, which gives an advantage over previous control designs that only allowed for the correction of pitch and yaw. The ability to control the roll of the submarine allows the pilot to counter the torque imparted by the propeller. The control planes are one-piece airfoils as seen in Figure 14.

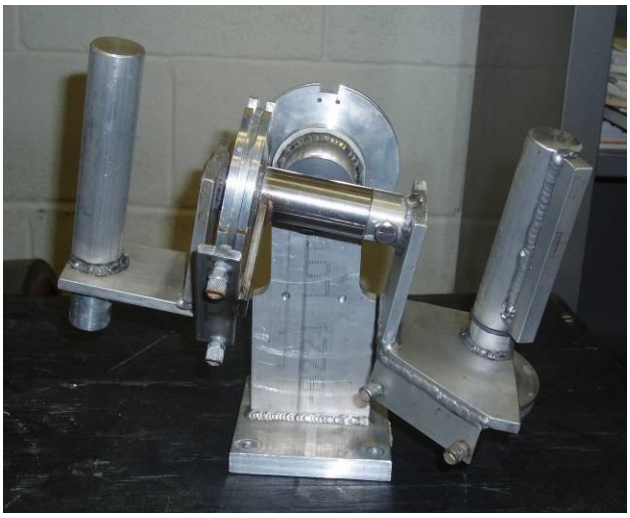

Figure 11: Steering Controls

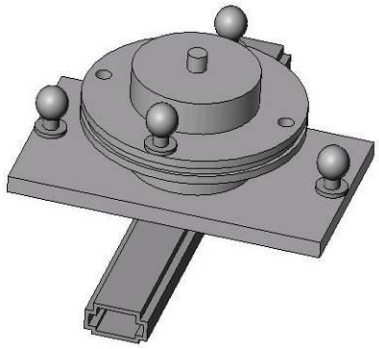

Figure 12: Control Plane System

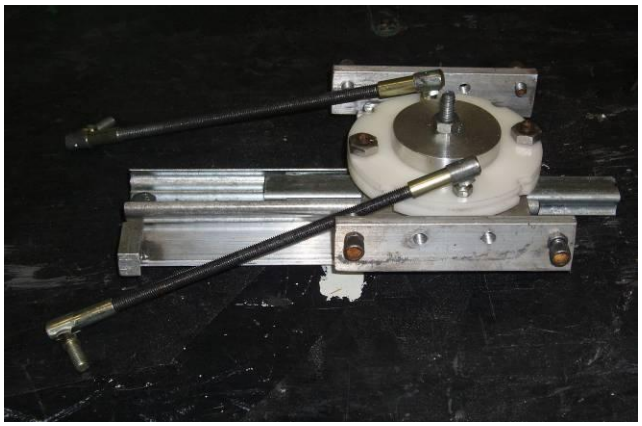

Figure 13: Slide Plate for Control System Located in Stern

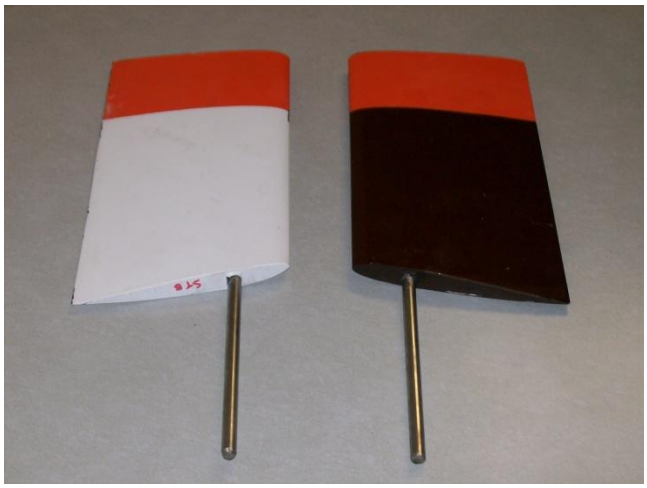

Figure 14: Control Planes

Braking

Braking is performed by a combination of reverse pedaling and banking into a turn to decrease momentum.

Drive Train

Gearbox

The gear box is designed for a pilot input of approximately 50 rpm, has a gear ratio of 4:1, and can also accommodate a 3:1 gear ratio. The resulting propeller speed is 200 to 150 rpm, depending upon the gear ratio used. The gearbox is positioned in the stern of the submarine and is mounted in the hull using adjustable threaded rods (Figure 15). The threaded rods are expanded to provide compression that keeps the gearbox in place. The use of threaded rods allows for adjustability in gearbox height in order to better align the drive shaft. The gearbox is screwed into two steel plates that have receivers for the threaded rods, and also contain a mounting bracket for the emergency buoy (discussed later). The output shaft of the gearbox is attached to the propeller shaft using a stainless steel rigid shaft coupling.

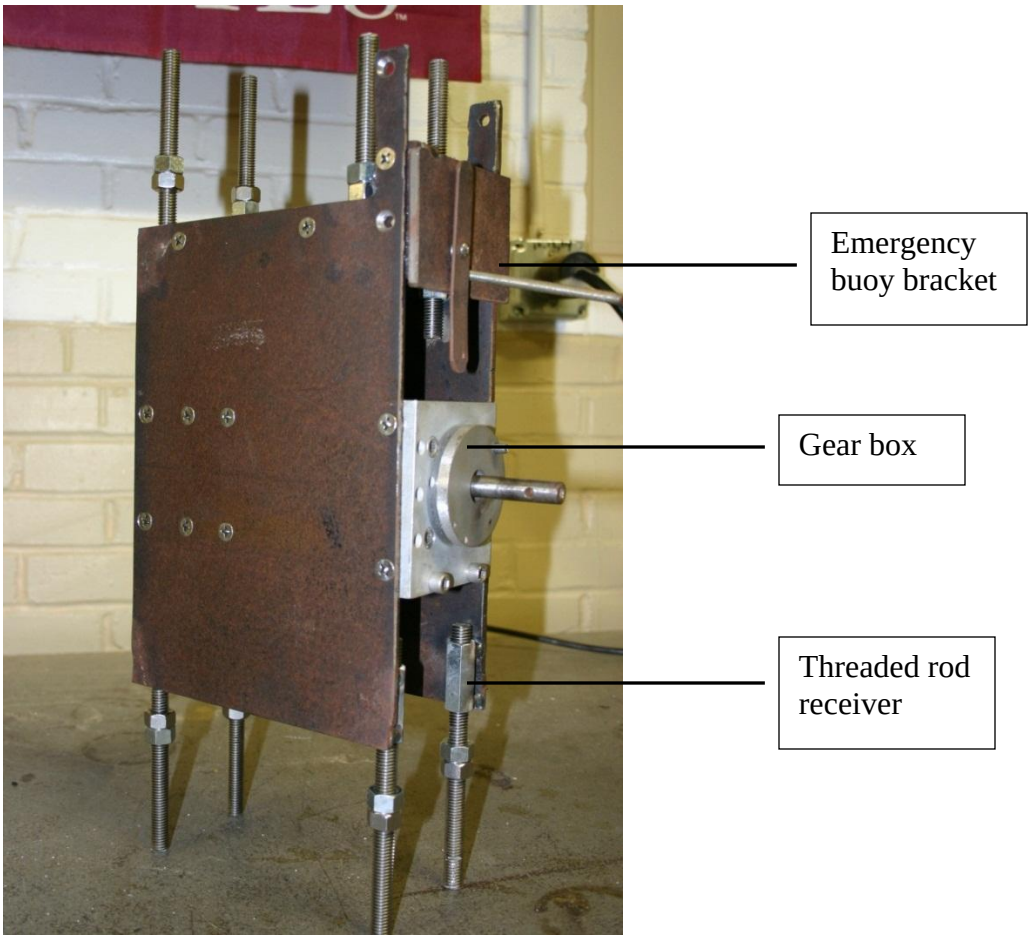

Figure 15: Gearbox Mounting Plates

Drive Shaft

The team designed a new drive shaft which was constructed and donated by Oceaneering International, Inc. in Houston, Texas. The driveshaft (Figure 16) is made from MIL-A-8625 anodized aluminum and is connected to the electronics can and torque sensor with a rigid shaft coupling and misalignment joint. The electronics can and torque sensor are discussed in detail later. The driveshaft passes through a bearing to outside the sub where it is attached to the propeller hub. The driveshaft is 22 inches long and is flanged at the hub end to mate with the propeller hub. The largest outer diameter is 0.97 inches and the coupling end tapers down to an O.D. of 0.623 inches.

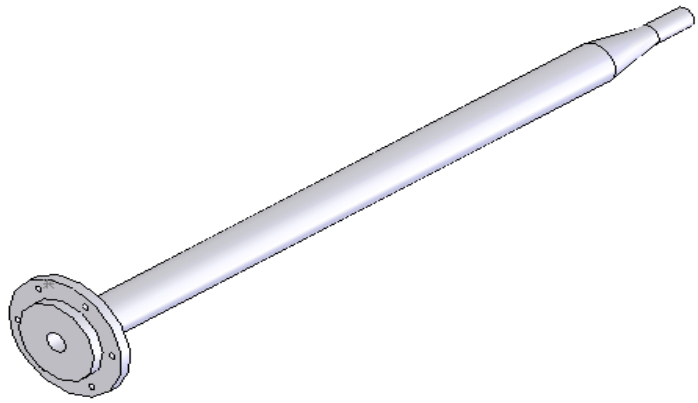

Figure 16: Driveshaft

Shaft Bearing

The team designed a new bearing attachment that fits inside of the tapered stern of the submarine, seen in (Figure 17). The bearing attachment holds two glass bead bearings securely in the stern through-hull by clamping against the taper made by the hull. The attachment is made from nylon and four Allen head cap screws tighten the clamp together.

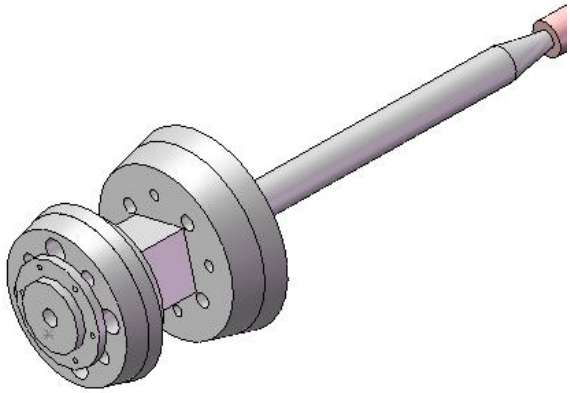

Figure 17: Bearing Schematic

Completed assembly

The completed assembly can be seen below in Figure 18, which demonstrates how the final assembly comes together.

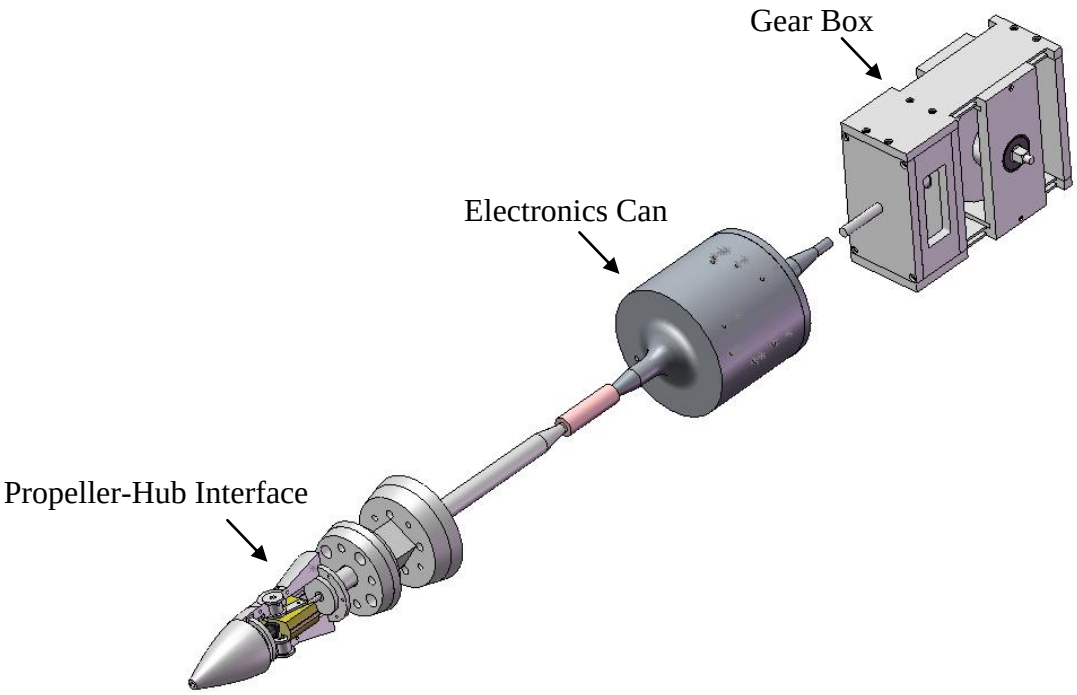

Figure 18: Complete Cyclical Drive System

Propulsion

Propellers

The team will compete with a variety of two bladed propellers attached to a new, variable pitch propeller hub (discussed later) which was designed by Texas A&M Submarine team members with the help of Oceaneering International Inc. The pitch of the blades can be altered before a race, but not while underway. Two sets of propeller blades were designed and fabricated according to the specifications of TAMU students by Baumann Marine in Houston, TX. The blades are optimized for an expected operator power output of 0.4 bhp and a design speed of 6.5-7 knots. The propeller in Figure 19 was the designed and used in previous races on the "Ol' Sarge" series of hulls. The team has tested various propeller shapes in order to find the most effective design and best pitch setting. These tests can be seen in the propeller test section below.

Figure 19: Propeller and Hub

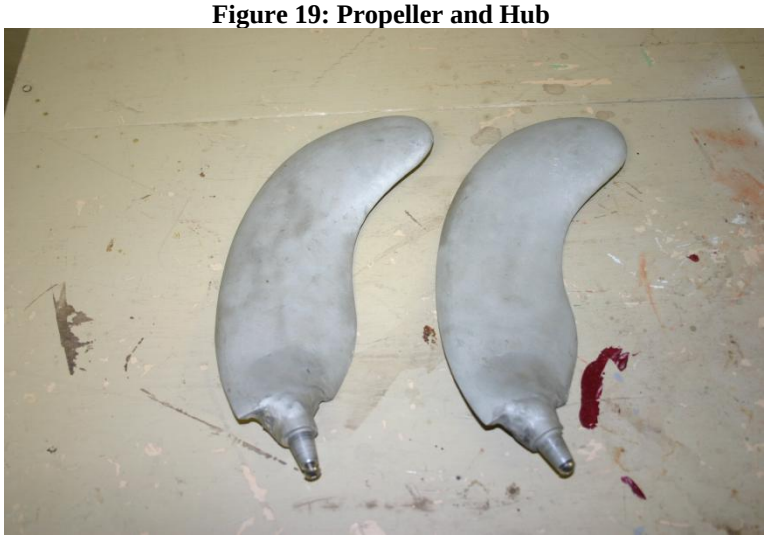

Figure 20: Tested Propellers

Propeller Hub

A major improvement to the drive system is the addition of a new propeller hub, seen above in Figure 19. This hub, which was designed by Texas A&M Submarine team members and built by Oceaneering International, Inc., allows for in situ adjustment of propeller pitch, something which previously required removing the drive shaft.

Inside the hub is a worm gear, which is turned by a nylon knob on the outside of the hub. This worm gear drives two cams which travel through downward angling grooves, forward or backward, in turn turning the blade attachments. The mechanism is shown in Figure 21.

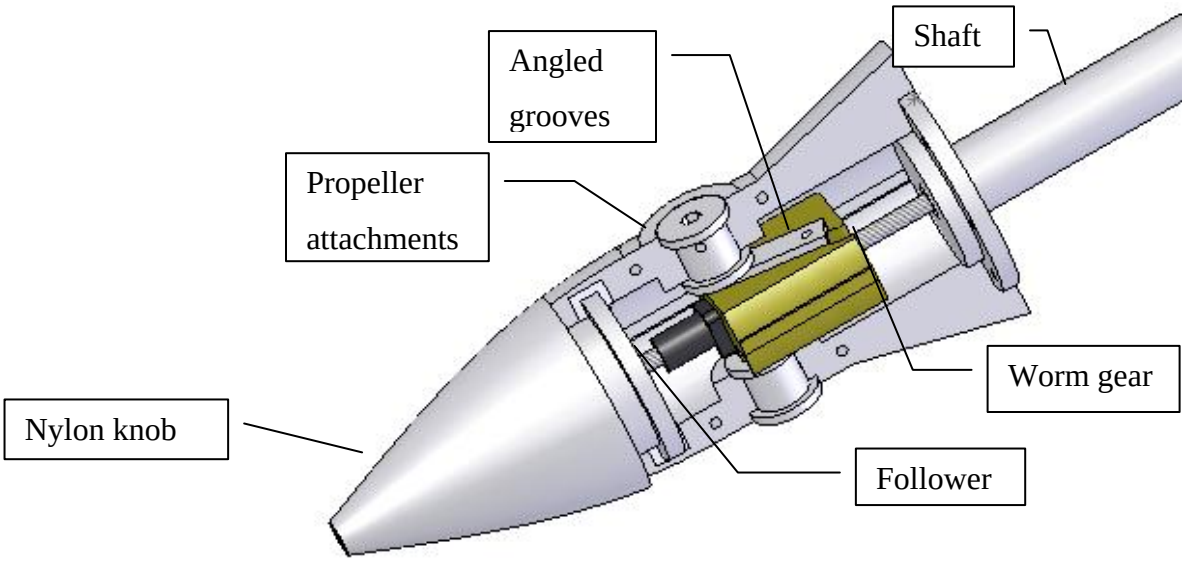

Figure 21: Propeller Hub

The blades are attached to the hub using tapered inserts which fit into the hub mechanism and are secured by a ¼-20 hex cap screw. The taper works like a Jacob's Taper on a lathe or mill, and prevents the blades from spinning out of their attachments. The propeller-hub interface is shown in Figure 22.

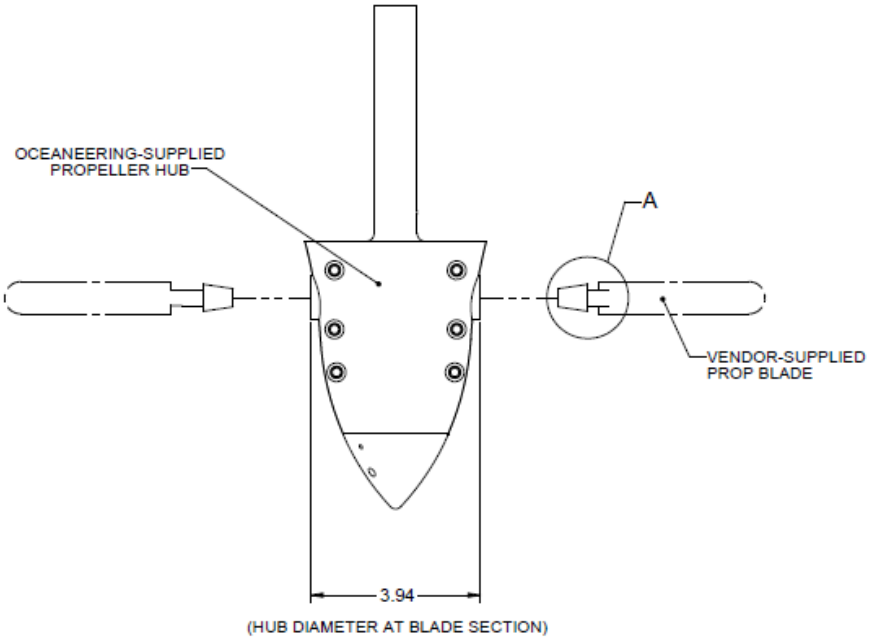

Figure 22: Propeller Hub Interface

Propeller tests

A propeller testing apparatus (PTA) was designed and built at Texas A&M University. The PTA, shown in Figure 23, is located at the towing tank at the Hydromechanics Laboratory. The purpose of the PTA is to determine the operating pitch that would optimize thrust for a given rpm and provide information for the design of a future propeller. Several propellers from previous races were tested and analyzed and two provided good results: the steel twisted propeller and the aluminum propeller.

Equipment

The PTA consists of a motor, motor controller, and data acquisition system. The motor is direct current and rated at 0.75 horsepower. This motor is controlled by a Dart Micro-Drive II. The controller allows the motors speed to be controlled via the front panel. The data collection system is comprised of a load cell (Figure 24), signal conditioner, and data acquisition unit. The load cell was calibrated once installed in the system. This was done so that the moment arm due to the distance between the load cell and the propeller line of action could be accounted for. This calibration data was entered into the Labview to obtain physical units during data acquisition. A program using Labview (Figure 27) was created to record the data at a 25Hz sampling rate and for thirty seconds. This data was stored in*.lvm files and a directory was created that sorts data by the test date.

Figure 23: Propeller Testing Apparatus

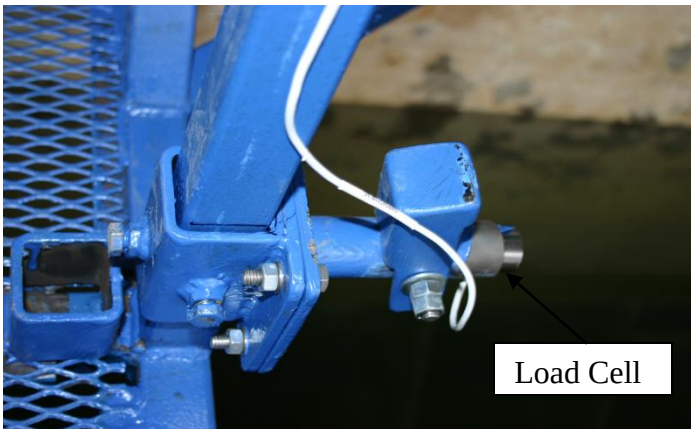

Figure 24: Load Cell

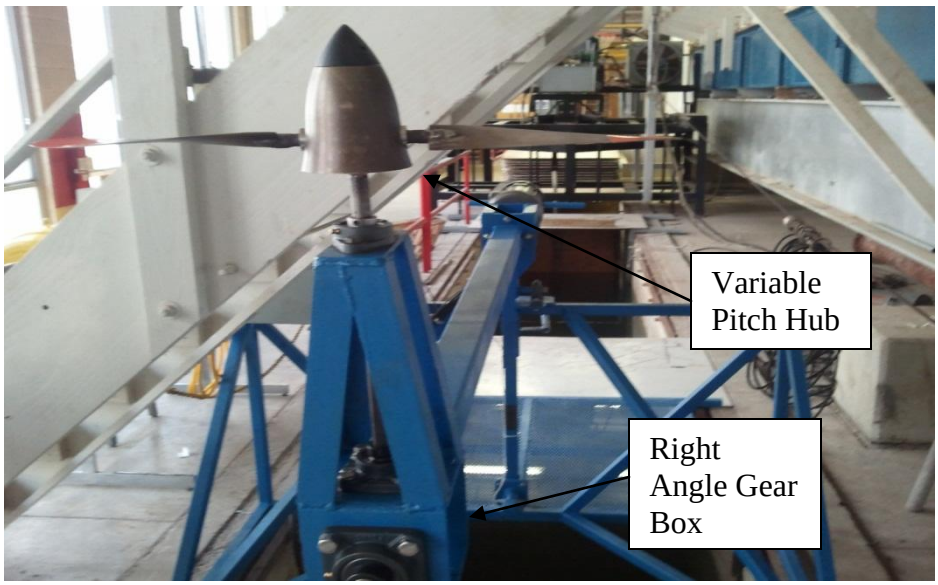

Figure 25: Propeller Hub on Test Apparatus

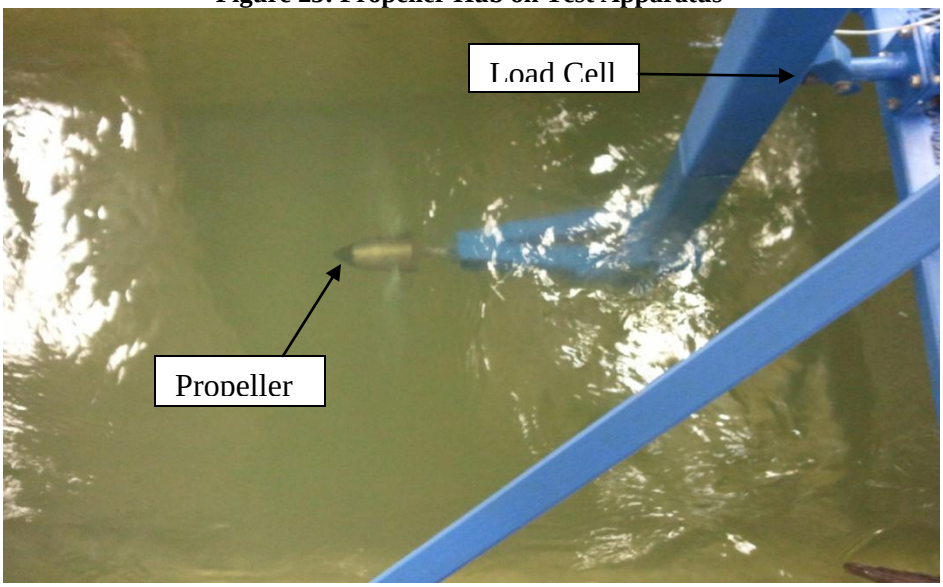

Figure 26: Propeller Spinning Underwater

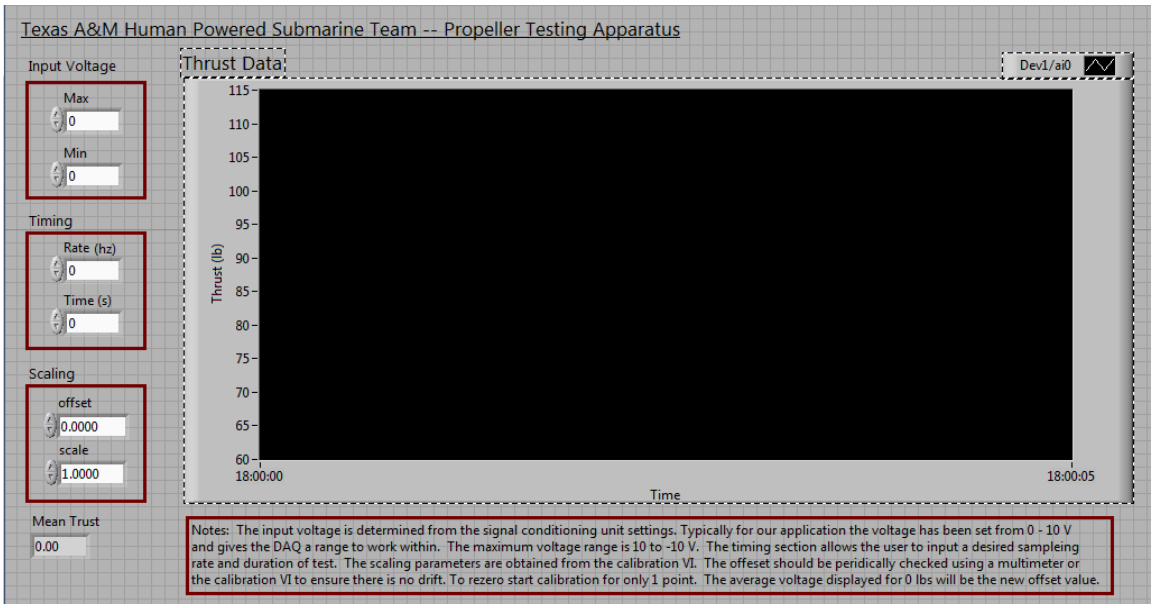

Figure 27: Labview Front Panel

Results

A Matlab program was written to post process the data collected (see Figure 29 for a sample of data). The program plots all data collected and provides a summary plot (Figure 28). The summary plot displays a curve of the average thrust vs. RPM for a given pitch. This plot also displays the expected hull resistance at 5, 6, and 7 knots.

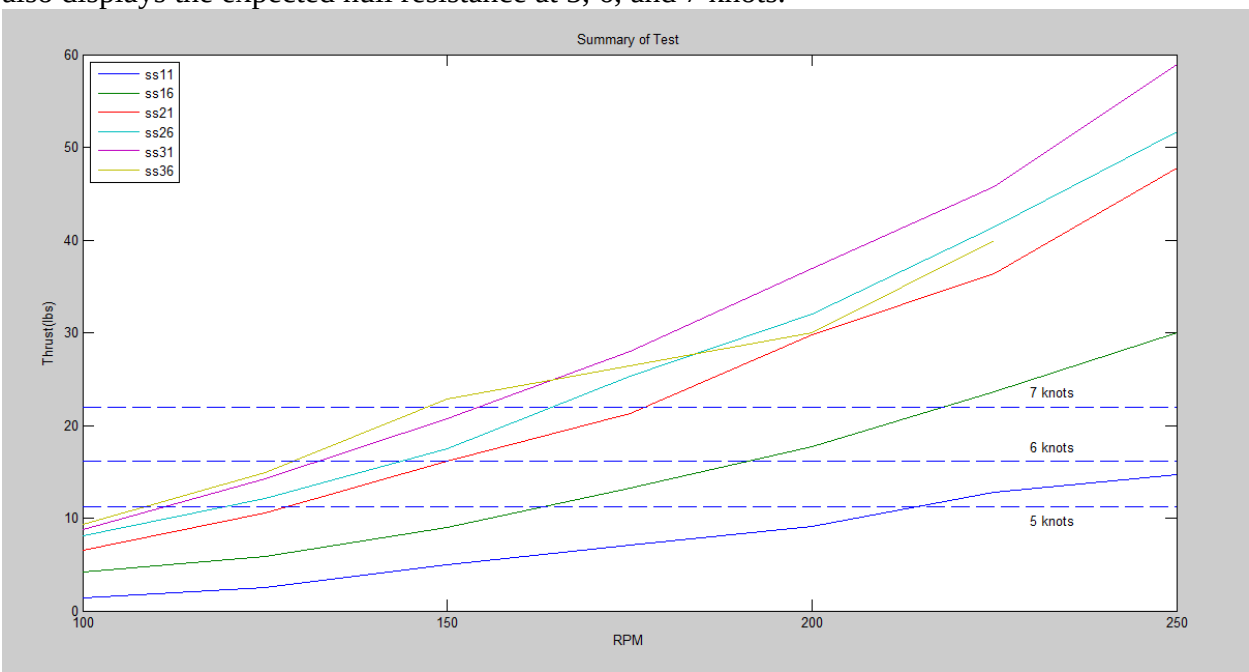

Figure 28: Stainless Steel Propeller Test

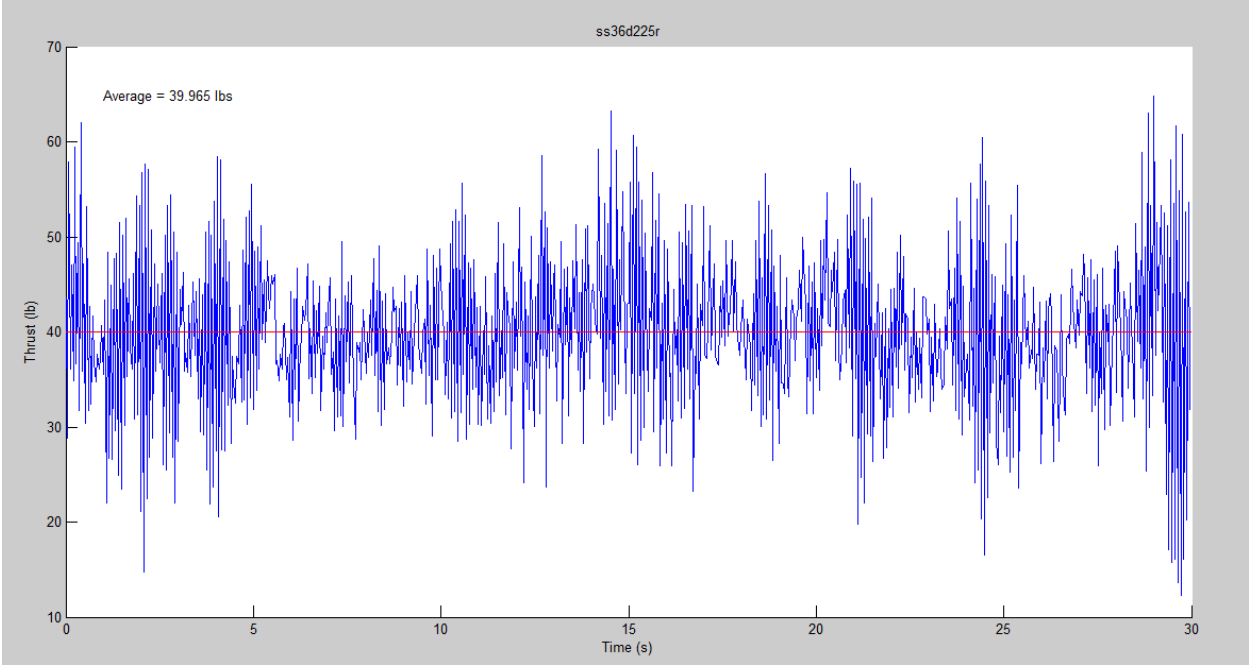

Figure 29: Sample of Collected Data

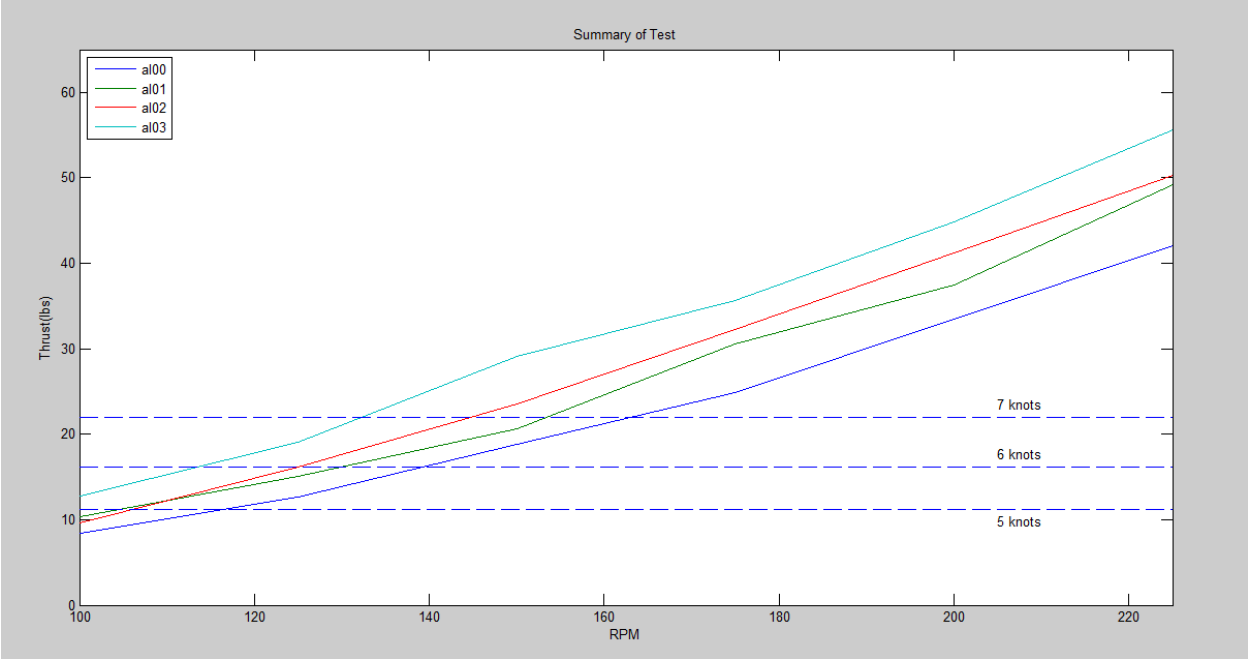

Figure 30: Aluminum Propeller Test

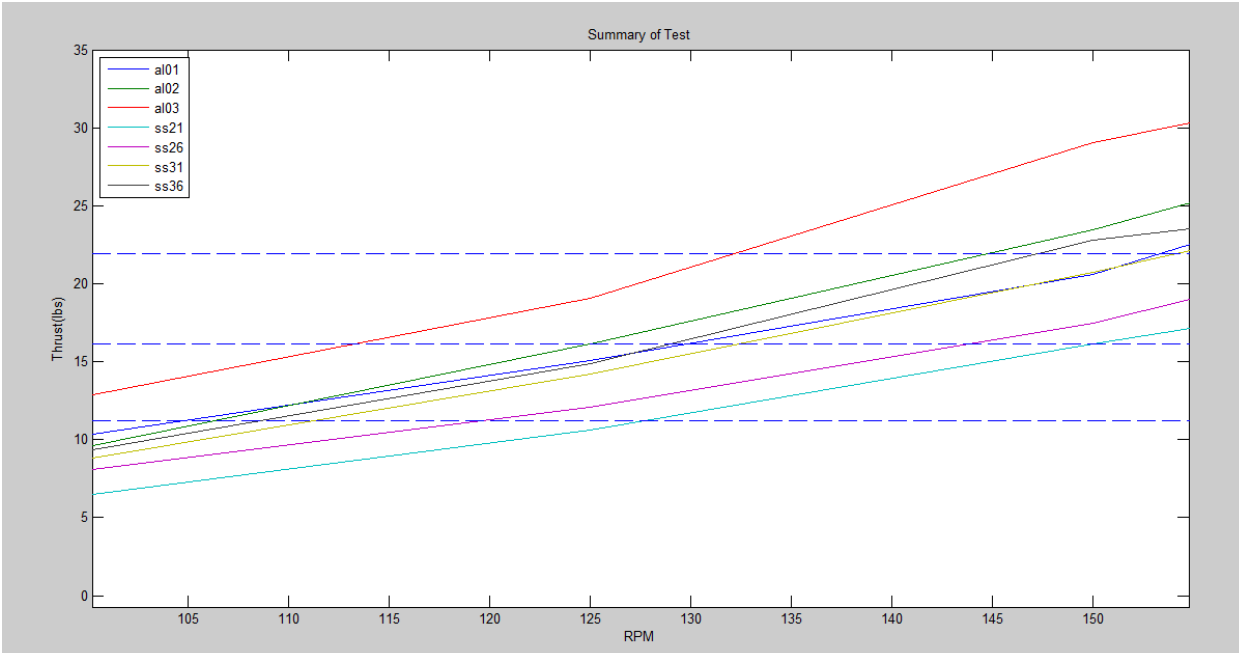

Figure 31: Aluminum and Stainless Steel Test

Procedure

The initial propeller angle was set using an inclinometer. For the stainless steel (ss) propeller, tests commenced at 11 degrees pitch at the tip. Pitch was increased to 36 degrees in 5 degree increments. The RPM was varied from 100 to 250 in 25 RPM increments.

The average thrust was computed for each test and plotted vs. RPM for each angle. These results were compared with hull resistance at 5, 6, and 7 knots. The hull resistance was calculated using drag equation.

$$F_D = .5\rho u^2 C_D A$$

$$\rho = density\ of\ water\ \left(1.94\frac{slugs}{ft^3}\right)$$

$$u = velocity\ of\ submarine\ \left(\frac{ft}{s}\right)$$

$$C_D = drag\ coefficient\ (.04)$$

$$A = projected\ area\ (3.69\ ft^2)$$

Instrumentation

Concept

The team decided it would be beneficial to be able to measure data while the sub is in motion in order to optimize the control systems. The ultimate goal is to design and build a variable pitch control system that changes the pitch of the propeller while in motion, and provide

RPM feedback to the pilot. The housing shown below in Figure 32 was machined and donated by Oceaneering International, Inc.

Figure 32: Electronics Water Tight Housing

Detail Description

Overview

The main components of the system are a torque sensor, microcontroller, Hall Effect sensor, memory stick data logger, system control and power supply. The system is mounted in line with the driveshaft and all the components except for the torque sensor are mounted inside the water tight container shown above (Figure 32). An overall logic diagram is shown in Figure 33 .

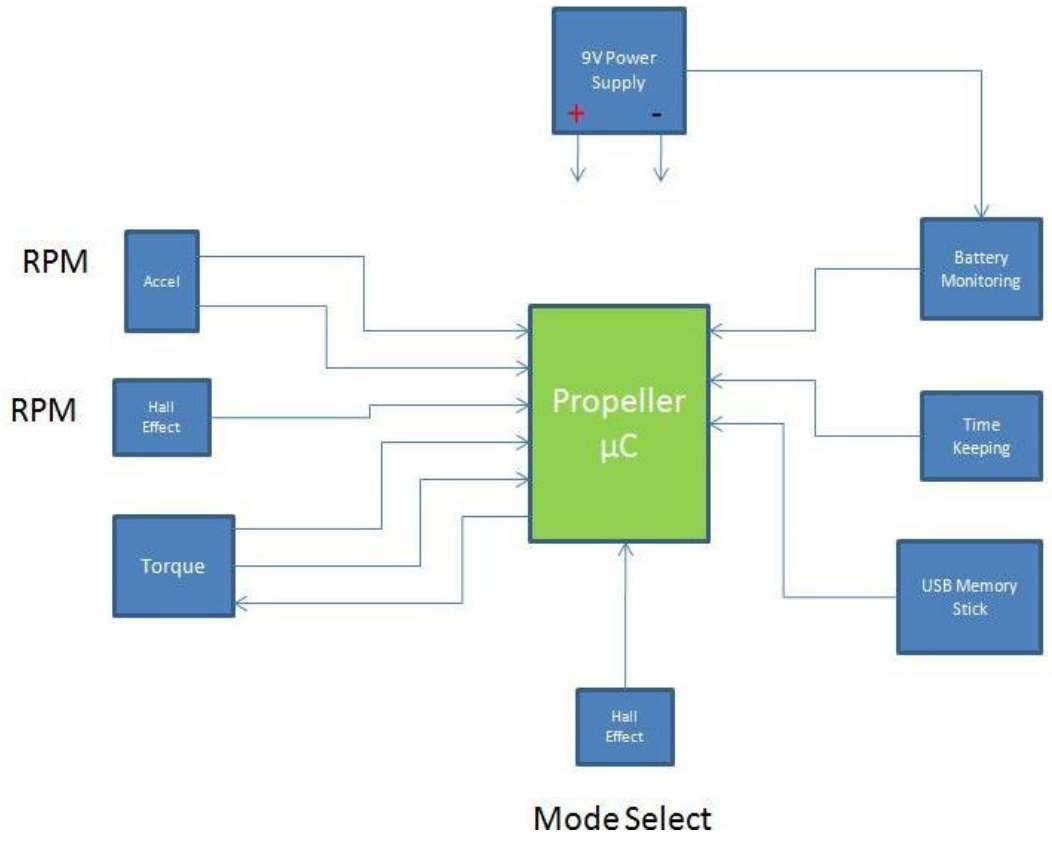

Figure 33: Propeller Micro Controller Logic Diagram

File System

Upon powering, the system initializes and a file 001.txt is created and saved on the USB memory stick. The file remains open, and torque and rpm of the system are recorded every 0.5 seconds. This is repeated until a standby command is received. While in standby, the user can safely remove the memory stick and transfer files to a PC. Receipt of the run mode command causes the system to create a new file 002.txt and begin to record data. The file names continue to increment sequentially as the standby and run sequence is repeated.

Torque Sensor

The torque sensor is an AWS-QC tester manufactured by Advanced Witness Series. The torque sensor was modified to work in line with the propeller shaft. The sensor has a balance mechanism attached to it. The balance mechanism (BM) allows for the torque sensor to be balanced. The various slots in the BM were filled with lead shot and 1/4 – 20 screws were used as end caps. The torque sensor can output various units of torque but is currently set to lb-ft. The output is serial RS232 9600 baud at a 9V level. The torque sensor must receive an ascii character "D" to trigger an output. The output of the torque sensor is then shifted to 3.2V via the PRT-08780 level shifter.

Microcontroller

The parallax propeller microcontroller used is a 40 pin dual in line package. The microcontroller is supplied 5VDC and then converts it to 3.2VDC. The 3.2VDC supply (pin32) of the microcontroller is used to supply power to the PRT08780 level shifter. The microcontroller is programmed in its proprietary language, Spin. Spin is an object oriented language, and many of the objects used were created previously and acquired from the Propeller Object Exchange online. A copy of the program with notes is attached.

Hall Effect Sensor

Two Melexis Hall Effect sensors are used to measure the RPM of the shaft. A magnet is mounted in the submarine. The sensor counts the pulses and the program computes RPM. The second sensor is used to switch between modes, close files, and create new files. The user passes a magnet over the sensor to change modes.

Memory Stick Data logger

The data logger is an interface that allows USB devices to be used via serial data. This is convenient for use with the propeller microcontroller. The data logger is used to interface the memory stick with the microcontroller.

Power Supply

The power supply is composed of eight AA batteries in series. The total voltage is 9.6VDC at 1600mAh. The voltage is directly supplied to the torque sensor. The voltage is then connected to a voltage regulator and converted to 5VDC for power to the microcontroller. The microcontroller contains an onboard voltage regulator to convert the voltage to 3.2VDC.

Assembly

The electronics were soldered to a circuit board and mounted to an aluminum project box. The power and signals to and from the torque sensor are through an eight pin underwater mateable connector (P1). The underwater USB memory stick has its own separate four pin connector (J2). Both the USB and torque signals are connected to P4 (DB9) in the electronics container. Then the signals are connected to the bread boards.

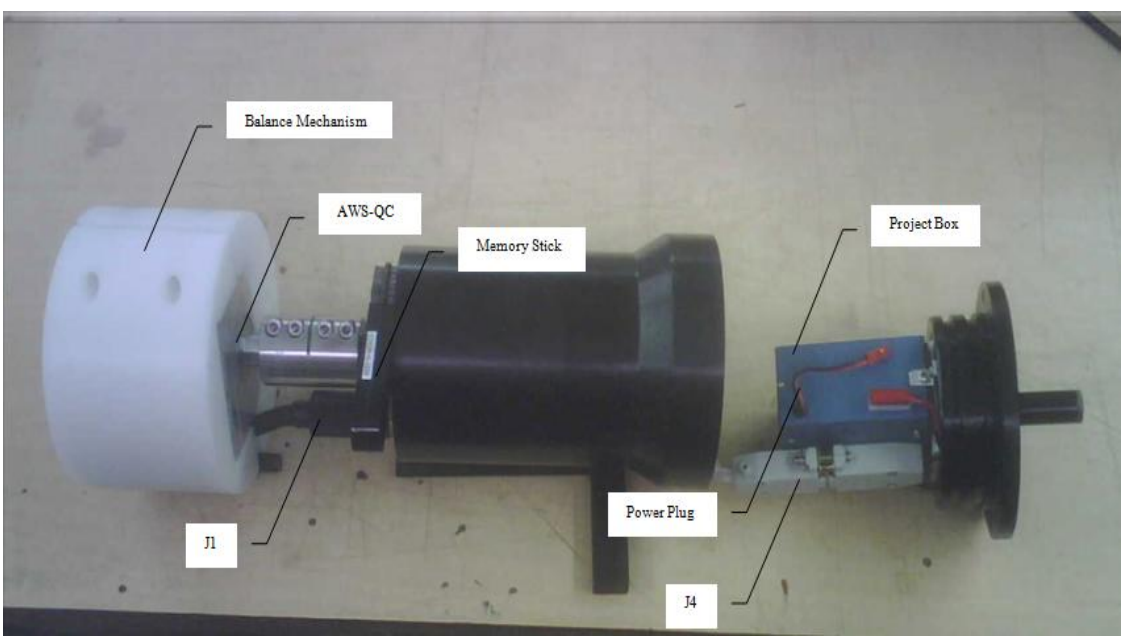

Figure 34: Instrumentation Assembly

Life Support and Safety

Life Support

The air supply requirements satisfy the guidelines in the IRS Contest Rules and Regulations. The air supply, with a minimum of 150% reserve for each crewmember, is used primarily for life support while underwater. All breathing air is compressed, normal, atmospheric air. The primary air supply (60 ft^3 cylinder) is located under the pilot's torso. A secondary air supply is attached to the pilot, and each support diver is equipped with an octopus regulator. No air tank supply is allowed to fall below 500 PSI.

Air Supply Requirement

The duration rate of air supply is dependent on a pilot/diver's consumption rate, depth, and the capacity/ recommended minimum pressure of the cylinder(s). Temperature is not considered because it is only an important factor under extreme conditions. The duration of air supply for the proposed cylinder, may be calculated using equation 1.

$$C = \frac{D+33}{33} RMV \tag{1}$$

where C is the pilot/diver's consumption rate in standard ft^3/min (scfm), D is the depth, and RMV is the diver's respiratory minute volume (scfm).

Table 2: Driver RMV and Consumption Chart

Level of Exertion	RMV	C
Heavy	1.7	2.16
Moderate	1.3	1.65
Light	.065	0.83

In order to calculate the capacity of air that is available to the pilot/diver, as opposed to the total capacity of cylinders, the equation on the next page is utilized:

$$V_a = \frac{V_c N (P_c - P_{rm})}{P_r + 14.7} \tag{2}$$

where V_a is the is the capacity available (scf), V_c is the rated capacity of each cylinder (scf), N is the number of cylinders, P_c is the measured cylinder pressure (psig), P_{rm} is the recommended minimum pressure of the cylinder (500 psig), P_r is the rated pressure of the cylinder (psig), and 14.7 is the standard atmospheric pressure (psi). To calculate the duration in minutes, the capacity available is divided by the consumption rate using the following equation:

$$Duration = \frac{V_a}{C} \tag{3}$$

To solve for the air supply and the consumption needs of the pilot, Tables 3 through 5 were used in association with the equations provided.

Table 3: SCUBA Cylinder Information

Rated Capacity / Rated Pressure	60 ft^3 / 3000 psi
Absolute Minimum Air Pressure	500 psi
Capacity Available per Cylinder	49.76 ft^3

Table 4: Time Calculations (all values in seconds unless noted otherwise)

Time to secure hatches and setup for run (max)	827
Time to accelerate to 6 knots in 150 feet	31
Time to transit gate area (100 meters = 328 feet)	32
Time for deceleration	10
Total time from setup to completion of run (min)	15

Table 5: Air Consumption and Available Resources

Case	Crewmember	RMV (scfm)	Rate of Consumption (scfm)	Duration of Air Supply (min)	Available Reserves (%)
A	Operator	1.70	2.16	22.41	153.58
B	Operator	1.30	1.65	30.16	201.05
C	Operator	0.65	0.83	59.95	399.69

These calculations demonstrate that even when conditions are harshest (case A); a 153.58% reserve is still maintained. These calculations are estimated for a speed of 7.0 knots.

Emergency Buoy System

The emergency buoy is constructed from a square cutout (Figure 35) of the top of the hull toward the stern of the submarine. The purpose of this buoy is to provide indication of possible pilot/driver distress by automatically releasing if the submarine pilot should lose consciousness. In Maroon Harpoon, the release mechanism is wired to a bicycle brake handle attached to the steering column.

During the race the pilot depresses the handle, and when distressed the handle will be released. When the pilot releases the handle, the release lever shown in Figure 36 is pulled upwards and the retaining rod is pulled out of the buoy. The device contains a spool of 30 feet of 1/16" highly visible line.

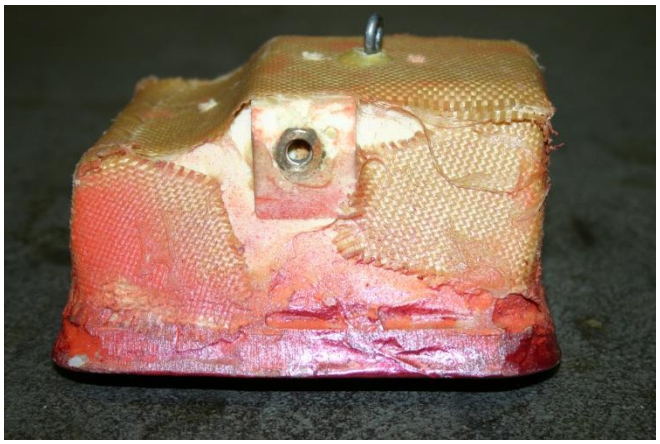

Figure 35: Dead Man Buoy

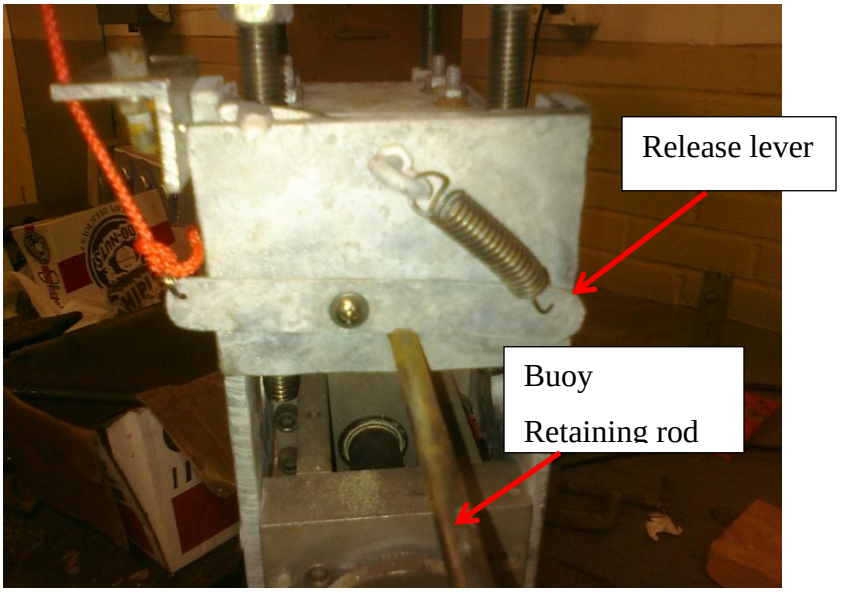

Figure 36: Dead Man Buoy Mechanism

Submarine Markings

External markings follow the procedures outlined in ISR 2011. The submarine is painted with contrasting maroon and white colors, with silver accents. The submarine name, logo, and team sponsors are also located on the hull. The propeller tips, dead man buoy, hatch release, harness belt release, rudder guard, and control plane tips are marked with orange paint for visibility and safety.

Strobe Light

For additional safety, a flashing white strobe light that is visible for 360 degrees in the horizontal plane is energized whenever the submarine is submerged. The strobe is placed at the top of the hull to achieve such visibility. The light flashes once every second, and it is visible for thirty feet under normal visibility conditions.

Figure 37: Emergency Strobe Light

Pilot Restraint

The pilot is harnessed into the sub in order to position the pilot in a manner that produces effective pedaling (or horsepower). The restraining strap has an orange airline seat buck release that is easily visible to safety divers (seen in Figure 38), and accessible by the pilot themselves. In order to satisfy safety requirements, all harnesses and toe clips are visibly marked with orange paint. In addition, the pilots all practiced self-egress maneuvers during testing at Offshore Technology Research Center.

Figure 38: Pilot Restraining Straps

Pilot Visibility

The only window, or view port, on this submarine is the nosecone. However, the pilot is positioned so that he can look straight out of the nose cone while pedaling and maneuvering the submarine.

Figure 39: Forward View

Rescue Egress

A four-inch orange patch displaying the word “Rescue” on the outside of the hatch marks the location of the latch release. On the inside of the hatch a painted orange handle is used by the pilot to release the hatch from the inside, it can also be accessed from the front after the nosecone has been removed. If an emergency situation is encountered, the safety divers are also able to remove the door from the outside of the submarine.

Testing and Training

Testing was conducted in the Offshore Technology Research Center (OTRC) on the Texas A&M University campus in College Station, Texas in April or May. The basin is 150 feet long by 100 feet wide by 20 feet deep. Full speed is not attainable within these dimensions. However, safety features and proper function of the submarine is checked and recorded to determine what adjustments needed to be made prior to the race. Pilots are trained for egression to the surface with assistance from support divers, and also without assistance. The pilots are also trained on general piloting skills, through short test runs. In addition the support diving crew was trained for launch and recovery of the submarine, as well as, unconscious and conscious pilot rescue techniques.

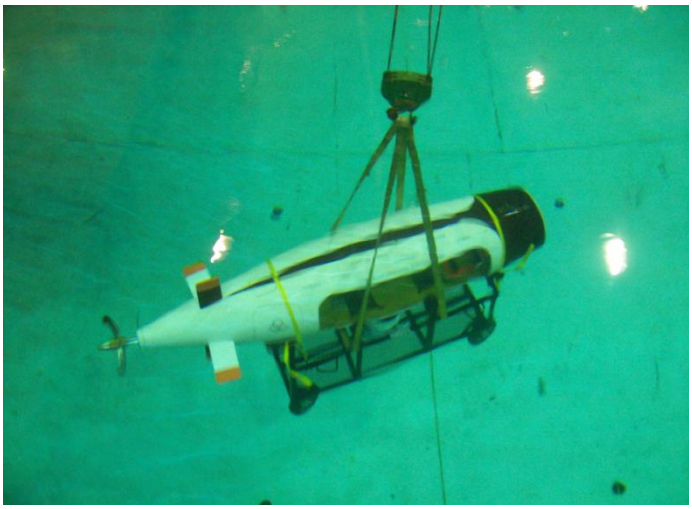

Figure 40: Underwater Testing at OTRC

Discussion of Improvements

After testing for two days in the OTRC, the improvements made throughout the year to the Maroon Harpoon were qualitatively analyzed.

Nosecone Attachment

The seal made by the rubber tubing and fasteners that are used to secure the nosecone lessen the effects of cavitation. In previous nosecone attachments, a small gap between the submarine and the nosecone would cause cavitation, possibly increasing the drag on the submarine and slowing the pilot down. With the new rubber tubing and tension fasteners, a more efficient seal is created, reducing the adverse effects of cavitation on the Maroon Harpoon.

Gearbox Mounting System

A new addition to the Maroon Harpoon, the steel gearbox mount provides much needed strength and durability to the drive column. Before, the gearbox was mounted within a foam block, providing too much buoyancy for the stern of the submarine. To alleviate the excess buoyancy, a new steel mount replaced the buoyant foam block. However, while at testing, it was noticed that the steel mount made the stern of the submarine too heavy, so a small piece of foam had to be added back to the drive column. Once the proper ballast was achieved, the new mount provided enough sturdy resistance for the driver to push against, making it easier for the driver to pedal.

Propeller

Though the OTRC testing basin is much shorter than that of David Taylor, the drivers were able to gain a feel for the new optimum propeller and pitch combination. After running tests on a variety of propeller shapes and pitches on the testing apparatus described in the Propeller Testing section, an optimum propeller shape and pitch were chosen to be the primary setup for testing and races. At testing, a number of drivers pedaled the submarine and were able to get a feel for what the races will be like. An exact speed was not measured during testing, so the races will be the debut of the new propeller combination. Even so, the team is confident that the new propeller shape and pitch will prove to be beneficial.

Dead Man Buoy

The new dead man buoy release system is much simpler and reliable than last race's system. The dead man can be retrieved and re-assembled quicker than before, making it more efficient for races.

Summary

Texas A&M University Ocean Engineering students designed and built "Maroon Harpoon" to compete in the One Man, Propeller-Driven category at the 11th International Submarine Races, held at the David Taylor Model Basin in Bethesda, MD.

Design Summary

There have been many improvements made to Maroon Harpoon during the 2010-2011 academic year. The nosecone attachment system was remade so that a tighter seal is achieved while keeping sharp parts away from the driver's head. A propeller testing cart and data acquisition system were also setup so that an optimum propeller pitch and design could be chosen before races. The dead man buoy was also redesigned for more rigid attachment. With these recent improvements and more to come before the races in June, the team is confident in the "Maroon Harpoon's" success in Bethesda.

Table 6. Summary of Basic Dimensions

Lightship Weight in Air	Dry, Equipped Weight in Air	Hull Thickness	Overall Length	Max. Diameter	Volume
72.5 lb	204.1 lb	0.375 in	10.3 ft	2.2 ft	25 ft^3

Areas for Further Development

The team plans to redesign the gearbox to further optimize the gearing, based on results from the new data collection equipment. The team also hopes to further develop the electronics system to include an additional accelerometer to determine speed, and to also add a LED numerical display for the pilot that displays speed, power, and possibly heading.

Sponsors

The Texas A&M University human powered submarine team would like to give special thanks to the sponsors who contributed to the 2010-2011 race year.

- Texas A&M Zachry Department of Civil Engineering
- Texas A&M Ocean Engineering Program
- Offshore Technology Research Center
- MTS (Houston Section)
- SNAME (Texas Section)
- Baumann Propellers, Inc
- Diab Group
- Oceaneering International, Inc.
- Resin Services
- Duna USA, Inc.
- TexStars Inc.
- Paradise Scuba
- Penske Truck Rentals

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